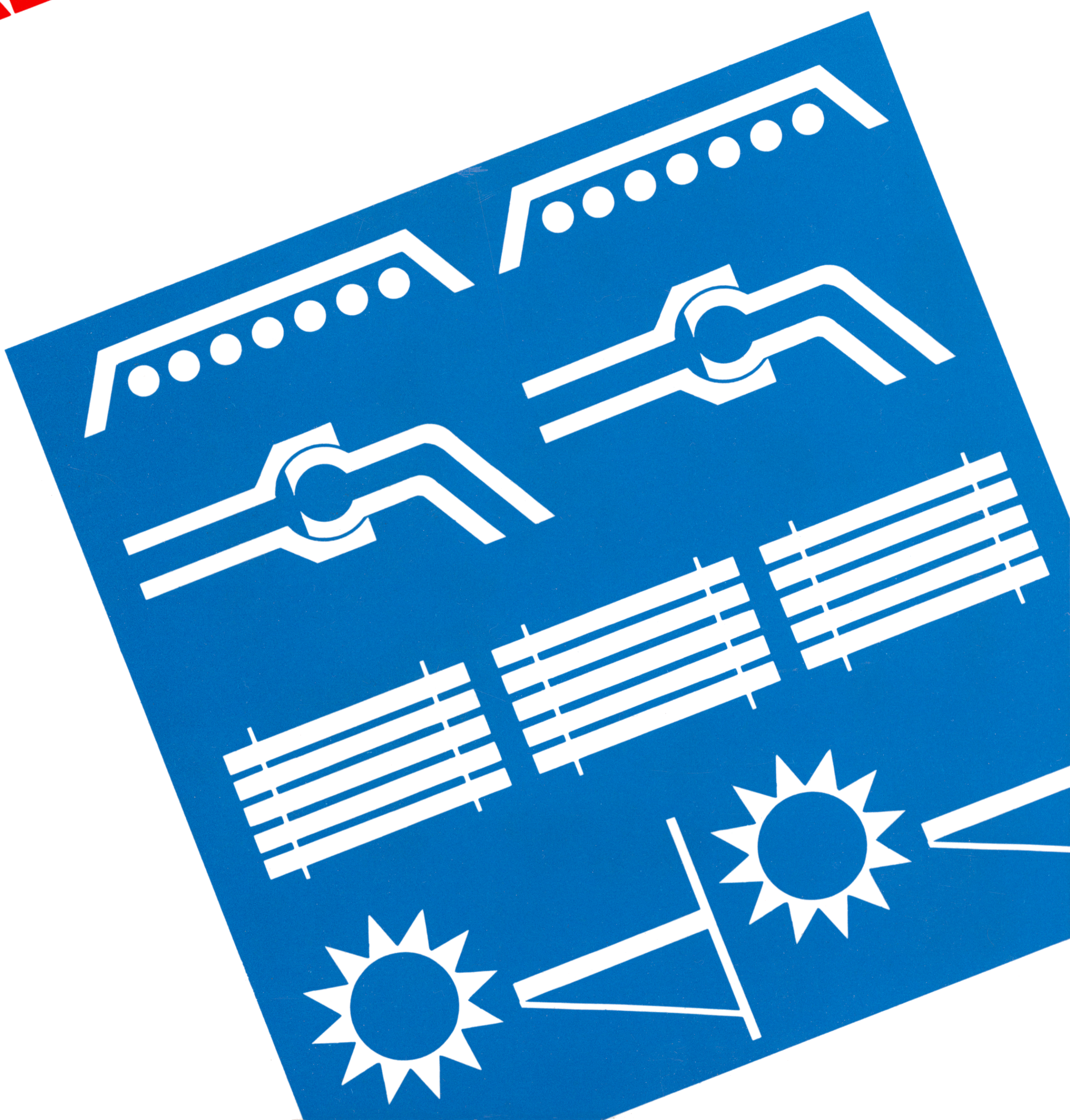
Sital Daryanani, P.E.

BUILDING SYSTEMS DESIGN WITH PROGRAMMABLE CALCULATORS



BUILDING SYSTEMS DESIGN WITH PROGRAMMABLE CALCULATORS

Sital Daryanani P.E.

This is the book that unlocks the vast potential of programmable calculators in building design. Any designer who knows how to use a programmable calculator can now save countless hours solving the most commonly encountered problems while finding optimum solutions. And *Building Systems Design with Programmable Calculators* presents all this time- and money-saving information—programs that could take thousands of hours to develop independently—in concise and easy-to-follow form.

The 22 programs in this book provide solutions to problems in: lighting design, life cycle cost analysis, sizing and heat loss in liquid, air and gas systems, a multitude of conversion programs, building heating loads, solar shading, and solar radiation. *None of these highly practical programs are available from manufacturers' program libraries or any other source.*

In the office, *Building Systems Design with Programmable Calculators* frees the designer from the chore of computation and allows concentration on the process of design and synthesis. In the field, designers and engineers can solve problems they could never before undertake without a computer.

Wherever readers use *Building Systems Design with Programmable Calculators*, they will find complete descriptions of the methodology for each design problem. Mr. Daryanani has identified and referenced all the relevant equations. Program labels, subroutines and storage registers used are outlined with a brief discussion of the function of each. Every section also contains several examples—so that the reader can quickly learn to use the program to solve the problem at hand. *Once a program has been debugged and tested by the user against the examples, use of the program eliminates all the errors inherent in the manual method.* No other book provides such a surefire method to save time and effort in building systems engineering.

While it is saving time for architectural designers, HVAC engineers, lighting designers and other professionals, this book can produce important long-range benefits. The programs encourage the designer to investigate alternate approaches, so that users of this book can find optimum solutions with unprecedented ease—not only improving the quality of the design and saving project costs, but conserving operating energy as well.

The specific problems that can be solved by users of *Building Systems Design with Programmable Calculators* include:

Piping Design A general piping system design program, based on the Colebrook and

(continued on back flap)

BUILDING SYSTEMS DESIGN WITH PROGRAMMABLE CALCULATORS

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Sital Daryanani

BUILDING SYSTEMS DESIGN WITH PROGRAMMABLE CALCULATORS

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To better engineering for
conservation of all resources:
human, material, and energy

IMPORTANT

Your investment in this timesaving tool will pay you dividends immediately if you first read, study, and understand the instructions given in the introduction.

Needless to say, you must be familiar with the basic features and functions of your calculator as explained in the owner's manual furnished with the calculator.

CONTENTS

PREFACE

Of all unlikely places, the idea for this book originated in Tehran, Iran. When I was there in 1976, we had to design mechanical systems for twenty-six large apartment buildings. We needed urgently, right in Tehran, a computer-aided design system to complete the project profitably and on time. A project of this type, due to large repetitions in the design process, is ideal for a computer-aided design system.

Since we had no access to our computers in the USA, we resorted to small programmable calculators. We had one set in Tehran which we used for developing the programs and, in the meantime, we ordered four more sets from New York. Once we had all the calculators and programs, we reduced the design time from three days per building to three hours per building. This incident was a convincing demonstration of the enormous potential of programmable calculators in the building design profession.

From that time on I became interested in programming techniques for programmable calculators and found this subject more exciting than reading detective novels or solving crossword puzzles during my long and frequent travels. Without this type of interest it would have been boring to travel and spend, say, five nights in Jeddah and three nights in Kuwait. Now I am used to working on a program while waiting at the airport. The time passes quickly. I can identify programs by the cities where I developed them.

It is one thing to develop programs for use in one's own office and another thing to put them together in the form of a book. It is a quantum jump of many orders. Having a contract from the publisher, a contract deadline, and an aggressive editor provided all the necessary driving forces for this quantum jump.

Apart from the driving forces and time, a project of this type requires a supportive environment. The creative and innovative atmosphere at Syska & Hennessy provided the necessary encouragement. The engineers in the office quickly adapted the new programs and helped in testing and application on actual projects.

I hope that other engineers and engineering students will benefit from this book. While this book does not directly address the problem of energy conservation, an efficient learning and problem-solving device can be indispensable for conserving human energy, which is the most expensive and precious type of energy. If the engineers use this book or other similar design techniques for analyzing alternate solutions to optimize their designs, they will also succeed in developing the most energy-efficient and cost-effective systems.

Since major portions of this book were written during my travels, I had to work alone on it. I am responsible for any errors of omission and commission. However, I have received comments, criticisms, and suggestions from many colleagues and friends who are too numerous to list and thank individually.

Typing of the manuscript turned out to be a monumental task. Apart from the volume of typing work, there were additional complications due to mathematical symbols and typing on "User Instructions and Examples." I doubt if I could have met the publisher's deadline without the full cooperation of my secretary, Ms. Dorothy Vance. In addition to her regular work, of which she had plenty, she managed to find time to type the manuscript, and supervise and coordinate the work of the other typists who pitched in. She had to guard the originals from the engineers in the office who were anxious to use some of the programs as they came off the typewriter. Mr. Steve Briggs also helped with typing, utilizing all the time he could spare. Many thanks to both of them.

Finally, I thank my family for allowing me to isolate myself during the last phase of this project and for their moral support and most patient understanding.

Sital Daryanani

INTRODUCTION

The computer has already made an impressive impact on the building design profession. Several architects and engineers have their own computers, or have easy access to them, and have learned to develop their own programs. Many package programs, some of excellent quality, are available at reasonable cost. These programs are being utilized through computer services by remote-access terminals or through users' own computers. Hundreds of users are benefiting from such services and programs without learning about computer programs.

On the other hand, there are still many engineers and engineering students in this country, and especially in other countries, who have still not had their first encounter with the computer. The volume of their work cannot justify their having their own computers, and time-sharing services are either unavailable or expensive. Their work may not benefit from available package programs and they cannot make the financial commitment of developing their own programs. These engineers and engineering students may find the programmable calculator within their economic reach and also suitable for most of their work. The main purpose of this book is to provide assistance to engineers and students who want to take their first step toward the application of computers for problem solving and design by way of the programmable calculator.

Some of my friends in academic circles have also mentioned the college students' concern about mainframe computers. While in college, these students have easy and inexpensive access to large computer systems on the campus. However, in real-life working situations, many of these students will have no access to large computers. These students are anxious to learn about the systems of the type they would be likely to encounter in the world outside the campus.

At present, the programmable calculator can in no way compete with the tremendous potential of the mainframe computer. However, programmable calculators do have their unique advantages which have attracted even those partial to the mainframe.

Why a Programmable Calculator?

When large, mainframe, electronic computers were first applied in the building design industry in the early 1960s, engineering jobs were presented to the mainframe computer in batches, and an engineer looking for the answers often had to wait days. Even today, the mainframe computer, costing thousands or millions of dollars, sits splendidly in glass-partitioned, air-conditioned rooms demanding, because of its expense, that it be kept working every possible second. Batch operation makes for the most efficient use of the mainframe computer.

This type of operation has made the computer remote from the engineer and the student, who cannot interact with a computer to ask brief questions and get immediate answers or to change the input data and see an immediate effect upon the results. "Timesharing" has been one solution, but has not been economical since it slows down the main computer, requires additional expensive hardware and software, and, in some cases, ties up expensive telephone lines.

Now engineers and students have many options, especially for small problems. One option is to have their own programmable calculators, costing only a few hundred dollars. The equipment is small enough to fit inside an attache case and is generally powered by rechargeable batteries so that it can be used while traveling. The programming language is simple and engineer oriented.

In recent years, the price of programmable calculators has dropped and their capability has increased. However, they will not replace the large mainframe computers, at least not in the near future. Computerized solutions of most engineering problems, as compared to business and accounting programs, do not require a large data base or elaborate output reports. Everyday engineering problems, involving repetitive and complex calculations, can now be handled easily on small, programmable calculators.

Problem solving in engineering is similar to going from one point to another. For short distances, a car may be more economical, while for long distances, a jet plane is indispensable. With a programmable calculator, the engineers have all the convenience of their own car for short-distance travel. On the other hand, it is foolish to use a jet plane for shopping in the neighborhood!

It is possible, considering the following specific advantages of programmable calculators, that more and more engineers will be attracted by their potential and the benefits applicable to their own areas of work:

- The equipment cost is relatively low and most engineers and offices can afford to have their own equipment.
- The equipment is small and portable and can be easily moved around from office, to home, to client's office, or taken on a trip.
- The engineer can solve problems instantly instead of putting up with the delay in turn-around time generally encountered with the mainframe computer systems. The immediate feedback will encourage engineers to test many alternate approaches to optimize the designs.
- Users do not have to waste time to complete the input forms generally required for use of programs on large computers.
- The building design process is constantly evolving. Multiple runs on the large computer, necessitated by these constant changes, can be expensive and time consuming. With programmable calculators, these changes do not become traumatic either in cost or in time delays.
- Greater accuracy of results can help in achieving exact sizing of systems and the selection of optimum equipment—all of which can minimize initial project cost, energy consumption, or life-cycle cost, depending on the project objectives.
- Because of the technical limitations of programmable calculators, the programs are developed in small modules which can be easily understood and modified by the engineer, instead of accepting the "black-box" concept of large programs.
- Since the programs and procedures are fully documented and easily understood, most of the calculations, especially when repetition is involved, can be performed by junior engineers and draftspersons with minimum supervision by a senior engineer. This arrangement saves time and money in addition to providing an efficient training tool.

It is hoped that this book will satisfy the needs of engineers wanting to benefit from programmable calculators, while serving as an aid in the training of engineers in offices and colleges.

ABOUT THE BOOK

The programs presented in this book have been developed for the following two calculators:

Texas Instrument TI-59 with PC-100A Printer
Hewlett-Packard HP-97

Other programmable calculators could have been included also. However, it was felt that the essential aspect was to present basic procedure and logic for solving problems on programmable calculators. The techniques are explained in detail in case users desire to apply them for any other models. It is hoped that basic procedures and logic will be equally valid for the future models.

If users desire, they can modify the programs so that they can obtain the answers with the calculator models not having a printer. It is recommended that users have a printer-type model, since a relatively small investment in the printer greatly amplifies the total return on the system. The printer provides the user with the following benefits:

- All intermediate answers are printed automatically, together with alphanumeric identification of the data. Without the printer, the program has to be modified to stop at each intermediate answer to enable the engineer to copy the figures. After copying the figures, the engineer can restart the program. This alternate procedure will take far more time and will increase the probability of error. Further, there would be no alphanumeric identification of data.
- The printer provides a record of both input and output.
- Even if the programs are tested and "debugged," the user could make input errors, which are difficult to detect without the written record.
- The printer is indispensable for revising and debugging programs.

Programming

Users will not have to learn Fortran or any other computer language to benefit from this book. If users do not wish to learn programming, they can still have all the advantages by copying the programs.

The main objective of this book is to encourage engineers and students to use programmable calculators for solving engineering problems without worrying about programming. If one were to make an analogy, this book is like a travel guide: it tells users what to see and do when they arrive at their location. It is not necessary to learn how to drive a car if one wants to travel, although, if one knows how to drive, one can have more freedom and fun while traveling. What driving a car is to traveling, programming is to engineering problem solving.

The programming techniques are quite simple and, in our office, we have been able to get the engineers started during the first session, which takes about two hours. Training in complete programming techniques takes three to four such sessions. From there on, the engineers must practice and apply the techniques to improve their programming skills. The following two books are excellent supplements to the manuals and handbooks which come with the calculators: *Programming Programmable Calculators,* by Harold S. Engelsohn; and *Programmable Calculators Business Application,* by Julius S. Aronofsky, Robert Frame, and Elber B. Grey, Jr.

As already mentioned, the programming techniques for the programmable calculator are simple, and engineers can improve their problem-solving abilities by learning to develop their own programs. On the other hand, it would waste a lot of engineering time and talent if all engineers developed their own programs. The objective of this book is to present basic programs for the building design profession so that engineers and students can avoid spending their time solving basic problems which have already been solved. However, they may find it very rewarding to modify these programs to meet their specific needs. Or, they could develop more complex design programs using basic programs in this book as building blocks. All the necessary information is given in the book to encourage users to make their own explorations.

The basic programs cannot satisfy the above objectives unless they are fully understood by engineers. Up to now, many engineers have been turned away from the computer program packages because they did not know, nor could they find out, the contents of the package. No attempt has been made to hide any information. On the contrary, users are encouraged to understand fully the contents and are at liberty to make all modifications required by them. They are given all the information about each program: description, theory involved, algorithm for solution, reference, program listing, user instructions, and trial examples.

Programming Arrangement

The main objective of programming has been to simplify its usage so that engineers could easily apply it for solving either a single problem or a series of similar problems. The secondary objective has been to "compress" the programs within the limitation of the equipment. Often, these objectives were contradictory, and the conflict was resolved in favor of simplification.

The programs have been limited to those which could be accommodated with a maximum of only two cards. Some engineering analyses require programs with more than two cards, and engineers with limited experience with programmable calculators may find such programs rather awkward and complex to use. Since the main objective has been to encourage application of programmable calculators to engineering problem solving, more advanced and complex programs could be the subject of a separate volume.

Since the programs have been developed over a period of two years, users will notice different techniques for solving similar problems. Once a program could fit within the limits of the programming steps, no attempt was made to eliminate the longer procedures. It was also felt that providing a variety of solutions would be beneficial to the learning experience.

It is possible to "compress" most of the programs further and reduce the programming steps. Actually, one can work on improving a program and never complete it! After all, better is the worst enemy of good. The users with expertise in programming can derive additional satisfaction by streamlining the programs further.

Most of the programs were originally developed for the TI-59 and were later converted for the HP-97. Some of the programs had to be changed completely to accommodate them within the limits of the programming steps for the HP-97. However, this was not a serious handicap and there has been no difference in the quality of the results. As a matter of fact, working with the HP-97 demonstrated that even long and complex engineering problems, if analyzed in small modules, can be handled by the HP-97, which has only 224 steps of programming.

One reviewer suggested that in order to encourage users to study the programs systematically, the programs should be graded by steps so that users do not get tangled up with a complex program at the very first attempt. The programs listed in the "Table of Contents" are identified as "Elementary," "Intermediate," and "Advanced," to indicate three levels of complexity. Users should try out the "Elementary" programs as the first step, the "Intermediate" programs as the next step, and, lastly, the "Advanced" programs.

The programs have been developed based on the following additional criteria:

- All input data are printed at the time of input so that the data can be verified before initiation of program calculation.
- Not only the final answer is printed, but a sufficient number of intermediate answers and variables are also printed so that users are assured that the calculations are done properly and they can get the feel of the entire process.
- In all cases, the input data are printed either at the time of input or with the answer to confirm the correctness of input and for ease of reading the output.
- As far as possible, the engineering procedures are adapted from the standard industry technical manuals, and references are given for further explanation. The lengthy explanations available in the reference texts are avoided, since this is not an engineering textbook.

Arrangement of the Book

Each program has the following sections:

- General Description
- Equations
- Operating Features
- Reference Data

For TI-59

- User Instructions and Examples
- Explanation of Labels and Subroutines
- Explanation of Storage Registers
- Program Listing

For HP-97

- Special Notes for HP-97 Users
- User Instructions and Examples
- Explanation of Labels and Subroutines
- Explanation of Storage Registers
- Program Listing

This arrangement minimized repetition since the first four sections are somewhat common to both of the calculators.

The "User Instructions and Examples" section follows techniques similar to those utilized in the manufacturers' instruction manuals.

Adequate practical examples are given to enable users to check the operation of the programs, keyed in by them in accordance with the "User Instructions and Examples."

Program Usage

Each program listing shows complete keying sequence so that users can easily key in the programs. It is a good practice to record the keyed-in program immediately on the magnetic card, even if the users suspect that they might have made a few errors in copying the programs. They can perform checking and editing later, but at least they will have a record of their keyed-in program. They should make a final copy of their corrected program: two copies are better than one, and the magnetic cards are inexpensive.

Next, users should read carefully and thoroughly the user instructions and test the program on the illustrated examples. If identical results are not obtained, users should recheck their programs and the "User Instructions and Examples." The program listings are produced by calculators from tested programs.

These programs have been used in actual engineering production of several projects, and modifications were made in both the programs and the working procedures to achieve the results in a most efficient manner. The necessary explanations are given with the programs.

It is reasonable to expect that users will make further innovative modifications in the programs and the working procedures to suit their own requirements. All the information is given to encourage users to make such modifications to enable them to derive full benefit from the programs.

Since the user is in full charge of the situation, the author cannot take any responsibility for the results or the use of the results.

TI-59 GENERAL DESCRIPTION OF PROGRAMS AND GENERAL INSTRUCTIONS FOR USERS

1. All programs have been developed in a modular manner, with generous use of subroutines. This slows down the program execution, but has the following advantages:

   a. Each subroutine can be checked and corrected independently.

   b. Subroutines can be combined to derive more results from a single program.

   c. Subroutines make it easy to understand and modify the programs.

2. Second-function (2nd) keys A′, B′, C′, D′, and E′ are generally used for one-time input only. The lower keys are used for repeated input in the interest of saving time.

3. Generous use has been made of alphanumeric characters for identification of data. In certain long programs, the alphanumeric identification has been minimized to fit the programs within the limits of programming steps.
The alphanumeric identification is limited to four characters, and, therefore, it is difficult to maintain complete consistency among the programs. However, the example for each program illustrates the function of the alphanumeric output.

4. No programs use absolute addressing or GTOxxx. While this instruction increases the program speed, it complicates any future changes and modifications.

5. Depending upon the extent of the data and length of the program, the data for computation are input in the following manner:

   a. *Directly through the Keyboard.* While this arrangement reduces the number of programming steps, users cannot get a record of input unless they put the printer in the TRACE mode. This method has been used very rarely.
   (Direct input through the keyboard can be helpful for correcting errors in input. That is one reason for explaining the function of all storage registers.)

   b. *Through Program Keys.* Most programs have been developed for input through programming keys. In this manner, the user gets an immediate print-out of the input, and any changes and corrections can be made immediately before proceeding to the next step.
   Corrections or changes can be performed easily in all cases, except when the result is totalized for the constant running total. In that instance, it is necessary to change the contents of the register, which totalizes the result.
   In some cases, this can be accomplished by using a negative entry.

   c. *Through the R/S Key.* Often, the data input exceeds the number of keys, in which case the data is entered through the R/S key.

   d. *Prompting Mode through the R/S Key.* This method has been adopted for programs requiring input of large amounts of data. Any corrections have to be made through the keyboard directly into the storage registers.

6. All the two-card programs are self-partitioning. After loading the program, the first instruction partitions the program.

7. The following instructions are suggested for "loading" the programs from magnetic cards to the calculator, and also for "recording" on new cards.

Instructions for Loading and Recording (Key Sequence)

To Load—1-Card Program
   2nd CP CLR
   INV 2nd Fix
   CLR INV 2nd Write—(Insert side 1)
   CLR INV 2nd Write—(Insert side 2)

To Load—2-Card Program (Self-partitioning)
   2nd CP CLR
   INV 2nd Fix
   CLR INV 2nd Write—(Insert side 1)
   CLR INV 2nd Write—(Insert side 2)
   CLR INV 2nd Write—(Insert side 3)
   CLR INV 2nd Write—(Insert side 4)

The program must be initialized to partition before any other function is performed.

To Load—2-Card Program (Requiring partitioning)
   2nd CP CLR
   INV 2nd Fix

xx 2nd OP 17 (xx partition number)
CLR INV 2nd Write—(Insert side 1)
CLR INV 2nd Write—(Insert side 2)
CLR INV 2nd Write—(Insert side 3)
CLR INV 2nd Write—(Insert side 4)

To Record—1-Card Program
INV 2nd Fix
CLR 1 2nd Write—(Insert side 1)
CLR 2 2nd Write—(Insert side 2)

To Record a 2-Card Program and make it self-partitioning:
Initialize
INV 2nd Fix CLR
6 2nd OP 17 CLR
INV 2nd Fix CLR
CLR 1 2nd Write—(Insert side 1)
CLR 2 2nd Write—(Insert side 2)
CLR 3 2nd Write—(Insert side 3)
CLR 4 2nd Write—(Insert side 4)

8. In some programs, the first step is initialization, which changes the contents of the totalizing registers to zero and also partitions the programs as required. It is necessary to initialize when a new problem is started.

9. Some inputs are in decimal format, which allows input of two variables at one time. The users should note carefully the number of decimal places required for correct input.

10. All programs are based on a "Master Library" module, which is included with the calculator.

11. All examples start with the assumption that the user has correctly loaded the program.
The program requiring partitioning will not function or list unless it is initialized, which is what causes the program to partition.

12. Some programs use the R/S key in the middle of the program for repeated analysis. If key RST is pressed by mistake, the following operations will take place:

a. The original sequence or position of the program is lost.

b. All flags are cleared or reset.

c. The program goes to the first step.

The error can be corrected in the following manner:

a. Set all the desired flags.

b. From program documentation, find out subroutines SBR *n* which initially started R/S operation. Press GTO *n* (*n* being the name of the subroutine). Input data and press R/S.

When the program stops, press R/S again, and, from there on, the program will come back to the desired sequence.

13. Each program section has an "Explanation of Storage Registers," which can be of great value in problem solving as explained below:

a. In case of an incorrect input, the execution of the program can be corrected immediately by inputting correct data directly into the storage register so as to avoid repeating the entire program sequence.

b. The contents of any storage register can be checked if some problem is encountered.

c. Suppose a user is working on a program, similar to, say, PP-2 or LP-1, and desires to discontinue computation before completing the entire sequence of pipe runs or rooms and would like to continue the computation at a later time or date. The user could do this by listing the contents of all the storage registers by keying in sequence, INV 2nd Fix. Later, after loading the program, the user can restart from the original point by first inputting data directly into the storage registers.

HP-97 GENERAL DESCRIPTION OF PROGRAMS AND GENERAL INSTRUCTIONS FOR USERS

1. All programs have been developed in a modular manner, with generous use of subroutines. This slows down the program, but has the following advantages:
   - **a.** Each subroutine can be checked and corrected independently.
   - **b.** Subroutines can be combined to derive more results from a single program.
   - **c.** Subroutines make it easy to understand and modify the programs.
2. Second-function (2nd) keys a, b, c, d, and e are generally used for one-time input only. The lower keys are used for repeated input in the interest of saving time.
3. The illustrated examples show identification of both input and output data. Users could make similar forms for permanent records of their executed problems.
4. No programs use absolute addressing. While this instruction increases the program speed, it complicates the making of any future changes and modifications.
5. Program data can be input in the following manner:
   - **a.** *Directly through the Keyboard.* While this arrangement reduces the number of programming steps, users cannot get records of input unless they put the printer in TRACE mode. This method has been used very rarely.
   - **b.** *Through Program Keys.* Most programs have been developed for input through programming keys. In this manner, the user gets an immediate print-out of the input, and any changes and corrections can be done immediately before proceeding to the next step. Corrections or changes can be performed easily in all cases, except when the result is summed to obtain the constant running total. In that instance, it is necessary to change the contents of the register which sums the result. In some cases, this can be accomplished by using a negative entry.
   - **c.** *Through the R/S Key.* Often, the data input exceeds the number of keys, in which case the data is entered through the R/S key.
6. Users should study the "Owners Handbook and Programming Guide" for loading program and data cards.
7. In some programs, the first step is initialization, which changes the contents of the totalizing registers to zero. It is necessary to initialize when a new problem is started.
8. Some inputs are in decimal format, which allows input of all the variables at one time. Users should note carefully the number of decimal places required for correct input.
9. All examples start with the assumption that the user has correctly loaded the program.
10. Due to the limitations of the programming steps, it is not feasible to maintain complete consistency between TI-59 and HP-97 programs, especially in the arrangement of input and output. However, the differences are insignificant.
11. Any modifications to the program description part are given separately before the "User Instructions and Examples" for HP-97.
12. In order to minimize the programming steps, the display generally is not controlled from the program. Users can change the display from the keyboard.
13. Each program section has an "Explanation of Storage Registers" which can be of great value in problem solving as explained below:
   - **a.** In case of an incorrect input, the execution of the program can be corrected immediately by inputting correct data directly into the storage register so as to avoid repeating the entire program sequence.
   - **b.** Contents of any storage register can be checked if some problem is encountered.
   - **c.** Suppose a user is working on a program similar to, say, PP-2 or LP-1, and desires to discontinue computation before completing the entire sequence of pipe runs or rooms and would like to continue the computation at a

later time or date. The user could do this by listing the contents of all the data registers or by recording data on a card. Later, after loading the program, the user can restart from the original point by first inputting data either through data cards or through the keyboard.

14. "Enter" instruction under 'Procedure' part of the "User Instructions and Examples" relates to data input and should not be confused with the 'Enter' key which when required is shown clearly under 'Press' column.

1
PIPING DESIGN PROGRAMS

PP-1
GENERAL PIPING SYSTEM DESIGN PROGRAM

GENERAL DESCRIPTION

This program can be used for any fluids, since the program computes the friction factor by first determining the Reynolds number for each input. While the results have a high degree of accuracy, the program is somewhat slow since the friction factor f number is determined by reiteration. Often it takes more than six reiterations to complete the calculation.

If the program is to be used for general water systems, the user also has the choice of a faster program, PP-2, which is based on the Williams-Hazen formula and gives reasonably accurate results for HVAC and Sanitary Engineering for water temperatures from 40 to 180°F. The user could also develop programs similar to PP-2 for fluids and piping systems commonly handled by them based on the f values, which can be determined from Program PP-1.

It is recommended that all the node points of the piping distribution system be numbered so that each section can be identified. Program UP-3 has been developed for adding flows from terminals as well as for delineating the piping circuits prior to sizing and determining friction loss. Examples No. 1 and 2 show application of Program UP-3.

EQUATIONS

Basic Fanning equation:

$$h_f = f \times L \times V^2/2 \times g \times D \qquad [1.1]$$

where

h_f = Loss of head in feet of fluid at average pressure and temperature in the pipe
L = Length of pipe in feet
V = Average velocity of fluid in pipe, fps
g = Gravitational constant 32.2 fps/sec
D = Internal diameter of pipe in feet
f = Friction factor

The program is based on the following modifications of the above formula:

L = 100 ft
D = Internal diameter in inches
h_f = Loss of head in psi

The revised equation is, therefore:

$$h_f = f \times 100 \times V^2 \times DS/2 \times 32.2 \times D \times 12$$
$$= f \times V^2 \times DS/D \times 7.73 \qquad [1.2]$$

where
DS = Specific weight of fluid in lb/cu ft

$$R = V \times D/\gamma \times 12 \quad [1.3]$$

where
γ = Kinematic viscosity in ft²/sec

Since kinematic viscosity values are usually tabulated in centipoises, the above equation can be rearranged by the following relationship:

$$\gamma = 0.00067 \times \mu/DS$$

where
μ = Viscosity in centipoises

Substituting in equation 1.3,

$$R = V \times D \times DS/\mu \times .00067 \times 12$$
$$= V \times D \times DS \times 124/\mu \quad [1.4]$$

If $R<2100$, $f = 64/2100$

The Colebrook equation for f is:

$$1/\sqrt{f} = -2 \log_{10} e \times 12/3.7 \times D + 2.51/R \times \sqrt{f} \quad [1.5]$$

where
e = Mean depth of surface roughness

If $Z = \dfrac{1}{\sqrt{f}}$, equation 1.5 can be rearranged

$$0 = Z + 2 \log_{10} [3.2 \times e/D + 2.51 \times Z/R]$$

The program solves the above equation by reiteration and finds the value of Z and f.

Dynamic losses for the fitting in psi

$$= FF \times DS \times V^2/(2 \times g \times 144)$$
$$= FF \times DS \times V^2/9{,}274 \quad [1.6]$$

where
FF = Total of fitting K factors for particular run

$$V = Q \times 576/(\pi \times DS \times D^2) \quad [1.7]$$

where
Q = Flow rate in lb/sec

For gases and vapors

$$DSX = DSI \times PAX/PAI \quad [1.8]$$

where
DSX = Specific weight at new pressure PAX
DSI = Specific weight at initial pressure PAI
PAX/PAI = New absolute and initial pressure

OPERATING FEATURES

The program can be used for determining flow rate capacities of the piping system based on the specified maximum velocity and pressure drop per 100 ft. Input of the maximum velocity sets up the internal flag for this computation. This flag has to be reset by pressing key 2nd E′. After that, the program will be ready for computing velocity and pressure drop based on the flow rates, pipe size, and description of the fittings. It should be noted that maximum velocity criteria are used for pipe sizing only and do not enter into the calculations when the program computes the pressure loss.

When computing the pressure drop, the program prints out continuous total pressure loss so that the designer can monitor it to ensure that the total pressure loss will not exceed the desired limit. The program allows the user to change the pressure drop and the pipe size so as not to exceed the desired total pressure loss. Since the pressure losses are printed out for all the node points, this information can be utilized for sizing the branch piping so as to equalize pressure loss of all the circuits in order to minimize pipe sizes within the limits of maximum velocity.

Designers can input either nominal pipe diameter or actual internal diameter, depending on the accuracy desired.

TABLE 1

Input and Output Format for Data		Conversion Factor
Flow:	lb/sec	1
	lb/min	1/60
	lb/hr	1/3600
	gal/sec	8.33
	gal/min	8.33/60
	gal/hr	8.33/3600
	cu ft/sec	DS
	cu ft/min	DS/60
	cu ft/hr	DS/3600
	DS = Specific density	
	Velocity—fps	1
	fpm	60
	fph	3600
	Pressure—psi	1
	Ft of water	2.31
	In. of water	27.74

As mentioned, the program can be used for all fluids. Generally, designers use different pressure and flow units for the liquids than for the gases. The basic program is based on the following units:

Pressure—psi
Velocity—fps
Flow—lb/sec

However, any other units can be used by inputting conversion constants. Table 1 shows some of the suggested conversion constants, and users can develop additional constants required by them.

The initial input, which requires eight items of data, is arranged in prompting mode for the convenience of users. *PA*, absolute pressure, has to be input for gases so that the program can compute the changes in the specific density. The program skips this step for liquids. This is achieved by inputting 0 for gases and 1 for liquids after prompt *G/L*.

The later input is not in the prompting mode since this arrangement expedites computation and saves paper.

REFERENCE DATA

Users should refer to the following manuals to obtain data for coefficients for fittings and pipe roughness factors:

ASHRAE *Handbook of Fundamentals*

Thermodynamic Properties of Water Including Vapor, Liquid and Solid Phases, by J. H. Keenan, F. G. Keyes, D. G. Hill, and J. G. Moore

Hydraulic Institute Pipe Friction Manual

EXAMPLE NO. 1

Determine pipe sizes and pressure loss for a steam system having the following data:

1. Absolute pressure at entrance	150 psi
2. Surface roughness of piping system	0.00017
3. Specific weight of steam at entrance	0.3316 lb/cu ft
4. Viscosity in centipoise	0.0158
5. Maximum velocity	11,000 fpm
6. Maximum pressure loss	3.5 psi

Run No. 1.02*

Flow	10,000 lb/hr
Piping length	250 ft
K factor for fittings	3.5

```
    1.02        R.NO
10000.00          QB
10000.00          QM
    0.00         DIA
    0.00  250      L
    0.00  3.5     FF
```

Run No. 2.03*

Flow	71,000 lb/hr
Piping length	150 ft
K factor for fittings	1.5

```
    2.03        R.NO
61000.00          QB
71000.00          QM
    0.00         DIA
    0.00  150      L
    0.00  1.5     FF
```

*These outputs have been obtained from Program UP-3. See page 295.

EXAMPLE NO. 2

Determine pipe sizes and pressure loss for hot water system having the following data:

1. Water temperature	350°F.
2. Surface roughness of piping system	.00013
3. Specific weight of water at design condition	55.29 lb/cu ft
4. Viscosity in centipoise	0.16
5. Equipment pressure loss	3.27 ft
6. Maximum velocity	7.5 fps
7. Maximum pressure loss	4 ft/100 ft

Run No. 1.02*

Flow	2500 gpm
Piping length	139 ft
K factor for fittings	2.9

```
   1.02        R.NO
2500.00          QB
2500.00          QM
   0.00         DIA
   0.00  139      L
   0.00  2.9     FF
```

Run No. 2.03*

Flow	1800 gpm
Piping length	120 ft.
K factor for fittings	3.7

```
   2.03        R.NO
-700.00          QB
1800.00          QM
   0.00         DIA
   0.00  120      L
   0.00  3.7     FF
```

*These outputs have been obtained from Program UP-3. See page 295.

PP-1
GENERAL PIPING SYSTEM DESIGN PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Initialize	—	—	2nd	E′		
2.	Enter conversion factor for pressure to convert to psi	1	—	—	R/S	CF 1.	What is conversion factor for pressure?
3.	Enter conversion factor for velocity to convert to fpm	60	—	—	R/S	CV 60.	What is conversion factor for velocity?
4.	Enter conversion factor for flow rate to convert to lb/hr	3600	—	1/x	R/S	CQ 000277778	What is conversion factor for flow rate?
5.	Enter pipe surface roughness	0.00017	—	—	R/S	e 0.00017	What is pipe surface roughness?
6.	Enter specific density of steam at 150 psi absolute	.3316	—	—	R/S	DS 0.3316	What is specific density of fluid?
7.	Enter viscosity in centipoise at 150 psi absolute	.0158	—	—	R/S	VS 0.0158	What is viscosity?
8.	Enter 0 for gas	0	0	0	R/S	G/L 0.	Is it gas or liquid?
9.	Enter absolute pressure	150	—	—	R/S	PA 150.	What is absolute pressure?
	To calculate flow rate for different pipe sizes						
10.	Enter maximum allowable velocity	11000	—	2nd	A′	11000.00 VM	
11.	Enter maximum allowable pressure drop	3.5	—	2nd	B′	3.50 PD/C	
12.	Enter diameter	12	—	—	B	12.00 DIA 171889.10 Q 11000.00 V 1.62 PD/C	 Flow, lb/hr Velocity, fpm Pressure drop, psi/100 ft

	Repeat step 12 as many times as desired.	10	–	–	B	10.00 119367.43 11000.00 2.02	DIA Q V PD/C	
		8	–	–	B	8.00 76395.16 11000.00 2.64	DIA Q V PD/C	
	The above information can be used for pipe sizing.	6	–	–	B	6.00 41541.93 10633.86 3.50	DIA Q V PD/C	
13.	Initialize and reset flag 0 for calculating p.d.	–	–	2nd	E′	CP		Without initialization, program will not compute pressure loss.
14.	Enter run no.	1.02	–	–	A	1.02	R.NO	
15.	Enter pipe diameter	10	–	–	B	10.00	DIA	
16.	Enter flow rate	100,000	–	–	C	100000.00 9215.24 1.42	Q V PD/C	 Velocity, fpm Pressure drop, psi/100 ft
17.	Enter length	250	–	–	D	250.00	L	
18.	Enter total *K* factor for fittings	3.5	–	–	E	3.50 6.51 6.51	FF PD ΣPD	 Pressure drop Total pressure drop
	Repeat steps 14 through 18.							
		2.03	–	–	A	2.03	R.NO	
		10	–	–	B	8.00	DIA	
		7100	–	–	C	71000.00 10686.62 2.39	Q V PD/C	
		150	–	–	D	150.00	L	
		1.50	–	–	E	1.50 5.21 11.72	FF PD ΣPD	

PP-1 *(Continued)*

GENERAL PIPING SYSTEM DESIGN PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	If users desire, they can find *f* value, new specific density, or the value of any other constants with the printer in TRACE mode.						
						CLR	
19.	To find *f* value	–	RCL	2	7	0. RCL 27	
						.0146800104	*f* value
						.0146800104 RCL 19	
20.	To find specific density	–	RCL	1	9	.2924418047	Specific density
	Example 2						
1.	Initialize	–	–	2nd	E′	CP	What is conversion factor for pressure?
2.	Enter conversion factor for pressure to convert to ft	2.3	–	–	R/S	2.3	
3.	Enter conversion factor for velocity to convert to fps	1	–	–	R/S	CV 1.	What is conversion factor for velocity?
4.	Enter conversion factor for flow rate to convert to gpm	8.33÷60	–	–	R/S	CQ .1388333333	What is conversion factor for flow rate?
5.	Enter surface roughness	0.00013	–	–	R/S	e 0.00013	What is surface roughness?
6.	Enter specific density	55.29	–	–	R/S	DS 55.29	What is specific density of fluid?
7.	Enter viscosity in centipoise	0.16	–	–	R/S	VS 0.16	What is viscosity?
8.	Enter 1 for liquid	1	–	–	R/S	G/L 1.	Is it gas or liquid?

	To calculate flow rate for different pipe sizes repeat steps 10 through 12 from Example no. 1.						
		7.5	–	2nd	A′	7.50 VM	
		4	–	2nd	B′	4.00 PD/C	
		12	–	–	B	12.00 DIA 2345.87 Q 7.50 V 1.00 PD/C	
		14	–	–	B	14.00 DIA 3192.99 Q 7.50 V 0.83 PD/C	
		8	–	–	B	8.00 DIA 1042.61 Q 7.50 V 1.63 PD/C	
	Initialize and reset flag 0 for calculating p.d. Repeat steps 14 through 18 from Example no. 1.	–	–	2nd	E′	CP	
		1.02	–	–	A	1.02 R.NO	
		12	–	–	B	12.00 DIA	– Changed to 14-in. diameter. Repeat steps 14 through 16.
		2500	–	–	C	2500.00 Q 7.99 V	
		1.02	–	–	A	1.02 R.NO	
		14	–	–	B	14.00 DIA	
		2500	–	–	C	2500.00 Q 5.87 V 0.51 PD/C	
		139	–	–	D	139.00 L	
		2.9	–	–	E	2.90 FF 2.09 PD 2.09 ΣPD	

PP-1 *(Continued)*

GENERAL PIPING SYSTEM DESIGN PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
		2.03	–	–	A	2.03	R.NO	
		12	–	–	B	12.00	DIA	
		1800	–	–	C	1800.00	Q	
						5.75	V	
						0.59	PD/C	
		120	–	–	D	120.00	L	
		3.7	–	–	E	3.70	FF	
						2.39	PD	
						4.48	ΣPD	
						3.27	EPD	
						7.75	ΣPD	
	To find *f*	–	RCL	2	7	0.	RCL	
							27	
						.0130824705		

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
INV	Prints alphanumeric identification of data
LNX	Prints questioning, prompts, and partitions
E′	Resets flag 1, stores initial value of *f* as .03, clears registers R16 and R29, prints prompt CP;
	with R/S, prints and stores display in R24 and prints CV;
	with R/S, prints and stores display in R23 and prints CQ;
	with R/S, prints and stores display in R22 and prints *e;*
	with R/S, prints and stores display in R18 and prints DS;
	with R/S, prints and stores display in R19 and prints VS;
	with R/S, prints and stores display in R20 and prints GL;
	with R/S, prints display if zero goes to SBR CLR, otherwise sets flag 0
CE	Prints CP, CV, and CQ
CLR	Sets and resets flag 0 for gas; prints PA;
	with R/S, prints and stores display in R25
A	Prints display and R No.
B	Calls SBR — and stores display in R11
C	Calls SBR SBR; converts flow to lb/hr using R22; computes and prints velocity; computes and prints pressure drop/100 ft
EE	Computes *f*
1/X	Reiterates for computing *f*
STO	Reiterates for computing *f*
$\sqrt{X}$	Stores 0.031 in R27 if flow is laminar
RCL	Computes pressure drop/100 ft; if flag 1 is set goes to SBR), otherwise prints value
SUM	Prints PD/C
—	Prints DIA
SBR	Prints Q
RST	Prints V
D	Stores display in R13 and prints display and L
E	Stores display in R14; prints display and FF; computes friction and dynamic loss; prints values; calls SBR Y^x
Y^x	Adds and totalizes pressure drop in R16; if flag 0 is set goes to R/S, otherwise adjusts specific weight for new pressure
R/S	Stops
A′	Prints and stores displays in R13; prints VM; converts R13 to velocity in FPS; sets flag 1; computes flow for 1-in. pipe and stores in R06
B′	Prints and stores display
X⇄T	Computes flow for a given pipe; computes pressure loss using SBR EE and if higher than limit goes to SBR), otherwise corrects flow units and prints data
)	Reduces velocity and flow in proportion required and prints data
÷	Prints data

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	DSZ for solving value of *f*
R01	Not used
R02	STO and RCL IND
R03	For solving value of *f*
R04	For solving vlaue of *f*
R05	PD/C
R06	QV1 = flow for 1-in. pipe
R07	$1/\sqrt{f}$
R08	3.24 × *e*/D
R09	1EE−3
R10	Reynolds number
R11	Diameter
R12	Flow
R13	Length; also velocity VM
R14	Fitting factor
R15	For adding or deducting pressure drop
R16	For total pressure drop
R17	Velocity maximum
R18	*e*,roughness
R19	Density, lb/cu ft
R20	Viscosity
R21	Velocity
R22	Constant for input flow conversion
R23	Constant for velocity conversion
R24	Constant for PD conversion
R25	Absolute pressure
R26	Limiting PD/C
R27	*f*
R28	Not used
R29	Alphanumeric code

PP-1 GENERAL PIPING SYSTEM DESIGN PROGRAM

LABELS & SUBROUTINES

001	22	INV
018	23	LNX
035	10	E'
133	24	CE
144	25	CLR
164	11	A
180	12	B
190	13	C
229	52	EE
279	35	1/X
286	42	STO
352	34	√X
364	43	RCL
401	44	SUM
417	75	-
431	71	SBR
441	81	RST
451	14	D
464	15	E
518	45	Y^X
554	91	R/S
558	16	A'
595	17	B'
603	32	X:T
639	54	)
680	55	÷
696	19	D'

LISTING

000	76	LBL
001	22	INV
002	22	INV
003	58	FIX
004	25	CLR
005	69	OP
006	00	00
007	43	RCL
008	29	29
009	69	OP
010	04	04
011	32	X:T
012	58	FIX
013	02	02
014	69	OP
015	06	06
016	92	RTN
017	76	LBL
018	23	LNX
019	22	INV
020	58	FIX
021	03	3
022	69	OP
023	17	17
024	25	CLR
025	69	OP
026	00	00
027	43	RCL
028	29	29
029	69	OP
030	02	02
031	69	OP
032	05	05
033	92	RTN
034	76	LBL
035	10	E'
036	22	INV
037	86	STF
038	01	01
039	06	6
040	42	STO
041	07	07
042	00	0
043	42	STO
044	16	16
045	42	STO
046	29	29
047	71	SBR
048	24	CE
049	91	R/S
050	42	STO
051	24	24
052	99	PRT
053	98	ADV
054	09	9
055	42	STO
056	29	29
057	71	SBR
058	24	CE
059	91	R/S
060	42	STO
061	23	23
062	99	PRT
063	98	ADV
064	01	1
065	42	STO
066	29	29
067	71	SBR
068	24	CE
069	91	R/S
070	42	STO
071	22	22
072	99	PRT
073	98	ADV
074	05	5
075	04	4
076	42	STO
077	29	29
078	71	SBR
079	23	LNX
080	91	R/S
081	42	STO
082	18	18
083	99	PRT
084	98	ADV
085	01	1
086	06	6
087	03	3
088	06	6
089	42	STO
090	29	29
091	71	SBR
092	23	LNX
093	91	R/S
094	42	STO
095	19	19
096	99	PRT
097	98	ADV
098	04	4
099	02	2
100	03	3
101	06	6
102	42	STO
103	29	29
104	71	SBR
105	23	LNX
106	91	R/S
107	42	STO
108	20	20
109	99	PRT
110	98	ADV
111	02	2
112	02	2
113	06	6
114	03	3
115	02	2
116	07	7
117	42	STO
118	29	29
119	71	SBR
120	23	LNX
121	29	CP
122	91	R/S
123	99	PRT
124	98	ADV
125	67	EQ
126	25	CLR
127	86	STF
128	00	00
129	98	ADV
130	98	ADV
131	91	R/S
132	76	LBL
133	24	CE
134	01	1
135	05	5
136	03	3
137	03	3
138	44	SUM
139	29	29
140	71	SBR
141	23	LNX
142	92	RTN
143	76	LBL
144	25	CLR
145	22	INV
146	86	STF
147	00	00
148	03	3
149	03	3
150	01	1
151	03	3
152	42	STO
153	29	29
154	71	SBR
155	23	LNX
156	91	R/S
157	42	STO
158	25	25
159	99	PRT
160	98	ADV
161	98	ADV
162	92	RTN
163	76	LBL
164	11	A
165	32	X:T
166	03	3
167	05	5
168	04	4
169	00	0
170	03	3
171	01	1
172	03	3
173	02	2
174	42	STO
175	29	29
176	71	SBR
177	22	INV
178	91	R/S
179	76	LBL
180	12	B
181	42	STO
182	11	11
183	71	SBR
184	75	-
185	87	IFF
186	01	01
187	32	X:T
188	91	R/S
189	76	LBL
190	13	C
191	71	SBR
192	71	SBR
193	98	ADV
194	53	(
195	24	CE
196	65	×
197	43	RCL
198	22	22
199	54	)
200	42	STO
201	12	12
202	53	(
203	53	(
204	43	RCL
205	12	12
206	65	×
207	05	5
208	07	7
209	06	6
210	55	÷
211	89	π
212	55	÷
213	43	RCL
214	19	19
215	55	÷
216	43	RCL
217	11	11

```
218  33  X²
219  54  )
220  42  STO
221  21  21
222  65  ×
223  43  RCL
224  23  23
225  54  )
226  71  SBR
227  81  RST
228  76  LBL
229  52  EE
230  02  2
231  01  1
232  00  0
233  00  0
234  32  X:T
235  53  (
236  43  RCL
237  21  21
238  65  ×
239  43  RCL
240  11  11
241  65  ×
242  43  RCL
243  19  19
244  65  ×
245  01  1
246  02  2
247  04  4
248  55  ÷
249  43  RCL
250  20  20
251  54  )
252  42  STO
253  10  10
254  22  INV
255  77  GE
256  34  √X
257  01  1
258  52  EE
259  03  3
260  94  +/-
261  42  STO
262  09  09
263  32  X:T
264  53  (
265  03  3
266  93  .
267  02  2
268  04  4
269  65  ×
270  43  RCL
271  18  18
272  55  ÷
273  43  RCL
274  11  11
275  54  )
276  42  STO
277  08  08
278  76  LBL
279  35  1/X
280  02  2
281  42  STO
282  02  02
283  42  STO
284  00  00
285  76  LBL
286  42  STO
287  69  OP
288  22  22
289  43  RCL
290  09  09
291  44  SUM
292  07  07
293  53  (
294  43  RCL
295  07  07
296  85  +
297  53  (
298  53  (
299  43  RCL
300  08  08
301  85  +
302  02  2
303  93  .
304  05  5
305  01  1
306  65  ×
307  43  RCL
308  07  07
309  55  ÷
310  43  RCL
311  10  10
312  54  )
313  28  LOG
314  54  )
315  65  ×
316  02  2
317  54  )
318  72  ST*
319  02  02
320  50  I×I
321  22  INV
322  77  GE
323  43  RCL
324  97  DSZ
325  00  00
326  42  STO
327  53  (
328  43  RCL
329  09  09
330  65  ×
331  53  (
332  02  2
333  85  +
334  43  RCL
335  04  04
336  55  ÷
337  53  (
338  24  CE
339  75  -
340  43  RCL
341  03  03
342  54  )
343  54  )
344  54  )
345  22  INV
346  44  SUM
347  07  07
348  71  SBR
349  35  1/X
350  92  RTN
351  76  LBL
352  34  √X
353  53  (
354  93  .
355  00  0
356  03  3
357  01  1
358  42  STO
359  27  27
360  71  SBR
361  43  RCL
362  92  RTN
363  76  LBL
364  43  RCL
365  43  RCL
366  07  07
367  33  X²
368  35  1/X
369  42  STO
370  27  27
371  53  (
372  24  CE
373  65  ×
374  43  RCL
375  24  24
376  65  ×
377  43  RCL
378  19  19
379  65  ×
380  43  RCL
381  21  21
382  33  X²
383  55  ÷
384  07  7
385  93  .
386  07  7
387  03  3
388  55  ÷
389  43  RCL
390  11  11
391  54  )
392  42  STO
393  05  05
394  87  IFF
395  01  01
396  91  R/S
397  71  SBR
398  44  SUM
399  92  RTN
400  76  LBL
401  44  SUM
402  32  X:T
403  03  3
404  03  3
405  01  1
406  06  6
407  06  6
408  03  3
409  01  1
410  05  5
411  42  STO
412  29  29
413  71  SBR
414  22  INV
415  92  RTN
416  76  LBL
417  75  -
418  32  X:T
419  01  1
420  06  6
421  02  2
422  04  4
423  01  1
424  03  3
425  42  STO
426  29  29
427  71  SBR
428  22  INV
429  92  RTN
430  76  LBL
431  71  SBR
432  32  X:T
433  03  3
434  04  4
435  42  STO
436  29  29
437  71  SBR
438  22  INV
439  92  RTN
440  76  LBL
441  81  RST
442  32  X:T
443  04  4
444  02  2
445  42  STO
446  29  29
447  71  SBR
448  22  INV
449  92  RTN
450  76  LBL
451  14  D
452  98  ADV
453  42  STO
454  13  13
455  32  X:T
456  02  2
457  07  7
458  42  STO
459  29  29
460  71  SBR
461  22  INV
462  91  R/S
463  76  LBL
464  15  E
465  42  STO
466  14  14
467  32  X:T
468  02  2
469  01  1
470  02  2
471  01  1
472  42  STO
473  29  29
```

```
474  71 SBR
475  22 INV
476  53  (
477  43 RCL
478  13  13
479  65  ×
480  43 RCL
481  05  05
482  55  ÷
483  01  1
484  00  0
485  00  0
486  85  +
487  43 RCL
488  14  14
489  65  ×
490  43 RCL
491  19  19
492  65  ×
493  43 RCL
494  24  24
495  65  ×
496  43 RCL
497  21  21
498  33 X²
499  55  ÷
500  09  9
501  02  2
502  07  7
503  04  4
504  54  )
505  32 X⇌T
506  03  3
507  03  3
508  01  1
509  06  6
510  42 STO
511  29  29
512  71 SBR
513  22 INV
514  71 SBR
515  45 Yˣ
516  91 R/S
517  76 LBL
518  45 Yˣ
519  44 SUM
520  16  16
521  43 RCL
522  16  16
523  32 X⇌T
524  07  7
525  07  7
526  03  3
527  03  3
528  01  1
529  06  6
530  42 STO
531  29  29
532  71 SBR
533  22 INV
534  98 ADV
535  87 IFF
536  00  00
537  91 R/S
538  53  (
539  53  (
540  43 RCL
541  25  25
542  75  -
543  43 RCL
544  16  16
545  54  )
546  55  ÷
547  43 RCL
548  25  25
549  54  )
550  49 PRD
551  19  19
552  92 RTN
553  76 LBL
554  91 R/S
555  92 RTN
556  91 R/S
557  76 LBL
558  16 A'
559  42 STO
560  13  13
561  32 X⇌T
562  04  4
563  02  2
564  03  3
565  08  8
566  42 STO
567  29  29
568  71 SBR
569  22 INV
570  55  ÷
571  43 RCL
572  23  23
573  95  =
574  42 STO
575  17  17
576  86 STF
577  01  01
578  53  (
579  89  π
580  65  ×
581  43 RCL
582  17  17
583  65  ×
584  43 RCL
585  19  19
586  55  ÷
587  05  5
588  07  7
589  06  6
590  54  )
591  42 STO
592  06  06
593  92 RTN
594  76 LBL
595  17 B'
596  71 SBR
597  44 SUM
598  42 STO
599  26  26
600  98 ADV
601  91 R/S
602  76 LBL
603  32 X⇌T
604  53  (
605  24 CE
606  33 X²
607  65  ×
608  43 RCL
609  06  06
610  54  )
611  42 STO
612  12  12
613  43 RCL
614  17  17
615  42 STO
616  21  21
617  71 SBR
618  52 EE
619  43 RCL
620  26  26
621  32 X⇌T
622  43 RCL
623  05  05
624  77 GE
625  54  )
626  43 RCL
627  22  22
628  22 INV
629  49 PRD
630  12  12
631  43 RCL
632  13  13
633  42 STO
634  21  21
635  71 SBR
636  55  ÷
637  92 RTN
638  76 LBL
639  54  )
640  53  (
641  53  (
642  43 RCL
643  26  26
644  55  ÷
645  43 RCL
646  05  05
647  54  )
648  34 √X
649  42 STO
650  14  14
651  65  ×
652  43 RCL
653  17  17
654  65  ×
655  43 RCL
656  23  23
657  54  )
658  42 STO
659  21  21
660  53  (
661  43 RCL
662  12  12
663  65  ×
664  43 RCL
665  14  14
666  55  ÷
667  43 RCL
668  22  22
669  54  )
670  42 STO
671  12  12
672  43 RCL
673  26  26
674  42 STO
675  05  05
676  71 SBR
677  55  ÷
678  92 RTN
679  76 LBL
680  55  ÷
681  43 RCL
682  12  12
683  71 SBR
684  71 SBR
685  43 RCL
686  21  21
687  71 SBR
688  81 RST
689  43 RCL
690  05  05
691  71 SBR
692  44 SUM
693  98 ADV
694  91 R/S
695  76 LBL
696  19 D'
697  32 X⇌T
698  01  1
699  07  7
700  03  3
701  03  3
702  01  1
703  06  6
704  42 STO
705  29  29
706  71 SBR
707  22 INV
708  71 SBR
709  45 Yˣ
710  91 R/S
711  00  0
712  00  0
713  00  0
714  00  0
715  00  0
```

SPECIAL NOTES FOR HP-97 USERS

1. As shown in the "User Instructions and Examples," some of the fixed data has to be input directly through the keyboard. This should be done with the printer in the TRACE mode so that proper record is kept of the data.
2. The program has two flags:

   Flag 0— Set flag 0 for liquid. Clear flag 0 for gases and vapor.

   Flag 1— Set flag 1 for pipe sizing. Clear flag 1 for pressure loss calculations.

   Flag 1 is set automatically, by input under "Labels." Both the flags have to be cleared manually.
3. The totalizing register R9 should be cleared manually prior to starting a new problem.

PP-1

GENERAL PIPING SYSTEM DESIGN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
	Put printer in TRACE mode	—	—	DSP	5		
1.	Enter absolute pressure	150	—	STO	0	150.00000 STO0	
2.	Enter viscosity	.158	—	STO	1	.01580 STO1	
3.	Enter conversion for flow	3600	—	—	1/X	3600.00000 1/X	
						0.00028 ***	
				STO	A	STOA	
4.	Enter conversion for velocity	60	—	STO	B	60.00000 STOB	
5.	Enter conversion for pressure	1	—	STO	C	1.00000 STOC	
6.	Enter specific density	.3316	—	STO	D	.33160 STOD	
7.	Enter roughness factor;	.00017	—	STO	E	.00017 STOE	Remove from TRACE mode
	clear flag 0 if set		*f*	GTO	0		after this step.
8.	Enter maximum velocity	11000	—	*f*	A	11000.00000 ***	
9.	Enter pressure loss/100 ft	3.5	—	*f*	B	3.50000 ***	
	Try different pipe sizes.						
10.	Enter pipe internal diameter	6	—	—	B	6.00000 ***	
						41615.67354 ***	Flow, lb/hr
						10632.45328 ***	Velocity, fpm
						3.50000 ***	Pressure loss, psi
	Repeat step 10 as many times as desired.	8	—	—	B	8.00000 ***	
						76539.60329 ***	
						11000.00000 ***	
						2.64320 ***	
		10	—	—	B	10.00000 ***	
						119593.4425 ***	
						11000.00000 ***	
						2.01963 ***	

	For calculating pressure loss with printer in TRACE mode	–	*f*	LBL	1	CF1	Remove from TRACE mode after this step.
1.	Enter run no.	1.02	–	–	A	1.02000 ***	
2.	Enter pipe diameter	10	–	–	B	10.00000 ***	
3.	Enter flow, lb/hr	10000	–	–	C	100000.0000 ***	
						9197.82871 ***	Velocity, fpm
						1.41689 ***	Pressure loss, lb/100 ft
4.	Enter length	250	–	–	D	250.00000 ***	
5.	Enter fitting factor	3.5	–	–	E	3.50000 ***	
						6.48314 ***	Pressure loss for run
						6.48314 ***	Total pressure loss
	Repeat steps 1 through 5 as many times as desired.	2.3	–	–	A	2.03000 ***	
		8	–	–	B	8.00000 ***	
		71000	–	–	C	71000.00000 ***	
						10203.84122 ***	
						2.27783 ***	
		150	–	–	D	150.00000 ***	
		1.5	–	–	E	1.50000 ***	
						4.36793 ***	
						11.45107 ***	
	Example 2						
	Put printer in TRACE mode						
1.	Clear register; display 5	–	CLX	DSP	5	0.000000 DSP5	
						0.00000 ***	
2.	Enter viscosity	.16	–	STO	1	.16000 STO1	
3.	Enter conversion for flow	8.33	Enter	–	–	8.33000 ENT↑	
		60	÷	–	–	60.00000 ÷	
						0.13883 ***	
		–	–	STO	A	STOA	
4.	Enter conversion for velocity	1	–	STO	B	1.00000 STOB	
5.	Enter conversion for pressure	2.3	–	STO	C	2.30000 STOC	
6.	Enter specific density	55.29	–	STO	D	55.29000 STOD	
7.	Enter roughness factor;	.00013	–	STO	E	.00013 STOE	
	switch off from TRACE mode; set flag 0 for liquids	–	*f*	LBL	0		

PP-1 *(Continued)*

GENERAL PIPING SYSTEM DESIGN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	For pipe sizing						
8.	Enter maximum velocity	7.5	—	f	A	7.50000 ***	
9.	Enter pressure loss/100 ft	4	—	f	B	4.00000 ***	
	Try different pipe sizes.						
						12.00000 ***	
10.	Enter pipe internal diameter	12	—	—	B	2345.87023 ***	
						7.50000 ***	Flow, gpm
						1.00278 ***	Velocity, fps
							Pressure drop, ft
	Repeat step 1 as many times as desired.						
		14	—	—	B	14.00000 ***	
						3192.99604 ***	
						7.50000 ***	
						0.83404 ***	
		8	—	—	B	8.00000 ***	
						1042.60899 ***	
						7.50000 ***	
						1.63025 ***	
	For calculating pressure loss with printer in TRACE mode						
1.	Clear Register R9	0	—	STO	9	0.00000 STO9	
2.	Clear flag 1	—	f	GTO	1	CF1	Switch off from TRACE mode after this step.

3.	Enter run no.	1.02	—	—	A	1.02000 ***	
4.	Enter pipe diameter	14	—	—	B	14.00000 ***	
5.	Enter flow, gpm	2500	—	—	C	2500.00000 ***	
						5.87224 ***	Velocity, fpm
						0.51539 ***	Pressure loss, ft/100 ft
6.	Enter length	139	—	—	D	139.00000 ***	
7.	Enter fitting factor	2.9	—	—	E	2.90000 ***	
						2.08762 ***	Pressure loss for run
						2.08762 ***	Total pressure loss
	Repeat steps 3 through 7 as	2.03	—	—	A	2.03000 ***	
	many times as desired.	12	—	—	B	12.00000 ***	
		1800	—	—	C	1800.00000 ***	
						5.83602 ***	
						0.60439 ***	
		120	—	—	D	120.00000 ***	
		3.7	—	—	E	3.70000 ***	
						2.42921 ***	
						4.51683 ***	
8.	To add equipment pressure drop						
	put printer in TRACE mode and	3.27	STO	+	9	3.27000 ST+9	
		—	—	RCL	9	RCL9	
						7.78683 ***	
	continue in this manner.						

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
a	Prints display (maximum velocity); divides by RB and stores in R4; sets flag 1
b	Prints display (pressure drop/100 ft); divides by RC; and stores in R3
A	Prints display (run no.)
B	Prints and stores display (diameter) in R2; if flag 1 is set goes to SBR 8
C	Prints display (flow rate); calculates and prints velocity and continues through LBL 5
5	Calculates Reynolds number; if < 2100 goes to SBR 0; continues through LBL 1
1	Calculates f
3	Calculates and prints friction loss/100 ft
D	Prints and stores display (length) in R4
E	Prints display (fitting factor); calculates dynamic pressure loss and frictional pressure loss; prints total pressure loss; totalizes in R9 and prints running total; if flag 0 is set goes to SBR 4, otherwise calculates revised absolute pressure for gas
0	Calculates value of equation 1.5
4	Stops execution
8	Recalls R4; stores in R5; goes to SBR 5
6	If R3 is more than calculated pressure, goes to SBR 7, otherwise computes revised velocity
7	Goes to SBR 9 and prints R6
9	Calculates and prints flow and velocity

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Absolute pressure
R1	Viscosity
R2	Diameter
R3	Pressure drop/100 ft criteria
R4	Maximum velocity
R5	Velocity
R6	f; calculated PD/C
R7	Reynolds number
R8	Variable
R9	Total pressure drop
RA	Constant for input flow conversion
RB	Constant for velocity conversion
RC	Constant for pressure drop conversion
RD	Density, lb/cu ft
RE	e—Roughness factor

PP-1 (HP-97) GENERAL PIPING SYSTEM DESIGN PROGRAM

LISTING

001	*LBLa	21 16 11
002	PRTX	-14
003	RCLB	36 12
004	÷	-24
005	STO4	35 04
006	SF1	16 21 01
007	R/S	51
008	*LBLb	21 16 12
009	PRTX	-14
010	RCLC	36 13
011	÷	-24
012	STO3	35 03
013	SPC	16-11
014	SPC	16-11
015	R/S	51
016	*LBLA	21 11
017	PRTX	-14
018	R/S	51
019	*LBLB	21 12
020	PRTX	-14
021	STO2	35 02
022	SPC	16-11
023	F1?	16 23 01
024	GTO8	22 08
025	R/S	51
026	*LBLC	21 13
027	PRTX	-14
028	RCLA	36 11
029	×	-35
030	1	01
031	6	06
032	3	03
033	×	-35
034	RCL2	36 02
035	X²	53
036	÷	-24
037	RCLD	36 14
038	÷	-24
039	STO5	35 05
040	RCLB	36 12
041	×	-35
042	PRTX	-14
043	*LBL5	21 05
044	RCL5	36 05
045	RCL2	36 02
046	×	-35
047	RCLD	36 14
048	×	-35
049	1	01
050	2	02
051	4	04
052	×	-35
053	RCL1	36 01
054	÷	-24
055	STO7	35 07
056	2	02
057	1	01
058	0	00
059	0	00
060	X>Y?	16-34
061	GTO0	22 00
062	*LBL1	21 01
063	GSB2	23 02
064	STO8	35 08
065	.	-62
066	1	01
067	ST-6	35-45 06
068	GSB2	23 02
069	ST-8	35-45 08
070	.	-62
071	1	01
072	×	-35
073	RCL8	36 08
074	÷	-24
075	ST-6	35-45 06
076	RCL8	36 08
077	ABS	16 31
078	.	-62
079	2	02
080	X≤Y?	16-35
081	GTO1	22 01
082	RCL6	36 06
083	X²	53
084	1/X	52
085	*LBL3	21 03
086	RCLC	36 13
087	×	-35
088	RCLD	36 14
089	×	-35
090	RCL5	36 05
091	X²	53
092	×	-35
093	7	07

```
094       .        -62
095       7         07
096       3         03
097       ÷        -24
098    RCL2      36 02
099       ÷        -24
100    STO6      35 06
101     F1?   16 23 01
102    GTO6      22 06
103    PRTX        -14
104     SPC      16-11
105     RTN         24
106   *LBLD      21 14
107    PRTX        -14
108    STO4      35 04
109     R/S         51
110   *LBLE      21 15
111    PRTX        -14
112    RCLD      36 14
113       ×        -35
114    RCLC      36 13
115       ×        -35
116    RCL5      36 05
117      X²         53
118       ×        -35
119       9         09
120       2         02
121       7         07
122       4         04
123       ÷        -24
124    RCL6      36 06
125    RCL4      36 04
126       ×        -35
127       1         01
128       0         00
129       0         00
130       ÷        -24
131       +        -55
132    PRTX        -14
133    ST+9   35-55 09
134    RCL9      36 09
135    PRTX        -14
136     F0?   16 23 00
137    GTO4      22 04
138    RCL0      36 00
139       -        -45
140     CHS        -22
141    RCL0      36 00
142       ÷        -24
143    RCLD      36 14
144       ×        -35
145    STOD      35 14
146     SPC      16-11
147     SPC      16-11
148     R/S         51
149   *LBL0      21 00
150       .        -62
151       0         00
152       3         03
153       1         01
154    GSB3      23 03
155   *LBL2      21 02
156       2         02
157       .        -62
158       5         05
159       1         01
160    RCL6      36 06
161       ×        -35
162    RCL7      36 07
163       ÷        -24
164       3         03
165       .        -62
166       2         02
167       4         04
168    RCLE      36 15
169       ×        -35
170    RCL2      36 02
171       ÷        -24
172       +        -55
173     LOG      16 32
174       2         02
175       ×        -35
176    RCL6      36 06
177       +        -55
178     RTN         24
179   *LBL4      21 04
180     SPC      16-11
181     RTN         24
182   *LBL8      21 08
183    RCL4      36 04
184    STO5      35 05
185    GSB5      23 05
186     SPC      16-11
187     SPC      16-11
188     RTN         24
189   *LBL6      21 06
190    RCL3      36 03
191    X>Y?      16-34
192    GTO7      22 07
193    RCL6      36 06
194       ÷        -24
195      √X         54
196    ST×5   35-35 05
197    GSB9      23 09
198    RCL3      36 03
199    PRTX        -14
200     RTN         24
201   *LBL7      21 07
202    GSB9      23 09
203    RCL6      36 06
204    PRTX        -14
205     RTN         24
206   *LBL9      21 09
207    RCL2      36 02
208      X²         53
209       1         01
210       8         08
211       3         03
212       ÷        -24
213    RCL5      36 05
214       ×        -35
215    RCLD      36 14
216       ×        -35
217    RCLA      36 11
218       ÷        -24
219    PRTX        -14
220    RCL5      36 05
221    RCLB      36 12
222       ×        -35
223    PRTX        -14
224     RTN         24
```

PP-2
WATER PIPING SYSTEM DESIGN PROGRAM

GENERAL DESCRIPTION

As explained under Program PP-1, Program PP-2 has the same features, but is based on the Williams-Hazen formula which makes it operate faster. This formula gives accurate values for water temperature at about 60°F. However, the results are reasonably valid for HVAC and Sanitary Engineering for water temperatures from 40 to 180°F. A comparison of the two programs, PP-1 and PP-2, is given under reference data. For further description, the user should read the description for Program PP-1.

EQUATIONS

$$h_f = 0.002083 \times L \times \left(\frac{100}{C}\right)^{1.85} \times \frac{Q^{1.85}}{d^{4.87}} \qquad [1.9]$$

where

h_f = Friction head loss in feet of water
d = Inside diameter of the pipe in inches
Q = Flow in gpm
L = Length of pipe in feet
C = Constant for inside pipe roughness

If d = 1 in., and L = 100 ft,

$$h_f = 0.002083 \times 100 \times (100)^{1.85} \times \left(\frac{Q_{f1}}{C}\right)^{1.85}$$

$$= 1044\left(\frac{Q_{f1}}{C}\right)^{1.85}$$

or $$Q_{f1} = (h_f/1044)^{1/1.85} \times C \qquad [1.10]$$

where

Q_{f1} = Flow through 1-in. pipe for specified friction loss/100 ft

$$Q = V \times \frac{\pi}{4} \times \left(\frac{d}{12}\right)^2 \times 60 \times 7.48 = d^2 \times V/.41 \qquad [1.11]$$

where

Q = Flow in gpm
V = Velocity in fps
d = Inside diameter of pipe in inches
60 = 60 sec/min
7.48 = 7.48 gal/cu ft

If d = 1 in.,

$$QV_1 = V/.41$$

where

QV_1 = Flow through 1-in. pipe for specified maximum velocity in fps

Also from equation 1.9

$$\frac{(Q_{f2})^{1.85}}{d_2^{4.87}} = \frac{(Q_{f1})^{1.85}}{d_1^{4.87}} \qquad [1.12]$$

If d = *1* in.,

$$Q_{f2} = Q_{f1} \times d_2^{\frac{4.87}{1.85}}$$

$$= Q_{f1} d_2^{2.63}$$

where

Q_{f2} = Flow based on friction loss through pipe with inside diameter d_2

From equation 1.11

$$\frac{Q_{V2}}{Q_{V1}} = \frac{d_2^2}{d_1^2} \qquad [1.13]$$

If d_1 = 1 in.,

$$Q_{V2} = Q_{V1} \times d_2^2$$

where

Q_{V2} = Flow based on velocity through pipe with inside diameter d_2

$$\text{Head loss through fittings} = K\frac{V^2}{2g} \qquad [1.14]$$

where

K = Total fitting K factor or dynamic loss coefficient
V = Pipe velocity in fps
g = Gravitational constant 32.2 ft/sec²

OPERATING FEATURES

This program has the same operating features as program PP-1 and is based on one flag only.

1. No flag—program calculates friction head loss.

2. Set flag—program can be used for pipe sizing in the following alternate modes:

a. Given the gallons per minute, friction head loss, maximum velocity, and length, the program calculates the pipe inside diameter in inches.

b. Given the pipe inside diameter, friction head loss, maximum velocity, and length, the program calculates flow in gallons per minute or, if required, a table of pipe diameters and flows.

REFERENCE DATA

The data for dynamic loss coefficients for fittings can be obtained from the *Hydraulic Institute Pipe Friction Manual*.

Suggested C values for different pipe materials are given below. For additional information, refer to ASHRAE *Handbook of Fundamentals*.

After studying the comparison of Programs PP-1 and PP-2, users could develop C values suitable for their applications.

C VALUES FOR DESIGN PURPOSES

Pipe Material	C
Plastic pipe	150
Cement asbestos	140
Copper, brass, tin, and lead	130
Steel closed circuit with water treatment	140
Steel open circuit without water treatment	100
Cast iron	100

COMPARISON OF FRICTION LOSS CALCULATIONS—FOR WATER SYSTEM

Run No.	Pipe Dia. (in.)	Flow Rate (gpm)	Pipe Run (ft)	Fitting Factor	PP-2 $C = 130$	PP-2 $C = 140$	PP-1 (e = .00015 ft for steel pipe) 40^0F	60^0F	80^0F	100^0F	150^0F	200^0F
1.02	12.00	3,546	25	0.75	1.85	1.77	1.82	1.79	1.77	1.75	1.70	1.66
2.03	10.02	1,797	30	1.10	1.46	1.39	1.44	1.41	1.39	1.37	1.34	1.30
3.04	10.02	1,690	16	0.09	0.33	0.29	0.32	0.30	0.29	0.29	0.27	0.26
4.05	7.98	1,193	12	0.30	0.58	0.54	0.57	0.56	0.55	0.54	0.52	0.51
5.06	7.98	1,086	29	0.10	0.70	0.62	0.68	0.66	0.63	0.61	0.58	0.56
6.07	7.98	979	29	0.10	0.58	0.51	0.57	0.54	0.52	0.50	0.48	0.46
7.08	3.07	107	10	1.90	0.95	0.91	0.96	0.94	0.93	0.91	0.88	0.86
8.09	3.07	107	13	0.15	0.45	0.40	0.47	0.45	0.43	0.41	0.39	0.37
9.10	3.07	101	12	0.15	0.38	0.34	0.40	0.38	0.36	0.35	0.32	0.31
10.11	3.07	96	12	0.15	0.35	0.31	0.36	0.34	0.33	0.31	0.29	0.28
		Friction loss =			7.64	7.09	7.59	7.37	7.20	7.05	6.79	6.58

EXAMPLE NO.1

Calculate the pressure loss in the piping system shown in Figure No. 1.

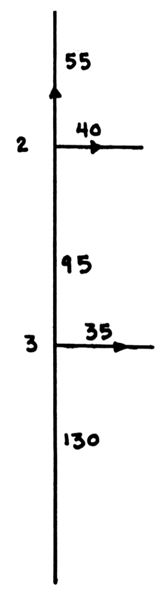
$C = 130$

```
  0.00

  1.02    R.NO
 55.00      QB
 55.00      QM
  0.00     DIA
  0.0075     L
  0.001·5   FF
```

```
  2.03    R.NO
 40.00      QB
 95.00      QM
  0.00     DIA
  0.00 49    L
  0.00 ·75  FF

  3.04    R.NO
 35.00      QB
130.00      QM
  0.00     DIA
  0.00       L
  0.00      FF
```



The top part of the diagram illustrates use of Program UP-3.

