COMPUTER PROGRAMS TO CORRELATE TEST DATA FOR AIR DIFFUSION DEVICES

By

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CHAPTER 1

INTRODUCTION

Air diffusers, returns and mixing boxes of a vast number of sizes and types are an essential part of modern HVAC systems. Each type of this equipment performs differently, and is used for different applications. To help designers to choose among these available devices, manufacturers have published catalogs describing not only dimensional information, but also laboratory performance data for their products. The designers use these catalog performance data to plan their building systems.

The process of data collection and analysis is conventionally performed manually. However, since these procedures are well defined and formulated, they can also be implemented into computer programs. As computers can perform calculations faster and more efficient than humans, then it should result in a significant saving of time and effort.

The main objective of this thesis is to develop computer programs which will record the experimental data, perform the required calculations, and produce the ADC data report forms and graphs necessary for the certification of a particular type of equipment according to the ADC test codes. The computer programs developed in this thesis are based on the testing procedures established by the Air Diffusion Council.

The Air Diffusion Council (ADC) was established in 1961. It was organized to provide testing standards for air diffusers, grilles, and registers, both supplies and returns, as well as mixing boxes. Not only has ADC developed a set of codes and standards for testing laboratory equipment and personnel qualifications, but they have also established a data certification program which verifies the validity and dependability of the performance data published and distributed by the manufacturers.

To obtain certification for their laboratories and products, the manufacturers need to perform a series of tests as described in the ADC 1062 R4 [1] and ADC 1062 :GRD-84 [3]. These tests include :

* Calibration of the company air flow meters by comparison against standard ADC meters.
* Measuring the static pressure drop as a function of air flow rates for various sizes and types of devices, including supplies, returns, and mixing boxes.
* Area - Velocity factors for the air diffusion devices.

* Throw - Velocity distribution for the air diffusion devices.

* Sound Power Levels of noise generated by all types of devices.

To generate the catalog data mentioned earlier, the experimenters either have to run many tests to report the point by point performance data, or a few tests to determine the relationships between air flow rates, pressure drops, areas, and noise criteria of various devices and then use some type of correlation equations or graphs to get the intermediate data. Since it is both costly and time consuming to test all possible sizes over the full flow rate ranges of all the devices produced by a manufacturer, the second method is usually employed. The actual test data are reported only when the experimenters cannot determine any predictable relationship between the data sets.

By using an appropriately chosen number of data sets, the relationship between these variables can be represented by means of a set of mathematical equations. The experimenters can then use these mathematical equations to predict the performance of the device within the independent variable ranges.

The current process for data collection and analysis usually requires long hours of laboratory preparation, tests, and calculations. The data analysis process involves reading of calibration charts, hand calculations and graphical solutions to fit data points. Since all these operations are done manually, there is much room for error. Should a set of data turn out to be unacceptable because of an apparent data collection error, the tests would have to be repeated days later to get a satisfactory result.

Data collection and analysis is a typical engineering problem and it often involves long, repetitive and sometimes complicated calculations and graphical analysis. For this reason, computers are well suited to simplify this process. By implementing the required data collection and analysis procedures into a computer program, the time required for the testing and analyzing processes for the equipment can be dramatically reduced. The use of computers should also significantly reduce the opportunity for human error. For example, instead of doing a graphical analysis by hand to obtain the fitting constants for the equations relating air flow rates, areas, and noise criteria, a multiple regression analysis can be employed on a computer. The multiple regression method is much too tedious and time consuming to be applied manually, but is easily implemented on a computer program where the results are more statistically reliable and accurate. The computer program can also generate the data in graphical form, for easier visualization and checking of the data correlation.

The details for using the computer programs, and examples for producing the forms, graphs and data analysis for experimental data are described fully in Appendix B.

