

COMPUTER AIDED DUCT DESIGN

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ABSTRACT

The circular slide rule is the industry standard for duct design. It is the simplest, most convenient way to take into account the many variables of ductwork analysis. The slide rule, however, is also relatively inaccurate. This means the ductwork is designed with a higher static pressure and greater noise and turbulence than is necessary. A computer model helps to resolve these problems, reducing the fan horsepower needed to deliver the air. Computer optimization also reduces noise and the high rate of heat transfer caused by turbulent flow in abrupt dynamic transitions. The result is energy savings at the fan, chiller and boiler. There are also first cost savings because of smaller ducts and transitions.

The design screen of the computer program is a simple Cartesian coordinate system with velocity and static pressure as the axes. A user-defined target curve is plotted on this background and each segment of the duct is plotted on the graph to permit a close approximation to the ideal, which is a uniform rate of change in velocity and static pressure. Different duct sizes for width and depth of each section can be tried by the user until the best combination is attained. Other controls are built into the program, such as office standards for minimum duct size or minimum change in width and height. The program is flexible, convenient and accurate. It generates a thorough data and graphical report for reference and evaluation.

INTRODUCTION

Many clients request documentation for the duct design, to include a listing of cfm's, static pressures, and velocities for each duct segment. It is also good design procedure to tabulate all of this data as part of the analysis, since it is easier to review the data and to modify portions of the design if all of the pertinent information is readily available.

The preferred duct design exhibits a uniform change in both velocity and static pressure along the length of a duct segment. This is easier said than done, and any data tabulation will show considerable deviation from this ideal. It is simply too difficult and time consuming to consider all the alternative sizes for each

segment during the design process. Computer-aided design is the most convenient and effective alternative.

A graphical perspective of this design approach is a plot of velocity versus static pressure on a Cartesian coordinate system. The ideal duct has a straight line of uniform slope on this screen.

As each section of duct is selected a point is plotted on the screen and the designer can see its position relative to both previous sections and to the target curve. Several combinations of width and height can be tried for every segment. Each selection is shown on the screen until the best combination is obtained. This is equivalent to trying several sizes on the circular slide rule, reading the velocity and static pressure of each, until an amenable solution is attained.

The duct designer strives for a uniform rate of change in velocity or static pressure, allowing the other parameter to vary. The computer based graphical approach allows both to be monitored constantly. The result is a tool that gives experienced designers a fast and effective design. Novices are able to achieve a thorough understanding of the interrelated criteria. The experts work faster and with more confidence, while those less experienced are able to create verifiable duct designs of high quality.

Another advantage to the program is the documentation generated by the software, in the form of graphs and tables. These permit ready review, swift revision and an authoritative report for the client.

SET UP

The first thing the duct designer does is to sketch a one-line duct diagram with the cfm values marked at each diffuser. He then specifies the range for velocity and static pressure down a main line, either from experience or from specific guidelines pertinent to the project. This same process should take place with the computer routine, to include the specification of design constraints or guidelines.

The cfm data at each branch off the main is input, along with an initial duct size, a beginning and ending velocity, and a static pressure. The user can review

the data (See Figure 1) on the screen before entering it into a permanent job file, then proceed to the actual design screen.

Before opening the design screen, several calculations are performed by the computer. First, it determines the cfm at each segment of the duct. Then it determines the velocity and static pressure for each segment, in order to obtain a uniform change in both along the length of the duct. These values can be calculated by a direct proportion, such as a 10% change in velocity for each of ten segments in the main duct. Another approach is by a system of proportions. A 25% change in velocity might be allowed in a section where a 25% reduction in cfm occurs, even if there are a total of ten segments of the line.

Either option can be specified in the "Defaults" screen (See Figure 2). This form also allows the user to establish acceptable values for max/min changes in width and height of the duct transitions, and other dimensional constraints on the ductwork. These constraints can be such things as a minimum final duct size, or a maximum height or width permissible at a specific section due to structural constraints. These values will be built into the target curve and serve to establish a fixed value for the duct at that point. Minimum/maximum values will also be in effect for adjacent sections, in accordance with default settings.

***** DUCT DATA ENTRY FORM *****

Project Name: _____
 Location: _____
 Job Number: _____
 Duct Line: Supply/Return/Exhaust
 Floor/Wing: _____
 Initial Size: X
 Initial velocity: _____
 Initial Pressure: _____

-----BRANCH CFM DATA---SECTION/CFM-----

1. _____ cfm	6. _____ cfm
2. _____	7. _____
3. _____	8. _____
4. _____	9. _____
5. _____	10. _____

Final velocity: _____ Final pressure: _____

Figure 1

THE TARGET DESIGN SCREEN

The ideal way to design a duct is with a constant change in both velocity and pressure. A "target" curve, calculated from the cfm data input by the method stipulated in the "Defaults" screen, is shown by a series of dots (see Figure 3). Each duct size, chosen by manipulating the four "Arrow" keys on the keyboard, is written on the screen in the (x) block. Its velocity and pressure are calculated and are represented with an asterisk (*) located at these coordinates.

The designer can try various combinations of length and width (constrained by previously input settings) by striking the proper arrow keys. Each increases/decreases the size by the standards given in the defaults menu. By trying several combinations, to see where the "*" falls relative to the curve for each, and ideal value is attained for each section of duct.