PP-2
WATER PIPING SYSTEM DESIGN PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
	For computing friction head loss of a distribution system							
1.	Initialize	0	—	2nd	E′	0.00		Flag 1 has to be reset if the program has been used for sizing. See next example.
2.	Reset flag 1	INV	2nd	St flg	1			
3.	Enter *C* value	130	—	2nd	C′	130.00	C	
4.	Enter run no.	1.02	—	—	A	1.02	R.NO	
5.	Enter inside pipe diameter, in.	2.0	—	—	B	2.00	DIA	
6.	Enter flow, gpm	55	—	—	C	55.00	GPM	
						5.64	FPS	Velocity, fps
						7.29	PD/C	Friction loss, ft/100 ft of pipe
7.	Enter pipe length, ft	75	—	—	D	75.00	L	
8.	Enter total *K* fitting factor for all fittings in that line	1.5	—	—	E	1.50	FF	
						6.21	PD	Friction loss of run
						6.21	ΣPD	Total friction loss
	Repeat steps 4 through 8 as many times as desired.	2.03	—	—	A	2.03	R.NO	
		2.5	—	—	B	2.50	DIA	
		95	—	—	C	95.00	GPM	
						6.23	FPS	
						6.77	PD/C	
		49	—	—	D	49.00	L	
		.75	—	—	E	0.75	FF	
						3.77	PD	
						9.98	ΣPD	
9.	To add or deduct equipment friction loss	12	—	2nd	D′	12.00	EPD	Equipment pressure drop
						21.98	ΣPD	

	Example 2							
	For computing individual pipe sizes							
1.	Initialize	0	—	2nd	E′	0.00		Reset flag 1 when using program for computing friction loss.
2.	Set flag 1		2nd	St flg	1			
3.	Enter *C* value	135	—	2nd	C′	135.00	C	
4.	Enter maximum velocity, fps	7	—	2nd	A′	7.00	VMAX	Vmax, fps
5.	Enter friction loss, ft/100 ft of pipe	4.5	—	2nd	B′	4.50	PD/C	
6.	Enter inside pipe diameter	8	—	—	B	8.00 1092.68 7.00 2.02	DIA GPM FPS PD/C	
	Repeat step 6 as many times as required.							
7.	Enter flow, gpm	1100	—	—	C	1100.00 8.03 1100.00 7.00 2.01	GPM DIA GPM FPS PD/C	
	Repeat step 7 as many times as required.							
8.	To print pipe size table for 3 in. and below enter	3	—	2nd	D′	3.00 127.80 5.82 4.50	DIA GPM FPS PD/C	*Note:* Pipe sizes reduce in increments of 1 in. Ignore pipe sizes not applicable.
						2.00 43.99 4.51 4.50	DIA GPM FPS PD/C	
						1.00 7.11 2.91 4.50	DIA GPM FPS PD/C	

PP-2 *(Continued)*

WATER PIPING SYSTEM DESIGN PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
						2.50	DIA	*Note:* Below 2.5 in., pipe sizes reduce in increments of .25 in Ignore pipe sizes not applicable.
						79.12	GPM	
						5.19	FPS	
						4.50	PD/C	
						2.25	DIA	
						59.97	GPM	
						4.86	FPS	
						4.50	PD/C	
						2.00	DIA	Table, if not required for smaller sizes, can be stopped by pressing R/S.
						43.99	GPM	
						4.51	FPS	
						4.50	PD/C	
						1.75	DIA	
						30.97	GPM	
						4.15	FPS	
						4.50	PD/C	
						1.50	DIA	
						20.64	GPM	
						3.76	FPS	
						4.50	PD/C	
						1.25	DIA	
						12.78	GPM	
						3.35	FPS	
						4.50	PD/C	
						1.00	DIA	
						7.11	GPM	
						2.91	FPS	
						4.50	PD/C	

0.75	DIA
3.34	GPM
2.43	FPS
4.50	PD/C
0.50	DIA
1.15	GPM
1.88	FPS
4.50	PD/C
0.25	DIA
0.19	GPM
1.22	FPS
4.50	PD/C

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E′	Initializes
A	Prints R No.
B	Prints and stores DIA
C	Prints and stores GPM; calculates velocity and FPS; calculates friction loss/100 ft; prints PD/C
D	Prints and stores length L
E	Prints and stores fitting factor; calculates friction loss for L and fittings; sums friction loss and prints
A′	Prints and stores VMAX; calculates QV2
B′	Prints and stores PD/C; calculates *Qf*1
C′	Prints and stores C value
D′	Without flag, prints and adds equipment pressure drop; with flag 1, goes to SBR X⇄T
INV	Prints alphanumeric characters to identify answers
LNX	Given diameter, calculates flow in GPM
CE	Calculates absolute difference between two numbers
CLR	Given GPM, calculates diameter
X⇄T	Prints table of pipe diameters for integer sizes
$\sqrt{X}$	Prints table of pipe diameter from 2.5 in. down, decreasing by .25 in.
STO	Sums or deducts pressure drop
RCL	Prints PD/C

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Counter for DSZ for piping table
R01	Pipe diameter
R02	Flow in GPM
R03	Velocity and QV1
R04	Length
R05	Fitting *K* factor
R06	Total pressure drop ΣPD
R07	VMAX
R08	PD/C
R09	C value
R10	For storage of alphanumeric code
R11	Calculated value of PD/C

PP-2 WATER PIPING SYSTEM DESIGN PROGRAM

LABELS & SUBROUTINES

```
001  10  E'
009  11  A
025  12  B
044  13  C
123  14  D
135  15  E
182  16  A'
207  17  B'
232  18  C'
245  19  D'
268  22  INV
285  23  LNX
330  24  CE
343  25  CLR
396  32  X:T
405  33  X²
426  34  √X
442  42  STO
461  43  RCL
```

LISTING

```
000  76  LBL
001  10  E'
002  00  0
003  42  STO
004  06  06
005  99  PRT
006  98  ADV
007  91  R/S
008  76  LBL
009  11  A
010  32  X:T
011  03  3
012  05  5
013  04  4
014  00  0
015  03  3
016  01  1
017  03  3
018  02  2
019  42  STO
020  10  10
021  71  SBR
022  22  INV
023  91  R/S
024  76  LBL
025  12  B
026  42  STO
027  01  01
028  32  X:T
029  01  1
030  06  6
031  02  2
032  04  4
033  01  1
034  03  3
035  42  STO
036  10  10
037  71  SBR
038  22  INV
039  87  IFF
040  01  01
041  23  LNX
042  92  RTN
043  76  LBL
044  13  C
045  42  STO
046  02  02
047  32  X:T
048  02  2
049  02  2
050  03  3
051  03  3
052  03  3
053  00  0
054  42  STO
055  10  10
056  71  SBR
057  22  INV
058  87  IFF
059  01  01
060  25  CLR
061  53  (
062  93  .
063  04  4
064  01  1
065  65  ×
066  43  RCL
067  02  02
068  55  ÷
069  43  RCL
070  01  01
071  33  X²
072  54  )
```

073	42	STO
074	03	03
075	32	X:T
076	02	2
077	01	1
078	03	3
079	03	3
080	03	3
081	06	6
082	42	STO
083	10	10
084	71	SBR
085	22	INV
086	53	(
087	53	(
088	53	(
089	43	RCL
090	02	02
091	55	÷
092	53	(
093	43	RCL
094	09	09
095	65	×
096	43	RCL
097	01	01
098	45	Y^X
099	02	2
100	93	.
101	06	6
102	03	3
103	54	)
104	54	)
105	45	Y^X
106	01	1
107	93	.
108	08	8
109	05	5
110	54	)
111	65	×
112	01	1
113	00	0
114	04	4
115	04	4
116	54	)
117	42	STO
118	11	11
119	71	SBR
120	43	RCL
121	92	RTN
122	76	LBL
123	14	D
124	42	STO
125	04	04
126	32	X:T
127	02	2
128	07	7
129	42	STO
130	10	10
131	71	SBR
132	22	INV
133	91	R/S
134	76	LBL
135	15	E
136	42	STO
137	05	05
138	32	X:T
139	02	2
140	01	1
141	02	2
142	01	1
143	42	STO
144	10	10
145	71	SBR
146	22	INV
147	43	RCL
148	11	11
149	65	×
150	43	RCL
151	04	04
152	55	÷
153	01	1
154	00	0
155	00	0
156	85	+
157	43	RCL
158	03	03
159	33	X^2
160	65	×
161	43	RCL
162	05	05
163	55	÷
164	06	6
165	04	4
166	93	.
167	04	4
168	54	)
169	32	X:T
170	03	3
171	03	3
172	01	1
173	06	6
174	42	STO
175	10	10
176	71	SBR
177	22	INV
178	71	SBR
179	42	STO
180	92	RTN
181	76	LBL
182	16	A'
183	42	STO
184	07	07
185	32	X:T
186	04	4
187	02	2
188	03	3
189	00	0
190	01	1
191	03	3
192	04	4
193	04	4
194	42	STO
195	10	10
196	71	SBR
197	22	INV
198	55	÷
199	93	.
200	04	4
201	01	1
202	95	=
203	42	STO
204	07	07
205	91	R/S
206	76	LBL
207	17	B'
208	71	SBR
209	43	RCL
210	55	÷
211	01	1
212	00	0
213	04	4
214	04	4
215	95	=
216	22	INV
217	45	Y^X
218	01	1
219	93	.
220	08	8
221	05	5
222	95	=
223	65	×
224	43	RCL
225	09	09
226	95	=
227	42	STO
228	08	08
229	98	ADV
230	91	R/S
231	76	LBL
232	18	C'
233	42	STO
234	09	09
235	32	X:T
236	01	1
237	05	5
238	42	STO
239	10	10
240	71	SBR
241	22	INV
242	98	ADV
243	91	R/S
244	76	LBL
245	19	D'
246	42	STO
247	05	05
248	87	IFF
249	01	01
250	32	X:T
251	43	RCL
252	05	05
253	32	X:T
254	01	1
255	07	7
256	03	3
257	03	3
258	01	1
259	06	6
260	42	STO
261	10	10
262	71	SBR
263	22	INV
264	71	SBR
265	42	STO
266	91	R/S
267	76	LBL
268	22	INV
269	22	INV
270	58	FIX
271	25	CLR
272	69	OP
273	00	00
274	43	RCL
275	10	10
276	69	OP
277	04	04
278	32	X:T
279	58	FIX
280	02	02
281	69	OP
282	06	06
283	92	RTN
284	76	LBL
285	23	LNX
286	53	(
287	43	RCL
288	01	01
289	33	X^2
290	65	×
291	43	RCL
292	07	07
293	54	)
294	42	STO
295	03	03
296	53	(
297	43	RCL
298	01	01
299	45	Y^X
300	02	2
301	93	.
302	06	6
303	03	3
304	65	×
305	43	RCL
306	08	08
307	54	)
308	42	STO
309	04	04
310	85	+
311	43	RCL
312	03	03
313	75	−
314	71	SBR
315	24	CE
316	95	=
317	55	÷
318	02	2
319	95	=
320	22	INV
321	86	STF
322	01	01
323	71	SBR
324	13	C
325	86	STF
326	01	01
327	98	ADV
328	92	RTN

```
329  76 LBL
330  24 CE
331  53  (
332  53  (
333  43 RCL
334  04  04
335  75  -
336  43 RCL
337  03  03
338  54  )
339  50 |X|
340  54  )
341  92 RTN
342  76 LBL
343  25 CLR
344  53  (
345  53  (
346  43 RCL
347  02  02
348  55  ÷
349  43 RCL
350  07  07
351  54  )
352  34 √X
353  42 STO
354  03  03
355  53  (
356  53  (
357  43 RCL
358  02  02
359  55  ÷
360  43 RCL
361  08  08
362  54  )
363  22 INV
364  45 Y^X
365  02  2
366  93  .
367  06  6
368  03  3
369  54  )
370  42 STO
371  04  04
372  85  +
373  43 RCL
374  03  03
375  85  +
376  71 SBR
377  24 CE
378  95  =
379  55  ÷
380  02  2
381  95  =
382  22 INV
383  86 STF
384  01  01
385  71 SBR
386  12  B
387  43 RCL
388  02  02
389  71 SBR
390  13  C
391  86 STF
392  01  01
393  98 ADV
394  92 RTN
395  76 LBL
396  32 X:T
397  43 RCL
398  05  05
399  42 STO
400  00  00
401  01  1
402  44 SUM
403  05  05
404  76 LBL
405  33 X²
406  69 OP
407  35  35
408  43 RCL
409  05  05
410  71 SBR
411  12  B
412  97 DSZ
413  00  00
414  33 X²
415  01  1
416  00  0
417  42 STO
418  00  00
419  02  2
420  93  .
421  07  7
422  05  5
423  42 STO
424  05  05
425  76 LBL
426  34 √X
427  93  .
428  02  2
429  05  5
430  22 INV
431  44 SUM
432  05  05
433  43 RCL
434  05  05
435  71 SBR
436  12  B
437  97 DSZ
438  00  00
439  34 √X
440  92 RTN
441  76 LBL
442  42 STO
443  44 SUM
444  06  06
445  43 RCL
446  06  06
447  32 X:T
448  07  7
449  07  7
450  03  3
451  03  3
452  01  1
453  06  6
454  42 STO
455  10  10
456  71 SBR
457  22 INV
458  98 ADV
459  92 RTN
460  76 LBL
461  43 RCL
462  32 X:T
463  03  3
464  03  3
465  01  1
466  06  6
467  06  6
468  03  3
469  01  1
470  05  5
471  42 STO
472  10  10
473  71 SBR
474  22 INV
475  98 ADV
476  92 RTN
477  00  0
478  00  0
479  00  0
```

PP-2
WATER PIPING SYSTEM DESIGN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
	For computing friction head loss of distribution system						
1.	Initialize	–	–	*f*	E	0.00 ***	Flag 1 has to be cleared first if program has been used for sizing.
2.	Enter *C* value	130	–	*f*	C	130.00 ***	
3.	Enter run no.	1.02	–	–	A	1.02 ***	
4.	Enter inside pipe diameter, in.	2	–	–	B	2.00 ***	
5.	Enter flow, gpm	55	–	–	C	55.00 ***	
						5.64 ***	Velocity, fps
						7.23 ***	Friction loss, ft/100 ft of pipe
6.	Enter pipe length, ft	75	–	–	D	75.00 ***	
7.	Enter total *K* factor for fittings	1.5	–	–	E	1.50 ***	
						6.21 ***	Friction loss of run
						6.21 ***	Total friction loss
	Repeat steps 3 through 7 as many times as desired.	2.03	–	–	A	2.03 ***	
		2.5	–	–	B	2.50 ***	
		95	–	–	C	95.00 ***	
						6.23 ***	
						6.77 ***	
		49	–	–	D	49.00 ***	
		.75	–	–	E	0.75 ***	
						3.77 ***	
						9.98 ***	
8.	To add or deduct equipment friction loss	12	–	*f*	D	12.00 ***	Equipment pressure drop
						21.98 ***	Total pressure loss

PP-2 *(Continued)*

WATER PIPING SYSTEM DESIGN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 2						
	For computing individual pipe sizes, set flag 1						
1.	To set flag 1	—	*f*	LBL	1		
2.	Initialize	—	—	*f*	E	0.00 ***	
3.	Enter *C* value	135	—	*f*	C	135.00 ***	
4.	Enter maximum velocity, fps	7	—	*f*	A	7.00 ***	
5.	Enter friction loss, ft/100 ft	4.5	—	*f*	B	4.50 ***	
6.	Enter inside pipe diameter Repeat step 6 as many times as desired.	8	—	—	B	8.00 *** 1052.00 *** 7.00 *** 2.62 ***	Gal/min Velocity, fps Pressure loss, ft/100 ft
7.	Enter flow, gpm Repeat step 7 as many times as desired.	1100	—	—	C	1100.00 *** 8.03 *** 1100.00 *** 7.00 *** 2.61 ***	Diameter Gal/min Velocity, fps Pressure loss, ft/100 ft
8.	To print pipe size table for 3 in. and below, enter	3	—	*f*	D	3.00 *** 127.80 *** 5.82 *** 4.50 *** 2.00 *** 43.93 *** 4.51 *** 4.50 ***	Gal/min Velocity, fps Pressure loss, ft/100 ft Pipe sizes reduce in increments of 1 in. Ignore pipe sizes not applicable.

						1.00 *** 7.11 *** 2.91 *** 4.50 ***	
						2.50 *** 79.12 *** 5.19 *** 4.50 ***	Below 2.5 in., pipe sizes reduce in increments of .25 in. Ignore pipe sizes not applicable.
						2.25 *** 59.97 *** 4.86 *** 4.50 ***	
						2.00 *** 43.39 *** 4.51 *** 4.50 ***	Press R/S, if table not required for smaller sizes.
						1.75 *** 30.97 *** 4.15 *** 4.50 ***	
						1.50 *** 20.64 *** 3.76 *** 4.50 ***	
						1.25 *** 12.78 *** 3.35 *** 4.50 ***	

PP-2 *(Continued)*

WATER PIPING SYSTEM DESIGN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
						1.00 ***	
						7.11 ***	
						2.91 ***	
						4.50 ***	
						0.75 ***	
						3.34 ***	
						2.43 ***	
						4.50 ***	
						0.50 ***	
						1.15 ***	
						1.88 ***	
						4.50 ***	
						0.25 ***	
						0.15 ***	
						1.22 ***	
						4.50 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
0	Given diameter, computes flow based on velocity and pressure loss; selects smaller of two; clears flag 1; goes to SBR C; sets flag 1
1	Given flow, computes diameter based on velocity and pressure loss; selects larger of two; clears flag 1; goes to SBR B, SBR C; sets flag 1
2	Totalizes pressure drop in R6
3	Recalls R5; stores in R1; reiterates to print table of pipe diameter, flow rates, and pressure loss using SBR B, LBL 5, and LBL 6
4	Computes absolute difference between R4 and R3
e	Clears register R6; prints zero
A	Prints display (run no.)
B	Prints and stores display (diameter) in R1; if flag 1 is set goes to SBR 0
C	Prints and stores display (GPM) in R2; if flag 1 is set goes to SBR 1; computes and prints velocity and pressure loss/100 ft
D	Prints and stores display (length) in R4
E	Prints and stores display (fitting factor) in R5; computes and prints dynamic and friction loss; goes to SBR 2
a	Prints display (velocity); computes flow through 1-in. pipe based on input velocity and stores in R7
b	Prints display (pressure drop/100 ft); computes flow through 1-in. pipe based on input pressure loss; stores in R8
c	Prints and stores display (C value) in R9
d	Stores in R5; if flag 1 is set goes to SBR 3, otherwise prints display and goes to SBR 2

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Pressure loss/100 ft
R1	Pipe diameter
R2	Flow in GPM
R3	Velocity
R4	Length
R5	Fitting factor per diameter or equipment pressure loss
R6	Total pressure drop
R7	QV1—flow through 1-in. pipe based on velocity
R8	QP1—flow through 1-in. pipe based on pressure loss criteria
R9	C value

PP-2 (HP-97) WATER PIPING SYSTEM DESIGN PROGRAM

LISTING

001	*LBL0	21 00
002	RCL1	36 01
003	X²	53
004	RCL7	36 07
005	×	-35
006	STO3	35 03
007	RCL1	36 01
008	2	02
009	.	-62
010	6	06
011	3	03
012	Yˣ	31
013	RCL8	36 08
014	×	-35
015	STO4	35 04
016	RCL3	36 03
017	+	-55
018	GSB4	23 04
019	-	-45
020	2	02
021	÷	-24
022	CF1	16 22 01
023	GSBC	23 13
024	SF1	16 21 01
025	SPC	16-11
026	RTN	24
027	*LBL1	21 01
028	RCL2	36 02
029	RCL7	36 07
030	÷	-24
031	√X	54
032	STO3	35 03
033	RCL2	36 02
034	RCL8	36 08
035	÷	-24
036	2	02
037	.	-62
038	6	06
039	3	03
040	1/X	52
041	Yˣ	31
042	STO4	35 04
043	RCL3	36 03
044	+	-55
045	GSB4	23 04
046	+	-55
047	2	02
048	÷	-24
049	CF1	16 22 01
050	GSBB	23 12
051	RCL2	36 02
052	GSBC	23 13
053	SF1	16 21 01
054	SPC	16-11
055	RTN	24
056	*LBL2	21 02
057	ST+6	35-55 06
058	RCL6	36 06
059	PRTX	-14
060	SPC	16-11
061	RTN	24
062	*LBL3	21 03
063	RCL5	36 05
064	STOI	35 46
065	1	01
066	ST+5	35-55 05
067	*LBL5	21 05
068	1	01
069	ST-5	35-45 05
070	RCL5	36 05
071	GSBB	23 12
072	DSZI	16 25 46
073	GTO5	22 05
074	1	01
075	0	00
076	STOI	35 46
077	2	02

```
078      .        -62
079      7         07
080      5         05
081   STO5      35 05
082  *LBL6      21 06
083      .        -62
084      2         02
085      5         05
086   ST-5   35-45 05
087   RCL5      36 05
088   GSBB      23 12
089   DSZI   16 25 46
090   GTO6      22 06
091    RTN         24
092  *LBL4      21 04
093   RCL4      36 04
094   RCL3      36 03
095      -        -45
096    ABS      16 31
097    RTN         24
098  *LBLe   21 16 15
099      0         00
100   STO6      35 06
101   PRTX        -14
102    SPC      16-11
103    RTN         24
104  *LBLA      21 11
105   PRTX        -14
106    RTN         24
107  *LBLB      21 12
108   STO1      35 01
109   PRTX        -14
110    F1?   16 23 01
111   GTO0      22 00
112    RTN         24
113  *LBLC      21 13
114   STO2      35 02
115   PRTX        -14
116    F1?   16 23 01
117   GTO1      22 01
118      .        -62
119      4         04
120      1         01
121      x        -35
122   RCL1      36 01
123     X²         53
124      ÷        -24
125   STO3      35 03
126   PRTX        -14
127   RCL1      36 01
128      2         02
129      .        -62
130      6         06
131      3         03
132     Yˣ         31
133   RCL9      36 09
134      x        -35
135    1/X         52
136   RCL2      36 02
137      x        -35
138      1         01
139      .        -62
140      8         08
141      5         05
142     Yˣ         31
143      1         01
144      0         00
145      4         04
146      4         04
147      x        -35
148   STO0      35 00
149   PRTX        -14
150    SPC      16-11
151    RTN         24
152  *LBLD      21 14
153   STO4      35 04
154   PRTX        -14
155    RTN         24
156  *LBLE      21 15
157   STO5      35 05
158   PRTX        -14
159   RCL3      36 03
160     X²         53
161      x        -35
162      6         06
163      4         04
164      .        -62
165      4         04
166      ÷        -24
167   RCL0      36 00
168   RCL4      36 04
169      x        -35
170      1         01
171      0         00
172      0         00
173      ÷        -24
174      +        -55
175   PRTX        -14
176   GSB2      23 02
177    RTN         24
178  *LBLa   21 16 11
179   PRTX        -14
180      .        -62
181      4         04
182      1         01
183      ÷        -24
184   STO7      35 07
185    RTN         24
186  *LBLb   21 16 12
187   PRTX        -14
188      1         01
189      0         00
190      4         04
191      4         04
192      ÷        -24
193      1         01
194      .        -62
195      8         08
196      5         05
197    1/X         52
198     Yˣ         31
199   RCL9      36 09
200      x        -35
201   STO8      35 08
202    SPC      16-11
203    RTN         24
204  *LBLc   21 16 13
205   STO9      35 09
206   PRTX        -14
207    SPC      16-11
208    RTN         24
209  *LBLd   21 16 14
210   STO5      35 05
211    F1?   16 23 01
212   GTO3      22 03
213   RCL5      36 05
214   PRTX        -14
215   GSB2      23 02
216    RTN         24
217    R/S         51
```

PP-3
PIPING SYSTEM VOLUME AND EXPANSION TANK SIZING PROGRAM

PROGRAM DESCRIPTION

This program will calculate the volume of a piping system in gallons by determining the volume in each piping branch and adding it up. The volume of the heat exchangers, coils, and other equipment can also be added up.

Given the volume of a piping system, the program can determine the volume of open and closed expansion tanks for hot-water heating systems.

The formula for relative expansion of water has been developed by use of a curve fitting program.

OPERATING FEATURES

Input for expansion tank calculation can be in any units for volume and pressures. However, input for temperature must be in degrees F.

Input for system volume and operating temperature is combined in decimal format—xxxx.xxx.

Integers represent volume while fractions represent temperature. For example:

1000.099	represents	1,000 gal 99°F
5400.375	represents	5,400 gal 375°F

EQUATIONS

$$\text{Pipe area in sq ft } (A) = \frac{\pi \times d^2}{576} \qquad [1.15]$$

where
d = Inside diameter in inches

$$\text{Pipe volume in cu ft } (C) = A \times L \qquad [1.16]$$

where
L = Length in feet

$$\text{Pipe volume in gallons} = C \times 7.48 \qquad [1.17]$$

$$\text{Expansion tank open } (V_{t0}) = V_s \times E \qquad [1.18]$$

where
V_s = Volume of water in system
E = Relative expansion at operating temperature

$$\text{Expansion tank closed } (V_c) = \frac{V_{t0}}{\dfrac{P_0 + P_1}{P_0 + P_2} - \dfrac{P_0 + P_1}{P_0 + P_3}} \qquad [1.19]$$

where
P_0 = Atmospheric pressure at site
P_1 = Gauge pressure in expansion tank when water first enters the tank
P_2 = Initial fill or minimum pressure gauge
P_3 = Operating pressure gauge

Relative expansion of water E

$$= (.97\, e^{(T_o - 18) \times .000446} - 1) - [1 - \left(\frac{T_o - 250}{150}\right) \text{abs} \times .02] \qquad [1.20]$$

where
T_o = Operating temperature in degrees F

PP-3
PIPING SYSTEM VOLUME AND EXPANSION TANK SIZING PROGRAM
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Initialize	—	—	2nd	E′	0.		
2.	Enter run no.	1.02	—	—	A	1.02	R.NO	
3.	Enter inside pipe diameter, in.	4.0	—	—	B	4.00	DIA	
						0.65	G/FT	Gal/ft of pipe
4.	Enter length of pipe, ft	594	—	—	C	594.00	L	
						388.	GALS	Gal
						388.	ΣGAL	Total gal
	Repeat steps 2, 3, & 4 as many times as desired.	2.03	—	—	A	2.03	R.NO	
		6	—	—	B	6.00	DIA	
						1.47	G/FT	
		954	—	—	C	954.00	L	
						1401.	GALS	
						1789.	ΣGAL	
5.	Enter equipment volume to add to system volume	700	—	—	E	700.0	EGAL	Equipment gal
						2489.	ΣGAL	Total gal
	Continue steps 2, 3, & 4 if desired.							
6.	Enter total system volume and operating temperature, °F	2500.375	—	2nd	A′	2500.	GALS	
						375.	TEMP	
						335.	GALS	Volume of open expansion tank, gal
7.	Enter atmospheric pressure at site	15	—	2nd	B′	15.00	PO	
8.	Enter tank pressure while filling	1	—	—	R/S	1.00	P1	

9.	Enter minimum initial fill pressure	2	—	—	R/S	2.00 P2	
10.	Enter operating pressure	150	—	—	R/S	150.00 P3	
						397. GALS	Volume of closed expansion tank, gal
	Note: 1. *P*0, *P*1, *P*2, & *P*3 — all four should be in same units 2. *P*0 — atmospheric pressure 3. *P*1 — pressure in tank when water enters tank gauge pressure — generally 0 4. *P*2 — Minimum initial fill gauge pressure 5. *P*3 — Operating gauge pressure						

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints run no.
B	Prints and stores DIA; calculates and prints G/FT, gallons per ft of pipe
C	Prints L in ft; calculates and prints GAL and ΣGAL, running subtotal of gallons
E	Prints equipment or error gallons; adds or deducts from the total volume and prints ΣGAL
A′	Separates volume and temperature input; prints GAL and TEMP; calculates size of open expansion tank and prints GAL
B′	With three R/S, accepts and prints P0, P1, P2, and P3 and calculates volume of closed expansion tank
E′	Initialize program
INV	Prints alphanumeric characters to identify data
LNX	Prints GAL
CE	Adds or deducts equipment or error gallons, prints EGAL and ΣGAL
CLR	Prints P1, P2, and P3

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Not used
R01	Not used
R02	Gallons per foot
R03	ΣGAL
R04	GAL
R05	Temperature
R06	Not used
R07	Not used
R08	P0
R09	P1
R10	P2
R11	P3
R12	Volume open expansion tank
R13	$\frac{P0 + P1}{P0 + P2} - \frac{P0 + P1}{P0 + P3}$
R14	For storage of alphanumeric code
R15	For storage of decimal places

PP-3 PIPING SYSTEM VOLUME AND EXPANSION TANK SIZING PROGRAM

LABELS & SUBROUTINES

```
001  11  A
020  12  B
069  13  C
091  15  E
113  16  A'
216  17  B'
285  10  E'
293  22  INV
311  23  LNX
330  24  CE
354  25  CLR
```

LISTING

```
      0.
000  76  LBL
001  11   A
002  32  X:T
003  03   3
004  05   5
005  04   4
006  00   0
007  03   3
008  01   1
009  03   3
010  02   2
011  42  STO
012  14   14
013  02   2
014  42  STO
015  15   15
016  71  SBR
017  22  INV
018  91  R/S
019  76  LBL
020  12   B
021  32  X:T
022  01   1
023  06   6
024  02   2
025  04   4
026  01   1
027  03   3
028  42  STO
029  14   14
030  02   2
031  42  STO
032  15   15
033  71  SBR
034  22  INV
035  33  X²
036  65   ×
037  89   π
038  65   ×
039  07   7
040  93   .
041  04   4
042  08   8
043  55   ÷
044  05   5
045  07   7
046  06   6
047  95   =
048  42  STO
049  02   02
050  32  X:T
051  02   2
052  02   2
053  06   6
054  03   3
055  02   2
056  01   1
057  03   3
058  07   7
059  42  STO
060  14   14
061  02   2
062  42  STO
063  15   15
064  71  SBR
065  22  INV
066  98  ADV
067  91  R/S
068  76  LBL
069  13   C
070  32  X:T
071  02   2
072  07   7
073  42  STO
074  14   14
075  02   2
076  42  STO
077  15   15
078  71  SBR
079  22  INV
080  65   ×
081  43  RCL
082  02   02
```

083	95	=
084	71	SBR
085	23	LNX
086	71	SBR
087	24	CE
088	98	ADV
089	91	R/S
090	76	LBL
091	15	E
092	98	ADV
093	32	X:T
094	01	1
095	07	7
096	02	2
097	02	2
098	01	1
099	03	3
100	02	2
101	07	7
102	42	STO
103	14	14
104	01	1
105	42	STO
106	15	15
107	71	SBR
108	22	INV
109	71	SBR
110	24	CE
111	91	R/S
112	76	LBL
113	16	A'
114	42	STO
115	05	05
116	59	INT
117	42	STO
118	04	04
119	71	SBR
120	23	LNX
121	43	RCL
122	05	05
123	22	INV
124	59	INT
125	65	×
126	01	1
127	00	0
128	00	0
129	00	0
130	95	=
131	42	STO
132	05	05
133	32	X:T
134	03	3
135	07	7
136	01	1
137	07	7
138	03	3
139	00	0
140	03	3
141	03	3
142	42	STO
143	14	14
144	00	0
145	42	STO
146	15	15
147	71	SBR
148	22	INV
149	53	(
150	53	(
151	53	(
152	53	(
153	43	RCL
154	05	05
155	75	-
156	01	1
157	08	8
158	54	)
159	65	×
160	93	.
161	00	0
162	00	0
163	00	0
164	04	4
165	04	4
166	06	6
167	54	)
168	22	INV
169	23	LNX
170	65	×
171	93	.
172	09	9
173	07	7
174	54	)
175	75	-
176	01	1
177	54	)
178	75	-
179	53	(
180	01	1
181	75	-
182	53	(
183	53	(
184	53	(
185	43	RCL
186	05	05
187	75	-
188	02	2
189	05	5
190	00	0
191	54	)
192	50	I×I
193	54	)
194	55	÷
195	01	1
196	05	5
197	00	0
198	54	)
199	54	)
200	65	×
201	93	.
202	00	0
203	02	2
204	95	=
205	65	×
206	43	RCL
207	04	04
208	95	=
209	42	STO
210	12	12
211	71	SBR
212	23	LNX
213	98	ADV
214	91	R/S
215	76	LBL
216	17	B'
217	42	STO
218	08	08
219	03	3
220	03	3
221	00	0
222	01	1
223	42	STO
224	14	14
225	43	RCL
226	08	08
227	71	SBR
228	25	CLR
229	91	R/S
230	42	STO
231	09	09
232	71	SBR
233	25	CLR
234	43	RCL
235	08	08
236	44	SUM
237	09	09
238	91	R/S
239	42	STO
240	10	10
241	71	SBR
242	25	CLR
243	43	RCL
244	08	08
245	44	SUM
246	10	10
247	91	R/S
248	42	STO
249	11	11
250	71	SBR
251	25	CLR
252	43	RCL
253	08	08
254	44	SUM
255	11	11
256	53	(
257	43	RCL
258	09	09
259	55	÷
260	43	RCL
261	10	10
262	54	)
263	75	-
264	53	(
265	43	RCL
266	09	09
267	55	÷
268	43	RCL
269	11	11
270	54	)
271	95	=
272	42	STO
273	13	13
274	43	RCL
275	12	12
276	55	÷
277	43	RCL
278	13	13
279	95	=
280	71	SBR
281	23	LNX
282	98	ADV
283	91	R/S
284	76	LBL
285	10	E'
286	00	0
287	42	STO
288	03	03
289	99	PRT
290	98	ADV
291	91	R/S
292	76	LBL
293	22	INV
294	22	INV
295	58	FIX
296	25	CLR
297	69	OP
298	00	00
299	43	RCL
300	14	14
301	69	OP
302	04	04
303	32	X:T
304	58	FIX
305	40	IND
306	15	15
307	69	OP
308	06	06
309	92	RTN
310	76	LBL
311	23	LNX
312	32	X:T
313	02	2
314	02	2
315	01	1
316	03	3
317	02	2
318	07	7
319	03	3
320	06	6
321	42	STO
322	14	14
323	00	0
324	42	STO
325	15	15
326	71	SBR
327	22	INV
328	92	RTN
329	76	LBL
330	24	CE
331	44	SUM
332	03	03
333	43	RCL
334	03	03

```
335   32 X:T
336   07  7
337   07  7
338   02  2
339   02  2
340   01  1
341   03  3
342   02  2
343   07  7
344   42 STO
345   14  14
346   00  0
347   42 STO
348   15  15
349   71 SBR
350   22 INV
351   98 ADV
352   92 RTN
353   76 LBL
354   25 CLR
355   32 X:T
356   02  2
357   42 STO
358   15  15
359   71 SBR
360   22 INV
361   01  1
362   44 SUM
363   14  14
364   92 RTN
365   00  0
366   00  0
367   00  0
368   00  0
369   00  0
370   00  0
```

PP-3
PIPING SYSTEM VOLUME AND EXPANSION TANK SIZING PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Initialize	–	–	*f*	E	0.00 ***	
						0.00 ***	
2.	Enter run no.	1.02	–	–	A	1.02 ***	
3.	Enter inside pipe diameter, in.	4	–	–	B	4.00 ***	
						0.65 ***	Gal/ft of pipe
4.	Enter length of pipe, ft	594	–	–	C	594.00 ***	
						387.74 ***	Gal
						387.74 ***	Total gal
	Repeat steps 2, 3, & 4 as many	2.03	–	–	A	2.03 ***	
	times as desired.	6	–	–	B	6.00 ***	
						1.47 ***	
		954	–	–	C	954.00 ***	
						1401.13 ***	
						1788.87 ***	
5.	Enter equipment volume to be added to system	700	–	–	E	700.00 ***	
						2488.87 ***	Total gal
	Continue in this manner for the entire system.						
6.	To compute size of open expansion tank, enter volume and temp.	2500.375	–	*f*	A	2500.00 ***	Volume of system
						375.00 ***	Temp.
	For closed expansion tank					335.22 ***	Size of expansion tank
7.	Enter atmospheric pressure	15	–	*f*	B	15.00 ***	
8.	Enter tank pressure – fill gauge	1	–	–	R/S	1.00 ***	
9.	Enter minimum initial pressure – gauge	2	–	–	R/S	2.00 ***	
10.	Enter operating pressure – gauge	150	–	–	R/S	150.00 ***	
						397.08 ***	Size of closed expansion tank

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
0	Totalizes in R3; prints value of R3
A	Prints display (run no.)
B	Prints display (diameter); computes and prints gallons per foot
C	Prints display (length); computes and prints gallons for pipe run and total gallons
E	Prints display (equipment gallons); goes to SBR 0
a	Accepts input in decimal format; separates volume, stores in R4; temperature in R5; calculates and prints size of open expansion tank
b	With three R/S, accepts and prints input (P0, P1, P2, and P3) and calculates volume of closed expansion tank
e	Clears register R3 and prints 0

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	Not used
R2	Gallons per foot
R3	Total gallons
R4	Gallons
R5	Temperature
R6	P0
R7	P1
R8	P2
R9	P3

PP-3 (HP-97) PIPING SYSTEM VOLUME AND EXPANSION TANK SIZING PROGRAM

LISTING

```
001  *LBL0     21 00
002  ST+3   35-55 03
003  RCL3      36 03
004  PRTX        -14
005  SPC       16-11
006  RTN          24
007  *LBLA     21 11
008  PRTX        -14
009  RTN          24
010  *LBLB     21 12
011  PRTX        -14
012  X²           53
013  Pi        16-24
014  x           -35
015  7            07
016  .           -62
017  4            04
018  8            08
019  x           -35
020  5            05
021  7            07
022  6            06
023  ÷           -24
024  STO2      35 02
025  PRTX        -14
026  SPC       16-11
027  RTN          24
028  *LBLC     21 13
029  PRTX        -14
030  RCL2      36 02
031  x           -35
032  PRTX        -14
033  GSB0      23 00
034  RTN          24
035  *LBLE     21 15
036  PRTX        -14
037  GSB0      23 00
038  RTN          24
039  *LBLa  21 16 11
040  STO5      35 05
041  INT       16 34
042  STO4      35 04
043  PRTX        -14
044  RCL5      36 05
045  FRC       16 44
046  1            01
047  0            00
048  0            00
049  0            00
050  x           -35
051  STO5      35 05
052  PRTX        -14
053  1            01
054  8            08
055  -           -45
056  .           -62
057  0            00
058  0            00
059  0            00
060  4            04
061  4            04
062  6            06
063  x           -35
064  eˣ           33
065  .           -62
066  9            09
067  7            07
068  x           -35
069  1            01
070  -           -45
071  RCL5      36 05
072  2            02
073  5            05
074  0            00
075  -           -45
076  ABS       16 31
077  1            01
078  5            05
079  0            00
080  ÷           -24
081  1            01
082  -           -45
083  CHS         -22
084  .           -62
085  0            00
086  2            02
087  x           -35
088  -           -45
089  RCL4      36 04
090  x           -35
091  STO1      35 01
092  PRTX        -14
093  SPC       16-11
094  RTN          24
095  *LBLb  21 16 12
096  STO6      35 06
097  PRTX        -14
098  RTN          24
099  STO7      35 07
100  PRTX        -14
101  RTN          24
102  STO8      35 08
103  PRTX        -14
104  RTN          24
105  STO9      35 09
106  PRTX        -14
107  RCL6      36 06
108  +           -55
109  1/X          52
110  RCL6      36 06
111  RCL7      36 07
112  +           -55
113  x           -35
114  RCL7      36 07
115  RCL6      36 06
116  +           -55
117  RCL6      36 06
118  RCL8      36 08
119  +           -55
120  ÷           -24
121  -           -45
122  CHS         -22
123  STO0      35 00
124  1/X          52
125  RCL1      36 01
126  x           -35
127  PRTX        -14
```

```
128  SPC       16-11
129  RTN          24
130  *LBLe  21 16 15
131  0            00
132  STO3      35 03
133  CLX         -51
134  PRTX        -14
135  SPC       16-11
136  RTN          24
137  R/S          51
```

2

AIR DUCT DESIGN PROGRAMS

DP-1
AIR DUCT SIZING PROGRAM

GENERAL DESCRIPTION

This program can be used for sizing supply, return, and exhaust air duct systems based on constant friction loss per foot of length for the entire system. Further, the designer has a choice of limiting the maximum velocity. In this manner, the design velocity will not exceed the maximum velocity limit while below the limiting velocity, the ductwork is sized on constant equal friction loss per foot of length, and the velocity is reduced automatically.

(It is suggested that the designer first use program UP-3, to add branch air flows and to define the distribution network.)

The program can automatically select round or rectangular ductwork.

The program is designed to calculate and print out external ductwork dimensions. In other words, thickness of lining is added to the internal dimension. The designer has the choice of specifying the roughness coefficient for the internal surface to compensate for the friction loss of different types of linings.

The calculated duct dimensions are increased by 0.9 in. and then rounded off to the nearest integer in inches.

In order to optimize the sheet metal, the program for the rectangular duct will first try to select the square duct to fit within the depth available. Should this not be possible, it will calculate the minimum width based on the available depth.

The program also calculates cfm for any given duct size to satisfy maximum velocity and equal friction loss criteria.

EQUATIONS

$$\Delta P = .03 \times f \times \frac{L}{\pi \times d^{1.22}} \times \left(\frac{V}{1000}\right)^{1.82} \qquad [2.1]$$

where

ΔP = Friction loss, in. w.g.
f = Interior surface roughness coefficient
L = Length of duct in feet
d = Duct diameter in inches or equivalent diameter for rectangular or flat-oval ductwork
V = Velocity in fpm

$$Q = \frac{\pi \times d^2 \times V}{576} \qquad V = \left(\frac{Q \times 576}{\pi \times d^2}\right) \qquad [2.2]$$

where

Q = Flow in cfm

Substituting V in equation 2.1,

$$\Delta P = .03 \times f \times \left(\frac{L}{\pi \times d^{1.22}}\right) \times \left(\frac{Q \times 576}{d^2}\right)^{1.82} \times \left(\frac{1}{1000}\right)^{1.82}$$

If L = 100 ft,

$$\Delta P = 3 \times f \times \frac{Q^{1.82}}{d^{4.86}} \times \frac{1}{21.92} = \frac{f}{7.31} \times \frac{Q^{1.82}}{d^{4.86}}$$

If d = 1 in.,

$$Q_{P1} = \left(\frac{\Delta P}{.137 f}\right)^{\frac{1}{1.82}}$$

where

Q_{P1} = cfm for 1-in. diameter duct based on pressure criteria

$$Q_{P2} = Q_{P1} \times d_2^{\frac{4.86}{1.82}} = Q_{P1} \times d_2^{2.67}$$

where

Q_{P2} = cfm for duct d_2 based on pressure criteria

From equation 2.2, where d = 1 in.,

$$Q_{V1} = \frac{V \times \pi}{576}$$

where

Q_{V1} = cfm for 1-in. diameter duct based on velocity criteria

$$Q_{V2} = Q_{V1} \times d_2^2$$

where

Q_{V2} = cfm for duct d_2 based on velocity criteria

The program calculates the diameter based on Q_{P1} and Q_{V1} and selects the larger of the two diameters.

$$\text{Rectangular duct } (De) = 1.3 \frac{(a \times b)^{.625}}{(a + b)^{.25}} \qquad [2.3]$$

For square duct $a = b$

$$De = 1.3 \frac{(a \times a)^{.625}}{(2a)^{.25}} = 1.09\,a$$

or $\quad a = \dfrac{De}{1.09}$

If value of b is small,

$$De \simeq 1.3 \times \frac{(a \times b)^{.625}}{a^{.25}} = 1.3 \times a^{.375} \times b^{.625} \qquad [2.4]$$

where

De = Diameter of equivalent round cut
a = Width of rectangular duct, in.
b = Depth of rectangular duct, in.

The program calculates b for rectangular ductwork by reiteration, which converges rapidly, since the assumed value of b is corrected by multiplying by

$$\left(\frac{De}{\text{calculated dia.}}\right)^2$$

till De equals the calculated diameter.

$$\text{Area of circular duct in sq ft} = \frac{\pi \times d^2}{576} \qquad [2.5]$$

where

d = Diameter in inches

$$\text{Area in sq. ft. of rectangular duct} = \frac{a \times b}{144} \qquad [2.6]$$

OPERATING FEATURES

The input under Label B is in decimal format; the decimal part is for depth available. For example, 6000.16 will mean 6000 cfm; depth available (*DA*) = 16 in. If no decimal input is provided, the program will automatically compute for round ductwork.

In the same manner, input for Label C is in decimal format; for example 40.16 will mean the duct is 40 in. wide by 16 in. deep. If decimal input is not provided, the program will automatically compute for round ductwork.

The output of duct dimensions for Label B is also in decimal format, similar to input for Label C.

Further, the program computes duct diameter and width in increments of one inch. If designers wish to have any other increment, alternate sizes can be investigated by them by inputting through Label C.

REFERENCE DATA

Suggested values for roughness coefficients for internal duct surfaces are given below:

Material	f
Aluminum or galvanized ductwork without lining	0.9
Lining of medium roughness	1.35
Very rough lining	1.90

Based on the interpolation of data in ASHRAE *Handbook of Fundamentals*.

DP-1
AIR DUCT SIZING PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
1.	Enter maximum velocity, fpm	1800	–	2nd	A′	1800.	VMAX	(Shows examples for sizing individual sections.)
2.	Enter maximum friction loss/100 ft	.1	–	2nd	B′	0.100	PD/C	
3.	Enter lining roughness coeff.	.9	–	2nd	C′	0.900	COEF	
4.	Enter lining thickness, in.	0	–	2nd	D′	0.00	L/TH	
5.	Enter duct diameter	12	–	–	C	12.	DIA	
						678.	CFM	
						864.	FPMC	Velocity for circ. duct
						0.100	PD/C	Friction loss/100 ft
	or							
6.	Enter duct dimensions	24.12	–	–	C	24.12	W.D	
						18.	DIA	Equivalent diameter
						2087.	CFM	
						1145.	FPMC	
						0.100	PD/C	
						1044.	FPMA	Average velocity based on rectangular duct
	or							
7.	Enter cfm	15000	–	–	B	15000.	CFM	
						39.	DIA	
						1800.	FPMC	
						0.090	PD/C	
	or							
8.	Enter cfm and depth available	15000.48	–	–	B	15000.	CFM	
						48.	DA	
						36.36	W.D	The program will select square duct if it can fit within the depth available.
						1800.	FPMC	
						0.090	PD/C	
						1667.	FPMA	
	or							
9.	Enter cfm and depth available	15000.20	–	–	B	15000.	CFM	
						20.	DA	
						71.20	W.D	
						1800.	FPMC	
						0.090	PD/C	
						1521.	FPMA	

DP-1 *(Continued)*

AIR DUCT SIZING PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	or							
10.	Enter diameter	39	–	–	C	39. 14932. 1800. 0.090	DIA CFM FPMC PD/C	*Note:* Computed cfm is slightly different for these two examples and one shown under step 7 due to rounding-off process.
11.	Enter dimensions	71.20	–	–	C	71.20 39. 15161. 1800. 0.089 1537.	W.D DIA CFM FPMC PD/C FPMA	
	Example 2							
	Example of sizing a duct system							
1.	Enter maximum velocity, fpm	1800	–	2nd	A′	1800.	VMAX	
2.	Enter maximum friction loss/100 ft	.15	–	2nd	B′	0.150	PD/C	
3.	Enter lining roughness coeff.	.9	–	2nd	C′	0.900	COEF	
4.	Enter lining thickness, in.	0	–	2nd	D′	0.00	L/TH	
5.	Enter run no.	1.02	–	–	A	1.02	R/NO	
6.	Enter cfm and depth	10500.24	–	–	B	10500. 24. 38.24 1800. 0.112 1658.	CFM DA W.D FPMC PD/C FPMA	
	Repeat steps 5 & 6 as many times as required.							

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A′	Stores and prints VMAX; calculates and stores QV1; partitions program
B′	Stores and prints PD/C
C′	Stores surface roughness coefficient; calculates and stores QP1
D′	Stores and prints lining thickness; doubles and stores lining thickness
A	Prints R No.
B	Accepts CFM and DA (depth available) in decimal format; separates two; if DA is not zero, sets flag 0 for rectangular ductwork; goes to SBR LNX
INV	Prints alphanumeric characters for identification of data
LNX	Calculates diameters for round duct based on QV1 and QP1; selects larger of two; rounds out to nearest integer after adding 0.9 in.; adds lining thickness; prints DIA; calculates and prints FPMC; calculates and prints PD/C; if flag 0 is set, goes to SBR CE
CE	Calculates size of square duct; compares with DA; if square duct can fit goes to SBR X^2, otherwise calculates width, based on duct depth as DA; uses SBR $\sqrt{X}$ for reiteration to accuracy of 0.01 in. (operating time can be reduced by accepting less accuracy); calculates W.D by rounding out to nearest integer after adding 0.9; adds lining thickness; prints W.D; calculates and prints FPMC; calculates and prints PD/C; calculates and prints FPMA
CLR	Calculates and prints FPMC (velocity in feet per minute based on circular duct)
X⇄T	Calculates and prints PD/C (friction loss/100 ft)
X^2	For square duct makes W.D equal; prints W.D; calculates and prints FPMC, PD/C, FPMA
1/X	Calculates equivalent diameter for given W and D
STO	Corrects interim value of calculated equivalent diameter for reiteration
RCL	Changes net size of W and D to external size by adding lining thickness; arranges and prints W.D
SUM	Calculates and prints FPMA (velocity in feet per minute for average rectangular duct)
Y^x	Prints PD/C
EE	Prints W.D
(	Prints CFM
)	Prints DIA
÷	Calls SBR); deducts lining thickness; uses SBR GTO
GTO	Calculates QV2; QP2; selects smaller of two; uses SBR CLR and SBR X⇄T
C	Checks for decimal input; if zero, goes to SBR ÷, if not zero prints W.D; computes net W and D after deducting lining thickness; uses SBR 1/X, SBR), and SBR GTO; adds lining thickness and uses SBR SUM

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Not used
R01	Duct surface roughness coefficient
R02	VMAX
R03	QV1
R04	PD/C
R05	QP1
R06	Lining thickness L/TH
R07	CFM
R08	DA; also width
R09	DIA based on velocity; CFM based on velocity
R10	DIA based on PD/C; CFM based on PD/C
R11	Equivalent DIA from CFM
R12	Depth
R13	Calculated equivalent diameter
R14	W.D
R15	D
R16	Not used

R17	Not used
R18	Alphanumeric code for printing
R19	For storing decimal places

DP-1 AIR DUCT SIZING PROGRAM

LABELS & SUBROUTINES

```
001  16  A'
036  17  B'
043  18  C'
084  19  D'
110  11  A
130  12  B
176  22  INV
194  23  LNX
268  24  CE
295  34  ΓX
322  25  CLR
355  32  X:T
387  33  X²
410  35  1/X
449  42  STO
474  43  RCL
500  44  SUM
545  45  Yˣ
564  52  EE
581  53  (
598  54  )
615  55  ÷
632  61  GTO
693  13  C
```

LISTING

```
000  76  LBL
001  16  A'
002  42  STO
003  02  02
004  32  X:T
005  04  4
006  02  2
007  03  3
008  00  0
009  01  1
010  03  3
011  04  4
012  04  4
013  42  STO
014  18  18
015  00  0
016  42  STO
017  19  19
018  71  SBR
019  22  INV
020  65  ×
021  89  π
022  55  ÷
023  05  5
024  07  7
025  06  6
026  95  =
027  42  STO
028  03  03
029  22  INV
030  58  FIX
031  02  2
032  69  OP
033  17  17
034  91  R/S
035  76  LBL
036  17  B'
037  42  STO
038  04  04
039  71  SBR
040  45  Yˣ
041  91  R/S
042  76  LBL
043  18  C'
044  42  STO
045  01  01
046  32  X:T
047  01  1
048  05  5
049  03  3
050  02  2
051  01  1
052  07  7
053  02  2
054  01  1
055  42  STO
056  18  18
057  03  3
058  42  STO
059  19  19
060  71  SBR
061  22  INV
062  65  ×
063  93  .
064  01  1
065  03  3
066  07  7
067  95  =
068  35  1/X
069  65  ×
070  43  RCL
071  04  04
072  95  =
073  22  INV
074  45  Yˣ
075  01  1
076  93  .
077  08  8
078  02  2
079  95  =
080  42  STO
081  05  05
082  91  R/S
083  76  LBL
084  19  D'
085  42  STO
086  06  06
087  32  X:T
088  02  2
089  07  7
090  06  6
091  03  3
092  03  3
093  07  7
094  02  2
095  03  3
096  42  STO
097  18  18
098  02  2
099  42  STO
100  19  19
101  71  SBR
102  22  INV
103  65  ×
104  02  2
105  95  =
106  42  STO
107  06  06
108  91  R/S
109  76  LBL
110  11  A
111  98  ADV
112  32  X:T
113  03  3
114  05  5
115  06  6
116  03  3
117  03  3
118  01  1
119  03  3
120  02  2
121  42  STO
122  18  18
123  02  2
124  42  STO
125  19  19
126  71  SBR
127  22  INV
128  91  R/S
129  76  LBL
130  12  B
131  42  STO
132  07  07
133  22  INV
134  86  STF
135  00  00
136  22  INV
137  59  INT
138  65  ×
139  01  1
140  00  0
141  00  0
142  95  =
143  42  STO
144  08  08
145  43  RCL
146  07  07
147  59  INT
148  71  SBR
149  53  (
150  29  CP
151  43  RCL
152  08  08
153  67  EQ
154  23  LNX
155  86  STF
156  00  00
157  43  RCL
158  08  08
159  32  X:T
160  01  1
161  06  6
162  01  1
163  03  3
164  42  STO
165  18  18
166  00  0
167  42  STO
168  19  19
169  71  SBR
170  22  INV
171  71  SBR
172  23  LNX
173  98  ADV
174  91  R/S
175  76  LBL
176  22  INV
177  22  INV
178  58  FIX
179  25  CLR
180  69  OP
181  00  00
182  43  RCL
183  18  18
184  69  OP
185  04  04
186  32  X:T
187  58  FIX
188  40  IND
189  19  19
190  69  OP
191  06  06
192  92  RTN
193  76  LBL
194  23  LNX
195  53  (
196  43  RCL
197  07  07
198  55  ÷
199  43  RCL
200  03  03
201  54  )
202  34  ΓX
203  42  STO
204  09  09
205  53  (
206  53  (
```

Step	Code	Key
207	43	RCL
208	07	07
209	55	÷
210	43	RCL
211	05	05
212	54	)
213	45	Y^X
214	93	.
215	03	3
216	07	7
217	05	5
218	54	)
219	42	STO
220	10	10
221	53	(
222	53	(
223	53	(
224	43	RCL
225	10	10
226	75	-
227	43	RCL
228	09	09
229	54	)
230	50	I×I
231	85	+
232	43	RCL
233	09	09
234	85	+
235	43	RCL
236	10	10
237	54	)
238	55	÷
239	02	2
240	54	)
241	42	STO
242	11	11
243	87	IFF
244	00	00
245	24	CE
246	53	(
247	53	(
248	43	RCL
249	11	11
250	85	+
251	93	.
252	09	9
253	54	)
254	59	INT
255	85	+
256	43	RCL
257	06	06
258	54	)
259	71	SBR
260	54	)
261	71	SBR
262	25	CLR
263	71	SBR
264	32	X:T
265	98	ADV
266	92	RTN
267	76	LBL
268	24	CE
269	43	RCL
270	06	06
271	22	INV
272	44	SUM
273	08	08
274	53	(
275	43	RCL
276	11	11
277	55	÷
278	01	1
279	93	.
280	00	0
281	09	9
282	54	)
283	42	STO
284	12	12
285	32	X:T
286	43	RCL
287	08	08
288	77	GE
289	33	X²
290	93	.
291	00	0
292	01	1
293	32	X:T
294	76	LBL
295	34	√X
296	71	SBR
297	35	1/X
298	71	SBR
299	42	STO
300	77	GE
301	34	√X
302	53	(
303	43	RCL
304	12	12
305	85	+
306	93	.
307	09	9
308	54	)
309	59	INT
310	42	STO
311	12	12
312	71	SBR
313	43	RCL
314	71	SBR
315	25	CLR
316	71	SBR
317	32	X:T
318	71	SBR
319	44	SUM
320	92	RTN
321	76	LBL
322	25	CLR
323	53	(
324	43	RCL
325	07	07
326	65	×
327	05	5
328	07	7
329	06	6
330	55	÷
331	89	π
332	55	÷
333	43	RCL
334	11	11
335	33	X²
336	54	)
337	32	X:T
338	02	2
339	01	1
340	03	3
341	03	3
342	03	3
343	00	0
344	01	1
345	05	5
346	42	STO
347	18	18
348	00	0
349	42	STO
350	19	19
351	71	SBR
352	22	INV
353	92	RTN
354	76	LBL
355	32	X:T
356	53	(
357	43	RCL
358	01	01
359	65	×
360	53	(
361	43	RCL
362	07	07
363	45	Y^X
364	01	1
365	93	.
366	08	8
367	02	2
368	54	)
369	55	÷
370	43	RCL
371	11	11
372	45	Y^X
373	04	4
374	93	.
375	08	8
376	06	6
377	55	÷
378	07	7
379	93	.
380	03	3
381	01	1
382	54	)
383	71	SBR
384	45	Y^X
385	92	RTN
386	76	LBL
387	33	X²
388	53	(
389	43	RCL
390	12	12
391	85	+
392	93	.
393	09	9
394	54	)
395	59	INT
396	42	STO
397	12	12
398	42	STO
399	08	08
400	71	SBR
401	43	RCL
402	71	SBR
403	25	CLR
404	71	SBR
405	32	X:T
406	71	SBR
407	44	SUM
408	92	RTN
409	76	LBL
410	35	1/X
411	53	(
412	01	1
413	93	.
414	03	3
415	65	×
416	53	(
417	53	(
418	43	RCL
419	08	08
420	65	×
421	43	RCL
422	12	12
423	54	)
424	45	Y^X
425	93	.
426	06	6
427	02	2
428	05	5
429	54	)
430	55	÷
431	53	(
432	53	(
433	43	RCL
434	08	08
435	85	+
436	43	RCL
437	12	12
438	54	)
439	45	Y^X
440	93	.
441	02	2
442	05	5
443	54	)
444	54	)
445	42	STO
446	13	13
447	92	RTN
448	76	LBL
449	42	STO
450	53	(
451	53	(
452	43	RCL
453	11	11
454	55	÷
455	43	RCL
456	13	13
457	54	)
458	33	X²
459	54	)
460	49	PRD
461	12	12
462	53	(

```
463  53  (
464  43  RCL
465  13  13
466  75  -
467  43  RCL
468  11  11
469  54  )
470  50  I×I
471  54  )
472  92  RTN
473  76  LBL
474  43  RCL
475  53  (
476  43  RCL
477  12  12
478  85  +
479  43  RCL
480  06  06
481  85  +
482  53  (
483  53  (
484  43  RCL
485  08  08
486  85  +
487  43  RCL
488  06  06
489  54  )
490  55  ÷
491  01  1
492  00  0
493  00  0
494  54  )
495  54  )
496  71  SBR
497  52  EE
498  92  RTN
499  76  LBL
500  44  SUM
501  53  (
502  43  RCL
503  07  07
504  65  ×
505  01  1
506  04  4
507  04  4
508  55  ÷
509  53  (
510  53  (
511  43  RCL
512  12  12
513  75  -
514  43  RCL
515  06  06
516  54  )
517  65  ×
518  53  (
519  43  RCL
520  08  08
521  75  -
522  43  RCL
523  06  06
524  54  )
525  54  )
526  54  )
527  32  X:T
528  02  2
529  01  1
530  03  3
531  03  3
532  03  3
533  00  0
534  01  1
535  03  3
536  42  STO
537  18  18
538  00  0
539  42  STO
540  19  19
541  71  SBR
542  22  INV
543  92  RTN
544  76  LBL
545  45  Y^X
546  32  X:T
547  03  3
548  03  3
549  01  1
550  06  6
551  06  6
552  03  3
553  01  1
554  05  5
555  42  STO
556  18  18
557  03  3
558  42  STO
559  19  19
560  71  SBR
561  22  INV
562  92  RTN
563  76  LBL
564  52  EE
565  32  X:T
566  04  4
567  03  3
568  04  4
569  00  0
570  01  1
571  06  6
572  42  STO
573  18  18
574  02  2
575  42  STO
576  19  19
577  71  SBR
578  22  INV
579  92  RTN
580  76  LBL
581  53  (
582  32  X:T
583  01  1
584  05  5
585  02  2
586  01  1
587  03  3
588  00  0
589  42  STO
590  18  18
591  00  0
592  42  STO
593  19  19
594  71  SBR
595  22  INV
596  92  RTN
597  76  LBL
598  54  )
599  32  X:T
600  01  1
601  06  6
602  02  2
603  04  4
604  01  1
605  03  3
606  42  STO
607  18  18
608  00  0
609  42  STO
610  19  19
611  71  SBR
612  22  INV
613  92  RTN
614  76  LBL
615  55  ÷
616  53  (
617  43  RCL
618  14  14
619  71  SBR
620  54  )
621  75  -
622  43  RCL
623  06  06
624  54  )
625  42  STO
626  13  13
627  71  SBR
628  61  GTO
629  98  ADV
630  92  RTN
631  76  LBL
632  61  GTO
633  53  (
634  43  RCL
635  13  13
636  33  X^2
637  65  ×
638  43  RCL
639  03  03
640  54  )
641  42  STO
642  09  09
643  53  (
644  43  RCL
645  13  13
646  45  Y^X
647  02  2
648  93  .
649  06  6
650  07  7
651  65  ×
652  43  RCL
653  05  05
654  54  )
655  42  STO
656  10  10
657  53  (
658  53  (
659  43  RCL
660  10  10
661  85  +
662  43  RCL
663  09  09
664  75  -
665  53  (
666  53  (
667  43  RCL
668  10  10
669  75  -
670  43  RCL
671  09  09
672  54  )
673  50  I×I
674  54  )
675  54  )
676  55  ÷
677  02  2
678  54  )
679  42  STO
680  07  07
681  71  SBR
682  53  (
683  43  RCL
684  13  13
685  42  STO
686  11  11
687  71  SBR
688  25  CLR
689  71  SBR
690  32  X:T
691  92  RTN
692  76  LBL
693  13  C
694  42  STO
695  14  14
696  29  CP
697  22  INV
698  59  INT
699  65  ×
700  01  1
701  00  0
702  00  0
703  95  =
704  42  STO
705  12  12
706  67  EQ
707  55  ÷
708  43  RCL
709  14  14
710  71  SBR
711  52  EE
712  59  INT
713  42  STO
714  08  08
715  43  RCL
716  06  06
717  22  INV
718  44  SUM
```

```
719  08  08
720  22  INV
721  44  SUM
722  12  12
723  71  SBR
724  35  1/X
725  43  RCL
726  13  13
727  71  SBR
728  54  )
729  71  SBR
730  61  GTO
731  43  RCL
732  06  06
733  44  SUM
734  12  12
735  44  SUM
736  08  08
737  71  SBR
738  44  SUM
739  98  ADV
740  22  INV
741  91  R/S
742  00  0
743  00  0
744  00  0
745  00  0
746  00  0
747  00  0
748  00  0
```

DP-1
AIR DUCT SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
	In order to keep record, put printer in TRACE mode						
1.	Clear register and print 0	–	CL*x*	PRINT*x*	CL*x*	CLX	
						0.0000 ***	
2.	Enter maximum velocity	1800	–	STO	0	1800.0000 STO0	
3.	Enter friction loss/100 ft	.1	–	STO	1	.1000 STO1	
4.	Enter lining roughness coeff.	.9	–	STO	2	.9000 STO2	
5.	Enter twice lining thickness	0	–	STO	3	0.0000 STO3	
6.	Enter constant	576	–	–	Enter	576.0000 ENT↑	
		–	–	*f*	÷	Fi	
						3.1416 ***	
		–	–	–	÷	÷	
						183.3465 ***	
		–	–	STO	4	ST04	Remove from TRACE mode after this step.
7.	Compute and store constants	–	–	*f*	E		
8.	Enter duct diameter	12	–	–	D	12.0000 ***	
						679.0000 ***	Cubic ft/min
						864.5257 ***	Velocity
						0.1002 ***	Friction loss/100 ft
	or						
8.	Enter duct width	24	–	–	E	24.0000 ***	
9.	Enter duct depth	12	–	–	R/S	12.0000 ***	
						18.2805 ***	Equivalent diameter
						2067.0000 ***	Cubic ft/min
						1145.0356 ***	Velocity
						0.1000 ***	Friction loss/100 ft
	or						
8.	Enter cfm	–	–	–	B	15000.0000 ***	Diameter
						39.0000 ***	Velocity
						1800.0000 ***	Friction loss/100 ft
						0.0902 ***	

	or						
8.	Enter depth available	48	–	–	C	48.0000 ***	
						36.0000 ***	Square duct
						36.0000 ***	36 x 36
	or						
8.	Enter depth available	20	–	–	C	20.0000 ***	
						71.0000 ***	Width
	Example 2						
	In order to keep record, put printer in TRACE mode						
1.	Clear registers and print 0	–	CL*x*	PRINT*x*	CL*x*	CLX	
						0.0000 ***	
2.	Enter maximum velocity	1800	–	STO	0	1800.0000 STO0	
3.	Enter friction loss/100 ft	.15	–	STO	1	.1500 STO1	
4.	Enter lining roughness coeff.	.9	–	STO	2	.9000 STO2	
5.	Enter twice lining thickness	0	–	STO	3	0.0000 STO3	
6.	Enter constant	576	–	–	Enter	576.0000 ENT↑	
		–	–	*f*	÷	Pi	
						3.1416 ***	
					÷	÷	
						183.3465 ***	
				STO	4	STO4	Remove from TRACE mode
7.	Compute and store constants	–	–	*f*	E		after this step
8.	Enter run no.	1.02	–	–	A	1.0200 ***	
9.	Enter cfm	10500	–	–	B	10500.0000 ***	
						33.0000 ***	Diameter
						1800.0200 ***	Velocity, fpm
						0.1121 ***	Friction loss/100 ft
10.	Enter depth available	24	–	–	C	24.0000 ***	
						38.0000 ***	Width

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
e	Calculates QV1 (CFM through 1-in. diameter duct) based on velocity; stores in RB; calculates QP1 (CFM through 1-in. diameter duct based on friction loss); stores in RA
A	Prints display (run no.)
B	Prints and stores display (CFM) in RI; calculates diameter R5 based on velocity and friction loss R6; if R5 > R6, goes to SBR 0
1	Calls SBR a; adds R3; calls SBR 2 and SBR 3
c	Prints display (depth available); deducts R3 and stores in R5; computes size of square duct R7; if R5 > R7 goes to SBR 4
5	Using SBR 6, computes width of rectangular ductwork; adds R3 and prints
D	Prints display (diameter); deducts R3 and stores in R6; calculates CFM based on velocity RD; calculates CFM based on friction loss RE; if RD is smaller than RE, goes to SBR 7
8	Goes to SBR a, prints results, stores in RI; stores RC in R6 and goes to SBR 2 and SBR 3
E	Prints display (duct width); deducts R3 and stores in R5; with R/S, prints display (duct depth), deducts R3, stores in R7, calls SBR 6, adds R3, and goes to SBR a
a	Adds 0.9 and finds nearest integer
0	Stores R5 in R6 and goes to SBR 1
2	Calculates velocity for round duct
3	Calculates friction loss/100 ft
4	Goes to SBR a; adds R3 and prints (size of square duct)
6	Calculates diameter of equivalent round duct
7	Stores RD in RE and goes to SBR 8

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	VMAX
R1	Friction loss/100 ft
R2	Duct surface roughness coefficient
R3	Twice lining thickness
R4	576 ÷ π
R5	Diameter based on velocity
R6	Diameter based on friction loss
R7	Dimension of square duct; also calculated duct depth
R8	Not used
R9	Not used
RA	QP1
RB	QV1
RC	Net diameter
RD	CFM based on velocity
RE	CFM based on friction loss
RI	CFM

DP-1 (HP-97) AIR DUCT SIZING PROGRAM

LISTING

```
001  *LBLe   21 16 15
002    SPC      16-11
003    SPC      16-11
004   RCL0      36 00
005   RCL4      36 04
006      ÷        -24
007   STOB      35 12
008   RCL1      36 01
009      .        -62
010      1         01
011      3         03
012      7         07
013      ÷        -24
014   RCL2      36 02
015      ÷        -24
016      1         01
017      .        -62
018      8         08
019      2         02
020    1/X         52
021     Y^X        31
022   STOA      35 11
023    RTN         24
024  *LBLA      21 11
025   PRTX        -14
026    RTN         24
027  *LBLB      21 12
028   PRTX        -14
029   STOI      35 46
030   RCLB      36 12
031      ÷        -24
032     √X         54
033   STO5      35 05
034   RCLI      36 46
035   RCLA      36 11
036      ÷        -24
037      .        -62
038      3         03
039      7         07
040      5         05
041     Y^X        31
```

```
042  STO6      35 06
043  RCL5      36 05
044  X>Y?      16-34
045  GTO0      22 00
046  *LBL1     21 01
047  RCL6      36 06
048  GSBa   23 16 11
049  RCL3      36 03
050  +           -55
051  PRTX        -14
052  GSB2      23 02
053  GSB3      23 03
054  SPC       16-11
055  RTN          24
056  *LBLC     21 13
057  PRTX        -14
058  SPC       16-11
059  RCL3      36 03
060  -           -45
061  STO5      35 05
062  RCL6      36 06
063  1            01
064  .           -62
065  0            00
066  9            09
067  ÷           -24
068  STO7      35 07
069  RCL5      36 05
070  X>Y?      16-34
071  GTO4      22 04
072  *LBL5     21 05
073  GSB6      23 06
074  RCL6      36 06
075  ÷           -24
076  1/X          52
077  X²           53
078  ST×7   35-35 07
079  RCLC      36 13
080  RCL6      36 06
081  -           -45
082  ABS       16 31
083  .           -62
084  0            00
085  1            01
086  X≤Y?      16-35
087  GTO5      22 05
088  RCL7      36 07
089  GSBa   23 16 11
090  RCL3      36 03
091  +           -55
092  PRTX        -14
093  SPC       16-11
094  RTN          24
095  *LBLD     21 14
096  PRTX        -14
097  SPC       16-11
098  RCL3      36 03
099  -           -45
100  STOC      35 13
101  X²           53
102  RCLB      36 12
103  ×           -35
104  STOD      35 14
105  RCLC      36 13
106  2            02
107  .           -62
108  6            06
109  7            07
110  Yˣ           31
111  RCLA      36 11
112  ×           -35
113  STOE      35 15
114  RCLD      36 14
115  X≤Y?      16-35
116  GTO7      22 07
117  *LBL8     21 08
118  RCLE      36 15
119  GSBa   23 16 11
120  PRTX        -14
121  SPC       16-11
122  STOI      35 46
123  RCLC      36 13
124  STO6      35 06
125  GSB2      23 02
126  GSB3      23 03
127  SPC       16-11
128  RTN          24
129  *LBLE     21 15
130  PRTX        -14
131  RCL3      36 03
132  -           -45
133  STO5      35 05
134  RTN          24
135  PRTX        -14
136  RCL3      36 03
137  -           -45
138  STO7      35 07
139  GSB6      23 06
140  RCL3      36 03
141  +           -55
142  STOC      35 13
143  GSBD      23 14
144  SPC       16-11
145  RTN          24
146  *LBLa  21 16 11
147  .           -62
148  9            09
149  +           -55
150  INT       16 34
151  RTN          24
152  *LBL0     21 00
153  RCL5      36 05
154  STO6      35 06
155  GSB1      23 01
156  RTN          24
157  *LBL2     21 02
158  RCLI      36 46
159  RCL4      36 04
160  ×           -35
161  RCL6      36 06
162  X²           53
163  ÷           -24
164  PRTX        -14
165  RTN          24
166  *LBL3     21 03
167  RCLI      36 46
168  RCLA      36 11
169  ÷           -24
170  RCL6      36 06
171  2            02
172  .           -62
173  6            06
174  7            07
175  Yˣ           31
176  ÷           -24
177  1            01
178  .           -62
179  8            08
180  2            02
181  Yˣ           31
182  RCL1      36 01
183  ×           -35
184  PRTX        -14
185  RTN          24
186  *LBL4     21 04
187  RCL7      36 07
188  GSBa   23 16 11
189  RCL3      36 03
190  +           -55
191  PRTX        -14
192  PRTX        -14
193  SPC       16-11
194  RTN          24
195  *LBL6     21 06
196  RCL5      36 05
197  RCL7      36 07
198  ×           -35
199  .           -62
200  6            06
201  2            02
202  5            05
203  Yˣ           31
204  1            01
205  .           -62
206  3            03
207  ×           -35
208  RCL5      36 05
209  RCL7      36 07
210  +           -55
211  .           -62
212  2            02
213  5            05
214  Yˣ           31
215  ÷           -24
216  STOC      35 13
217  RTN          24
218  *LBL7     21 07
219  RCLD      36 14
220  STOE      35 15
221  GSB8      23 08
222  SPC       16-11
223  RTN          24
224  R/S          51
```

DP-2
AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD

PROGRAM DESCRIPTION

The ductwork is sized so that the increase in static pressure due to reduction in velocity at each link just equals the frictional loss in the succeeding section of the duct. In this manner, each node or terminal is maintained at constant static pressure, and velocity pressure is used for overcoming the duct friction loss.

The ductwork designed on the basis of the static regain method is easier to balance and requires less energy to operate as compared to the constant friction loss method.

The program will handle both circular and rectangular ductwork. In the case of rectangular ductwork, the width can be computed to suit the available depth. The duct sizes are calculated to the nearest inch.

The users have two options for inputting data for dynamic losses for ductwork fittings:

Option 1. Use the data given in ASHRAE *Handbook of Fundamentals,* chapter on air duct design. This method will yield accurate results.

Option 2. Convert duct fittings data to the equivalent duct length based on information given in *Handbook of Air Conditioning Systems Design,* Carrier Air Conditioning Company, by McGraw-Hill Inc. This method is faster but less accurate.

The program will take into account the duct lining thickness and internal surface roughness coefficient. The duct sizes computed are external sizes with a specified lining thickness.

EQUATIONS

In addition to the equations given under Program DP-1, this program is based on the following equations:

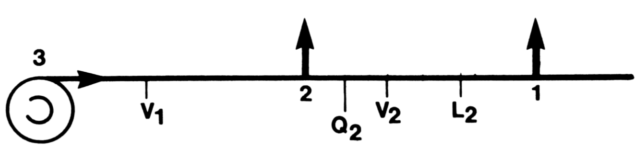


FIGURE 2A

Static regain at node 2

$$= \left[\left(\frac{V_1}{4005}\right)^2 - \left(\frac{V_2}{4005}\right)^2\right] \times K1 \qquad [2.7]$$

where

V_1 = Velocity in fps preceeding the node
V_2 = Velocity in fps after the node
K_1 = Regain factor depending on construction (0.75 to 0.95)

Friction loss in duct run, see Figure 2A,

$$\Delta P = .03 \times f \times \left(\frac{L_2}{d_2^{1.22}}\right) \times \left(\frac{V_2}{1000}\right)^{1.82} \qquad [2.8]$$

$$\text{also} \quad Q_2 = \frac{\pi}{516} \times V_2 \times d_2^2$$

$$\text{or} \quad d_2 = \left(\frac{Q_2 \times 576}{V_2 \times \pi}\right)^{1/2} \qquad [2.9]$$

Substituting d_2 in equation 2.8,

$$\Delta P = .03 \times f \times (L_2) \times \frac{V_2^{1.82}}{(V_2^{\frac{1}{2}})^{1.22}} \times \frac{1}{1000^{1.82}} \times \frac{(\pi^{\frac{1}{2}})^{1.22}}{576} \times \frac{1}{(Q_2^{\frac{1}{2}})^{1.22}}$$

$$= 433 \times 10^{-11} \times f \times \frac{L_2 \times V_2^{2.43}}{Q_2^{.61}}$$

$$= \frac{K_2 \times L_2 \times V_2^{2.43}}{Q_2^{.61}}$$

$$K_2 = (433 \times 10^{-11} \times f) \qquad [2.10]$$

$$\text{Energy loss due to fittings} = C\left(\frac{V_2}{4005}\right)^2 \qquad [2.11]$$

where

C = Total velocity pressure loss coefficient for fittings
V_2 = Velocity in fps

$$\text{Total loss} = \frac{K_2 \times L_2 \times V_2^{2.43}}{Q^{.61}} + C\left(\frac{V_2}{4005}\right)^2 \qquad [2.12]$$

Since static regain should equal loss

$$[K_1 \times ((V_1/4005)^2 - (V_2/4005)^2)] = (K_2 \times L_2 \times V_2^{2.43}/Q_2^{.61}) + C \times (V_2/4005)^2$$

or, rearranging,

$$(K_2 \times L_2 \times V_2^{2.43}/Q_2^{.61}) + C\,(V_2/4005)^2 - [K_1 \times ([V_1/4005]^2 - [V_2/4005]^2)] = 0 \qquad [2.13]$$

Value of V_2 is computed by reiteration of Newton's method for solving

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)} \qquad [2.14]$$

where

x_1 = Initial value of variable
$f(x_1)$ = Value of function with x_1 as variable
$f'(x_1)$ = Value of first differential of function with x_1 as variable
x_2 = Revised more accurate value of variable

$$f'(x_1) = [2.43 \times K_2 \times \frac{L_2}{Q_2^{.61}} \times V_2^{1.43}] + [2 \times \frac{C}{4005^2} \times V_2] + [2 \times \frac{K_1}{4005^2} \times V_2]$$

$$= [2.43 \times K_2 \times \frac{L_2}{Q_2^{.61}} \times V_2^{1.43}] + [2 \times \frac{C+K_1}{4005^2} \times V_2]$$

OPERATING FEATURES

The following features have been incorporated, in order to fit the program within the limit of programming steps and minimize computing time:

a. Alphanumeric output for identification has been reduced to one or two characters. The same subroutine is used for printing V_1 and V_2; PD, PN, and $P\Sigma$.

b. Velocity V_2 is calculated to accuracy of 10 fpm. If velocity reduction is 10%, it takes about 40 seconds to compute the diameter. The computing time will increase as the value of V_2 decreases, since it will increase number of reiterations. If accuracy of less than 10 fpm is desired, it can be achieved at the cost of computing time. On the other hand, computing time can be reduced by accepting accuracy of, say, 50 fpm or 99 fpm; any of these changes can be made without increasing the number of programming steps (change steps 192 and 193).

c. Duct length and fitting coefficient data are input in decimal format as explained later. As shown under "User Instructions and Examples," the first duct run is sized based on the velocity selected by the user. Any number of trial selections can be made by entering the initial velocity under Label B and repeating inputs under Labels A, B, and C.

Once the first duct run is sized, the program will automatically size ductwork based on static regain. The first output will be for round ductwork. If the user desires to change the calculated diameter, it can be done by entering the new diameter and pressing R/S. Change in this manner can be done only when computing the duct size based on static regain. Further change in diameter through R/S can be done as many times as desired.

While calculating the width for rectangular ductwork, the user can also make as many trials as required.

When sizing ductwork based on static regain, the program first computes V_2, the diameter based on V_2, and rounds it to an integer after adding 0.9. Since the result is a slightly larger duct size, the computation will generally show slightly smaller static regain; that is, the value of PN will be negative, if not zero. Due to this reason, actual velocity for the first duct run will be slightly lower than the specified input. If the computed value of the diameter is changed, the program will recalculate pressure losses.

While calculating the width for rectangular ductwork, the program, for sake of accuracy, uses the actual diamater based on V_2, rather than the printed diameter. As in the case of the diameter, the calculated width is rounded off to an integer after adding 0.9.

For further accuracy, the program can recompute duct velocities and pressure losses. This can be achieved by resetting flag 1 (INV—2nd—st. flg 1).

However, this will also increase computing time. All of the above features are further explained by examples.

Length and fitting information has to be input in decimal format as shown in the following examples:

Length	Fitting Coefficient	Input Under Label C
50	.7	50.07
40	1.2	40.12
65	.05	65.005

Length has to be an integer.