CHAPTER 2

2.0 DEVICE DESCRIPTIONS

The Air Diffusion Council was established in 1961 by companies who manufacture air diffusion devices. These devices include grilles, registers, diffusers, as well as flow , pressure and temperature control devices and related equipment. The ADC has developed various technical codes for testing and rating of the performance characteristics of these air diffusion devices, as well as codes for certifying laboratories and their personnel. These codes are described in detail in the ADC 1062 R4 [1] and ADC 1062 LCM [2]. The manufacturers must observe these test codes to obtain "ADC certified" catalog data for their products.

In this thesis, only the testing of air diffusers and mixing boxes will be discussed. The testing procedures for grilles, registers and diffusers must observe the ADC 1062 GRD-84 [3]. The mixing box test is decribed in ADC 1062R4 [1]. Since diffusers and mixing boxes are different types of equipment, some of the tests applicable to diffusers are not appropriate for mixing boxes. For example, the throw-velocity and the area factor tests are only implemented on diffusers. As for the sound tests, the number of independent variables are different for diffusers and mixing boxes. These devices will be discussed briefly in the following sections.

2.1 AIR DIFFUSERS

The direct discharge of conditioned air into the occupied zone of a room may be uncomfortable and undesirable to the occupants. Therefore, it is necessary to decelerate the supply air, mix it with room air and distribute it to different locations of the room in a way that will achieve an acceptable environment. By proper selection of type, size and location of grilles, registers and diffusers, the designers or the occupants will be able to control the climatic conditions of the room to a desirable level.

The ADC 1062 GRD-84 [3] is written for the testing of grilles, registers and diffusers. In the ASHRAE Fundamentals [6], air diffusers are described as devices used to discharge supply air in various directions and planes. Diffusers come in various shapes and sizes. Some common circular diffusers are shown in Figure 2.1.1. A grille is a covering through which air can pass. A register is a grille equipped with a damper or control valve. An air diffuser can be either a grille or a register. The air flow rate through the device is adjusted by deflecting the dampers or control valves. Grilles, registers and diffusers are all used to control the climatic conditions of a room.

To determine the performance characteristics of diffusers, the ADC requires the manufacturers to perform the following tests:

1) Air flow rate and pressure drop measurements.
2) Sound measurements.
3) Throw-velocity measurements.
4) Area factor measurements.

The above tests are used to determine the relationships between different performance parameters for the devices. For example, the pressure drop through the diffuser is expected to be a function of air flow rate and size. However, for some devices, the pressure drop is a function of the air flow rate only. The sound power level is generally expected to be a function of the air flow rate and size, but sometimes it can be a function of air flow rates only.

The area factor measurements are made to ensure that the nominal area of the device is a function of size only, and not a function of air flow rate. The area factor measurement is discussed in detail in Chapter 3.6. The throw-velocity tests are used for comfort studies, and are discussed in Chapter 3.5.

Here is a summary of the relationships used in the tests:

FOR GRILLES, REGISTERS AND DIFFUSERS

DP = function of (CFM, SIZE)

SOUND = function of (CFM , SIZE)

Ak = function of (SIZE)

where,

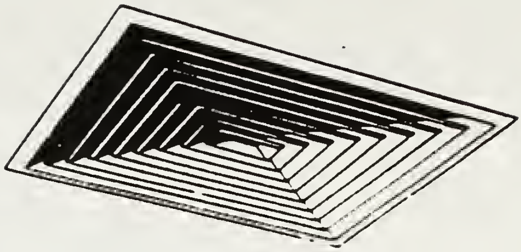
CFM is the air volumetric flow rate through the device.

DP is the pressure drop through the device.

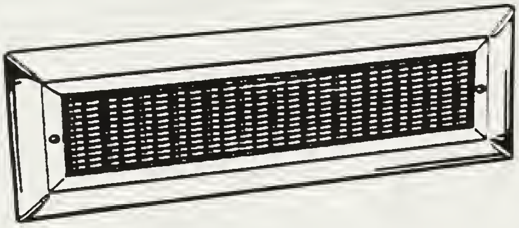
Ak is the area factor for the device.