Once sized to the designer's satisfaction, the dimensions are saved to the file. This size is recorded on the screen in a box, and the velocity/pressure point is placed on the screen as the number of that section located at the proper coordinates. A few sample points as they might appear part way through the design routine are shown in Fig. 3. These points can be shown with or without a line segment drawn between them, as specified by the user.

One of the output report options prints the final design screen, showing the transition of the pressure and velocity values. These values can be plotted together, or on two separate forms showing (velocity vs. cfm) or (static pressure vs. cfm.)

***** DUCT CALCULATION DEFAULTS *****

Dimensions: inches/millimeters

Allowable changes in duct parameters:

- Max/width: _____
- Max/height: _____
- Min/width: _____
- Min/height: _____

Target curve properties:

Calculation of values: proportional/geometric

Display functions: lines/numbers

Dimensional/structural constraints:

Min. duct size: _____

Section #	Width	Height
1.	_____	_____
2.	_____	_____
3.	_____	_____
4.	_____	_____
5.	_____	_____

Figure 2

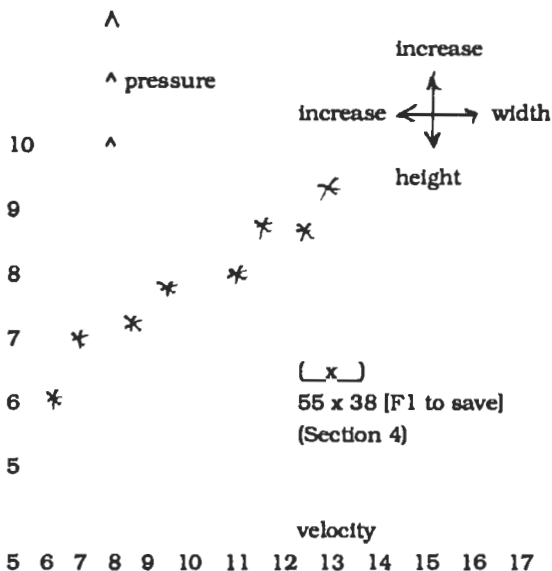


Figure 3

STATIC PRESSURE CALCULATIONS

Another feature of the program is to input the type of transition that occurs at each branch and the length of each section. These transitions are given by inputting a number, obtained from a keyed reference which has all of the standard SMACNA fittings.

There are other elements which may contribute to the static pressure of the duct line. The most common are also listed in the fittings reference, although entering a series of **s in the "Type" column allows the user to specify a safety factor independent of any fitting type. The "Description" column in the table is filled in automatically when a transition type is supplied. This is to verify the input fitting characteristics.

When supplying data in this screen, as with all others, the user is free to move the cursor anywhere in the data entry blocks, to change numbers, etc. Even when the "Escape" key is hit, signifying the data is ready to be saved, a confirmation is required. Other safety features are built into the routine to limit the dimensions, data types, values, and ranges of most of the numbers provided by the user.

REPORTS & FILES

A full set of reports can be generated, both in graphical and tabular format. These will be modeled on the design screens, and will include referenced notes explaining each type of data. This documentation is suitable for client review, and is stored under the job name so that it can be changed and re-calculated as necessary.

***** STATIC PRESSURE CALCULATIONS***

<u>Section #</u>	<u>Length</u>	<u>Transition</u>	<u>Description</u>
------------------	---------------	-------------------	--------------------

- | | | | |
|----|-------|--|--|
| 1. | _____ | | |
| 2. | _____ | | |
| 3. | _____ | | |
| 4. | _____ | | |
| 5. | _____ | | |

Additional Elements (e.g. filter, flex, duct, diffuser)

<u>Type</u>	<u>Static</u>	<u>Description</u>
-------------	---------------	--------------------

- | | | |
|---------|-------|--|
| 1. | _____ | |
| 2. | _____ | |
| 3. | _____ | |
| 4.***** | _____ | |

Total S.P.: _____

FUTURE

The duct design program is written in dBase, a powerful database management tool. AutoCAD programs store all information in dBase type of data files and have the means to import and export data to them. This is a seamless link between the drafting and design/analysis software that can be exploited for future design applications.

CONCLUSION

The standard method of duct design using a circular slide rule, is an art. A complete design, encompassing the entire duct line, can also be done using a computer-generated display of the important parameters. The result of design decisions can be seen immediately upon input, and the effect upon the overall design judged accordingly.

The biggest advantage of the software over the slide rule is enhanced accuracy: the program uses the standard SMACNA equations rather than a graphical representation of them. This not only permits a more uniform flow of air to be produced in the duct, reducing turbulence, but has economic consequences as well. The smaller pressure loss will require smaller fans and motors, plus smaller ductwork. Lower turbulence will result in less heat loss from the air stream, and a higher rate of delivery to the target space.

Another bonus is that the program standardizes the duct design process: by following the same procedure, each design is consistent and relatively independent of the mechanical designer. Furthermore, the program allows specific office standards to be built into the routine: e.g. for a minimum of 2" change in duct size, or a minimum branch size of 6" x 8".

REFERENCES

1. HVAC DUCT SYSTEM DESIGN, Sheet Metal and Air Conditioning Contractor's National Association, Inc. 1981 Edition.
2. LANGUAGE REFERENCE, Ashton-Tate Corporation 1990
3. FUNDAMENTALS, 1993 ASHRAE HANDBOOK