DP-2
AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD
USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
	Illustrates sizing of round duct without any trials							
1.	Initialize	—	—	2nd	E′	0.		
2.	Input static regain factor	0.85	—	2nd	A′	0.8500	PR	Static regain factor
3.	Input initial velocity desired	3600	—	2nd	B′	3600.	V1	Initial velocity, fpm desired
4.	Input lining surface — surface roughness coeff.	0.9	—	2nd	C′	0.90	SC	Surface coefficient
						1.	LT	Lining thickness
5.	Input lining thickness, in.	1	—	2nd	D′			
6.	Input run no.	1.02	—	—	A	1.02	RN	Run no.
7.	Input cfm	10000	10000	—	B	10000.	Q	Cubic ft/min
8.	Input length and fitting coeff.	30.05	—	—	C	30.	L	Length
						0.500	FF	Fitting coefficient
						25.	[DI	Diameter
						3466.	[V1	Actual = initial velocity, fpm
						0.5441	[PD	Friction loss, in. w.g.
9.	Input second run no. to be sized on basis of static regain	2.03	—	—	A	2.03	RN	
10.	Input cfm	8000	—	—	B	8000.	Q	
						20.	L	
11.	Length and fitting factor	20.009	—	—	C	0.090	FF	
						24.	DI	Diameter
						3031.	V2	Velocity in run 2.03
						0.1451	PD	Friction loss, in. w.g.
						-0.0048	PN	Net gain or loss
						0.5393	PΣ	Total friction loss up to run 2.03
	Repeat steps 8, 9, & 10 as many times as required.	3.04	—	—	A	3.04	RN	
		6000	—	—	B	6000.	Q	
		25.0025	—	—	C	25.	L	
						0.025	FF	
						23.	DI	
						2495.	V2	
						0.0965	PD	
						-0.0604	PN	Negative value of PN indicates slight gain since actual duct size is rounded off to an integer.
						0.4789	PΣ	

	Example 2							
	Illustrates sizing of rectangular duct without any trials							
1.	Initialize	–	–	2nd	E′	0.0000		
2.	Input static regain factor	.9	–	2nd	A′	0.9000	PR	
3.	Input initial velocity desired	2800	–	2nd	B′	2800.	V1	
4.	Input lining surface roughness coeff.	1.2	–	2nd	C′	1.20	SC	
						1.	LT	
5.	Input lining thickness, in.	1	–	2nd	D′			
6.	Input run no.	1.02	–	–	A	1.02	RN	
7.	Input cfm	15000	–	–	B	15000.	Q	
8.	Input length and fitting coeff.	30.001	–	–	C	30.	L	
						0.010	FF	
						34.	DI	
						2686.	V1	Actual velocity based on round duct
						0.0996	PD	
9.	Input duct depth desired	24	–	–	D	24.	DP	
						40.	W	Width
10.	Input second run no. to be sized on basis of static regain	2.03	–	–	A	2.03	RN	
						12500.	Q	
11.	Enter cfm	12500	–	–	B	25.	L	
12.	Enter length and fitting coeff.	25.0001	–	–	C	0.001	FF	
						33.	DI	
						2385.	V2	Data based on round duct
						0.0667	PD	
						-0.0189	PN	
						0.0806	PΣ	
13.	Input duct depth desired	22	–	–	D	22.	DP	
						43.	W	Width
	Repeat steps 10, 11, 12, & 13 as many times as required.	3.04	–	–	A	3.04	RN	
		8500	–	–	B	8500.	Q	
		45.0008	–	–	C	45.	L	
						0.008	FF	
						30.	DI	
						1988.	V2	
						0.0989	PD	
						0.0015	PN	
						0.0821	PΣ	
						18.	DP	
						46.	W	

DP-2 *(Continued)*

AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 3							
	Illustrates various options							
1.	Initialize	—	—	2nd	E′	0.		
2.	Input static regain factor	.8	—	2nd	A′	0.8000	PR	
3.	Input initial velocity desired	2600	—	2nd	B′	2600.	V1	
4.	Input lining surface roughness coeff.	.9	—	2nd	C′	0.90	SC	
5.	Input lining thickness, in.	0	—	2nd	D′	0.	LT	
6.	Input run no. 1.02	1.02	—	—	A	1.02	RN	
7.	Input cfm	15000	—	—	B	15000.	Q	
8.	Input length and fitting coeff.	45.0008	—	—	C	45.	L	
						0.008	FF	
						33.	DI	If this size is not acceptable, change Vmax in step 3; repeat steps 6, 7, & 8.
						2525.	V1	
						0.0951	PD	
9.	Input duct depth desired	24	—	—	D	24.	DP	
						38.	W	Width
	Repeat step 9 as many times as desired.					30.	DP	
						30.	W	
						20.	DP	
						47.	W	
10.	Input second run no. to be sized on basis of static regain	2.03	—	—	A	2.03	RN	
11.	Enter cfm	12500	—	—	B	12500.	Q	
12.	Enter length and fitting coeff.	20.0005	—	—	C	20.	L	
						0.005	FF	
						32.	DI	
						2238.	V2	
						0.0357	PD	
						-0.0326	PN	
						0.0625	PΣ	
13.	If you desire to try out a different diameter	30	—	—	R/S	30.	DI	
						2525.	V1	

						2546.	V2	*Note:* Smaller duct increases velocity and friction loss.
						0.0487	PD	
						0.0540	PN	
						0.1493	PΣ	
	Repeat step 13 as many times as required.	28	—	—	R/S	28.	DI	
						2525.	V1	
	Either proceed with next duct run or compute for rect. duct.					2923.	V2	
						0.0679	PD	
						0.1760	PN	
						0.2713	PΣ	
	Example 4							
	Shows how first duct run can be changed							
1.	Initialize	0	—	2nd	E′	0.0000		
2.	Input static regain factor	.9	—	2nd	A′	0.9000	PR	
3.	Input initial velocity desired	3600	—	2nd	B′	3600.	V1	
4.	Input lining surface roughness coeff.	.9	—	2nd	C′	0.90	SC	
						0.	LT	
5.	Input lining thickness, in.	0	—	2nd	D′			
6.	Input run no.	1.02	—	—	A	1.02	RN	
7.	Input cfm	10000	—	—	B	10000.	Q	
8.	Input length and fitting coeff.	30.05	—	—	C	30.	L	
						0.500	FF	
						23.	DI	
	If larger duct diameter is desired					3466.	V1	
						0.5441	PD	
9.	Try lower velocity	3200	—	2nd	A′	3200.	V1	
	Repeat steps 6, 7, & 8.					1.02	RN	
						10000.	Q	
						30.	L	
	Repeat as many times as desired before sizing ductwork based on static regain method.					0.500	FF	
						24.	DI	
						3183.	V1	
						0.4538	PD	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E	Initializes; prints 0 and partitions
A′	Stores and prints static pressure regain factor (K_1) PR
B′	Stores and prints starting velocity V1; sets flag 0 and flag 1
C′	Prints SC and multiplies by 433 E−11 and stores
D′	Prints LT and stores double of lining thickness
A	Prints RN
B	Stores and prints CFM
C	Stores and prints length L; stores and prints FF; if flag 0 is set goes to SBR CLR; computes V2 by using V1; uses SBR STO and SBR C; stores V2; with input of new diameter and R/S, recomputes
X⇄T	Reiterates for computing V2
Y^x	Reiterates for new diameter
D	Prints depth; computes net depth; computes approximate width; computes width; if flag 1 is set goes to SBR X^2
)	Reiterates for computing width
E	In case of error or desired change, restores previous value of V1, and total pressure loss PΣ
INV	Prints alphanumeric characters for identification of data
LNX	Prints PR, PD, PN, and PΣ
CE	Prints V1, V2
CLR	Computes initial duct size based on velocity; uses SBR STO, SBR RCL, SBR CE, SBR $\sqrt{X}$; resets flag 0 for subsequent sizing based on static regain
X^2	Stops program
$\sqrt{X}$	Computes duct friction loss
1/X	Computes velocity gain
STO	Computes diameter
RCL	Computes velocity
SUM	Computes equivalent diameter for rectangular ductwork
EE	Prints diameter DI
(	Uses SBR RCL, SBR CE, SBR $\sqrt{X}$, prints PD; uses SBR $\sqrt{X}$ and computes and prints pressure difference PN; stores PN; computes, prints, and stores total running pressure loss PΣ

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	PN
R01	Net diameter of round duct
R02	Static regain recovery factor PR
R03	Initial velocity V1
R04	Duct internal surface roughness coefficient SC × 433 E−11
R05	Duct lining thickness LT
R06	Air flow in CFM
R07	Velocity pressure loss coefficient factors for fittings FF
R08	Length of ductwork
R09	Calculated velocity for static regain V2
R10	Duct diameter with lining; duct depth
R11	Duct width
R12	4005
R13	Interim value of width
R14	Total pressure drop PΣ
R15	Initial velocity V1
R16	Duct diameter without lining
R17	= 2 × (RCL 07 + RCL 02) ÷ RCL 12 X^2
R18	Alphanumeric code
R19	Number of decimal places

DP-2 AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD

LABELS & SUBROUTINES

```
015  16  A'
027  17  B'
042  18  C'
074  19  D'
095  11   A
110  12   B
125  13   C
196  32  X:T
272  45  YX
292  14   D
323  54   )
419  15   E
439  22  INV
457  23  LNX
471  24  CE
485  25  CLR
521  33  X²
525  34  ΓX
```

```
568  35  1/X
595  42  STO
633  43  RCL
663  44  SUM
702  52  EE
717  53  (
```

LISTING

```
000  76  LBL
001  10  E'
002  98  ADV
003  00  0
004  42  STO
005  14  14
006  99  PRT
007  98  ADV
008  22  INV
009  58  FIX
010  02  2
011  69  OP
012  17  17
013  91  R/S
014  76  LBL
015  16  A'
016  42  STO
017  02  02
018  32  X:T
019  03  3
020  05  5
021  42  STO
022  18  18
023  71  SBR
024  23  LNX
025  91  R/S
026  76  LBL
027  17  B'
028  42  STO
029  03  03
030  32  X:T
031  01  1
032  42  STO
033  18  18
034  71  SBR
035  24  CE
036  86  STF
037  00  00
038  86  STF
039  01  01
040  91  R/S
041  76  LBL
042  18  C'
043  42  STO
044  04  04
045  32  X:T
046  03  3
047  06  6
048  01  1
049  05  5
050  42  STO
051  18  18
052  02  2
053  42  STO
054  19  19
055  71  SBR
056  22  INV
057  04  4
058  03  3
059  03  3
060  52  EE
061  01  1
062  01  1
063  94  +/-
064  49  PRD
065  04  04
066  04  4
067  00  0
068  00  0
069  05  5
070  42  STO
071  12  12
072  91  R/S
073  76  LBL
074  19  D'
075  42  STO
076  05  05
077  32  X:T
078  02  2
079  07  7
080  03  3
081  07  7
082  42  STO
083  18  18
084  00  0
085  42  STO
086  19  19
087  71  SBR
088  22  INV
089  02  2
090  49  PRD
091  05  05
092  98  ADV
093  91  R/S
094  76  LBL
095  11  A
096  32  X:T
097  03  3
098  05  5
099  03  3
100  01  1
101  42  STO
102  18  18
103  02  2
104  42  STO
105  19  19
106  71  SBR
107  22  INV
108  91  R/S
109  76  LBL
110  12  B
111  42  STO
112  06  06
113  32  X:T
114  03  3
115  04  4
116  42  STO
117  18  18
118  00  0
119  42  STO
120  19  19
121  71  SBR
122  22  INV
123  91  R/S
124  76  LBL
125  13  C
126  42  STO
127  07  07
128  59  INT
129  42  STO
130  08  08
131  32  X:T
132  02  2
133  07  7
134  42  STO
135  18  18
136  00  0
137  42  STO
138  19  19
139  71  SBR
140  22  INV
141  43  RCL
142  07  07
143  22  INV
144  59  INT
145  65  ×
146  01  1
147  00  0
148  95  =
149  42  STO
150  07  07
151  32  X:T
152  02  2
153  01  1
154  02  2
155  01  1
156  42  STO
157  18  18
158  03  3
159  42  STO
160  19  19
161  71  SBR
162  22  INV
163  87  IFF
164  00  00
165  25  CLR
166  43  RCL
167  03  03
168  65  ×
169  93  .
170  08  8
171  05  5
172  95  =
173  42  STO
174  09  09
175  53  (
176  02  2
177  65  ×
178  53  (
179  43  RCL
180  07  07
181  85  +
182  43  RCL
183  02  02
184  54  )
185  55  ÷
186  43  RCL
187  12  12
188  33  X²
189  54  )
190  42  STO
191  17  17
192  01  1
193  00  0
194  32  X:T
195  76  LBL
196  32  X:T
197  53  (
198  43  RCL
199  09  09
200  75  -
201  53  (
202  53  (
203  71  SBR
204  34  √X
205  75  -
206  71  SBR
207  35  1/X
208  54  )
209  55  ÷
210  53  (
211  53  (
212  43  RCL
213  08  08
214  65  ×
215  43  RCL
216  04  04
217  65  ×
218  53  (
219  43  RCL
220  09  09
221  45  YX
222  01  1
223  93  .
224  06  6
225  03  3
226  54  )
227  55  ÷
228  43  RCL
229  06  06
230  54  )
231  85  +
232  43  RCL
233  17  17
234  65  ×
235  43  RCL
236  09  09
237  54  )
238  54  )
239  54  )
240  42  STO
241  10  10
242  48  EXC
243  09  09
244  42  STO
245  10  10
246  53  (
247  43  RCL
248  10  10
249  75  -
250  43  RCL
```

```
251  09  09
252  54  )
253  50  I×I
254  77  GE
255  32  X:T
256  43  RCL
257  03  03
258  42  STO
259  15  15
260  43  RCL
261  09  09
262  71  SBR
263  42  STO
264  71  SBR
265  53  (
266  43  RCL
267  09  09
268  42  STO
269  03  03
270  98  ADV
271  76  LBL
272  45  Y^X
273  91  R/S
274  42  STO
275  10  10
276  71  SBR
277  52  EE
278  15  E
279  43  RCL
280  10  10
281  71  SBR
282  53  (
283  98  ADV
284  43  RCL
285  09  09
286  42  STO
287  03  03
288  71  SBR
289  45  Y^X
290  91  R/S
291  76  LBL
292  14  D
293  32  X:T
294  01  1
295  06  6
296  03  3
297  03  3
298  42  STO
299  18  18
300  00  0
301  42  STO
302  19  19
303  71  SBR
304  22  INV
305  75  -
306  43  RCL
307  05  05
308  95  =
309  42  STO
310  10  10
311  35  1/X
312  65  ×
313  43  RCL
314  01  01
315  33  X^2
```

```
316  95  =
317  42  STO
318  11  11
319  93  .
320  01  1
321  32  X:T
322  76  LBL
323  54  )
324  71  SBR
325  44  SUM
326  53  (
327  53  (
328  43  RCL
329  01  01
330  55  ÷
331  43  RCL
332  13  13
333  54  )
334  33  X^2
335  54  )
336  49  PRD
337  11  11
338  53  (
339  53  (
340  43  RCL
341  13  13
342  75  -
343  43  RCL
344  01  01
345  54  )
346  50  I×I
347  77  GE
348  54  )
349  53  (
350  43  RCL
351  11  11
352  85  +
353  93  .
354  09  9
355  54  )
356  59  INT
357  42  STO
358  11  11
359  85  +
360  43  RCL
361  05  05
362  95  =
363  32  X:T
364  04  4
365  03  3
366  42  STO
367  18  18
368  00  0
369  42  STO
370  19  19
371  71  SBR
372  22  INV
373  87  IFF
374  01  01
375  33  X^2
376  71  SBR
377  44  SUM
378  43  RCL
379  05  05
380  44  SUM
```

```
381  13  13
382  43  RCL
383  13  13
384  42  STO
385  10  10
386  15  E
387  71  SBR
388  53  (
389  43  RCL
390  09  09
391  42  STO
392  03  03
393  53  (
394  43  RCL
395  06  06
396  65  ×
397  01  1
398  04  4
399  04  4
400  55  ÷
401  43  RCL
402  10  10
403  55  ÷
404  43  RCL
405  11  11
406  54  )
407  32  X:T
408  03  3
409  42  STO
410  18  18
411  00  0
412  42  STO
413  19  19
414  71  SBR
415  24  CE
416  98  ADV
417  91  R/S
418  76  LBL
419  15  E
420  98  ADV
421  43  RCL
422  15  15
423  42  STO
424  03  03
425  32  X:T
426  01  1
427  42  STO
428  18  18
429  71  SBR
430  24  CE
431  98  ADV
432  43  RCL
433  00  00
434  22  INV
435  44  SUM
436  14  14
437  92  RTN
438  76  LBL
439  22  INV
440  22  INV
441  58  FIX
442  25  CLR
443  69  OP
444  00  00
445  43  RCL
```

```
446  18  18
447  69  OP
448  04  04
449  32  X:T
450  58  FIX
451  40  IND
452  19  19
453  69  OP
454  06  06
455  92  RTN
456  76  LBL
457  23  LNX
458  03  3
459  03  3
460  00  0
461  00  0
462  44  SUM
463  18  18
464  04  4
465  42  STO
466  19  19
467  71  SBR
468  22  INV
469  92  RTN
470  76  LBL
471  24  CE
472  04  4
473  02  2
474  00  0
475  01  1
476  44  SUM
477  18  18
478  00  0
479  42  STO
480  19  19
481  71  SBR
482  22  INV
483  92  RTN
484  76  LBL
485  25  CLR
486  43  RCL
487  03  03
488  42  STO
489  09  09
490  71  SBR
491  42  STO
492  71  SBR
493  43  RCL
494  32  X:T
495  01  1
496  42  STO
497  18  18
498  71  SBR
499  24  CE
500  71  SBR
501  34  √X
502  32  X:T
503  01  1
504  06  6
505  42  STO
506  18  18
507  71  SBR
508  23  LNX
509  42  STO
510  14  14
```

```
511  22  INV
512  86  STF
513  00  00
514  98  ADV
515  43  RCL
516  09  09
517  42  STO
518  03  03
519  92  RTN
520  76  LBL
521  33  X²
522  98  ADV
523  91  R/S
524  76  LBL
525  34  ΓX
526  53  (
527  53  (
528  53  (
529  43  RCL
530  09  09
531  45  Y^X
532  02  2
533  93  .
534  04  4
535  03  3
536  54  )
537  65  ×
538  43  RCL
539  08  08
540  65  ×
541  43  RCL
542  04  04
543  55  ÷
544  53  (
545  43  RCL
546  06  06
547  45  Y^X
548  93  .
549  06  6
550  01  1
551  54  )
552  54  )
553  85  +
554  43  RCL
555  07  07
556  65  ×
557  53  (
558  43  RCL
559  09  09
560  55  ÷
561  43  RCL
562  12  12
563  54  )
564  33  X²
565  54  )
566  92  RTN
567  76  LBL
568  35  1/X
569  53  (
570  43  RCL
571  02  02
572  65  ×
573  53  (
574  53  (
575  43  RCL
576  03  03
577  55  ÷
578  43  RCL
579  12  12
580  54  )
581  33  X²
582  75  -
583  53  (
584  43  RCL
585  09  09
586  55  ÷
587  43  RCL
588  12  12
589  54  )
590  33  X²
591  54  )
592  54  )
593  92  RTN
594  76  LBL
595  42  STO
596  53  (
597  53  (
598  53  (
599  53  (
600  53  (
601  43  RCL
602  06  06
603  65  ×
604  05  5
605  07  7
606  06  6
607  55  ÷
608  43  RCL
609  09  09
610  55  ÷
611  89  π
612  54  )
613  34  ΓX
614  54  )
615  42  STO
616  01  01
617  85  +
618  93  .
619  09  9
620  54  )
621  59  INT
622  54  )
623  85  +
624  43  RCL
625  05  05
626  54  )
627  42  STO
628  10  10
629  71  SBR
630  52  EE
631  92  RTN
632  76  LBL
633  43  RCL
634  53  (
635  43  RCL
636  10  10
637  75  -
638  43  RCL
639  05  05
640  54  )
641  42  STO
642  16  16
643  53  (
644  43  RCL
645  06  06
646  65  ×
647  05  5
648  07  7
649  06  6
650  55  ÷
651  53  (
652  89  π
653  65  ×
654  43  RCL
655  16  16
656  33  X²
657  54  )
658  54  )
659  42  STO
660  09  09
661  92  RTN
662  76  LBL
663  44  SUM
664  53  (
665  01  1
666  93  .
667  03  3
668  65  ×
669  53  (
670  53  (
671  43  RCL
672  10  10
673  65  ×
674  43  RCL
675  11  11
676  54  )
677  45  Y^X
678  93  .
679  06  6
680  02  2
681  05  5
682  54  )
683  55  ÷
684  53  (
685  53  (
686  43  RCL
687  10  10
688  85  +
689  43  RCL
690  11  11
691  54  )
692  45  Y^X
693  93  .
694  02  2
695  05  5
696  54  )
697  54  )
698  42  STO
699  13  13
700  92  RTN
701  76  LBL
702  52  EE
703  32  X:T
704  01  1
705  06  6
706  02  2
707  04  4
708  42  STO
709  18  18
710  00  0
711  42  STO
712  19  19
713  71  SBR
714  22  INV
715  92  RTN
716  76  LBL
717  53  (
718  71  SBR
719  43  RCL
720  32  X:T
721  02  2
722  42  STO
723  18  18
724  71  SBR
725  24  CE
726  53  (
727  71  SBR
728  34  ΓX
729  32  X:T
730  01  1
731  06  6
732  42  STO
733  18  18
734  71  SBR
735  23  LNX
736  75  -
737  71  SBR
738  35  1/X
739  54  )
740  42  STO
741  00  00
742  32  X:T
743  03  3
744  01  1
745  42  STO
746  18  18
747  71  SBR
748  23  LNX
749  44  SUM
750  14  14
751  43  RCL
752  14  14
753  32  X:T
754  07  7
755  07  7
756  42  STO
757  18  18
758  71  SBR
759  23  LNX
760  92  RTN
```

SPECIAL NOTES FOR HP–97 USERS

1. The program prints out integer values for round duct sizes, but the duct velocity and pressure loss calculations are based on the actual calculated duct diameter.
2. In the same manner, the rectangular ductwork calculations are based on the actual calculated duct diameter, rather than the printed value of the diameter, which is rounded off to the nearest integer.

   The difference in results is rather insignificant.
3. The value of V_2 is computed by reiteration instead of the procedure shown in the "Program Description."

   Other differences are evident from the illustrated examples.

DP-2

AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
	For round ductwork						
1.	Initialize	—	—	f	E	0.00 ***	
	Switch printer to TRACE mode						
2.	Enter static regain factor	.85	—	STO	A	.85 STOA	
3.	Enter lining surface roughness	.9	—		Enter	.90 ENT↑	
	coeff.	433EEX	CHS	11	X	433.-11 x	
						3.897000000-09 ***	
		—	—	STO	B	STOB	
4.	Enter lining thickness	1	—	STO	C	1.00 STOC	Remove from TRACE mode
5.	Enter velocity pressure constant	4005	—	STO	D	4005.00 STOD	after this step.
6.	Enter initial velocity	3600	—	f	A	3600.00 ***	
7.	Enter run no.	1.02	—	—	A	1.02 ***	
8.	Enter cfm	10000	—	—	B	10000.00 ***	
9.	Enter duct length	30	—	—	C	30.00 ***	
10.	Enter fitting factor	.5	—	—	R/S	0.50 ***	
						25.00 ***	Diameter of round duct
	Steps 6 through 10 can be					3459.36 ***	Velocity, fpm
	repeated any number of times till					0.54 ***	Static pressure loss
	desired size is obtained.					0.54 ***	Net total static pressure
11.	Enter run no.	2.03	—	—	A	2.03 ***	
12.	Enter cfm	8000	—	—	B	8000.00 ***	
13.	Enter duct length	20	—	—	C	20.00 ***	
14.	Enter fitting factor	.09	—	—	R/S	0.09 ***	
						24.00 ***	Diameter of round duct
						3024.79 ***	Velocity, fpm
						0.14 ***	Static pressure loss
						0.69 ***	Total loss without regain
						0.00 ***	Net gain or loss for run
						0.53 ***	Total static pressure loss

DP-2 *(Continued)*

AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Repeat steps 11 through 14 as many times as required.	3.04	—	—	A	3.04 ***	
		6000	—	—	B	6000.00 ***	
		25	—	—	C	25.00 ***	
		.03	—	—	R/S	0.03 ***	
						23.00 ***	
						2463.00 ***	
						0.10 ***	
						0.02 ***	
						0.00 ***	
						0.52 ***	
	Example 2						
	For rectangular ductwork						
	Follow steps 1 thorugh 10 as in Example no. 1.	—	—	*f*	E	0.0000 ***	
		.9	—	STO	A	.9000 STOA	
		1.2	—	—	Enter	1.2000 ENT↑	
		433EEX	CHS	11	X	433.-11 ×	
						5.19600000-03 ***	
		—	—	STO	B	STOB	
		1	—	STO	C	1.0000 STOC	
		4005	—	STO	D	4005.0000 STOD	
		2800	—	*f*	A	2800.0000 ***	
		1.02	—	—	A	1.0200 ***	
		15000	—	—	B	15000.0000 ***	
		30	—	—	C	30.0000 ***	
		.01	—	—	R/S	0.0100 ***	
						34.0000 ***	
						2660.6641 ***	

						0.0591 ***	
						0.0591 ***	
10a.	To compute width of rect. duct, enter depth	24	–	–	D	24.0000 ***	
						42.0000 ***	Width
	Repeat steps 11 through 14.	2.03	–	–	A	2.0300 ***	
		12500	–	–	B	12500.0000 ***	
		25	–	–	C	25.0000 ***	
		.001	–	–	R/S	0.0010 ***	
						33.0000 ***	
						2380.3330 ***	
						0.0664 ***	
						0.1655 ***	
						0.0000 ***	
						0.0592 ***	
15.	To compute width of rect. duct, enter depth	22	–	–	D	22.0000 ***	
						44.0000 ***	
	Repeat steps 11 through 15 as many times as desired.	3.04	–	–	A	3.0400 ***	
		8500	–	–	B	8500.0000 ***	
		45	–	–	C	45.0000 ***	
		.008	–	–	R/S	0.0080 ***	
						31.0000 ***	
						1845.5530 ***	
						0.0632 ***	
						0.1522 ***	
						0.0000 ***	
						0.0579 ***	
		18	–	–	D	18.0000 ***	
						50.0000 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
a	Prints and stores display (initial velocity) and sets flag 2
e	Clears register R9 and prints 0
A	Prints display (run no.)
B	Prints and stores display (CFM) in R2
C	Prints and stores display (length) in R4;
	with R/S, prints and stores display (fitting factor) in R3; if flag 2 is set goes to SBR 9, otherwise computes new velocity for static regain using LBL 6 for reiteration; using SBR 9, computes and prints total static loss based on new velocity; computes and prints static regain; computes and prints net static pressure loss or gain
D	Prints and stores display (duct depth) in R6; calculates size of square duct and stores in R7; if R6 > R7, goes to SBR 5, otherwise continues; computes width using LBL 3 for reiteration, goes to SBR 2, and prints value
0	Computes $(V/4005)^2$
1	Computes friction loss
2	Adds 0.9; calculates integer value; adds twice lining thickness
4	Computes diameter for equivalent round duct
5	Prints R7
7	Computes dynamic and friction loss and totalizes it in R6
8	Computes net static regain
9	Computes diameter for given velocity, adds twice the lining thickness, and prints; computes and prints velocity for round duct; computes and prints dynamic and friction losses; totalizes in R9, and prints total

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	Diameter
R2	CFM
R3	Fitting factor for dynamic losses
R4	Length
R5	Velocity
R6	Dynamic and friction loss; also duct depth
R7	Size of square duct
R8	Velocity
R9	Total static pressure drop
RA	Static regain recovery factor
RB	Duct internal surface roughness coefficient × 433 E−11
RC	Duct lining thickness
RD	4005
RE	Initial velocity
RI	Not used

DP-2 (HP-97) AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD

LISTING

```
001  *LBLa   21 16 11
002   STOE      35 15
003   SPC       16-11
004   PRTX        -14
005   SF2    16 21 02
006   SPC       16-11
007   RTN          24
008  *LBLe   21 16 15
009   0            00
010   STO9      35 09
011   PRTX        -14
012   SPC       16-11
013   RTN          24
014  *LBLA      21 11
015   PRTX        -14
016   RTN          24
017  *LBLB      21 12
018   STO2      35 02
019   PRTX        -14
020   RTN          24
021  *LBLC      21 13
022   STO4      35 04
023   PRTX        -14
024   RTN          24
025   STO3      35 03
026   PRTX        -14
027   SPC       16-11
028   F2?    16 23 02
029   GTO9      22 09
030   RCLE      36 15
031   STO5      35 05
032   STO8      35 08
033  *LBL6      21 06
034   .           -62
035   9            09
036   9            09
037   ST×5   35-35 05
038   GSB7      23 07
039   RCLE      36 15
040   GSB8      23 08
041   -           -45
042   1            01
043   EEX         -23
044   6            06
045   CHS         -22
046   X≤Y?      16-35
047   GTO6      22 06
048   RCL5      36 05
049   STOE      35 15
050   GSB9      23 09
051   RCL8      36 08
052   GSB7      23 07
053   ST-9   35-45 09
054   ST-6   35-45 06
055   RCL6      36 06
056   PRTX        -14
057   RCL9      36 09
058   PRTX        -14
059   SPC       16-11
060   SPC       16-11
061   SPC       16-11
```

```
062   RTN       24
063   *LBLD     21 14
064   STO6      35 06
065   PRTX      -14
066   RCL1      36 01
067   1         01
068   .         -62
069   0         00
070   9         09
071   ÷         -24
072   GSB2      23 02
073   STO7      35 07
074   RCL6      36 06
075   X>Y?      16-34
076   GTO5      22 05
077   RCLC      36 13
078   2         02
079   x         -35
080   ST-6      35-45 06
081   *LBL3     21 03
082   GSB4      23 04
083   RCL1      36 01
084   ÷         -24
085   1/X       52
086   X²        53
087   ST×7      35-35 07
088   RCL8      36 08
089   RCL1      36 01
090   -         -45
091   ABS       16 31
092   .         -62
093   0         00
094   1         01
095   X≤Y?      16-35
096   GTO3      22 03
097   RCL7      36 07
098   GSB2      23 02
099   PRTX      -14
100   SPC       16-11
101   SPC       16-11
102   RTN       24
103   *LBL0     21 00
104   RCLD      36 14
105   ÷         -24
106   X²        53
107   RTN       24
108   *LBL1     21 01
109   2         02
110   .         -62
111   4         04
112   3         03
113   Yˣ        31
114   RCL4      36 04
115   x         -35
116   RCLB      36 12
117   x         -35
118   RCL2      36 02
119   .         -62
120   6         06
121   1         01
122   Yˣ        31
123   ÷         -24
124   RTN       24
125   *LBL2     21 02
126   .         -62
127   9         09
128   +         -55
129   INT       16 34
130   RCLC      36 13
131   2         02
132   x         -35
133   +         -55
134   RTN       24
135   *LBL4     21 04
136   RCL6      36 06
137   RCL7      36 07
138   x         -35
139   .         -62
140   6         06
141   2         02
142   5         05
143   Yˣ        31
144   1         01
145   .         -62
146   3         03
147   x         -35
148   RCL6      36 06
149   RCL7      36 07
150   +         -55
151   .         -62
152   2         02
153   5         05
154   Yˣ        31
155   ÷         -24
156   STO8      35 08
157   RTN       24
158   *LBL5     21 05
159   RCL7      36 07
160   PRTX      -14
161   PRTX      -14
162   SPC       16-11
163   RTN       24
164   *LBL7     21 07
165   GSB0      23 00
166   RCL3      36 03
167   x         -35
168   RCL5      36 05
169   GSB1      23 01
170   +         -55
171   STO6      35 06
172   RTN       24
173   *LBL8     21 08
174   GSB0      23 00
175   RCL5      36 05
176   GSB0      23 00
177   -         -45
178   RCLA      36 11
179   x         -35
180   RTN       24
181   *LBL9     21 09
182   RCL2      36 02
183   RCLE      36 15
184   ÷         -24
185   1         01
186   8         08
187   3         03
188   x         -35
189   √X        54
190   .         -62
191   9         09
192   +         -55
193   INT       16 34
194   STO1      35 01
195   RCLC      36 13
196   2         02
197   x         -35
198   +         -55
199   PRTX      -14
200   RCL2      36 02
201   1         01
202   8         08
203   3         03
204   x         -35
205   RCL1      36 01
206   X²        53
207   ÷         -24
208   PRTX      -14
209   SPC       16-11
210   STOE      35 15
211   STO5      35 05
212   GSB7      23 07
213   PRTX      -14
214   ST+9      35-55 09
215   RCL9      36 09
216   PRTX      -14
217   SPC       16-11
218   RTN       24
219   R/S       51
```

DP-3
AIR DUCT FRICTION LOSS PROGRAM

PROGRAM DESCRIPTION

This program enables the designer to calculate frictional loss through supply, return, and exhaust air duct systems. The program also calculates velocity based on an equivalent round duct, velocity based on actual area, and velocity pressure.

The program adds up the frictional loss of each branch so that the total frictional loss of the longest run, or of any run, can be computed. Further, it is possible to add or deduct pressure drop due to equipment or any error.

The program can handle circular, flat-oval, and rectangular ductwork.

The user has two options for inputting data for dynamic losses for fittings:

Option 1: Use data given in ASHRAE *Handbook of Fundamentals,* chapter on air duct design. This method will yield accurate results.

Option 2: Convert duct fittings data to the equivalent duct length based on information given in *Handbook of Air Conditioning Systems Design,* by Carrier Air Conditioning Company, McGraw Hill Inc. This is a faster but less accurate method.

The program takes into account the duct lining thickness and internal surface roughness coefficient. The duct sizes input should be duct external dimensions.

EQUATIONS

The program is based on the equations given under Programs DP–1 and DP–2.

OPERATING FEATURES

Duct length and fitting information has to be input in decimal format as shown in the following example:

Length	Fitting Coefficient	Input Under Label D
50	.7	50.07
40	1.2	40.12
65	.005	65.0005

Duct length has to be an integer.

REFERENCE DATA

See Program DP–1.

DP-3
AIR DUCT FRICTION LOSS PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Initialize	0	–	2nd	E′	0.000		
2.	Select duct type – 'Rect'	2	–	2nd	A′	2.	RECT	Rect. input 0 for circ. Rect. input 1 for F/OV
3.	Input run no.	1.02	–	–	A	1.02	R/NO	
4.	Input cfm	1000	–	–	B	1000.	CFM	
5.	Input duct size	14.08	–	–	C	14.08	W.D	
						2195.	FPMC	Velocity, fpm based on equi. circ. duct
						2000.	FPMA	Velocity, average fpm
						1.096	PD/C	Frictional loss, in. w.g./100 ft
6.	Input length and fitting coeff.	12.005	–	–	D	12.00	L	
						0.050	FF	
						0.147	PD	Frictional and dynamic loss
						0.147	ΣPD	Total running loss, in. w.g.
		2.03	–	–	A	2.03	R/NO	
		1800	–	–	B	1800.	CFM	
	Repeat steps 3, 4, 5, & 6 as many times as desired.	14.14	–	–	C	14.14	W.D	
						1918.	FPMC	
						1800.	FPMA	
						0.552	PD/C	
		25.007	–	–	D	25.00	L	
						0.070	FF	
						0.154	PD	
						0.301	ΣPD	
7.	To add or deduct equipment pressure	.175	–	–	E	0.175	E/PD	Equipment pressure
						0.476	ΣPD	Total pressure drop, in. w.g.
8.	To calculate velocity pressure	2300	–	2nd	B′	2300.	FPM	
						0.330	VP	Velocity pressure, in. w.g.

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E′	Initializes and prints 0
A′	Selects and prints duct type
B′	Calculates velocity pressure VP
C′	Stores and prints internal surface coefficient COEF
D′	Stores and prints lining thickness L/TH
INV	Prints alphanumeric characters for identification of data
LNX	Prints duct type CIRC and sets flag 0
CE	Prints duct type F/OV and sets flag 1
CLR	Prints DIA; changes to internal diameter by deducting lining thickness
X⇄T	For flat-oval duct; calculates equivalent diameter for round duct and area of round duct
X^2	Prints W.D
$\sqrt{X}$	Converts W.D input to W and D and deducts lining thickness
1/X	Calculates velocity in circular duct
STO	Calculates and prints PD/C
RCL	Given area, calculates velocity
SUM	Computes and prints ΣPD
A	Prints run no. and R No.
B	Prints and stores CFM
C	With input of duct dimension calculates equivalent diameter, velocity, and PD/C based on duct type
D	Accepts length and fitting coefficient in decimal format; stores and prints duct run length L; prints fitting coefficient; computes PD and ΣPD
E	Adds or deducts equipment pressure drop, prints EPD, and computes new ΣPD

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Not used
R01	Not used
R02	Internal lining roughness coefficient COEF
R03	Lining thickness L/TH
R04	CFM
R05	W.D
R06	W actual after deducting lining thickness
R07	D actual after deducting lining thickness
R08	Area
R09	Equivalent diameter DE
R10	PD/C
R11	ΣPD
R12	Not used
R13	Length
R14	Length and FF
R15	Not used
R16	Not used
R17	Duct type
R18	Storing alphanumeric code for printing
R19	For storing decimal places

DP-3 AIR DUCT FRICTION LOSS PROGRAM

LABELS & SUBROUTINES

001	10	E'
014	16	A'
053	17	B'
090	18	C'
111	19	D'
132	22	INV
150	23	LNX
171	24	CE
192	25	CLR
227	32	X:T
327	33	X^2
344	34	√X
378	35	1/X
415	42	STO
469	43	RCL
495	44	SUM
516	11	A
536	12	B
555	13	C
626	14	D
703	15	E

LISTING

000	76	LBL
001	10	E'
002	00	0
003	42	STO
004	11	11
005	99	PRT
006	98	ADV
007	22	INV
008	58	FIX
009	02	2
010	69	OP
011	17	17
012	91	R/S
013	76	LBL
014	16	A'
015	42	STO
016	17	17
017	22	INV
018	86	STF
019	00	00
020	22	INV
021	86	STF

```
022  01  01
023  22  INV
024  86  STF
025  02  02
026  43  RCL
027  17  17
028  32  X:T
029  00  0
030  67  EQ
031  23  LNX
032  01  1
033  67  EQ
034  24  CE
035  03  3
036  05  5
037  01  1
038  07  7
039  01  1
040  05  5
041  03  3
042  07  7
043  42  STO
044  18  18
045  00  0
046  42  STO
047  19  19
048  71  SBR
049  22  INV
050  98  ADV
051  91  R/S
052  76  LBL
053  17  B'
054  32  X:T
055  02  2
056  01  1
057  03  3
058  03  3
059  03  3
060  00  0
061  42  STO
062  18  18
063  00  0
064  42  STO
065  19  19
066  71  SBR
067  22  INV
068  55  ÷
069  04  4
070  00  0
071  00  0
072  05  5
073  95  =
074  33  X^2
075  32  X:T
076  04  4
077  02  2
078  03  3
079  03  3
080  42  STO
081  18  18
082  03  3
083  42  STO
084  19  19
085  71  SBR
086  22  INV
087  98  ADV
088  91  R/S
089  76  LBL
090  18  C'
091  42  STO
092  02  02
093  32  X:T
094  01  1
095  05  5
096  03  3
097  02  2
098  01  1
099  07  7
100  02  2
101  01  1
102  42  STO
103  18  18
104  03  3
105  42  STO
106  19  19
107  71  SBR
108  22  INV
109  91  R/S
110  76  LBL
111  19  D'
112  42  STO
113  03  03
114  32  X:T
115  02  2
116  07  7
117  06  6
118  03  3
119  03  3
120  07  7
121  02  2
122  03  3
123  42  STO
124  18  18
125  02  2
126  42  STO
127  19  19
128  71  SBR
129  22  INV
130  91  R/S
131  76  LBL
132  22  INV
133  22  INV
134  58  FIX
135  25  CLR
136  69  OP
137  00  00
138  43  RCL
139  18  18
140  69  OP
141  04  04
142  32  X:T
143  58  FIX
144  40  IND
145  19  19
146  69  OP
147  06  06
148  92  RTN
149  76  LBL
150  23  LNX
151  01  1
152  05  5
153  02  2
154  04  4
155  03  3
156  05  5
157  01  1
158  05  5
159  42  STO
160  18  18
161  00  0
162  42  STO
163  19  19
164  71  SBR
165  22  INV
166  86  STF
167  00  00
168  98  ADV
169  92  RTN
170  76  LBL
171  24  CE
172  02  2
173  01  1
174  06  6
175  03  3
176  03  3
177  02  2
178  04  4
179  02  2
180  42  STO
181  18  18
182  00  0
183  42  STO
184  19  19
185  71  SBR
186  22  INV
187  86  STF
188  01  01
189  98  ADV
190  92  RTN
191  76  LBL
192  25  CLR
193  43  RCL
194  05  05
195  59  INT
196  32  X:T
197  01  1
198  06  6
199  02  2
200  04  4
201  01  1
202  03  3
203  42  STO
204  18  18
205  00  0
206  42  STO
207  19  19
208  71  SBR
209  22  INV
210  53  (
211  43  RCL
212  05  05
213  75  -
214  02  2
215  65  ×
216  43  RCL
217  03  03
218  54  )
219  42  STO
220  09  09
221  71  SBR
222  35  1/X
223  71  SBR
224  42  STO
225  92  RTN
226  76  LBL
227  32  X:T
228  71  SBR
229  33  X^2
230  71  SBR
231  34  √X
232  53  (
233  01  1
234  93  .
235  05  5
236  04  4
237  08  8
238  65  ×
239  53  (
240  53  (
241  53  (
242  43  RCL
243  06  06
244  33  X^2
245  65  ×
246  89  π
247  55  ÷
248  04  4
249  54  )
250  85  +
251  43  RCL
252  06  06
253  65  ×
254  53  (
255  43  RCL
256  07  07
257  75  -
258  43  RCL
259  06  06
260  54  )
261  54  )
262  45  Y^X
263  93  .
264  06  6
265  02  2
266  05  5
267  54  )
268  55  ÷
269  53  (
270  53  (
271  43  RCL
272  06  06
273  65  ×
274  89  π
275  85  +
276  02  2
277  65  ×
```

```
278  53  (
279  43  RCL
280  07   07
281  75  -
282  43  RCL
283  06   06
284  54  )
285  54  )
286  45  Y^X
287  93  .
288  02  2
289  05  5
290  54  )
291  54  )
292  42  STO
293  09   09
294  53  (
295  43  RCL
296  07   07
297  65  ×
298  53  (
299  43  RCL
300  07   07
301  65  ×
302  89  π
303  55  ÷
304  04  4
305  75  -
306  43  RCL
307  07   07
308  85  +
309  43  RCL
310  06   06
311  54  )
312  55  ÷
313  01  1
314  04  4
315  04  4
316  54  )
317  42  STO
318  08   08
319  71  SBR
320  35  1/X
321  71  SBR
322  43  RCL
323  71  SBR
324  42  STO
325  92  RTN
326  76  LBL
327  33  X^2
328  32  X:T
329  04  4
330  03  3
331  04  4
332  00  0
333  01  1
334  06  6
335  42  STO
336  18   18
337  02  2
338  42  STO
339  19   19
340  71  SBR
341  22  INV
342  92  RTN
343  76  LBL
344  34  √X
345  53  (
346  53  (
347  43  RCL
348  05   05
349  22  INV
350  59  INT
351  65  ×
352  01  1
353  00  0
354  00  0
355  54  )
356  75  -
357  02  2
358  65  ×
359  43  RCL
360  03   03
361  54  )
362  42  STO
363  07   07
364  53  (
365  43  RCL
366  05   05
367  59  INT
368  75  -
369  02  2
370  65  ×
371  43  RCL
372  03   03
373  54  )
374  42  STO
375  06   06
376  92  RTN
377  76  LBL
378  35  1/X
379  53  (
380  43  RCL
381  04   04
382  65  ×
383  05  5
384  07  7
385  06  6
386  55  ÷
387  53  (
388  43  RCL
389  09   09
390  33  X^2
391  65  ×
392  89  π
393  54  )
394  54  )
395  42  STO
396  12   12
397  32  X:T
398  02  2
399  01  1
400  03  3
401  03  3
402  03  3
403  00  0
404  01  1
405  05  5
406  42  STO
407  18   18
408  00  0
409  42  STO
410  19   19
411  71  SBR
412  22  INV
413  92  RTN
414  76  LBL
415  42  STO
416  53  (
417  53  (
418  53  (
419  43  RCL
420  12   12
421  55  ÷
422  01  1
423  00  0
424  00  0
425  00  0
426  54  )
427  45  Y^X
428  01  1
429  93  .
430  08  8
431  02  2
432  54  )
433  65  ×
434  03  3
435  65  ×
436  43  RCL
437  02   02
438  55  ÷
439  53  (
440  43  RCL
441  09   09
442  45  Y^X
443  01  1
444  93  .
445  02  2
446  02  2
447  54  )
448  54  )
449  42  STO
450  10   10
451  32  X:T
452  03  3
453  03  3
454  01  1
455  06  6
456  06  6
457  03  3
458  01  1
459  05  5
460  42  STO
461  18   18
462  03  3
463  42  STO
464  19   19
465  71  SBR
466  22  INV
467  92  RTN
468  76  LBL
469  43  RCL
470  53  (
471  43  RCL
472  04   04
473  55  ÷
474  43  RCL
475  08   08
476  54  )
477  32  X:T
478  02  2
479  01  1
480  03  3
481  03  3
482  03  3
483  00  0
484  01  1
485  03  3
486  42  STO
487  18   18
488  00  0
489  42  STO
490  19   19
491  71  SBR
492  22  INV
493  92  RTN
494  76  LBL
495  44  SUM
496  44  SUM
497  11   11
498  43  RCL
499  11   11
500  32  X:T
501  07  7
502  07  7
503  03  3
504  03  3
505  01  1
506  06  6
507  42  STO
508  18   18
509  03  3
510  42  STO
511  19   19
512  71  SBR
513  22  INV
514  92  RTN
515  76  LBL
516  11  A
517  98  ADV
518  32  X:T
519  03  3
520  05  5
521  06  6
522  03  3
523  03  3
524  01  1
525  03  3
526  02  2
527  42  STO
528  18   18
529  02  2
530  42  STO
531  19   19
532  71  SBR
533  22  INV
```

534	91	R/S
535	76	LBL
536	12	B
537	42	STO
538	04	04
539	32	X⇌T
540	01	1
541	05	5
542	02	2
543	01	1
544	03	3
545	00	0
546	42	STO
547	18	18
548	00	0
549	42	STO
550	19	19
551	71	SBR
552	22	INV
553	91	R/S
554	76	LBL
555	13	C
556	42	STO
557	05	05
558	87	IFF
559	00	00
560	25	CLR
561	87	IFF
562	01	01
563	32	X⇌T
564	71	SBR
565	33	X^2
566	71	SBR
567	34	√X
568	53	(
569	43	RCL
570	06	06
571	65	×
572	43	RCL
573	07	07
574	55	÷
575	01	1
576	04	4
577	04	4
578	54	)
579	42	STO
580	08	08
581	53	(
582	01	1
583	93	.
584	03	3
585	65	×
586	53	(
587	53	(
588	43	RCL
589	06	06
590	65	×
591	43	RCL
592	07	07
593	54	)
594	45	Y^X
595	93	.
596	06	6
597	02	2
598	05	5
599	54	)
600	55	÷
601	53	(
602	53	(
603	43	RCL
604	06	06
605	85	+
606	43	RCL
607	07	07
608	54	)
609	45	Y^X
610	93	.
611	02	2
612	05	5
613	54	)
614	54	)
615	42	STO
616	09	09
617	71	SBR
618	35	1/X
619	71	SBR
620	43	RCL
621	71	SBR
622	42	STO
623	98	ADV
624	91	R/S
625	76	LBL
626	14	D
627	42	STO
628	14	14
629	59	INT
630	42	STO
631	13	13
632	32	X⇌T
633	02	2
634	07	7
635	42	STO
636	18	18
637	02	2
638	42	STO
639	19	19
640	71	SBR
641	22	INV
642	43	RCL
643	14	14
644	22	INV
645	59	INT
646	65	×
647	01	1
648	00	0
649	95	=
650	32	X⇌T
651	02	2
652	01	1
653	02	2
654	01	1
655	42	STO
656	18	18
657	03	3
658	42	STO
659	19	19
660	71	SBR
661	22	INV
662	95	=
663	65	×
664	53	(
665	43	RCL
666	12	12
667	55	÷
668	04	4
669	00	0
670	00	0
671	05	5
672	54	)
673	33	X^2
674	95	=
675	85	+
676	43	RCL
677	10	10
678	65	×
679	43	RCL
680	13	13
681	55	÷
682	01	1
683	00	0
684	00	0
685	95	=
686	32	X⇌T
687	03	3
688	03	3
689	01	1
690	06	6
691	42	STO
692	18	18
693	03	3
694	42	STO
695	19	19
696	71	SBR
697	22	INV
698	71	SBR
699	44	SUM
700	98	ADV
701	91	R/S
702	76	LBL
703	15	E
704	98	ADV
705	32	X⇌T
706	01	1
707	07	7
708	06	6
709	03	3
710	03	3
711	03	3
712	01	1
713	06	6
714	42	STO
715	18	18
716	03	3
717	42	STO
718	19	19
719	71	SBR
720	22	INV
721	71	SBR
722	44	SUM
723	98	ADV
724	91	R/S

DP-3
AIR DUCT FRICTION LOSS PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
	To display 3 decimal places	–	–	DSP	3		
1.	Initialize	–	–	*f*	E	0.000 ***	
2.	Enter duct type 2 for rect.	2	–	*f*	A	2.000 ***	Enter 0 for round ductwork.
3.	Enter surface roughness coeff.	1.3	–	*f*	C	1.300 ***	
4.	Enter lining thickness	1	–	*f*	D	1.000 ***	
5.	Enter run no.	1.02	–	–	A	1.020 ***	
6.	Enter cfm	1000	–	–	B	1000.000 ***	
7.	Enter W x D (14 x 8)	14.08	–	–	C	14.080 ***	Note decimal format
						2194.606 ***	Velocity, fpm, round duct
						2000.000 ***	Velocity, fpm, rect. duct
						1.096 ***	Friction loss, in. w.g./100 ft
8.	Enter length and fitting factor	12.005	–	–	D	12.000 ***	Note decimal format
						0.050 ***	
						0.147 ***	Frictional and dynamic loss
						0.147 ***	Totalized total loss
	Repeat steps 5 through 8 as many times as desired.	2.03	–	–	A	2.030 ***	
		1800	–	–	B	1800.000 ***	
		14.14	–	–	C	14.140 ***	
						1917.834 ***	
						1800.000 ***	
						0.552 ***	

		25.007	—	—	D	25.000 *** 0.070 *** 0.154 *** 0.301 ***	
9.	To add or deduct equipment pressure	.175	—	—	E	0.175 *** 0.476 ***	Total pressure loss
10.	To calculate velocity pressure, enter velocity	2300	—	*f*	B	2300.000 *** 0.330 ***	Velocity pressure, in. w.g.

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
0	Sets flag 0
1	Deducts twice lining thickness R3
2	Separates W.D from decimal format; stores in R7 and R6
3	Computes velocity based on round duct
4	Computes frictional loss
5	Computes and prints velocity based on rectangular duct
6	Totalizes pressure loss and prints total value
7	For round duct, calculates net size using SBR 1; calculates velocity using SBR 3 and frictional loss using SBR 4
e	Clears register R0 and prints 0
a	Prints and stores display (duct type) in RD; clears flag 0; if display equals zero, goes to SBR 0
b	Computes and prints velocity pressure
c	Prints and stores display (internal surface coefficient) in R2
d	Prints display (lining thickness), multiplies by 2, and stores in R3
A	Prints display (run no.)
B	Prints and stores display (CFM) in R4
C	Stores display (W.D or DIA) in R5; if flag 0 is set goes to SBR 7, otherwise calls SBR 2 and computes area and diameter of equivalent round duct R9; using SBR 3, computes and prints velocity based on rectangular duct; using SBR 4, computes and prints friction loss/100 ft
D	Accepts input in decimal format; prints and stores length in RC; prints and stores fitting factor in RE; computes and prints total losses
E	Adds or deducts equipment pressure loss

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Total pressure loss
R1	Velocity
R2	Duct internal surface roughness coefficient
R3	Twice lining thickness
R4	CFM
R5	Duct width or diameter
R6	Width
R7	Depth
R8	Area
R9	Equivalent diameter of round duct
RA	Frictional loss/100 ft
RB	Not used
RC	Length
RD	Not used
RE	Fitting factor for dynamic losses
RI	Not used

DP-3 (HP-97) AIR DUCT FRICTION LOSS PROGRAM

LISTING

```
001  *LBL0     21 00
002   SF0   16 21 00
003   SPC     16-11
004   RTN        24
005  *LBL1     21 01
006  RCL3     36 03
007     -       -45
008   RTN        24
009  *LBL2     21 02
010   FRC     16 44
011     1        01
012     0        00
013     0        00
014     x       -35
015  GSB1     23 01
016  STO7     35 07
017  RCL5     36 05
018   INT     16 34
019  GSB1     23 01
020  STO6     35 06
021   RTN        24
022  *LBL3     21 03
023  RCL9     36 09
024    X²        53
025    Pi     16-24
026     x       -35
027     5        05
028     7        07
029     6        06
030     ÷       -24
031   1/X        52
032  RCL4     36 04
033     x       -35
034  STO1     35 01
035   RTN        24
036  *LBL4     21 04
037  RCL1     36 01
038     1        01
039     0        00
040     0        00
041     0        00
042     ÷       -24
043     1        01
044     .       -62
045     8        08
046     2        02
047    Yˣ        31
048     3        03
049     x       -35
050  RCL2     36 02
051     x       -35
052  RCL9     36 09
053     1        01
054     .       -62
055     2        02
056     2        02
057    Yˣ        31
```

058	÷	-24
059	STOA	35 11
060	PRTX	-14
061	RTN	24
062	*LBL5	21 05
063	RCL4	36 04
064	RCL8	36 08
065	÷	-24
066	PRTX	-14
067	RTN	24
068	*LBL6	21 06
069	ST+0	35-55 00
070	RCL0	36 00
071	PRTX	-14
072	RTN	24
073	*LBL7	21 07
074	PRTX	-14
075	GSB1	23 01
076	STO9	35 09
077	GSB3	23 03
078	PRTX	-14
079	GSB4	23 04
080	SPC	16-11
081	RTN	24
082	*LBLe	21 16 15
083	0	00
084	STO0	35 00
085	PRTX	-14
086	SPC	16-11
087	RTN	24
088	*LBLa	21 16 11
089	STOD	35 14
090	PRTX	-14
091	CF0	16 22 00
092	X=0?	16-43
093	GTO0	22 00
094	RTN	24
095	*LBLb	21 16 12
096	PRTX	-14
097	4	04
098	0	00
099	0	00
100	5	05
101	÷	-24
102	X²	53
103	PRTX	-14
104	SPC	16-11
105	RTN	24
106	*LBLc	21 16 13
107	STO2	35 02
108	PRTX	-14
109	RTN	24
110	*LBLd	21 16 14
111	PRTX	-14
112	2	02
113	×	-35
114	STO3	35 03
115	SPC	16-11
116	RTN	24
117	*LBLA	21 11
118	PRTX	-14
119	SPC	16-11
120	RTN	24
121	*LBLB	21 12
122	STO4	35 04
123	PRTX	-14
124	RTN	24
125	*LBLC	21 13
126	STO5	35 05
127	F0?	16 23 00
128	GTO7	22 07
129	PRTX	-14
130	GSB2	23 02
131	RCL6	36 06
132	RCL7	36 07
133	×	-35
134	1	01
135	4	04
136	4	04
137	÷	-24
138	STO8	35 08
139	RCL6	36 06
140	RCL7	36 07
141	×	-35
142	.	-62
143	6	06
144	2	02
145	5	05
146	Y^x	31
147	RCL6	36 06
148	RCL7	36 07
149	+	-55
150	.	-62
151	2	02
152	5	05
153	Y^x	31
154	÷	-24
155	1	01
156	.	-62
157	3	03
158	×	-35
159	STO9	35 09
160	GSB3	23 03
161	PRTX	-14
162	GSB5	23 05
163	GSB4	23 04
164	SPC	16-11
165	RTN	24
166	*LBLD	21 14
167	STOE	35 15
168	INT	16 34
169	STOC	35 13
170	PRTX	-14
171	RCLE	36 15
172	FRC	16 44
173	1	01
174	0	00
175	×	-35
176	STOE	35 15
177	PRTX	-14
178	RCL1	36 01
179	4	04
180	0	00
181	0	00
182	5	05
183	÷	-24
184	X²	53
185	×	-35
186	RCLA	36 11
187	RCLC	36 13
188	×	-35
189	1	01
190	0	00
191	0	00
192	÷	-24
193	+	-55
194	PRTX	-14
195	GSB6	23 06
196	SPC	16-11
197	RTN	24
198	*LBLE	21 15
199	SPC	16-11
200	PRTX	-14
201	GSB6	23 06
202	SPC	16-11
203	RTN	24
204	R/S	51

DP-4
AIR DUCT HEAT LOSS/GAIN PROGRAM

GENERAL DESCRIPTION

Program computes heat loss from round and rectangular ducts with internal lining, with outside insulation, or without any lining and insulation. The program can be used for supply air and return air systems with air temperature either higher or lower than outside ambient temperature.

EQUATIONS

$$De = 2 \times W \times D/(W+D) \quad [2.15]$$

where
De = Equivalent hydraulic diameter
W = Width of duct
D = Depth of duct

$$h_i = 0.0144 \times C_p \times G^{0.8}/D_e^{0.2} \quad [2.16]$$

where
h_i = Heat transfer coefficient at inner surface in Btu/hr —due to forced convection
C_p = specific heat at constant pressure of air—assumed value of .24Btu/lb
G = mass velocity, lb/hr = air density $\times$ Vfph = 0.075 $\times$ Vfpm $\times$ 60 = 4.5 V

Substituting values in equation 2.16

$$h_i = 0.0189\, V^{0.8}/De^{0.2}$$

where
V = velocity in fpm

$$h_c = 0.19 \times (T_o - T_s)^{1/3} \quad [2.17]$$

where
h_c = Heat loss by convection from outside surface in Btu/hr °F
T_o = Air temperature outside duct
T_s = Surface temperature outside duct

$$h_r = 0.173 \times e \times [([T_o + 460]/100)^4 - ([T_s + 460]/100)^4]/(T_o - T_s) \quad [2.18]$$

where
h_r = Heat loss by radiation, Btu/hr
e = Surface emissivity—generally 0.9 for dirty surfaces

$$U_o = 1/[1/(h_c + h_r + 1/h_i + R_1 \times X_1 + R_2 \times X_2)] \quad [2.19]$$

where
U_o = Over-all U factor
R_1 = Resistance of duct lining; reciprocal of thermal conductance; (h_r ft^2 °F)/Btu
X_1 = thickness of duct lining in inches
R_2 = resistance of duct insulation; reciprocal of thermal conductance; (h_r ft^2 °F)/Btu
X_2 = thickness of duct insulation, inches

$$[(T_s - T_o)/1/(h_i + R_1 x_1 + R_2 x_2)] = (T_o - T_e) \times U_o \quad [2.20]$$

T_s is computed from the above equation.

Heat loss from duct H_l

$$= A \times U_o \times (T_{av} - T_o)$$
$$= Q \times (T_e - T_l) \times 1.08 \quad [2.21]$$

where
A = area of duct in sq ft
$T_{av} = (T_e + T_l) \div 2$
T_o = Temperature of air outside duct
$T_l = [A \times U_o \times (T_o - T_e/2) + Q \times 1.08 \times T_e]/(1.08 \times Q + A \times U_o/2)$
T_e = Temperature of air entering duct
T_l = Temperature of air leaving duct
T_{av} = Average temperature of air in duct

OPERATING FEATURES

Due to the limits of the programming steps, the program is based on heat flow through a flat plate rather than a pipe or tube. The reduction in accuracy is negligible.

The duct size is the *actual* sheet metal size; the program will compute the net dimension based on input of lining and insulation thickness. The rectangular duct should be input in decimal format. For example, 12.08 will mean the duct is 12 by 8. If the decimal part of input is zero, the program will recognize it as a round duct.

The program reiterates three times to find the value of T_s (surface temperature). Accuracy of results can be increased by increasing the number of reiterations at a cost of slowing down the program. This is not necessary, since the first time the program uses the average value of T_o and T_e to compute T_s. The next time around, it uses the previous value of T_s and continues to improve accuracy.

The program has the following flags which have to be set and reset (cleared) manually from the keyboard:

No flag	Prints all output
Set flag 1	Skips U_o and T_s
Set flag 2	Skips U_o but prints T_s
Set flag 3	Skips H_l but prints T_l

Equation 2.21 is not valid for long ducts of very small cross section, say below 10 in. round or its equivalent. Accurate results can be obtained by inputting a small length under Label D and repeating the calculation as many times as required by using key E to compute for the entire length. When computing in this mode, the program will print out the end results only, rather than the intermediate answers.

DP-4
AIR DUCT HEAT LOSS/GAIN PROGRAM
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Enter temp. of air outside duct	90	–	2nd	A′	90.00	TO	
2.	Enter temp. of air entering duct	55	–	–	R/S	55.00	TE	
3.	Enter lining resistance	4	–	2nd	B′	4.00	R1	
4.	Enter lining thickness	1	–	–	R/S	1.00	X1	
5.	Enter insul. resistance	4	–	2nd	C′	4.00	R2	
6.	Enter insul. thickness	1	–	–	R/S	1.00	X2	
7.	Enter outer surface emmissivity	.9	–	–	R/S	0.900	e	
8.	Enter run no.	1.02	–	–	A	1.02	R.NO	
9.	Enter duct dimension	36.24	–	–	B	36.24	W.D	
10.	Enter cfm	7500	–	–	C	7500.	CFM	
						87.01377	TS	Surface temp.
						0.111	UO	Over-all *U* factor
11.	Enter length of duct	10	–	–	D	10.0	L	
						55.03729	TL	Temp. of air leaving
	Repeat steps 8, 9, 10, & 11 as many times as required.					-302.	HL	Heat gain: negative for gain, positive for loss
12.	To repeat 3 times	3	–	–	E	3.	RPT	
						87.02327	TS	
	Same duct could pass through space having different temp. and could have no insul. Only input changes.					0.111	UO	
						55.14893	TL	
						-904.	HL	
12.	Enter new temp. of air around duct	80	–	2nd	A′	80.00	TO	
13.	Change lining resistance	0	–	2nd	C′	0.00	R1	
14.	Change insul. resistance	0	–	2nd	D′	0.00	X1	
	Repeat steps 8, 9, 10, & 11.					0.00	R2	
						0.00	X2	

		2.03	–	–	A	2.03	R.NO	
		32.24	–	–	B	32.24	W.D	
		7000	–	–	C	7000.	CFM	
						61.99106	TS	
	To delete TS and UO	–	2nd	St flg	1	1.033	UO	
						20.0	L	
						55.63201	TL	
						-3652.	HL	
		3.04	–	–	A	3.04	R.NO	
		28.24	–	–	B	28.24	W.D	
		6000	–	–	C	6000.	CFM	
						10.0	L	
						55.89200	TL	
						-1685.	HL	
	To print TS again	INV	2nd	St flg	1			
	To delete UO		2nd	St flg	2			
	To delete HL		2nd	St flg	3			
		4.05	–	–	A	4.05	R.NO	
		24.24	–	–	B	24.24	W.D	
		5000	–	–	C	5000.	CFM	
						62.65435	TS	
						10.0	L	
						56.17722	TL	
	For round ducts, input 0 after decimal under step 9.	5.06	–	–	A	5.06	R.NO	
		20	–	–	B	20.	DIA	
		4000	–	–	C	4000.	CFM	
						62.17408	TS	
						15.0	L	
						56.63454	TL	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A′	Stores and prints T0; with R/S, stores and prints TE
B′	Stores and prints R1; with R/S, prints X1 and stores twice X1
C′	Stores and prints R2; with R/S, prints X2 and stores twice X2
A	Prints R No.
B	Accepts duct size in decimal format; if round duct goes to SBR LNX, for rectangular ductwork prints W.D; computes net size and equivalent hydraulic diameter
C	Prints and stores CFM; computes velocity; calls SBR X^2 and SBR $\sqrt{X}$
X^2	Computes surface temperature using SBR CE
$\sqrt{X}$	Computes over-all *U* factor and prints
D	Prints and stores length; computes heat loss per degrees F; calls SBR 1/X and STO
1/X	Computes TL
STO	Prints TL and computes and prints heat loss
E	Reiterates for long duct
RCL	For reiteration
INV	Alphanumeric identification of data
LNX	For circular duct
CE	Computes UO and TS
CLR	Reiterates for computing TS
X⇄T	Stops when flags are set

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Reiterates for finding value of surface temperature TS
R01	Reiterates for long duct
R02	TO—air temperature outside duct
R03	TE—temperature of air entering duct
R04	Rl—resistance of lining inside ductwork
R05	Xl—thickness of lining
R06	R2—resistance of insulation
R07	X2—thickness of insulation
R08	*e*—outside surface emissivity
R09	Duct dimension W or DIA or DE
R10	Duct dimension D
R11	CFM
R12	Velocity
R13	Not used
R14	Surface temperature
R15	(1/HI) + R1X1 + R2X2
R16	UO (over-all *U* factor); last value of TL (leaving air temperature)
R17	Length; heat loss, °F
R18	Alphanumeric code
R19	For FIX IND for number of decimal places

DP-4 AIR DUCT HEAT LOSS/GAIN PROGRAM

LABELS & SUBROUTINES

```
001  16 A'
050  17 B'
086  18 C'
135  11  A
154  12  B
222  13  C
260  33 X²
291  34 √X
343  14  D
378  35 1/X
440  42 STO
488  15  E
513  43 RCL
539  22 INV
557  23 LNX
584  24 CE
630  25 CLR
736  32 X:T
```

LISTING

```
000  76 LBL
001  16 A'
002  42 STO
003  02  02
004  22 INV
005  58 FIX
006  02  2
007  69 OP
008  17  17
009  43 RCL
010  02  02
011  32 X:T
012  03  3
013  07  7
014  03  3
015  02  2
016  42 STO
017  18  18
018  02  2
019  42 STO
020  19  19
021  71 SBR
022  22 INV
023  91 R/S
024  42 STO
025  03  03
026  32 X:T
027  03  3
028  07  7
029  01  1
030  07  7
031  42 STO
032  18  18
033  02  2
034  42 STO
035  19  19
036  71 SBR
037  22 INV
038  98 ADV
039  85  +
040  43 RCL
041  02  02
042  95  =
043  55  ÷
```

044	02	2
045	95	=
046	42	STO
047	14	14
048	91	R/S
049	76	LBL
050	17	B'
051	42	STO
052	04	04
053	32	X:T
054	03	3
055	05	5
056	00	0
057	02	2
058	42	STO
059	18	18
060	02	2
061	42	STO
062	19	19
063	71	SBR
064	22	INV
065	91	R/S
066	32	X:T
067	04	4
068	04	4
069	00	0
070	02	2
071	42	STO
072	18	18
073	02	2
074	42	STO
075	19	19
076	71	SBR
077	22	INV
078	65	×
079	02	2
080	95	=
081	42	STO
082	05	05
083	98	ADV
084	91	R/S
085	76	LBL
086	18	C'
087	42	STO
088	06	06
089	32	X:T
090	03	3
091	05	5
092	00	0
093	03	3
094	42	STO
095	18	18
096	02	2
097	42	STO
098	19	19
099	71	SBR
100	22	INV
101	91	R/S
102	32	X:T
103	04	4
104	04	4
105	00	0
106	03	3
107	42	STO
108	18	18
109	02	2
110	42	STO
111	19	19
112	71	SBR
113	22	INV
114	65	×
115	02	2
116	95	=
117	42	STO
118	07	07
119	91	R/S
120	42	STO
121	08	08
122	32	X:T
123	05	5
124	04	4
125	42	STO
126	18	18
127	03	3
128	42	STO
129	19	19
130	71	SBR
131	22	INV
132	98	ADV
133	91	R/S
134	76	LBL
135	11	A
136	32	X:T
137	03	3
138	05	5
139	04	4
140	00	0
141	03	3
142	01	1
143	03	3
144	02	2
145	42	STO
146	18	18
147	02	2
148	42	STO
149	19	19
150	71	SBR
151	22	INV
152	91	R/S
153	76	LBL
154	12	B
155	42	STO
156	09	09
157	29	CP
158	53	(
159	24	CE
160	22	INV
161	59	INT
162	65	×
163	01	1
164	00	0
165	00	0
166	54	)
167	42	STO
168	10	10
169	67	EQ
170	23	LNX
171	43	RCL
172	09	09
173	32	X:T
174	04	4
175	03	3
176	04	4
177	00	0
178	01	1
179	06	6
180	42	STO
181	18	18
182	02	2
183	42	STO
184	19	19
185	71	SBR
186	22	INV
187	59	INT
188	53	(
189	24	CE
190	75	-
191	43	RCL
192	05	05
193	54	)
194	42	STO
195	09	09
196	43	RCL
197	05	05
198	22	INV
199	44	SUM
200	10	10
201	53	(
202	02	2
203	65	×
204	43	RCL
205	09	09
206	65	×
207	43	RCL
208	10	10
209	55	÷
210	53	(
211	43	RCL
212	09	09
213	85	+
214	43	RCL
215	10	10
216	54	)
217	54	)
218	42	STO
219	09	09
220	91	R/S
221	76	LBL
222	13	C
223	42	STO
224	11	11
225	32	X:T
226	01	1
227	05	5
228	02	2
229	01	1
230	03	3
231	00	0
232	42	STO
233	18	18
234	00	0
235	42	STO
236	19	19
237	71	SBR
238	22	INV
239	53	(
240	24	CE
241	65	×
242	05	5
243	07	7
244	06	6
245	55	÷
246	89	π
247	55	÷
248	43	RCL
249	09	09
250	33	X²
251	54	)
252	42	STO
253	12	12
254	71	SBR
255	33	X²
256	71	SBR
257	34	√X
258	91	R/S
259	76	LBL
260	33	X²
261	03	3
262	42	STO
263	00	00
264	71	SBR
265	24	CE
266	53	(
267	53	(
268	43	RCL
269	14	14
270	75	-
271	43	RCL
272	03	03
273	54	)
274	55	÷
275	43	RCL
276	15	15
277	55	÷
278	53	(
279	43	RCL
280	02	02
281	75	-
282	43	RCL
283	03	03
284	54	)
285	54	)
286	54	)
287	42	STO
288	16	16
289	92	RTN
290	76	LBL
291	34	√X
292	53	(
293	43	RCL
294	09	09
295	85	+
296	43	RCL
297	05	05
298	85	+
299	43	RCL
300	07	07
301	55	÷
302	02	2
303	54	)

304	42	STO
305	09	09
306	87	IFF
307	01	01
308	32	X:T
309	43	RCL
310	14	14
311	32	X:T
312	03	3
313	07	7
314	03	3
315	06	6
316	42	STO
317	18	18
318	05	5
319	42	STO
320	19	19
321	71	SBR
322	22	INV
323	87	IFF
324	02	02
325	32	X:T
326	43	RCL
327	16	16
328	32	X:T
329	04	4
330	01	1
331	03	3
332	02	2
333	42	STO
334	18	18
335	03	3
336	42	STO
337	19	19
338	71	SBR
339	22	INV
340	98	ADV
341	92	RTN
342	76	LBL
343	14	D
344	42	STO
345	17	17
346	32	X:T
347	02	2
348	07	7
349	42	STO
350	18	18
351	01	1
352	42	STO
353	19	19
354	71	SBR
355	22	INV
356	53	(
357	24	CE
358	65	×
359	43	RCL
360	09	09
361	65	×
362	89	π
363	65	×
364	43	RCL
365	16	16
366	55	÷
367	01	1
368	02	2
369	54	)
370	42	STO
371	17	17
372	71	SBR
373	35	1/X
374	71	SBR
375	42	STO
376	91	R/S
377	76	LBL
378	35	1/X
379	53	(
380	53	(
381	53	(
382	53	(
383	43	RCL
384	02	02
385	75	-
386	53	(
387	43	RCL
388	03	03
389	55	÷
390	02	2
391	54	)
392	54	)
393	65	×
394	43	RCL
395	17	17
396	54	)
397	85	+
398	53	(
399	53	(
400	43	RCL
401	11	11
402	65	×
403	01	1
404	93	.
405	00	0
406	08	8
407	54	)
408	42	STO
409	16	16
410	65	×
411	43	RCL
412	03	03
413	54	)
414	54	)
415	55	÷
416	53	(
417	43	RCL
418	16	16
419	85	+
420	53	(
421	43	RCL
422	17	17
423	55	÷
424	02	2
425	54	)
426	54	)
427	54	)
428	42	STO
429	13	13
430	43	RCL
431	03	03
432	42	STO
433	16	16
434	43	RCL
435	13	13
436	42	STO
437	03	03
438	92	RTN
439	76	LBL
440	42	STO
441	32	X:T
442	03	3
443	07	7
444	02	2
445	07	7
446	42	STO
447	18	18
448	05	5
449	42	STO
450	19	19
451	71	SBR
452	22	INV
453	87	IFF
454	03	03
455	32	X:T
456	53	(
457	53	(
458	43	RCL
459	16	16
460	75	-
461	43	RCL
462	13	13
463	54	)
464	65	×
465	43	RCL
466	11	11
467	65	×
468	01	1
469	93	.
470	00	0
471	08	8
472	54	)
473	32	X:T
474	02	2
475	03	3
476	02	2
477	07	7
478	42	STO
479	18	18
480	00	0
481	42	STO
482	19	19
483	71	SBR
484	22	INV
485	98	ADV
486	92	RTN
487	76	LBL
488	15	E
489	32	X:T
490	03	3
491	05	5
492	03	3
493	03	3
494	03	3
495	07	7
496	42	STO
497	18	18
498	00	0
499	42	STO
500	19	19
501	71	SBR
502	22	INV
503	75	-
504	01	1
505	95	=
506	42	STO
507	01	01
508	43	RCL
509	03	03
510	42	STO
511	10	10
512	76	LBL
513	43	RCL
514	71	SBR
515	33	X^2
516	71	SBR
517	35	1/X
518	97	DSZ
519	01	01
520	43	RCL
521	71	SBR
522	33	X^2
523	71	SBR
524	34	√X
525	71	SBR
526	35	1/X
527	43	RCL
528	10	10
529	42	STO
530	16	16
531	43	RCL
532	03	03
533	71	SBR
534	42	STO
535	98	ADV
536	98	ADV
537	91	R/S
538	76	LBL
539	22	INV
540	22	INV
541	58	FIX
542	25	CLR
543	69	OP
544	00	00
545	43	RCL
546	18	18
547	69	OP
548	04	04
549	32	X:T
550	58	FIX
551	40	IND
552	19	19
553	69	OP
554	06	06
555	92	RTN
556	76	LBL
557	23	LNX
558	43	RCL
559	09	09
560	32	X:T
561	01	1
562	06	6
563	02	2

```
564  04   4
565  01   1
566  03   3
567  42  STO
568  18   18
569  00   0
570  42  STO
571  19   19
572  71  SBR
573  22  INV
574  53   (
575  24  CE
576  75   -
577  43  RCL
578  05   05
579  54   )
580  42  STO
581  09   09
582  92  RTN
583  76  LBL
584  24  CE
585  53   (
586  53   (
587  93   .
588  00   0
589  01   1
590  08   8
591  09   9
592  65   ×
593  53   (
594  43  RCL
595  12   12
596  45  Y^X
597  93   .
598  08   8
599  54   )
600  55   ÷
601  53   (
602  43  RCL
603  09   09
604  45  Y^X
605  93   .
606  02   2
607  54   )
608  54   )
609  35  1/X
610  85   +
611  43  RCL
612  04   04
613  65   ×
614  43  RCL
615  05   05
616  55   ÷
617  02   2
618  85   +
619  43  RCL
620  06   06
621  65   ×
622  43  RCL
623  07   07
624  55   ÷
625  02   2
626  54   )
627  42  STO
628  15   15
629  76  LBL
630  25  CLR
631  53   (
632  43  RCL
633  03   03
634  85   +
635  53   (
636  43  RCL
637  02   02
638  75   -
639  43  RCL
640  03   03
641  54   )
642  65   ×
643  43  RCL
644  15   15
645  55   ÷
646  53   (
647  43  RCL
648  15   15
649  85   +
650  53   (
651  53   (
652  53   (
653  43  RCL
654  02   02
655  75   -
656  43  RCL
657  14   14
658  54   )
659  50  I×I
660  45  Y^X
661  93   .
662  03   3
663  03   3
664  54   )
665  65   ×
666  93   .
667  01   1
668  09   9
669  85   +
670  53   (
671  53   (
672  53   (
673  53   (
674  43  RCL
675  02   02
676  85   +
677  04   4
678  06   6
679  00   0
680  54   )
681  55   ÷
682  01   1
683  00   0
684  00   0
685  54   )
686  45  Y^X
687  04   4
688  54   )
689  75   -
690  53   (
691  53   (
692  53   (
693  43  RCL
694  14   14
695  85   +
696  04   4
697  06   6
698  00   0
699  54   )
700  55   ÷
701  01   1
702  00   0
703  00   0
704  54   )
705  45  Y^X
706  04   4
707  54   )
708  54   )
709  65   ×
710  43  RCL
711  08   08
712  65   ×
713  93   .
714  01   1
715  07   7
716  03   3
717  55   ÷
718  53   (
719  43  RCL
720  02   02
721  75   -
722  43  RCL
723  14   14
724  54   )
725  54   )
726  35  1/X
727  54   )
728  54   )
729  42  STO
730  14   14
731  97  DSZ
732  00   00
733  25  CLR
734  92  RTN
735  76  LBL
736  32  X⇌T
737  98  ADV
738  91  R/S
```

SPECIAL NOTES FOR HP–97 USERS

1. The program is based on the following arrangement of flags:

No flag	Prints all output
Set flag 0	Skips U_o and T_s
Set flag 1	Skips U_o
Set flag 2	Skips H_l

Flag 2 has to be set after every usage.

2. For ducts of small cross section and having low air velocities, repeat step 15 of the example with small increments of length to obtain accurate results.

DP-4
AIR DUCT HEAT LOSS/GAIN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	To display 4 decimal places	–	–	DSP	4		
2.	In order to record input, switch printer to TRACE mode	–	CL*x*	PRINT*x*	CL*x*		
3.	Clear display and print 0	–	–	–	CL*x*	CLX	
						0.0000 ***	
4.	Enter lining resistance	4	–	STO	A	4.0000 STOA	
5.	Enter lining thickness	1	–	STO	B	1.0000 STOB	
6.	Enter insul. resistance	4	–	STO	C	4.0000 STOC	
7.	Enter insul. thickness	1	–	STO	D	1.0000 STOD	
8.	Enter outer surface emissivity	.9	–	STO	E	.9000 STOE	
9.	Enter temp. of air outside duct	90	–	STO	0	90.0000 STO0	
10.	Enter temp of air entering duct	55	–	STO	9	55.0000 STO9	
					+	+	
						145.0000 ***	
		2	–	–	÷	2.0000 ÷	
						72.5000 ***	
		–	–	STO	5	STO5	
11.	Enter run no.	1.02	–	–	A	1.0200 ***	
12.	Enter duct width	36	–	–	B	36.0000 ***	
13.	Enter duct depth	24	–	–	R/S	24.0000 ***	
14.	Enter cfm	7500	–	–	C	7500.0000 ***	
						87.0139 ***	Surface temp.
						0.1110 ***	Over-all *U* factor
15.	Enter length	40	–	–	D	40.0000 ***	
						55.1489 ***	Leaving air temp.
	Repeat steps 11 through 15 as many times as desired.					-1206.2510 ***	Heat gain: negative for gain, positive for loss

DP-4 *(Continued)*

AIR DUCT HEAT LOSS/GAIN PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Switch printer to TRACE mode to eliminate lining.	0	–	STO	A	0.0000 STOA	
		–	–	STO	B	STOB	
		–	–	STO	C	STOC	
		–	–	STO	D	STOD	
	To change ambient temp. to 80°F	80	–	STO	0	80.0000 STO0	After this step, remove printer from TRACE mode.
	Repeat steps 11 through 15 as many times as desired.	2.03	–	–	A	2.0300 ***	
		32	–	–	B	32.0000 ***	
		24	–	–	R/S	24.0000 ***	
		7000	–	–	C	7000.0000 ***	
						61.9964 ***	
						1.0329 ***	
		20	–	–	D	20.0000 ***	
						55.6316 ***	
						-3650.5154 ***	
	To eliminate leaving air temp. and over-all U value	–	f	LBL	0		
		3.04	–	–	A	3.0400 ***	
		28	–	–	B	28.0000 ***	
		24	–	–	R/S	24.0000 ***	
		6000	–	–	C	6000.0000 ***	
		10	–	–	D	10.0000 ***	
	To print surface temp. and eliminate over-all U factor	–	f	GTO	0	55.8917 ***	
		–	f	LBL	1	-1664.0310 ***	
	To eliminate heat loss, set flag 2	–	f	LBL	2		
		4.05	–	–	A	4.0500 ***	
		24	–	–	B	24.0000 ***	
		24	–	–	R/S	24.0000 ***	
		5000	–	–	C	5000.0000 ***	
						62.6613 ***	
		10	–	–	D	10.0000 ***	
						56.1768 ***	

	For circular ductwork input one dimension only						
		5.06	–	–	A	5.0600 ***	
		20	–	–	B	20.0000 ***	
		4000	–	–	C	4000.0000 ***	
						62.8946 ***	
		15	–	–	D	15.0000 ***	
						56.6537 ***	
						-2060.3141 ***	*Note:* Flag 2 has to be set after every usage.