All the ADC required tests for grilles, registers and diffusers are described in detail in ADC 1062: GRD-84 [3]. Chapter 3 also describes some of these test procedures and discusses how they are implemented into a computer program.

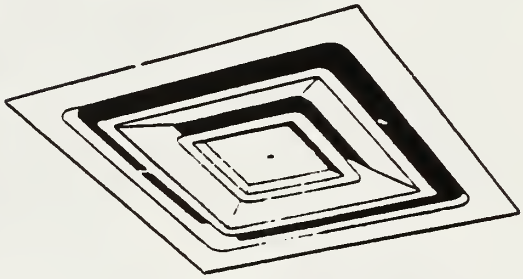
Adjustable core sidewall grille.



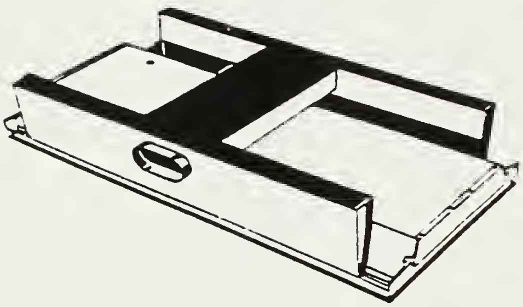
Louver-face ceiling diffuser.



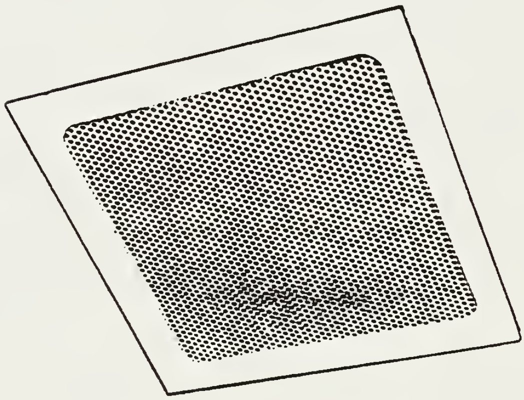
Adjustable round ceiling diffuser.



Louver-face diffuser, square-adjustable pattern.



Supply air fitting for regressed or surface slot troffers, combination air/light units



Perforated face square diffuser, removable face.

Figure 2.2.1 Common Air Diffusers.

2.2 MIXING BOXES

It is difficult to precisely define a mixing box because they have a vast variety of functions and applications. Generally, mixing boxes are used to control the environment of a space by supplying a certain amount of air at a certain temperature. Mixing boxes may be used to provide a constant or variable amount of air to a room, as well as to regulate the supply air temperature to the room. One prominent manufacturer, for example, produces six different models of mixing boxes, each with several variations. Two basic types of mixing boxes, the mechanical constant volume mixing box and the variable volume control mixing box, are described as follows. The mechanical constant volume mixing box is designed to deliver a constant volume of air to a room regardless of the supply duct pressure variations. The air flow rate is kept constant by controlling an adjustable damper. For example, if there is a sudden drop in system pressure causing a reduced supply air volume, the damper will open more to allow less static pressure drop, thereby maintaining the outlet air volumetric flow rate. The cooling load of the space may be satisfied by varying the supply air temperature. The supply air temperature may be varied by any of several means.

A second type of mixing box is a variable air volume, single duct control unit. This type of mixing box satisfies the cooling load of a room by varying the volumetric flow rate while the supply air temperature is kept constant.

To obtain certification for supply and return air mixing boxes, ADC requires the manufacturers to perform the following tests:-

1) Air flow rate versus static pressure drop (internal damper is fully open) and size.
2) Sound tests versus static pressure drop, air flow rate and size (internal damper is controlling flow rates).

For these tests, the pressure drop is assumed to be a function of air flow rate and size only. The sound power level is a function of air flow rate, size and pressure drop. A summary of these relationships is as follows:

FOR SUPPLY AND RETURN AIR MIXING BOXES

DP = function(CFM , SIZE)

SOUND = function(CFM , SIZE , DP)

where,

CFM is the air volumetric flow rate.

DP is the pressure drop.

CHAPTER 3

3.1 PREVIEW

To obtain certification from the Air Diffusion Council, the manufacturers must submit data sets tested which conform to the ADC 1062 R4 [1]. The test code requires manufacturers to run several standard experiments on their devices. These tests include:-

* Company meter calibration.
* Static pressure drops and total pressure drop versus air flow rates.
* Sound power level measurements.
* Isothermal throw -velocity measurements.
* Area factor measurements.

The tests administered depends on the nature of the device. For example, in the case of grilles, registers and diffusers, the pressure drop test, the isothermal throw-velocity test, the sound test and the area factor test must be performed. On the other hand, for mixing boxes, the pressure drop measurements and sound test measurements are sufficient. Each of these tests will be discussed in detail in this chapter.

3.2 COMPANY METER CALIBRATION

To obtain certification for the product performance data, the manufacturers are required to submit to the ADC various test forms, graphs and results of their testing. The ADC will verify the validity and correctness of this data. This permits the company to state in their catalogs that the performance data presented are "ADC Certified".

Since the manufacturers and ADC use different equipment for air flow measurements, it is important to have a test standard which forces agreement on the minimum number of data sets acquired. To ensure that the data sets are within allowable limits, the manufacturers are required to calibrate their measuring equipment against ADC's equipment.

Flow meters are used to determine the volumetric air flow rate through them by measuring the pressure drop between the air inlet and air outlet. To calibrate the company flow meter, it is placed in series with the ADC standard meter. The standard ADC flow meter has a calibration curve of the form:

$$Q = A * (DP)^{B} \quad \text{........(3.2.1)}$$

where,

Q is the volumetric air flow rate at standard density

(0.075 lbm/cu.ft) in cubic feet per minute (CFM).

DP is the pressure drop across the flow meter.

A, B are calibration constants for the particular flow meter.

Basically, the calibration of the company flow meter consists of two steps. They are :

(I) Measuring the air flow rates through the ADC meter and correcting these measurements to laboratory conditions.

(II) Measuring the air flow rates through the company meter at laboratory conditions and converting them to standard conditions.

Since the calibration constants and graphs for the ADC flow meter are presented at standard conditions, it is necessary to adjust the measurements to obtain the true air flow rates at laboratory conditions. The reverse is also true for the company flow meter. The correction procedures are described in detail in the ADC 1062R3 [1].

After the experiment, a set of data relating "standard" air flow rates and pressure drops for the company meter would be available. Since Equation 3.2.1 applies to the company meter as well, the air flow rate is then a function of pressure drop only. That is :

$$Q = A1 * (DP)^{B1} \quad \ldots\ldots\ldots\ldots\ldots (3.2.2)$$

The calibration constants A1 and B1 for the company meter can be determined readily using a linear-logarithmic curve fitting technique. The ADC Air Flow Calibration Report Form is shown in Figure 3.2.1.

By implementing the above procedure in a computer program, the data processing speed is dramatically improved. Since the experimental data is fed to the computer interactively through a simplified process, there is less probability for error. The computer program also produces the standardized report forms and graphs automatically.

Since it is possible to complete the calibration process in a short time and display the calibration graphs almost instantaneously on the computer screen, the experimenters can check their work quickly and decide if the data sets are within acceptable limits. As the testing information can be stored and retrieved readily, the report forms and graphs can be reproduced at any convenient moment.

After the company meter is calibrated against the ADC flow meter, it is ready to take air flow measurements for testing of the company product.