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints display (run no.)
B	Prints and stores display (duct dimension) in R1; with R/S, prints and stores display (duct dimension) in R2
C	Prints and stores display (CFM) in R3; stores 3 in RI; if R3 = 0 (circular duct) goes to SBR 0, otherwise computes net duct size; computes diameter of equivalent round duct and velocity based on round duct; using LBL 1, computes (1/HI) + R1 × X1 + R2 × X2; using LBL 2 computes and prints outside surface temperature R5 and computes over-all U factor R7; if flag 0 is set goes to SBR 4, otherwise prints R7
D	Prints and stores display in R8; calculates leaving air temperature; if flag 2 is set goes to SBR 4; calculates and prints heat loss
0	Calculates net duct size for round duct; goes to SBR 1
3	Calculates $[(T + 460)/100]^4$
4	Stops execution

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	TO—air temperature outside duct
R1	Duct dimension; diameter of equivalent round duct; over-all diameter
R2	Duct dimension
R3	CFM
R4	Velocity
R5	Surface temperature
R6	(1/HI) + R1 × X1 + R2 × X2
R7	Over-all U factor
R8	Length; area of duct; heat loss per degrees F
R9	TE—temperature of air entering duct
RA	R1—resistance of lining inside ductwork
RB	X1—thickness of lining
RC	R2—resistance of insulation
RD	X2—thickness of insulation
RE	e—outside surface emissivity
RI	For reiteration

DP-4 (HP-97) AIR DUCT HEAT LOSS/GAIN PROGRAM

LISTING

```
*LBLA    21 11
PRTX       -14
RTN         24
*LBLB    21 12
STO1     35 01
PRTX       -14
R/S         51
STO2     35 02
PRTX       -14
R/S         51
*LBLC    21 13
STO3     35 03
PRTX       -14
3           03
STOI     35 46
RCL2     36 02
X=0?     16-43
GTO0     22 00
RCLB     36 12
2           02
x          -35
ST-1  35-45 01
ST-2  35-45 02
RCL1     36 01
RCL2     36 02
x          -35
2           02
x          -35
RCL1     36 01
RCL2     36 02
+          -55
÷          -24
STO1     35 01
X²          53
1/X         52
RCL3     36 03
x          -35
1           01
8           08
3           03
x          -35
STO4     35 04
*LBL1    21 01
.          -62
8           08
Y^x         31
.          -62
0           00
1           01
8           08
9           09
x          -35
RCL1     36 01
.          -62
2           02
Y^x         31
÷          -24
1/X         52
RCLA     36 11
RCLB     36 12
x          -35
+          -55
RCLC     36 13
RCLD     36 14
x          -35
+          -55
STO6     35 06
*LBL2    21 02
RCL0     36 00
GSB3     23 03
RCL5     36 05
GSB3     23 03
-          -45
RCLE     36 15
x          -35
.          -62
1           01
7           07
3           03
x          -35
RCL0     36 00
RCL5     36 05
-          -45
÷          -24
LSTX     16-63
ABS      16 31
.          -62
3           03
3           03
Y^x         31
.          -62
1           01
9           09
```

```
094      x        -35
095      +        -55
096     1/X        52
097    RCL6     36 06
098      +        -55
099     1/X        52
100    RCL6     36 06
101      x        -35
102    RCL0     36 00
103    RCL9     36 09
104      -        -45
105      x        -35
106    RCL9     36 09
107      +        -55
108    ST05     35 05
109    DSZI  16 25 46
110    GT02     22 02
111    RCL9     36 09
112      -        -45
113    RCL6     36 06
114      ÷        -24
115    RCL0     36 00
116    RCL9     36 09
117      -        -45
118      ÷        -24
119    ST07     35 07
120    RCL1     36 01
121    RCLB     36 12
122      2         02
123      x        -35
124      +        -55
125    RCLD     36 14
126      +        -55
127    ST01     35 01
128     F0?  16 23 00
129    GT04     22 04
130    RCL5     36 05
131    PRTX       -14
132     F1?  16 23 01
133    GT04     22 04
134    RCL7     36 07
135    PRTX       -14
136     SPC     16-11
137     RTN        24
138   *LBLD     21 14
139    ST08     35 08
140    PRTX       -14
141    RCL1     36 01
142      x        -35
143      Pi     16-24
144      x        -35
145    RCL7     36 07
146      x        -35
147      1         01
148      2         02
149      ÷        -24
150    ST08     35 08
151    RCL9     36 09
152      2         02
153      ÷        -24
154    RCL0     36 00
155      -        -45
156     CHS       -22
157    RCL8     36 08
158      x        -35
159    RCL3     36 03
160      1         01
161      .        -62
162      0         00
163      8         08
164      x        -35
165    ST07     35 07
166    RCL9     36 09
167      x        -35
168      +        -55
169    RCL8     36 08
170      2         02
171      ÷        -24
172    RCL7     36 07
173      +        -55
174      ÷        -24
175    ST08     35 08
176    RCL9     36 09
177    ST07     35 07
178    RCL8     36 08
179    ST09     35 09
180    PRTX       -14
181     F2?  16 23 02
182    GT04     22 04
183    RCL7     36 07
184    RCL8     36 08
185      -        -45
186    RCL3     36 03
187      x        -35
188      1         01
189      .        -62
190      0         00
191      8         08
192      x        -35
193    PRTX       -14
194     SPC     16-11
195     RTN        24
196   *LBL0     21 00
197    RCLB     36 12
198      2         02
199      x        -35
200    ST-1  35-45 01
201    RCL1     36 01
202    GSB1     23 01
203     RTN        24
204   *LBL3     21 03
205      4         04
206      6         06
207      0         00
208      +        -55
209      1         01
210      0         00
211      0         00
212      ÷        -24
213      4         04
214     Y^X        31
215     RTN        24
216   *LBL4     21 04
217     SPC     16-11
218     RTN        24
219     R/S        51
```

3

LIGHTING DESIGN PROGRAMS

LP-1
LIGHTING POWER BUDGET PROGRAM

GENERAL DESCRIPTION

This program computes lighting power budget based on IES Recommended Lighting Power Budget Determination Procedure—EMS-1 and ASHRAE Standard 90-75R.

EQUATIONS

$$H_2 = H_i - HWP \qquad [3.1]$$

where
- H_2 = Height of luminaire from work plane
- HWP = Height of work plane (2.5 ft unless changed)
- H_i = Height of luminaire above floor—or ceiling height if luminaire is recessed in the ceiling

$$A = L \times W \qquad [3.2]$$

where
- A = Area of room
- L = Length of room
- W = Width of room

$$RCR = 5 \times H_2 \times (L+W)/A \qquad [3.3]$$

where
- RCR = Room cavity ratio

$$\text{kW} = \frac{A \times \text{fc}}{CU \times LE \times 700} \qquad [3.4]$$

Based on LLF = .07.

where
- kW = Kilowatts
- fc = Foot-candles
- CU = Coefficient of utilization
- LE = Lamp efficiency, lumens/watt

Note: CU has to be computed separately based on luminaire data.

$$\text{fc average} = \Sigma\, \text{fc}_1 \times A_1/\Sigma A_1 \qquad [3.5]$$

$$\text{kW} = A \times \text{fc}/LE \times MBE \times .75 \times 700 \qquad [3.6]$$

where
- MBE = Minimum beam efficiency

OPERATING FEATURES

Program provides value of LE based on the following task types:

Task Type	LE
1. Where moderate color rendition is appropriate	55
2. Where good color rendition is appropriate	40
3. Where high color rendition is appropriate	25

If a special value of *LE* is to be used, change the value of *CU* in the appropriate ratio and store the new value of *CU* under key B′.

The program also provides for the following options under WS.A:

1. The task area can be specified by percent. In that case, input percent figure as negative—for example, 30 +/−.
2. If the room has no specific task and is to be designed for one general level, input 0.
3. If only the number of work stations is input, the program will assume 50 sq ft per work station—for example, 13.0 will mean 13 work stations, each 50 sq ft.
4. The number of work stations and the area of each work station can be input in decimal format—for example, 9.35 will mean 9 work stations, each 35 sq ft.

If the total area of work stations exceeds 50% of the room area, the program will flash an error message and the computation has to be repeated from the beginning.

EXAMPLE NO. 1

Compute lighting power budget for rooms having the following data:

1. Room type	19
2. Number of similar rooms	2
3. Length, ft	108.7
4. Width, ft	29.3
5. Height of lumnaire over work surface, ft	9.7
6. Luminaire type	12
7. Number of work stations	23
8. Illumination for work surface	80 fc
9. Color rendition	Good

EXAMPLE NO. 2

Same data, but 20 work stations, each 50 sq ft.

EXAMPLE NO. 3

Same data, but 100 fc throughout the room; *CU* = 0.57; color rendition moderate.

EXAMPLE NO. 4

Same data, but task area 35%; 65 fc; color rendition high.

EXAMPLE NO. 5

Same data, but 35 work stations, 50 sq ft each; 80 fc; color rendition good.

LP-1
LIGHTING POWER BUDGET PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Initialize	0	–	2nd	E′	0.	
2. 3.	To compute area and RCR Enter room type	– 19	– –	– –	A R/S	?RT 19.	What is room type?
4.	Enter room length	108.7	–	–	R/S	L 108.7	What is room length?
5.	Enter room width	29.3	–	–	R/S	W 29.3	What is room width?
6.	Enter height	9.7	–	–	R/S	H 9.7	What is height of luminaire over work surface?
						3185. A	Room area
						1.56 RCR	Room cavity ratio
7.	Enter CU	.63	–	–	R/S	CU 0.63	What is coeff. of utilization?
8. 9.	To compute power budget Enter luminaire type	– 12	– –	– –	B R/S	?LT 12.	What is luminaire type?
10.	Enter no. of work stations	23	–	–	R/S	WS. A 23. 50.	How many work stations and area?

LP-1 *(Continued)*
LIGHTING POWER BUDGET PROGRAM
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
11.	Enter lighting level and type	80.2	–	–	R/S	FC. T 80. 2.	How many foot-candles and what type?
						40. LE	Lamp efficiency
						1150. AT	Area of task
						5.2 KW	Power for luminaire
12.	To compute power budget for non-task areas	–	–	–	C	1150. AG	General area
						27. FC	Illumination level 1/3 of task or minimum 20 fc
						1.7 KW	Power for luminaires
						885. ANC	Area of non-critical space
						10. FC	Illumination level 1/3 of illumination for general area or minimum 10 fc
						0.5 KW	Power demand
						7.5 ΣKW	Total power demand for room
						2.34 W/A	Watts/sq ft

Step	Procedure	Input data/units	Keys			Output data/units	Comments
						41. FC	Average foot-candles
13.	Enter no of typical rooms	2	—	—	R/S	?X 2.	How many rooms of this type?
						14.9 ΣKW	Total power demand
		—	—	—	D	14.9 ΣKW	Total power demand for the project
						6370. ΣA	Total area of project
						2.34 W/A	Watts/sq ft based on total project
	To change height of work plane	3	—	2nd	A′	3. HWP	
	To change CU	.69	—	2nd	B′	0.69 CU	
	To input MBE	.85	—	2nd	C′	0.85 MBE	
	Example 2						
	Follow steps 1 through 7 as in Example no. 1.						
8.	To compute power budget	—	—	—	B	?LT	
9.	Enter luminaire type	12	—	—	R/S	12.	See Example no. 1 for explanation.
10.	Enter no. of work stations and area of each station	20.50	—	—	R/S	WS.A 20. 50.	

LP-1 *(Continued)*

LIGHTING POWER BUDGET PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
11.	Enter lighting level and type	70.2	–	–	R/S	FC. T 70. 2.	
	From here on, follow same procedure as for Example no. 1.					40. LE 1000. AT 4.0 KW 1000. AG 23. FC 1.3 KW 1185. ANC 10. FC 0.7 KW 6.0 ΣKW 1.87 W/A	

		2	—	—	R/S	?X 2.	
						11.9 ΣKW	
		—	—	—	D	11.9 ΣKW	
						6370. ΣA	
						1.87 W/A	
	Example 3						
	To change CU	.57	—	2nd	B′	0.57 CU	
	Follow steps 1 through 7 as in Example no. 1.						
8.	To compute power budget	—	—	—	B	?LT	
9.	Enter luminaire type	12	—	—	R/S	12.	
9.	Enter 0 for area	0	—	—	R/S	WS. A 0.	
10.	Enter lighting level and type	100.1	—	—	R/S	FC. T 100. 1.	
	From here on, follow same procedure as for Example no. 1.					100. FC	
						14.5 KW	
		2	—	—	R/S	?X 2.	
						41.0 ΣKW	

LP-1 *(Continued)*
LIGHTING POWER BUDGET PROGRAM
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
		–	–	–	D	41.0 ΣKW	
						12740. ΣA	
						3.21 W/A	
	Example 4						
	Follow steps 1 through 7 as in Example no. 1.						
8.	To compute power budget	–	–	–	B	%LT	
9.	Enter luminaire type	12	–	–	R/S	12.	
						WS. A	
	Enter 35%	35	–	+/–	R/S	35. %	
						FC. T	
10.	Enter lighting level and type	65.3	–	–	R/S	65. 3.	
	From here on, follow same procedure as for Example no. 1.					25. LE	
						1115. AT	
						7.3 KW	
						1115. AG	

		3	—	—	R/S	22. FC 2.4 KW 955. ANC 10. FC 1.0 KW 10.6 ΣKW 3.34 W/A 33. FC ?X 3. 72.9 ΣKW 72.9 ΣKW 22294. ΣA 3.27 W/A	

LP-1 *(Continued)*

LIGHTING POWER BUDGET PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 5						
	Follow steps 1 through 7 as in Example no. 1.						
8.	To compute power budget	—	—	—	B	?LT	
9.	Enter luminaire type	19	—	—	R/S	19.	
	Enter no. of work stations and area of each	35.50	—	—	R/S	WS. A 35. 50.	
10.	Enter lighting level and type					FC. T 80. 2.	
	Note: Program prints out error message since the task area is greater than 50% of the room area. Go back to step 8 with proper area.					40. LE 1750. AT 1750. 9.9999999 99?	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E′	Clears all registers; prints zero; stores 2.5 in R04; partitions
A	Prints room type R/T; with R/S, prints room type no. and prints L; with R/S, prints and stores length, prints W; with R/S, prints and stores width, prints H; with R/S, prints room height, computes height of luminaire above the work phase, computes and prints RCR, prints CU; with R/S, stores and prints coefficient of utilization
A′	Stores and prints HWP
B′	Stores and prints CU
B	Prints F/T; with R/S, prints fixture type and WS. A; with R/S, stores input in R07; if WS. is negative (% of area), goes to SBR EE; if zero, goes to SBR (; separates and stores WS. and A; if A=0, goes to LNX; prints FC.T; with R/S, stores input in R07; separates and prints FC and T; if T=1, goes to SBR CE; if T = 2, goes to SBR CLR; if T=2, stores 25 in R12; if flag 1 is set, goes to); computes total area of work stations, and if total area is greater than 50% goes to SBR X^2; calls SBR $\sqrt{X}$ for computing and printing KW
Y^x	For continuing LBL B program
X⇄T	For continuing LBL B program
C	Computes and prints general area as equal to area of task; computes 1/3 of task FC level, and if less than 20 goes to SBR 1/X, calls SBR LOG and SBR $\sqrt{X}$; computes and prints non-critical area; computes 1/3 of general FC level, and if less than 10, goes to SBR RCL, calls SBR LOG, and SBR $\sqrt{X}$; computes and prints ΣKW; FC (average); prints ?X; with R/S, computes ΣKW; multiplies area by number of typical rooms and totalizes area; clears registers R14, R15, and R16
STO	For continuing LBL C program
SUM	For continuing LBL C program
÷	For continuing LBL C program
INV	Prints alphanumeric identification of data
LNX	Stores 50 in R08, prints, and goes to SBR Y^x
CE	Stores 55 in R12; if flag 1 is set, goes to SBR (, otherwise goes to SBR X⇄T
CLR	Stores 40 in R12; if flag 1 is set, goes to SBR), otherwise goes to SBR X⇄T
X^2	Prints total area of task (R14); clears R14; prints error message
$\sqrt{X}$	Computes FC1 × A1; computes KW; calls SBR −
1/X	Calls T register; stores in R10; goes to SBR STO
RCL	Calls T register; stores in R10; goes to SBR SUM
C′	Multiplies by 0.75; stores product in R06; prints MBE
EE	Recalls R07 and changes to negative sign; prints revised value of R07 and %; computes number of work stations based on 50 sq ft/work station and stores in R09; stores 50 in R08; goes to SBR Y^x
(	Sets flag 1; goes to SBR Y^x
)	Sets flag 1; RCL 05 stores in R13; calls SBR LOG, SBR $\sqrt{X}$, and SBR ÷
D	Prints ΣKW; prints ΣA; computes and prints W/A
GTO	Prints CU
X	Prints FC
SBR	Prints LE
LOG	Recalls R10; prints value; calls SBR X
RST	Prints ΣKW
+	Prints W/A
−	Prints KW

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Not used
R01	L; also number of similar spaces

EXPLANATION OF STORAGE REGISTERS *(continued)*

Register	Function
R02	W
R03	H− HWP
R04	HWP (height of work plane)
R05	Area
R06	CU
R07	Interim
R08	Area of work stations
R09	Number of work stations
R10	Foot-candles
R11	Type of task
R12	LE
R13	Area of task
R14	Total area of task
R15	ΣFC1 × A1
R16	Total KW for room
R17	ΣKW
R18	ΣA
R19	Alphanumeric code

LP-1 LIGHTING POWER BUDGET PROGRAM

LABELS & SUBROUTINES

```
001  10 E'
018  11  A
128  16 A'
145  17 B'
154  12  B
214  45 Y^X
266  32 X:T
314  13  C
355  42 STO
398  44 SUM
432  55  ÷
477  22 INV
490  23 LNX
501  24 CE
513  25 CLR
525  33 X²
537  34 √X
566  35 1/X
574  43 RCL
582  18 C'
603  52 EE
638  53  (
645  54  )
661  14  D
695  61 GTO
706  65  ×
721  71 SBR
733  28 LOG
740  81 RST
757  85  +
774  75  -
```

LISTING

```
000  76 LBL
001  10 E'
002  22 INV
003  58 FIX
004  02  2
005  69 OP
006  17  17
007  47 CMS
008  25 CLR
009  99 PRT
010  02  2
011  93  .
012  05  5
013  42 STO
014  04  04
015  98 ADV
016  91 R/S
017  76 LBL
018  11  A
019  06  6
020  09  9
021  03  3
022  05  5
023  03  3
024  07  7
025  42 STO
026  19  19
027  71 SBR
028  22 INV
029  91 R/S
030  99 PRT
031  98 ADV
032  02  2
033  07  7
034  42 STO
035  19  19
036  71 SBR
037  22 INV
038  91 R/S
039  42 STO
040  01  01
041  99 PRT
042  98 ADV
043  04  4
044  03  3
045  42 STO
046  19  19
047  71 SBR
048  22 INV
049  91 R/S
050  42 STO
051  02  02
052  99 PRT
053  98 ADV
054  02  2
055  03  3
056  42 STO
057  19  19
058  71 SBR
059  22 INV
060  91 R/S
061  99 PRT
062  98 ADV
063  75  -
064  43 RCL
065  04  04
066  95  =
067  42 STO
068  03  03
069  43 RCL
070  02  02
071  65  ×
072  43 RCL
073  01  01
074  95  =
075  42 STO
076  05  05
077  58 FIX
078  00  00
079  99 PRT
080  01  1
081  03  3
082  42 STO
083  19  19
084  71 SBR
085  22 INV
086  98 ADV
087  05  5
088  65  ×
089  43 RCL
090  03  03
091  65  ×
092  53  (
093  43 RCL
094  01  01
095  85  +
096  43 RCL
097  02  02
098  54  )
099  55  ÷
100  43 RCL
101  05  05
102  95  =
103  58 FIX
104  02  02
105  99 PRT
106  03  3
107  05  5
108  01  1
109  05  5
110  03  3
111  05  5
112  42 STO
113  19  19
114  71 SBR
115  22 INV
116  98 ADV
117  98 ADV
118  71 SBR
119  61 GTO
120  91 R/S
121  42 STO
122  06  06
123  99 PRT
124  98 ADV
125  98 ADV
126  91 R/S
127  76 LBL
128  16 A'
129  42 STO
130  04  04
131  99 PRT
132  02  2
133  03  3
134  04  4
135  03  3
136  03  3
```

137	03	3
138	42	STO
139	19	19
140	71	SBR
141	22	INV
142	98	ADV
143	91	R/S
144	76	LBL
145	17	B'
146	42	STO
147	06	06
148	99	PRT
149	71	SBR
150	61	GTO
151	98	ADV
152	91	R/S
153	76	LBL
154	12	B
155	06	6
156	09	9
157	02	2
158	07	7
159	03	3
160	07	7
161	42	STO
162	19	19
163	71	SBR
164	22	INV
165	91	R/S
166	99	PRT
167	98	ADV
168	04	4
169	03	3
170	03	3
171	06	6
172	04	4
173	00	0
174	01	1
175	03	3
176	42	STO
177	19	19
178	71	SBR
179	22	INV
180	29	CP
181	25	CLR
182	91	R/S
183	42	STO
184	07	07
185	22	INV
186	77	GE
187	52	EE
188	43	RCL
189	07	07
190	59	INT
191	42	STO
192	09	09
193	99	PRT
194	67	EQ
195	53	(
196	43	RCL
197	07	07
198	22	INV
199	59	INT
200	65	×
201	01	1
202	00	0
203	00	0
204	95	=
205	42	STO
206	08	08
207	67	EQ
208	23	LNX
209	43	RCL
210	08	08
211	99	PRT
212	98	ADV
213	76	LBL
214	45	Y^X
215	02	2
216	01	1
217	01	1
218	05	5
219	04	4
220	00	0
221	03	3
222	07	7
223	42	STO
224	19	19
225	71	SBR
226	22	INV
227	91	R/S
228	42	STO
229	07	07
230	59	INT
231	42	STO
232	10	10
233	99	PRT
234	43	RCL
235	07	07
236	22	INV
237	59	INT
238	65	×
239	01	1
240	00	0
241	95	=
242	42	STO
243	11	11
244	99	PRT
245	98	ADV
246	01	1
247	32	X:T
248	43	RCL
249	11	11
250	67	EQ
251	24	CE
252	02	2
253	32	X:T
254	43	RCL
255	11	11
256	67	EQ
257	25	CLR
258	02	2
259	05	5
260	42	STO
261	12	12
262	87	IFF
263	01	01
264	54	)
265	76	LBL
266	32	X:T
267	43	RCL
268	12	12
269	99	PRT
270	71	SBR
271	71	SBR
272	53	(
273	43	RCL
274	08	08
275	65	×
276	43	RCL
277	09	09
278	54	)
279	42	STO
280	13	13
281	44	SUM
282	14	14
283	58	FIX
284	00	00
285	99	PRT
286	01	1
287	03	3
288	03	3
289	07	7
290	42	STO
291	19	19
292	71	SBR
293	22	INV
294	98	ADV
295	53	(
296	43	RCL
297	05	05
298	55	÷
299	02	2
300	54	)
301	32	X:T
302	53	(
303	43	RCL
304	14	14
305	75	-
306	01	1
307	54	)
308	77	GE
309	33	X^2
310	71	SBR
311	34	√X
312	91	R/S
313	76	LBL
314	13	C
315	43	RCL
316	14	14
317	58	FIX
318	00	00
319	99	PRT
320	01	1
321	03	3
322	02	2
323	02	2
324	42	STO
325	19	19
326	71	SBR
327	22	INV
328	98	ADV
329	43	RCL
330	14	14
331	42	STO
332	13	13
333	53	(
334	53	(
335	43	RCL
336	15	15
337	55	÷
338	43	RCL
339	14	14
340	54	)
341	55	÷
342	03	3
343	54	)
344	42	STO
345	10	10
346	02	2
347	00	0
348	32	X:T
349	43	RCL
350	10	10
351	22	INV
352	77	GE
353	35	1/X
354	76	LBL
355	42	STO
356	71	SBR
357	28	LOG
358	71	SBR
359	34	√X
360	53	(
361	43	RCL
362	05	05
363	75	-
364	02	2
365	65	×
366	43	RCL
367	14	14
368	54	)
369	42	STO
370	13	13
371	58	FIX
372	00	00
373	99	PRT
374	01	1
375	03	3
376	02	2
377	09	9
378	01	1
379	05	5
380	42	STO
381	19	19
382	71	SBR
383	22	INV
384	98	ADV
385	03	3
386	22	INV
387	49	PRD
388	10	10
389	01	1
390	00	0
391	32	X:T
392	43	RCL
393	10	10
394	22	INV
395	77	GE
396	43	RCL

```
397  76  LBL
398  44  SUM
399  71  SBR
400  28  LOG
401  71  SBR
402  34  ΓX
403  43  RCL
404  16   16
405  71  SBR
406  81  RST
407  98  ADV
408  53   (
409  43  RCL
410  16   16
411  65   ×
412  01   1
413  00   0
414  00   0
415  00   0
416  55   ÷
417  43  RCL
418  05   05
419  54   )
420  71  SBR
421  85   +
422  53   (
423  43  RCL
424  15   15
425  55   ÷
426  43  RCL
427  05   05
428  54   )
429  71  SBR
430  65   ×
431  76  LBL
432  55   ÷
433  06   6
434  09   9
435  04   4
436  04   4
437  42  STO
438  19   19
439  71  SBR
440  22  INV
441  91  R/S
442  99  PRT
443  98  ADV
444  42  STO
445  01   01
446  53   (
447  24  CE
448  65   ×
449  43  RCL
450  16   16
451  54   )
452  44  SUM
453  17   17
454  43  RCL
455  17   17
456  71  SBR
457  81  RST
458  53   (
459  43  RCL
460  01   01
461  65   ×
462  43  RCL
463  05   05
464  54   )
465  44  SUM
466  18   18
467  00   0
468  42  STO
469  14   14
470  42  STO
471  15   15
472  42  STO
473  16   16
474  98  ADV
475  91  R/S
476  76  LBL
477  22  INV
478  22  INV
479  58  FIX
480  69  OP
481  00   00
482  43  RCL
483  19   19
484  69  OP
485  02   02
486  69  OP
487  05   05
488  92  RTN
489  76  LBL
490  23  LNX
491  05   5
492  00   0
493  42  STO
494  08   08
495  99  PRT
496  98  ADV
497  71  SBR
498  45  Y^X
499  92  RTN
500  76  LBL
501  24  CE
502  05   5
503  05   5
504  42  STO
505  12   12
506  87  IFF
507  01   01
508  54   )
509  71  SBR
510  32  X:T
511  92  RTN
512  76  LBL
513  25  CLR
514  04   4
515  00   0
516  42  STO
517  12   12
518  87  IFF
519  01   01
520  54   )
521  71  SBR
522  32  X:T
523  92  RTN
524  76  LBL
525  33  X^2
526  43  RCL
527  14   14
528  99  PRT
529  00   0
530  42  STO
531  14   14
532  35  1/X
533  99  PRT
534  98  ADV
535  92  RTN
536  76  LBL
537  34  ΓX
538  53   (
539  53   (
540  43  RCL
541  13   13
542  65   ×
543  43  RCL
544  10   10
545  54   )
546  44  SUM
547  15   15
548  55   ÷
549  43  RCL
550  06   06
551  55   ÷
552  43  RCL
553  12   12
554  55   ÷
555  07   7
556  00   0
557  00   0
558  54   )
559  44  SUM
560  16   16
561  71  SBR
562  75   -
563  98  ADV
564  92  RTN
565  76  LBL
566  35  1/X
567  32  X:T
568  42  STO
569  10   10
570  71  SBR
571  42  STO
572  92  RTN
573  76  LBL
574  43  RCL
575  32  X:T
576  42  STO
577  10   10
578  71  SBR
579  44  SUM
580  92  RTN
581  76  LBL
582  18  C'
583  99  PRT
584  65   ×
585  93   .
586  07   7
587  05   5
588  95   =
589  42  STO
590  06   06
591  02   2
592  08   8
593  01   1
594  04   4
595  01   1
596  07   7
597  42  STO
598  19   19
599  71  SBR
600  22  INV
601  91  R/S
602  76  LBL
603  52  EE
604  43  RCL
605  07   07
606  94  +/-
607  99  PRT
608  06   6
609  01   1
610  42  STO
611  19   19
612  71  SBR
613  22  INV
614  98  ADV
615  53   (
616  43  RCL
617  07   07
618  65   ×
619  43  RCL
620  05   05
621  55   ÷
622  05   5
623  00   0
624  00   0
625  00   0
626  54   )
627  94  +/-
628  42  STO
629  09   09
630  05   5
631  00   0
632  42  STO
633  08   08
634  71  SBR
635  45  Y^X
636  92  RTN
637  76  LBL
638  53   (
639  86  STF
640  01   01
641  71  SBR
642  45  Y^X
643  92  RTN
644  76  LBL
645  54   )
646  22  INV
647  86  STF
648  01   01
649  43  RCL
650  05   05
651  42  STO
652  13   13
653  71  SBR
654  28  LOG
655  71  SBR
656  34  ΓX
657  71  SBR
658  55   ÷
659  92  RTN
660  76  LBL
```

```
14  D
43  RCL
17   17
71  SBR
81  RST
43  RCL
18   18
58  FIX
00   00
99  PRT
07   7
07   7
01   1
03   3
42  STO
19   19
71  SBR
22  INV
98  ADV
43  RCL
17   17
65   ×
01   1
00   0
00   0
00   0
55   ÷
43  RCL
18   18
95   =
71  SBR
85   +
91  R/S
76  LBL
61  GTO
01   1
05   5
04   4
01   1
42  STO
19   19
71  SBR
22  INV
92  RTN
76  LBL
65   ×
58  FIX
00   00
99  PRT
02   2
01   1
01   1
05   5
42  STO
19   19
71  SBR
22  INV
98  ADV
92  RTN
76  LBL
71  SBR
02   2
07   7
01   1
07   7
42  STO
19   19
71  SBR
22  INV
98  ADV
92  RTN
76  LBL
28  LOG
43  RCL
10   10
71  SBR
65   ×
92  RTN
76  LBL
81  RST
58  FIX
01   01
99  PRT
07   7
07   7
02   2
06   6
04   4
03   3
42  STO
19   19
71  SBR
22  INV
98  ADV
92  RTN
76  LBL
85   +
58  FIX
02   02
99  PRT
04   4
03   3
06   6
03   3
01   1
03   3
42  STO
19   19
71  SBR
22  INV
98  ADV
92  RTN
76  LBL
75   -
58  FIX
01   01
99  PRT
02   2
06   6
04   4
03   3
42  STO
19   19
71  SBR
22  INV
98  ADV
92  RTN
00   0
```

SPECIAL NOTES FOR HP-97 USERS

1. The program is in two parts: LP-1A for determining room area and cavity ratios; LP-1B for determining power budget.
2. Program LP-1A should be used first to determine areas and cavity ratios prior to determination of the power budget by program LP-1B.

LP-1A
LIGHTING POWER BUDGET PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
	Use program LP-1A for computing areas and CU for all rooms.						
1.	Enter height of work plane	2.5	–	–	E	2.50 ***	
2.	Enter room number	19	–	–	A	19.00 ***	
3.	Enter room length	198.7	–	–	B	108.70 ***	
4.	Enter room width	29.3	–	–	C	29.30 ***	
						3184.91 ***	Room area
5.	Enter room height	9.7	–	–	D	9.70 ***	
						1.56 ***	Room cavity ratio
	Compute and tabulate areas and CU for all rooms before proceeding with program LP-1B.						

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints display (room no.)
B	Prints and stores display (room length) in RB
C	Prints and stores display (room width) in RC; computes and prints area and stores in RD
D	Computes and prints coefficient of utilization CU
E	Prints and stores display (height of work plane) in RA

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	Height of work plane
RB	Room length
RC	Room width
RD	Area

LP-1A (HP-97) LIGHTING POWER BUDGET PROGRAM

LISTING

```
001  *LBLA   21 11
002   PRTX     -14
003    SPC   16-11
004    R/S      51
005  *LBLB   21 12
006   STOB   35 12
007   PRTX     -14
008    R/S      51
009  *LBLC   21 13
010   STOC   35 13
011   PRTX     -14
012   RCLB   36 12
013      x     -35
014   STOD   35 14
015   PRTX     -14
016    SPC   16-11
017    R/S      51
018  *LBLD   21 14
019   PRTX     -14
020   RCLA   36 11
021      -     -45
022      5      05
023      x     -35
024   RCLB   36 12
025   RCLC   36 13
026      +     -55
027      x     -35
028   RCLD   36 14
029      ÷     -24
030   PRTX     -14
031    SPC   16-11
032    SPC   16-11
033    R/S      51
034  *LBLE   21 15
035   STOA   35 11
036   PRTX     -14
037    SPC   16-11
038    SPC   16-11
039    R/S      51
```

LP-1B

LIGHTING POWER BUDGET PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Enter room type	19	–	–	A	19.00 ***	
3.	Enter room area	3185	–	–	R/S	3185.00 ***	
4.	Enter CU	.63	–	–	R/S	0.63 ***	
5.	Enter luminaire type	12	–	–	B	12.00 ***	
6.	Enter fc and LE	80.4	–	–	R/S	80.00 ***	Foot-candles
						40.00 ***	LE
7.	Enter number of work stations and area of each	23.50	–	–	R/S	23.00 ***	
						50.00 ***	
						1150.00 ***	Total work area
						5.22 ***	kW
8.	To compute power demand for remaining space	–	–	–	C	1150.00 ***	General area
						26.67 ***	Foot-candles
						1.74 ***	kW
						885.00 ***	Circ. area
						10.00 ***	Foot-candles
						0.50 ***	kW
						7.46 ***	Total kW
						2.34 ***	Watts/sq ft
						41.29 ***	Average fc
9.	Enter number of similar rooms	2	–	–	D	2.00 ***	Total kW
						14.91 ***	
						14.91 ***	Total kW for project
						6370.00 ***	Total area of project
						2.34 ***	Watts/sq ft

Example 2						
Follow same steps as for Example no. 1 except for step 7. Input number of work stations only and program will select 50 sq ft/station.	—	—	*f*	E	0.00 ***	
	19	—	—	A	19.00 ***	
	3185	—	—	R/S	3185.00 ***	
	.63	—	—	R/S	0.63 ***	
	12	—	—	B	12.00 ***	
	70.4	—	—	R/S	70.00 ***	
					40.00 ***	
	20	—	—	R/S	20.00 ***	
					50.00 ***	Area of each work station
					1000.00 ***	Total work area
					3.97 ***	kW
	—	—	—	C	1000.00 ***	
					23.33 ***	
					1.32 ***	
					1185.00 ***	
					10.00 ***	
					0.67 ***	
					5.96 ***	
					1.67 ***	
					33.02 ***	
	2	—	—	D	2.00 ***	
					11.93 ***	
					11.93 ***	
					6370.00 ***	
					1.87 ***	
Example 3					0.00 ***	
Follow same steps as in Example no. 1 except for step 7. Input 0 for uniform illumination of entire room.	—	—	*f*	E	0.00 ***	
	19	—	—	A	19.00 ***	
	3185	—	—	R/S	3185.00 ***	
	.57	—	—	R/S	0.57 ***	

LP-1B *(Continued)*
LIGHTING POWER BUDGET PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
		12	–	–	B	12.00 ***	
		100.55	–	–	R/S	100.00 ***	
						55.00 ***	
		0	–	–	R/S	3185.00 ***	Area illuminated
						14.51 ***	kW
		2	–	–	D	2.00 ***	
						29.03 ***	
						29.03 ***	
						6370.00 ***	
						4.56 ***	
	Example 4						
	Follow same steps as for Example	–	–	*f*	E	0.00 ***	
	no. 1 except for step 7. Input	19	–	–	A	19.00 ***	
	percent of total area.	3185	–	–	R/S	3185.00 ***	
		.58	–	–	R/S	0.58 ***	
		12	–	–	B	12.00 ***	
		65.25	–	–	R/S	65.00 ***	
						25.00 ***	
		35	CHS	–	R/S	35.00 ***	35%
						1114.75 ***	Area illuminated
						7.14 ***	kW
						1114.75 ***	
						21.67 ***	
						2.38 ***	
	Program automatically goes						
	through step 8.					955.50 ***	
						10.00 ***	
						0.94 ***	

					10.46 ***	
					3.26 ***	
					33.33 ***	
	3	–	–	D	3.00 ***	
					31.38 ***	
					31.38 ***	
					9555.00 ***	
					3.26 ***	
Example 5						
Follow same steps as for Example no. 1 except for step 7. See what happens if work area is more than 50% of total area.	–	–	*f*	E	0.00 ***	
	19	–	–	A	19.00 ***	
	3185	–	–	R/S	3185.00 ***	
	.63	–	–	R/S	0.63 ***	
	12	–	–	B	12.00 ***	
	80.4	–	–	R/S	80.00 ***	
					40.00 ***	
	35	–	–	R/S	35.00 ***	
					50.00 ***	
					1750.00 ***	
					1750.00 ***	Area to be illuminated Stops execution; shows error message

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints display (room no.); with R/S, prints and stores display (area) in RA; with R/S, prints and stores display (CU) in RB
B	Prints display (luminaire type); with R/S, accepts input in decimal format; separates, prints, and stores FC in R1, LE in R3; with R/S, stores in RC; if less than 0, goes to SBR 0, otherwise stores integral value (number of work stations) in RD; if equal to 0 goes to SBR 1; prints RD; stores fraction multiplied by 100 (area of work stations) in RE; if equal to 0 goes to SBR 2, otherwise computes and prints total work area; if more than 1/2 of total area, goes to SBR 6
C	Prints total area of work stations; makes general area equal to work stations; computes 1/3 of FC in work area; if less than 20 goes to SBR 8; continues with SBR 9
9	Calls SBR a, SBR 7; computes and prints area of circulation space; computes 1/3 of FC in general area; if less than 10, goes to SBR b
c	Calls SBR a, SBR 7; computes and prints watts/sq ft; computes and prints average FC; continues through LBL d and stops execution; with R/S, prints and stores display (number of similar spaces) in R2; calculates total wattage and prints and totalizes in R8; calculates and prints total area and totalizes in R9
D	Prints total wattage, total area, and total watts/sq ft
0	Changes sign of RC (% area), stores in RC, and prints; divides by 5,000; stores in RD (number of work stations); stores 50 in RE and goes to SBR 3 and SBR C
1	Recalls RA; stores R4; goes to SBR 7 and SBR d
2	Stores 50 in RE; goes to SBR e
6	Prints R5 and error message
7	Computes FC × A and totalizes in R6; calculates and prints KW; totalizes KW in R7
8	Stores display in R1; goes to SBR 9
a	Recalls and prints R1
b	Stores display in R1; goes to SBR c
e	Clears registers

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	FC
R2	Variable; number of similar rooms
R3	LE
R4	Area
R5	Area of work stations
R6	Totalized FC × A
R7	KW
R8	Total KW
R9	Total area
RA	Area
RB	CU
RC	Variable
RD	Number of work stations
RE	Area of work stations
RI	Area ÷ 2

LP-1B (HP-97) LIGHTING POWER BUDGET PROGRAM

LISTING

```
001  *LBLA    21 11      014  STO2    35 02
002   PRTX      -14      015   INT    16 34
003    R/S       51      016  STO1    35 01
004   STOA    35 11      017  PRTX      -14
005   PRTX      -14      018  RCL2    36 02
006    R/S       51      019   FRC    16 44
007   STOB    35 12      020     1       01
008   PRTX      -14      021     0       00
009    SFC    16-11      022     0       00
010    R/S       51      023     ×      -35
011  *LBLB    21 12      024  STO3    35 03
012   PRTX      -14      025  PRTX      -14
013    R/S       51      026   SFC    16-11
                         027   R/S       51
```

```
028  STOC     35 13
029  X<0?     16-45
030  GTO0     22 00
031  INT      16 34
032  STOD     35 14
033  X=0?     16-43
034  GTO1     22 01
035  PRTX       -14
036  RCLC     36 13
037  FRC      16 44
038  1           01
039  0           00
040  0           00
041  ×          -35
042  STOE     35 15
043  X=0?     16-43
044  GTO2     22 02
045  PRTX       -14
046  *LBL3    21 03
047  RCLE     36 15
048  RCLD     36 14
049  ×          -35
050  STO4     35 04
051  ST+5  35-55 05
052  PRTX       -14
053  RCLA     36 11
054  2           02
055  ÷          -24
056  STOI     35 46
057  RCL5     36 05
058  1           01
059  -          -45
060  RCLI     36 46
061  X≤Y?     16-35
062  GTO6     22 06
063  GSB7     23 07
064  SPC      16-11
065  RTN         24
066  *LBLC    21 13
067  RCL5     36 05
068  PRTX       -14
069  STO4     35 04
070  RCL6     36 06
071  RCL5     36 05
072  ÷          -24
073  3           03
074  ÷          -24
075  STO1     35 01
076  2           02
077  0           00
078  X>Y?     16-34
079  GTO8     22 08
080  *LBL9    21 09
081  GSBa  23 16 11
082  GSB7     23 07
083  SPC      16-11
084  RCLA     36 11
085  RCL5     36 05
086  2           02
087  ×          -35
088  -          -45
089  STO4     35 04
090  PRTX       -14
091  3           03
092  ST÷1  35-24 01
093  RCL1     36 01
094  1           01
095  0           00
096  X>Y?     16-34
097  GTOb  22 16 12
098  *LBLc 21 16 13
099  GSBa  23 16 11
100  GSB7     23 07
101  SPC      16-11
102  RCL7     36 07
103  PRTX       -14
104  1           01
105  EEX        -23
106  3           03
107  ×          -35
108  RCLA     36 11
109  ÷          -24
110  PRTX       -14
111  RCL6     36 06
112  RCLA     36 11
113  ÷          -24
114  PRTX       -14
115  *LBLd 21 16 14
116  SPC      16-11
117  R/S         51
118  STO2     35 02
119  PRTX       -14
120  RCL7     36 07
121  ×          -35
122  ST+8  35-55 08
123  RCL8     36 08
124  PRTX       -14
125  SPC      16-11
126  RCL2     36 02
127  RCLA     36 11
128  ×          -35
129  ST+9  35-55 09
130  0           00
131  STO5     35 05
132  STO6     35 06
133  STO7     35 07
134  RTN         24
135  *LBLD    21 14
136  RCL8     36 08
137  PRTX       -14
138  RCL9     36 09
139  PRTX       -14
140  RCL8     36 08
141  1           01
142  EEX        -23
143  3           03
144  ×          -35
145  RCL9     36 09
146  ÷          -24
147  PRTX       -14
148  SPC      16-11
149  SPC      16-11
150  RTN         24
151  *LBL0    21 00
152  RCLC     36 13
153  CHS        -22
154  STOC     35 13
155  PRTX       -14
156  RCLA     36 11
157  ×          -35
158  5           05
159  EEX        -23
160  3           03
161  ÷          -24
162  STOD     35 14
163  5           05
164  0           00
165  STOE     35 15
166  GSB3     23 03
167  GSBC     23 13
168  RTN         24
169  *LBL1    21 01
170  RCLA     36 11
171  STO4     35 04
172  PRTX       -14
173  GSB7     23 07
174  GSBd  23 16 14
175  RTN         24
176  *LBL2    21 02
177  5           05
178  0           00
179  STOE     35 15
180  PRTX       -14
181  GTO3     22 03
182  RTN         24
183  *LBL6    21 06
184  RCL5     36 05
185  PRTX       -14
186  0           00
187  STO5     35 05
188  1/X         52
189  RTN         24
190  *LBL7    21 07
191  RCL4     36 04
192  RCL1     36 01
193  ×          -35
194  ST+6  35-55 06
195  RCLB     36 12
196  ÷          -24
197  RCL3     36 03
198  ÷          -24
199  7           07
200  0           00
201  0           00
202  ÷          -24
203  ST+7  35-55 07
204  PRTX       -14
205  RTN         24
206  *LBL8    21 08
207  STO1     35 01
208  GSB9     23 09
209  RTN         24
210  *LBLa 21 16 11
211  RCL1     36 01
212  PRTX       -14
213  RTN         24
214  *LBLb 21 16 12
215  STO1     35 01
216  GSBc  23 16 13
217  SPC      16-11
218  RTN         24
219  R/S         51
220  *LBLe 21 16 15
221  CLRG     16-53
222  CLX        -51
223  PRTX       -14
224  R/S         51
```

LP-2
LIGHTING DESIGN PROGRAM, LUMEN METHOD

GENERAL DESCRIPTION

This program designs lighting systems and computes electrical demand load. The program also keeps account of type and number of luminaires.

EQUATIONS

$A = L \times W$ [3.7]

where
A = Area of room
L = Length of room
W = Width of room

$CR = 5 \times H \times (L \times W)/A$ [3.8]

where
CR = Cavity ratio
H = Hrc for the room cavity ratio, RCR
= Hcc for the ceiling cavity ratio, CCR
= Hfc for the floor cavity ratio, FCR

Number of luminaires
$= \text{fc} \times A/IL \times CU \times LLF \times L$ [3.9]

where
fc = Foot-candles
A = Area
IL = Lumens per lamp
CU* = Coefficient of utilization
LLF* = Light loss factor
L = Number of lamps per luminaire

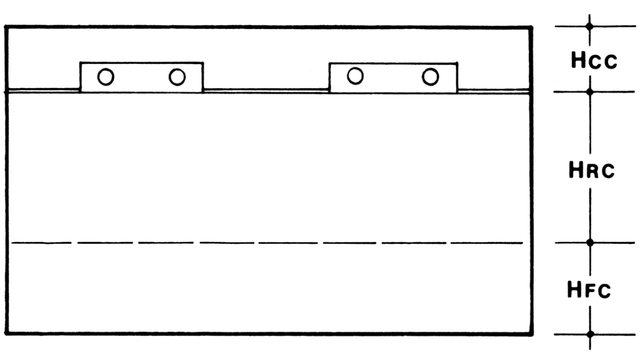


FIGURE 3A

**Note:* Both *CU* and *LLF* have to be calculated separately based on cavity ratios and the procedure given in *Illuminating Engineering Society Handbook.*

$\text{kW} = \text{Number of luminaires} \times L \times W/1000$ [3.10]

where
W = Watts per luminaire

$\text{fc average} = \Sigma \text{fc}_1 \times A_1/\Sigma A_1$ [3.11]

OPERATING FEATURES

Program provides two options: fc level can be determined using number of luminaires as input or vice-versa. Each room can be divided into any number of sub-areas which can have different lighting levels and different types of luminaires.

The program has the capacity for storing nine types of luminaires. If input exceeds more than nine different types, it will print out the list of luminaires and start recording nine more types.

EXAMPLE NO. 1

Design the lighting system and also compute the total kW demand for the rooms having the following data:

Room Type 1

Number of similar rooms	2
Length	108 ft
Width	24.7 ft
Height of luminaire over work surface	6.7 ft
Height of work surface above floor	2.3 ft
Luminaire type	0.12 ft
Watts per luminaire	97
Lamps per luminaire	2
Initial lumens per lamp	2,860
Task area	50%
Approximate illumination for task area	200 fc
Approximate illumination for rest of area	70 fc

Room Type 2

Number of similar rooms	3
Area, sq ft	4,500
Number of luminaires	100
Type of luminaire	0.13
Watts per luminaire	205
Number of lamps per luminaire	4
Initial lumens per lamp	2,450
Coefficient of utilization	0.58
Light loss factor	0.72

LP-2
LIGHTING DESIGN PROGRAM, LUMEN METHOD

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Initialize	—	—	2nd	E′	0.	
2.	To compute room area and cavity ratios	—	—	—	A	?RT 1.	What is room type?
3.	Enter room type	1	—	—	R/S		
						L	What is room length?
4.	Enter length of room	108	—	—	R/S	108.	
						W	What is room width?
5.	Enter width of room	24.7	—	—	R/S	24.7	
						2668. A	Area of room
						H	What is height?
6.	Enter height	6.7	—	—	R/S	6.7	Enter height of luminaire to work surface.
						1.67 CR	Cavity ratio
						H	Enter height of ceiling
7.	Enter height	2.3	—	—	R/S	2.3	above luminaire.
	Repeat step 7 as many times as desired.					0.57 CR	Cavity ratio
8.	To compute fc or number of luminaires	—	—	—	B	L.T 0.12	What is luminaire type? *Note:* Decimal format
9.	What is luminaire type	0.12	—	—	R/S		
						W.L	How many watts/luminaire
10.	Enter watts and number of lamps	97.2	—	—	R/S	97. 2.	and number of lamps/luminaire?

11.	Enter initial lumens and coeff. of utilization	2860.61	—	—	R/S	IL. CU 2860. 0. 61	How many lumens/lamp and what is coeff. of utilization?
12.	Enter light loss factor	.73	—	—	R/S	LLF 0. 73	What is light loss factor?
						2668.	Should area be 2,668?
13.	Enter area if you do not wish to base on 2,668 sq ft	1334	—	—	R/S	A 1334.	
14.	Enter illumination level desired	200	—	—	R/S	FC 200.	What should illumination level be?
						104. 7 LMNS	Number of luminaires
	Input integer number of luminaires to complete calculation.					FC	Do you wish to try for different illumination level?
15.	Input integer number of luminaires	100	—	2nd	B′	100. LMNS	
						191. FC	
16.	To compute power demand	—	—	—	C	?x	How many such spaces?
17.	Enter number of spaces	1	—	—	R/S	1.	
						1334. A	Area
						9. 7 KW	Power demand
						7. 3 W/A	Watts/sq ft
						0. 12 L. T 100. LMNS	Luminaire type and quantity

LP-2 *(Continued)*

LIGHTING DESIGN PROGRAM, LUMEN METHOD

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
18.	If luminaire-type CU and power is same	–	–	2nd	A′	A 1334.	What is area?
19.	Enter area	1334	–	–	R/S		
20.	Enter illumination level	70	–	–	R/S	FC 70.	How many fc?
						36.7 LMNS	Number of luminaires
						FC	
	Enter integer number of luminaires similar to step 15.	40	–	2nd	B′	40. LMNS	
						76. FC	
	Repeat step 16.	–	–	–	C	?x 1.	
						1334. A	
						3.9 KW	
						2.9 W/A	
						0.12 L.T 40. LMNS	
21.	To repeat for similar rooms	–	–	–	D	?x	Repeat how many times?
22.	Enter 2	2	–	–	R/S	2.	

							Total for two rooms
						5336. ΣA	Total area
						27.2 ΣKW	Total kW
						5.1 W/A	
						134. FC	Average illumination level
						0.12 L.T 280. LMNS	Total luminaires for this space
23.	To compute for another space	—	—	—	B	L.T	What is luminaire type and number of luminaires?
24.	Enter quantity and type	100.13	—	—	R/S	100.13	100 luminaires of type 13
25.	Enter watts and number of lamps	205.4	—	—	R/S	W.L 205. 4.	How many watts/luminaire and lamps/luminaire?
26.	Enter initial lumens and coeff. of utilization	2450.58	—	—	R/S	IL.CU 2450. 0.58	How many lumens/lamp and what is coeff. of utilization?
27.	Enter light loss factor	0.72	—	—	R/S	LLF 0.72	What is light loss factor?
28.	Enter desired area	4500	—	—	R/S	5336. A 4500.	Should area be 5,336?
29.	Since fc is not known, enter 0	0	—	—	R/S	FC 100. LMNS	What is illumination level?
						91. FC	Illumination level

LP-2 *(Continued)*

LIGHTING DESIGN PROGRAM, LUMEN METHOD

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Similar to steps 16 & 17	—	—	—	C	?x	How many such spaces?
		1	—	—	R/S	1.	
						4500. A	
						20.5 KW	
						4.6 W/A	
						0.13 L.T	
						100. LMNS	
						?x	How many such rooms?
	Similar to step 20	—	—	—	D	3.	
		—	—	—	R/S		
						13500. ΣA	
						61.5 ΣKW	
						4.6 W/A	
						91. FC	

30.	To find total for the building	—	—	—	E	0.13 L.T 300. LMNS 18836. ΣA 88.7 ΣKW 4.7 W/A 0.12 L.T 280. LMNS 0.13 L.T 300. LMNS	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
INV	Prints alphanumeric identification of data and partitions
E′	Clears all registers; stores 20 in R00
A	Prints ? RT;
	with R/S, prints room type and L;
	with R/S, prints and stores in R01 and prints W;
	with R/S, prints and stores in R02, computes and prints area A, and prints H;
	with R/S, computes and prints CR and prints H for recomputing CR
CE	For getting back to printing H
B	Prints LT;
	with R/S, prints number of luminaires and type in decimal format; separates number of luminaires and stores in R04; if luminaire type is similar to previous type, goes to SBR R/S; stores luminaire type in R20; if value of R00 exceeds 30, goes to SBR —; adds 1 to R03; prints WL;
	with R/S, separates, stores, and prints W and L and prints ILCU;
	with R/S, separates, stores, and prints IL and CU; recalls R10 (area) and prints A;
	with R/S, prints and stores in R10; prints FC (SBR X⇄T);
	with R/S, stores in R11; if equal to zero goes to SBR X^2, computes number of luminaires, and goes back to print FC
	For skipping a part of LBL B sequence
GTO	For getting back to print A from SBR LNX
RCL	For getting back to print FC from SBR X⇄T·
B′	For getting back to SBR R/S; stores and prints LMNS (SBR STO); computes and prints FC level
C	Calls SBR SUM to print ?X;
	with R/S, prints and stores in R13; computes total area and totalizes and prints area; computes, prints, and stores KW; computes FC1 × A1; prints luminaire type; computes and prints number of luminaires; stores luminaire type and number
D	Calls SBR SUM to print ?X;
	with R/S, prints and stores in R13; computes total area, totalizes, and prints; computes, totalizes, and prints KW; computes and prints W/A; computes and prints average FC; clears registers R14, R15, and R16; prints fixture type and number using SBR SBR
E	Prints total area, KW, W/A; prints fixture type using SBR RST
+	For reiteration
LNX	Prints A
X⇄T	Prints FC
X^2	Recalls R04 and goes to LBL B′
$\sqrt{X}$	Computes luminaires/FC
1/X	Prints LMNS
SUM	Prints ?X
Y^x	Prints ΣA
EE	Prints KW
(	Computes and prints W/A
)	Prints ΣKW
A′	Goes to last part of LBL B by using SBR GTO
–	Prints table of luminaire types and quantity; stores 20 in R00; goes to B
R/S	If luminaire type is same, deducts 1 from R00; goes to SBR·
STO	Prints LT

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For RCL IND 00 and STO IND 00 for table of luminaire types and number of luminaires
R01	Length
R02	Width
R03	For DSZ for storing and printing luminaire type and number of luminaires
R04	Number of luminaires

R05	Watts
R06	Number of lamps per luminaire
R07	Lumens per lamp
R08	Coefficient of utilization
R09	Light loss factor
R10	Area
R11	Foot-candle level
R12	Number of luminaires
R13	Number of similar spaces
R14	A
R15	KW
R16	ΣFC1 × A1
R17	ΣA
R18	ΣKW
R19	Alphanumeric code
R20	Luminaire type
R21	Number of luminaires
R22–R29	For storing combination of luminaire type and number of luminaires

LP-2 LIGHTING DESIGN PROGRAM, LUMEN METHOD

LABELS & SUBROUTINES

```
001  22 INV
018  10 E'
026  11  A
074  24 CE
114  12  B
138  93  .
233  61 GTO
243  43 RCL
270  17 B'
294  13  C
382  14  D
443  71 SBR
483  15  E
504  81 RST
519  85  +
544  23 LNX
553  32 X:T
564  33 X²
570  34 ΓX
589  35 1/X
605  44 SUM
616  45 Y^X
629  52 EE
640  53  (
669  54  )
686  16 A'
691  75  -
701  91 R/S
708  42 STO
```

LISTING

```
000  76 LBL
001  22 INV
002  22 INV
003  58 FIX
004  03  3
005  69 OP
006  17  17
007  25 CLR
008  69 OP
009  00  00
010  43 RCL
011  19  19
012  69 OP
013  02  02
014  69 OP
015  05  05
016  92 RTN
017  76 LBL
018  10 E'
019  47 CMS
020  02  2
021  00  0
022  42 STO
023  00  00
024  91 R/S
025  76 LBL
026  11  A
027  06  6
028  09  9
029  03  3
030  05  5
031  03  3
032  07  7
033  42 STO
034  19  19
035  71 SBR
036  22 INV
037  91 R/S
038  99 PRT
039  98 ADV
040  02  2
041  07  7
042  42 STO
043  19  19
044  71 SBR
045  22 INV
046  91 R/S
047  42 STO
048  01  01
049  99 PRT
050  98 ADV
051  04  4
052  03  3
053  42 STO
054  19  19
055  71 SBR
056  22 INV
057  91 R/S
058  99 PRT
059  98 ADV
060  42 STO
061  02  02
062  65  ×
063  43 RCL
064  01  01
065  95  =
066  42 STO
067  10  10
068  58 FIX
069  00  00
070  99 PRT
071  71 SBR
072  23 LNX
073  76 LBL
074  24 CE
075  98 ADV
076  02  2
077  03  3
078  42 STO
079  19  19
080  71 SBR
081  22 INV
082  91 R/S
083  99 PRT
084  98 ADV
085  65  ×
086  05  5
087  65  ×
088  53  (
089  43 RCL
090  01  01
091  85  +
092  43 RCL
093  02  02
094  54  )
095  55  ÷
096  43 RCL
097  10  10
098  95  =
099  58 FIX
100  02  02
101  99 PRT
102  01  1
103  05  5
104  03  3
105  05  5
106  42 STO
107  19  19
108  71 SBR
109  22 INV
110  98 ADV
111  71 SBR
112  24 CE
113  76 LBL
114  12  B
115  98 ADV
116  71 SBR
117  42 STO
118  91 R/S
119  42 STO
120  01  01
121  99 PRT
122  59 INT
123  42 STO
124  04  04
125  43 RCL
126  01  01
127  22 INV
128  59 INT
129  32 X:T
130  43 RCL
131  20  20
132  67 EQ
133  91 R/S
134  00  0
135  42 STO
136  12  12
137  76 LBL
138  93  .
139  32 X:T
140  42 STO
141  20  20
142  03  3
143  00  0
144  32 X:T
```

```
145  69  OP
146  20   20
147  43  RCL
148  00   00
149  67   EQ
150  75   -
151  69  OP
152  23   23
153  98  ADV
154  04   4
155  03   3
156  04   4
157  00   0
158  02   2
159  07   7
160  42  STO
161  19   19
162  71  SBR
163  22  INV
164  91  R/S
165  42  STO
166  06   06
167  59  INT
168  42  STO
169  05   05
170  99  PRT
171  43  RCL
172  06   06
173  22  INV
174  59  INT
175  65   ×
176  01   1
177  00   0
178  95   =
179  42  STO
180  06   06
181  99  PRT
182  98  ADV
183  02   2
184  04   4
185  02   2
186  07   7
187  04   4
188  00   0
189  01   1
190  05   5
191  04   4
192  01   1
193  42  STO
194  19   19
195  71  SBR
196  22  INV
197  91  R/S
198  42  STO
199  08   08
200  59  INT
201  42  STO
202  07   07
203  99  PRT
204  43  RCL
205  08   08
206  22  INV
207  59  INT
208  42  STO
209  08   08
210  99  PRT
211  98  ADV
212  02   2
213  07   7
214  02   2
215  07   7
216  02   2
217  01   1
218  42  STO
219  19   19
220  71  SBR
221  22  INV
222  91  R/S
223  42  STO
224  09   09
225  99  PRT
226  98  ADV
227  43  RCL
228  10   10
229  58  FIX
230  00   00
231  99  PRT
232  76  LBL
233  61  GTO
234  71  SBR
235  23  LNX
236  43  RCL
237  10   10
238  91  R/S
239  42  STO
240  10   10
241  99  PRT
242  76  LBL
243  43  RCL
244  98  ADV
245  71  SBR
246  32  X:T
247  29  CP
248  91  R/S
249  42  STO
250  11   11
251  67   EQ
252  33  X^2
253  99  PRT
254  98  ADV
255  65   ×
256  71  SBR
257  34  √X
258  95   =
259  42  STO
260  04   04
261  58  FIX
262  01   01
263  99  PRT
264  71  SBR
265  35  1/X
266  98  ADV
267  71  SBR
268  43  RCL
269  76  LBL
270  17  B'
271  98  ADV
272  42  STO
273  04   04
274  99  PRT
275  71  SBR
276  35  1/X
277  98  ADV
278  43  RCL
279  04   04
280  55   ÷
281  71  SBR
282  34  √X
283  95   =
284  42  STO
285  11   11
286  58  FIX
287  00   00
288  99  PRT
289  71  SBR
290  32  X:T
291  98  ADV
292  92  RTN
293  76  LBL
294  13   C
295  71  SBR
296  44  SUM
297  91  R/S
298  42  STO
299  13   13
300  99  PRT
301  98  ADV
302  53   (
303  24  CE
304  65   ×
305  43  RCL
306  10   10
307  54   )
308  42  STO
309  10   10
310  44  SUM
311  14   14
312  99  PRT
313  71  SBR
314  23  LNX
315  98  ADV
316  53   (
317  43  RCL
318  04   04
319  65   ×
320  43  RCL
321  05   05
322  65   ×
323  43  RCL
324  13   13
325  55   ÷
326  01   1
327  00   0
328  00   0
329  00   0
330  54   )
331  42  STO
332  01   01
333  44  SUM
334  15   15
335  58  FIX
336  01   01
337  99  PRT
338  71  SBR
339  52  EE
340  98  ADV
341  71  SBR
342  53   (
343  53   (
344  43  RCL
345  11   11
346  65   ×
347  43  RCL
348  10   10
349  54   )
350  44  SUM
351  16   16
352  43  RCL
353  20   20
354  99  PRT
355  71  SBR
356  42  STO
357  53   (
358  43  RCL
359  04   04
360  65   ×
361  43  RCL
362  13   13
363  54   )
364  44  SUM
365  12   12
366  99  PRT
367  71  SBR
368  35  1/X
369  98  ADV
370  53   (
371  43  RCL
372  12   12
373  85   +
374  43  RCL
375  20   20
376  54   )
377  72  ST*
378  00   00
379  98  ADV
380  91  R/S
381  76  LBL
382  14   D
383  71  SBR
384  44  SUM
385  91  R/S
386  42  STO
387  13   13
388  99  PRT
389  98  ADV
390  53   (
391  24  CE
392  65   ×
393  43  RCL
394  14   14
395  54   )
396  42  STO
397  10   10
398  44  SUM
399  17   17
400  71  SBR
401  45  Y^X
402  53   (
403  43  RCL
404  13   13
```

```
405  65  ×
406  43  RCL
407  15   15
408  54  )
409  42  STO
410  01   01
411  44  SUM
412  18   18
413  71  SBR
414  54  )
415  71  SBR
416  53  (
417  53  (
418  43  RCL
419  16   16
420  55  ÷
421  43  RCL
422  14   14
423  54  )
424  58  FIX
425  00   00
426  99  PRT
427  71  SBR
428  32  X:T
429  98  ADV
430  00   0
431  42  STO
432  14   14
433  42  STO
434  15   15
435  42  STO
436  16   16
437  43  RCL
438  03   03
439  22  INV
440  44  SUM
441  00   00
442  76  LBL
443  71  SBR
444  69  OP
445  20   20
446  73  RC*
447  00   00
448  22  INV
449  59  INT
450  42  STO
451  20   20
452  99  PRT
453  71  SBR
454  42  STO
455  53  (
456  73  RC*
457  00   00
458  59  INT
459  65  ×
460  43  RCL
461  13   13
462  54  )
463  99  PRT
464  42  STO
465  12   12
466  71  SBR
467  35  1/X
468  98  ADV
469  53  (
470  43  RCL
471  12   12
472  85  +
473  43  RCL
474  20   20
475  54  )
476  72  ST*
477  00   00
478  97  DSZ
479  03   03
480  71  SBR
481  91  R/S
482  76  LBL
483  15  E
484  43  RCL
485  17   17
486  71  SBR
487  45  Y^X
488  43  RCL
489  18   18
490  71  SBR
491  54  )
492  43  RCL
493  18   18
494  42  STO
495  01   01
496  43  RCL
497  17   17
498  42  STO
499  10   10
500  71  SBR
501  53  (
502  98  ADV
503  76  LBL
504  81  RST
505  02   2
506  00   0
507  22  INV
508  44  SUM
509  00   00
510  43  RCL
511  00   00
512  42  STO
513  03   03
514  02   2
515  00   0
516  42  STO
517  00   00
518  76  LBL
519  85  +
520  69  OP
521  20   20
522  73  RC*
523  00   00
524  22  INV
525  59  INT
526  99  PRT
527  71  SBR
528  42  STO
529  73  RC*
530  00   00
531  59  INT
532  99  PRT
533  71  SBR
534  35  1/X
535  98  ADV
536  97  DSZ
537  03   03
538  85  +
539  98  ADV
540  92  RTN
541  92  RTN
542  91  R/S
543  76  LBL
544  23  LNX
545  01   1
546  03   3
547  42  STO
548  19   19
549  71  SBR
550  22  INV
551  92  RTN
552  76  LBL
553  32  X:T
554  02   2
555  01   1
556  01   1
557  05   5
558  42  STO
559  19   19
560  71  SBR
561  22  INV
562  92  RTN
563  76  LBL
564  33  X^2
565  43  RCL
566  04   04
567  17  B'
568  92  RTN
569  76  LBL
570  34  √X
571  53  (
572  43  RCL
573  10   10
574  55  ÷
575  43  RCL
576  06   06
577  55  ÷
578  43  RCL
579  07   07
580  55  ÷
581  43  RCL
582  08   08
583  55  ÷
584  43  RCL
585  09   09
586  54  )
587  92  RTN
588  76  LBL
589  35  1/X
590  02   2
591  07   7
592  02   2
593  08   8
594  02   2
595  09   9
596  03   3
597  06   6
598  42  STO
599  19   19
600  71  SBR
601  22  INV
602  92  RTN
603  92  RTN
604  76  LBL
605  44  SUM
606  07   7
607  01   1
608  04   4
609  08   8
610  42  STO
611  19   19
612  71  SBR
613  22  INV
614  92  RTN
615  76  LBL
616  45  Y^X
617  99  PRT
618  07   7
619  07   7
620  01   1
621  03   3
622  42  STO
623  19   19
624  71  SBR
625  22  INV
626  98  ADV
627  92  RTN
628  76  LBL
629  52  EE
630  02   2
631  06   6
632  04   4
633  03   3
634  42  STO
635  19   19
636  71  SBR
637  22  INV
638  92  RTN
639  76  LBL
640  53  (
641  53  (
642  43  RCL
643  01   01
644  65  ×
645  01   1
646  00   0
647  00   0
648  00   0
649  55  ÷
650  43  RCL
651  10   10
652  54  )
653  58  FIX
654  01   01
655  99  PRT
656  04   4
657  03   3
658  06   6
659  03   3
660  01   1
661  03   3
662  42  STO
663  19   19
664  71  SBR
```

```
665  22 INV
666  98 ADV
667  92 RTN
668  76 LBL
669  54  )
670  58 FIX
671  01  01
672  99 PRT
673  07  7
674  07  7
675  02  2
676  06  6
677  04  4
678  03  3
679  42 STO
680  19  19
681  71 SBR
682  22 INV
683  98 ADV
684  92 RTN
685  76 LBL
686  16 A'
687  71 SBR
688  61 GTO
689  92 RTN
690  76 LBL
691  75  -
692  71 SBR
693  81 RST
694  02  2
695  00  0
696  42 STO
697  00  00
698  12  B
699  92 RTN
700  76 LBL
701  91 R/S
702  69 OP
703  30  30
704  71 SBR
705  93  .
706  92 RTN
707  76 LBL
708  42 STO
709  02  2
710  07  7
711  04  4
712  00  0
713  03  3
714  07  7
715  42 STO
716  19  19
717  71 SBR
718  22 INV
719  92 RTN
```

LP-2
LIGHTING DESIGN PROGRAM, LUMEN METHOD
HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Initialize	—	—	*f*	E	0.00 ***	
2.	Enter room type	1	—	—	A	1.00 ***	
3.	Enter room length	108	—	—	R/S	108.00 ***	
4.	Enter room width	24.7	—	—	R/S	24.70 ***	
						2667.60 ***	Area of room
5.	Enter height of luminaire over work plane	6.7	—	—	R/S	6.70 ***	
						1.67 ***	RCR
6.	Enter height of work plane above floor	2.3	—	—	R/S	2.30 ***	
						0.57 ***	FCR
7.	Enter luminaire type	.12	—	—	B	0.12 ***	
8.	Enter watts and number of lamps	97.2	—	—	R/S	97.00 ***	
						2.00 ***	
9.	Enter lumens/lamp and CU	2860.61	—	—	R/S	2860.00 ***	
						0.61 ***	
10.	Enter LLF	.73	—	—	R/S	0.73 ***	
11.	Enter area	1334	—	—	R/S	1334.00 ***	
12.	Enter fc	200	—	—	R/S	200.00 ***	
						104.75 ***	Number of luminaires
13.	Enter number of luminaires	100	—	*f*	B	100.00 ***	
						190.94 ***	Foot-candles
14.	Enter number of similar spaces	1	—	—	C	1.00 ***	
						1334.00 ***	Area
						9.70 ***	kW
						7.27 ***	Watts/sq ft

LP-2 *(Continued)*

LIGHTING DESIGN PROGRAM, LUMEN METHOD

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
15.	Enter area	1334	–	–	R/S	1334.00 ***	
16.	Enter fc	70	–	–	R/S	70.00 ***	
						36.66 ***	Number of luminaires
17.	Enter number of luminaires	40	–	–	R/S	40.00 ***	
						76.38 ***	Foot-candles
18.	Enter number of similar spaces	1	–	–	C	1.00 ***	
						1334.00 ***	
						3.88 ***	
						2.91 ***	
19.	Enter number of similar rooms	2	–	–	D	2.00 ***	
						5336.00 ***	Total area
						27.16 ***	Total kW
						5.09 ***	Watts/sq ft
						133.66 ***	Average fc
20.	Enter luminaire type	.13	–	–	B	0.13 ***	
21.	Enter watts and number of lamps	205.4	–	–	R/S	205.00 ***	
						4.00 ***	
22.	Enter lumens/lamp and CU	2450.58	–	–	R/S	2450.00 ***	
						0.56 ***	
23.	Enter LLF	.72	–	–	R/S	0.72 ***	
24.	Enter area	4500	–	–	R/S	4500.00 ***	
25.	Enter fc	90	–	–	R/S	90.00 ***	
						98.96 ***	Number of luminaires
26.	Enter number of luminaires	100	–	*f*	B	100.00 ***	
						90.94 ***	Foot-candles

27.	Enter number of similar spaces	1	–	–	C	1.00 ***	
						4500.00 ***	Area
						20.50 ***	kW
						4.56 ***	Watts/sq ft
28.	Enter number of similar rooms	3	–	–	D	3.00 ***	
						13500.00 ***	Total area
						61.50 ***	Total kW
						4.56 ***	Watts/sq ft
						90.94 ***	Average fc
29.	To find total load for project	–	–	–	E	18836.00 ***	Total area of project
						88.66 ***	Total kW load
						4.71 ***	Watts/sq ft

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
e	Clears primary and secondary registers; prints 0
A	Prints display (room number);
	with R/S, stores display (room dimension) in R4;
	with R/S, stores display (room dimension) in R2; calculates, prints, and stores area in RA and goes through LBL 0;
	with R/S, prints display (cavity), computes and prints CU; goes back to SBR 0 for further calculation of CU for other cavities
B	Prints display (luminaire type);
	with R/S, accepts input in decimal format and separates;
	with R/S, accepts input in decimal format; separates, prints, and stores (IL) in R6 and (CU) in RC;
	with R/S, prints and stores display (LLF) in R1 and goes through LBL 2;
	with R/S, prints and stores display (area) in RA;
	with R/S, prints and stores display (FC) in RD; computes and prints number of luminaires and stores in RE; goes to SBR 1 for recalculation if desired
b	Prints and stores display (number of luminaires); calculates and prints FC; stores in RD
C	Prints and stores display (number of similar spaces) in R2; calculates and prints area and totalizes in R8; calculates and prints KW and totalizes in R9; calculates and prints watts/sq ft; calculates for part of the room if remaining
D	Prints and stores display (number of similar rooms) in R2; calculates and prints total area, total KW, watts/sq ft, and average FC; totalizes in R8, R10, and R9 on R11
E	Prints total area, KW, and watts/sq ft

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	Room dimension; also light loss factor
R2	Room dimension; also number of similar spaces
R3	Not used
R4	Number of lamps per luminaire
R5	Watts
R6	Lumens per lamp
R7	Totalized FC × A
R8	Totalized area
R9	Totalized KW
RA	Area
RB	Watts
RC	Coefficient of utilization
RD	Foot-candles
RE	Number of luminaires
RI	For indirect storage and recall
R10	Total area of project
R11	Total KW for project

LP-2 (HP-97) LIGHTING DESIGN PROGRAM, LUMEN METHOD

LISTING

```
RTN        24
*LBLe      21 16 15
CLRG       16-53
P⇄S        16-51
CLRG       16-53
CLX        -51
PRTX       -14
SPC        16-11
R/S        51
*LBLA      21 11
PRTX       -14
R/S        51
STO1       35 01
PRTX       -14
R/S        51
STO2       35 02
PRTX       -14
RCL1       36 01
x          -35
STOA       35 11
PRTX       -14
*LBL0      21 00
SPC        16-11
R/S        51
PRTX       -14
5          05
x          -35
RCL1       36 01
RCL2       36 02
+          -55
x          -35
```

```
032  RCLA    36 11
033  ÷         -24
034  PRTX      -14
035  GSB0    23 00
036  R/S        51
037  *LBLB   21 12
038  PRTX      -14
039  R/S        51
040  STO4    35 04
041  INT     16 34
042  STO5    35 05
043  PRTX      -14
044  RCL4    36 04
045  FRC     16 44
046  1          01
047  0          00
048  ×         -35
049  STO4    35 04
050  PRTX      -14
051  SPC     16-11
052  R/S        51
053  STOC    35 13
054  INT     16 34
055  STO6    35 06
056  PRTX      -14
057  RCLC    36 13
058  FRC     16 44
059  STOC    35 13
060  PRTX      -14
061  SPC     16-11
062  R/S        51
063  STO1    35 01
064  PRTX      -14
065  *LBL2   21 02
066  R/S        51
067  PRTX      -14
068  STOA    35 11
069  *LBL1   21 01
070  SPC     16-11
071  R/S        51
072  PRTX      -14
073  STOD    35 14
074  RCLA    36 11
075  ×         -35
076  RCL6    36 06
077  ÷         -24
078  RCL4    36 04
079  ÷         -24
080  RCLC    36 13
081  ÷         -24
082  RCL1    36 01
083  ÷         -24
084  PRTX      -14
085  STOE    35 15
086  GSB1    23 01
087  R/S        51
088  *LBLb  21 16 12
089  STOE    35 15
090  PRTX      -14
091  RCL4    36 04
092  ×         -35
093  RCL6    36 06
094  ×         -35
095  RCLC    36 13
096  ×         -35
097  RCL1    36 01
098  ×         -35
099  RCLA    36 11
100  ÷         -24
101  STOD    35 14
102  PRTX      -14
103  SPC     16-11
104  R/S        51
105  *LBLC   21 13
106  STO2    35 02
107  PRTX      -14
108  RCLA    36 11
109  ×         -35
110  PRTX      -14
111  ST+8  35-55 08
112  RCL2    36 02
113  RCLE    36 15
114  ×         -35
115  RCL5    36 05
116  ×         -35
117  STOB    35 12
118  1          01
119  0          00
120  0          00
121  0          00
122  ÷         -24
123  PRTX      -14
124  ST+9  35-55 09
125  RCLB    36 12
126  RCLA    36 11
127  ÷         -24
128  PRTX      -14
129  RCLA    36 11
130  RCLD    36 14
131  ×         -35
132  ST+7  35-55 07
133  SPC     16-11
134  GSB2    23 02
135  R/S        51
136  *LBLD   21 14
137  STO2    35 02
138  PRTX      -14
139  ST×8  35-35 08
140  RCL8    36 08
141  PRTX      -14
142  RCL2    36 02
143  ST×9  35-35 09
144  RCL9    36 09
145  PRTX      -14
146  1          01
147  0          00
148  0          00
149  0          00
150  ×         -35
151  RCL8    36 08
152  ÷         -24
153  PRTX      -14
154  SPC     16-11
155  RCL2    36 02
156  ST×7  35-35 07
157  RCL7    36 07
158  RCL8    36 08
159  ÷         -24
160  PRTX      -14
161  1          01
162  0          00
163  STOI    35 46
164  RCL8    36 08
165  ST+i  35-55 45
166  ISZI  16 26 46
167  RCL9    36 09
168  ST+i  35-55 45
169  0          00
170  STO7    35 07
171  STO8    35 08
172  STO9    35 09
173  SPC     16-11
174  R/S        51
175  *LBLE   21 15
176  1          01
177  0          00
178  STOI    35 46
179  RCLi    36 45
180  PRTX      -14
181  ISZI  16 26 46
182  RCLi    36 45
183  PRTX      -14
184  ÷         -24
185  1/X        52
186  1          01
187  0          00
188  0          00
189  0          00
190  ×         -35
191  PRTX      -14
192  SPC     16-11
193  R/S        51
```

4

SANITARY ENGINEERING PROGRAMS

SEP-1
STORM WATER SYSTEM PIPE SIZING PROGRAM

PROGRAM DESCRIPTION

With input of rainfall intensity and roof area, the program can select pipe sizes for horizontal pipes of different slopes and vertical stacks. The sizing procedure is based on the BOCA Basic Plumbing Code, which is similar to the National Standard Plumbing Code.

EQUATIONS

The tables are based on a 4-in. rainfall, and conversion for other rainfall intensities is done by the following formula:

$$\text{Equivalent roof area} = \frac{\text{Roof area} \times 4}{\text{Input rainfall rate}} \qquad [4.1]$$

OPERATING FEATURES

The sizing information is stored by combining pipe size and roof area in decimal format. For example, 29,200.1 will mean 29,200 sq ft; 10-in. pipe.