ADC AIR FLOW CALIBRATION SHEET NO.____FORM NO. ADC 1.0/1

MANUFACTURER__________ OBSERVER__________ AMBIENT TEMPERATURE__________ BARO________ DATE________

ADC METER__________ | COMPANY METER__________

RUN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	ΔP_1	P_{s1}		PASS.	TEMP.		e_1	Ratio	Q.075	Q_1	ΔP_2	P_{s2}		PASS	TEMP.		e_2	e_1/e_2	Q_2	e_s/e_2	ΔP_{2SD}
			(2) .0736	(3)+P_B	D.B.	W.B.	From Buffalo Chart	$\sqrt{\frac{.075}{(7)}}$	@ ΔP_1	(8)×(9)			(12)÷.0736	(13)+P_B	D.B.	W.B.	From Buffalo Chart	(7)/(17)	(10)×(18)	.075/(17)	(11)×(20)
	"H_2O	"H_2O	"Hg	"Hg	°F	°F	#/FT^3		CFM	CFM	"H_2O	"H_2O	"Hg	"Hg	°F	°F	#/FT^3		CFM		"H_2O

PLOT COL. 19 vs 21

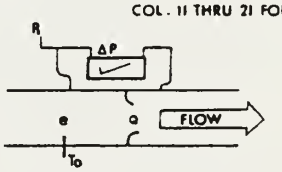
COL. 1 THRU 10 FOR ADC METER

COL. 11 THRU 21 FOR COMPANY METER

REFERENCE DENSITY = .075 #/FT.^{3}

$Q_{.075}$ FROM CALIBRATED CHART.

MOIST AIR DENSITY FROM BUFFALO FORGE FAN ENGINEERING HANDBOOK.



CONNECTIONS SHOWN FOR ADC OR COMPANY METER

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Figure 3.2.1 The ADC Air Flow Calibration Form.

3.3 DEVICE AIR FLOW MEASUREMENTS

Air diffusers and mixing boxes are an integrated part of HVAC systems. Designers use these devices to control and manipulate the rates of air flow into a ventilated space, so that its "room" conditions are suitable for human occupancy. Since "off the shelf" types of diffusers and mixing boxes are readily available from the market, the designer can simply choose the type of device that best fits his design goals. To select a device for use in a HVAC system, the designer has to know its performance characteristics. Therefore, it is important for the manufacturers to carry out tests on the products to report their performance data.

After the calibration of the company meter, the manufacturers can begin the air flow measurement testing. The procedures are described in detail in ADC 1062 R4 [1]. In this thesis, both diffuser and mixing box will be referred to as the "terminal device".

To obtain measurements of pressure drops for different air flow rates for a terminal device, the company flow meter is connected in series with the device. The volumetric air flow rates through the experimental setup can be determined by measuring the pressure drop across the flow meter. For a certain pressure drop, the air flow rate can be read from the company flow meter calibration curve, or can be calculated from the equation:

$$Q = A1 * (DP)^{B1} \ldots\ldots\ldots\ldots (3.3.1)$$

where,

Q is the volumetric air flow rate at standard density (0.075 lbm/cu.ft) in cubic feet per minute (CFM).

DP is the pressure drop across the flow meter in inches of water.

A1, B1 are calibration constants for the company flow meter.

For both the company flow meter and terminal device, the volumetric air flow rate is a function of pressure drop only (for a certain size). By measuring the pressure drops across the equipment, the air flow rates through the devices can be determined from equation 3.3.1, or can be determined from the company meter calibration curve.

The data collection procedure for air flow measurements is very similar to that of the company meter calibration. It consists of two steps:

(I) Measuring the air flow rates through the company meter and correcting these measurements to laboratory conditions. This is also the air flow rate through the terminal device.

(II) Obtaining the air flow rate through the terminal device as a function of pressure drop at laboratory conditions and adjusting them to standard conditions.

After testing, the data sets obtained at standard conditions can be used to determine the relationship between air flow rates and pressure drops. The data sets have the following relationship:

$$Q = A * (DP)^{B} \quad \ldots\ldots\ldots\ldots (3.3.2)$$

where,

Q is the air flow rate through the terminal device.

DP is the pressure drop

A, B are numeric constants.

The experimental data set can be used to plot the performance characteristic curve for the particular device, or a logarithmic curve fitting technique can be used to obtain the constants A and B. The ADC Air Flow Measurement Report Form is shown in Figure 3.3.1.