As shown under "User Instructions and Examples," the program can select pipe sizes for the following types of distribution systems:

Distribution System	Input Under Label B
Horizontal with 1% slope	1
Horizontal with 2% slope	2
Horizontal with 4% slope	4
Vertical leaders	5

REFERENCE DATA

BOCA Basic Plumbing Code or the National Standard Plumbing Code.

TABLE P803.1
SIZE OF HORIZONTAL BUILDING STORM DRAINS AND BUILDING STORM SEWERS[1]

Diameter of drain	Maximum projected area in square feet and gallons per minute flow for various slopes					
	1/8 in. per ft. slope		1/4 in. per ft. slope		1/2 in. per ft. slope	
Inches	Square feet	gpm	Square feet	gpm	Square feet	gpm
3	822	34	1160	48	1644	68
4	1880	78	2650	110	3760	156
5	3340	139	4720	196	6680	278
6	5350	222	7550	314	10700	445
8	11500	478	16300	677	23000	956
10	20700	860	29200	1214	41400	1721
12	33300	1384	47000	1953	66600	2768
15	59500	2473	84000	3491	119000	4946

Note 1. Table P-803.1 is based upon a maximum rate of rainfall of four (4) inches per hour for a five (5) minute duration and a ten (10) year return period. Where maximum rates are more or less than four (4) inches per hour, the figures for drainage area shall be adjusted by multiplying by four (4) and dividing by the local rate in inches per hour.

P-803.2 Size of vertical conductors and leaders:

Vertical leaders shall be sized on the maximum projected roof area, according to Table P-803.2, Size of Vertical Conductors and Leaders.

TABLE P803.2
SIZE OF VERTICAL CONDUCTORS AND LEADERS[1]

Size of leader or conductor[2]	Maximum projected roof area	
Inches	Square feet	gpm
2	544	23
2½	987	41
3	1,610	67
4	3,460	144
5	6,280	261
6	10,200	424
8	22,000	913

Note 1. Table P-803.2 is based upon a maximum rate of rainfall of four (4) inches per hour for a five (5) minute duration and ten (10) year period. Where maximum rates are more or less than four (4) inches per hour, the figures for drainage area shall be adjusted by multiplying by four (4) and dividing by the local rate in inches per hour.
Note 2. The area of rectangular leaders shall be equivalent to the circular leader or conductor required. The ratio of width to depth of rectangular leaders shall not exceed three-to-one (3:1).

SEP-1

STORM WATER SYSTEM PIPE SIZING PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
1.	Input rainfall rate, in./hr	4	–	–	A	4.0	RIPH	
2.	Input 1 for 1% slope	1	–	–	B	1.0	1%H	
3.	Input roof area, sq ft	1500	–	–	C	1500.0	SQFT	
						4.0	DIA	
	or							
2.	Input 2 for 2% slope	2	–	–	B	2.0	2%H	
3.	Input roof area, sq ft	3000	–	–	C	3000.0	SQFT	
						5.0	DIA	
	or							
2.	Input 4 for 4% slope	4	–	–	B	4.0	4%H	
3.	Input roof area, sq ft	4000	–	–	C	4000.0	SQFT	
						5.0	DIA	
	Example 2							
1.	Input rainfall rate, in./hr	5	–	–	A	5.0	RIPH	
2.	Input 5 for leaders	5	–	–	B	5.0	LDR	
3.	Input roof area, sq ft	5000	–	–	C	5000.0	SQFT	
						5.0	DIA	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Stores and prints rainfall in inches per hour (RIPH)
B	Selects system type and prints
C	Prints roof area; converts roof area from tables to suit input rainfall intensity and finds diameter
STO	Reiterates for finding pipe size
INV	Prints alphanumeric characters for identification of data
LNX	Prints 1%H and calls SBR X⇄T
CE	Prints 2%H and calls SBR X^2
CLR	Prints 4%H and calls SBR $\sqrt{X}$
X⇄T	Stores table for 1/8 in./ft or 1% slope
X^2	Stores table for 1/4 in./ft or 2% slope
$\sqrt{X}$	Stores table for 1/2 in./ft or 4% slope
1/X	Stores table for vertical leaders

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For RCL IND for pipe sizing
R01–R08	For storing tables of pipe size and roof area
R09–R19	Not used
R20	Alphanumeric code
R21	Not used
R22	Not used
R23	Rainfall intensity
R24	Not used
R25	Not used
R26	Not used
R27	Not used

SEP-1 STORM WATER SYSTEM PIPE SIZING PROGRAM

LABELS & SUBROUTINES

```
001  11  A
019  12  B
044  13  C
063  42  STO
101  22  INV
118  23  LNX
133  24  CE
148  25  CLR
163  32  X:T
240  33  X²
318  34  ΓX
397  35  1/X
```

LISTING

```
000  76  LBL
001  11  A
002  42  STO
003  23   23
004  32  X:T
005  03   3
006  05   5
007  02   2
008  04   4
009  03   3
010  03   3
011  02   2
012  03   3
013  42  STO
014  20   20
015  71  SBR
016  22  INV
017  91  R/S
018  76  LBL
019  12  B
020  32  X:T
021  01   1
022  67   EQ
023  23  LNX
024  02   2
025  67   EQ
026  24  CE
027  04   4
028  67   EQ
029  25  CLR
030  02   2
031  07   7
032  01   1
033  06   6
034  03   3
035  05   5
036  42  STO
037  20   20
038  71  SBR
039  22  INV
040  71  SBR
041  35  1/X
042  91  R/S
043  76  LBL
044  13  C
045  32  X:T
046  03   3
047  06   6
048  03   3
049  04   4
050  02   2
051  01   1
052  03   3
053  07   7
054  42  STO
055  20   20
056  71  SBR
057  22  INV
058  32  X:T
059  00   0
060  42  STO
061  00   00
062  76  LBL
063  42  STO
064  69  OP
065  20   20
066  73  RC*
067  00   00
068  59  INT
069  65   ×
070  04   4
071  55   ÷
072  43  RCL
073  23   23
074  95   =
075  22  INV
076  77   GE
077  42  STO
078  73  RC*
079  00   00
080  22  INV
081  59  INT
082  65   ×
083  01   1
084  00   0
085  00   0
086  95   =
087  32  X:T
088  01   1
089  06   6
090  02   2
091  04   4
092  01   1
093  03   3
094  42  STO
095  20   20
096  71  SBR
097  22  INV
098  98  ADV
099  91  R/S
100  76  LBL
101  22  INV
102  22  INV
103  58  FIX
104  25  CLR
105  69  OP
106  00   00
107  43  RCL
108  20   20
109  69  OP
110  04   04
111  32  X:T
112  58  FIX
113  01   01
114  69  OP
115  06   06
116  92  RTN
117  76  LBL
118  23  LNX
119  00   0
120  02   2
121  06   6
122  01   1
123  02   2
124  03   3
125  42  STO
```

126	20	20
127	71	SBR
128	22	INV
129	71	SBR
130	32	X:T
131	92	RTN
132	76	LBL
133	24	CE
134	00	0
135	03	3
136	06	6
137	01	1
138	02	2
139	03	3
140	42	STO
141	20	20
142	71	SBR
143	22	INV
144	71	SBR
145	33	X^2
146	92	RTN
147	76	LBL
148	25	CLR
149	00	0
150	05	5
151	06	6
152	01	1
153	02	2
154	03	3
155	42	STO
156	20	20
157	71	SBR
158	22	INV
159	71	SBR
160	34	√X
161	92	RTN
162	76	LBL
163	32	X:T
164	08	8
165	02	2
166	02	2
167	93	.
168	00	0
169	03	3
170	42	STO
171	01	01
172	01	1
173	08	8
174	08	8
175	00	0
176	93	.
177	00	0
178	04	4
179	42	STO
180	02	02
181	03	3
182	03	3
183	04	4
184	00	0
185	93	.
186	00	0
187	05	5
188	42	STO
189	03	03
190	05	5
191	03	3
192	05	5
193	00	0
194	93	.
195	00	0
196	06	6
197	42	STO
198	04	04
199	01	1
200	01	1
201	05	5
202	00	0
203	00	0
204	93	.
205	00	0
206	08	8
207	42	STO
208	05	05
209	02	2
210	00	0
211	07	7
212	00	0
213	00	0
214	93	.
215	01	1
216	42	STO
217	06	06
218	03	3
219	03	3
220	03	3
221	00	0
222	00	0
223	93	.
224	01	1
225	02	2
226	42	STO
227	07	07
228	05	5
229	09	9
230	05	5
231	00	0
232	00	0
233	93	.
234	01	1
235	05	5
236	42	STO
237	08	08
238	92	RTN
239	76	LBL
240	33	X^2
241	01	1
242	01	1
243	06	6
244	00	0
245	93	.
246	00	0
247	03	3
248	42	STO
249	01	01
250	02	2
251	06	6
252	05	5
253	00	0
254	93	.
255	00	0
256	04	4
257	42	STO
258	02	02
259	04	4
260	07	7
261	02	2
262	00	0
263	93	.
264	00	0
265	05	5
266	42	STO
267	03	03
268	07	7
269	05	5
270	05	5
271	00	0
272	93	.
273	00	0
274	06	6
275	42	STO
276	04	04
277	01	1
278	06	6
279	03	3
280	00	0
281	00	0
282	93	.
283	00	0
284	08	8
285	42	STO
286	05	05
287	02	2
288	09	9
289	02	2
290	00	0
291	00	0
292	93	.
293	01	1
294	42	STO
295	06	06
296	04	4
297	07	7
298	00	0
299	00	0
300	00	0
301	93	.
302	01	1
303	02	2
304	42	STO
305	07	07
306	08	8
307	04	4
308	00	0
309	00	0
310	00	0
311	93	.
312	01	1
313	05	5
314	42	STO
315	08	08
316	92	RTN
317	76	LBL
318	34	√X
319	01	1
320	06	6
321	04	4
322	04	4
323	93	.
324	00	0
325	03	3
326	42	STO
327	01	01
328	03	3
329	07	7
330	06	6
331	00	0
332	93	.
333	00	0
334	04	4
335	42	STO
336	02	02
337	06	6
338	06	6
339	08	8
340	00	0
341	93	.
342	00	0
343	05	5
344	42	STO
345	03	03
346	01	1
347	00	0
348	07	7
349	00	0
350	00	0
351	93	.
352	00	0
353	06	6
354	42	STO
355	04	04
356	02	2
357	03	3
358	00	0
359	00	0
360	00	0
361	93	.
362	00	0
363	08	8
364	42	STO
365	05	05
366	04	4
367	01	1
368	04	4
369	00	0
370	00	0
371	93	.
372	01	1
373	42	STO
374	06	06
375	06	6
376	06	6
377	06	6
378	00	0
379	00	0
380	93	.
381	01	1
382	02	2
383	42	STO
384	07	07
385	01	1
386	09	9
387	00	0
388	00	0
389	00	0

```
390  93  .
391  01  1
392  05  5
393  42  STO
394  08  08
395  92  RTN
396  76  LBL
397  35  1/X
398  05  5
399  04  4
400  04  4
401  93  .
402  00  0
403  02  2
404  42  STO
405  01  01
406  09  9
407  08  8
408  07  7
409  93  .
410  00  0
411  02  2
412  05  5
413  42  STO
414  02  02
415  01  1
416  06  6
417  01  1
418  00  0
419  93  .
420  00  0
421  03  3
422  42  STO
423  03  03
424  03  3
425  04  4
426  06  6
427  00  0
428  93  .
429  00  0
430  04  4
431  42  STO
432  04  04
433  06  6
434  02  2
435  08  8
436  00  0
437  93  .
438  00  0
439  05  5
440  42  STO
441  05  05
442  01  1
443  00  0
444  02  2
445  00  0
446  00  0
447  93  .
448  00  0
449  06  6
450  42  STO
451  06  06
452  02  2
453  02  2
454  00  0
455  00  0
456  00  0
457  93  .
458  00  0
459  08  8
460  42  STO
461  07  07
462  92  RTN
463  00  0
```

SPECIAL NOTES FOR HP-97 USERS

1. The program has two cards:

   SEP-1—contains the basic program and tables for 1% and 2% slopes.

   SEP-1A—contains tables for a 4% slope and vertical leaders.

2. When using program SEP-1A, first load Program SEP-1 and then merge Program SEP-1A using the following instructions:

   a. Set the PRGM-RUN switch to RUN;
   b. Use GTO · 049 operation from keyboard;
   c. Press *f* MERGE;
   d. Pass both sides of magnetic card.

SEP-1
STORM WATER SYSTEM PIPE SIZING PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Input rainfall rate, in./hr	4	—	—	A	4.00 ***	
2.	Input 1 for 1% slope	1	—	—	B	1.00 ***	
3.	Input roof area, sq ft	1500	—	—	C	1500.00 ***	
						4.00 ***	Pipe diameter
	or						
2.	Input 2 for 2% slope	2	—	—	B	2.00 ***	
3.	Input roof area, sq ft	3000	—	—	C	3000.00 ***	
						5.00 ***	
	or						
2.	Input 4 for 4% slope	4	—	—	B	4.00 ***	
3.	Input roof area, sq ft	4000	—	—	C	4000.00 ***	
						5.00 ***	
	Example 2						
1.	Input rainfall rate, in./hr	5	—	—	A	5.00 ***	
2.	Input 5 for leaders	5	—	—	B	5.00 ***	
3.	Input roof area, sq ft	5000	—	—	C	5000.00 ***	
						5.00 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints and stores display in RA
B	Prints display and selects system type
C	Prints display (roof area); converts roof area from table to suit rainfall intensity and finds diameter using LBL 0 for reiteration
1	Stores table for 1% slope
2	Stores table for 2% slope
3	Stores table for 4% slope
4	Stores table for vertical leaders

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	Rainfall intensity
RB	Roof area
RI	For reiteration
R1–R8	For storing tables of pipe size and roof area
R0 & R9	Not used

SEP-1 & SEP-1A (HP-97) STORM WATER SYSTEM PIPE SIZING PROGRAM

SEP-1 LISTING

```
001  *LBLA    21 11
002  STOA     35 11
003  PRTX       -14
004  RTN         24
005  *LBLB    21 12
006  PRTX       -14
007  1           01
008  X=Y?     16-33
009  GTO1     22 01
010  CLX        -51
011  2           02
012  X=Y?     16-33
013  GTO2     22 02
014  CLX        -51
015  4           04
016  X=Y?     16-33
017  GTO3     22 03
018  CLX        -51
019  5           05
020  X=Y?     16-33
021  GTO4     22 04
022  CLX        -51
023  RTN         24
024  *LBLC    21 13
025  STOB     35 12
026  PRTX       -14
027  0           00
028  STOI     35 46
029  *LBL0    21 00
030  ISZI  16 26 46
031  RCLi     36 45
032  INT      16 34
033  4           04
034  x          -35
035  RCLA     36 11
036  ÷          -24
037  RCLB     36 12
038  X>Y?     16-34
039  GTO0     22 00
040  RCLi     36 45
041  FRC      16 44
042  1           01
043  0           00
044  0           00
045  x          -35
046  PRTX       -14
047  SPC      16-11
048  RTN         24
049  *LBL1    21 01
050  8           08
051  2           02
052  2           02
053  .          -62
054  0           00
055  3           03
056  STO1     35 01
057  1           01
058  8           08
059  8           08
060  0           00
061  .          -62
062  0           00
063  4           04
064  STO2     35 02
065  3           03
066  3           03
067  4           04
068  0           00
069  .          -62
070  0           00
071  5           05
072  STO3     35 03
073  5           05
074  3           03
075  5           05
076  6           06
077  .          -62
078  0           00
079  6           06
080  STO4     35 04
081  1           01
082  1           01
083  5           05
084  0           00
085  0           00
086  .          -62
087  0           00
088  8           08
089  STO5     35 05
090  2           02
091  0           00
092  7           07
093  0           00
094  0           00
095  .          -62
096  1           01
097  STO6     35 06
098  3           03
099  3           03
100  3           03
101  0           00
102  0           00
103  .          -62
104  1           01
105  2           02
106  STO7     35 07
107  5           05
108  9           09
109  5           05
110  0           00
111  0           00
112  .          -62
113  1           01
114  5           05
115  STO8     35 08
116  RTN         24
117  *LBL2    21 02
118  1           01
119  1           01
120  6           06
121  0           00
122  .          -62
123  0           00
124  3           03
125  STO1     35 01
126  2           02
127  6           06
128  5           05
129  0           00
130  .          -62
131  0           00
132  4           04
133  STO2     35 02
134  4           04
135  7           07
136  2           02
137  0           00
138  .          -62
139  0           00
140  5           05
141  STO3     35 03
142  7           07
143  5           05
144  5           05
145  0           00
146  .          -62
147  0           00
```

148	6	06
149	STO4	35 04
150	1	01
151	6	06
152	3	03
153	0	00
154	0	00
155	.	-62
156	0	00
157	8	08
158	STO5	35 05
159	2	02
160	9	09
161	2	02
162	0	00
163	0	00
164	.	-62
165	1	01
166	STO6	35 06
167	4	04
168	7	07
169	0	00
170	0	00
171	0	00
172	.	-62
173	1	01
174	2	02
175	STO7	35 07
176	8	08
177	4	04
178	0	00
179	0	00
180	0	00
181	.	-62
182	1	01
183	5	05
184	STO8	35 08
185	RTN	24

SEP-1A LISTING

001	*LBL3	21 03
002	1	01
003	6	06
004	4	04
005	4	04
006	.	-62
007	0	00
008	3	03
009	STO1	35 01
010	3	03
011	7	07
012	6	06
013	0	00
014	.	-62
015	0	00
016	4	04
017	STO2	35 02
018	6	06
019	6	06
020	8	08
021	0	00
022	.	-62
023	0	00
024	5	05
025	STO3	35 03
026	1	01
027	0	00
028	7	07
029	0	00
030	0	00
031	.	-62
032	0	00
033	6	06
034	STO4	35 04
035	2	02
036	3	03
037	0	00
038	0	00
039	0	00
040	.	-62
041	0	00
042	8	08
043	STO5	35 05
044	4	04
045	1	01
046	4	04
047	0	00
048	0	00
049	.	-62
050	1	01
051	STO6	35 06
052	6	06
053	6	06
054	6	06
055	0	00
056	0	00
057	.	-62
058	1	01
059	2	02
060	STO7	35 07
061	1	01
062	9	09
063	0	00
064	0	00
065	0	00
066	.	-62
067	1	01
068	5	05
069	STO8	35 08
070	RTN	24
071	*LBL4	21 04
072	5	05
073	4	04
074	4	04
075	.	-62
076	0	00
077	2	02
078	STO1	35 01
079	9	09
080	8	08
081	7	07
082	.	-62
083	0	00
084	2	02
085	5	05
086	STO2	35 02
087	1	01
088	6	06
089	1	01
090	0	00
091	.	-62
092	0	00
093	3	03
094	STO3	35 03
095	3	03
096	4	04
097	6	06
098	0	00
099	.	-62
100	0	00
101	4	04
102	STO4	35 04
103	6	06
104	2	02
105	8	08
106	0	00
107	.	-62
108	0	00
109	5	05
110	STO5	35 05
111	1	01
112	0	00
113	2	02
114	0	00
115	0	00
116	.	-62
117	0	00
118	6	06
119	STO6	35 06
120	2	02
121	2	02
122	0	00
123	0	00
124	0	00
125	.	-62
126	0	00
127	8	08
128	STO7	35 07
129	RTN	24
130	R/S	51

SEP-2
SOIL AND WASTE WATER SYSTEM PIPE SIZING PROGRAM

PROGRAM DESCRIPTION

With input of fixture units, the program selects pipe size for horizontal pipes of different slopes and for vertical stacks.

The sizing procedure is based on the BOCA Basic Plumbing Code and the National Standard Plumbing Code. The designer can compute fixture units for different fixtures based on the information given in these codes. The relevant sections of the BOCA Code are included as reference data for the designer's convenience.

EQUATIONS

None.

OPERATING FEATURES

The sizing information is stored by combining pipe size and fixture units in decimal format. For example, 4,600.12 means that a 12-in. pipe will handle up to 4,600 fixture units.

As shown under "User Instructions and Examples," the program can select pipes for the following types of distribution systems:

Distribution System	Input Under Label A
Any horizontal branch interval	0
One stack of three branch intervals or less	1
Total for stack: for stacks with more than three branch intervals	2
Total at one branch interval: for stacks with more than three branch intervals	3
Building drains—slope of 1/16 in./ft or 0.5%	4
Building drains—slope of 1/8 in./ft or 1%	5
Building drains—slope of 1/4 in./ft or 2%	6

REFERENCE DATA

Please see the following extracts from the BOCA Basic Plumbing Code.

ARTICLE 6 DRAINAGE SYSTEMS

Section P600.0 General

P-600.1 Scope: The provisions of this article shall set forth the requirements for the design and installation of the drainage system. Storm drainage shall conform to Article 8.

Section P-601.0 Determining Size of Drainage System

P-601.1 Load on drainage piping: The load on drainage piping shall be computed in terms of drainage fixture unit values in accordance with Tables P-601.1 and P-601.1.1.

TABLE P-601.1
DRAINAGE FIXTURE UNIT VALUES FOR VARIOUS PLUMBING FIXTURES

Type of fixture or group of fixtures	Drainage fixture unit value (dfu)	Trap size in inches
Automatic clothes washer (2″ standpipe)	3	
Bathroom group consisting of a water closet, lavatory and bathtub or shower stall		
Flushometer valve closet	8	
Tank type closet	6	
Bathtub[1] (with or without overhead shower)	2	1½
Bidet	3	1½
Combination sink-and-tray with food disposal unit	2	1½
Combination sink-and-tray with 1½″ trap	2	1½
Combination sink-and-tray with separate 1½″ traps	3	1½
Dental unit or cuspidor	1	1¼
Dental lavatory	1	1¼
Drinking fountain	½	1¼
Dishwasher, commercial	2	2
Dishwasher, domestic	2	1½
Food waste grinder	–	1½
Floor drains with 2″ waste	2	2
Kitchen sink, domestic, with one 1½″ waste	2	1½
Kitchen sink, domestic, with food waste grinder	2	1½
Lavatory with 1¼″ waste	1	1¼
Lavatory (barber shop, beauty parlor)	2	1½
Laundry tray (1 or 2 compartments)	2	1½
Shower stall, domestic	2	2
Showers (group) per head[2]	2	–
Sinks:		
Surgeon's	3	1½
Flushing rim (with valve)	6	3
Service (trap standard)	3	3
Service (P trap)	2	2
Pot, scullery, etc.[2]	4	2
Commercial with food grinder unit		2
Urinal, pedestal, syphon jet blowout	6	–
Urinal, wall lip	4	1½
Urinal, stall, washout	4	2
Urinal trough[2] (each 6 ft. section)	2	–
Washing machine (commercial)	3	2
Wash sink[2] (circular or multiple) each set of faucets	2	1½
Water closet, tank-operated	4	–
Water closet, valve-operated	6	–
Unlisted fixture drain or trap size:		
1¼″ or less	1	
1½″	2	
2″	3	
2½″	4	
3″	5	
4″	6	

Note 1. A shower head over a bathtub does not increase the fixture value.

Note 2. See Section P-601.1.1 for method of computing unit value of devices with continuous or semi-continuous flows.

TABLE P-601.1.1
DISCHARGE CAPACITY IN GALLONS PER MINUTE SEMI-CONTINUOUS FLOW

Up to 7½	Equals	1 Unit
8 to 15	Equals	2 Units
16 to 30	Equals	4 Units
31 to 50	Equals	6 Units

Note 1. Drainage fixture unit values for continuous and semi-continuous flow, over fifty (50) gallons shall be computed at one (1) fixture unit for each gallon per minute of flow.
Note 2. To convert continuous condensate flow from air conditioning units, a condensate flow of three-hundredths (0.03) gpm/100 cfm across the cooling coil shall be used.

P-601.1.1 Values for continuous flow: Drainage fixture unit values for continuous or semi-continuous flow into a drainage system, such as from a pump, sump ejector, air conditioning equipment, or similar device shall be computed on the basis of Table P-601.1.1, Discharge Capacity in Gallons per Minute Semi-continuous Flow.
P-601.2 Selecting size of drainage piping: Pipe sizes shall be determined from Tables P-601.2a and P601.2a.1 on the basis of drainage load computed from Table P 601.1 and Section P-601.1.1.

TABLE P-601.2a
BUILDING DRAINS AND SEWERS

Diameter of pipe Inches	Maximum number of fixture units that may be connected to any portion of the building drain or the building sewer including branches of the building drain. Fall per foot 1/16-Inch	1/8-Inch	1/4-Inch	1/2-Inch
2			21	26
2½			24	31
3		36*	42*	50*
4		180	216	250
5		390	480	575
6		700	840	1,000
8	1,400	1,600	1,920	2,300
10	2,500	2,900	3,500	4,200
12	2,900	4,600	5,600	6,700
15	7,000	8,300	10,000	12,000

*Not over two (2) water closets or two (2) bathroom groups.

TABLE P-601.2a.1
HORIZONTAL FIXTURE BRANCHES AND STACKS[1]

Diameter of pipe inches	Maximum number of fixture units that may be connected to: Any horizontal branch interval	One stack of three branch intervals or less	Stacks with more than three branch intervals[3]: Total for stack	Total at one branch interval
1½	3	4	8	2
2	6	10	24	6
2½	12	20	42	9
3	20[2]	48[2]	72[2]	20[2]
4	160	240	500	90
5	360	540	1,100	200
6	620	960	1,900	350
8	1,400	2,200	3,600	600
10	2,500	3,800	5,600	1,000
12	3,900	6,000	8,400	1,500
15	7,000	*	*	*

*Sizing load based on design criteria.

Note 1. Does not include branches of the building drain. Refer to Table P-601.2a.
Note 2. Not more than two (2) water closets or bathroom groups within each branch interval nor more than six (6) water closets or bathroom groups on the stack.
Note 3. Stacks shall be sized according to the total accumulated connected load at each story or branch interval and may be reduced in size as this load decreases to a minimum diameter of one-half (½) of the largest size required.

SEP-2
SOIL & WASTE WATER SYSTEM PIPE SIZING PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Select distribution system	0	—	—	A	0.0	HBI	Any horiz. branch interval
2.	Input fixture units	100	—	—	B	100.0	FU	
						4.0	DIA	
	Repeat steps 1 & 2 for different distribution systems and fixture units.	1	—	—	A	1.0	V3BI	1 stack of 3 branch intervals
		200	—	—	B	200.0	FU	
						4.0	DIA	
		2	—	—	A	2.0	STK	Total for stack
		300	—	—	B	300.0	FU	
						4.0	DIA	
		3	—	—	A	3.0	V1BI	Total at 1 branch for stack with 3 or more intervals
		400	—	—	B	400.0	FU	
						8.0	DIA	
		4	—	—	A	4.0	.5%D	Drain 5% slope
		500	—	—	B	500.0	FU	
						8.0	DIA	
		5	—	—	A	5.0	1%HD	Drain 1% slope
		450	—	—	B	450.0	FU	
						6.0	DIA	
		6	—	—	A	6.0	2%HD	Drain 2% slope
		499	—	—	B	499.0	FU	
						6.0	DIA	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Selects type of distribution system and prints; partitions the program
B	Prints fixture units; selects and prints pipe sizes
)	Reiterates for selection of pipe size
INV	Prints alphanumeric characters for identification of data
LNX	Prints HBI and calls SBR 1/X
CE	Prints V3BI and calls SBR STO
CLR	Prints STK and calls SBR RCL
$X \rightleftarrows T$	Prints V1B1 and calls SBR SUM
X^2	Prints 0.5%D and calls SBR Y^x
$\sqrt{X}$	Prints 1%HD and calls SBR EE
1/X	Stores table for any horizontal branch interval
STO	Stores table for one stack of three branch intervals or less
RCL	Stores table for stack with more than three branch intervals—total for stack
SUM	Same as above but total at one branch interval
Y^x	Table for horizontal drain with 1/16 in./ft or 0.5% slope
EE	Table for horizontal drain with 1/8 in./ft or 1% slope
(	Table for horizontal drain with 1/4 in./ft or 2% slope

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For RCL IND for pipe sizing
R01	Distribution type—also for tables
R02–R11	Storing tables
R12	Alphanumeric code

SEP-2 SOIL AND WASTE WATER SYSTEM PIPE SIZING PROGRAM

LABELS & SUBROUTINES

```
001  11  A
046  12  B
061  54  )
093  22  INV
110  23  LNX
125  24  CE
142  25  CLR
157  32  X:T
174  33  X^2
191  34  √X
208  35  1/X
298  42  STO
380  43  RCL
464  44  SUM
542  45  Y^X
580  52  EE
648  53  (
```

LISTING

```
000  76  LBL
001  11  A
002  42  STO
003  01  01
004  22  INV
005  58  FIX
006  02  2
007  69  OP
008  17  17
009  43  RCL
010  01  01
011  32  X:T
012  00  0
013  67  EQ
014  23  LNX
015  01  1
016  67  EQ
017  24  CE
018  02  2
019  67  EQ
020  25  CLR
021  03  3
022  67  EQ
023  32  X:T
024  04  4
025  67  EQ
026  33  X^2
027  05  5
028  67  EQ
029  34  √X
030  00  0
031  03  3
032  06  6
033  01  1
034  02  2
035  03  3
036  01  1
037  06  6
038  42  STO
039  12  12
040  71  SBR
041  22  INV
042  71  SBR
043  53  (
044  91  R/S
045  76  LBL
046  12  B
047  32  X:T
048  02  2
049  01  1
050  04  4
051  01  1
052  42  STO
053  12  12
054  71  SBR
055  22  INV
056  32  X:T
057  00  0
058  42  STO
059  00  00
060  76  LBL
061  54  )
062  69  OP
063  20  20
064  73  RC*
065  00  00
066  59  INT
067  22  INV
068  77  GE
069  54  )
070  73  RC*
071  00  00
072  22  INV
073  59  INT
074  65  ×
075  01  1
076  00  0
077  00  0
078  95  =
079  32  X:T
080  01  1
081  06  6
082  02  2
083  04  4
084  01  1
085  03  3
086  42  STO
087  12  12
088  71  SBR
089  22  INV
090  98  ADV
091  91  R/S
092  76  LBL
093  22  INV
094  22  INV
095  58  FIX
096  25  CLR
```

```
097 69 OP
098 00 00
099 43 RCL
100 12 12
101 69 OP
102 04 04
103 32 X:T
104 58 FIX
105 01 01
106 69 OP
107 06 06
108 92 RTN
109 76 LBL
110 23 LNX
111 02 2
112 03 3
113 01 1
114 04 4
115 02 2
116 04 4
117 42 STO
118 12 12
119 71 SBR
120 22 INV
121 71 SBR
122 35 1/X
123 92 RTN
124 76 LBL
125 24 CE
126 04 4
127 02 2
128 00 0
129 04 4
130 01 1
131 04 4
132 02 2
133 04 4
134 42 STO
135 12 12
136 71 SBR
137 22 INV
138 71 SBR
139 42 STO
140 92 RTN
141 76 LBL
142 25 CLR
143 03 3
144 06 6
145 03 3
146 07 7
147 02 2
148 06 6
149 42 STO
150 12 12
151 71 SBR
152 22 INV
153 71 SBR
154 43 RCL
155 92 RTN
156 76 LBL
157 32 X:T
158 04 4
159 02 2
160 00 0
161 02 2
162 01 1
163 04 4
164 02 2
165 04 4
166 42 STO
167 12 12
168 71 SBR
169 22 INV
170 71 SBR
171 44 SUM
172 92 RTN
173 76 LBL
174 33 X^2
175 04 4
176 00 0
177 00 0
178 06 6
179 06 6
180 01 1
181 01 1
182 06 6
183 42 STO
184 11 11
185 71 SBR
186 22 INV
187 71 SBR
188 45 Y^X
189 92 RTN
190 76 LBL
191 34 √X
192 00 0
193 02 2
194 06 6
195 01 1
196 02 2
197 03 3
198 01 1
199 06 6
200 42 STO
201 12 12
202 71 SBR
203 22 INV
204 71 SBR
205 52 EE
206 92 RTN
207 76 LBL
208 35 1/X
209 03 3
210 93 .
211 00 0
212 01 1
213 05 5
214 42 STO
215 01 01
216 06 6
217 93 .
218 00 0
219 02 2
220 42 STO
221 02 02
222 01 1
223 02 2
224 93 .
225 00 0
226 02 2
227 05 5
228 42 STO
229 03 03
230 02 2
231 00 0
232 93 .
233 00 0
234 03 3
235 42 STO
236 04 04
237 01 1
238 06 6
239 00 0
240 93 .
241 00 0
242 04 4
243 42 STO
244 05 05
245 03 3
246 06 6
247 00 0
248 93 .
249 00 0
250 05 5
251 42 STO
252 06 06
253 06 6
254 02 2
255 00 0
256 93 .
257 00 0
258 06 6
259 42 STO
260 07 07
261 01 1
262 04 4
263 00 0
264 00 0
265 93 .
266 00 0
267 08 8
268 42 STO
269 08 08
270 02 2
271 05 5
272 00 0
273 00 0
274 93 .
275 01 1
276 42 STO
277 09 09
278 03 3
279 09 9
280 00 0
281 00 0
282 93 .
283 01 1
284 02 2
285 42 STO
286 10 10
287 07 7
288 00 0
289 00 0
290 00 0
291 93 .
292 01 1
293 05 5
294 42 STO
295 11 11
296 92 RTN
297 76 LBL
298 42 STO
299 04 4
300 93 .
301 00 0
302 01 1
303 05 5
304 42 STO
305 01 01
306 01 1
307 00 0
308 93 .
309 00 0
310 02 2
311 42 STO
312 02 02
313 02 2
314 00 0
315 93 .
316 00 0
317 02 2
318 05 5
319 42 STO
320 03 03
321 04 4
322 08 8
323 93 .
324 00 0
325 03 3
326 42 STO
327 04 04
328 02 2
329 04 4
330 00 0
331 93 .
332 00 0
333 04 4
334 42 STO
335 05 05
336 05 5
337 04 4
338 00 0
339 93 .
340 00 0
341 05 5
342 42 STO
343 06 06
344 09 9
345 06 6
346 00 0
347 93 .
348 00 0
349 08 8
350 42 STO
351 07 07
352 02 2
353 02 2
354 00 0
355 00 0
356 93 .
```

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360  08  08
361  03  3
362  08  8
363  00  0
364  00  0
365  93  .
366  01  1
367  42  STO
368  09  09
369  06  6
370  00  0
371  00  0
372  00  0
373  93  .
374  01  1
375  02  2
376  42  STO
377  10  10
378  92  RTN
379  76  LBL
380  43  RCL
381  08  8
382  93  .
383  00  0
384  01  1
385  05  5
386  42  STO
387  01  01
388  02  ?
389  04  4
390  93  .
391  00  0
392  02  2
393  42  STO
394  02  02
395  04  4
396  02  2
397  93  .
398  00  0
399  02  2
400  05  5
401  42  STO
402  03  03
403  07  7
404  02  2
405  93  .
406  00  0
407  03  3
408  42  STO
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410  05  5
411  00  0
412  00  0
413  93  .
414  00  0
415  04  4
416  42  STO
417  05  05
418  01  1
419  01  1
420  00  0
421  00  0
422  93  .
423  00  0
424  05  5
425  42  STO
426  06  06
427  01  1
428  09  9
429  00  0
430  00  0
431  93  .
432  00  0
433  06  6
434  42  STO
435  07  07
436  03  3
437  06  6
438  00  0
439  00  0
440  93  .
441  00  0
442  08  8
443  42  STO
444  08  08
445  05  5
446  06  6
447  00  0
448  00  0
449  93  .
450  01  1
451  42  STO
452  09  09
453  08  8
454  04  4
455  00  0
456  00  0
457  93  .
458  01  1
459  02  2
460  42  STO
461  10  10
462  92  RTN
463  76  LBL
464  44  SUM
465  02  2
466  93  .
467  00  0
468  01  1
469  05  5
470  42  STO
471  01  01
472  06  6
473  93  .
474  00  0
475  02  2
476  42  STO
477  02  02
478  09  9
479  93  .
480  00  0
481  02  2
482  05  5
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485  02  2
486  00  0
487  93  .
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490  42  STO
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495  00  0
496  04  4
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501  00  0
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505  42  STO
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507  03  3
508  05  5
509  00  0
510  93  .
511  00  0
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513  42  STO
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515  06  6
516  00  0
517  00  0
518  93  .
519  00  0
520  08  8
521  42  STO
522  08  08
523  01  1
524  00  0
525  00  0
526  00  0
527  93  .
528  01  1
529  42  STO
530  09  09
531  01  1
532  05  5
533  00  0
534  00  0
535  93  .
536  01  1
537  02  2
538  42  STO
539  10  10
540  92  RTN
541  76  LBL
542  45  YX
543  01  1
544  04  4
545  00  0
546  00  0
547  93  .
548  00  0
549  08  8
550  42  STO
551  01  01
552  02  2
553  05  5
554  00  0
555  00  0
556  93  .
557  01  1
558  42  STO
559  02  02
560  02  2
561  09  9
562  00  0
563  00  0
564  93  .
565  01  1
566  02  2
567  42  STO
568  03  03
569  07  7
570  00  0
571  00  0
572  00  0
573  93  .
574  01  1
575  05  5
576  42  STO
577  04  04
578  92  RTN
579  76  LBL
580  52  EE
581  03  3
582  06  6
583  93  .
584  00  0
585  03  3
586  42  STO
587  01  01
588  01  1
589  08  8
590  00  0
591  93  .
592  00  0
593  04  4
594  42  STO
595  02  02
596  03  3
597  09  9
598  00  0
599  93  .
600  00  0
601  05  5
602  42  STO
603  03  03
604  07  7
605  00  0
606  00  0
607  93  .
608  00  0
609  06  6
610  42  STO
611  04  04
612  01  1
613  06  6
614  00  0
615  93  .
616  00  0
```

```
617  08   8
618  42  STO
619  05   05
620  02   2
621  09   9
622  00   0
623  00   0
624  93   .
625  01   1
626  42  STO
627  06   06
628  04   4
629  06   6
630  00   0
631  00   0
632  93   .
633  01   1
634  02   2
635  42  STO
636  07   07
637  08   8
638  03   3
639  00   0
640  00   0
641  93   .
642  01   1
643  05   5
644  42  STO
645  08   08
646  92  RTN
647  76  LBL
648  53   (
649  02   2
650  01   1
651  93   .
652  00   0
653  02   2
654  42  STO
655  01   01
656  02   2
657  04   4
658  93   .
659  00   0
660  02   2
661  05   5
662  42  STO
663  02   02
664  04   4
665  02   2
666  93   .
667  00   0
668  03   3
669  42  STO
670  03   03
671  02   2
672  01   1
673  06   6
674  93   .
675  00   0
676  04   4
677  42  STO
678  04   04
679  04   4
680  08   8
681  00   0
682  93   .
683  00   0
684  05   5
685  42  STO
686  05   05
687  08   8
688  04   4
689  00   0
690  93   .
691  00   0
692  06   6
693  42  STO
694  06   06
695  01   1
696  09   9
697  02   2
698  00   0
699  93   .
700  00   0
701  08   8
702  42  STO
703  07   07
704  03   3
705  05   5
706  00   0
707  00   0
708  93   .
709  01   1
710  42  STO
711  08   08
712  05   5
713  06   6
714  00   0
715  00   0
716  93   .
717  01   1
718  02   2
719  42  STO
720  09   09
721  01   1
722  00   0
723  00   0
724  00   0
725  00   0
726  93   .
727  01   1
728  05   5
729  42  STO
730  10   10
731  92  RTN
732  00   0
```

SPECIAL NOTES FOR HP-97 USERS

1. Load Program SEP-2A when inputting 2, 3, or 4 under A.
2. Load Program SEP-2B when inputting 5 or 6 under A.
3. After loading Program SEP-2, merge Program SEP-2A or SEP-2B using the following instructions:
   a. Set the PRGM-RUN switch to RUN;
   b. Use GTO · 050 operation from keyboard;
   c. Press *f* MERGE;
   d. Pass both sides of magnetic card.

SEP-2, SEP-2A, SEP-2B
SOIL & WASTE WATER SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: THREE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Select distribution type	0	—	—	A	0.00 ***	
2.	Enter fixture units	100	—	—	B	100.00 ***	
						4.00 ***	Diameter
	Repeat steps 1 & 2 as many	1	—	—	A	1.00 ***	
	times as desired.	200	—	—	B	200.00 ***	
						4.00 ***	
	For next 3 examples, merge SEP-2A.	2	—	—	A	2.00 ***	
		300	—	—	B	300.00 ***	
						4.00 ***	
		3	—	—	A	3.00 ***	
		400	—	—	B	400.00 ***	
						8.00 ***	
		4	—	—	A	4.00 ***	
		500	—	—	B	500.00 ***	
						9.00 ***	
	For next 3 examples, merge	5	—	—	A	5.00 ***	
	SEP-2B.	450	—	—	B	450.00 ***	
						6.00 ***	
		6	—	—	A	6.00 ***	
		499	—	—	B	499.00 ***	
						6.00 ***	
		8000	—	—	B	8000.00 ***	
						15.00 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints and stores display in RA; selects sizing table based on input
B	Prints and stores display in RB; selects pipe diameter using LBL 7 for reiteration
0	Table for any horizontal branch interval
1	Table for one stack of three branch intervals or less
2	Table for stacks with more than three branch intervals—SEP-2A
3	Table for one branch interval for stacks with more than three branch intervals—SEP-2A
4	Building drains with 0.5% slope—SEP-2A
5	Building drains with 1% slope—SEP-2B
6	Building drains with 2% slope—SEP-2B

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	Distribution type
RB	Fixture units
RI	For reiteration
R0–R9	For storing tables of fixture units and pipe diameters

SEP-2, SEP-2A & SEP-2B (HP-97) SOIL AND WASTE WATER SYSTEM PIPE SIZING PROGRAM

SEP-2 LISTING

001	*LBLA	21 11
002	STOA	35 11
003	PRTX	-14
004	X=0?	16-43
005	GTO0	22 00
006	1	01
007	X=Y?	16-33
008	GTO1	22 01
009	2	02
010	RCLA	36 11
011	X=Y?	16-33
012	GTO2	22 02
013	3	03
014	X=Y?	16-33
015	GTO3	22 03
016	4	04
017	RCLA	36 11
018	X=Y?	16-33
019	GTO4	22 04
020	5	05
021	X=Y?	16-33
022	GTO5	22 05
023	GSB6	23 06
024	RTN	24
025	*LBLB	21 12
026	STOB	35 12
027	PRTX	-14
028	1	01
029	CHS	-22
030	STOI	35 46
031	*LBL7	21 07
032	ISZI	16 26 46
033	RCL0	36 00
034	RCLi	36 45
035	INT	16 34
036	RCLB	36 12
037	X>Y?	16-34
038	GTO7	22 07
039	RCLi	36 45
040	FRC	16 44
041	1	01
042	0	00
043	0	00
044	×	-35
045	PRTX	-14
046	SPC	16-11
047	SPC	16-11
048	SPC	16-11
049	RTN	24
050	*LBL0	21 00
051	3	03
052	.	-62
053	0	00
054	1	01
055	5	05
056	STO0	35 00
057	6	06
058	.	-62
059	0	00
060	2	02
061	STO1	35 01
062	1	01
063	2	02
064	.	-62
065	0	00
066	2	02
067	5	05
068	STO2	35 02
069	2	02
070	0	00
071	.	-62
072	0	00
073	3	03
074	STO3	35 03
075	1	01
076	6	06
077	0	00
078	.	-62
079	0	00
080	4	04
081	STO4	35 04
082	3	03
083	6	06
084	0	00
085	.	-62
086	0	00
087	5	05
088	STO5	35 05
089	6	06
090	2	02
091	0	00
092	.	-62
093	0	00
094	6	06
095	STO6	35 06
096	1	01
097	4	04
098	0	00
099	0	00
100	.	-62
101	0	00
102	8	08
103	STO7	35 07
104	2	02
105	5	05
106	0	00
107	0	00
108	.	-62
109	1	01
110	STO8	35 08
111	3	03
112	9	09
113	0	00
114	0	00
115	.	-62
116	1	01
117	2	02
118	STO9	35 09
119	RTN	24
120	*LBL1	21 01
121	4	04
122	.	-62
123	0	00
124	1	01
125	5	05
126	STO0	35 00
127	1	01
128	0	00
129	.	-62
130	0	00
131	2	02
132	STO1	35 01
133	2	02
134	0	00
135	.	-62
136	0	00
137	2	02
138	5	05
139	STO2	35 02
140	4	04
141	8	08
142	.	-62
143	0	00
144	3	03

```
145  STO3  35 03
146     2     02
147     4     04
148     0     00
149     .    -62
150     0     00
151     4     04
152  STO4  35 04
153     5     05
154     4     04
155     0     00
156     .    -62
157     0     00
158     5     05
159  STO5  35 05
160     9     09
161     6     06
162     0     00
163     .    -62
164     0     00
165     8     08
166  STO6  35 06
167     2     02
168     2     02
169     0     00
170     0     00
171     .    -62
172     0     00
173     8     08
174  STO7  35 07
175     3     03
176     8     08
177     0     00
178     0     00
179     .    -62
180     1     01
181  STO8  35 08
182     6     06
183     0     00
184     0     00
185     0     00
186     .    -62
187     1     01
188     2     02
189  STO9  35 09
190   RTN     24
191   R/S     51
```

SEP-2A LISTING

```
001 *LBL2  21 02
002     8     08
003     .    -62
004     0     00
005     1     01
006     5     05
007  STO0  35 00
008     2     02
009     4     04
010     .    -62
011     0     00
012     2     02
013  STO1  35 01
014     4     04
015     2     02
016     .    -62
017     0     00
018     2     02
019     5     05
020  STO2  35 02
021     7     07
022     2     02
023     .    -62
024     0     00
025     3     03
026  STO3  35 03
027     5     05
028     0     00
029     0     00
030     .    -62
031     0     00
032     4     04
033  STO4  35 04
034     1     01
035     1     01
036     0     00
037     0     00
038     .    -62
039     0     00
040     5     05
041  STO5  35 05
042     1     01
043     9     09
044     0     00
045     0     00
046     .    -62
047     0     00
048     6     06
049  STO6  35 06
050     3     03
051     6     06
052     0     00
053     0     00
054     .    -62
055     0     00
056     8     08
057  STO7  35 07
058     6     06
059     5     05
060     0     00
061     0     00
062     .    -62
063     1     01
064  STO8  35 08
065     8     08
066     4     04
067     0     00
068     0     00
069     .    -62
070     1     01
071     2     02
072  STO9  35 09
073   RTN     24
074 *LBL3  21 03
075     2     02
076     .    -62
077     0     00
078     1     01
079     5     05
080  STO0  35 00
081     6     06
082     .    -62
083     0     00
084     2     02
085  STO1  35 01
086     9     09
087     .    -62
088     0     00
089     2     02
090     5     05
091  STO2  35 02
092     2     02
093     0     00
094     .    -62
095     0     00
096     3     03
097  STO3  35 03
098     9     09
099     0     00
100     .    -62
101     0     00
102     4     04
103  STO4  35 04
104     2     02
105     0     00
106     0     00
107     .    -62
108     0     00
109     5     05
110  STO5  35 05
111     3     03
112     5     05
113     0     00
114     .    -62
115     0     00
116     6     06
117  STO6  35 06
118     6     06
119     0     00
120     0     00
121     .    -62
122     0     00
123     8     08
124  STO7  35 07
125     1     01
126     0     00
127     0     00
128     0     00
129     .    -62
130     1     01
131  STO8  35 08
132     1     01
133     5     05
134     0     00
135     0     00
136     .    -62
137     1     01
138     2     02
139  STO9  35 09
140   RTN     24
141 *LBL4  21 04
142     1     01
143     4     04
144     0     00
145     0     00
146     .    -62
147     0     00
148     8     08
149  STO0  35 00
150     2     02
151     5     05
152     0     00
153     0     00
154     .    -62
155     1     01
156  STO1  35 01
157     2     02
158     9     09
159     0     00
160     0     00
161     .    -62
162     1     01
163     2     02
164  STO2  35 02
165     7     07
166     0     00
167     0     00
168     0     00
169     .    -62
170     1     01
171     5     05
172  STO3  35 03
173   RTN     24
```

SEP-2B LISTING

001	*LBL5	21 05
002	3	03
003	6	06
004	.	-62
005	0	00
006	3	03
007	STO0	35 00
008	1	01
009	8	08
010	0	00
011	.	-62
012	0	00
013	4	04
014	STO1	35 01
015	3	03
016	9	09
017	0	00
018	.	-62
019	0	00
020	5	05
021	STO2	35 02
022	7	07
023	0	00
024	0	00
025	.	-62
026	0	00
027	6	06
028	STO3	35 03
029	1	01
030	6	06
031	0	00
032	.	-62
033	0	00
034	8	08
035	STO4	35 04
036	2	02
037	9	09
038	0	00
039	0	00
040	.	-62
041	1	01
042	STO5	35 05
043	4	04
044	6	06
045	0	00
046	0	00
047	.	-62
048	1	01
049	2	02
050	STO6	35 06
051	8	08
052	3	03
053	0	00
054	0	00
055	.	-62
056	1	01
057	5	05
058	STO7	35 07
059	RTN	24
060	*LBL6	21 06
061	2	02
062	1	01
063	.	-62
064	0	00
065	2	02
066	STO0	35 00
067	2	02
068	4	04
069	.	-62
070	0	00
071	2	02
072	5	05
073	STO1	35 01
074	4	04
075	2	02
076	.	-62
077	0	00
078	3	03
079	STO2	35 02
080	2	02
081	1	01
082	6	06
083	.	-62
084	0	00
085	4	04
086	STO3	35 03
087	4	04
088	8	08
089	0	00
090	.	-62
091	0	00
092	5	05
093	STO4	35 04
094	8	08
095	4	04
096	0	00
097	.	-62
098	0	00
099	6	06
100	STO5	35 05
101	1	01
102	9	09
103	2	02
104	0	00
105	.	-62
106	0	00
107	8	08
108	STO6	35 06
109	3	03
110	5	05
111	0	00
112	0	00
113	.	-62
114	1	01
115	STO7	35 07
116	5	05
117	6	06
118	0	00
119	0	00
120	.	-62
121	1	01
122	2	02
123	STO8	35 08
124	1	01
125	0	00
126	0	00
127	0	00
128	0	00
129	.	-62
130	1	01
131	5	05
132	STO9	35 09
133	RTN	24
134	R/S	51

SEP-3
WATER SYSTEM PIPE SIZING PROGRAM

PROGRAM DESCRIPTION

With input of fixture units, program computes diversified flow in gallons per minute based on the modified Hunter Curves. In addition to the diversified flow, the program will handle constant flow required for equipment, such as a laundry.

Four curves have been stored in the program:

- Two curves for buildings similar to hospitals, having relatively high water consumption.
- Two curves for buildings similar to office buildings, having relatively low water consumption.
- Each building type has two curves: one for a distribution system using "flush valves" and the other using "flush tanks."

After calculating the flow in gallons per minute, the program computes pipe sizes based on maximum velocity and friction loss using the Williams-Hazen formula, which requires input of *C* value, safety factor, total pressure drop, and length. With this information, the designer can select the pipe size based either on velocity or on friction loss.

The program can also be used to compute pipe diameter for required flow or compute flow for a selected pipe size.

EQUATIONS

See Program PP-2 for equations based on the Williams-Hazen formula.

OPERATING FEATURES

As shown under "User Instructions and Examples," different fixture curves can be selected in the following manner:

Fixture Curve	Input Under Label B
Flush valves: for buildings with relatively low water consumption; *FV/G*	1
Flush tanks: for buildings with relatively low water consumption; *FT/G*	2
Flush valves: for buildings with relatively high water consumption; *FV/H*	3
Flush tanks: for buildings with relatively high water consumption; *FT/H*	4

It is essential to initialize the program before sizing any distribution system or starting a new distribution system. The fixture curves can be changed while sizing a distribution system. Pipe sizing can also be done (gallons per minute to diameter or diameter to gallons per minute) while designing a distribution system.

The program will also continuously add any constant flow required for the equipment to the diversified flow of the fixtures.

REFERENCE DATA

In order to conserve programming steps, different fixture units per gallons per minute (FU/gpm) tables are developed by combining short tables. Composite tables are reproduced here for the designer's information and convenience. These tables are based on prevailing engineering judgment and the user is at liberty to modify them to suit his or her own judgment.

BUILDINGS WITH RELATIVELY HIGH WATER CONSUMPTION

FLUSH VALVES		FLUSH TANKS	
Fixture Units	gpm	Fixture Units	gpm
Table stored under SBR X⇄T		Table stored under SBR X^2	
0	25	0	2
55	52	10	15
120	73	40	26
400	127	100	44
		500	130
Table stored under SBR 1/X		Table stored under SBR 1/X	
3,000	286	3,000	286
4,000	365	4,000	365
5,000	430	5,000	430
6,000	490	6,000	490
8,000	600	8,000	600
10,000	720	10,000	720
13,000	875	13,000	875

BUILDINGS WITH RELATIVELY LOW WATER CONSUMPTION

FLUSH VALVES		FLUSH TANKS	
Fixture Units	gpm	Fixture Units	gpm
Table stored under SBR X⇄T		Table stored under SBR X^2	
0	25	0	2
55	52	10	15
120	73	40	26
400	127	100	44
		500	130
Table stored under SBR $\sqrt{X}$		Table stored under SBR $\sqrt{X}$	
3,000	265	3,000	265
4,000	320	4,000	320
5,000	380	5,000	380
6,000	435	6,000	435
7,000	490	7,000	490
8,000	540	8,000	540

SEP-3

WATER SYSTEM PIPE SIZING PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
1.	Initialize	0	–	2nd	E′	0.00		
2.	Enter *C* value	130	–	2nd	C′	130.00	C	*C* value
3.	Select type of fixture curve	1	–	2nd	A′	1.00	FV/G	Flush valves: general
4.	Enter factor for ftgs. or safety	1.25	–	2nd	D′	1.25	FF	Fitting or safety factor
5.	Enter available pressure drop, ft	25	–	–	R/S	25.00	PD	Available pressure drop, ft
6.	Enter total system length, ft	285	–	–	R/S	285.00	L	System length, ft
						7.02	PD/C	Pressure drop, ft/100 ft
7.	Enter desired velocity, fpm	7.00	–	–	A	7.00	FPS	Velocity, fps
8.	Enter fixture units	25	–	–	B	25.00	FU	Fixture units
						25.00	ΣFU	Total fixture units
						37.27	GPM	Gal/min
						37.27	ΣGPM	Total gpm
						1.74	DIAP	Diameter based on friction loss
						1.48	DIAV	Diameter based on velocity
	Repeat step 7 as many times as desired.	35	–	–	B	35.00	FU	
						60.00	ΣFU	
						53.62	GPM	
						53.62	ΣGPM	
						2.00	DIAP	
						1.77	DIAV	
9.	To add flow of equipment having constant load, enter gpm	25	–	2nd	B′	25.00	EGPM	Equipment, gpm
		50	–	–	B	50.00	FU	
						110.00	ΣFU	
						69.77	GPM	Flow related to FU
						94.77	ΣGPM	Total gpm including equipment gpm
						2.48	DIAP	
						2.36	DIAV	

SEP-3 *(Continued)*
WATER SYSTEM PIPE SIZING PROGRAM
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 2							
1.	Initialize	0	—	2nd	E′	0.00		
	Repeat steps 2 through 9 as many times as desired.	135	—	2nd	A′	135.00	C	
		2	—	2nd	A′	2.00	FT/G	Flush tanks: general
		1.2	—	2nd	D′	1.20	FF	
		30	—	—	R/S	30.00	PD	
		250	—	—	R/S	250.00	L	
						10.00	PD/C	
		6.5	—	—	A	6.50	FPS	
		150	—	—	B	150.00	FU	
						150.00	ΣFU	
						54.75	GPM	
						54.75	ΣGPM	
						1.84	DIAP	
						1.86	DIAV	
		250	—	—	B	250.00	FU	
						400.00	ΣFU	
						108.50	GPM	
						108.50	ΣGPM	
						2.39	DIAP	
						2.62	DIAV	
		75	—	2nd	B′	75.00	EGPM	
		275	—	—	B	275.00	FU	
						675.00	ΣFU	
						139.45	GPM	
						214.45	ΣGPM	
						3.10	DIAP	
						3.68	DIAV	

	Example 3							
1.	Initialize	0	–	2nd	E′	0.00		
	Repeat steps 2 through 9 as many times as desired.	135	–	2nd	C′	135.00	C	
		3	–	2nd	A′	3.00	FV/H	Flush valve: high consumption
		1.2	–	2nd	D′	1.30	FF	
		28	–	–	R/S	28.00	PD	
		200	–	–	R/S	290.00	L	
						7.43	PD/C	
		7	–	–	B	7.00	FPS	
		100	–	–	B	100.00	FU	
						100.00	ΣFU	
						66.54	GPM	
						66.54	ΣGPM	
						2.11	DIAP	
						1.97	DIAV	
		200	–	–	B	200.00	FU	
						300.00	ΣFU	
						107.71	GPM	
						107.71	ΣGPM	
						2.53	DIAP	
						2.51	DIAV	
		50	–	2nd	B′	50.00	EGPM	
		300	–	–	B	300.00	FU	
						600.00	ΣFU	
						139.15	GPM	
						189.15	ΣGPM	
						3.14	DIAP	
						3.33	DIAV	

SEP-3 *(Continued)*
WATER SYSTEM PIPE SIZING PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 4							
1.	Initialize	0	–	2nd	E′	0.00		
	Repeat steps 2 through 9 as many times as desired.	135	–	2nd	C′	135.00	C	Flush tanks: high consumption
		4	–	2nd	A′	4.00	FT/H	
		1.5	–	2nd	D′	1.50	FF	
		32	–	–	R/S	32.00	PD	
		372	–	–	R/S	372.00	L	
						5.73	PD/C	
		6	–	–	A	6.00	FPS	
		300	–	–	B	300.00	FU	
						300.00	ΣFU	
						87.00	GPM	
						87.00	ΣGPM	
						2.46	DIAP	
						2.44	DIAV	
		400	–	–	B	400.00	FU	
						700.00	ΣFU	
						142.40	GPM	
						142.40	ΣGPM	
						2.97	DIAP	
						3.12	DIAV	
		95	–	2nd	B′	95.00	EGPM	
						500.00	FU	
						1200.00	ΣFU	
						173.40	GPM	
						268.40	ΣGPM	
						3.78	DIAP	
						4.28	DIAV	

	Example 5							
1.	Initialize	0	—	2nd	E′	0.00		Illustrates use of program for pipe sizing.
2.	Enter *C* value	130	—	2nd	C′	130.00	C	
3.	Enter factor for ftgs. or safety	1.25	—	2nd	D′	1.25	FF	
4.	Enter available pressure drop, ft	4.5	—	—	R/S	4.50	PD	
5.	Enter system length, ft	100	—	—	R/S	100.00	L	
						3.60	PD/C	
6.	Enter desired velocity, fps	6	—	—	A	6.00	FPS	
7.	Enter gpm	120	—	—	C	120.00	ΣGPM	
						3.11	DIAP	Diameter based on friction loss
						2.86	DIAV	Diameter based on velocity
	Repeat step 7 as many times as desired.	15	—	—	C	15.00	ΣGPM	
						1.41	DIAP	
						1.01	DIAV	
		3	—	—	C	3.00	ΣGPM	
						0.77	DIAP	
						0.45	DIAV	
8.	Enter pipe inside diameter, in.	2.5	—	—	D	2.50	DIA	
						67.53	GPMP	Gal/min based on friction loss
						91.46	GPMV	Gal/min based on velocity
	Repeat step 8 as many times as desired.	5.00	—	—	D	5.00	DIA	
						418.03	GPMP	
						365.85	GPMV	
		.75	—	—	D	0.75	DIA	
						2.85	GPMP	
						8.23	GPMV	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E′	Initializes; prints out; partitions program
B′	Sums constant equipment flow and prints equipment GPM
C′	Stores and prints C value
A′	Selects type FU/GPM curve
D′	Stores and prints fitting factor;
	with R/S, stores and prints total PD;
	with R/S, prints length, computes and prints PD/C, calculates flow QP1 through 1-in. diameter pipe based on friction loss criteria
A	Stores and prints maximum velocity and computes flow QV1 through 1-in. diameter pipe based on velocity criteria
B	Stores and prints FU; sums and prints running total of fixture units; computes and prints GPM; sums equipment GPM and calls SBR C
C	Prints GPM; computes and prints diameter based on pressure loss DIAP and diameter based on velocity DIAV
D	Prints DIA; computes and prints GPM based on pressure loss GPMP and GPM based on velocity GPMV
INV	Prints alphanumeric characters for identification of data
LNX	Prints FV/G and calls SBR X⇄T; SBR $\sqrt{X}$
CE	Prints FT/G and calls SBR X^2; SBR $\sqrt{X}$
CLR	Prints FV/H and calls SBR X⇄T; SBR 1/X
X⇄T	See tables under "Reference Data"
X^2	See tables under "Reference Data"
$\sqrt{X}$	See tables under "Reference Data"
1/X	See tables under "Reference Data"

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For RCL IND for finding GPM
R01	Not used
R02	Fitting or safety factor
R03	Total PD; pressure drop/100 ft; QPI
R04	C Value
R05	Constant flow from equipment
R06	Not used
R07	VMAX; QV1
R08	FU
R09	ΣFU
R10	Interim values for numbers in tables
R11	Interim values for numbers in tables
R12	GPM from fixture units; diameter
R13	Not used
R14	Alphanumeric code
R15–R26	For storage of tables

SEP-3 WATER SYSTEM PIPE SIZING PROGRAM

LABELS & SUBROUTINES

```
001  10 E'
016  17 B'
034  18 C'
046  16 A'
075  19 D'
162  11  A
185  12  B
219  42 STO
304  13  C
372  14  D
432  22 INV
449  23 LNX
468  24 CE
487  25 CLR
507  32 X:T
544  33 X²
587  34 ГX
646  35 1/X
```

LISTING

```
000  76 LBL
001  10 E'
002  00  0
003  42 STO
004  05  05
005  42 STO
006  09  09
007  99 PRT
008  98 ADV
009  22 INV
010  58 FIX
011  03  3
012  69 OP
013  17  17
014  91 R/S
015  76 LBL
016  17 B'
017  44 SUM
018  05  05
019  32 X:T
020  01  1
021  07  7
022  02  2
023  02  2
024  03  3
025  03  3
026  03  3
027  00  0
028  42 STO
029  14  14
030  71 SBR
031  22 INV
032  91 R/S
033  76 LBL
034  18 C'
035  42 STO
036  04  04
037  32 X:T
038  01  1
039  05  5
040  42 STO
041  14  14
042  71 SBR
043  22 INV
044  91 R/S
045  76 LBL
```

```
046  16  A'
047  32  X:T
048  01   1
049  67   EQ
050  23  LNX
051  02   2
052  67   EQ
053  24  CE
054  03   3
055  67   EQ
056  25  CLR
057  02   2
058  01   1
059  03   3
060  07   7
061  06   6
062  03   3
063  02   2
064  03   3
065  42  STO
066  14   14
067  71  SBR
068  22  INV
069  71  SBR
070  33  X²
071  71  SBR
072  35  1/X
073  91  R/S
074  76  LBL
075  19  D'
076  42  STO
077  02   02
078  32  X:T
079  02   2
080  01   1
081  02   2
082  01   1
083  42  STO
084  14   14
085  71  SBR
086  22  INV
087  91  R/S
088  42  STO
089  03   03
090  32  X:T
091  03   3
092  03   3
093  01   1
094  06   6
095  42  STO
096  14   14
097  71  SBR
098  22  INV
099  91  R/S
100  32  X:T
101  02   2
102  07   7
103  42  STO
104  14   14
105  71  SBR
106  22  INV
107  65   ×
108  43  RCL
109  02   02
110  55   ÷
111  01   1
112  00   0
113  00   0
114  95   =
115  35  1/X
116  65   ×
117  43  RCL
118  03   03
119  95   =
120  42  STO
121  03   03
122  32  X:T
123  03   3
124  03   3
125  01   1
126  06   6
127  06   6
128  03   3
129  01   1
130  05   5
131  42  STO
132  14   14
133  71  SBR
134  22  INV
135  53   (
136  43  RCL
137  04   04
138  65   ×
139  53   (
140  53   (
141  43  RCL
142  03   03
143  55   ÷
144  01   1
145  00   0
146  04   4
147  04   4
148  54   )
149  22  INV
150  45  YX
151  01   1
152  93   .
153  08   8
154  05   5
155  54   )
156  54   )
157  42  STO
158  03   03
159  98  ADV
160  91  R/S
161  76  LBL
162  11   A
163  42  STO
164  07   07
165  32  X:T
166  02   2
167  01   1
168  03   3
169  03   3
170  03   3
171  06   6
172  42  STO
173  14   14
174  71  SBR
175  22  INV
176  93   .
177  04   4
178  01   1
179  22  INV
180  49  PRD
181  07   07
182  98  ADV
183  91  R/S
184  76  LBL
185  12   B
186  98  ADV
187  42  STO
188  08   08
189  32  X:T
190  02   2
191  01   1
192  04   4
193  01   1
194  42  STO
195  14   14
196  71  SBR
197  22  INV
198  44  SUM
199  09   09
200  43  RCL
201  09   09
202  32  X:T
203  07   7
204  07   7
205  02   2
206  01   1
207  04   4
208  01   1
209  42  STO
210  14   14
211  71  SBR
212  22  INV
213  32  X:T
214  01   1
215  04   4
216  42  STO
217  00   00
218  76  LBL
219  42  STO
220  69  OP
221  20   20
222  73  RC*
223  00   00
224  59  INT
225  22  INV
226  77   GE
227  42  STO
228  73  RC*
229  00   00
230  42  STO
231  10   10
232  69  OP
233  30   30
234  73  RC*
235  00   00
236  42  STO
237  11   11
238  53   (
239  53   (
240  43  RCL
241  10   10
242  22  INV
243  59  INT
244  75   -
245  43  RCL
246  11   11
247  22  INV
248  59  INT
249  54   )
250  65   ×
251  53   (
252  43  RCL
253  09   09
254  75   -
255  43  RCL
256  11   11
257  59  INT
258  54   )
259  55   ÷
260  53   (
261  43  RCL
262  10   10
263  59  INT
264  75   -
265  43  RCL
266  11   11
267  59  INT
268  54   )
269  85   +
270  43  RCL
271  11   11
272  22  INV
273  59  INT
274  54   )
275  65   ×
276  01   1
277  00   0
278  00   0
279  00   0
280  95   =
281  42  STO
282  12   12
283  32  X:T
284  02   2
285  02   2
286  03   3
287  03   3
288  03   3
289  00   0
290  42  STO
291  14   14
292  71  SBR
293  22  INV
294  43  RCL
295  05   05
296  44  SUM
297  12   12
298  43  RCL
299  12   12
300  71  SBR
301  13   C
302  91  R/S
303  76  LBL
304  13   C
305  98  ADV
```

```
306  42  STO
307  12   12
308  32  X:T
309  07   7
310  07   7
311  02   2
312  02   2
313  03   3
314  03   3
315  03   3
316  00   0
317  42  STO
318  14   14
319  71  SBR
320  22  INV
321  53   (
322  53   (
323  43  RCL
324  12   12
325  55   ÷
326  43  RCL
327  03   03
328  54   )
329  45  Y^X
330  93   .
331  03   3
332  08   8
333  54   )
334  32  X:T
335  01   1
336  06   6
337  02   2
338  04   4
339  01   1
340  03   3
341  03   3
342  03   3
343  42  STO
344  14   14
345  71  SBR
346  22  INV
347  53   (
348  53   (
349  43  RCL
350  12   12
351  55   ÷
352  43  RCL
353  07   07
354  54   )
355  54   )
356  34  √X
357  32  X:T
358  01   1
359  06   6
360  02   2
361  04   4
362  01   1
363  03   3
364  04   4
365  02   2
366  42  STO
367  14   14
368  71  SBR
369  22  INV
370  91  R/S
371  76  LBL
372  14   D
373  98  ADV
374  42  STO
375  12   12
376  32  X:T
377  01   1
378  06   6
379  02   2
380  04   4
381  01   1
382  03   3
383  42  STO
384  14   14
385  71  SBR
386  22  INV
387  45  Y^X
388  02   2
389  93   .
390  06   6
391  03   3
392  65   ×
393  43  RCL
394  03   03
395  95   =
396  32  X:T
397  02   2
398  02   2
399  03   3
400  03   3
401  03   3
402  00   0
403  03   3
404  03   3
405  42  STO
406  14   14
407  71  SBR
408  22  INV
409  43  RCL
410  12   12
411  33  X^2
412  65   ×
413  43  RCL
414  07   07
415  95   =
416  32  X:T
417  02   2
418  02   2
419  03   3
420  03   3
421  03   3
422  00   0
423  04   4
424  02   2
425  42  STO
426  14   14
427  71  SBR
428  22  INV
429  98  ADV
430  91  R/S
431  76  LBL
432  22  INV
433  22  INV
434  58  FIX
435  25  CLR
436  69  OP
437  00   00
438  43  RCL
439  14   14
440  69  OP
441  04   04
442  32  X:T
443  58  FIX
444  02   02
445  69  OP
446  06   06
447  92  RTN
448  76  LBL
449  23  LNX
450  02   2
451  01   1
452  04   4
453  02   2
454  06   6
455  03   3
456  02   2
457  02   2
458  42  STO
459  14   14
460  71  SBR
461  22  INV
462  71  SBR
463  32  X:T
464  71  SBR
465  34  √X
466  92  RTN
467  76  LBL
468  24  CE
469  02   2
470  01   1
471  03   3
472  07   7
473  06   6
474  03   3
475  02   2
476  02   2
477  42  STO
478  14   14
479  71  SBR
480  22  INV
481  71  SBR
482  33  X^2
483  71  SBR
484  34  √X
485  92  RTN
486  76  LBL
487  25  CLR
488  02   2
489  01   1
490  04   4
491  02   2
492  06   6
493  03   3
494  02   2
495  03   3
496  42  STO
497  14   14
498  71  SBR
499  22  INV
500  71  SBR
501  32  X:T
502  71  SBR
503  35  1/X
504  92  RTN
505  92  RTN
506  76  LBL
507  32  X:T
508  93   .
509  00   0
510  02   2
511  05   5
512  42  STO
513  15   15
514  05   5
515  05   5
516  93   .
517  00   0
518  05   5
519  02   2
520  42  STO
521  16   16
522  01   1
523  02   2
524  00   0
525  93   .
526  00   0
527  07   7
528  03   3
529  42  STO
530  17   17
531  04   4
532  00   0
533  00   0
534  93   .
535  01   1
536  02   2
537  07   7
538  42  STO
539  18   18
540  42  STO
541  19   19
542  92  RTN
543  76  LBL
544  33  X^2
545  93   .
546  00   0
547  00   0
548  02   2
549  42  STO
550  15   15
551  01   1
552  00   0
553  93   .
554  00   0
555  01   1
556  05   5
557  42  STO
558  16   16
559  04   4
560  00   0
561  93   .
562  00   0
563  02   2
564  06   6
565  42  STO
```

566	17	17
567	01	1
568	00	0
569	00	0
570	93	.
571	00	0
572	04	4
573	04	4
574	42	STO
575	18	18
576	05	5
577	00	0
578	00	0
579	93	.
580	01	1
581	03	3
582	00	0
583	42	STO
584	19	19
585	92	RTN
586	76	LBL
587	34	√X
588	03	3
589	00	0
590	00	0
591	00	0
592	93	.
593	02	2
594	06	6
595	05	5
596	42	STO
597	20	20
598	04	4
599	00	0
600	00	0
601	00	0
602	93	.
603	03	3
604	02	2
605	42	STO
606	21	21
607	05	5
608	00	0
609	00	0
610	00	0
611	93	.
612	03	3
613	08	8
614	42	STO
615	22	22
616	06	6
617	00	0
618	00	0
619	00	0
620	93	.
621	04	4
622	03	3
623	05	5
624	42	STO
625	23	23
626	07	7
627	00	0
628	00	0
629	00	0
630	93	.
631	04	4
632	09	9
633	42	STO
634	24	24
635	08	8
636	00	0
637	00	0
638	00	0
639	93	.
640	05	5
641	04	4
642	42	STO
643	25	25
644	92	RTN
645	76	LBL
646	35	1/X
647	03	3
648	00	0
649	00	0
650	00	0
651	93	.
652	02	2
653	08	8
654	05	5
655	42	STO
656	20	20
657	04	4
658	00	0
659	00	0
660	00	0
661	93	.
662	03	3
663	06	6
664	05	5
665	42	STO
666	21	21
667	05	5
668	00	0
669	00	0
670	00	0
671	93	.
672	04	4
673	03	3
674	42	STO
675	22	22
676	06	6
677	00	0
678	00	0
679	00	0
680	93	.
681	04	4
682	09	9
683	42	STO
684	23	23
685	08	8
686	00	0
687	00	0
688	00	0
689	93	.
690	06	6
691	42	STO
692	24	24
693	01	1
694	00	0
695	00	0
696	00	0
697	00	0
698	93	.
699	07	7
700	02	2
701	42	STO
702	25	25
703	01	1
704	03	3
705	00	0
706	00	0
707	00	0
708	93	.
709	08	8
710	07	7
711	05	5
712	42	STO
713	26	26
714	92	RTN
715	00	0
716	00	0
717	00	0
718	00	0
719	00	0

SPECIAL NOTES FOR HP-97 USERS

1. In addition to the basic Program SEP-3, the program requires four additional data cards as outlined below:

SEP-3A LISTING

Data card for buildings with relatively high water consumption—with flush valves.

0.025	0
55.052	1
120.073	2
400.127	3
3000.286	4
4000.365	5
5000.430	6
6000.490	7
8000.600	8
10000.720	9

SEP-3B LISTING

Data card for buildings with relatively high water consumption—with flush tanks.

0.002	0
10.015	1
40.026	2
100.044	3
500.130	4
3000.286	5
4000.365	6
5000.430	7
6000.490	8
8000.600	9

SEP-3C LISTING

Data card for buildings with relatively low water consumption—with flush valves.

0.025	0
55.052	1
120.073	2
400.127	3
3000.265	4
4000.320	5
5000.380	6
6000.435	7
7000.490	8
8000.540	9

SEP-3D LISTING

Data Card for buildings with relatively low water consumption—with flush tanks.

0.002	0
10.015	1
40.026	2
100.044	3
500.130	4
3000.265	5
4000.320	6
5000.380	7
6000.435	8
7000.490	9

2. All the data is stored in the secondary registers. The data is printed by P⇄S operation.
3. The appropriate data card should be loaded together with the program.
4. Users should compare the above data with the table given under the "Program Description" to see the limit of sizing.

SEP-3
WATER SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE for Program   FOUR for Data

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
	This example is based on data card SEP-3C.						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Enter *C* value	130	–	*f*	C	130.00 ***	
3.	Enter safety factor	1.25	–	*f*	D	1.25 ***	
4.	Enter available pressure, ft	25	–	–	R/S	25.00 ***	
5.	Enter system length, ft	285	–	–	R/S	285.00 ***	
						7.02 ***	Pressure drop, ft/100 ft
6.	Enter maximum velocity	7	–	–	A	7.00 ***	
7.	Enter fixture units	25	–	–	B	25.00 ***	Fixture units
						25.00 ***	Total fixture units
						37.27 ***	Gal/min
						37.27 ***	Gal/min
						1.74 ***	Diameter based on pressure
						1.48 ***	Diameter based on velocity
	Repeat step 7 as many times as desired.	35	–	–	B	35.00 ***	
						60.00 ***	
						53.62 ***	
						53.62 ***	
						2.00 ***	
						1.77 ***	
8.	To add flow of equipment having constant load, enter gpm as in step 7	25	–	*f*	B	25.00 ***	
		50	–	–	B	50.00 ***	

SEP-3 *(Continued)*

WATER SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE for Program FOUR for Data

Step	Procedure	Enter	Press			Print Out	Explanation
						110.00 ***	Gal/min based on fixture units
						69.77 ***	
						94.77 ***	Gal/min total including equipment
						2.48 ***	
						2.36 ***	
	Example 2						
	Based on data card SEP-3D	—	—	*f*	E	0.00 ***	
	Same steps as Example no. 1	135	—	*f*	C	135.00 ***	
		1.2	—	*f*	D	1.20 ***	
		30	—	—	R/S	30.00 ***	
		250	—	—	R/S	250.00 ***	
						10.00 ***	
		6.5	—	—	A	6.50 ***	
		150	—	—	B	150.00 ***	
						150.00 ***	
						54.75 ***	
						54.75 ***	
						1.84 ***	
						1.86 ***	
		250	—	—	B	250.00 ***	
						400.00 ***	
						108.50 ***	
						108.50 ***	
						2.39 ***	
						2.62 ***	

		75	–	f	B	75.00 ***	
		275	–	–	B	275.00 ***	
						675.00 ***	
						139.45 ***	
						214.45 ***	
						3.10 ***	
						3.68 ***	
	Example 3						
	Based on data card SEP-3A						
		–	–	f	E	0.00 ***	
	Same steps as Example no. 1	135	–	f	C	135.00 ***	
		1.3	–	f	D	1.30 ***	
		28	–	–	R/S	28.00 ***	
		290	–	–	R/S	290.00 ***	
						7.43 ***	
		7	–	–	A	7.00 ***	
						100.00 ***	
		100	–	–	B	100.00 ***	
						66.54 ***	
						66.54 ***	
						2.11 ***	
						1.97 ***	
	Example 4						
	Based on data card SEP-3B						
		–	–	f	E	0.000 ***	
	Same steps as Example no. 1	135	–	f	C	135.000 ***	
		1.5	–	f	D	1.500 ***	
		32	–	–	R/S	32.000 ***	
		372	–	–	R/S	372.000 ***	
						5.735 ***	

SEP-3 *(Continued)*

WATER SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE for Program   FOUR for Data

Step	Procedure	Enter	Press			Print Out	Explanation
		6	–	–	A	6.000 ***	
		300	–	–	B	300.000 *** 300.000 *** 87.000 *** 87.000 *** 2.465 *** 2.438 ***	
		400	–	–	B	400.000 *** 700.000 *** 142.480 *** 142.480 *** 2.973 *** 3.120 ***	
		200	–	–	B	200.00 *** 300.00 *** 107.71 *** 107.71 *** 2.53 *** 2.51 ***	
		50	–	*f*	B	50.00 ***	
		300	–	–	B	300.00 *** 600.00 *** 139.23 *** 139.23 *** 3.14 *** 3.33 ***	

		95	—	*f*	B	95.000 ***	
		500	—	—	B	500.000 ***	
						1200.000 *** 173.660 ***	
						268.680 *** 3.783 *** 4.285 ***	
	Example 5						
	Data card not required; sizing only						
1.	Initialize	—	—	*f*	E	0.000 ***	
2.	Enter *C* value	130	—	*f*	C	130.000 ***	
3.	Enter safety factor	1.25	—	*f*	D	1.250 ***	
4.	Enter available pressure, ft	4.5	—	—	R/S	4.500 ***	
5.	Enter system length, ft	100	—	—	R/S	100.000 *** 3.600 ***	 Pressure drop, ft/100 ft
6.	Enter maximum velocity	6	—	—	A	6.000 ***	
7.	Enter gpm	120	—	—	C	120.000 *** 3.109 *** 2.864 ***	 Diameter based on pressure Diameter based on velocity
	or						
7.	Enter gpm	15	—	—	C	15.000 *** 1.411 *** 1.012 ***	
	or						
7.	Enter gpm	3	—	—	C	3.000 *** 0.765 *** 0.453 ***	

SEP-3 *(Continued)*

WATER SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE for Program FOUR for Data

Step	Procedure	Enter	Press			Print Out	Explanation
8.	Enter diameter	2.5	–	–	D	2.50 ***	
						67.53 ***	Gal/min based on pressure
						91.46 ***	Gal/min based on velocity
	or						
8.	Enter diameter	5	–	–	D	5.00 ***	
						416.03 ***	
						365.85 ***	
	or						
8.	Enter diameter	.75	–	–	D	0.75 ***	
						2.85 ***	
						8.23 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints and stores display in R7; computes flow QV1 through 1-in. diameter pipe based on velocity
b	Prints and totalizes display (constant equipment flow) in R5
c	Prints and stores display in R4
d	Prints and stores display in R2; with R/S, prints and stores display in R3; with R/S, prints display (length), computes and prints pressure drop/100 ft, computes flow QP1 through 1-in. diameter pipe based on friction loss criteria
e	Clears registers R5 and R9
B	Prints and stores display (fixture units) in R8; totalizes in R9 and prints value of R9; using LBL 0, computes and prints GPM corresponding to R9; adds equipment GPM; goes to SBR C
C	Computes and prints pipe size based on maximum velocity and maximum friction loss criteria
D	Prints and stores display (diameter) in RC; computes flow based on maximum friction loss criteria

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	Not used
R2	Safety factor or factor for fittings, etc.
R3	Total pressure drop; pressure drop/100 ft
R4	C value
R5	Totalized flow in GPM
R6	Not used
R7	VMAX; QV1
R8	Fixture units
R9	Fixture units totalized
RA	Interim value
RB	Interim value
RC	GPM calculated; also diameter
RD	Not used
RE	Not used
R10–R19	For storing table of fixture units and GPM

SEP-3 (HP-97) WATER SYSTEM PIPE SIZING PROGRAM

LISTING

```
001  *LBLA     21 11
002   STO7     35 07
003   PRTX       -14
004      .       -62
005      4        04
006      1        01
007  ST÷7   35-24 07
008    SPC     16-11
009    RTN        24
010  *LBLb  21 16 12
011   PRTX       -14
012   ST+5  35-55 05
013    SPC     16-11
014    RTN        24
015  *LBLc  21 16 13
016   STO4     35 04
017   PRTX       -14
018    RTN        24
019  *LBLd  21 16 14
020   STO2     35 02
021   PRTX       -14
022    RTN        24
023   STO3     35 03
024   PRTX       -14
025    RTN        24
026   PRTX       -14
027   RCL2     36 02
028      x       -35
029      1        01
030      0        00
031      0        00
032      ÷       -24
033    1/X        52
034   ST×3  35-35 03
035   RCL3     36 03
036   PRTX       -14
037      1        01
038      0        00
039      4        04
040      4        04
041      ÷       -24
042      1        01
043      .       -62
044      8        08
045      5        05
046    1/X        52
047     Yˣ        31
048   RCL4     36 04
049      x       -35
050   STO3     35 03
051    SPC     16-11
052    RTN        24
053  *LBLe  21 16 15
054      0        00
055   STO5     35 05
056   STO9     35 09
057    CLX       -51
058   PRTX       -14
059    SPC     16-11
060    SPC     16-11
061    RTN        24
062  *LBLB     21 12
063   STO8     35 08
064   PRTX       -14
065    SPC     16-11
066   ST+9  35-55 09
067   RCL9     36 09
068   PRTX       -14
069      9        09
070   STOI     35 46
071  *LBL0     21 00
072   ISZI  16 26 46
073   RCLi     36 45
074   STOA     35 11
075    INT     16 34
076   RCL9     36 09
077   X>Y?     16-34
078   GTO0     22 00
079   DSZI  16 25 46
080   RCLi     36 45
081   STOB     35 12
082    FRC     16 44
083   RCLA     36 11
084    FRC     16 44
085      -       -45
```

```
086   CHS      -22
087   RCL9   36 09
088   RCLB   36 12
089   INT    16 34
090   -        -45
091   x        -35
092   RCLA   36 11
093   INT    16 34
094   RCLB   36 12
095   INT    16 34
096   -        -45
097   ÷        -24
098   RCLB   36 12
099   FRC    16 44
100   +        -55
101   1         01
102   0         00
103   0         00
104   0         00
105   x        -35
106   STOC   35 13
107   PRTX     -14
108   RCL5   36 05
109   RCLC   36 13
110   +        -55
111   STOC   35 13
112   GSBC   23 13
113   SPC    16-11
114   SPC    16-11
115   RTN       24
116   *LBLC  21 13
117   SPC    16-11
118   STOC   35 13
119   PRTX     -14
120   RCLC   36 13
121   RCL3   36 03
122   ÷        -24
123   .        -62
124   3         03
125   8         08
126   Yx        31
127   PRTX     -14
128   RCLC   36 13
129   RCL7   36 07
130   ÷        -24
131   √X        54
132   PRTX     -14
133   SPC    16-11
134   SPC    16-11
135   RTN       24
136   *LBLD  21 14
137   SPC    16-11
138   STOC   35 13
139   PRTX     -14
140   2         02
141   .        -62
142   6         06
143   3         03
144   Yx        31
145   RCL3   36 03
146   x        -35
147   PRTX     -14
148   RCLC   36 13
149   X²        53
150   RCL7   36 07
151   x        -35
152   PRTX     -14
153   SPC    16-11
154   RTN       24
155   R/S       51
```

SEP-4
GAS SYSTEM PIPE SIZING PROGRAM

GENERAL DESCRIPTION

This program can size vertical and horizontal gas piping for apartment houses. The program is based on Polyflo formula for natural gas used for the development of Table 1-B2 of the National Fire Protection Association #54 Industrial Gas Code.

EQUATIONS

$$Q_h = 2313\, d^{2.623} \times (h/CL)^{.541} \qquad [4.2]$$

where

Q_h = Gas flow rate, cu ft/hr, at 60° F and 30 inches Hg
d = Inside diameter, in.
h = Pressure drop, in. w.g.
C = Factor for viscosity, density, and temperature; 0.595 for 0.6 specific gravity for paraffin-based gas at 60°F
L = Length of pipe in feet

Apartment house gas usage = 65,000 Btu/hr/Apt [4.3]

$$\text{Diversity factor in percent} = \frac{95}{(\Sigma \text{Apt})^{.4}} \qquad [4.4]$$

Vertical pipe is sized for pressure gain of 0.1 in. w.g. for 15-ft vertical rise.

OPERATING FEATURES

It is essential to initialize the program before sizing any distribution system or starting a new distribution system.

In addition to the gas consumed by the apartment, the program will also add continuously and constant gas required for the equipment to the diversified flow of the apartments.

The type of distribution system, either "vertical" or "horizontal," can be changed while designing a distribution system.

Individual pipe sizes for each apartment or for equipment can be computed by initializing each time, since otherwise the program works with the running total flow. While sizing pipe for the equipment, input the number of apartments as zero. The procedure is further explained under "User Instructions and Examples."

REFERENCE DATA

None.

SEP-4
GAS SYSTEM PIPE SIZING PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Initialize	0	–	2nd	E′	0.00		
2.	Input maximum p.d., in. w.g.	0.3	–	2nd	A′	0.30	PD	
3.	Input gas calorific value	1000	–	2nd	B′	1000.00	BTU	
4.	Input total system length, ft	200	–	2nd	C′	200.00	TOTL	
5.	Input 1 for vert. distribution or 2 for horiz. distribution	1	–	2nd	D′	1.00	VERT	Vert. distribution
6.	Input no. of apartments in distribution systems starting from beginning	1	–	–	A	1.00	APT	
						1.00	ΣAPT	Total apartments
						61.75	ACFH	Apartment gas, cfh
						61.75	ΣCFH	Total gas, cfh
						0.64	DIAC	Computed diameter
						0.75	DIA	Pipe size available
	Repeat step 6. Input number of apartments at next node.	6	–	–	A	6.00	APT	
						7.00	ΣAPT	
						198.47	ACFH	
						198.47	ΣCFH	
						0.99	DIAC	
						1.00	DIA	
	Repeat step 6. Input number of apartments at next node.	9	–	–	A	9.00	APT	
						16.00	ΣAPT	
						325.92	ACFH	
						325.92	ΣCFH	
						1.20	DIAC	
						1.25	DIA	
7.	If calculation is desired for horiz. distribution system	2	–	2nd	D′	2.00	HORZ	Horiz. distribution
8.	If distribution system has constant gas load, enter Btu/hr	90000	–	–	E	90000.00	EBTU	Const. equipment load, Btu/hr
						90.00	ECFH	Equipment cfh
						90.00	ΣEGH	Total equipment cfh

9.	To size for combination of equipment and previous apartments, input 0 apartments	0	–	–	A	0.00 APT 16.00 ΣAPT 325.92 ACFH 415.92 ΣCFH 1.79 DIAC 2.00 DIA	Adds 90 cfh to apartment load
10.	Continue sizing; input number of apartments	10	–	–	A	10.00 APT 26.00 ΣAPT 436.14 ACFH 526.14 ΣCFH 1.96 DIAC 2.00 DIA	
11.	To start new distribution, initialize	–	–	2nd	E′	0.00	
12.	Input load, Btu/hr	15000	–	–	E	150000.00 EBTU 150.00 ECFH 150.00 ΣEGH	
13.	Input number of apartments as 0	0	–	–	A	0.00 APT 0.00 ΣAPT 0.00 ACFH 150.00 ΣCFH 0.89 DIAC 1.00 DIA	Equipment connection
14.	Initialize for next branch	–	–	2nd	E	0.00	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A′	Stores and prints maximum pressure drop, in. w.g.
B′	Stores and prints calorific value in BTU
C′	Stores and prints total system length
D′	If vertical, goes to SBR X⇄T; for horizontal calculates ratio of length/PD
X⇄T	Use length/PD ratio 150 for vertical pipe
A	Prints APT and ΣAPT; calculates diversity factor; calculates and prints apartment gas ACFH: adds equipment gas; calculates and prints ΣCFH; calculates diameter and prints DIAC; finds and prints actual pipe diameter
CLR	Reiterates for finding actual pipe diameter
INV	Prints alphanumeric characters for identification of data
LNX	Computes pipe diameter
CE	Table for pipe sizes
E′	Initializes
E	Prints equipment gas load in BTU; converts into CFH and prints equipment gas load ECFH; calculates and prints total equipment gas load ΣCFH

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For RCL IND
R01	Maximum PD for system, in. w.g.
R02	Gas calorific value, Btu/cu ft
R03	System length
R04	For selecting vertical or horizontal
R05	Ratio of length/PD
R06	Total number of apartments
R07	Gas, cu ft
R08	Alphanumeric code
R09	Total equipment CFH
R10–R18	Pipe sizes 0.5 thru 4 in.

SEP-4 GAS SYSTEM PIPE SIZING PROGRAM

LABELS & SUBROUTINES

```
001  16  A'
015  17  B'
031  18  C'
049  19  D'
082  32  X:T
102  11   A
208  25  CLR
233  22  INV
250  23  LNX
286  24  CE
326  10  E'
336  15   E
```

LISTING

```
000  76  LBL
001  16  A'
002  42  STO
003  01   01
004  32  X:T
005  03   3
006  03   3
007  01   1
008  06   6
009  42  STO
010  08   08
011  71  SBR
012  22  INV
013  91  R/S
014  76  LBL
015  17  B'
016  42  STO
017  02   02
018  32  X:T
019  01   1
020  04   4
021  03   3
022  07   7
023  04   4
024  01   1
025  42  STO
026  08   08
027  71  SBR
028  22  INV
029  91  R/S
030  76  LBL
031  18  C'
032  42  STO
033  03   03
034  32  X:T
035  03   3
036  07   7
037  03   3
038  02   2
039  03   3
040  07   7
041  02   2
042  07   7
043  42  STO
044  08   08
045  71  SBR
046  22  INV
047  91  R/S
048  76  LBL
049  19  D'
050  42  STO
051  04   04
052  32  X:T
053  01   1
054  67  EQ
055  32  X:T
056  43  RCL
057  03   03
058  55   ÷
059  43  RCL
060  01   01
061  95   =
062  42  STO
063  05   05
064  43  RCL
065  04   04
066  32  X:T
067  02   2
068  03   3
069  03   3
070  02   2
071  03   3
072  05   5
073  04   4
074  06   6
075  42  STO
076  08   08
077  71  SBR
078  22  INV
079  98  ADV
080  91  R/S
081  76  LBL
082  32  X:T
083  04   4
084  02   2
085  01   1
086  07   7
087  03   3
088  05   5
089  03   3
090  07   7
091  42  STO
092  08   08
093  71  SBR
094  22  INV
095  01   1
096  05   5
097  00   0
098  42  STO
099  05   05
100  92  RTN
101  76  LBL
102  11   A
103  98  ADV
104  32  X:T
105  01   1
106  03   3
107  03   3
```

```
108  03  3
109  03  3
110  07  7
111  42  STO
112  08  08
113  71  SBR
114  22  INV
115  44  SUM
116  06  06
117  43  RCL
118  06  06
119  32  X⇌T
120  07  7
121  07  7
122  01  1
123  03  3
124  03  3
125  03  3
126  03  3
127  07  7
128  42  STO
129  08  08
130  71  SBR
131  22  INV
132  45  YX
133  93  .
134  04  4
135  95  =
136  35  1/X
137  65  ×
138  93  .
139  09  9
140  05  5
141  65  ×
142  06  6
143  05  5
144  00  0
145  00  0
146  00  0
147  65  ×
148  43  RCL
149  06  06
150  55  ÷
151  43  RCL
152  02  02
153  95  =
154  32  X⇌T
155  01  1
156  03  3
157  01  1
158  05  5
159  02  2
160  01  1
161  02  2
162  03  3
163  42  STO
164  08  08
165  71  SBR
166  22  INV
167  85  +
168  43  RCL
169  09  09
170  95  =
171  42  STO
172  07  07
173  32  X⇌T
174  07  7
175  07  7
176  01  1
177  05  5
178  02  2
179  01  1
180  02  2
181  03  3
182  42  STO
183  08  08
184  71  SBR
185  22  INV
186  71  SBR
187  23  LNX
188  32  X⇌T
189  01  1
190  06  6
191  02  2
192  04  4
193  01  1
194  03  3
195  01  1
196  05  5
197  42  STO
198  08  08
199  71  SBR
200  22  INV
201  32  X⇌T
202  71  SBR
203  24  CE
204  09  9
205  42  STO
206  00  00
207  76  LBL
208  25  CLR
209  69  OP
210  20  20
211  73  RC*
212  00  00
213  22  INV
214  77  GE
215  25  CLR
216  73  RC*
217  00  00
218  32  X⇌T
219  01  1
220  06  6
221  02  2
222  04  4
223  01  1
224  03  3
225  42  STO
226  08  08
227  71  SBR
228  22  INV
229  98  ADV
230  92  RTN
231  91  R/S
232  76  LBL
233  22  INV
234  22  INV
235  58  FIX
236  25  CLR
237  69  OP
238  00  00
239  43  RCL
240  08  08
241  69  OP
242  04  04
243  32  X⇌T
244  58  FIX
245  02  02
246  69  OP
247  06  06
248  92  RTN
249  76  LBL
250  23  LNX
251  53  (
252  53  (
253  43  RCL
254  07  07
255  55  ÷
256  02  2
257  03  3
258  01  1
259  03  3
260  65  ×
261  53  (
262  53  (
263  93  .
264  06  6
265  65  ×
266  43  RCL
267  05  05
268  54  )
269  45  YX
270  93  .
271  05  5
272  04  4
273  01  1
274  54  )
275  54  )
276  22  INV
277  45  YX
278  02  2
279  93  .
280  06  6
281  02  2
282  03  3
283  54  )
284  92  RTN
285  76  LBL
286  24  CE
287  93  .
288  05  5
289  42  STO
290  10  10
291  93  .
292  07  7
293  05  5
294  42  STO
295  11  11
296  01  1
297  42  STO
298  12  12
299  01  1
300  93  .
301  02  2
302  05  5
303  42  STO
304  13  13
305  01  1
306  93  .
307  05  5
308  42  STO
309  14  14
310  02  2
311  42  STO
312  15  15
313  02  2
314  93  .
315  05  5
316  42  STO
317  16  16
318  03  3
319  42  STO
320  17  17
321  04  4
322  42  STO
323  18  18
324  92  RTN
325  76  LBL
326  10  E'
327  00  0
328  42  STO
329  06  06
330  42  STO
331  09  09
332  99  PRT
333  98  ADV
334  91  R/S
335  76  LBL
336  15  E
337  98  ADV
338  32  X⇌T
339  01  1
340  07  7
341  01  1
342  04  4
343  03  3
344  07  7
345  04  4
346  01  1
347  42  STO
348  08  08
349  71  SBR
350  22  INV
351  55  ÷
352  43  RCL
353  02  02
354  95  =
355  32  X⇌T
356  01  1
357  07  7
358  01  1
359  05  5
360  02  2
361  01  1
362  02  2
363  03  3
```

```
364  42  STO        383  71  SBR
365  08   08        384  22  INV
366  71  SBR        385  98  ADV
367  22  INV        386  91  R/S
368  44  SUM        387  00   0
369  09   09        388  00   0
370  43  RCL        389  00   0
371  09   09        390  00   0
372  32  X:T        391  00   0
373  07   7         392  00   0
374  07   7         393  00   0
375  01   1         394  00   0
376  07   7         395  00   0
377  02   2         396  00   0
378  02   2         397  00   0
379  02   2         398  00   0
380  03   3         399  00   0
381  42  STO        400  00   0
382  08   08        401  00   0
```

SEP-4
GAS SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Input maximum p.d., in. w.g.	–	–	*f*	A	0.30 ***	
3.	Input gas calorific value	1000	–	*f*	B	1000.00 ***	
4.	Input total system length, ft	200	–	*f*	C	200.00 ***	
5.	Input 1 for vert. distribution	1	–	*f*	D	1.00 ***	
6.	Input number of apartments in distribution system starting from beginning of distribution	1	–	–	A	1.00 ***	
						1.00 ***	Total number of apartments
						61.75 ***	Apartment gas cfh
						61.75 ***	Total gas, cfh
						0.64 ***	Calculated diameter
						0.75 ***	Pipe size available
	Repeat step 6. Input number of apartments at next node.	6	–	–	A	6.00 ***	
						7.00 ***	
						198.47 ***	
						198.47 ***	
						0.99 ***	
						1.00 ***	
	Repeat step 6. Input number of apartments at next node.	9	–	–	A	9.00 ***	
						16.00 ***	
						325.92 ***	
						325.92 ***	
						1.20 ***	
						1.25 ***	
7.	If calculation is desired for horiz. system	2	–	*f*	D	2.00 ***	

SEP-4 *(Continued)*

GAS SYSTEM PIPE SIZING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
8.	If distribution system has constant gas load, enter Btu/hr	9000	—	—	—	90000.00 *** 90.00 *** 90.00 ***	Btu/hr Cubic ft/hr equipment Total cfh equipment
9.	To size for combination of equipment and previous apartments, input 0 for apartments	0	—	—	A	0.00 *** 16.00 *** 325.32 *** 415.32 *** 1.79 *** 2.00 ***	 Adds 90 cfh to apartment load
	Continue repeating step 6.	10	—	—	A	10.00 *** 26.00 *** 436.14 *** 526.14 *** 1.96 *** 2.00 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
a	Prints and stores display (maximum PD) in R1; calls SBR 2
b	Prints and stores display (calorific value in Btu) in R2
c	Prints and stores display (total system length) in R3
d	Prints and stores display in R4; if input = 1, goes to SBR 0, otherwise calculates ratio of length /PD and stores in R5
0	Stores 150 in R5
A	Prints display (number of apartments), totalizes in R6, and prints value of R6; calculates diversity factor; calculates and prints gas required for apartments; calculates and prints total gas required; calculates and prints pipe diameter by SBR 1; using LBL 3 finds actual pipe diameter
1	Calculates pipe diameter
2	Actual pipe size table; stores in secondary registers
e	Clears registers R6 and R9; prints zero
E	Prints display (equipment BTU), divides by R2, and totalizes in R9

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	Maximum PD for system, in. w.g.
R2	Gas calorific value, Btu/cu ft
R3	System length
R4	For selecting vertical or horizontal
R5	Ratio of length/PD
R6	Total number of apartments
R7	Gas, cu ft
R8	Not used
R9	Total equipment CFH
R10–R19	For pipe size table

SEP-4 (HP-97) GAS SYSTEM PIPE SIZING PROGRAM

LISTING

```
001  *LBLa   21 16 11
002  STO1       35 01
003  PRTX         -14
004  GSB2       23 02
005  RTN           24
006  *LBLb   21 16 12
007  STO2       35 02
008  PRTX         -14
009  RTN           24
010  *LBLc   21 16 13
011  STO3       35 03
012  PRTX         -14
013  RTN           24
014  *LBLd   21 16 14
015  STO4       35 04
016  PRTX         -14
017  1             01
018  X=Y?       16-33
019  GTO0       22 00
020  RCL3       36 03
021  RCL1       36 01
022  ÷            -24
023  STO5       35 05
024  SPC        16-11
025  RTN           24
026  *LBL0      21 00
027  1             01
028  5             05
029  0             00
030  STO5       35 05
031  RTN           24
032  *LBLA      21 11
033  SPC        16-11
034  PRTX         -14
035  ST+6    35-55 06
036  RCL6       36 06
037  PRTX         -14
038  .            -62
039  4             04
040  Yˣ            31
041  1/X           52
042  .            -62
043  9             09
044  5             05
045  x            -35
046  6             06
047  5             05
048  0             00
049  0             00
050  0             00
051  x            -35
052  RCL6       36 06
053  x            -35
054  RCL2       36 02
055  ÷            -24
056  PRTX         -14
057  RCL9       36 09
058  +            -55
059  STO7       35 07
060  PRTX         -14
061  GSB1       23 01
062  PRTX         -14
063  STO0       35 00
064  9             09
065  STOI       35 46
066  *LBL3      21 03
067  CLX          -51
068  ISZI    16 26 46
069  RCLi       36 45
070  RCL0       36 00
071  X>Y?       16-34
072  GTO3       22 03
073  RCLi       36 45
074  PRTX         -14
075  SPC        16-11
076  RTN           24
077  *LBL1      21 01
078  RCL5       36 05
079  .            -62
080  6             06
081  x            -35
082  .            -62
083  5             05
084  4             04
085  1             01
086  Yˣ            31
087  RCL7       36 07
088  x            -35
089  2             02
090  3             03
091  1             01
092  3             03
093  ÷            -24
094  2             02
095  .            -62
096  6             06
097  2             02
098  3             03
099  1/X           52
100  Yˣ            31
101  RTN           24
102  *LBL2      21 02
103  .            -62
104  5             05
105  STO0       35 00
106  .            -62
107  7             07
```

```
108      5        05
109   ST01     35 01
110      1        01
111   ST02     35 02
112      1        01
113      .       -62
114      2        02
115      5        05
116   ST03     35 03
117      1        01
118      .       -62
119      5        05
120   ST04     35 04
121      2        02
122   ST05     35 05
123      2        02
124      .       -62
125      5        05
126   ST06     35 06
127      3        03
128   ST07     35 07
129      4        04
130   ST08     35 08
131      5        05
132   ST09     35 09
133    P⇄S     16-51
134    RTN        24
135  *LBLe  21 16 15
136      0        00
137   ST06     35 06
138   ST09     35 09
139    CLX       -51
140   PRTX       -14
141    SPC     16-11
142    RTN        24
143  *LBLE     21 15
144    SPC     16-11
145   PRTX       -14
146   RCL2     36 02
147      ÷       -24
148   PRTX       -14
149   ST+9  35-55 09
150   PRTX       -14
151    SPC     16-11
152    RTN        24
153    R/S        51
```

5

HEAT TRANSMISSION COEFFICIENT PROGRAMS

BHTP-1

HEAT TRANSMISSION COEFFICIENT PROGRAM

GENERAL DESCRIPTION

While this program is intended for computing over-all heat transmission coefficients, the data input can be any combination of resistances, conductivities, and thermal transmittances.

This program can also be used for computing the average thermal transmittance of the gross wall area or for computing the area of fenestration required to satisfy the average thermal transmittance.

EQUATIONS

$$R_o = 1/h_i + L_1/K_1 + L_2/K_2 + L_3 \times R_3 + 1/h_o \quad [5.1]$$

$$R_o = 1/U_{x1} + 1/U_{x2} - - - \quad [5.2]$$

$$U_o = 1/R_o \quad [5.3]$$

$$U_o = \Sigma U_x \times A_x / \Sigma A_x \quad [5.4]$$

$$A_o = \Sigma A_x \quad [5.5]$$

where

R_o = Total thermal resistance of combination, the reciprocal of thermal conductance, hr ft^2 °F/Btu
h_i, h_o = Film or surface conductance; Btu/hr ft^2 °F
L_1, L_2 = Thickness of material, inches
K_1, K_2 = conductivity of material, Btu/hr ft^2 °F/in
R = Resistance per inch, hr ft^2 °F/Btu
U_x = Thermal transmittance of different materials Btu/hr ft^2 °F
U_o = Total or over-all or average thermal transmittance of combination, Btu/hr ft^2 °F
A_x = Area of different material
A_o = Total area

OPERATING FEATURES

Since the program works on ratios only, it can be used with any other units so long as consistency of units is maintained.

EXAMPLE NO. 1

Compute R_o and U_o for the following combination:

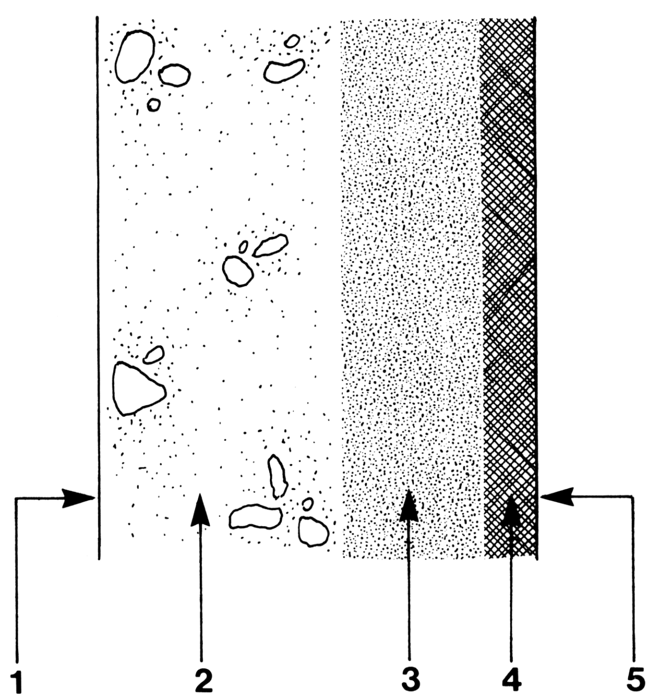

FIGURE 5A

HEAT TRANSFER COEFFICIENTS, BHTP-1

	L, in.	K	R
1. Outside surface (15 mph wind)	–	–	.17
2. Concrete	7	12.0	–
3. Insulation material	3		4
4. Plaster	.8	5.6	–
5. Inside surface (still air)	–	–	.68

While the example shows only 5 materials, the program can handle any number of materials.

EXAMPLE NO. 2

A wall has thermal transmittance of 0.37 Btu/hr ft² °F. What will be its thermal transmittance with 1.5 in. of insulation having a resistance of 4.2 hr ft² °F/Btu?

EXAMPLE NO. 3

Find the average thermal transmittance of a wall having the following data:

U wall = .2

U window = 1.13

U door = .6

A wall = 1,100 sq ft

A window = 120 sq ft

A door = 40 sq ft

EXAMPLE NO. 4

Find window area and net wall area for a wall having the following data:

U door = 0.6

U window = 1.13

U wall = 0.2

$U_o = 0.3$

A door = 40 sq ft

$A_o = 1{,}260$ sq ft

BHTP-1
HEAT TRANSMISSION COEFFICIENT PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
1.	Initialize	—	—	2nd	E′	0.00		
2. 3.	Enter resistance Enter thickness; if none, enter 1	.17 1	— —	2nd —	A′ R/S	0.17 1.00	RX TH	
4. 5.	Enter conductance Enter thickness	12 7	— —	— —	A R/S	12.00 7.00	KX TH	
	Continue steps 2, 3, 4, & 5 as many times as required.	4 3	— —	2nd —	A′ R/S	4.00 3.00	RX TH	
		5.6 .8	— —	— —	A R/S	5.60 0.80	KX TH	
		.68 1	— —	2nd —	A′ R/S	0.68 1.00	RX TH	
6.	To compute resistance and transmittance	—	—	—	R/S	13.58 0.07	RO UO	Total resistance Total transmittance
	Example 2							
1.	Initialize	—	—	2nd	E′	0.		
2. 3.	Enter conductance Enter thickness; if none, enter 1	.3 1	— —	— —	A R/S	0.30 1.00	KX TH	
4. 5.	Enter resistance Enter thickness	4.2 1.5	— —	2nd —	A′ R/S	4.20 1.50	RX TH	
6.	To compute transmittance	—	—	—	R/S	9.63 0.10	RO UO	Total resistance Total transmittance

BHTP-1 *(Continued)*

HEAT TRANSMISSION COEFFICIENT PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 3							
1.	Initialize	—	—	2nd	E′	0.00		
2.	Enter *U* of component	.2	—	—	B	0.20	UX	
3.	Enter area of component	1100	—	—	R/S	1100.00	AX	
	Repeat steps 2 & 3 as many times times as required.	1.13	—	—	B	1.13	UX	
		120	—	—	R/S	120.00	AX	
		.6	—	—	B	0.60	UX	
		40	—	—	R/S	40.00	AX	
4.	To complete computation	—	—	—	R/S	1260.0	A□	Total area of all components
						0.30	U□	Average *U* value
	Example 4							
1.	Initialize	—	—	2nd	E′	0.00		
2.	Enter *U* of components	.6	—	—	B	0.60	UX	
3.	Enter area of components	40	—	—	R/S	40.00	AX	
	Repeat steps 2 & 3 for all known components.							
4.	Enter *U* value of components with area unknown	1.13	—	—	C	1.13	UX	
		.2	—	—	R/S	0.20	UX	
5.	Repeat step 4		—	—	R/S			
6.	Enter average *U* value	0.3	—	—	R/S	0.30	U□	
7.	Enter total area of all components to compute areas	1260	—	—	R/S	1260.0	A□	
						1.13	UX	
						118.3	AX	Area of components having *U* = 1.13
						0.20	UX	
						1101.7	AX	Area of component having *U* = .2

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Calls SBR STO; stores inverse of display in R01;
	with R/S, calls SBR 1/X;
	with R/S, calls SBR CE
A	Stores display in R01 and prints RX;
	with R/S, calls SBR 1/X;
	with R/S, calls SBR CE
B	Stores display in R01 and calls SBR LNX;
	with R/S, stores display in R02 and sums it into R03; prints AX; multiplies by UX and stores sum in R04;
	with R/S, computes and prints AO and UO
C	Stores display in R01 and calls SBR LNX;
	with R/S, stores display in R02 and calls SBR LNX;
	with R/S, stores display in R05 and calls SBR CLR;
	with R/S, stores display in R06 and call SBR X⇌T; computes and prints values of AX1 and AX2
INV	Prints alphanumeric identification of data
CE	Prints value of R0; computes and prints UO
LNX	Prints UX
CLR	Prints UO
X⇌T	Prints AO
X^2	Prints AX
$\sqrt{X}$	Prints TH
1/X	Calls SBR $\sqrt{X}$; multiplies display by R01 and sums into R03
STO	Prints KX
E′	Clears all registers, clears display, and prints zero

EXPLANATION OF STORAGE REGISTERS

Register	Function
R01	Inverse of KX
R02	UX
R03	ΣUx
R04	ΣUX × AX
R05	UO
R06	AO
R07	AO − ΣAX
R08	AX
R09–R17	Not used
R18	For number of decimal places
R19	Alphanumeric code

BHTP-1 HEAT TRANSMISSION COEFFICIENT PROGRAM

LABELS & SUBROUTINES

```
001  11  A
015  16  A'
038  12  B
085  13  C
168  22  INV
186  24  CE
210  23  LNX
225  25  CLR
240  32  X⇌T
255  33  X²
270  34  √X
285  35  1/X
297  42  STO
312  10  E'
```

LISTING

```
000  76  LBL
001  11  A
002  71  SBR
003  42  STO
004  35  1/X
005  42  STO
006  01  01
007  91  R/S
008  71  SBR
009  35  1/X
010  91  R/S
011  71  SBR
012  24  CE
013  91  R/S
014  76  LBL
015  16  A'
016  42  STO
017  01  01
018  32  X⇌T
019  03  3
020  05  5
021  04  4
022  04  4
023  42  STO
024  19  19
025  02  2
026  42  STO
027  18  18
028  71  SBR
029  22  INV
030  91  R/S
031  71  SBR
032  35  1/X
033  91  R/S
034  71  SBR
035  24  CE
036  91  R/S
037  76  LBL
038  12  B
039  42  STO
040  01  01
041  71  SBR
042  23  LNX
043  91  R/S
044  42  STO
045  02  02
046  44  SUM
047  03  03
048  32  X⇌T
049  01  1
050  03  3
051  04  4
052  04  4
053  42  STO
054  19  19
055  71  SBR
056  22  INV
057  65  ×
058  43  RCL
059  01  01
060  95  =
061  44  SUM
062  04  04
063  98  ADV
064  91  R/S
065  43  RCL
```

066	03	03
067	71	SBR
068	32	X⇌T
069	35	1/X
070	65	×
071	43	RCL
072	04	04
073	95	=
074	71	SBR
075	25	CLR
076	98	ADV
077	00	0
078	42	STO
079	03	03
080	42	STO
081	04	04
082	98	ADV
083	91	R/S
084	76	LBL
085	13	C
086	42	STO
087	01	01
088	71	SBR
089	23	LNX
090	91	R/S
091	42	STO
092	02	02
093	71	SBR
094	23	LNX
095	98	ADV
096	91	R/S
097	42	STO
098	05	05
099	71	SBR
100	25	CLR
101	91	R/S
102	42	STO
103	06	06
104	71	SBR
105	32	X⇌T
106	98	ADV
107	43	RCL
108	05	05
109	65	×
110	43	RCL
111	06	06
112	75	-
113	43	RCL
114	04	04
115	95	=
116	75	-
117	53	(
118	43	RCL
119	02	02
120	65	×
121	53	(
122	43	RCL
123	06	06
124	75	-
125	43	RCL
126	03	03
127	54	)
128	42	STO
129	07	07
130	54	)
131	95	=
132	55	÷
133	53	(
134	43	RCL
135	01	01
136	75	-
137	43	RCL
138	02	02
139	54	)
140	95	=
141	42	STO
142	08	08
143	43	RCL
144	01	01
145	71	SBR
146	23	LNX
147	43	RCL
148	08	08
149	71	SBR
150	33	X²
151	98	ADV
152	43	RCL
153	02	02
154	71	SBR
155	23	LNX
156	43	RCL
157	08	08
158	22	INV
159	44	SUM
160	07	07
161	43	RCL
162	07	07
163	71	SBR
164	33	X²
165	98	ADV
166	91	R/S
167	76	LBL
168	22	INV
169	22	INV
170	58	FIX
171	25	CLR
172	69	OP
173	00	00
174	43	RCL
175	19	19
176	69	OP
177	04	04
178	32	X⇌T
179	58	FIX
180	40	IND
181	18	18
182	69	OP
183	06	06
184	92	RTN
185	76	LBL
186	24	CE
187	43	RCL
188	03	03
189	32	X⇌T
190	03	3
191	05	5
192	03	3
193	02	2
194	42	STO
195	19	19
196	02	2
197	42	STO
198	18	18
199	71	SBR
200	22	INV
201	35	1/X
202	71	SBR
203	25	CLR
204	98	ADV
205	00	0
206	42	STO
207	03	03
208	91	R/S
209	76	LBL
210	23	LNX
211	32	X⇌T
212	04	4
213	01	1
214	04	4
215	04	4
216	42	STO
217	19	19
218	02	2
219	42	STO
220	18	18
221	71	SBR
222	22	INV
223	92	RTN
224	76	LBL
225	25	CLR
226	32	X⇌T
227	04	4
228	01	1
229	03	3
230	02	2
231	42	STO
232	19	19
233	02	2
234	42	STO
235	18	18
236	71	SBR
237	22	INV
238	92	RTN
239	76	LBL
240	32	X⇌T
241	32	X⇌T
242	01	1
243	03	3
244	03	3
245	02	2
246	42	STO
247	19	19
248	01	1
249	42	STO
250	18	18
251	71	SBR
252	22	INV
253	92	RTN
254	76	LBL
255	33	X²
256	32	X⇌T
257	01	1
258	03	3
259	04	4
260	04	4
261	42	STO
262	19	19
263	01	1
264	42	STO
265	18	18
266	71	SBR
267	22	INV
268	92	RTN
269	76	LBL
270	34	√X
271	32	X⇌T
272	03	3
273	07	7
274	02	2
275	03	3
276	42	STO
277	19	19
278	02	2
279	42	STO
280	18	18
281	71	SBR
282	22	INV
283	92	RTN
284	76	LBL
285	35	1/X
286	71	SBR
287	34	√X
288	98	ADV
289	65	×
290	43	RCL
291	01	01
292	95	=
293	44	SUM
294	03	03
295	92	RTN
296	76	LBL
297	42	STO
298	32	X⇌T
299	02	2
300	06	6
301	04	4
302	04	4
303	42	STO
304	19	19
305	02	2
306	42	STO
307	18	18
308	71	SBR
309	22	INV
310	92	RTN
311	76	LBL
312	10	E'
313	47	CMS
314	25	CLR
315	98	ADV
316	99	PRT
317	98	ADV
318	91	R/S
319	00	0

BHTP-1
HEAT TRANSMISSION COEFFICIENT PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Enter resistance	.17	–	*f*	A	0.17 ***	
3.	Enter thickness; if none, enter 1	1	–	–	R/S	1.00 ***	
4.	Enter conductance	12	–	–	A	12.00 ***	
5.	Enter thickness	7	–	–	R/S	7.00 ***	
	Repeat steps 2 through 5 as	4	–	*f*	A	4.00 ***	
	many times as desired.	3	–	–	R/S	3.00 ***	
		5.6	–	–	A	5.60 ***	
		.8	–	–	R/S	0.80 ***	
		.68	–	*f*	A	0.68 ***	
		1	–	–	R/S	1.00 ***	
6.	To compute resistance and transmittance	–	–	–	R/S	13.58 ***	Resistance
						0.07 ***	Transmittance
	Example 2						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Enter conductance	.3	–	–	A	0.30 ***	
	Enter thickness; if none, enter 1	1	–	–	R/S	1.00 ***	
3.	Enter resistance	4.2	–	*f*	A	4.20 ***	
4.	Enter thickness	1.5	–	–	R/S	1.50 ***	
5.	To compute transmittance	–	–	–	R/S	9.63 ***	Total resistance
						0.10 ***	Total transmittance

BHTP-1 *(Continued)*

HEAT TRANSMISSION COEFFICIENT PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 3						
1.	Initialize	—	—	*f*	E	0.00 ***	
2.	Enter U of components	.2	—	—	B	0.20 ***	
3.	Enter area of components	1100	—	—	R/S	1100.00 ***	
	Repeat steps 2 & 3.	1.13	—	—	B	1.13 ***	
		120	—	—	R/S	120.00 ***	
		.6	—	—	B	0.60 ***	
		40	—	—	R/S	40.00 ***	
4.	To complete computation	—	—	—	R/S	1260.00 ***	Total area of components
						0.30 ***	Average U value
	Example 4						
1.	Initialize	—	—	*f*	E	0.00 ***	
2.	Enter U of components	.6	—	—	B	0.60 ***	
3.	Enter area of components	40	—	—	R/S	40.00 ***	
4.	Enter U with area unknown	1.13	—	—	C	1.13 ***	
	Repeat step 4.	.2	—	—	R/S	0.20 ***	
5.	Enter average U value	.3	—	—	R/S	0.30 ***	
6.	Enter total area	1260	—	—	R/S	1260.00 ***	
						1.13 ***	
						118.28 ***	Area of component having $U = 1.13$
						0.20 ***	
						1101.72 ***	Area of component having $U = .2$

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints display (KX) and stores inverse of display in R1; with R/S, goes to SBR 0; with R/S, goes to SBR 1
a	Prints display (RX) and stores display in R1; with R/S, goes to SBR 0; with R/S, goes to SBR 1
B	Prints and stores display (U) in R1; with R/S, prints and stores display (area) in R2 and totalizes in R3; multiplies R1 by R2 and totalizes product in R4; with R/S, computes and prints total area and over-all U factor
C	Prints and stores display (UX) in R1; with R/S, prints and stores display (AX) in R2; with R/S, prints and stores display (UO) in R5; with R/S, prints and stores display (AO) in R6; computes and prints UX and AX
0	Prints display, multiplies by R1, and totalizes product in R3
1	Prints R3 and inverse of R3 and clears register R3
e	Clears registers and prints 0

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Not used
R1	Inverse of KX or RX
R2	UX
R3	ΣUX
R4	ΣUX × AX
R5	UO
R6	AO
R7	AO − ΣAX
R8	AX
R9	Not used

BHTP-1 (HP-97) HEAT TRANSMISSION COEFFICIENT PROGRAM

LISTING

```
001    RTN        24
002  *LBLA     21 11
003   PRTX       -14
004    1/X        52
005   STO1     35 01
006    R/S        51
007   GSB0     23 00
008    R/S        51
009   GSB1     23 01
010    R/S        51
011  *LBLa  21 16 11
012   STO1     35 01
013   PRTX       -14
014    R/S        51
015   GSB0     23 00
016    R/S        51
017   GSB1     23 01
018    R/S        51
019  *LBLB     21 12
020   STO1     35 01
021   PRTX       -14
022    R/S        51
023   STO2     35 02
024   ST+3  35-55 03
025   PRTX       -14
026   RCL1     36 01
027      x       -35
028   ST+4  35-55 04
029    SPC     16-11
030    R/S        51
031   RCL3     36 03
032   PRTX       -14
033    1/X        52
034   RCL4     36 04
035      x       -35
036   PRTX       -14
037    SPC     16-11
038      0        00
039   STO3     35 03
040   STO4     35 04
041    SPC     16-11
042    R/S        51
043  *LBLC     21 13
044   STO1     35 01
045   PRTX       -14
046    R/S        51
047   STO2     35 02
048   PRTX       -14
049    SPC     16-11
050    R/S        51
051   STO5     35 05
052   PRTX       -14
053    R/S        51
054   STO6     35 06
055   PRTX       -14
056    SPC     16-11
057   RCL5     36 05
058      x       -35
059   RCL4     36 04
060      -       -45
061   RCL6     36 06
062   RCL3     36 03
063      -       -45
064   STO7     35 07
065   RCL2     36 02
066      x       -35
067      -       -45
068   RCL1     36 01
069   RCL2     36 02
070      -       -45
071      ÷       -24
072   STO8     35 08
073   RCL1     36 01
074   PRTX       -14
075   RCL8     36 08
076   PRTX       -14
077    SPC     16-11
078   RCL2     36 02
079   PRTX       -14
080   RCL8     36 08
081   ST-7  35-45 07
082   RCL7     36 07
083   PRTX       -14
084    SPC     16-11
085    R/S        51
086  *LBL0     21 00
087   PRTX       -14
088    SPC     16-11
089   RCL1     36 01
090      x       -35
091   ST+3  35-55 03
092    RTN        24
093  *LBL1     21 01
094   RCL3     36 03
095   PRTX       -14
096    1/X        52
097   PRTX       -14
098    SPC     16-11
099      0        00
100   STO3     35 03
101    RTN        24
102  *LBLe  21 16 15
103   CLRG     16-53
104    CLX       -51
105    SPC     16-11
106   PRTX       -14
107    SPC     16-11
108    R/S        51
```

BHTP-2
OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM

GENERAL DESCRIPTION

This program is based on ASHRAE Standard 90-75R, "Energy Conservation in New Buildings."

The program can compute either $OTTV$ or A_w and A_x for a specified value of $OTTV$.

Due to the large amount of data input required, this program is arranged in prompting mode.

EQUATIONS

$$OTTV = (U_w \times A_w \times TDEQ) + (A_x \times SF \times SC) + (U_x \times A_x \times \Delta T)/A_o \qquad [5.6]$$

where

$OTTV$ = Over-all thermal transmittance value
U_w = The thermal transmittance of all elements of the opaque wall area, Btu/hr ft^2 °F
A_w = Opaque wall area in sq ft
$TEDQ$ = Equivalent temperature difference based on mass of the wall construction
A_x = Area of fenestration in sq ft
SF = Solar factor value in Btu/hr ft^2
SC = Shading coefficient
U_x = The thermal transmittance of fenestration
ΔT = Temperature difference between exterior and interior design conditions in °F
A_o = Total area

The above equation can also be used for a roof or ceiling in which case the symbols should be read as below:

U_w = The thermal transmittance of all elements of the opaque roof area, Btu/hr ft^2 °F
A_w = Opaque roof area in sq ft
$TEDQ$ = Equivalent temperature difference based on mass of the roof construction
A_x = Skylight area
SF = Solar factor in Btu/hr ft^2 —suggested value of 138 for skylights
SC = Shading coefficient for skylight
U_x = The thermal conductance of skylight in Btu/hr ft^2
$OTTV$ = Suggested value for skylight, 8.5

OPERATING FEATURES

As already mentioned, the program can be used for both walls and roofs. It can also be used for computing the value of U/TC or I/H, required for finding $TDEQR$ for roof.

EXAMPLE NO. 1

Compute $OTTV$ for a wall having the following data:

$U_w = 0.2$
$A_w = 1100$
$TDEQ = 30$
$A_x = 140$
$SF = 128$
$SC = 0.55$
$U_x = 0.65$
$\Delta T = 17$

EXAMPLE NO. 2

Compute A_x and A_w for a wall having the following data:

$U_w = 0.2$
$TDEQ = 30$
$SF = 128$
$SC = 0.55$
$U_x = 0.65$
$\Delta T = 17$
$A_o = 1240$
$OTTV = 14.5$

EXAMPLE NO. 3

Compute I/H or U/TC for a roof having the following data:

U_x = 0.15 Btu/hr ft^2 °F
Sp. heat = 0.2 Btu/lb °F
Density = 80 lb/cu ft
Thickness = .75 ft

BHTP-2
OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	To start computation	—	—	—	A	UW	Prompt by printer
2.	Enter *U* value for wall	0.2	—	—	R/S	0. 2	What is *U* value for wall?
3.	Enter area of wall	1100	—	—	R/S	AW 1100.	What is area of wall?
4.	Enter equivalent temp. diff.	30	—	—	R/S	TDEQ 30.	What is equivalent temp.?
5	Enter area of component having solar heat gain	140	—	—	R/S	AX 140.	What is area of fenestration or skylight?
6.	Enter solar factor	128	—	—	R/S	SF 128.	What is solar factor?
7.	Enter shading coeff.	0.55	—	—	R/S	SC 0. 55	What is shading coeff.?
8.	Enter *U* value of component having solar heat gain	0.65	—	—	R/S	UX 0. 65	What is *U* value of *x*?
9.	Enter design temp. diff.	17	—	—	R/S	ΔT 17.	What is temp. diff.?
						1240. 0 AO	Total area
						14. 5 OTTV	Over-all thermal transmittance value

BHTP-2 *(Continued)*

OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 2						
1.	To start computation	–	–	–	A		Prompt by printer
2.	Enter *U* value for wall	.2	–	–	R/S	UW 0.2	What is *U* value of wall?
3.	Enter 0 for unknown area	0	–	–	R/S	AW 0.	What is area of wall? Since unknown, enter 0
4.	Enter temp. diff.	30	–	–	R/S	TDEQ 30.	What is equivalent temp. diff.?
5.	Enter 0 for unknown area	0	–	–	R/S	AX 0.	What is area of fenestration or skylight? Since unknown, enter 0
6.	Enter solar factor	128	–	–	R/S	SF 128.	What is solar factor?
7.	Enter shading coeff.	.55	–	–	R/S	SC 0.55	What is shading coeff.?
8.	Enter *U* value of component having solar transmittance	0.65	–	–	R/S	UX 0.65	What is *U* value of *x*?
9.	Enter design temp. diff.	17	–	–	R/S	ΔT 17.	What is temp. diff.?
10.	Enter total area	1240	–	–	R/S	AO 1240.	What is total area?
11.	Enter over-all thermal transmittance value	14.5	–	–	R/S	OTTV 14.5	What is over-all thermal transmittance?

						139.7 AX	Area of fenestration
						1100.3 AW	Area of wall
	Example 3						
1.	Start computation	—	—	—	B	UR	What is *U* value of roof?
2.	Enter *U* roof	0.15	—	—	R/S	0.15	
						SPHT	What is specific heat?
3.	Enter specific heat of roof	0.2	—	—	R/S	0.2	
						DS	What is density?
4.	Enter density of roof, lb/cu ft	80	—	—	R/S	80.	
						TH	What is thickness?
5.	Enter thickness of roof, ft	0.75	—	—	R/S	0.75	
						0.012 I/H	Answer

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Clears all registers; resets flag 1 if set; prints UW; with R/S, stores display in R01, prints value, and calls SBR 1/X; with R/S, stores display in R02, prints value, and prints TDEQ; with R/S, stores display in R03 and prints value, multiplies UW by TDEQ, and stores value in R11; with R/S, stores display in R04 and prints value; if equal to zero goes to SBR LNX and prints SF; with R/S, stores display in R05, prints value and prints SC; with R/S, stores display in R06, prints value and prints UX; with R/S, stores display in R07, prints value and prints ΔT; with R/S, stores display in R08, prints value, computes SF × SC + UX × ΔT and stores value in R12; if flag 1 is set goes to SBR CLR, otherwise continues, computes, and prints value of OTTV by calling SBR X^2
INV	Prints alphanumeric identification of data
LNX	Sets flag 1 and goes to SBR CE
CE	Continues sequence for computing OTTV
CLR	Continues sequence when OTTV is known; with R/S, stores display in R10, prints value, and calls SBR X^2; with R/S, stores display in STO 09, prints value, computes and prints AX and AW
X⇄T	Prints AO
X^2	Prints OTTV
$\sqrt{X}$	Prints AX
1/X	Prints AW
B	Computes and prints I/H

EXPLANATION OF STORAGE REGISTERS

Register	Function
R01	UW or UR
R02	AW or SPHT
R03	TDEQ or DS
R04	AX
R05	SF
R06	SC
R07	UX
R08	ΔT
R09	OTTV
R10	AO
R11	UW or TDEQ
R12	SF × SC + UX × ΔT
R13	AX
R14–R18	Not used
R19	Alphanumeric code

BHTP-2 OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM

LABELS & SUBROUTINES

```
001  11  A
063  24  CE
173  22  INV
187  23  LNX
194  25  CLR
255  32  X:T
266  33  X²
281  34  √X
292  35  1/X
303  12  B
```

LISTING

```
000  76  LBL
001  11  A
002  47  CMS
003  22  INV
004  86  STF
005  01  01
006  04  4
007  01  1
008  04  4
009  03  3
010  42  STO
011  19  19
012  71  SBR
013  22  INV
014  91  R/S
015  42  STO
016  01  01
017  99  PRT
018  98  ADV
019  71  SBR
020  35  1/X
021  91  R/S
022  42  STO
023  02  02
024  99  PRT
025  98  ADV
026  03  3
027  07  7
028  01  1
029  06  6
030  01  1
031  07  7
032  03  3
033  04  4
034  42  STO
035  19  19
036  71  SBR
037  22  INV
```

```
038  91  R/S
039  42  STO
040  03   03
041  99  PRT
042  98  ADV
043  43  RCL
044  01   01
045  65   ×
046  43  RCL
047  03   03
048  95   =
049  42  STO
050  11   11
051  98  ADV
052  71  SBR
053  34  ΓX
054  29  CP
055  91  R/S
056  42  STO
057  04   04
058  99  PRT
059  98  ADV
060  67   EQ
061  23  LNX
062  76  LBL
063  24  CE
064  03   3
065  06   6
066  02   2
067  01   1
068  42  STO
069  19   19
070  71  SBR
071  22  INV
072  91  R/S
073  42  STO
074  05   05
075  99  PRT
076  98  ADV
077  03   3
078  06   6
079  01   1
080  05   5
081  42  STO
082  19   19
083  71  SBR
084  22  INV
085  91  R/S
086  42  STO
087  06   06
088  99  PRT
089  98  ADV
090  98  ADV
091  04   4
092  01   1
093  04   4
094  04   4
095  42  STO
096  19   19
097  71  SBR
098  22  INV
099  91  R/S
100  42  STO
101  07   07
102  99  PRT
103  98  ADV
104  07   7
105  05   5
106  03   3
107  07   7
108  42  STO
109  19   19
110  71  SBR
111  22  INV
112  91  R/S
113  42  STO
114  08   08
115  99  PRT
116  98  ADV
117  98  ADV
118  43  RCL
119  05   05
120  65   ×
121  43  RCL
122  06   06
123  85   +
124  43  RCL
125  07   07
126  65   ×
127  43  RCL
128  08   08
129  95   =
130  42  STO
131  12   12
132  87  IFF
133  01   01
134  25  CLR
135  43  RCL
136  02   02
137  85   +
138  43  RCL
139  04   04
140  95   =
141  42  STO
142  10   10
143  58  FIX
144  01   01
145  99  PRT
146  71  SBR
147  32  X↕T
148  98  ADV
149  43  RCL
150  11   11
151  65   ×
152  43  RCL
153  02   02
154  85   +
155  43  RCL
156  12   12
157  65   ×
158  43  RCL
159  04   04
160  95   =
161  55   ÷
162  43  RCL
163  10   10
164  95   =
165  58  FIX
166  01   01
167  99  PRT
168  71  SBR
169  33  X²
170  98  ADV
171  91  R/S
172  76  LBL
173  22  INV
174  22  INV
175  58  FIX
176  25  CLR
177  69  OP
178  00   00
179  43  RCL
180  19   19
181  69  OP
182  02   02
183  69  OP
184  05   05
185  92  RTN
186  76  LBL
187  23  LNX
188  86  STF
189  01   01
190  71  SBR
191  24  CE
192  92  RTN
193  76  LBL
194  25  CLR
195  71  SBR
196  32  X↕T
197  91  R/S
198  42  STO
199  10   10
200  99  PRT
201  98  ADV
202  71  SBR
203  33  X²
204  91  R/S
205  42  STO
206  09   09
207  99  PRT
208  98  ADV
209  98  ADV
210  53   (
211  53   (
212  43  RCL
213  09   09
214  65   ×
215  43  RCL
216  10   10
217  75   -
218  43  RCL
219  10   10
220  65   ×
221  43  RCL
222  11   11
223  54   )
224  55   ÷
225  53   (
226  43  RCL
227  12   12
228  75   -
229  43  RCL
230  11   11
231  54   )
232  54   )
233  42  STO
234  13   13
235  58  FIX
236  01   01
237  99  PRT
238  71  SBR
239  34  ΓX
240  98  ADV
241  43  RCL
242  10   10
243  75   -
244  43  RCL
245  13   13
246  95   =
247  58  FIX
248  01   01
249  99  PRT
250  71  SBR
251  35  1/X
252  98  ADV
253  91  R/S
254  76  LBL
255  32  X↕T
256  01   1
257  03   3
258  03   3
259  02   2
260  42  STO
261  19   19
262  71  SBR
263  22  INV
264  92  RTN
265  76  LBL
266  33  X²
267  03   3
268  02   2
269  03   3
270  07   7
271  03   3
272  07   7
273  04   4
274  02   2
275  42  STO
276  19   19
277  71  SBR
278  22  INV
279  92  RTN
280  76  LBL
281  34  ΓX
282  01   1
283  03   3
284  04   4
285  04   4
286  42  STO
287  19   19
288  71  SBR
289  22  INV
```

```
290  92 RTN
291  76 LBL
292  35 1/X
293  01  1
294  03  3
295  04  4
296  03  3
297  42 STO
298  19  19
299  71 SBR
300  22 INV
301  92 RTN
302  76 LBL
303  12  B
304  04  4
305  01  1
306  03  3
307  05  5
308  42 STO
309  19  19
310  71 SBR
311  22 INV
312  91 R/S
313  42 STO
314  01  01
315  99 PRT
316  98 ADV
317  03  3
318  06  6
319  03  3
320  03  3
321  02  2
322  03  3
323  03  3
324  07  7
325  42 STO
326  19  19
327  71 SBR
328  22 INV
329  91 R/S
330  42 STO
331  02  02
332  99 PRT
333  98 ADV
334  01  1
335  06  6
336  03  3
337  06  6
338  42 STO
339  19  19
340  71 SBR
341  22 INV
342  91 R/S
343  42 STO
344  03  03
345  99 PRT
346  98 ADV
347  03  3
348  07  7
349  02  2
350  03  3
351  42 STO
352  19  19
353  71 SBR
354  22 INV
355  91 R/S
356  99 PRT
357  98 ADV
358  98 ADV
359  35 1/X
360  65  ×
361  43 RCL
362  01  01
363  55  ÷
364  43 RCL
365  03  03
366  55  ÷
367  43 RCL
368  02  02
369  95  =
370  58 FIX
371  03  03
372  99 PRT
373  02  2
374  04  4
375  06  6
376  03  3
377  02  2
378  03  3
379  42 STO
380  19  19
381  71 SBR
382  22 INV
383  98 ADV
384  91 R/S
385  00  0
386  00  0
387  00  0
388  00  0
389  00  0
390  00  0
391  00  0
392  00  0
393  00  0
394  00  0
395  00  0
396  00  0
```

BHTP-2
OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Enter *U* value of wall	.2	—	—	A	0.20 ***	
2.	Enter area of wall	1100	—	—	R/S	1100.00 ***	
3.	Enter equivalent temp. diff.	30	—	—	R/S	30.00 ***	
4.	Enter area of component having solar gain	140	—	—	R/S	140.00 ***	
5.	Enter solar gain	128	—	—	R/S	128.00 ***	
6.	Enter shading coeff.	.55	—	—	R/S	0.55 ***	
7.	Enter *U* value of component having solar gain	.65	—	—	R/S	0.65 ***	
8.	Enter design temp. diff.	17	—	—	R/S	17.00 ***	
						1240.00 ***	Total area
						14.52 ***	Over-all thermal transmittance
	Example 2						
1.	Enter *U* value of wall	.2	—	—	A	0.20 ***	
2.	Enter 0 if area is unknown	0	—	—	R/S	0.00 ***	
3.	Enter temp. diff.	30	—	—	R/S	30.00 ***	
4.	Enter 0 if area is unknown	0	—	—	R/S	0.00 ***	
5.	Enter solar factor	128	—	—	R/S	128.00 ***	
6.	Enter shading coeff.	.55	—	—	R/S	0.55 ***	
7.	Enter *U* value of component having solar gain	.65	—	—	R/S	0.65 ***	
8.	Enter design temp. diff.	17	—	—	R/S	17.00 ***	

BHTP-2 *(Continued)*

OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
9.	Enter total area	1240	—	—	R/S	1240.00 ***	
10.	Enter over-all thermal transmittance value	14.5	—	—	R/S	14.50 ***	
						139.70 ***	Area of fenestration
						1100.30 ***	Area of wall
	Example 3						
1.	Enter *U* value for roof	.15	—	—	B	0.15 ***	
2.	Enter specific heat of roof	.2	—	—	R/S	0.20 ***	
3.	Enter density of roof, lb/cu ft	80	—	—	R/S	80.00 ***	
4.	Enter thickness of roof, ft	.75	—	—	R/S	0.75 ***	
						0.013 ***	I/H

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Clears all registers; clears flag 1; prints and stores display (UW) in R1;
	with R/S, prints and stores display (AW) in R2;
	with R/S, prints and stores display (TDEQ) in R3, calculates TDEQ × R1, and stores in RA;
	with R/S, prints and stores display (AX) in R4 and if equal to 0, goes to SBR 0;
	with R/S, prints and stores display (SF) in R5; with R/S, prints and stores display (SC) in R6;
	with R/S, prints and stores display (UX) in R7;
	with R/S, prints and stores display (temperature difference) in R8; if flag 1 is set goes to SBR 2; calculates and prints over-all area and over-all thermal transfer value
0	Sets flag 1; goes to SBR 1 (mid-part of LBL A)
2	Stops computations
	with R/S, prints and stores display in R9; computes and prints AX and AW
B	Prints and stores display (UR) in R1; prints and stores display (SPHT) in R2; prints and stores display (DS) in R3; prints display (TH) and computes I/H

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	AO
R1	UW or UR
R2	AW or SPHT
R3	TDEQ or DS
R4	AX
R5	SF
R6	SC
R7	UX
R8	Temperature difference
R9	OTTV
RA	TDEQ × UW
RB	SF × SC + UX × ΔT
RC	AX

BHTP-2 (HP-97) OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM

LISTING

```
001  *LBLA     21 11
002   CLRG     16-53
003    CF1  16 22 01
004   STO1     35 01
005   PRTX       -14
006    R/S        51
007   STO2     35 02
008   PRTX       -14
009    R/S        51
010   STO3     35 03
011   PRTX       -14
012    SPC     16-11
013   RCL1     36 01
014      x       -35
015   STOA     35 11
016    R/S        51
017   STO4     35 04
018   PRTX       -14
019   X=0?     16-43
020   GTO0     22 00
021  *LBL1     21 01
022    R/S        51
023   STO5     35 05
024   PRTX       -14
025    R/S        51
026   STO6     35 06
027   PRTX       -14
028    SPC     16-11
029    R/S        51
030   STO7     35 07
031   PRTX       -14
032    R/S        51
033   STO8     35 08
034   PRTX       -14
035    SPC     16-11
036    SPC     16-11
037   RCL7     36 07
038      x       -35
039   RCL5     36 05
040   RCL6     36 06
041      x       -35
042      +       -55
043   STOB     35 12
044    F1?  16 23 01
045   GTO2     22 02
046   RCL2     36 02
047   RCL4     36 04
048      +       -55
049   STO0     35 00
050   PRTX       -14
051   RCLA     36 11
052   RCL2     36 02
053      x       -35
054   RCLB     36 12
055   RCL4     36 04
056      x       -35
057      +       -55
058   RCL0     36 00
059      ÷       -24
060   PRTX       -14
061    SPC     16-11
062    SPC     16-11
063    R/S        51
064  *LBL0     21 00
065    SF1  16 21 01
066   GSB1     23 01
067    RTN        24
068  *LBL2     21 02
069    R/S        51
070   STO0     35 00
071   PRTX       -14
072    R/S        51
073   STO9     35 09
074   PRTX       -14
075    SPC     16-11
076    SPC     16-11
077   RCL0     36 00
078      x       -35
079   RCL0     36 00
080   RCLA     36 11
081      x       -35
082      -       -45
083   RCLB     36 12
084   RCLA     36 11
085      -       -45
086      ÷       -24
087   PRTX       -14
088   RCL0     36 00
089      -       -45
```

```
090   CHS      -22     106   SPC    16-11
091   PRTX     -14     107   SPC    16-11
092   SPC    16-11     108   1/X       52
093   RTN       24     109   RCL1   36 01
094  *LBLB  21 12      110   x        -35
095   STO1  35 01      111   RCL3   36 03
096   PRTX     -14     112   ÷        -24
097   R/S       51     113   RCL2   36 02
098   STO2  35 02      114   ÷        -24
099   PRTX     -14     115   DSP3  -63 03
100   SPC    16-11     116   PRTX     -14
101   R/S       51     117   DSP2  -63 02
102   STO3  35 03      118   SPC    16-11
103   PRTX     -14     119   SPC    16-11
104   R/S       51     120   R/S       51
105   PRTX     -14
```

6
SOLAR ENERGY PROGRAMS

SOLP-1
SOLAR SHADING PROGRAM

PROGRAM DESCRIPTION

This program will be of interest to both architects and engineers. It can be used for computing sun altitude angle, azimuth angle, and shading from exterior shading devices, such as overhangs and fins. The program is based on information given in the ASHRAE *Handbook Fundamentals Volume*.

The program can be used for designing exterior solar shading and also for calculating the shading effect for making heat load calculations. While Figures 1 and 2 show the shading devices at a right angle to the wall, the program can be used for shading devices at any angle by measuring the perpendicular distance from the tip of the shading device to the wall.

EQUATIONS

$$\sin A = \cos D \times \sin H / \cos B \quad [6.1]$$

$$\sin B = \cos L \times \cos D \times \cos H + \sin L \times \sin D \quad [6.2]$$

where

A = Solar azimuth

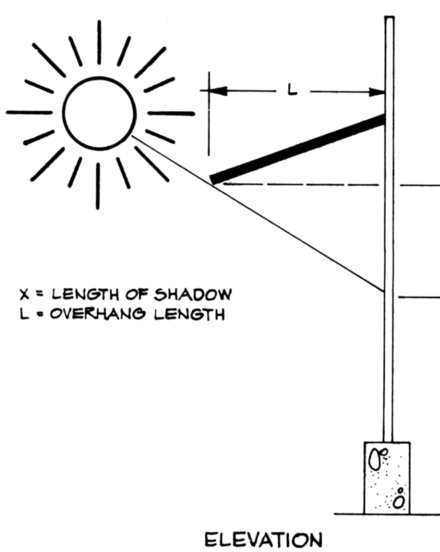

FIGURE 6A

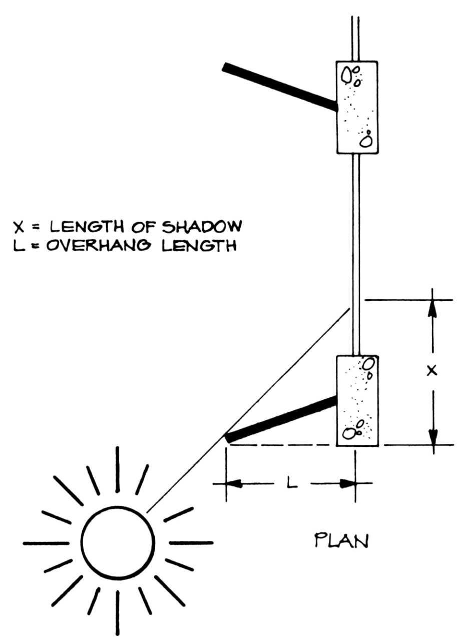

FIGURE 6B

B = Solar altitude
L = Site latitude
D = Declination
H = Hour angle

$$D = 23.46 \times \sin[(30M + 275) \times 360/365] \quad [6.3]$$

where
M = Month number, January being 1, and so on

$$H = [(\text{Hour}-12) \times 60-C] \times .25 \quad [6.4]$$

where
C = Correction for equation of time from Table 1 of chapter 26, *ASHRAE Handbook Fundamentals Volume*

$$\text{Shade by overhang} = \text{Overhang length} \times \frac{\tan B}{\cos (A-A_w)} \quad [6.5]$$

where
A_w = Azimuth of wall

$$\text{Shade by fin} = \text{Fin length} \times \tan (A-A_w) \quad [6.6]$$

OPERATING FEATURES

Wall azimuth. The wall azimuth is the normal to the wall measured from the south. *Clock-wise rotation is measured as positive while counter-clockwise rotation is measured as negative.* Refer to Table 1 for common wall azimuth angles. However, the program will accept any other angles.

Overhang length. The overhang length can be in any units: feet, inches, centimeters, etc. Since the program is arranged to print without any decimal numbers, better accuracy can be obtained if the overhang length is entered in either inches or centimeters. As shown in Figure 6A, the overhang is perpendicular to the wall. Actually, the overhang can be at any angle, but the length is the perpendicular distance to the wall and the shadow calculated will be from the point where the perpendicular from the overhang meets the wall.

Right and left fin lengths. The above comments also apply to the fins. Please see Figure 6B for an explanation of fin length and geometry.

Starting and final months. The calculations are done for the twenty-first day of each month (±3 three days). The program will calculate for any number of months, commencing from the desired month and terminating with the final month. The months must be entered numerically, i.e., number 1 for January, number 2 for February, and so on.
Actually, it is not necessary to make calculations for all the 12 months. As shown in Table 2B, calculations for June through December (6 through 12) will give all the information required for 12 months.

Starting and final hours. As in the case of months, it is not necessary to make calculations for all hours. Table 2A shows how calculations for the 12th through the 18th hour are the same as that for the 6th through the 12th. Neglect negative shading values.

The program calculates the azimuth by calculating the sine of the angle. Since the sine of, say, 85° is the same as that of 95°, the program does not discriminate when the sun passes the east-west axis. This has been corrected for afternoon hours, but this correction is not feasible for the morning hours. As shown in the examples, during the afternoon hours, the azimuth does exceed 90°, but for morning hours it often remains below −90°. This can be overcome by two means:

1. By inputting exposures in east zones as a mirror image of the west zone. For example, a wall with a −27° azimuth can be input as 27° azimuth and information for 13th hours will be the same as that for the 11th hours as shown in Tables 1, 2A, and 2B.
2. Correction for morning hours can be made manually, as shown in the example.

TABLE 1

	N	NE	E	SE	S	SW	W	NW
Actual azimuth	180	−135	−90	−45	0	45	90	135
Input azimuth	180	135	90	45	0	45	90	135
Input hours	15/19	13/19	13/19	12/17	12/16	12/17	13/19	13/19
Information will correspond to	9/5	11/5	11/5	–	–	–	–	–

TABLE 2A
SIMILAR HOURS

Solar Time		Solar Time
6	=	18
7	=	17
8	=	16
9	=	15
10	=	14
11	=	13
12	=	12

Hours 12 through 19 will give information for the entire day.

TABLE 2B
SIMILAR MONTHS

		Dec—12
Jan—1	=	Nov—11
Feb—2	=	Oct—10
Mar—3	=	Sept—9
Apr—4	=	Aug—8
May—5	=	July—7
June—6	=	

Months 6 through 12 will give information for the entire year.

SOLP-1
SOLAR SHADING PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
1.	Enter site latitude	43	–	2nd	A′	43.	LAT	
2.	Enter wall azimuth	37	+/–	2nd	B′	-37.	WAZ	*Note:* Negative sign for eastern half
3.	Enter overhang length	10	–	2nd	C′	10.	OH	
4.	Enter right fin length	10	–	2nd	D′	10.	RF	
5.	Enter left fin length	10	–	–	R/S	10.	LF	
6.	Enter starting month	5	–	2nd	E′	5.	MS	
7.	Enter final month	10	–	–	R/S	10.	MF	
8.	Enter starting hour	9	–	–	A	9.	HS	
9.	Enter final hour	14	–	–	R/S	14.	HF	*Note:* 24-hour clock
10.	To start computation	–	–	–	B			
						5.	M	Month
						9.	HR	
						46.	ALT	
						-73.	AZ	Negative for eastern half
						13.	OHS	Shadow by overhang
						7.	RFS	Shadow by right fin
						-7.	LFS	Neglect negative number
	Output will continue in this manner. For next example, input only the changes and press B.					10.	HR	
						56.	ALT	
						-57.	AZ	
						16.	OHS	
						4.	RFS	
						-4.	LFS	
						11.	HR	
						64.	ALT	
						-34.	AZ	
						20.	OHS	
						-1.	RFS	
						1.	LFS	

	(Will continue — computer operation stopped by pressing R/S)					12. HR 67. ALT 0. AZ 30. OHS -8. RFS 8. LFS 13. HR 64. ALT 34. AZ 61. OHS -28. RFS 28. LFS 14. HR 56. ALT 57. AZ -203. OHS 136. RFS -136. LFS 6. M 9. HR 48. ALT -77. AZ 15. OHS 8. RFS -8. LFS 10. HR 58. ALT -61. AZ 18. OHS 5. RFS -5. LFS	

SOLP-1 *(Continued)*

SOLAR SHADING PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 2							
1.	Enter starting month	5	–	2nd	E′	5.	MS	
2.	Enter final month	6	–	–	R/S	6.	MF	
3.	Enter starting hour	6	–	–	A	6.	HS	
4.	Enter final hour	9	–	–	R/S	9.	HF	
5.	To start computation	–	–	–	B			
						5.	M	
	Comparison of results at hours 8 and 9 shows that AZ at hour 6 should be −105, and at hour 7 should be −95.					6.	HR	
						14.	ALT	
						75.	AZ	Should be −105
						3.	DHS	
						8.	RFS	
						-8.	LFS	
						7.	HR	
						24.	ALT	
						85.	AZ	Should be −95
						7.	DHS	
						11.	RFS	
						11.	LFS	

```
  8.      HR

 35.     ALT
-85.      AZ
 11.     OHS
 11.     RFS
-11.     LFS

  9.      HR

 46.     ALT
-73.      AZ
 13.     OHS
  7.     RFS
 -7.     LFS
```

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A′	Prints and stores latitude LAT; partitions program
B′	Prints and stores WAZ
C′	Prints and stores overhang length OH
D′	Prints and stores right fin length RF;
	with R/S, prints and stores left fin length LF
E′	Prints and stores month start MS; with R/S, prints and stores month start MS;
	with R/S, prints and stores month finish MF
A	Prints and stores hour start HS;
	with R/S, prints and stores hour finish HF
INV	Prints alphanumeric identification of data
CE	Calculates declination
X⇄T	Calculates hour angle
X^2	Prints ALT; prints AZ
$\sqrt{X}$	Calculates shadow by overhang
1/X	Calculates shadow by right fin
STO	Calculates shadow by left fin
B	Starts calculation
LNX	Repeats monthly cycle
CLR	Repeats hourly cycle
RCL	Stores table for correcting equation of time
SUM	For finding correction for equation of time
Y^x	For reiterating month for correcting equation of time
EE	To adjust azimuth when it exceeds 90°
(	To store previous value of azimuth

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	DSZ for month
R01	DSZ for hour
R02–R08	Not used
R09	Alphanumeric code
R10	Site latitude
R11	Wall azimuth
R12	Overhang length
R13	Right fin length
R14	Left fin length
R15	Month start
R16	Month finish
R17	Hour start
R18	Hour finish
R19 & R20	Not used
R21	Declination
R22	Hour angle; also azimuth
R23	Altitude
R24	Not used
R25–R36	For storing table for correcting equation of time
R37	For converting azimuth to above 90°
R38	Equation of time correction
R39	For RLC IND for equation of time

SOLP-1 SOLAR SHADING PROGRAM

LABELS & SUBROUTINES

```
001  16 A'
022  17 B'
038  18 C'
052  19 D'
078  10 E'
104  11  A
145  22 INV
162  24 CE
197  32 X⇄T
280  33 X²
307  34 √X
341  35 1/X
368  42 STO
395  12  B
399  23 LNX
441  25 CLR
476  43 RCL
573  44 SUM
584  45 Yˣ
609  52 EE
622  53  (
```

LISTING

```
000  76 LBL
001  16 A'
002  42 STO
003  10  10
004  32 X⇄T
005  02  2
006  07  7
007  01  1
008  03  3
009  03  3
010  07  7
011  42 STO
012  09  09
013  71 SBR
014  22 INV
015  22 INV
016  58 FIX
```

```
017  04  4
018  69  OP
019  17  17
020  91  R/S
021  76  LBL
022  17  B'
023  42  STO
024  11  11
025  32  X:T
026  04  4
027  03  3
028  01  1
029  03  3
030  04  4
031  06  6
032  42  STO
033  09  09
034  71  SBR
035  22  INV
036  91  R/S
037  76  LBL
038  18  C'
039  42  STO
040  12  12
041  32  X:T
042  03  3
043  02  2
044  02  2
045  03  3
046  42  STO
047  09  09
048  71  SBR
049  22  INV
050  91  R/S
051  76  LBL
052  19  D'
053  42  STO
054  13  13
055  32  X:T
056  03  3
057  05  5
058  02  2
059  01  1
060  42  STO
061  09  09
062  71  SBR
063  22  INV
064  91  R/S
065  42  STO
066  14  14
067  32  X:T
068  02  2
069  07  7
070  02  2
071  01  1
072  42  STO
073  09  09
074  71  SBR
075  22  INV
076  91  R/S
077  76  LBL
078  10  E'
079  42  STO
080  15  15
081  32  X:T
082  03  3
083  00  0
084  03  3
085  06  6
086  42  STO
087  09  09
088  71  SBR
089  22  INV
090  91  R/S
091  42  STO
092  16  16
093  32  X:T
094  03  3
095  00  0
096  02  2
097  01  1
098  42  STO
099  09  09
100  71  SBR
101  22  INV
102  91  R/S
103  76  LBL
104  11  A
105  42  STO
106  17  17
107  32  X:T
108  02  2
109  03  3
110  03  3
111  06  6
112  42  STO
113  09  09
114  71  SBR
115  22  INV
116  91  R/S
117  42  STO
118  18  18
119  32  X:T
120  02  2
121  03  3
122  02  2
123  01  1
124  42  STO
125  09  09
126  71  SBR
127  22  INV
128  53  (
129  43  RCL
130  16  16
131  75  -
132  43  RCL
133  15  15
134  85  +
135  01  1
136  54  )
137  42  STO
138  00  00
139  01  1
140  22  INV
141  44  SUM
142  15  15
143  92  RTN
144  76  LBL
145  22  INV
146  22  INV
147  58  FIX
148  25  CLR
149  69  OP
150  00  00
151  43  RCL
152  09  09
153  69  OP
154  04  04
155  32  X:T
156  58  FIX
157  00  00
158  69  OP
159  06  06
160  92  RTN
161  76  LBL
162  24  CE
163  53  (
164  53  (
165  53  (
166  43  RCL
167  15  15
168  65  ×
169  03  3
170  00  0
171  85  +
172  02  2
173  07  7
174  05  5
175  54  )
176  65  ×
177  03  3
178  06  6
179  00  0
180  55  ÷
181  03  3
182  06  6
183  05  5
184  54  )
185  38  SIN
186  65  ×
187  02  2
188  03  3
189  93  .
190  04  4
191  06  6
192  54  )
193  42  STO
194  21  21
195  92  RTN
196  76  LBL
197  32  X:T
198  53  (
199  53  (
200  53  (
201  53  (
202  43  RCL
203  24  24
204  75  -
205  01  1
206  02  2
207  54  )
208  65  ×
209  06  6
210  00  0
211  54  )
212  75  -
213  43  RCL
214  38  38
215  54  )
216  55  ÷
217  04  4
218  54  )
219  42  STO
220  22  22
221  53  (
222  43  RCL
223  10  10
224  39  COS
225  65  ×
226  43  RCL
227  21  21
228  39  COS
229  65  ×
230  43  RCL
231  22  22
232  39  COS
233  85  +
234  43  RCL
235  10  10
236  38  SIN
237  65  ×
238  43  RCL
239  21  21
240  38  SIN
241  54  )
242  22  INV
243  38  SIN
244  42  STO
245  23  23
246  53  (
247  43  RCL
248  21  21
249  39  COS
250  65  ×
251  43  RCL
252  22  22
253  38  SIN
254  55  ÷
255  43  RCL
256  23  23
257  39  COS
258  54  )
259  22  INV
260  38  SIN
261  42  STO
262  22  22
263  32  X:T
264  00  0
265  77  GE
266  53  (
267  00  0
268  67  EQ
269  53  (
270  43  RCL
271  37  37
272  77  GE
273  52  EE
274  43  RCL
275  22  22
276  42  STO
```