The number of data sets required to determine the relationship between air flow rates and pressure drops depends on how well the data fits the description of Equation 3.3.2. As laboratory testings are costly, a small sample of data sets are usually taken and analyzed. If the data sets turn out to be unsatisfactory, that is, if the data sets do not match the description of Equation 3.3.2, more tests would have to be performed, or data error has to be eliminated.

The data collection and analysis procedure can be implemented into a computer program. Computer analysis of the data is not only faster but also more efficient. Since it is possible to observe the results in a relatively short time, the experimenter can decide much more quickly if the number of data sets are sufficient. Also, since the report forms and graphs can be created automatically through a computer, the experimenter will save both time and effort for further decision making.

ADC AIR FLOW MEASUREMENT SHEET NO. ________ FORM NO. 1.0/2

Manufacturer ______________________ Observer ______________ Ambient Temp. __________ Baro. __________ Date ______________

Company Meter ______________________________________ | Terminal Device ______________________________________

	1	2	3*	4	5	6	7	8	9	10	11	12*	13	14	15	16	17	18	19	20
	ΔP_1	P_{s_1}		Pabs.	TEMP.		ρ_1	RATIO	Q.075	Q_1	ΔP_2		Pabs.	TEMP.		ρ_2	ρ_1/ρ_2	Q_2	ρ_2/ρ_3	ΔP_{TSD}
RUN			(2).0734	(3) + P_b	D.B.	W.B.	FROM BUFFALO CHART †	$\sqrt{.075/(7)}$	$\bullet\Delta P_1$	(8) x (9)		(11) x .0734	(12)+P_b	D.B.	W.B.	FROM CHART	(7)/(16)	(10)x(17)	.075/(16)	(11)x(19)
	"H_2O	"H_2O	"Hg	"Hg	°F	°F	#/FT.³		C.F.M.	C.F.M.	"H_2O		"Hg	°F	°F	#/FT.³		C.F.M.		"H_2O

* CORRECTION NOT REQUIRED WHEN P_s OR ΔP_2 < 2.5 W.G.

COL. 16 MAY BE CONSIDERED EQUAL TO COL. 7 WHEN { $T_{DB_2} = T_{DB_1} \pm 5°F$; $P_2 = P_{s_1} \pm 2.5$ "W.G. }

COL. 1 THRU 10 FOR METER

REFERENCE DENSITY = .075 #/FT.³

Q .075 FROM CALIBRATION CHART.

† MOIST AIR DENSITY FROM BUFFALO FORGE CO. FAN ENGINEERING HANDBOOK.

COL. 11 THRU 20 FOR TERMINAL DEVICE

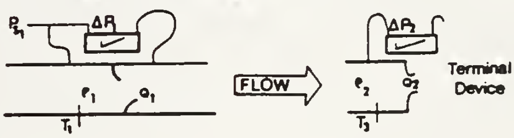

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Figure 3.3.1 The ADC Air Flow Measurement Form.

3.4 SOUND TESTS FOR EQUIPMENT

In the design, installation and use of HVAC systems, it is inadvisable to exclude the effects of noise on the occupants. The acceptable noise levels will vary, depending mainly on the type of structure where the system would be installed. For example, low level of background noise is essential for conference rooms, auditoriums and recording studios, whereas, in open-plan offices and music practice rooms, a much higher background noise level can be tolerated. Since diffusers and mixing boxes generate noise as a result of the air flow and pressure drop, it is important for the designer to consider the device's noise output capability and determine whether it is appropriate for the application.

To help the designer choose the appropriate devices for the HVAC system, the manufacturers are required to perform sound tests on their products. Sound is a form of energy caused by variation in pressure, stress, particle displacement and velocity [6]. It is usually measured in terms of decibels (db), and is reported as the sound power level.