```
277  37  37
278  92  RTN
279  76  LBL
280  33  X²
281  43  RCL
282  23  23
283  32  X:T
284  01  1
285  03  3
286  02  2
287  07  7
288  03  3
289  07  7
290  42  STO
291  09  09
292  71  SBR
293  22  INV
294  43  RCL
295  22  22
296  32  X:T
297  01  1
298  03  3
299  04  4
300  06  6
301  42  STO
302  09  09
303  71  SBR
304  22  INV
305  92  RTN
306  76  LBL
307  34  ΓX
308  53  (
309  43  RCL
310  12  12
311  65  ×
312  43  RCL
313  23  23
314  30  TAN
315  55  ÷
316  53  (
317  53  (
318  43  RCL
319  22  22
320  75  -
321  43  RCL
322  11  11
323  54  )
324  50  I×I
325  54  )
326  39  COS
327  54  )
328  32  X:T
329  03  3
330  02  2
331  02  2
332  03  3
333  03  3
334  06  6
335  42  STO
336  09  09
337  71  SBR
338  22  INV
339  92  RTN
340  76  LBL
341  35  1/X
342  53  (
343  53  (
344  43  RCL
345  11  11
346  75  -
347  43  RCL
348  22  22
349  54  )
350  30  TAN
351  65  ×
352  43  RCL
353  13  13
354  54  )
355  32  X:T
356  03  3
357  05  5
358  02  2
359  01  1
360  03  3
361  06  6
362  42  STO
363  09  09
364  71  SBR
365  22  INV
366  92  RTN
367  76  LBL
368  42  STO
369  53  (
370  53  (
371  43  RCL
372  22  22
373  75  -
374  43  RCL
375  11  11
376  54  )
377  30  TAN
378  65  ×
379  43  RCL
380  14  14
381  54  )
382  32  X:T
383  02  2
384  07  7
385  02  2
386  01  1
387  03  3
388  06  6
389  42  STO
390  09  09
391  71  SBR
392  22  INV
393  92  RTN
394  76  LBL
395  12  B
396  98  ADV
397  98  ADV
398  76  LBL
399  23  LNX
400  98  ADV
401  98  ADV
402  98  ADV
403  01  1
404  44  SUM
405  15  15
406  43  RCL
407  15  15
408  32  X:T
409  03  3
410  00  0
411  42  STO
412  09  09
413  71  SBR
414  22  INV
415  00  0
416  42  STO
417  37  37
418  98  ADV
419  71  SBR
420  24  CE
421  53  (
422  43  RCL
423  17  17
424  75  -
425  01  1
426  54  )
427  42  STO
428  24  24
429  53  (
430  43  RCL
431  18  18
432  75  -
433  43  RCL
434  17  17
435  85  +
436  01  1
437  54  )
438  42  STO
439  01  01
440  76  LBL
441  25  CLR
442  98  ADV
443  01  1
444  44  SUM
445  24  24
446  43  RCL
447  24  24
448  32  X:T
449  02  2
450  03  3
451  03  3
452  05  5
453  42  STO
454  09  09
455  71  SBR
456  22  INV
457  98  ADV
458  71  SBR
459  32  X:T
460  71  SBR
461  33  X²
462  71  SBR
463  34  ΓX
464  71  SBR
465  35  1/X
466  71  SBR
467  42  STO
468  97  DSZ
469  01  01
470  25  CLR
471  97  DSZ
472  00  00
473  23  LNX
474  91  R/S
475  76  LBL
476  43  RCL
477  01  1
478  93  .
479  01  1
480  01  1
481  02  2
482  94  +/-
483  42  STO
484  25  25
485  02  2
486  93  .
487  01  1
488  03  3
489  09  9
490  94  +/-
491  42  STO
492  26  26
493  03  3
494  93  .
495  00  0
496  07  7
497  05  5
498  94  +/-
499  42  STO
500  27  27
501  04  4
502  93  .
503  00  0
504  01  1
505  01  1
506  42  STO
507  28  28
508  05  5
509  93  .
510  00  0
511  03  3
512  03  3
513  42  STO
514  29  29
515  06  6
516  93  .
517  00  0
518  01  1
519  04  4
520  94  +/-
521  42  STO
522  30  30
523  07  7
524  93  .
525  00  0
526  06  6
527  02  2
528  94  +/-
529  42  STO
530  31  31
531  08  8
532  93  .
533  00  0
534  02  2
535  04  4
536  94  +/-
```

```
537  42 STO
538  32  32
539  09  9
540  93  .
541  00  0
542  07  7
543  05  5
544  94 +/-
545  42 STO
546  33  33
547  01  1
548  00  0
549  93  .
550  01  1
551  05  5
552  04  4
553  42 STO
554  34  34
555  01  1
556  01  1
557  93  .
558  01  1
559  03  3
560  08  8
561  42 STO
562  35  35
563  01  1
564  02  2
565  93  .
566  00  0
567  01  1
568  06  6
569  42 STO
570  36  36
571  92 RTN
572  76 LBL
573  44 SUM
574  71 SBR
575  43 RCL
576  43 RCL
577  15  15
578  32 X:T
579  02  2
580  04  4
581  42 STO
582  39  39
583  76 LBL
584  45 YX
585  01  1
586  44 SUM
587  39  39
588  73 RC*
589  39  39
590  59 INT
591  50 |X|
592  22 INV
593  67  EQ
594  45 YX
595  53  (
596  73 RC*
597  39  39
598  22 INV
599  59 INT
600  65  X
601  01  1
602  00  0
603  00  0
604  54  )
605  42 STO
606  38  38
607  92 RTN
608  76 LBL
609  52 EE
610  53  (
611  01  1
612  08  8
613  00  0
614  75  -
615  43 RCL
616  22  22
617  54  )
618  42 STO
619  22  22
620  92 RTN
621  76 LBL
622  53  (
623  43 RCL
624  22  22
625  42 STO
626  37  37
627  92 RTN
628  00  0
629  00  0
630  00  0
631  00  0
632  00  0
633  00  0
634  00  0
635  00  0
636  00  0
637  00  0
638  00  0
639  00  0
```

TABLE 3

Month	Input
1	1.112
2	2.139
3	3.075
4	4.011
5	5.033
6	6.014
7	7.062
8	8.024
9	9.075
10	10.154
11	11.138
12	12.016

SPECIAL NOTES FOR HP-97 USERS

1. A separate computation has to be done for each month.
2. Input correction for the equation of time from Table 3.

SOLP-1
SOLAR SHADING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Enter site latitude	43	—	*f*	A	43.00 ***	
2.	Enter wall azimuth	37	CHS	*f*	B	-37.00 ***	
3.	Enter overhang length	10	—	*f*	C	10.00 ***	
4.	Enter right fin length	10	—	—	R/S	10.00 ***	
5.	Enter left fin length	10	—	—	R/S	10.00 ***	
6.	Enter starting and ending hours	9.14	—	*f*	D	9.00 ***	
						14.00 ***	
7.	Enter month and correction of time from Table 3; start computation	5.33	—	—	A	5.00 ***	
						3.30 ***	
							Typical hourly output
	Note: Inputs under steps 6 & 7 are in decimal format.					9.00 ***	Hour
						45.50 ***	Altitude
						-73.90 ***	Azimuth
						12.73 ***	Shading by overhang
						7.51 ***	Shading by right fin
						-7.51 ***	Shading by left fin
							Note: Ignore negative values.
							Output continues
						10.00 ***	
						55.53 ***	
						-58.22 ***	
						15.63 ***	
						3.88 ***	
						-3.88 ***	

11.00	***
63.56	***
-35.10	***
20.12	***
-0.33	***
0.33	***
12.00	***
67.13	***
-1.99	***
28.94	***
-7.00	***
7.00	***
13.00	***
64.23	***
31.52	***
57.60	***
-25.95	***
25.95	***
14.00	***
56.55	***
56.12	***
-277.81	***
183.29	***
-183.29	***

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
a	Prints and stores display in RA
b	Prints and stores display in RB
c	Prints and stores display in RC; with R/S, prints and stores display in RD; with R/S, prints and stores display in RE
d	Accepts input in decimal format; separates, prints, and stores starting hour in R2 and finishing hour in R3
A	Accepts input in decimal format; separates, prints, and stores month in R7 and correction of time in R1; computes and prints altitude, azimuth, shading by overhang, right fin, and left fin
0	Reiterates
1	Computes hour angle, altitude, and azimuth
2	Computes and prints shade by overhang
3	Computes and prints shade by right fin
4	Computes and prints shade by left fin
5	Recalls R4; stores in R6
6	Stores (180-R4) in R4
7	Computes declination

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	Site latitude
RB	Wall azimuth
RC	Overhang length
RD	Right fin length
RE	Left fin length
RI	For reiteration
R0	Declination
R1	Correction of time
R2	Starting hour
R3	Finishing hour
R4	Hour angle, azimuth
R5	Altitude
R6	Azimuth
R7	Month
R8 & R9	Not used

SOLP-1 (HP-97) SOLAR SHADING PROGRAM

LISTING

001	*LBLa	21 16 11
002	STOA	35 11
003	PRTX	-14
004	R/S	51
005	*LBLb	21 16 12
006	STOB	35 12
007	PRTX	-14
008	SPC	16-11
009	R/S	51
010	*LBLc	21 16 13
011	STOC	35 13
012	PRTX	-14
013	R/S	51
014	STOD	35 14
015	PRTX	-14
016	R/S	51
017	STOE	35 15
018	PRTX	-14
019	SPC	16-11
020	SPC	16-11
021	R/S	51
022	*LBLd	21 16 14
023	STO3	35 03
024	INT	16 34
025	STO2	35 02
026	PRTX	-14
027	RCL3	36 03
028	FRC	16 44
029	1	01
030	0	00
031	0	00
032	×	-35
033	STO3	35 03
034	PRTX	-14
035	SPC	16-11
036	SPC	16-11
037	R/S	51
038	*LBLA	21 11
039	STO1	35 01
040	INT	16 34
041	STO7	35 07
042	PRTX	-14
043	RCL1	36 01
044	FRC	16 44
045	1	01
046	0	00
047	0	00
048	×	-35
049	STO1	35 01
050	PRTX	-14
051	GSB7	23 07
052	SPC	16-11
053	SPC	16-11
054	SPC	16-11
055	SPC	16-11
056	RCL3	36 03
057	RCL2	36 02
058	-	-45
059	1	01
060	+	-55
061	STOI	35 46
062	1	01
063	ST-2	35-45 02
064	*LBL0	21 00
065	1	01
066	ST+2	35-55 02
067	RCL2	36 02
068	PRTX	-14
069	SPC	16-11
070	GSB1	23 01
071	RCL5	36 05
072	PRTX	-14
073	RCL4	36 04
074	PRTX	-14
075	SPC	16-11
076	GSB2	23 02
077	GSB3	23 03
078	GSB4	23 04
079	SPC	16-11
080	SPC	16-11
081	DSZI	16 25 46
082	GTO0	22 00
083	R/S	51
084	*LBL1	21 01
085	RCL2	36 02
086	1	01
087	2	02
088	-	-45
089	6	06
090	0	00
091	×	-35
092	RCL1	36 01
093	-	-45
094	4	04
095	÷	-24
096	STO4	35 04
097	COS	42

```
098   RCL0    36 00
099   COS        42
100   x         -35
101   RCLA    36 11
102   COS        42
103   x         -35
104   RCLA    36 11
105   SIN        41
106   RCL0    36 00
107   SIN        41
108   x         -35
109   +         -55
110   SIN-1   16 41
111   STO5    35 05
112   COS        42
113   1/X        52
114   RCL0    36 00
115   COS        42
116   x         -35
117   RCL4    36 04
118   SIN        41
119   x         -35
120   SIN-1   16 41
121   STO4    35 04
122   X<0?    16-45
123   GTO5    22 05
124   X=0?    16-43
125   GTO5    22 05
126   RCL6    36 06
127   X>Y?    16-34
128   GTO6    22 06
129   RCL4    36 04
130   STO6    35 06
131   RTN        24
132   *LBL2   21 02
133   RCL4    36 04
134   RCLB    36 12
135   -         -45
136   ABS     16 31
137   COS        42
138   1/X        52
139   RCL5    36 05
140   TAN        43
141   x         -35
142   RCLC    36 13
143   x         -35
144   PRTX      -14
145   RTN        24
146   *LBL3   21 03
147   RCLB    36 12
148   RCL4    36 04
149   -         -45
150   TAN        43
151   RCLD    36 14
152   x         -35
153   PRTX      -14
154   RTN        24
155   *LBL4   21 04
156   RCL4    36 04
157   RCLB    36 12
158   -         -45
159   TAN        43
160   RCLE    36 15
161   x         -35
162   PRTX      -14
163   RTN        24
164   *LBL5   21 05
165   RCL4    36 04
166   STO6    35 06
167   RTN        24
168   *LBL6   21 06
169   1          01
170   8          08
171   0          00
172   RCL4    36 04
173   -         -45
174   STO4    35 04
175   RTN        24
176   *LBL7   21 07
177   RCL7    36 07
178   3          03
179   0          00
180   x         -35
181   2          02
182   7          07
183   5          05
184   +         -55
185   3          03
186   6          06
187   5          05
188   ÷         -24
189   3          03
190   6          06
191   0          00
192   x         -35
193   SIN        41
194   2          02
195   3          03
196   .         -62
197   4          04
198   5          05
199   x         -35
200   STO0    35 00
201   RTN        24
202   R/S        51
```

SOLP-2
MONTHLY AND ANNUAL AVERAGE INSOLATION ON TILTED SURFACES

GENERAL DESCRIPTION

The program computes an estimate of total monthly and annual insolation on tilted surfaces. This program can be useful for preliminary optimization of tilt and azimuth angles for solar panels. The data from the program can also be used as input for further design of solar energy collecton systems.

The program is based on a paper by S.A. Klein, published in *Solar Energy*, vol. 19.

EQUATIONS

$$d = 23.45 \sin [360 \times (284 + n)/365] \quad [6.7]$$

where
d = Declination
n = Day of year (D/Y)

$$\cos\omega = -(\tan\phi \times \tan d) \quad [6.8]$$

where
ϕ = Latitude
ω = Hour angle

$$H_o = (24 \times I_o/\pi) \times [1 + .033 \times \cos(360 \times n/365)] \times [\cos\phi \times \cos d \times \sin\omega + (\omega \times 2\pi/360) \times \sin\phi \times \sin d] \quad [6.9]$$

where
H_o = Extraterrestrial radiation on a horizontal surface on day n
I_o = Solar constant = 429 Btu/sq ft/hr

$$\overline{H}_d/\overline{H} = 1.39 - 4.027\,K_t + 5.53\,\overline{K}_t^2 - 3.108\overline{K}_t^3 \quad [6.10]$$

where
$\overline{H}_d$ = Monthly average of daily total diffuse radiation
$\overline{H}$ = Monthly average of daily total radiation on a horizontal surface
$\overline{K}_t$ = Ratio of actual daily radiation to the daily extraterrestrial radiation

$$\overline{R}_b = \{[\cos s \times \sin d \times \sin\phi] \times [(\pi/180) \times (\omega_{ss} - \omega_{sr})] - [\sin d \times \cos\phi \times \sin s \times \cos\gamma] \times [(\pi/180) \times (\omega_{ss} - \omega_{sr})] + [\cos\phi \times \cos d \times \cos s] \times [\sin\omega_{ss} - \sin\omega_{sr}] + [\cos d \times \cos\gamma \times \sin\phi \times \sin s] \times [\sin\omega_{ss} - \sin\omega_{sr}] - [\cos d \times \sin s \times \sin\gamma] \times [\cos\omega_{ss} - \cos\omega_{sr}]\} / \{2[\cos\phi \times \cos d \times \sin\omega_{ss} + (\pi/180) \times \omega \times \sin\phi \times \sin d]\} \quad [6.11]$$

where
$\overline{R}_b$ = Ratio of the monthly average beam radiation on the tilted surface to that on a horizontal surface for each month.
γ = Azimuth angle
ω_{sr} = Sunrise angle
ω_{ss} = Sunset angle
s = tilt angle of collector

If $\gamma < 0$,

$$\omega_{sr} = -\min[\omega_{sr}, \arccos[(A \times B + \sqrt{A^2-B^2+1})/(A^2+1)]]$$

$$\omega_{ss} = \min[\omega_{ss}, \arccos[(A \times B - \sqrt{A^2-B^2+1})/(A^2+1)]]$$

If $\gamma > 0$,

$$\omega_{sr} = -\min[\omega_{sr}, \arccos[(A \times B - \sqrt{A^2-B^2+1})/(A^2+1)]]$$

$$\omega_{ss} = \min[\omega_{sr}, \arccos[(A \times B + \sqrt{A^2-B^2+1})/(A^2+1)]]$$

where
$A = \cos\phi/[\sin\gamma \times \tan s] + \sin\phi/\tan\gamma$
$B = \tan d \times [(\cos\phi/\tan\gamma) - \sin\phi/(\sin\gamma \times \tan s)]$

$$\overline{R} = (1-\overline{H}_d/\overline{H}) \times \overline{R}_b + (\overline{H}_d/\overline{H}) \times (1 + \cos s)/2 + \rho \times (1-\cos s)/2 \quad [6.12]$$

where
$\overline{R}$ = Ratio of the monthly average daily radiation on a tilted surface to that on a horizontal surface for each month
ρ = Ground reflectivity—varies from 0.2 to 0.7 depending on snow cover

$$HD = \overline{R} \times \overline{K}_t \times H_o \quad [6.13]$$

where
HD = Average daily total radiation on a tilted surface

$$HM = HD \times (D/M) \quad [6.14]$$

where
HM = Monthly total radiation on a tilted surface
D/M = Days in month

OPERATING FEATURES

The program prints out the following data:

$\underline{H}_o$
$\underline{R}_b$
$\overline{R}$
HD
HM
HY

Azimuth angle is measured from south, due west being positive and due east being negative. Due south would be zero but should be input as 0.1.

REFERENCE DATA

Value of $\overline{K}_t$ and latitude can be obtained from *Low Temperature Engineering Application of Solar Energy*, published by the American Society of Heating, Refrigerating and Air Conditioning Engineers.

Table 1 shows values for D/Y and D/M for the different months of the year.

TABLE 1

	D/Y	D/M
January	17	31
February	47	28
March	75	31
April	105	30
May	135	31
June	162	30
July	198	31
August	228	31
September	258	30
October	288	31
November	318	30
December	344	31

SOLP-2
MONTHLY AND ANNUAL AVERAGE INSOLATION ON TILTED SURFACES PROGRAM

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Initialize	–	–	–	E	0.		
2.	Enter site latitude	36	–	–	A	36.0	LAT	
3.	Enter solar panel azimuth angle	.1	–	–	R/S	0.1	AZ	
4.	Enter ground reflectivity	.2	–	–	R/S	0.20	GR	
5.	Enter $\overline{KT}$ for month	.382	–	–	B	0.382	KT	
6.	Enter day of the year	17	–	–	R/S	17.	D/Y	
7.	Enter days/month	31	–	–	R/S	31.	D/M	
8.	Enter tilt angle of solar panel	45	–	–	C	45.0	TILT	
						1540.	HO	
						2.10436	RB	
						1.52633	R	
						898.	HD	
						27826.	HM	
	Repeat steps 5 through 8.							
		.435	–	–	B	0.435	KT	
		47	–	–	R/S	47.	D/Y	
		28	–	–	R/S	28.	D/M	

		45	—	—	C	45.0 TILT	
						1986. HD	
						1.68480 RB	
						1.35746 R	
						1173. HD	
						32833. HM	
9.	To compute annual insolation	—	—	—	D	60659. HY	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E	Clears register R1
INV	Prints alphanumeric identification of data; partitions program
A	Stores display in R14 and prints LAT;
	with R/S, stores display in R18 and prints AZ;
	with R/S, stores display in R19 and prints GR
B	Stores display in R16 and prints KT;
	with R/S, stores display in R15 and prints D/Y;
	with R/S, stores display in R13 and prints D/M
C	Stores display in R17 and prints tilt; computes declinations and ω; computes and prints HO; computes HD/HO; continues using SBR CE and other subroutines
X^2	Recalls R10 and stores in R03; if R02 is greater than R10, goes to SBR $\sqrt{X}$, otherwise goes to SBR 1/X
$\sqrt{X}$	Recalls R10 and stores in R03; continues
1/X	If R18 is greater than 0, goes to SBR CLR, otherwise recalls R03; changes sign and stores in R04; recalls R04 and stores in R00; goes to SBR RCL
CLR	Recalls R02; changes sign and stores in R04; recalls R03 and stores in R00; goes to SBR RCL
CE	Computes arc cos $[(AB \pm \sqrt{A^2-B^2+1}) / (A^2+1)]$
RCL	Computes and prints $\overline{\text{R}}$B, R, HD, and HM
D	Prints HY

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Variable; ω_{ss}
R01	HY
R02	arc cos $[(AB - \sqrt{A^2-B^2+1})/(A^2+1)]$; also variable
R03	arc cos $[(AB + \sqrt{A^2-B^2+1})/(A^2+1)]$; also variable
R04	ω_{rr}
R05	Alphanumeric code
R06	For FIX IND
R07	A; also variable
R08	Variable; also B
R09	HD/HO
R10	ω
R11	Declination
R12	360/365; also HO
R13	Days in month
R14	Latitude
R15	Day of year
R16	$\overline{\text{K}}$T
R17	Tilt angle
R18	Azimuth
R19	Ground reflectivity

SOLP-2 MONTHLY AND ANNUAL AVERAGE INSOLATION ON TILTED SURFACES

LABELS & SUBROUTINES

```
001  15   E
010  22  INV
031  11   A
082  12   B
135  13   C
387  33  X²
399  34  √X
405  35  1/X
423  25  CLR
436  24  CE
478  43  RCL
747  14   D
```

LISTING

```
000  76  LBL
001  15   E
002  00   0
003  42  STO
004  01   01
005  99  PRT
006  98  ADV
007  98  ADV
008  91  R/S
009  76  LBL
010  22  INV
011  22  INV
012  58  FIX
013  02   2
014  69  OP
015  17   17
016  25  CLR
017  69  OP
018  00   00
019  43  RCL
020  05   05
021  69  OP
022  04   04
023  32  X:T
024  58  FIX
025  40  IND
026  06   06
027  69  OP
028  06   06
029  92  RTN
030  76  LBL
031  11   A
032  42  STO
033  14   14
034  32  X:T
035  02   2
```

036	07	7
037	01	1
038	03	3
039	03	3
040	07	7
041	42	STO
042	05	05
043	01	1
044	42	STO
045	06	06
046	71	SBR
047	22	INV
048	91	R/S
049	42	STO
050	18	18
051	32	X⇌T
052	01	1
053	03	3
054	04	4
055	06	6
056	42	STO
057	05	05
058	01	1
059	42	STO
060	06	06
061	71	SBR
062	22	INV
063	91	R/S
064	42	STO
065	19	19
066	32	X⇌T
067	02	2
068	02	2
069	03	3
070	05	5
071	42	STO
072	05	05
073	02	2
074	42	STO
075	06	06
076	71	SBR
077	22	INV
078	98	ADV
079	98	ADV
080	91	R/S
081	76	LBL
082	12	B
083	42	STO
084	16	16
085	32	X⇌T
086	02	2
087	06	6
088	03	3
089	07	7
090	42	STO
091	05	05
092	03	3
093	42	STO
094	06	06
095	71	SBR
096	22	INV
097	91	R/S
098	42	STO
099	15	15
100	32	X⇌T
101	01	1
102	06	6
103	06	6
104	03	3
105	04	4
106	05	5
107	42	STO
108	05	05
109	00	0
110	42	STO
111	06	06
112	71	SBR
113	22	INV
114	91	R/S
115	42	STO
116	13	13
117	32	X⇌T
118	01	1
119	06	6
120	06	6
121	03	3
122	03	3
123	08	8
124	42	STO
125	05	05
126	00	0
127	42	STO
128	06	06
129	71	SBR
130	22	INV
131	98	ADV
132	98	ADV
133	91	R/S
134	76	LBL
135	13	C
136	42	STO
137	17	17
138	32	X⇌T
139	03	3
140	07	7
141	02	2
142	04	4
143	02	2
144	07	7
145	03	3
146	07	7
147	42	STO
148	05	05
149	01	1
150	42	STO
151	06	06
152	71	SBR
153	22	INV
154	98	ADV
155	98	ADV
156	03	3
157	06	6
158	00	0
159	55	÷
160	03	3
161	06	6
162	05	5
163	95	=
164	42	STO
165	12	12
166	43	RCL
167	15	15
168	85	+
169	02	2
170	08	8
171	04	4
172	95	=
173	65	×
174	43	RCL
175	12	12
176	95	=
177	38	SIN
178	65	×
179	02	2
180	03	3
181	93	.
182	04	4
183	05	5
184	95	=
185	42	STO
186	11	11
187	30	TAN
188	65	×
189	43	RCL
190	14	14
191	30	TAN
192	95	=
193	94	+/-
194	22	INV
195	39	COS
196	42	STO
197	10	10
198	65	×
199	89	π
200	65	×
201	43	RCL
202	14	14
203	38	SIN
204	65	×
205	43	RCL
206	11	11
207	38	SIN
208	55	÷
209	01	1
210	08	8
211	00	0
212	95	=
213	85	+
214	53	(
215	43	RCL
216	14	14
217	39	COS
218	65	×
219	43	RCL
220	10	10
221	38	SIN
222	65	×
223	43	RCL
224	11	11
225	39	COS
226	54	)
227	95	=
228	65	×
229	53	(
230	53	(
231	43	RCL
232	15	15
233	65	×
234	43	RCL
235	12	12
236	54	)
237	39	COS
238	65	×
239	93	.
240	00	0
241	03	3
242	03	3
243	85	+
244	01	1
245	54	)
246	65	×
247	03	3
248	02	2
249	07	7
250	07	7
251	95	=
252	42	STO
253	12	12
254	32	X⇌T
255	02	2
256	03	3
257	03	3
258	02	2
259	42	STO
260	05	05
261	00	0
262	42	STO
263	06	06
264	71	SBR
265	22	INV
266	98	ADV
267	01	1
268	93	.
269	03	3
270	09	9
271	75	-
272	04	4
273	93	.
274	00	0
275	02	2
276	07	7
277	65	×
278	43	RCL
279	16	16
280	85	+
281	05	5
282	93	.
283	05	5
284	03	3
285	01	1
286	65	×
287	43	RCL
288	16	16
289	33	X²
290	75	-
291	03	3

```
292  93  .
293  01  1
294  00  0
295  08  8
296  65  ×
297  43  RCL
298  16  16
299  45  Y^X
300  03  3
301  95  =
302  42  STO
303  09  09
304  43  RCL
305  18  18
306  38  SIN
307  65  ×
308  43  RCL
309  17  17
310  30  TAN
311  95  =
312  35  1/X
313  42  STO
314  08  08
315  65  ×
316  43  RCL
317  14  14
318  39  COS
319  95  =
320  85  +
321  53  (
322  43  RCL
323  14  14
324  38  SIN
325  55  ÷
326  43  RCL
327  18  18
328  30  TAN
329  54  )
330  95  =
331  42  STO
332  07  07
333  43  RCL
334  14  14
335  39  COS
336  55  ÷
337  43  RCL
338  18  18
339  30  TAN
340  95  =
341  75  -
342  53  (
343  43  RCL
344  08  08
345  65  ×
346  43  RCL
347  14  14
348  38  SIN
349  54  )
350  95  =
351  65  ×
352  43  RCL
353  11  11
354  30  TAN
355  95  =
356  42  STO
357  08  08
358  01  1
359  42  STO
360  00  00
361  71  SBR
362  24  CE
363  42  STO
364  03  03
365  01  1
366  94  +/-
367  42  STO
368  00  00
369  71  SBR
370  24  CE
371  42  STO
372  02  02
373  43  RCL
374  10  10
375  32  X:T
376  43  RCL
377  03  03
378  77  GE
379  33  X²
380  43  RCL
381  02  02
382  77  GE
383  34  √X
384  71  SBR
385  35  1/X
386  76  LBL
387  33  X²
388  43  RCL
389  10  10
390  42  STO
391  03  03
392  43  RCL
393  02  02
394  77  GE
395  34  √X
396  71  SBR
397  35  1/X
398  76  LBL
399  34  √X
400  43  RCL
401  10  10
402  42  STO
403  02  02
404  76  LBL
405  35  1/X
406  29  CP
407  43  RCL
408  18  18
409  77  GE
410  25  CLR
411  43  RCL
412  03  03
413  94  +/-
414  42  STO
415  04  04
416  43  RCL
417  02  02
418  42  STO
419  00  00
420  71  SBR
421  43  RCL
422  76  LBL
423  25  CLR
424  43  RCL
425  02  02
426  94  +/-
427  42  STO
428  04  04
429  43  RCL
430  03  03
431  42  STO
432  00  00
433  71  SBR
434  43  RCL
435  76  LBL
436  24  CE
437  53  (
438  53  (
439  53  (
440  53  (
441  43  RCL
442  07  07
443  33  X²
444  75  -
445  43  RCL
446  08  08
447  33  X²
448  85  +
449  01  1
450  54  )
451  34  √X
452  65  ×
453  43  RCL
454  00  00
455  54  )
456  85  +
457  53  (
458  43  RCL
459  07  07
460  65  ×
461  43  RCL
462  08  08
463  54  )
464  54  )
465  55  ÷
466  53  (
467  43  RCL
468  07  07
469  33  X²
470  85  +
471  01  1
472  54  )
473  54  )
474  22  INV
475  39  COS
476  92  RTN
477  76  LBL
478  43  RCL
479  53  (
480  43  RCL
481  11  11
482  38  SIN
483  65  ×
484  89  π
485  55  ÷
486  01  1
487  08  8
488  00  0
489  54  )
490  42  STO
491  03  03
492  53  (
493  53  (
494  53  (
495  24  CE
496  65  ×
497  43  RCL
498  17  17
499  39  COS
500  65  ×
501  43  RCL
502  14  14
503  38  SIN
504  54  )
505  65  ×
506  53  (
507  43  RCL
508  00  00
509  75  -
510  43  RCL
511  04  04
512  54  )
513  42  STO
514  02  02
515  75  -
516  53  (
517  43  RCL
518  03  03
519  65  ×
520  43  RCL
521  14  14
522  39  COS
523  65  ×
524  43  RCL
525  17  17
526  38  SIN
527  65  ×
528  43  RCL
529  18  18
530  39  COS
531  54  )
532  65  ×
533  43  RCL
534  02  02
535  85  +
536  53  (
537  43  RCL
538  14  14
539  39  COS
540  65  ×
541  43  RCL
542  11  11
543  39  COS
544  65  ×
545  43  RCL
546  17  17
547  39  COS
```

548	54	)
549	65	×
550	53	(
551	43	RCL
552	00	00
553	38	SIN
554	75	-
555	43	RCL
556	04	04
557	38	SIN
558	54	)
559	42	STO
560	02	02
561	85	+
562	53	(
563	53	(
564	43	RCL
565	11	11
566	39	COS
567	65	×
568	43	RCL
569	17	17
570	38	SIN
571	54	)
572	42	STO
573	07	07
574	65	×
575	43	RCL
576	18	18
577	39	COS
578	65	×
579	43	RCL
580	14	14
581	38	SIN
582	65	×
583	43	RCL
584	02	02
585	54	)
586	75	-
587	53	(
588	43	RCL
589	07	07
590	65	×
591	43	RCL
592	18	18
593	38	SIN
594	54	)
595	65	×
596	53	(
597	43	RCL
598	00	00
599	39	COS
600	75	-
601	43	RCL
602	04	04
603	39	COS
604	54	)
605	54	)
606	55	÷
607	53	(
608	02	2
609	65	×
610	53	(
611	43	RCL
612	14	14
613	39	COS
614	65	×
615	43	RCL
616	11	11
617	39	COS
618	65	×
619	43	RCL
620	10	10
621	38	SIN
622	85	+
623	43	RCL
624	10	10
625	65	×
626	43	RCL
627	03	03
628	65	×
629	43	RCL
630	14	14
631	38	SIN
632	54	)
633	54	)
634	54	)
635	42	STO
636	03	03
637	32	X:T
638	03	3
639	05	5
640	01	1
641	04	4
642	42	STO
643	05	05
644	05	5
645	42	STO
646	06	06
647	71	SBR
648	22	INV
649	53	(
650	53	(
651	24	CE
652	65	×
653	53	(
654	01	1
655	75	-
656	43	RCL
657	09	09
658	54	)
659	54	)
660	85	+
661	53	(
662	53	(
663	43	RCL
664	17	17
665	39	COS
666	85	+
667	01	1
668	54	)
669	65	×
670	43	RCL
671	09	09
672	55	÷
673	02	2
674	54	)
675	54	)
676	85	+
677	53	(
678	53	(
679	01	1
680	75	-
681	43	RCL
682	17	17
683	39	COS
684	54	)
685	65	×
686	43	RCL
687	19	19
688	55	÷
689	02	2
690	54	)
691	54	)
692	32	X:T
693	03	3
694	05	5
695	42	STO
696	05	05
697	05	5
698	42	STO
699	06	06
700	71	SBR
701	22	INV
702	98	ADV
703	53	(
704	24	CE
705	65	×
706	43	RCL
707	16	16
708	65	×
709	43	RCL
710	12	12
711	54	)
712	32	X:T
713	02	2
714	03	3
715	01	1
716	06	6
717	42	STO
718	05	05
719	00	0
720	42	STO
721	06	06
722	71	SBR
723	22	INV
724	53	(
725	24	CE
726	65	×
727	43	RCL
728	13	13
729	54	)
730	44	SUM
731	01	01
732	32	X:T
733	02	2
734	03	3
735	03	3
736	08	8
737	42	STO
738	05	05
739	00	0
740	42	STO
741	06	06
742	71	SBR
743	22	INV
744	98	ADV
745	91	R/S
746	76	LBL
747	14	D
748	43	RCL
749	01	01
750	32	X:T
751	02	2
752	03	3
753	04	4
754	05	5
755	42	STO
756	05	05
757	00	0
758	42	STO
759	06	06
760	71	SBR
761	22	INV
762	98	ADV
763	98	ADV
764	91	R/S
765	00	0

SPECIAL NOTES FOR HP-97 USERS

1. All data has to be input through the keyboard. This can be done in TRACE mode to keep a record of data.
2. The program requires two cards, SOLP-2A and SOLP-2B.
3. The monthly solar radiation data has to be totaled to calculate solar radiation for a year or a number of months.

SOLP-2
MONTHLY AND ANNUAL AVERAGE INSOLATION ON TILTED SURFACES PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
	Load SOLP-2A and switch printer to TRACE mode						
1.	Enter number of days/month	31	–	STO	0	31.00 STO0	
2.	Enter site latitude	36		STO	1	36.00 STO1	
3.	Enter day of the year	17	–	STO	2	17.00 STO2	
4.	Enter $\overline{KT}$ for month	.382	–	STO	3	.382 STO3	
5.	Enter tilt of solar panel	45	–	STO	4	45.00 STO4	
6.	Enter solar panel azimuth angle	.1	–	STO	5	.10 STO5	
7.	Enter ground reflectivity	.2	–	STO	6	.20 STO6	Switch off from TRACE mode after this step.
8.	To start computation	–	–	–	E		
9.	Load SOLP-2B and continue	–	–	–	E	1539.50 ***	Ho
						2.10436 ***	$\overline{R}b$
						1.50054 ***	$\overline{R}$
						882. ***	HD
	Load SOLP-2A and repeat input to be changed. Switch printer to TRACE mode.					27356. ***	HM
		28	–	STO	0	28.00 STO0	
		47	–	STO	2	47.00 STO2	
		.435	–	STO	3	.435 STO3	Switch off from TRACE mode after this step.
	Load SOLP-2B and continue.	–	–	–	E	1985.78 ***	Ho
						1.68480 ***	$\overline{R}b$

	Continue in this manner. Add insolation for different months to find out total insolation.					1.33859 *** 1157. *** 32386. ***	$\bar{R}$ HD HM

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
E	Computes declination D; computes and prints HO; computes HD/HO; continues using SBR 0 and other subroutines
1	Recalls R8 and stores in RD; if RE is greater than R8 goes to SBR 2, otherwise goes to SBR 3
2	Recalls R8 and stores in RE; goes to SBR 3
3	If R5 is greater than 0 goes to SBR 4, otherwise recalls RD, changes sign, and stores in RI
4	Recalls RE; changes sign; stores in RI; recalls RD; stores in RE
0	Calculates arc cos $[(AB \pm \sqrt{A^2-B^2+1})/(A^2+1)]$
E	SOLP−2B; computes and prints $\overline{\text{RB}}$, R, HD, and HM

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Days in month
R1	Latitude
R2	Day of year
R3	$\overline{\text{KT}}$
R4	Tilt angle
R5	Azimuth
R6	Ground reflectivity
R7	Declination
R8	ω
R9	HO
RA	HD/HO
RB	A; also variable
RC	B; also variable
RD	arc cos $[(AB+\sqrt{A^2-B^2+1})/(A^2+1)]$; variable
RE	360/365; arc cos $[(AB+\sqrt{A^2-B^2+1})/(A^2+1)]$; ω_{ss}
RI	Variable; ω_{rr}

SOLP-2A & SOLP-2B (HP-97) MONTHLY AND ANNUAL AVERAGE INSOLATION ON TILTED SURFACES

SOLP-2A LISTING

001	*LBLE	21 15	052	+	-55
002	RCL2	36 02	053	RCL2	36 02
003	2	02	054	RCLE	36 15
004	8	08	055	×	-35
005	4	04	056	COS	42
006	+	-55	057	.	-62
007	3	03	058	0	00
008	6	06	059	3	03
009	0	00	060	3	03
010	ENT↑	-21	061	×	-35
011	3	03	062	1	01
012	6	06	063	+	-55
013	5	05	064	×	-35
014	÷	-24	065	3	03
015	STOE	35 15	066	2	02
016	×	-35	067	7	07
017	SIN	41	068	7	07
018	2	02	069	×	-35
019	3	03	070	STO9	35 09
020	.	-62	071	PRTX	-14
021	4	04	072	SPC	16-11
022	5	05	073	RCL3	36 03
023	×	-35	074	X²	53
024	STO7	35 07	075	5	05
025	TAN	43	076	.	-62
026	RCL1	36 01	077	5	05
027	TAN	43	078	3	03
028	×	-35	079	×	-35
029	CHS	-22	080	RCL3	36 03
030	COS⁻¹	16 42	081	3	03
031	STO8	35 08	082	Yˣ	31
032	Pi	16-24	083	3	03
033	×	-35	084	.	-62
034	1	01	085	1	01
035	8	08	086	×	-35
036	0	00	087	-	-45
037	÷	-24	088	RCL3	36 03
038	RCL1	36 01	089	4	04
039	SIN	41	090	×	-35
040	×	-35	091	-	-45
041	RCL7	36 07	092	1	01
042	SIN	41	093	.	-62
043	×	-35	094	4	04
044	RCL1	36 01	095	+	-55
045	COS	42	096	STOA	35 11
046	RCL8	36 08	097	RCL5	36 05
047	SIN	41	098	SIN	41
048	×	-35	099	RCL4	36 04
049	RCL7	36 07	100	TAN	43
050	COS	42	101	×	-35
051	×	-35	102	1/X	52
			103	STOC	35 13

```
104  RCL1   36 01
105  COS       42
106  x        -35
107  RCL1   36 01
108  SIN       41
109  RCL5   36 05
110  TAN       43
111  ÷        -24
112  +        -55
113  STOB   35 12
114  RCLC   36 13
115  RCL1   36 01
116  SIN       41
117  x        -35
118  CHS      -22
119  RCL1   36 01
120  COS       42
121  RCL5   36 05
122  TAN       43
123  ÷        -24
124  +        -55
125  RCL7   36 07
126  TAN       43
127  x        -35
128  STOC   35 13
129  1         01
130  STOI   35 46
131  GSB0   23 00
132  STOD   35 14
133  1         01
134  CHS      -22
135  STOI   35 46
136  GSB0   23 00
137  STOE   35 15
138  RCLD   36 14
139  RCL8   36 08
140  X≤Y?   16-35
141  GTO1   22 01
142  RCLE   36 15
143  X>Y?   16-34
144  GTO2   22 02
145  GSB3   23 03
146  *LBL1  21 01
147  RCL8   36 08
148  STOD   35 14
149  RCLE   36 15
150  X>Y?   16-34
151  GTO2   22 02
152  GSB3   23 03
153  *LBL2  21 02
154  RCL8   36 08
155  STOE   35 15
156  GSB3   23 03
157  *LBL3  21 03
158  RCL5   36 05
159  X>0?   16-44
160  GTO4   22 04
161  RCLD   36 14
162  CHS      -22
163  STOI   35 46
164  R/S       51
165  *LBL4  21 04
166  RCLE   36 15
167  CHS      -22
168  STOI   35 46
169  RCLD   36 14
170  STOE   35 15
171  R/S       51
172  *LBL0  21 00
173  RCLB   36 12
174  X^2       53
175  RCLC   36 13
176  X^2       53
177  -        -45
178  1         01
179  +        -55
180  √X        54
181  RCLI   36 46
182  x        -35
183  RCLB   36 12
184  RCLC   36 13
185  x        -35
186  +        -55
187  RCLB   36 12
188  X^2       53
189  1         01
190  +        -55
191  ÷        -24
192  COS^-1 16 42
193  RTN       24
194  R/S       51
```

SOLP-2B LISTING

```
001  *LBLE  21 15
002  RCL7   36 07
003  SIN       41
004  Pi     16-24
005  x        -35
006  1         01
007  8         08
008  0         00
009  ÷        -24
010  STOB   35 12
011  RCL4   36 04
012  COS       42
013  x        -35
014  RCL1   36 01
015  SIN       41
016  x        -35
017  RCLE   36 15
018  RCLI   36 46
019  -        -45
020  STOC   35 13
021  x        -35
022  RCLB   36 12
023  RCL1   36 01
024  COS       42
025  x        -35
026  RCL4   36 04
027  SIN       41
028  x        -35
029  RCL5   36 05
030  COS       42
031  x        -35
032  RCLC   36 13
033  x        -35
034  -        -45
035  RCL1   36 01
036  COS       42
037  RCL7   36 07
038  COS       42
039  x        -35
040  RCL4   36 04
041  COS       42
042  x        -35
043  RCLE   36 15
044  SIN       41
045  RCLI   36 46
046  SIN       41
047  -        -45
048  STOC   35 13
049  x        -35
050  +        -55
051  RCL7   36 07
052  COS       42
053  RCL4   36 04
054  SIN       41
055  x        -35
056  STOD   35 14
057  RCL5   36 05
058  COS       42
059  x        -35
060  RCL1   36 01
061  SIN       41
062  x        -35
063  RCLC   36 13
064  x        -35
065  +        -55
066  RCLD   36 14
067  RCL5   36 05
068  SIN       41
069  x        -35
070  RCLE   36 15
071  COS       42
072  RCLI   36 46
073  COS       42
074  -        -45
075  x        -35
076  -        -45
077  RCL1   36 01
078  COS       42
079  RCL7   36 07
080  COS       42
081  x        -35
082  RCL8   36 08
083  SIN       41
084  x        -35
085  RCL8   36 08
086  RCLB   36 12
087  x        -35
088  RCL1   36 01
089  SIN       41
090  x        -35
091  +        -55
092  2         02
093  x        -35
094  ÷        -24
095  DSP5   -63 05
096  PRTX     -14
097  SPC    16-11
098  1         01
099  RCLA   36 11
100  -        -45
101  x        -35
102  RCL4   36 04
103  COS       42
104  1         01
105  +        -55
106  RCLA   36 11
107  x        -35
108  2         02
109  ÷        -24
110  +        -55
111  1         01
112  RCL4   36 04
113  COS       42
114  -        -45
115  RCL6   36 06
116  x        -35
117  2         02
118  ÷        -24
119  +        -55
120  PRTX     -14
121  SPC    16-11
122  RCL3   36 03
123  x        -35
124  RCL9   36 09
125  x        -35
```

```
126  DSP0   -63 00      132  DSP2   -63 02
127  PRTX      -14      133   SPC    16-11
128   SPC    16-11      134   SPC    16-11
129  RCL0    36 00      135   SPC    16-11
130    x       -35      136   R/S       51
131  PRTX      -14
```

7

ENGINEERING ECONOMIC ANALYSIS PROGRAM

EP-1
LIFE CYCLE COST ANALYSIS PROGRAM, PART I

GENERAL DESCRIPTION

Life-cycle cost analysis of alternate economic proposals can be accomplished with this program, since it can compute present value as well as annual flow.

The program is based on information contained in "Solar Heating and Cooling in Buildings: Methods of Economic Evaluation," by Ms. Rosalie T. Ruegg, published by the U.S. Department of Commerce, National Bureau of Standards, Center for Building Technology. The user should study this booklet to get the full benefit of this program.

EQUATIONS

The equation given below is a very slight modification of the equation contained in the reference booklet. Further, the abbreviations used are the same as those given under "Explanation of Storage Registers." (See page 250.)

Total Present Value $PV\Sigma = IC \;+ RC$

$$\times \sum_{j=1}^{NR+1} [(1+INF)/(1+DS)^{N2}]^j - RC$$

$$\times (1+INF)^{NR \times N2} \times (N3/N2)$$

$$\times 1/(1+DS)^{N1} + (1-TXI) \times MLC$$

$$\times \sum_{j=1}^{N1} [(1+INF)/(1+DS)]^j + (1-TXI) \times MSC$$

$$\times \sum_{j=1}^{N1} 1/(1+DS)^j + (1+TXI) \times ENC$$

$$\times \sum_{j=1}^{N1} [(1+EES)/(1+DS)]^j - (TXI)$$

$$\times \sum_{j=1}^{N1} DEP/(1+DS)^j + (1-TXI)$$

$$\times \sum_{j=1}^{N1} TXP \times IC/(1+DS)^j - (TXI)$$

$$\times \sum_{j=1}^{N1} INT \text{ on } MTG/(1+DS)^j - (1-TXI)$$

$$\times \sum_{j=1}^{N1} INC/(1+DS)^j \qquad [7.1]$$

NOTES:

1. *INF, DS, EES, TXI, TXP* and *INT* are input initially as percents, but the above formula is based on their fractional value, which is arrived at by dividing the percent by 100.

2. Depreciation is based on the straight line method, and initial cost also includes the net present value of the total replacement cost.

2.2 Interest on the mortgage is calculated based on the following equations:

Annual interest $= IC\Sigma \times (N_1 + 1)/N_1 \times 2$

$IC\Sigma$ = total initial cost inclusive of net present worth of the total replacement cost

2.3 Annualized cost $= PV\Sigma \times INT \times [(1+INT)^{N1}/(1+INT)^{N1} - 1]$

OPERATING FEATURES

As can be seen from the equations, inflation is not applicable to the miscellaneous cost. Any items subject to inflation should be grouped with maintenance cost.

The input of data has been arranged in such a way as to permit easy sensitivity analysis of the variables. This is well illustrated by the examples.

EXAMPLE NO. 1

Compute the present value of an energy conservation proposal having the following data:

Total initial cost	$1,000,000
Period of analysis	20 years
Discount rate	11%
Replacement cost of some part of the system	$285,000
Frequency of replacement in years	15 years
Inflation rate	8%
Annual maintenance cost	$35,000
Miscellaneous cost	$15,000
Energy cost savings	$100,000
Escalation in energy	9%
Interest on mortgage	8.75%
Tax on property, %	3%
Income tax	45%
Annual income	$30,000

EXAMPLE NO. 2

Also compute the effect of the following:

1. If annual income = 0
2. Also if income tax = 0
3. If analysis neglects tax on the property and interest on the mortgage

EXAMPLE NO. 3

Find sensitivity of analysis under Example No. 1 if escalation in the energy cost varies from 9% to 6%.

EXAMPLE NO. 4

Compute annualized flow of the last estimate of the present worth. To solve this problem with HP-97, use program EP-2.

EP-1
LIFE CYCLE COST ANALYSIS PROGRAM, PART I

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 1							
1.	Enter total initial cost	1000000	–	2nd	A′	1000000.	IC	
2.	Enter period of analysis, yr	20	–	–	R/S	20.	N1	
3.	Enter discount rate, %	11	–	–	R/S	11.	DR	
4.	Enter replacement cost	285000	–	–	A	285000.	RC	
5.	Enter frequency of replacement years	15	–	–	R/S	15.	N2	
6.	Enter inflation rate, %	8	–	–	R/S	8.	INF	
7.	Enter annual maintenance cost	35000	–	2nd	B′	35000.	MLC	
8.	Enter annual miscellaneous cost	15000	–	–	R/S	15000.	MSC	
9.	Enter annual energy cost savings	100000	+/–	–	B	-100000.	ENC	Since there is saving in the energy cost, enter this as negative number.
10.	Enter escalation rate, %, in energy cost	9	–	–	R/S	9.	EES	
11.	Enter interest rate, % on mortgage	8.75	–	2nd	C′	9.	INT	The calculation will be based on 8.75%, but the program will print out integers only.
12.	Enter property tax rate % as related to initial cost	3	–	–	R/S	3.	TXP	
13.	Enter total income tax rate, %	45	–	–	C	45.	TX I	
14.	Enter total annual income resulting from improvement	30000	–	–	R/S	30000.	INC	
15.	To compute present value	–	–	–	D	0.	PV	Present value
						1000000.	IC	Initial cost
						1.	NR	Number of replacements
						188954.	RCΣ	Total cost of replacements

EP-1 *(Continued)*

LIFE CYCLE COST ANALYSIS PROGRAM, PART I

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
						10.	N3	Years of useful life remaining after period of analysis
						74757.	SV	Salvage value
						292365.	MLC	Maintenance: labor and material cost
						65697.	MSC	Miscellaneous cost
						-913827.	ENC	Energy cost
						131395.	TXPN	Tax on property net
						199636.	TXBD	Tax benefit on depreciation
						183416.	TXBI	Tax benefit on interest
						131395.	INC	Income
						175381.	PVΣ	Total present value
	Example 2.1							
1.	Enter total income tax rate, %	45	—	—	C	45.	TX I	*Note:* Since only one item is to be changed, there is no need to re-enter all the data.
2.	Enter income	0	—	—	R/S	0.	INC	
3.	To compute present value	—	—	—	D	0.	PV	
						1000000.	IC	
						1.	NR	
						188954.	RCΣ	
						10.	N3	
						74757.	SV	

						292365. MLC 65697. MSC	
						-913827. ENC	
						131395. TXPN 199636. TXBD 183416. TXBI	
						0. INC	
						306776. PVΣ	
	Example 2.2						
	Same as steps 1, 2, & 3 of Example no. 2.1	0 0	– –	– –	C R/S	0. TX I 0. INC	
						0. PV	
						1000000. IC 1. NR 188954. RCΣ	
						10. N3 74757. SV	
						531573. MLC 119450. MSC	
						-1661504. ENC	
						238900. TXPN 0. TXBD 0. TXBI	
						0. INC	
						342617. PVΣ	

EP-1 *(Continued)*
LIFE CYCLE COST ANALYSIS PROGRAM, PART I
USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
	Example 2.3							
1.	Enter interest rate on mortgage, %	0	–	2nd	C′	0.	INT	
2.	Enter property tax rate, %	0	–	–	R/S	0.	TXP	
3.	To compute present value	–	–	–	D	0.	PV	
						1000000.	IC	
						1.	NR	
						188954.	RCΣ	
						10.	N3	
						74757.	SV	
						531573.	MLC	
						119450.	MSC	
						1661504.	ENC	
						0.	TXPN	
						0.	TXBD	
						0.	TXBI	
						0.	INC	
						103717.	PVΣ	
	Example 3							
1.	Enter annual energy cost saving	100000	+/–	–	B	-100000.	ENC	
2.	Enter revised escalation rate	8	–	–	R/S	8.	EES	
3.	Enter interest rate, %	8.75	–	2nd	C′	9.	INT	This data has to be re-input since it was zeroed previously
4.	Enter property tax % as related to initial cost	3	–	–	R/S	3.	TXP	
5.	Enter total income tax rate, %	45	–	–	C	45.	TX I	
6.	Enter annual income	30000	–	–	R/S	30000.	INC	

7.	To compute present value	—	—	—	D	0.	PV
						1000000. 1. 188954.	IC NR RCΣ
						10. 74757.	N3 SV
						292365. 65697.	MLC MSC
						-835329.	ENC
						131395. 199636. 183416.	TXPN TXBD TXBI
						131395.	INC
						253879.	PVΣ
	For next run, change EES only.						
8.	Enter annual energy cost	100000	+/—	—	B	-10000u.	ENC
9.	Enter escalation rate, % in energy cost	7	—	—	R/S	7.	EES
10.	To compute present value	—	—	—	D	0.	PV
						1000000. 1. 188954.	IC NR RCΣ
						10. 74757.	N3 SV
						292365. 65697.	MLC MSC

EP-1 *(Continued)*

LIFE CYCLE COST ANALYSIS PROGRAM, PART I

USER INSTRUCTIONS AND EXAMPLES Number of Cards: TWO

Step	Procedure	Enter	Press			Print Out		Explanation
						-765091.	ENC	
						131395.	TXPN	
						199636.	TXBD	
						183416.	TXBI	
						131395.	INC	
						324117.	PVΣ	
	Continue steps 8, 9, & 10 as many times as desired with different values of EES.	100000	+/–	–	B	-100000.	ENC	
		6	–	–	R/S	6.	EES	
		–	–	–	D	0.	PV	
						1000000.	IC	
						1.	NR	
						188954.	RCΣ	
						10.	N3	
						74757.	SV	
						292365.	MLC	
						65697.	MSC	
						-702173.	ENC	
						131395.	TXPN	
						199636.	TXBD	
						183416.	TXBI	
						131395.	INC	
	Annualized flow for Example no. 4 is based on this figure.					387035.	PVΣ	

	Example 4 To compute annualized cost use Solid State Software, Module "Master Library," or Program EC-2.						*Note:* Use of "Master Library" program will change contents of some of the storage registers. It will be necessary to restore the register content if the analysis has to continue with the same data.
1.	Set calculator for printing	–	2nd	PGM	01		
2.	Select program	19	–	STO	00	19.00	
3.	Initialize	–	–	2nd	E′	0.	
4.	Select routine for ordinary annuity	–	–	2nd	C′	0. 0.	
5.	Enter number of periods	20	–	–	A	20. 20.	
6.	Enter interest rate, %	8.75	–	–	B	8.75 8.7500	
7.	Enter present value (PV)	387035	–	–	D	387035.0000 387035.00	
8.	To compute annualized flow	0	–	–	C	0.00 41645.65	Annualized flow

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
INV	For printing alphanumeric identification of data; partitions
A′	Stores display in R02 and prints
LNX	As part of SBR A′, prints IC;
	with R/S, stores and prints display in R03; using SBR CE, prints N1
CE	As part of SBR A′, prints display and N1 or N2;
	with R/S, stores and prints display in R04 and prints DS, calls SBR CLR, and stores result in R04
A	Prints display and stores in R05; prints RC
X⇄T	As part of SBR A prints RC;
	with R/S, stores displays in R06; using SBR CE, prints display and N2;
	with R/S, stores display in R07, prints display and INF, calls SBR CLR, and stores result in R07
B′	Stores display in R08; prints display and MLC using SBR X^2
X^2	Prints MLC and MSC;
	with R/S, stores display in R09 and prints MSC
B	Stores display in R10 and uses SBR $\sqrt{X}$
$\sqrt{X}$	Prints ENC or EES;
	with R/S, stores display in R11 and prints display and EEC
C′	Stores display in R12 and using SBR 1/X prints display and INT; calls SBR RCL and stores result in R12;
	with R/S, stores display in R13 and using SBR STO prints display and TXP; calls SBR RCL and stores result in R13
1/X	Prints INT and INTΣ
RCL	Divides display by 100
STO	Prints TXBI and other variations
C	Stores display in R14 and using SBR STO prints display and TXI; calls SBR RCL and stores result in R14;
	with R/S, prints display in R15 and using SBR SUM prints display and INC
SUM	Prints INC
Y^x	Prints PV and PVΣ
EE	Computes $\sum_{j=1}^{n} (1+x)^n$
D	Computes and prints PV; total initial cost—IC; total number of replacements—NR; total cost of replacement—RCΣ; years of remaining life—NS; salvage value—SV; maintenance cost: material and labor—MLC; miscellaneous cost—MSC; energy cost—ENC; tax on property, net—TXPN; tax benefit of depreciation—TXBD; tax benefit of interest on depreciation—TXBI; income—INC; total present worth—PVΣ

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Not used
R01	Not used
R02	IC—initial cost of improvement (total, material, labor, space, etc.)
R03	N1—years of analysis
R04	DS—discount rate, %
R05	RC—replacement cost
R06	N2—frequency of replacement in years
R07	INF—inflation rate, %
R08	MLC—annual maintenance cost (material and labor)
R09	MSC—annual miscellaneous cost (material and labor)
R10	ENC—annual energy cost
R11	EES—escalation rate in energy cost, %
R12	INT—interest rate on mortgage (MTG), %
R13	TXP—tax on property as percent of initial cost
R14	TXI—income tax, %
R15	INC—annual income if any
R16	For subroutine EE

R17	For subroutine EE
R18	N1/N2; also ICΣ
R19	(1+INF)/(1+DS)
R20	(1−RCL 14)
R21	1 / $(1+DS)^{N1}$
R22	Not used
R23	Not used
R24	Not used
R25	PVΣ
R26–R28	Not used
R29	Alphanumeric code

EP-1 LIFE CYCLE COST ANALYSIS PROGRAM, PART I

LABELS & SUBROUTINES

```
001  22 INV
021  16 A'
025  23 LNX
043  24 CE
071  25 CLR
085  11  A
093  32 X:T
134  17 B'
142  33 X^2
167  12  B
175  34 √X
206  18 C'
241  35 1/X
256  43 RCL
266  42 STO
281  13  C
306  44 SUM
323  45 Y^X
338  52 EE
366  14  D
```

LISTING

```
000  76 LBL
001  22 INV
002  22 INV
003  58 FIX
004  03  3
005  69 OP
006  17  17
007  25 CLR
008  69 OP
009  00  00
010  43 RCL
011  29  29
012  69 OP
013  04  04
014  32 X:T
015  58 FIX
016  00  00
017  69 OP
018  06  06
019  92 RTN
020  76 LBL
021  16 A'
022  42 STO
023  02  02
024  76 LBL
025  23 LNX
026  32 X:T
027  02  2
028  04  4
029  01  1
030  05  5
031  42 STO
032  29  29
033  71 SBR
034  22 INV
035  92 RTN
036  42 STO
037  03  03
038  32 X:T
039  00  0
040  42 STO
041  29  29
042  76 LBL
043  24 CE
044  03  3
045  09  9
046  00  0
047  02  2
048  44 SUM
049  29  29
050  71 SBR
051  22 INV
052  92 RTN
053  42 STO
054  04  04
055  32 X:T
056  01  1
057  06  6
058  03  3
059  05  5
060  42 STO
061  29  29
062  71 SBR
063  22 INV
064  71 SBR
065  25 CLR
066  42 STO
067  04  04
068  98 ADV
069  91 R/S
070  76 LBL
071  25 CLR
072  53  (
073  53  (
074  24 CE
075  55  ÷
076  01  1
077  00  0
078  00  0
079  54  )
080  85  +
081  01  1
082  54  )
083  92 RTN
084  76 LBL
085  11  A
086  42 STO
087  05  05
088  32 X:T
089  00  0
090  42 STO
091  29  29
092  76 LBL
093  32 X:T
094  03  3
095  05  5
096  01  1
097  05  5
098  00  0
099  00  0
100  44 SUM
101  29  29
102  71 SBR
103  22 INV
104  92 RTN
105  42 STO
106  06  06
107  32 X:T
108  01  1
109  42 STO
110  29  29
111  71 SBR
112  24 CE
113  91 R/S
114  42 STO
115  07  07
116  32 X:T
117  02  2
118  04  4
119  03  3
120  01  1
121  02  2
122  01  1
123  42 STO
124  29  29
125  71 SBR
126  22 INV
127  71 SBR
128  25 CLR
129  42 STO
130  07  07
131  98 ADV
132  91 R/S
133  76 LBL
134  17 B'
135  42 STO
136  08  08
137  32 X:T
138  00  0
139  42 STO
140  29  29
141  76 LBL
142  33 X^2
143  03  3
144  08  8
145  02  2
146  07  7
147  01  1
148  05  5
149  44 SUM
150  29  29
151  71 SBR
152  22 INV
153  92 RTN
154  42 STO
155  09  09
156  32 X:T
157  09  9
158  00  0
159  00  0
160  42 STO
161  29  29
162  71 SBR
163  33 X^2
164  98 ADV
165  91 R/S
166  76 LBL
167  12  B
168  42 STO
169  10  10
170  32 X:T
171  00  0
172  42 STO
173  29  29
174  76 LBL
175  34 √X
176  01  1
177  07  7
178  02  2
179  09  9
180  01  1
181  05  5
182  44 SUM
183  29  29
```

184	71	SBR
185	22	INV
186	92	RTN
187	42	STO
188	11	11
189	32	X:T
190	01	1
191	01	1
192	07	7
193	09	9
194	94	+/-
195	42	STO
196	29	29
197	71	SBR
198	34	√X
199	71	SBR
200	25	CLR
201	42	STO
202	11	11
203	98	ADV
204	91	R/S
205	76	LBL
206	18	C'
207	42	STO
208	12	12
209	32	X:T
210	02	2
211	02	2
212	00	0
213	00	0
214	42	STO
215	29	29
216	71	SBR
217	35	1/X
218	71	SBR
219	43	RCL
220	42	STO
221	12	12
222	91	R/S
223	42	STO
224	13	13
225	32	X:T
226	01	1
227	08	8
228	07	7
229	06	6
230	42	STO
231	29	29
232	71	SBR
233	42	STO
234	71	SBR
235	43	RCL
236	42	STO
237	13	13
238	98	ADV
239	91	R/S
240	76	LBL
241	35	1/X
242	02	2
243	04	4
244	03	3
245	09	9
246	01	1
247	05	5
248	00	0
249	00	0
250	44	SUM
251	29	29
252	71	SBR
253	22	INV
254	92	RTN
255	76	LBL
256	43	RCL
257	53	(
258	24	CE
259	55	÷
260	01	1
261	00	0
262	00	0
263	54	)
264	92	RTN
265	76	LBL
266	42	STO
267	03	3
268	07	7
269	04	4
270	04	4
271	01	1
272	04	4
273	02	2
274	04	4
275	44	SUM
276	29	29
277	71	SBR
278	22	INV
279	92	RTN
280	76	LBL
281	13	C
282	42	STO
283	14	14
284	32	X:T
285	01	1
286	04	4
287	00	0
288	00	0
289	94	+/-
290	42	STO
291	29	29
292	71	SBR
293	42	STO
294	71	SBR
295	43	RCL
296	42	STO
297	14	14
298	91	R/S
299	42	STO
300	15	15
301	32	X:T
302	00	0
303	42	STO
304	29	29
305	76	LBL
306	44	SUM
307	02	2
308	04	4
309	03	3
310	01	1
311	01	1
312	05	5
313	00	0
314	00	0
315	42	STO
316	29	29
317	71	SBR
318	22	INV
319	98	ADV
320	98	ADV
321	92	RTN
322	76	LBL
323	45	Y^X
324	03	3
325	03	3
326	04	4
327	02	2
328	00	0
329	00	0
330	44	SUM
331	29	29
332	71	SBR
333	22	INV
334	98	ADV
335	98	ADV
336	92	RTN
337	76	LBL
338	52	EE
339	53	(
340	53	(
341	53	(
342	43	RCL
343	17	17
344	45	Y^X
345	53	(
346	43	RCL
347	16	16
348	85	+
349	01	1
350	54	)
351	54	)
352	75	-
353	43	RCL
354	17	17
355	54	)
356	55	÷
357	53	(
358	43	RCL
359	17	17
360	75	-
361	01	1
362	54	)
363	54	)
364	92	RTN
365	76	LBL
366	14	D
367	00	0
368	32	X:T
369	00	0
370	42	STO
371	29	29
372	71	SBR
373	45	Y^X
374	43	RCL
375	02	02
376	44	SUM
377	25	25
378	71	SBR
379	23	LNX
380	53	(
381	53	(
382	53	(
383	43	RCL
384	03	03
385	55	÷
386	43	RCL
387	06	06
388	54	)
389	85	+
390	93	.
391	09	9
392	09	9
393	54	)
394	59	INT
395	75	-
396	01	1
397	54	)
398	42	STO
399	16	16
400	32	X:T
401	03	3
402	03	3
403	42	STO
404	29	29
405	71	SBR
406	24	CE
407	53	(
408	53	(
409	43	RCL
410	07	07
411	55	÷
412	43	RCL
413	04	04
414	54	)
415	42	STO
416	19	19
417	45	Y^X
418	43	RCL
419	06	06
420	54	)
421	42	STO
422	17	17
423	71	SBR
424	52	EE
425	53	(
426	24	CE
427	65	×
428	43	RCL
429	05	05
430	54	)
431	32	X:T
432	07	7
433	07	7
434	42	STO
435	29	29
436	71	SBR
437	32	X:T
438	44	SUM
439	25	25

```
440  98 ADV
441  53  (
442  53  (
443  43 RCL
444  16  16
445  85  +
446  01  1
447  54  )
448  65  ×
449  43 RCL
450  06  06
451  75  -
452  43 RCL
453  03  03
454  54  )
455  32 X:T
456  02  2
457  42 STO
458  29  29
459  71 SBR
460  24 CE
461  53  (
462  53  (
463  24 CE
464  65  ×
465  43 RCL
466  05  05
467  65  ×
468  53  (
469  43 RCL
470  07  07
471  45 Yˣ
472  53  (
473  43 RCL
474  16  16
475  65  ×
476  43 RCL
477  06  06
478  54  )
479  54  )
480  54  )
481  55  ÷
482  43 RCL
483  06  06
484  55  ÷
485  53  (
486  43 RCL
487  04  04
488  45 Yˣ
489  43 RCL
490  03  03
491  54  )
492  54  )
493  32 X:T
494  03  3
495  06  6
496  04  4
497  02  2
498  42 STO
499  29  29
500  71 SBR
501  22 INV
502  22 INV
503  44 SUM
504  25  25
505  43 RCL
506  25  25
507  42 STO
508  18  18
509  98 ADV
510  53  (
511  43 RCL
512  19  19
513  42 STO
514  17  17
515  43 RCL
516  03  03
517  42 STO
518  16  16
519  71 SBR
520  52 EE
521  65  ×
522  43 RCL
523  08  08
524  65  ×
525  53  (
526  01  1
527  75  -
528  43 RCL
529  14  14
530  54  )
531  42 STO
532  20  20
533  54  )
534  32 X:T
535  00  0
536  42 STO
537  29  29
538  71 SBR
539  33 X²
540  44 SUM
541  25  25
542  53  (
543  43 RCL
544  04  04
545  35 1/X
546  42 STO
547  17  17
548  71 SBR
549  52 EE
550  42 STO
551  21  21
552  65  ×
553  43 RCL
554  09  09
555  65  ×
556  43 RCL
557  20  20
558  54  )
559  32 X:T
560  09  9
561  00  0
562  00  0
563  42 STO
564  29  29
565  71 SBR
566  33 X²
567  44 SUM
568  25  25
569  98 ADV
570  53  (
571  43 RCL
572  11  11
573  55  ÷
574  43 RCL
575  04  04
576  54  )
577  42 STO
578  17  17
579  53  (
580  71 SBR
581  52 EE
582  65  ×
583  43 RCL
584  10  10
585  65  ×
586  43 RCL
587  20  20
588  54  )
589  32 X:T
590  00  0
591  42 STO
592  29  29
593  71 SBR
594  34 √X
595  44 SUM
596  25  25
597  98 ADV
598  53  (
599  43 RCL
600  02  02
601  65  ×
602  43 RCL
603  13  13
604  65  ×
605  43 RCL
606  21  21
607  65  ×
608  43 RCL
609  20  20
610  54  )
611  32 X:T
612  01  1
613  09  9
614  01  1
615  05  5
616  42 STO
617  29  29
618  71 SBR
619  42 STO
620  44 SUM
621  25  25
622  53  (
623  43 RCL
624  03  03
625  22 INV
626  49 PRD
627  18  18
628  43 RCL
629  18  18
630  65  ×
631  43 RCL
632  14  14
633  65  ×
634  43 RCL
635  21  21
636  54  )
637  32 X:T
638  08  8
639  94 +/-
640  42 STO
641  29  29
642  71 SBR
643  42 STO
644  22 INV
645  44 SUM
646  25  25
647  53  (
648  53  (
649  43 RCL
650  18  18
651  65  ×
652  53  (
653  43 RCL
654  03  03
655  85  +
656  01  1
657  54  )
658  55  ÷
659  02  2
660  54  )
661  65  ×
662  43 RCL
663  12  12
664  65  ×
665  43 RCL
666  14  14
667  65  ×
668  43 RCL
669  21  21
670  54  )
671  32 X:T
672  00  0
673  42 STO
674  29  29
675  71 SBR
676  42 STO
677  22 INV
678  44 SUM
679  25  25
680  98 ADV
681  53  (
682  43 RCL
683  15  15
684  65  ×
685  43 RCL
686  20  20
687  65  ×
688  43 RCL
689  21  21
690  54  )
691  32 X:T
692  03  3
693  09  9
694  42 STO
695  29  29
```

```
696  71 SBR          708  29  29
697  44 SUM          709  71 SBR
698  22 INV          710  45 YX
699  44 SUM          711  98 ADV
700  25  25          712  00  0
701  98 ADV          713  42 STO
702  43 RCL          714  25  25
703  25  25          715  91 R/S
704  32 X:T          716  00  0
705  07  7           717  00  0
706  07  7           718  00  0
707  42 STO          719  00  0
```

SPECIAL NOTES FOR HP-97 USERS

1. As shown in "User Instructions and Examples," the output, as compared to the TI-59 output, has been rearranged to accommodate the program within the limits of registers and programming steps.
2. Inputs should be based on the following conventions:

   Expenses—positive
   Income—negative

EP-1
LIFE CYCLE COST ANALYSIS PROGRAM, PART I

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Enter replacement cost	285000	–	*f*	A	285000.00 ***	
3.	Enter frequency of replacement, yr	15	–	–	R/S	15.00 ***	
4.	Enter discount rate, %	11	–	*f*	B	11.00 ***	
5.	Enter inflation rate, %	8	–	–	R/S	8.00 ***	
6.	Enter interest rate, %	8.75	–	–	R/S	8.75 ***	
7.	Enter tax rate on property	3	–	*f*	C	3.00 ***	
8.	Enter income tax rate	45	–	–	R/S	45.00 ***	
9.	Enter initial cost	1000000	–	–	A	1000000.00 ***	
	Enter number of years of analysis	20	–	–	R/S	20.00 ***	
						1.00 ***	Number of replacements
						188554.18 ***	PV of replacement
						10.00 ***	Years of useful life remaining
						74756.74 ***	Salvage value
						131394.91 ***	PV of tax on property
						-199636.20 ***	PV of tax benefit on depreciation
						-183415.76 ***	PV of tax benefit on interest
10.	Enter miscellaneous annual cost	15000	–	–	B	15000.00 ***	
						65697.45 ***	PV of miscellaneous cost
11.	Enter annual income	30000	CHS	–	B	-30000.00 ***	
						-131394.91 ***	PV of income
12.	Enter annual maintenance cost: labor and materials	35000	–	–	C	35000.00 ***	
						292365.11 ***	PV of maintenance cost

EP-1 *(Continued)*

LIFE CYCLE COST ANALYSIS PROGRAM, PART I

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
13.	Enter saving in energy cost	100000	CHS	—	D	-100000.00 ***	
14.	Enter escalation rate in energy cost	9	—	—	R/S	9.00 ***	
						-313826.95 ***	PV of savings in energy cost
15.	To compute total PV	—	—	—	E	175381.11 ***	Total PV
	Example 2.1						
	Initialize	0	—	*f*	E	0.00 ***	
	Follow steps 9 through 14 from Example no. 1.	1000000	—	—	A	1000000.00 ***	
		20	—	—	R/S	20.00 ***	
						1.00 ***	
						188954.18 ***	
						10.00 ***	
						74756.74 ***	
						131394.91 ***	
						-199636.26 ***	
	Note: Income = 0					-183415.76 ***	
		15000	—	—	B	15000.00 ***	
						65697.46 ***	
		35000	—	—	C	35000.00 ***	
						292365.11 ***	
		100000	CHS	—	D	-100000.00 ***	
		9	—	—	R/S	9.00 ***	

						-913826.95 ***	
		—	—	—	E	306776.02 ***	Total PV
	Example 2.2						
						0.00 ***	
	After initialization, change tax rates.	3 0	— —	*f* —	C R/S	3.00 *** 0.00 ***	
	Follow steps 9 through 14 from Example no. 1.					1000000.00 *** 20.00 ***	
						1.00 *** 188954.18 ***	
						10.00 *** 74756.74 ***	
						238695.54 ***	
						0.00 ***	
						0.00 ***	
		15000	—	—	B	15000.00 *** 119449.92 ***	
		35000	—	—	C	35000.00 *** 531572.93 ***	
		100000 9	CHS —	— —	D R/S	-100000.00 *** 9.00 ***	
						-1661503.54 ***	
		—	—	—	E	342616.53 ***	Total PV

EP-1 *(Continued)*

LIFE CYCLE COST ANALYSIS PROGRAM, PART I

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 2.3	–					
	Make changes after initialization.					0.00 ***	
		11	–	*f*	B	11.00 ***	
		8	–	–	R/S	8.00 ***	
	Interest = 0	0	–	–	R/S	0.00 ***	
		0	–	*f*	C	0.00 ***	
		0	–	–	R/S	0.00 ***	
	Follow steps 9 through 14 from Example no. 1.					1000000.00 ***	
						20.00 ***	
						1.00 ***	
						186354.10 ***	
						10.00 ***	
						74756.74 ***	
						0.00 ***	
						0.00 ***	
						0.00 ***	
		15000	–	–	B	15000.00 ***	
						119449.92 ***	
		35000	–	–	C	35000.00 ***	
						531572.53 ***	
		100000	CHS	–	D	-100000.00 ***	
		9	–	–	R/S	9.00 ***	
						-1661563.54 ***	

		–	–	–	E	183716.75 ***	Total PV
						6.00 ***	
	Example 3						
	Follow same steps as for Example no. 1, but change input under step 14.	–	–	*f*	E	3.00 ***	
		285000	–	*f*	A	285000.00 ***	
		15	–	–	R/S	15.00 ***	
		11	–	*f*	B	11.00 ***	
		8	–	–	R/S	8.00 ***	
		8.75	–	–	R/S	8.75 ***	
		3	–	*f*	C	3.00 ***	
		45	–	–	R/S	45.00 ***	
		100000	–	–	A	100000.00 ***	
		20	–	–	R/S	20.00 ***	
						1.00 ***	
						188954.18 ***	
						10.00 ***	
						74756.74 ***	
						131334.91 ***	
						-195636.20 ***	
						-183415.76 ***	
		15000	–	–	B	15000.00 ***	
						65697.46 ***	
		30000	CHS	–	B	-30000.00 ***	
						-131394.91 ***	
		35000	–	–	C	35000.00 ***	
						292365.11 ***	

EP-1 *(Continued)*

LIFE CYCLE COST ANALYSIS PROGRAM, PART I

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
		100000 8	CHS –	– –	D R/S	-100000.00 *** 8.00 ***	
						-835328.88 ***	
		–	–	–	E	253879.17 ***	Total PV
	For next run, either repeat all the steps or change value of R9.	835328.88	–	–	+	835328.88 + 1089208.05 ***	Switch to TRACE mode to keep record.
		–	–	STO	9	STO9	Remove from TRACE mode.
		100000 7	CHS –	– –	D R/S	-100000.00 *** 7.00 ***	
						-765091.07 ***	
		–	–	–	E	324116.98 ***	Total PV
	Continue in this manner for other energy escalation rates.						
	Example 4						
	For Example no. 4, use EP-2.						

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
0	Computes present value factor
1	Computes present value, prints result, and sums into register R9
2	Uses SBR 3 and adds 1
3	Prints display and divides by 100
a	Prints and stores display in R3
b	Calls SBR 2 and stores display in RA;
	with R/S, calls SBR 2 and stores display in RB;
	with R/S, calls SBR 3 and stores display in RC
c	Calls SBR 3 and stores display in RD;
	with R/S, calls SBR 3 and stores display in RE
e	Clears register R9 and prints 0
A	Prints and stores display in R0; sums into R9;
	with R/S, prints and stores display in R1; computes and prints number of replacements, PV of replacement, years of useful life, salvage value, PV of tax on property, tax benefit of depreciation, and tax benefit on interest on mortgage
B	Computes and prints PV of miscellaneous cost and income on property; also income
C	Computes and prints PV of maintenance: labor and material
D	Computes and prints PV of energy cost
E	Computes total present value

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	(Discount rate, %/100) + 1
RB	(Inflation, %/100) + 1
RC	Interest, %/100
RD	Tax on property, %/100
RE	Income tax, %/100
RI	1 − RE
R0	Variable
R1	Years of analysis
R2	Frequency of replacement years
R3	Replacement cost
R4	Present value factor with inflation
R5	PV of replacement + initial cost
R6	For SBR 0
R7	RB/RA
R8	For SBR 0
R9	Total present value

EP-1 (HP-97) LIFE CYCLE COST ANALYSIS PROGRAM, PART I

LISTING

```
001  *LBL0      21 00
002   RCL6      36 06
003   RCL8      36 08
004      1         01
005      +        -55
006     Y^x        31
007   RCL6      36 06
008      -        -45
009   RCL6      36 06
010      1         01
011      -        -45
012      ÷        -24
013    RTN         24
014  *LBL1      21 01
015   RCL1      36 01
016   STO8      35 08
017   GSB0      23 00
018   RCL0      36 00
019      x        -35
020   RCLI      36 46
021      x        -35
022   ST+9   35-55 09
023   PRTX        -14
024    SPC      16-11
025    RTN         24
026  *LBL2      21 02
027   GSB3      23 03
028      1         01
029      +        -55
030    RTN         24
031  *LBL3      21 03
032   PRTX        -14
033      1         01
034      0         00
035      0         00
036      ÷        -24
037    RTN         24
038  *LBLa   21 16 11
039   PRTX        -14
040   STO3      35 03
041    R/S         51
042   PRTX        -14
043   STO2      35 02
044    SPC      16-11
045    R/S         51
046  *LBLb   21 16 12
047   GSB2      23 02
048   STOA      35 11
049    R/S         51
050   GSB2      23 02
051   STOB      35 12
052    R/S         51
053   GSB3      23 03
054   STOC      35 13
055    SPC      16-11
056    R/S         51
057  *LBLc   21 16 13
058   GSB3      23 03
059   STOD      35 14
060    R/S         51
061   GSB3      23 03
062   STOE      35 15
063    SPC      16-11
064    R/S         51
065  *LBLe   21 16 15
066      0         00
067   STO9      35 09
```

```
068   SPC     16-11
069   PRTX      -14
070   SPC     16-11
071   R/S        51
072   *LBLA   21 11
073   STO0    35 00
074   PRTX      -14
075   ST+9 35-55 09
076   R/S        51
077   STO1    35 01
078   PRTX      -14
079   SPC     16-11
080   RCL2    36 02
081   ÷         -24
082   .         -62
083   9          09
084   9          09
085   +         -55
086   INT     16 34
087   1          01
088   -         -45
089   STO8    35 08
090   PRTX      -14
091   RCLB    36 12
092   RCLA    36 11
093   ÷         -24
094   STO7    35 07
095   RCL2    36 02
096   Y^x        31
097   STO6    35 06
098   GSB0    23 00
099   RCL3    36 03
100   x         -35
101   PRTX      -14
102   SPC     16-11
103   ST+9 35-55 09
104   RCL8    36 08
105   1          01
106   +         -55
107   RCL2    36 02
108   x         -35
109   RCL1    36 01
110   -         -45
111   PRTX      -14
112   RCLB    36 12
113   RCL8    36 08
114   RCL2    36 02
115   x         -35
116   Y^x        31
117   x         -35
118   RCL3    36 03
119   x         -35
120   RCL2    36 02
121   ÷         -24
122   RCLA    36 11
123   RCL1    36 01
124   Y^x        31
125   ÷         -24
126   PRTX      -14
127   ST-9 35-45 09
128   RCL9    36 09
129   STO5    35 05
130   SPC     16-11
131   RCLA    36 11
132   1/X        52
133   STO6    35 06
134   RCL1    36 01
135   STO8    35 08
136   GSB0    23 00
137   STO4    35 04
138   RCL0    36 00
139   x         -35
140   RCLD    36 14
141   x         -35
142   1          01
143   RCLE    36 15
144   -         -45
145   STOI    35 46
146   x         -35
147   PRTX      -14
148   ST+9 35-55 09
149   SPC     16-11
150   RCL1    36 01
151   ST÷5 35-24 05
152   RCL5    36 05
153   RCLE    36 15
154   x         -35
155   RCL4    36 04
156   x         -35
157   CHS       -22
158   ST+9 35-55 09
159   PRTX      -14
160   SPC     16-11
161   RCL1    36 01
162   1          01
163   +         -55
164   RCL5    36 05
165   x         -35
166   2          02
167   ÷         -24
168   RCLC    36 13
169   x         -35
170   RCLE    36 15
171   x         -35
172   RCL4    36 04
173   x         -35
174   CHS       -22
175   ST+9 35-55 09
176   PRTX      -14
177   SPC     16-11
178   RTN        24
179   *LBLB   21 12
180   STO0    35 00
181   PRTX      -14
182   RCL4    36 04
183   x         -35
184   RCLI    36 46
185   x         -35
186   ST+9 35-55 09
187   PRTX      -14
188   SPC     16-11
189   RTN        24
190   *LBLC   21 13
191   STO0    35 00
192   PRTX      -14
193   RCL7    36 07
194   STO6    35 06
195   GSB1    23 01
196   RTN        24
197   *LBLD   21 14
198   STO0    35 00
199   PRTX      -14
200   R/S        51
201   GSB2    23 02
202   SPC     16-11
203   RCLA    36 11
204   ÷         -24
205   STO6    35 06
206   GSB1    23 01
207   RTN        24
208   *LBLE   21 15
209   SPC     16-11
210   SPC     16-11
211   RCL9    36 09
212   PRTX      -14
213   SPC     16-11
214   RTN        24
215   RTN        24
216   R/S        51
```

EP-2
LIFE CYCLE COST ANALYSIS PROGRAM, PART II

GENERAL DESCRIPTION

This program is complementary to Program EP-1 and computes the following information generally required for profitability analysis of a proposal:

1. Annualized flow

2. Profitability index

3. Discounted payback years

4. Internal rate of return

Full definitions of the factors involved in this program are given below:

Present Value—PV is the sum total of all net cash flows throughout the period of analysis discounted to present value.

The merit of the "present value" method is that it represents all future cash flows, which may be uneven, by one figure.

Annualized Flow—AF is the present value of uneven cash flows when converted into uniform annual cash flow.

Profitability Index—PI is the ratio of the present value of future net cash flows over the initial cash outlay; also called "profitability ratio."

Discounted Payback Years—PBYR: The number of years when the present value of discounted annualized flow will equal the initial outlay is called PBYR.

Internal Rate of Return—IRR: The rate that discounts the stream of future cash flows to equal the initial outlay.

Input for this program can be either from Program EP-1 or from any other analysis.

EQUATIONS

$$PV = AF/(1+DR) + AF/(1+DR)^2 ----AF/(1+DR)^n \quad [7.2]$$

If $1/(1+DR) = a$,

$$PV = AF \times a \times (1+a+a^2-----+a^{n-1})$$
$$= AF \times a \times (1-a^n/1-a)$$

where

PV = Present value
AF = Annualized flow
DR = Discount rate (fraction)
n = Analysis period in years

To calculate payback years,

$$IC = AF \times a \times (1 - a^{nx}/1 - a) \quad [7.3]$$

where

IC = Initial cost
nx = Payback years

To calculate internal rate of return,

$$IC = AF \times a \times (1-ax^n/1-ax) \quad [7.4]$$

where

ax = 1/1+Dx
Dx = Internal rate of return (fraction)

EP-2
LIFE CYCLE COST ANALYSIS PROGRAM, PART II
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Enter total initial cost	150000	–	–	A	150000.00	IC	
2.	Enter present value of savings	210000	–	–	B	210000.00	PV	
3.	Enter discount rate	9.87	–	–	C	9.87	DR	
4.	Enter number of years analysis is based on	19	–	–	D	19.00	YR	
5.	To compute annualized flow and profitability index	–	–	2nd	A′	24889.02 1.40	AF P. I	These three outputs can be obtained simultaneously by pressing 2nd D′.
6.	To compute payback years	–	–	2nd	B′	9.60	PBYR	
7.	To compute internal rate of return	–	–	2nd	C′	15.51	IRR	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Stores display in R10; prints display and IC
B	Stores display in R11; prints display and PV
C	Prints display and DR; divides display by 100, adds 1, and stores result in R12
D	Stores display in R10; prints display and YR
A′	Calls SBR CE; prints AC; computes and prints PI
B′	Calls SBR CE, computes payback years using LBL CLR, LBL X^2, and SBR Y^x
CLR	First part of reiteration process
X^2	Second part of reiteration process
C′	Calls SBR CE; computes internal rate of return using LBL X⇄T, LBL STO, and SBR Y^x
$\sqrt{X}$	Reduces R08 by 1 and prints PBYR
RCL	Computes percent internal rate of return
1/X	Calculates correction for reiteration process
INV	Prints alphanumeric identification of data
CE	Calculates annualized flow
Y^x	Part of reiteration process—computes difference between initial cost and new present value based on new interest rate or number of years
LNX	Computes present value
D′	Uses A′, B′, and C′

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For DSZ 00 for reiteration
R01	Not used
R02	For STO IND and RCL IND
R03	For storing values during reiteration
R04	For storing values during reiteration
R05–R07	Not used
R08	Exponent in equation for computing present value
R09	1/1+DR used in equation for computing present value
R10	Initial cost IC
R11	Present worth PV
R12	Discount rate DR
R13	Number of years YR
R14	Annualized cost
R15	Small increment, used during reiteration
R16–R19	Not used
R20	Alphanumeric code

EP-2 LIFE CYCLE COST ANALYSIS PROGRAM, PART II

LABELS & SUBROUTINES

```
001  11  A
015  12  B
029  13  C
051  14  D
066  16  A'
098  17  B'
119  25  CLR
126  33  X²
150  18  C'
182  32  X⇄T
189  42  STO
213  34  √X
236  43  RCL
264  35  1/X
285  22  INV
302  24  CE
328  45  Yx
344  23  LNX
365  19  D'
```

LISTING

```
000  76  LBL
001  11   A
002  42  STO
003  10   10
004  32  X⇄T
005  02   2
006  04   4
007  01   1
008  05   5
009  42  STO
010  20   20
011  71  SBR
012  22  INV
013  91  R/S
014  76  LBL
015  12   B
016  42  STO
017  11   11
018  32  X⇄T
019  03   3
020  03   3
021  04   4
022  02   2
023  42  STO
024  20   20
025  71  SBR
026  22  INV
027  91  R/S
028  76  LBL
029  13   C
030  32  X⇄T
031  01   1
032  06   6
033  03   3
034  05   5
035  42  STO
036  20   20
037  71  SBR
038  22  INV
039  55   ÷
040  01   1
041  00   0
042  00   0
043  95   =
044  85   +
045  01   1
046  95   =
047  42  STO
048  12   12
049  91  R/S
050  76  LBL
```

051	14	D
052	42	STO
053	13	13
054	32	X:T
055	04	4
056	05	5
057	03	3
058	05	5
059	42	STO
060	20	20
061	71	SBR
062	22	INV
063	98	ADV
064	91	R/S
065	76	LBL
066	16	A'
067	71	SBR
068	24	CE
069	32	X:T
070	01	1
071	03	3
072	02	2
073	01	1
074	42	STO
075	20	20
076	71	SBR
077	22	INV
078	43	RCL
079	11	11
080	55	÷
081	43	RCL
082	10	10
083	95	=
084	32	X:T
085	03	3
086	03	3
087	04	4
088	00	0
089	02	2
090	04	4
091	42	STO
092	20	20
093	71	SBR
094	22	INV
095	98	ADV
096	92	RTN
097	76	LBL
098	17	B'
099	71	SBR
100	24	CE
101	05	5
102	42	STO
103	08	08
104	93	.
105	01	1
106	42	STO
107	15	15
108	53	(
109	43	RCL
110	10	10
111	55	÷
112	01	1
113	00	0
114	00	0
115	00	0
116	54	)
117	32	X:T
118	76	LBL
119	25	CLR
120	02	2
121	42	STO
122	00	00
123	42	STO
124	02	02
125	76	LBL
126	33	X^2
127	69	OP
128	22	22
129	43	RCL
130	15	15
131	44	SUM
132	08	08
133	71	SBR
134	45	Y^X
135	22	INV
136	77	GE
137	34	√X
138	97	DSZ
139	00	00
140	33	X^2
141	71	SBR
142	35	1/X
143	22	INV
144	44	SUM
145	08	08
146	71	SBR
147	25	CLR
148	92	RTN
149	76	LBL
150	18	C'
151	71	SBR
152	24	CE
153	43	RCL
154	13	13
155	85	+
156	01	1
157	95	=
158	42	STO
159	08	08
160	01	1
161	52	EE
162	06	6
163	94	+/-
164	42	STO
165	15	15
166	93	.
167	09	9
168	05	5
169	42	STO
170	09	09
171	53	(
172	43	RCL
173	10	10
174	55	÷
175	01	1
176	00	0
177	00	0
178	00	0
179	54	)
180	32	X:T
181	76	LBL
182	32	X:T
183	02	2
184	42	STO
185	00	00
186	42	STO
187	02	02
188	76	LBL
189	42	STO
190	69	OP
191	22	22
192	43	RCL
193	15	15
194	44	SUM
195	09	09
196	71	SBR
197	45	Y^X
198	22	INV
199	77	GE
200	43	RCL
201	97	DSZ
202	00	00
203	42	STO
204	71	SBR
205	35	1/X
206	22	INV
207	44	SUM
208	09	09
209	71	SBR
210	32	X:T
211	92	RTN
212	76	LBL
213	34	√X
214	53	(
215	43	RCL
216	08	08
217	75	-
218	01	1
219	54	)
220	32	X:T
221	03	3
222	03	3
223	01	1
224	04	4
225	04	4
226	05	5
227	03	3
228	05	5
229	42	STO
230	20	20
231	71	SBR
232	22	INV
233	98	ADV
234	92	RTN
235	76	LBL
236	43	RCL
237	53	(
238	53	(
239	43	RCL
240	09	09
241	35	1/X
242	75	-
243	01	1
244	54	)
245	65	×
246	01	1
247	00	0
248	00	0
249	54	)
250	32	X:T
251	02	2
252	04	4
253	03	3
254	05	5
255	03	3
256	05	5
257	42	STO
258	20	20
259	71	SBR
260	22	INV
261	98	ADV
262	92	RTN
263	76	LBL
264	35	1/X
265	53	(
266	43	RCL
267	15	15
268	65	×
269	53	(
270	02	2
271	85	+
272	43	RCL
273	04	04
274	55	÷
275	53	(
276	24	CE
277	75	-
278	43	RCL
279	03	03
280	54	)
281	54	)
282	54	)
283	92	RTN
284	76	LBL
285	22	INV
286	22	INV
287	58	FIX
288	25	CLR
289	69	OP
290	00	00
291	43	RCL
292	20	20
293	69	OP
294	04	04
295	32	X:T
296	58	FIX
297	02	02
298	69	OP
299	06	06
300	92	RTN
301	76	LBL
302	24	CE
303	43	RCL
304	12	12
305	35	1/X
306	42	STO
307	09	09
308	53	(
309	43	RCL
310	13	13

311	85	+
312	01	1
313	54	)
314	42	STO
315	08	08
316	53	(
317	71	SBR
318	23	LNX
319	35	1/X
320	65	×
321	43	RCL
322	11	11
323	54	)
324	42	STO
325	14	14
326	92	RTN
327	76	LBL
328	45	Y×
329	53	(
330	43	RCL
331	10	10
332	75	-
333	43	RCL
334	14	14
335	65	×
336	71	SBR
337	23	LNX
338	54	)
339	72	ST*
340	02	02
341	50	I×I
342	92	RTN
343	76	LBL
344	23	LNX
345	53	(
346	53	(
347	43	RCL
348	09	09
349	75	-
350	24	CE
351	45	Y×
352	43	RCL
353	08	08
354	54	)
355	55	÷
356	53	(
357	01	1
358	75	-
359	43	RCL
360	09	09
361	54	)
362	54	)
363	92	RTN
364	76	LBL
365	19	D'
366	16	A'
367	17	B'
368	18	C'
369	91	R/S
370	00	0
371	00	0
372	00	0
373	00	0
374	00	0
375	00	0
376	00	0

EP-2
LIFE CYCLE COST ANALYSIS PROGRAM, PART II

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Enter total initial cost	150000	—	—	A	150000.00 ***	
2.	Enter present value of savings	210000	—	—	B	210000.00 ***	
3.	Enter discount rate	9.87	—	—	C	9.87 ***	
4.	Enter number of years analysis is based on	19	—	—	D	19.00 ***	
5.	To compute annualized flow and profitability index	—	—	*f*	A	24889.02 *** 1.40 ***	Annualized flow Profitability index
6.	To compute payback years	—	—	*f*	B	9.60 ***	Discounted payback years
7.	To compute internal rate of return	—	—	*f*	C	15.52 ***	Internal rate of return, %
							The above outputs can be obtained simultaneously by pressing *f* D.

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints and stores display in RA; stores 0.1% of display in R6
B	Prints and stores display in RB
C	Prints display; divides by 100; adds 1; stores in RC
D	Prints and stores display
a	Computes annualized flow using SBR 0; prints annualized flow; computes and prints profitability index
b	Computes annualized flow; computes and prints discounted years by reiteration using SBR 2 for computing present value
c	Computes annualized flow; computes and prints internal rate of return using SBR 2 for computing present value
d	Uses SBR a, SBR b, and SBR c
0	Computes input factors for SBR 4 and using SBR 4 computes annualized flow
4	Computes present value factor
2	Computes difference between actual and calculated present initial costs

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	Initial cost
RB	Present value
RC	(Discount rate/100)+1
RD	Number of years of analysis
RE	Annualized flow
R0–R4	Not used
R5	Difference between actual and calculated initial cost
R6	0.1% of initial cost
R7	EE-6
R8	5, starting value of payback years
R9	0.95, starting value of 1/(DR/100)+1

EP-2 (HP-97) LIFE CYCLE COST ANALYSIS PROGRAM, PART II

LISTING

```
001  *LBLA      21 11
002   STOA      35 11
003   PRTX        -14
004      .        -62
005      1         01
006      %         55
007   STO6      35 06
008    R/S         51
009  *LBLB      21 12
010   STOB      35 12
011   PRTX        -14
012    SPC      16-11
013    R/S         51
014  *LBLC      21 13
015   PRTX        -14
016      1         01
017      0         00
018      0         00
019      ÷        -24
020      1         01
021      +        -55
022   STOC      35 13
023    R/S         51
024  *LBLD      21 14
025   PRTX        -14
026   STOD      35 14
027    SPC      16-11
028    R/S         51
029  *LBLa   21 16 11
030   GSB0      23 00
031   RCLE      36 15
032   PRTX        -14
033   RCLB      36 12
034   RCLA      36 11
035      ÷        -24
036   PRTX        -14
037    SPC      16-11
038    RTN         24
039  *LBLb   21 16 12
040   GSB0      23 00
041      5         05
042   STO8      35 08
043  *LBL1      21 01
044   GSB2      23 02
045   STO5      35 05
046      .        -62
047      1         01
048   ST-8   35-45 08
049   GSB2      23 02
050   RCL5      36 05
051      -        -45
052      .        -62
053      1         01
054      ÷        -24
055    1/X         52
056   RCL5      36 05
057      x        -35
058   ST+8   35-55 08
059      .        -62
060      1         01
061   ST+8   35-55 08
062   RCL5      36 05
063    ABS      16 31
064   RCL6      36 06
065  X≤Y?       16-35
066   GTO1      22 01
067   RCL8      36 08
068      1         01
069      -        -45
070   PRTX        -14
071    SPC      16-11
072    RTN         24
073  *LBLc   21 16 13
074   GSB0      23 00
075      .        -62
076      9         09
077      5         05
078   STO9      35 09
079      1         01
080    EEX        -23
081      6         06
082    CHS        -22
083   STO7      35 07
084  *LBL3      21 03
085   GSB2      23 02
086   STO5      35 05
087   RCL7      36 07
088   ST-9   35-45 09
089   GSB2      23 02
090   RCL5      36 05
091      -        -45
092   RCL7      36 07
093      ÷        -24
094    1/X         52
095   RCL5      36 05
096      x        -35
097   ST+9   35-55 09
098   RCL7      36 07
099   ST+9   35-55 09
100   RCL5      36 05
101    ABS      16 31
102   RCL6      36 06
103  X≤Y?       16-35
104   GTO3      22 03
105   RCL9      36 09
```

```
1/X        52
1          01
-         -45
1          01
0          00
0          00
x         -35
PRTX      -14
SPC     16-11
RTN        24
*LBLd   21 16 14
GSBa    23 16 11
GSBb    23 16 12
GSBc    23 16 13
RTN        24
*LBL0   21 00
RCLC    36 13
1/X        52
STO9    35 09
RCLD    36 14
1          01
+         -55
STO8    35 08
GSB4    23 04
1/X        52
RCLB    36 12
x         -35
STOE    35 15
RTN        24
*LBL4   21 04
RCL9    36 09
RCL9    36 09
RCL8    36 08
Yx         31
-         -45
1          01
RCL9    36 09
-         -45
÷         -24
RTN        24
*LBL2   21 02
RCLE    36 15
GSB4    23 04
x         -35
RCLA    36 11
-         -45
RTN        24
R/S        51
```

8

GENERAL UTILITY PROGRAMS

UP-1
PRELIMINARY DESIGN CONDITIONS PROGRAM

GENERAL DESCRIPTION

With input of gross building area and perimeter, the program computes preliminary design and planning information such as:

1. Total air required for cooling air-conditioning system
2. Area of fan room
3. Height of fan room
4. Area of duct shaft
5. Cooling load in tons
6. Size of mechanical equipment room
7. Water required for cooling tower make-up
8. Electrical demand in kW

EQUATIONS

$$\text{cfm} = (A - P \times 15) \times C_2 + P \times C_1 \qquad [8.1]$$

where
A = Total area in sq ft
P = Total perimeter of all zones
C_1 = cfm/sq ft for exterior zone
C_2 = cfm/sq ft for interior zone

(Based on the assumption that exterior zone is 15 ft deep.)

$$\text{Volume of fan room in cu ft} = \text{cfm}/2.5 \qquad [8.2]$$

$$\text{Tonnage} = A/C_4 \qquad [8.3]$$

where
C_4 = sq ft/ton

$$\text{Fan room height in ft} = 4 \times (\text{tons})^{.16} \qquad [8.4]$$

where
Minimum height = 10 ft, maximum height = 15 ft

$$\text{Area of duct shaft in sq ft} = \text{volume of fan room}/200 \qquad [8.5]$$

(Based on low-velocity ductwork.)

$$\text{Volume of mechanical equipment in cu ft} = \text{tons} \times 60 \qquad [8.6]$$

$$\text{Mechanical equipment room height in ft} = 1.25 \times (\text{tons})^{.36} \qquad [8.7]$$

$$\text{gpm}_1 = \text{tons}/33 \qquad [8.8]$$

where
gpm_1 = Make-up water for electrical refrigeration

$$\text{gpm}_2 = \text{gpm}_1 \times 1.67 \qquad [8.9]$$

where
gpm_2 = Make-up water for steam refrigeration, about 13,000 Btu/ton input

$$\text{gpm}_3 = \text{gpm}_2 \times 1.28 \qquad [8.10]$$

where
gpm_3 = Make-up water for steam refrigeration, about 20,000 Btu/ton input

$$kW = A \times C_5/1000 \qquad [8.11]$$

where
C_5 = Watts/sq ft

OPERATING FEATURES

The program illustrates a methodology for estimating preliminary space conditions for three types of buildings. Considering the variety of building systems and applications, it is expected that the results may have wide variation from the actual conditions. However, the users can input their own constants after reviewing the methodology.

REFERENCE DATA

The program is based on the following types of spaces and constants:

Space Type 1—Building with exterior zone having an air/water system and relatively low internal heat gain.
$C_1 = .5$
$C_2 = .85$
$C_4 = 375$
$C_5 = 4$

Space Type 2—Building with exterior zone having all-air variable air volume system and internal load similar to a commercial office building.
$C_1 = 1.5$
$C_2 = .85$
$C_4 = 300$
$C_5 = 6$

Space Type 3—Building with exterior zone having constant volume all-air system and heavy internal load.
$C_1 = 2.5$
$C_2 = 2.0$
$C_4 = 200$
$C_5 = 10$

UP-1
PRELIMINARY DESIGN CONDITIONS PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Enter space type	1	–	–	A	1.	S/T	
2.	Enter gross area, sq ft	50000	–	–	B	50000.	A	
3.	Enter total perimeter, ft	2000	–	–	C	2000.	P	
						32000.	CFM	Total air supply
						1280.	AFRM	Area of fan rooms
						10.	FRHT	Height of fan room
						64.	AD	Area of duct shaft
						133.	TONS	Tons of refrigeration
						800.	AMRM	Area of mech. equipment room
						10.	MRHT	Height of mech. equipment room
								Make-up water for cooling tower
						4.	GPM1	Electric refrigeration
						7.	GPM2	Steam turbine refrigeration
						9.	GPM3	Absorption system
						200.	KW	Electric power demand
						2.	S/T	
	Repeat steps 1, 2, & 3 for other types of spaces.					200000.	A	
						10000.	P	
						267500.	CFM	
						8917.	AFRM	
						12.	FRHT	
						535.	AD	
						667.	TONS	
						3077.	AMRM	
						13.	MRHT	

UP-1 *(Continued)*

PRELIMINARY DESIGN CONDITIONS PROGRAM

USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
						20. GPM1 34. GPM2 43. GPM3 1200. KW 3. S/T 500000. A 16000. P 1120000. CFM 32000. AFRM 14. FRHT 2240. AD 2500. TONS 7143. AMRM 21. MRHT 76. GPM1 127. GPM2 162. GPM3 5000. KW	

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints S/T and stores constants related to type of space
B	Stores and prints area A
C	Prints perimeter P; calculates CFM; computes fan room volume, tonnage, and fan room height; if height is smaller than 10 or more than 15, goes to SBR 1/X; continues with SBR STO; computes and prints fan room area AFRM, fan room height FRHT, and area of shaft AD; prints tons; computes mechanical room height; if smaller than 10 or more than 25 goes to SBR RCL; continues with SBR SUM; computes and prints mechanical equipment room area AMRM and mechanical equipment height MRHT; computes and prints GPM1, GPM2, GPM3, and KW
INV	Prints alphanumeric identification of data
LNX	Prints 1 S/T and stores constants for space type 1
CE	Prints 2 S/T and stores constants for space type 2
$\sqrt{X}$	Prints S/T
1/X	Establishes value in R11 and goes to SBR STO
RCL	Establishes value in R11 and goes to SBR SUM

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	Not used
R01	CFM per sq ft for exterior zone
R02	CFM per sq ft for interior zone
R03	Not used
R04	Sq ft/ton
R05	Watts/sq ft
R06	Areas
R07	Area of perimeter; tons
R08	Not used
R09	Alphanumeric code
R10	Volume of fan room
R11	Fan room height

UP-1 PRELIMINARY DESIGN CONDITIONS PROGRAM

LABELS & SUBROUTINES

001	11	A
030	12	B
042	13	C
128	42	STO
236	44	SUM
343	22	INV
360	23	LNX
383	24	CE
407	34	ΓX
420	35	1/X
428	43	RCL

LISTING

000	76	LBL
001	11	A
002	32	X:T
003	01	1
004	67	EQ
005	23	LNX
006	02	2
007	67	EQ
008	24	CE
009	02	2
010	93	.
011	05	5
012	42	STO
013	01	01
014	02	2
015	42	STO
016	02	02
017	02	2
018	00	0
019	00	0
020	42	STO
021	04	04
022	01	1
023	00	0
024	42	STO
025	05	05
026	71	SBR
027	34	ΓX
028	91	R/S
029	76	LBL
030	12	B
031	42	STO
032	06	06
033	32	X:T
034	01	1
035	03	3
036	42	STO
037	09	09
038	71	SBR
039	22	INV
040	91	R/S
041	76	LBL
042	13	C
043	32	X:T
044	03	3
045	03	3
046	42	STO
047	09	09
048	71	SBR
049	22	INV
050	98	ADV
051	65	×
052	01	1
053	05	5
054	95	=
055	42	STO
056	07	07
057	75	-
058	43	RCL
059	06	06
060	95	=
061	94	+/-
062	65	×
063	43	RCL
064	02	02
065	85	+
066	43	RCL
067	07	07
068	65	×
069	43	RCL
070	01	01
071	95	=
072	32	X:T
073	01	1
074	05	5
075	02	2
076	01	1
077	03	3
078	00	0
079	42	STO
080	09	09
081	71	SBR
082	22	INV
083	55	÷
084	02	2
085	93	.
086	05	5
087	95	=
088	42	STO
089	10	10
090	43	RCL
091	06	06
092	55	÷

```
093  43  RCL
094  04   04
095  95   =
096  42  STO
097  07   07
098  45  Y^X
099  93   .
100  01   1
101  06   6
102  95   =
103  65   ×
104  04   4
105  85   +
106  93   .
107  09   9
108  95   =
109  59  INT
110  42  STO
111  11   11
112  01   1
113  00   0
114  32  X:T
115  43  RCL
116  11   11
117  22  INV
118  77   GE
119  35  1/X
120  01   1
121  05   5
122  32  X:T
123  43  RCL
124  11   11
125  77   GE
126  35  1/X
127  76  LBL
128  42  STO
129  53   (
130  43  RCL
131  10   10
132  55   ÷
133  43  RCL
134  11   11
135  54   )
136  32  X:T
137  01   1
138  03   3
139  02   2
140  01   1
141  03   3
142  05   5
143  03   3
144  00   0
145  42  STO
146  09   09
147  71  SBR
148  22  INV
149  43  RCL
150  11   11
151  32  X:T
152  02   2
153  01   1
154  03   3
155  05   5
156  02   2
157  03   3
158  03   3
159  07   7
160  42  STO
161  09   09
162  71  SBR
163  22  INV
164  53   (
165  43  RCL
166  10   10
167  55   ÷
168  02   2
169  00   0
170  00   0
171  54   )
172  32  X:T
173  01   1
174  03   3
175  01   1
176  06   6
177  42  STO
178  09   09
179  71  SBR
180  22  INV
181  98  ADV
182  43  RCL
183  07   07
184  32  X:T
185  03   3
186  07   7
187  03   3
188  02   2
189  03   3
190  01   1
191  03   3
192  06   6
193  42  STO
194  09   09
195  71  SBR
196  22  INV
197  53   (
198  53   (
199  53   (
200  43  RCL
201  07   07
202  45  Y^X
203  93   .
204  03   3
205  06   6
206  54   )
207  65   ×
208  01   1
209  93   .
210  02   2
211  05   5
212  54   )
213  85   +
214  93   .
215  09   9
216  54   )
217  59  INT
218  42  STO
219  11   11
220  01   1
221  00   0
222  32  X:T
223  43  RCL
224  11   11
225  22  INV
226  77   GE
227  43  RCL
228  02   2
229  05   5
230  32  X:T
231  43  RCL
232  11   11
233  77   GE
234  43  RCL
235  76  LBL
236  44  SUM
237  53   (
238  43  RCL
239  07   07
240  65   ×
241  06   6
242  00   0
243  55   ÷
244  43  RCL
245  11   11
246  54   )
247  32  X:T
248  01   1
249  03   3
250  03   3
251  00   0
252  03   3
253  05   5
254  03   3
255  00   0
256  42  STO
257  09   09
258  71  SBR
259  22  INV
260  43  RCL
261  11   11
262  32  X:T
263  03   3
264  00   0
265  03   3
266  05   5
267  02   2
268  03   3
269  03   3
270  07   7
271  42  STO
272  09   09
273  71  SBR
274  22  INV
275  98  ADV
276  43  RCL
277  07   07
278  55   ÷
279  03   3
280  03   3
281  95   =
282  32  X:T
283  02   2
284  02   2
285  03   3
286  03   3
287  03   3
288  00   0
289  00   0
290  02   2
291  42  STO
292  09   09
293  71  SBR
294  22  INV
295  65   ×
296  01   1
297  93   .
298  06   6
299  07   7
300  95   =
301  32  X:T
302  01   1
303  44  SUM
304  09   09
305  71  SBR
306  22  INV
307  65   ×
308  01   1
309  93   .
310  02   2
311  08   8
312  95   =
313  32  X:T
314  01   1
315  44  SUM
316  09   09
317  71  SBR
318  22  INV
319  98  ADV
320  43  RCL
321  06   06
322  65   ×
323  43  RCL
324  05   05
325  55   ÷
326  01   1
327  00   0
328  00   0
329  00   0
330  95   =
331  32  X:T
332  02   2
333  06   6
334  04   4
335  03   3
336  42  STO
337  09   09
338  71  SBR
339  22  INV
340  98  ADV
341  91  R/S
342  76  LBL
343  22  INV
344  22  INV
345  58  FIX
346  25  CLR
347  69  OP
348  00   00
349  43  RCL
350  09   09
351  69  OP
352  04   04
```

353	32	X:T
354	58	FIX
355	00	00
356	69	OP
357	06	06
358	92	RTN
359	76	LBL
360	23	LNX
361	01	1
362	71	SBR
363	34	√X
364	93	.
365	05	5
366	42	STO
367	01	01
368	93	.
369	08	8
370	05	5
371	42	STO
372	02	02
373	03	3
374	07	7
375	05	5
376	42	STO
377	04	04
378	04	4
379	42	STO
380	05	05
381	91	R/S
382	76	LBL
383	24	CE
384	02	2
385	71	SBR
386	34	√X
387	01	1
388	93	.
389	05	5
390	42	STO
391	01	01
392	93	.
393	08	8
394	05	5
395	42	STO
396	02	02
397	03	3
398	00	0
399	00	0
400	42	STO
401	04	04
402	06	6
403	42	STO
404	05	05
405	92	RTN
406	76	LBL
407	34	√X
408	03	3
409	06	6
410	06	6
411	03	3
412	03	3
413	07	7
414	42	STO
415	09	09
416	71	SBR
417	22	INV
418	92	RTN
419	76	LBL
420	35	1/X
421	32	X:T
422	42	STO
423	11	11
424	71	SBR
425	42	STO
426	92	RTN
427	76	LBL
428	43	RCL
429	32	X:T
430	42	STO
431	11	11
432	71	SBR
433	44	SUM
434	92	RTN
435	91	R/S
436	00	0

UP-1
PRELIMINARY DESIGN CONDITIONS PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Enter space type	1	—	—	A	1.00 ***	
2.	Enter gross area, sq ft	50000	—	—	B	50000.00 ***	
3.	Enter total perimeter, ft	2000	—	—	C	2000.00 ***	
						32000.00 ***	Total air supply
						1260.00 ***	Area of fan rooms
						16.00 ***	Height of fan room
						64.00 ***	Area of duct shaft
						133.33 ***	Tons
						800.00 ***	Area of mech. equipment room
						10.00 ***	Height of mech. equipment room
							Make-up water for cooling tower
						4.64 ***	Electric refrigeration
						6.75 ***	Steam turbine refrigeration
						8.64 ***	Absorption refrigeration
						200.00 ***	Electric power demand, kW
	Repeat steps 1, 2, & 3 as many times as desired.	2	—	—	A	2.00 ***	
		200000	—	—	B	200000.00 ***	
		10000	—	—	C	10000.00 ***	
						267500.00 ***	
						8916.67 ***	
						12.00 ***	
						535.00 ***	
						666.67 ***	
						3076.92 ***	
						13.00 ***	

						20.20 ***	
						33.74 ***	
						43.18 ***	
						1200.00 ***	
		3	—	—	A	3.00 ***	
		500000	—	—	B	500000.00 ***	
		16000	—	—	C	16000.00 ***	
						1120000.00 ***	
						32000.00 ***	
						14.00 ***	
						2240.00 ***	
						2500.00 ***	
						7142.86 ***	
						21.00 ***	
						75.76 ***	
						126.52 ***	
						161.94 ***	
						5000.00 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Prints and stores display in R0 (space type); selects constants based on space type
B	Prints and stores display in R6
C	Prints display; calculates CFM, fan room volume, tonnage, and fan room height; if height is less than 10 ft goes to SBR 3; if more than 15 ft goes to SBR 3
4	Computes and prints area of fan room, height of fan room, and area of duct shaft; prints tonnage; computes height of mechanical equipment room; if less than 10 goes to SBR 5; if more than 25 goes to SBR 5
6	Computes and prints area of mechanical equipment room; prints height of mechanical equipment room; computes and prints water make-up rates and demand KW
1	Stores constant for space type 1
2	Stores constant for space type 2
3	Stores value in R3 and goes to SBR 4
5	Stores value in R3 and goes to SBR 6

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R0	Space type
R1	Constant
R2	Constant
R3	Fan room height; mechanical equipment room height
R4	Constant
R5	Constant
R6	Gross area
R7	Interim values
R8	Tonnage
R9	Fan room volume

UP-1 (HP-97) PRELIMINARY DESIGN CONDITIONS PROGRAM

LISTING

001	*LBLA	21 11
002	STO0	35 00
003	PRTX	-14
004	1	01
005	X=Y?	16-33
006	GTO1	22 01
007	2	02
008	RCL0	36 00
009	X=Y?	16-33
010	GTO2	22 02
011	2	02
012	.	-62
013	5	05
014	STO1	35 01
015	2	02
016	STO2	35 02
017	2	02
018	0	00
019	0	00
020	STO4	35 04
021	1	01
022	0	00
023	STO5	35 05
024	R/S	51
025	*LBLB	21 12
026	STO6	35 06
027	PRTX	-14
028	R/S	51
029	*LBLC	21 13
030	PRTX	-14
031	SPC	16-11
032	1	01
033	5	05
034	x	-35
035	STO7	35 07
036	RCL6	36 06
037	-	-45
038	CHS	-22
039	RCL2	36 02
040	x	-35
041	RCL7	36 07
042	RCL1	36 01
043	x	-35
044	+	-55
045	PRTX	-14
046	2	02
047	.	-62
048	5	05
049	÷	-24
050	STO9	35 09
051	RCL6	36 06
052	RCL4	36 04
053	÷	-24
054	STO8	35 08
055	.	-62
056	1	01
057	6	06
058	Y^x	31
059	4	04
060	x	-35
061	.	-62
062	9	09
063	+	-55
064	INT	16 34
065	STO3	35 03
066	1	01
067	0	00
068	X>Y?	16-34
069	GTO3	22 03
070	RCL3	36 03
071	1	01
072	5	05
073	X≤Y?	16-35
074	GTO3	22 03
075	*LBL4	21 04
076	RCL9	36 09
077	RCL3	36 03
078	÷	-24
079	PRTX	-14
080	RCL3	36 03
081	PRTX	-14
082	RCL9	36 09
083	2	02
084	0	00
085	0	00
086	÷	-24
087	PRTX	-14
088	SPC	16-11
089	RCL8	36 08
090	PRTX	-14
091	.	-62
092	3	03
093	6	06
094	Y^x	31
095	1	01
096	.	-62
097	2	02
098	5	05
099	x	-35
100	.	-62
101	9	09

102	+	-55	148	0	00
103	INT	16 34	149	0	00
104	STO3	35 03	150	÷	-24
105	1	01	151	PRTX	-14
106	0	00	152	SPC	16-11
107	X>Y?	16-34	153	RTN	24
108	GTO5	22 05	154	*LBL1	21 01
109	RCL3	36 03	155	.	-62
110	2	02	156	5	05
111	5	05	157	STO1	35 01
112	X≤Y?	16-35	158	.	-62
113	GTO5	22 05	159	8	08
114	*LBL6	21 06	160	5	05
115	RCL8	36 08	161	STO2	35 02
116	6	06	162	3	03
117	0	00	163	7	07
118	x	-35	164	5	05
119	RCL3	36 03	165	STO4	35 04
120	÷	-24	166	4	04
121	PRTX	-14	167	STO5	35 05
122	RCL3	36 03	168	RTN	24
123	PRTX	-14	169	*LBL2	21 02
124	SPC	16-11	170	1	01
125	RCL8	36 08	171	.	-62
126	3	03	172	5	05
127	3	03	173	STO1	35 01
128	÷	-24	174	.	-62
129	PRTX	-14	175	8	08
130	1	01	176	5	05
131	.	-62	177	STO2	35 02
132	6	06	178	3	03
133	7	07	179	0	00
134	x	-35	180	0	00
135	PRTX	-14	181	STO4	35 04
136	1	01	182	6	06
137	.	-62	183	STO5	35 05
138	2	02	184	RTN	24
139	8	08	185	*LBL3	21 03
140	x	-35	186	STO3	35 03
141	PRTX	-14	187	GSB4	23 04
142	SPC	16-11	188	RTN	24
143	RCL6	36 06	189	*LBL5	21 05
144	RCL5	36 05	190	STO3	35 03
145	x	-35	191	GSB6	23 06
146	1	01	192	RTN	24
147	0	00	193	R/S	51

UP-2
SPACE PLANNING PROGRAM

GENERAL DESCRIPTION

With input of type of space and net area, the program can compute the following:

Net area	*AN*
Area of circulation spaces	*AC*
Area for mechanical systems	*AM*
Gross area	*AG*
Cost related to net area	*CAN*
Cost related to area for circulations	*CAC*
Cost related to mechanical systems	*CAM*
Cost related to gross area	*CAG*
Total net area	Σ*AN*
Total circulation area	Σ*AC*
Total area for mechanical systems	Σ*AM*
Total gross area	Σ*AG*
Percent net to gross ratio	*N/G%*
Total cost related to net area	Σ*CNA*
Total cost related to circulation area	Σ*CCA*
Total cost of mechanical systems	Σ*CMS*
Total construction cost	Σ*CC*
Cost per sq ft based on gross area	*C/CG*
Cost per sq ft of mechanical systems based on gross area	*C/MS*

EQUATIONS

None.

OPERATING FEATURES

Flags as below:

Flags	Print-Out
None	Areas and costs for space input
Flag 1	Will also print running total of areas
Flag 2	Will also print running total costs

The data related to the ratio of circulation spaces, mechanical spaces, and costs are for demonstration only. The designers should input their own data related to their types of projects. The listing shows data for five types of spaces only and the remaining Registers 6 through 10 have no data. Actually, the program can handle 16 types of spaces and the user can program the additional spaces as required.

REFERENCE DATA

Table 1 shows the format for inputting data for different types of spaces.

TABLE 1

Register	Actual Number Stored				
R01	20	20	65	15	20
R02	16	16	45	10	15
R03	12	13	30	08	21
R04	10	09	25	06	10
R05	06	05	15	03	06
	C-I	C-II	C-III	C-IV	C-V

Column I	Cost for mechanical and electrical systems per net area
Column II	Cost for circulation space per sq ft
Column III	Cost for net area per sq ft
Column IV	Percent of space for mechanical and electrical systems as related to net area
Column V	Percent of space for circulation space as related to net area

UP-2
SPACE PLANNING PROGRAM
USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Initialize	—	—	2nd	E′	0.		
2.	Enter net area and space type (Note decimal format. Space type 1 should be input as .01, type 2 as .02, type 11 as .11, and so on.)	100.01	—	—	A	1.	S. NO	Space type no.
						100.	AN	Net area
						20.	AC	Area of circ. spaces
						15.	AM	Area for M & E systems
						135.	AG	Gross area
						6500.	CAN	Cost related to net area
						400.	CAC	Cost related to circ. space
						2000.	CAM	Cost related to M & E systems
						8900.	CAG	Cost related to gross area
	Repeat step 2 as many times as desired. To print running subtotal of areas	—	2nd	St flg	1			
		200.02	—	—	A	2.	S. NO	
						200.	AN	
						30.	AC	
						20.	AM	
						250.	AG	
						300.	ΣAN	Total net area
						50.	ΣAC	Total area of circ. space
						35.	ΣAM	Total area of mech. spaces
						385.	ΣAG	Total gross area
						9000.	CAN	
						480.	CAC	
						3200.	CAM	
	To print running subtotal of cost	—	2nd	St flg	2	12680.	CAG	

UP-2 *(Continued)*
SPACE PLANNING PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
		300.03	–	–	A	3.	S. NO	
						300.	AN	
						63.	AC	
						24.	AM	
						387.	AG	
						600.	ΣAN	
						113.	ΣAC	
						59.	ΣAM	
						772.	ΣAG	
						9000.	CAN	
						819.	CAC	
						3600.	CAM	
						13419.	CAG	
						24500.	ΣCNA	Total cost related to net space
						1699.	ΣCCA	Total cost related to circ. space
						8800.	ΣCMS	Total cost related to M & E systems
						34999.	ΣCC	Total construction cost
	Continue with or without flags 1 & 2, as many times as desired.	400.04	–	–	A	4.	S. NO	
						400.	AN	
						40.	AC	
						24.	AM	
						464.	AG	
						1000.	ΣAN	
						153.	ΣAC	
						83.	ΣAM	
						1236.	ΣAG	
						10000.	CAN	
						360.	CAC	
						4000.	CAM	
						14360.	CAG	

3.	To summarize	—	—	—	E	34500. ΣCNA 2059. ΣCCA 12800. ΣCMS 49359. ΣCC 1000. ΣAN 153. ΣAC 83. ΣAM 1236. ΣAG 81. N/G% 34500. ΣCNA 2059. ΣCCA 12800. ΣCMS 49359. ΣCC 40. C/CG 10. C/MS	 Net/gross ratio, % Cost/gross area Cost of mech. systems

EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Accepts input in decimal format; separates and prints R. No.; prints and stores AN; computes and prints AC, AM, AG, and CAN, CAC, CAM, and CAG; if flag 1 is set, computes and prints ΣAN, ΣAC, ΣAM, and ΣAG; if flag 2 is set, computes and prints ΣCNA, ΣCCA, ΣCMS, and ΣCC
1/X	Computes and prints CAN, CAC, CAM, and CAG
E′	Equalizes and partitions
E	Computes and prints N/G%; uses SBR STO; computes and prints C/CG and C/MS
INV	Prints alphanumeric identification of data
LNX	Prints AC, AM, and AG
CE	Prints AC, AM, and AG
CLR	Prints CCA, CCM, CCG, and CC
X⇄T	Reads tables
X^2	Reads tables
$\sqrt{X}$	Uses SBR RCL and SBR 1/X
STO	Prints CNA, CCA, CMS, and CC
RCL	Prints ΣAN, ΣAC, ΣAM, and ΣAG
Y^x	Prints CAC, CAN, CAM, and CAG
SUM	Stores table

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For type of space
R01–16	For table under SBR SUM
R17	AN
R18	AC
R19	ΣAN
R20	ΣAC
R21	ΣAM
R22	ΣAG
R23	ΣCNA
R24	ΣCCA
R25	ΣCMS
R26	CAG
R27	Interim value of table
R28	Interim value of table
R29	Alphanumeric code

UP-2 SPACE PLANNING PROGRAM

LABELS & SUBROUTINES

```
001  11   A
088  35  1/X
152  10  E'
167  15   E
242  22  INV
259  23  LNX
270  24  CE
283  25  CLR
298  32  X:T
325  33  X²
356  34  √X
364  42  STO
418  43  RCL
466  45  Yˣ
479  44  SUM
```

LISTING

```
000  76  LBL
001  11   A
002  42  STO
003  17   17
004  22  INV
005  59  INT
006  65   ×
007  01   1
008  00   0
009  00   0
010  95   =
011  42  STO
012  00   00
013  32  X:T
014  03   3
015  06   6
016  04   4
017  00   0
018  03   3
019  01   1
020  03   3
021  02   2
022  42  STO
023  29   29
024  71  SBR
025  22  INV
026  43  RCL
027  17   17
028  59  INT
029  42  STO
030  17   17
031  44  SUM
032  19   19
033  32  X:T
034  01   1
035  06   6
036  42  STO
037  29   29
038  71  SBR
039  23  LNX
040  98  ADV
041  73  RC*
042  00   00
043  42  STO
044  28   28
045  71  SBR
046  32  X:T
047  42  STO
048  18   18
049  44  SUM
050  20   20
051  32  X:T
052  00   0
053  42  STO
054  29   29
055  71  SBR
056  23  LNX
057  71  SBR
058  32  X:T
059  44  SUM
060  21   21
061  32  X:T
062  01   1
063  05   5
064  42  STO
065  29   29
066  71  SBR
067  23  LNX
068  53   (
069  24  CE
070  85   +
071  43  RCL
072  18   18
```

073	85	+
074	43	RCL
075	17	17
076	54	)
077	32	X:T
078	07	7
079	42	STO
080	29	29
081	71	SBR
082	23	LNX
083	98	ADV
084	87	IFF
085	01	01
086	34	√X
087	76	LBL
088	35	1/X
089	71	SBR
090	33	X^2
091	44	SUM
092	23	23
093	42	STO
094	26	26
095	32	X:T
096	01	1
097	06	6
098	42	STO
099	29	29
100	71	SBR
101	45	Y^X
102	85	+
103	53	(
104	71	SBR
105	33	X^2
106	65	×
107	43	RCL
108	18	18
109	55	÷
110	43	RCL
111	17	17
112	54	)
113	44	SUM
114	24	24
115	44	SUM
116	26	26
117	32	X:T
118	00	0
119	42	STO
120	29	29
121	71	SBR
122	45	Y^X
123	85	+
124	71	SBR
125	33	X^2
126	44	SUM
127	25	25
128	44	SUM
129	26	26
130	32	X:T
131	01	1
132	05	5
133	42	STO
134	29	29
135	71	SBR
136	45	Y^X
137	43	RCL
138	26	26
139	32	X:T
140	07	7
141	42	STO
142	29	29
143	71	SBR
144	45	Y^X
145	98	ADV
146	87	IFF
147	02	02
148	42	STO
149	98	ADV
150	91	R/S
151	76	LBL
152	10	E'
153	22	INV
154	58	FIX
155	03	3
156	69	OP
157	17	17
158	25	CLR
159	47	CMS
160	99	PRT
161	98	ADV
162	98	ADV
163	71	SBR
164	44	SUM
165	91	R/S
166	76	LBL
167	15	E
168	71	SBR
169	43	RCL
170	98	ADV
171	53	(
172	43	RCL
173	19	19
174	65	×
175	01	1
176	00	0
177	00	0
178	55	÷
179	43	RCL
180	22	22
181	54	)
182	32	X:T
183	03	3
184	01	1
185	06	6
186	03	3
187	02	2
188	02	2
189	06	6
190	01	1
191	42	STO
192	29	29
193	71	SBR
194	22	INV
195	98	ADV
196	71	SBR
197	42	STO
198	53	(
199	43	RCL
200	17	17
201	55	÷
202	43	RCL
203	22	22
204	54	)
205	32	X:T
206	01	1
207	05	5
208	06	6
209	03	3
210	01	1
211	05	5
212	02	2
213	02	2
214	42	STO
215	29	29
216	71	SBR
217	22	INV
218	98	ADV
219	53	(
220	43	RCL
221	25	25
222	55	÷
223	43	RCL
224	22	22
225	54	)
226	32	X:T
227	01	1
228	05	5
229	06	6
230	03	3
231	03	3
232	00	0
233	03	3
234	06	6
235	42	STO
236	29	29
237	71	SBR
238	22	INV
239	98	ADV
240	92	RTN
241	76	LBL
242	22	INV
243	22	INV
244	58	FIX
245	25	CLR
246	69	OP
247	00	00
248	43	RCL
249	29	29
250	69	OP
251	04	04
252	32	X:T
253	58	FIX
254	00	00
255	69	OP
256	06	06
257	92	RTN
258	76	LBL
259	23	LNX
260	01	1
261	03	3
262	01	1
263	05	5
264	44	SUM
265	29	29
266	71	SBR
267	22	INV
268	92	RTN
269	76	LBL
270	24	CE
271	07	7
272	07	7
273	01	1
274	03	3
275	01	1
276	05	5
277	44	SUM
278	29	29
279	71	SBR
280	22	INV
281	92	RTN
282	76	LBL
283	25	CLR
284	07	7
285	07	7
286	01	1
287	05	5
288	01	1
289	05	5
290	01	1
291	03	3
292	44	SUM
293	29	29
294	71	SBR
295	22	INV
296	92	RTN
297	76	LBL
298	32	X:T
299	53	(
300	53	(
301	43	RCL
302	28	28
303	55	÷
304	01	1
305	00	0
306	00	0
307	54	)
308	42	STO
309	27	27
310	59	INT
311	42	STO
312	28	28
313	43	RCL
314	27	27
315	22	INV
316	59	INT
317	65	×
318	43	RCL
319	17	17
320	54	)
321	92	RTN
322	71	SBR
323	22	INV
324	76	LBL
325	33	X^2
326	53	(
327	53	(
328	43	RCL
329	28	28
330	55	÷
331	01	1
332	00	0

```
333  00  0
334  54  )
335  42  STO
336  27  27
337  59  INT
338  42  STO
339  28  28
340  43  RCL
341  27  27
342  22  INV
343  59  INT
344  65  ×
345  01  1
346  00  0
347  00  0
348  65  ×
349  43  RCL
350  17  17
351  54  )
352  92  RTN
353  71  SBR
354  22  INV
355  76  LBL
356  34  √X
357  71  SBR
358  43  RCL
359  71  SBR
360  35  1/X
361  98  ADV
362  92  RTN
363  76  LBL
364  42  STO
365  43  RCL
366  23  23
367  32  X:T
368  01  1
369  06  6
370  00  0
371  00  0
372  42  STO
373  29  29
374  71  SBR
375  25  CLR
376  43  RCL
377  24  24
378  32  X:T
379  00  0
380  42  STO
381  29  29
382  71  SBR
383  25  CLR
384  43  RCL
385  25  25
386  32  X:T
387  01  1
388  05  5
389  02  2
390  03  3
391  42  STO
392  29  29
393  71  SBR
394  25  CLR
395  53  (
396  43  RCL
397  23  23
398  85  +
399  43  RCL
400  24  24
401  85  +
402  43  RCL
403  25  25
404  54  )
405  42  STO
406  17  17
407  32  X:T
408  01  1
409  03  3
410  94  +/-
411  42  STO
412  29  29
413  71  SBR
414  25  CLR
415  98  ADV
416  92  RTN
417  76  LBL
418  43  RCL
419  43  RCL
420  19  19
421  32  X:T
422  01  1
423  06  6
424  42  STO
425  29  29
426  71  SBR
427  24  CE
428  43  RCL
429  20  20
430  32  X:T
431  00  0
432  42  STO
433  29  29
434  71  SBR
435  24  CE
436  43  RCL
437  21  21
438  32  X:T
439  01  1
440  05  5
441  42  STO
442  29  29
443  71  SBR
444  24  CE
445  53  (
446  43  RCL
447  19  19
448  85  +
449  43  RCL
450  20  20
451  85  +
452  43  RCL
453  21  21
454  54  )
455  42  STO
456  22  22
457  32  X:T
458  07  7
459  42  STO
460  29  29
461  71  SBR
462  24  CE
463  98  ADV
464  92  RTN
465  76  LBL
466  45  YX
467  01  1
468  05  5
469  01  1
470  03  3
471  01  1
472  05  5
473  44  SUM
474  29  29
475  71  SBR
476  22  INV
477  92  RTN
478  76  LBL
479  44  SUM
480  02  2
481  00  0
482  02  2
483  00  0
484  06  6
485  05  5
486  01  1
487  05  5
488  02  2
489  00  0
490  42  STO
491  01  01
492  01  1
493  06  6
494  01  1
495  06  6
496  04  4
497  05  5
498  01  1
499  00  0
500  01  1
501  05  5
502  42  STO
503  02  02
504  01  1
505  02  2
506  01  1
507  03  3
508  03  3
509  00  0
510  00  0
511  08  8
512  02  2
513  01  1
514  42  STO
515  03  03
516  01  1
517  00  0
518  00  0
519  09  9
520  02  2
521  05  5
522  00  0
523  06  6
524  01  1
525  00  0
526  42  STO
527  04  04
528  00  0
529  06  6
530  00  0
531  05  5
532  01  1
533  05  5
534  00  0
535  03  3
536  00  0
537  06  6
538  42  STO
539  05  05
540  00  0
541  00  0
542  00  0
543  00  0
544  00  0
545  00  0
546  00  0
547  00  0
548  00  0
549  00  0
550  42  STO
551  07  07
552  00  0
553  00  0
554  00  0
555  00  0
556  00  0
557  00  0
558  00  0
559  00  0
560  00  0
561  00  0
562  42  STO
563  08  08
564  00  0
565  00  0
566  00  0
567  00  0
568  00  0
569  00  0
570  00  0
571  00  0
572  00  0
573  00  0
574  42  STO
575  09  09
576  00  0
577  00  0
578  00  0
579  00  0
580  00  0
581  00  0
582  00  0
583  00  0
584  00  0
585  00  0
586  42  STO
587  10  10
588  92  RTN
589  00  0
590  00  0
```

SPECIAL NOTES FOR HP-97 USERS

1. A data card has to be made for the data shown in Table 1 of "General Description" to obtain results similar to those given in the example. The users can also input their own data.
2. The data is stored in secondary registers R10 to R19.
3. The program uses flags 0 and 1, as explained under "User Instructions and Examples."

UP-2
SPACE PLANNING PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE for Program   ONE for Data

Step	Procedure	Enter	Press			Print Out	Explanation
	Example						
1.	Initialize	–	–	*f*	E	0.00 ***	
2.	Enter net area and space type	100.01	–	–	A	1.00 ***	Note decimal format of input
						100.00 ***	
						20.00 ***	Area of circ. spaces
						15.00 ***	Area for M & E systems
						135.00 ***	Gross area
						6500.00 ***	Cost related to net area
						400.00 ***	Cost related to circ. space
						2000.00 ***	Cost related to M & E systems
						8900.00 ***	Cost related to gross area
	Repeat step 2 as many times as desired. To print running subtotal of areas also	–	*f*	LBL	0		Set flag 0
		200.02	–	–	A	2.00 ***	
						200.00 ***	
						30.00 ***	
						20.00 ***	
						250.00 ***	Running subtotal of area
						300.00 ***	Total net area
						50.00 ***	Total area of circ. space
						35.00 ***	Total area of M & E spaces
						385.00 ***	Total gross area
						9000.00 ***	
						400.00 ***	
						3200.00 ***	
						12600.00 ***	
	To print running subtotal of cost	–	*f*	LBL	1		Set flag 1

		300.03	–	–	A	3.00 ***	
						320.00 ***	
						63.00 ***	
						24.00 ***	
						367.00 ***	
						600.00 ***	
						113.00 ***	
						59.00 ***	
						772.00 ***	
						9000.00 ***	
						819.00 ***	
						3600.00 ***	
						13419.00 ***	
						24500.00 ***	Total cost related to net space
						1639.00 ***	Total cost related to circ. space
						8800.00 ***	Total cost related to M & E systems
						34939.00 ***	Total construction cost
	Repeat as required for other spaces.	400.04	–	–	A	4.00 ***	
						400.00 ***	
						40.00 ***	
						24.00 ***	
						464.00 ***	
						1000.00 ***	
						153.00 ***	
						83.00 ***	
						1236.00 ***	
						10000.00 ***	
						360.00 ***	
						4000.00 ***	
						14360.00 ***	
						34500.00 ***	
						2059.00 ***	
						12800.00 ***	
						49359.00 ***	

UP-2 *(Continued)*
SPACE PLANNING PROGRAM
HP-97 USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE for Program ONE for Data

Step	Procedure	Enter	Press			Print Out	Explanation
	To summarize	—	—	—	E	1000.00 ***	Total net area
						153.00 ***	Total area of circ. spaces
						83.00 ***	Total area of M & E spaces
						1236.00 ***	Total gross area
						80.91 ***	Net/gross ratio
						34500.00 ***	Total cost related to net area
						2059.00 ***	Total cost related to circ. space
						12800.00 ***	Total cost related to M & E systems
						45359.00 ***	Total construction cost
						39.93 ***	Cost per sq ft gross area
						10.36 ***	Cost of M & E systems per sq ft

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
A	Accepts input in decimal format; separates, prints, and stores space type in RE; stores net area in RA; computes and prints area and costs; if flag 0 is set, prints subtotal of areas; if flag 1 is set, prints subtotal of costs
2	Computes and prints costs using SBR 3
e	Clears registers
E	Computes and prints summary using SBR 5 and SBR 4
0	Calculates area of circulation space and area of M & E spaces
3	Calculates costs
1	Goes to SBR 5 and SBR 2
4	Computes and prints subtotal of costs
5	Computes and prints subtotal of areas

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
RA	Net area
RB	Circulation area
RC	Not used
RD	Interim values
RE	Space type; also interim values
RI	For indirect recall
R0	Total net area
R1	Total area of circulation spaces
R2	Total area of M & E spaces
R3	Total gross area
R4	Total cost related to net area
R5	Total cost related to circulation spaces
R6	Total cost related to M & E systems
R7	Total cost
R8 & R9	Not used

UP-2 (HP-97) SPACE PLANNING PROGRAM

LISTING

001	*LBLA	21 11
002	STOA	35 11
003	FRC	16 44
004	1	01
005	0	00
006	0	00
007	×	-35
008	STOE	35 15
009	PRTX	-14
010	9	09
011	+	-55
012	STOI	35 46
013	RCLA	36 11
014	INT	16 34
015	STOA	35 11
016	PRTX	-14
017	SPC	16-11
018	ST+0	35-55 00
019	RCLi	36 45
020	STOE	35 15
021	GSB0	23 00
022	STOB	35 12
023	ST+1	35-55 01
024	PRTX	-14
025	GSB0	23 00
026	ST+2	35-55 02
027	PRTX	-14
028	RCLB	36 12
029	+	-55
030	RCLA	36 11
031	+	-55
032	PRTX	-14
033	SPC	16-11
034	F0?	16 23 00
035	GTO1	22 01
036	*LBL2	21 02
037	GSB3	23 03
038	ST+4	35-55 04
039	STO7	35 07
040	PRTX	-14
041	GSB3	23 03
042	RCLB	36 12
043	×	-35
044	RCLA	36 11
045	÷	-24
046	ST+5	35-55 05
047	ST+7	35-55 07
048	PRTX	-14
049	GSB3	23 03
050	ST+6	35-55 06
051	ST+7	35-55 07
052	PRTX	-14
053	RCL7	36 07
054	PRTX	-14
055	SPC	16-11
056	F1?	16 23 01
057	GSB4	23 04
058	SPC	16-11
059	RTN	24
060	*LBLe	21 16 15
061	CLRG	16-53
062	CLRG	16-53
063	CLX	-51
064	PRTX	-14
065	SPC	16-11
066	SPC	16-11
067	RTN	24
068	*LBLE	21 15
069	GSB5	23 05
070	SPC	16-11
071	RCL0	36 00
072	1	01
073	0	00
074	0	00
075	×	-35
076	RCL3	36 03
077	÷	-24
078	PRTX	-14
079	SPC	16-11
080	GSB4	23 04
081	RCLA	36 11
082	RCL3	36 03
083	÷	-24
084	PRTX	-14
085	SPC	16-11
086	RCL6	36 06
087	RCL3	36 03
088	÷	-24
089	PRTX	-14
090	SPC	16-11
091	RTN	24
092	*LBL0	21 00
093	RCLE	36 15
094	1	01
095	0	00
096	0	00
097	÷	-24
098	STOD	35 14
099	INT	16 34
100	STOE	35 15
101	RCLD	36 14
102	FRC	16 44
103	RCLA	36 11
104	×	-35
105	RTN	24
106	*LBL3	21 03
107	RCLE	36 15
108	1	01
109	0	00

110	0	00	136	RCL4	36 04
111	÷	-24	137	RCL5	36 05
112	STOD	35 14	138	+	-55
113	INT	16 34	139	RCL6	36 06
114	STOE	35 15	140	+	-55
115	RCLD	36 14	141	STOA	35 11
116	FRC	16 44	142	PRTX	-14
117	1	01	143	SPC	16-11
118	0	00	144	RTN	24
119	0	00	145	*LBL5	21 05
120	×	-35	146	RCL0	36 00
121	RCLA	36 11	147	PRTX	-14
122	×	-35	148	RCL1	36 01
123	RTN	24	149	PRTX	-14
124	*LBL1	21 01	150	RCL2	36 02
125	GSB5	23 05	151	PRTX	-14
126	GSB2	23 02	152	RCL0	36 00
127	SPC	16-11	153	RCL1	36 01
128	RTN	24	154	+	-55
129	*LBL4	21 04	155	RCL2	36 02
130	RCL4	36 04	156	+	-55
131	PRTX	-14	157	STO3	35 03
132	RCL5	36 05	158	PRTX	-14
133	PRTX	-14	159	SPC	16-11
134	RCL6	36 06	160	RTN	24
135	PRTX	-14	161	R/S	51

UP-3
DISTRIBUTION NETWORK PROGRAM

GENERAL DESCRIPTION

This program can be very useful for delineating any distribution system having a large number of branches.

After the network is sketched, all the node points should be numbered to identify the piping runs. A node point is defined as a point where change in the quantity of flow takes place by the fluid, either entering a branch or returning from the branch.

The input of the branch flow rate and node numbers will print out flow rates in piping mains and identification of the piping section. Further, space is allowed on the output tape to mark the pipe diameter when sized, length of the piping section, and the dynamic loss coefficient for the fittings. This simple program reduces the production time, since the output when completed forms an organized input for the next steps. Further, this part of the program can be handled easily by a person less skilled than the engineer.

OPERATING FEATURES

If space on the tape is not required for pipe diameter, length, and fitting coefficient, flag 1 should be set to delete this operation.

In case several branches in one sequence have the same flow rate, the input time can be reduced by automatically repeating the arrangement under Label C, as shown in the example.

UP-3
DISTRIBUTION NETWORK PROGRAM
USER INSTRUCTIONS AND EXAMPLES Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out		Explanation
	Example							
1.	Initialize	0	–	2nd	E′	0.00		
2.	Enter run no.	1.02	–	–	A	1.02	R.NO	
3.	Enter branch flow	2.00	–	–	B	2.00	QB	
						2.00	QM	Flow in mains
						0.00	DIA	Diameter
						0.00	L	Length
						0.00	FF	Fitting coeff.
	Repeat steps 2 & 3 for different	2.03	–	–	A	2.03	R.NO	
	flow rates.	3	–	–	B	3.00	QB	
						5.00	QM	
						0.00	DIA	
						0.00	L	
						0.00	FF	
4.	To repeat same branch flow twice	2	–	–	C	3.04	R.NO	Run no. will change consecutively
						3.00	QB	
						8.00	QM	
						0.00	DIA	
						0.00	L	
						0.00	FF	
						4.05	R.NO	
						3.00	QB	
						11.00	QM	
						0.00	DIA	
						0.00	L	
						0.00	FF	
	To delete diameter, length, and fitting coeff.	–	2nd	St flg	1			
	Repeat steps 1, 2, 3, & 4.	0	–	2nd	E′	0.00		

		1.02	–	–	A	1.02	R.NO
		2	–	–	B	2.00	QB
						2.00	QM
		2.03	–	–	A	2.03	R.NO
		3	–	–	B	3.00	QB
						5.00	QM
		3.04	–	–	A	3.04	R.NO
		3	–	–	B	3.00	QB
						8.00	QM
		4.05	–	–	A	4.05	R.NO
		3	–	–	B	3.00	QB
						11.00	QM
		5.06	–	–	A	5.06	R.NO
		3	–	–	B	3.00	QB
						14.00	QM

EXPLANATION OF LABELS AND SUBROUTINES

Label	Function
A	Prints and stores R No.
B	Prints and stores QB; computes, prints, and stores QM; if flag 1 is set goes to CE, otherwise prints DIA, L, and FF
C	Repeats A after increasing R No. by 1; repeats B
LNX	For reiterating
INV	Prints alphanumeric identification of data
CE	Stops if flag 1 is set
E′	For clearing registers

EXPLANATION OF STORAGE REGISTERS

Register	Function
R00	For repeating DSZ 0
R01	Not used
R02	Not used
R03	Not used
R04	Decimal part of R No.
R05	Run no.
R06	Branch flow QB
R07	Total flow in main QM
R08	Integer part of R No.
R09	Alphanumeric code

UP-3 DISTRIBUTION NETWORK PROGRAM

LABELS & SUBROUTINES

```
001  11  A
020  12  B
082  13  C
102  23  LNX
129  22  INV
146  24  CE
149  10  E'
```

LISTING

```
000  76  LBL
001  11  A
002  98  ADV
003  42  STO
004  05  05
005  32  X:T
006  03  3
007  05  5
008  04  4
009  00  0
010  03  3
011  01  1
012  03  3
013  02  2
014  42  STO
015  09  09
016  71  SBR
017  22  INV
018  92  RTN
019  76  LBL
020  12  B
021  42  STO
022  06  06
023  32  X:T
024  03  3
025  04  4
026  01  1
027  04  4
028  42  STO
029  09  09
030  71  SBR
031  22  INV
032  44  SUM
033  07  07
034  43  RCL
035  07  07
036  32  X:T
037  03  3
038  04  4
039  03  3
040  00  0
041  42  STO
042  09  09
043  71  SBR
044  22  INV
045  87  IFF
046  01  01
047  24  CE
048  00  0
049  00  0
050  32  X:T
051  01  1
052  06  6
053  02  2
054  04  4
055  01  1
056  03  3
057  42  STO
058  09  09
059  71  SBR
060  22  INV
061  00  0
062  00  0
063  32  X:T
064  02  2
065  07  7
066  42  STO
067  09  09
068  71  SBR
069  22  INV
070  00  0
071  32  X:T
072  02  2
073  01  1
074  02  2
075  01  1
076  42  STO
077  09  09
078  71  SBR
079  22  INV
080  92  RTN
081  76  LBL
082  13  C
083  42  STO
084  00  00
085  43  RCL
086  05  05
087  22  INV
088  59  INT
089  65  ×
090  01  1
091  00  0
092  00  0
093  95  =
094  42  STO
095  04  04
096  43  RCL
097  05  05
098  59  INT
099  42  STO
100  08  08
101  76  LBL
102  23  LNX
103  53  (
104  43  RCL
105  08  08
106  85  +
107  01  1
108  85  +
109  53  (
110  43  RCL
111  04  04
112  85  +
113  01  1
114  54  )
115  55  ÷
116  01  1
117  00  0
118  00  0
119  54  )
120  11  A
121  43  RCL
122  06  06
123  12  B
124  97  DSZ
125  00  00
126  23  LNX
127  91  R/S
128  76  LBL
129  22  INV
130  22  INV
131  58  FIX
132  25  CLR
133  69  OP
134  00  00
135  43  RCL
136  09  09
137  69  OP
138  04  04
139  32  X:T
140  58  FIX
141  02  02
142  69  OP
143  06  06
144  92  RTN
```

```
145  76 LBL
146  24 CE
147  92 RTN
148  76 LBL
149  10 E'
150  98 ADV
151  47 CMS
152  25 CLR
153  99 PRT
154  98 ADV
155  91 R/S
156  00  0
157  00  0
158  00  0
159  00  0
160  00  0
```

UP-3
DISTRIBUTION NETWORK PROGRAM

HP-97 USER INSTRUCTIONS AND EXAMPLES   Number of Cards: ONE

Step	Procedure	Enter	Press			Print Out	Explanation
	Example 1						
1.	Initialize	—	—	*f*	E	0.00 ***	
2.	Enter run no.	1.02	—	—	A	1.02 ***	
3.	Enter branch flow	2	—	—	B	2.00 ***	
						2.00 ***	Flow in mains
						0.00 ***	Space for diameter
						0.00 ***	Space for length
						0.00 ***	Space for fitting factors
4.	To repeat 3 times	3	—	—	C	2.03 ***	
						3.00 ***	
						5.00 ***	
						0.00 ***	
						0.00 ***	
						0.00 ***	
						3.04 ***	
						3.00 ***	
						8.00 ***	
						0.00 ***	
						0.00 ***	
						0.00 ***	
						4.05 ***	
						3.00 ***	
						11.00 ***	
						0.00 ***	
						0.00 ***	
						0.00 ***	

	Example 2						
	To delete spaces for diameter, length, and fitting factors	—	*f*	LBL	0		Set flag 0
1.	Repeat steps 1 through 4	—	—	*f*	E	0.00 ***	
		1.02	—	—	A	1.02 ***	
		2	—	—	B	2.00 *** 2.00 ***	
		2.03	—	—	A	2.03 ***	
		3	—	—	B	3.00 *** 5.00 ***	
	To repeat 3 times	3	—	—	C	3.04 *** 3.00 *** 8.00 *** 4.05 *** 3.00 *** 11.00 *** 5.06 *** 3.00 *** 14.00 ***	

HP-97 EXPLANATION OF LABELS & SUBROUTINES

Label	Function
e	Clears registers
A	Prints and stores display in R5
B	Prints and stores display in R6; totalizes in R7; prints R7; if flag 0 is set goes to SBR 0, otherwise prints 0 three times
c	Stores in R1 and repeats A and B once, increasing value of R5 by .01 each time
1	For reiteration
0	Stops execution

HP-97 EXPLANATION OF STORAGE REGISTERS

Register	Function
R5	Run no.
R6	Branch flow
R7	Total flow
RI	For reiteration
	Remaining registers not used

UP-3 (HP-97) DISTRIBUTION NETWORK PROGRAM

LISTING

```
001  *LBLe   21 16 15
002   CLRG      16-53
003    CLX        -51
004   PRTX        -14
005    SPC      16-11
006    RTN         24
007  *LBLA      21 11
008   STO5      35 05
009   PRTX        -14
010    RTN         24
011  *LBLB      21 12
012   STO6      35 06
013   PRTX        -14
014   ST+7   35-55 07
015   RCL7      36 07
016   PRTX        -14
017    F0?   16 23 00
018   GTO0      22 00
019    CLX        -51
020   PRTX        -14
021   PRTX        -14
022   PRTX        -14
023    SPC      16-11
024    RTN         24
025  *LBLC      21 13
026   STOI      35 46
027  *LBL1      21 01
028      1         01
029      .        -62
030      0         00
031      1         01
032   ST+5   35-55 05
033   RCL5      36 05
034   PRTX        -14
035   RCL6      36 06
036   GSBB      23 12
037   DSZI   16 25 46
038   GTO1      22 01
039    RTN         24
040  *LBL0      21 00
041    SPC      16-11
042    RTN         24
043    R/S         51
```

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(continued from front flap)

Fanning equations, can compute piping system friction, dynamic losses, and flow rates—and it can be used for any fluid.

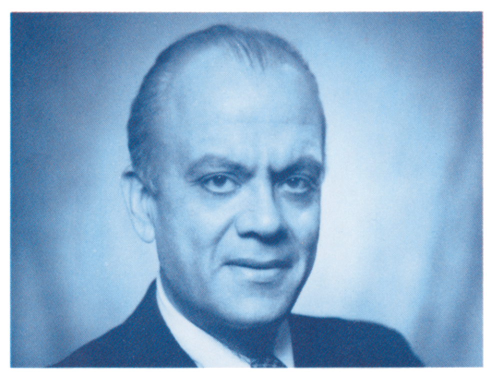
Air Duct Design A program in this book brings the Static Regain Method within the range of all designers. This design method, which saves energy and balances effort, is seldom used by designers because manual solution is extremely time-consuming. But with the procedure outlined, the designer can use the Static Regain Method in a matter of minutes.

Lighting Design A program based on the Lumen Method can compute different cavity ratios, the number of luminaires for desired illumination, and power in kW and watts per square foot. The program also prints out take-off for the luminaire, giving its type, number, and quantity.

Solar Energy Programs allow the engineer to compute shading from external shading devices for any latitude in the Northern Hemisphere, and to optimize the tilt angle of solar panels.

Engineering Economic Analysis Problems related to life cycle cost are generally solved on large main-frame computers—the programs in this book can handle depreciation, interest, discounts, inflation, escalation in cost of energy, taxes on property, and income tax.

With these programs and the TI-59 or HP-97 calculator, the designer has a versatile means of handling day-to-day calculations with speed and ease. *Building Systems Design with Programmable Calculators* is more than an economical and practical set of programs: it is a valuable tool which can increase the quality of design—and make the process faster and cheaper at the same time.



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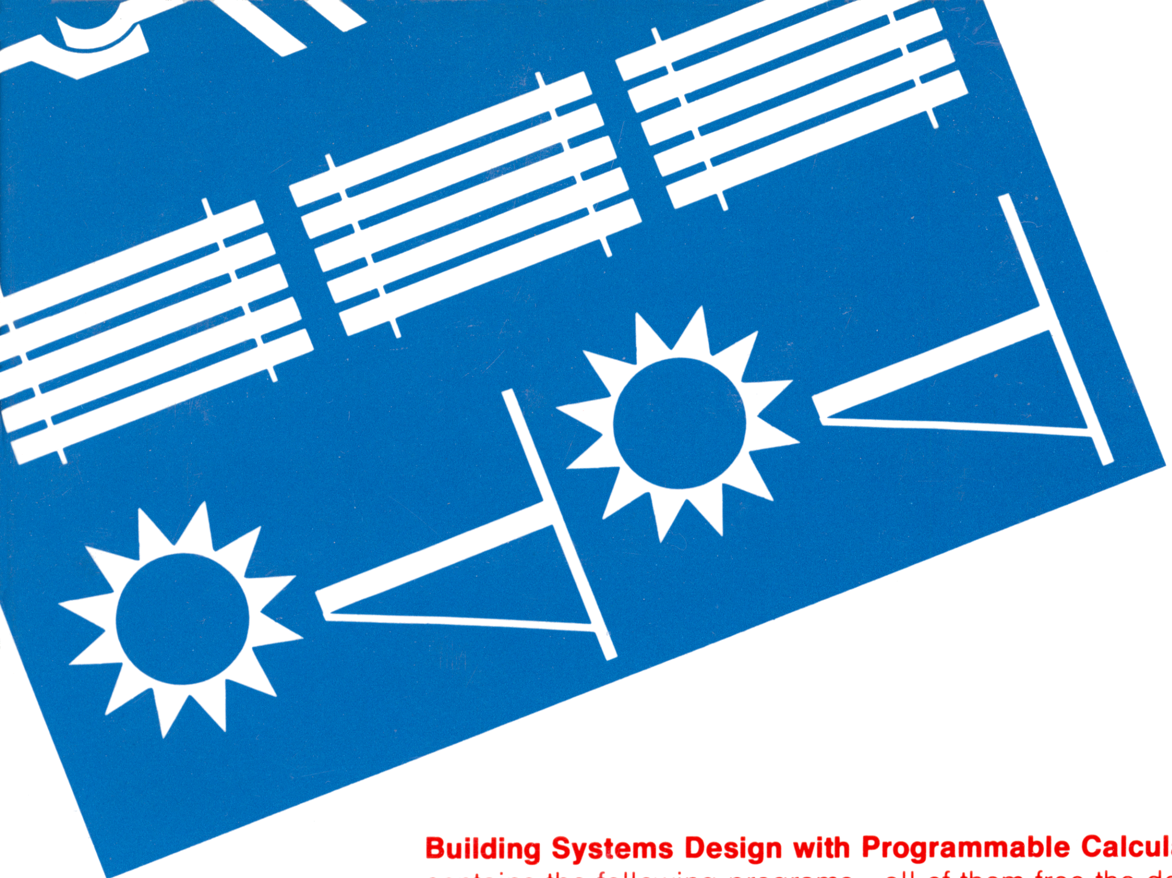
Jacket design by Elliot Epstein



Building Systems Design with Programmable Calculators
contains the following programs—all of them free the designer from the chore of computation and allow concentration on design and synthesis—

- PP-1 **GENERAL PIPING SYSTEM DESIGN PROGRAM**
- PP-2 **WATER PIPING SYSTEM DESIGN PROGRAM**
- PP-3 **PIPING SYSTEM VOLUME AND EXPANSION TANK SIZING PROGRAM**
- DP-1 **AIR DUCT SIZING PROGRAM**
- DP-2 **AIR DUCT DESIGN PROGRAM, STATIC REGAIN METHOD**
- DP-3 **AIR DUCT FRICTION LOSS PROGRAM**
- DP-4 **AIR DUCT HEAT LOSS/GAIN PROGRAM**
- LP-1 **LIGHTING POWER BUDGET PROGRAM**
- LP-2 **LIGHTING DESIGN PROGRAM, LUMEN METHOD**
- SEP-1 **STORM WATER SYSTEM PIPE SIZING PROGRAM**
- SEP-2 **SOIL AND WASTE WATER SYSTEM PIPE SIZING PROGRAM**
- SEP-3 **WATER SYSTEM PIPE SIZING PROGRAM**
- SEP-4 **GAS SYSTEM PIPE SIZING PROGRAM**
- BHTP-1 **HEAT TRANSMISSION COEFFICIENT PROGRAM**
- BHTP-2 **OVER-ALL THERMAL TRANSMITTANCE VALUE PROGRAM**
- SOLP-1 **SOLAR SHADING PROGRAM**
- SOLP-2 **MONTHLY AND ANNUAL AVERAGE INSOLATION ON TILTED SURFACES**
- EP-1 **LIFE CYCLE COST ANALYSIS PROGRAM, PART I**
- EP-2 **LIFE CYCLE COST ANALYSIS PROGRAM, PART II**
- UP-1 **PRELIMINARY DESIGN CONDITIONS PROGRAM**
- UP-2 **SPACE PLANNING PROGRAM**
- UP-3 **DISTRIBUTION NETWORK PROGRAM**

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