Sound power level can not be determined directly. The most common method of determination for sound power level is to use the " Substitution Technique ". For this method, only sound pressure measurements are used. Then the sound power level is evaluated with reference to the known sound power level produced by an ILG fan. The ILG fan is equipment manufactured by ILG Industries, Inc and is a device which has a know sound power level. The ILG fan serves as a standard device for comparing sound power level produced by different equipment. The method of measuring sound power level is described in detail in the ASHRAE standards 36-72 [6], ISO 3741 [5] and ISO 5135 [4]. In the laboratory, the sound pressure level is measured by a microphone and is reported in units of decibels or microbars.

The parameters measured in the laboratory for the sound tests are the background noise, the ILG data, and the actual sound pressure data corresponding to various sizes, air flow rates and pressure drops for the tested device. These data are measured in the same room.

Before the actual sound tests are run, the background and the ILG sound pressure levels are recorded for each of the seven frequency bands of interest (BAND 2-8). An octave band is a frequency band with an upper frequency limit that is twice the lower band frequency limit. For testing of diffusers and mixing boxes, band one is usually omitted.

The experimental sound pressure level measurements (Lp for the tested device) are the next set of data taken. The actual sound power level (Lw) for each of the seven bands corresponding to a specific size, air flow rate and pressure drop is given by:

$$Lw = (Lp) - (BKGND\ Lp) + R.A. \quad ....(\ 3.4.1\ )$$

where,

BKGND Lp is the background correction.

ILG Lp is the measured reference device sound pressure level.

Lp is the sound pressure level measured for the device being tested.

Lw is the sound power level of the device after correction from pressure level.

R.A. is the difference between BKGND Lp and ILG Lp. It is dependent upon the absorption characteristics of the room in which the data are taken.

To correlate the sound power level of a device to the actual loudness to the human ear, it is evaluated in terms of the Noise Criteria (NC). The NC values for different bands are based on experimental work done many years ago and are supposed to represent noise levels of "equal loudness" to the human ear. The Noise Criteria of diffusers and mixing boxes has to be taken into account in a properly designed HVAC system.

The Noise Criteria (NC) Curves, as shown in Fig.3.4.1, have been widely used for many years. A NC curve is a curve connecting the sound pressure measurements (spl) for different bands which have the same NC value. For example, the NC-35 curve indicates that in band one, the related spl is 61; in band two, the spl is 53; etc. These curves are presented to show the variation of sound pressure level for various NC corresponding to different octave bands. The octave band center frequencies can be found in ASHRAE Fundamentals [6]. The NC curves are used for specifying the design limits that the octave-band pressure level of a noise source must not exceed to attain a level of occupant acceptance. For example, the NC-35 curve is usually used as a upper design limit for offices. If none of the devices' band pressure level exceed the NC-35 curve, the design is considered satisfactory.

After the experiment, the experimenter will have a set of sound power level data corresponding to each of the seven bands for each air flow rate. By plotting these data on the NC graph, the Noise Criteria of the device corresponding to various air flow rates, sizes and pressure drops can be found. Samples of the Noise Criteria graphs and the sound test report form are shown in Fig.3.4.2.

By grouping the data into different bands, it is possible to predict the relationship between air flow rates, pressure drops, sizes and noise criteria. The following equations describe this relationship:

For an air diffuser,

$$NC = A \log(Q) + B \log(An) + C \quad \ldots\ldots\ldots\ldots\ldots (3.4.2)$$

For a mixing box

$$NC = A \log(Q) + B \log(An) + D \log(DP) + C \quad \ldots (3.4.3)$$

where,

NC is the Noise Criteria for the device.

Q is the air flow rate in cubic feet per minute (CFM).

DP is the pressure drop in inches of water (inH_2O).

An is the nominal flow area for diffusers or mixing boxes in square feet (ft^2)

A, B, C and D are numeric constants.

There are no theoretical derivations for these equations, but previous experimental works done [10] in this area shows that these relationships work reasonably well for the test data of air diffusers and mixing boxes. With a suitably large number of data sets, it is possible to determine the curve fitting constants by a multiple regression analysis. The details for using this regression analysis is discussed in Chapter four and Chapther 5.

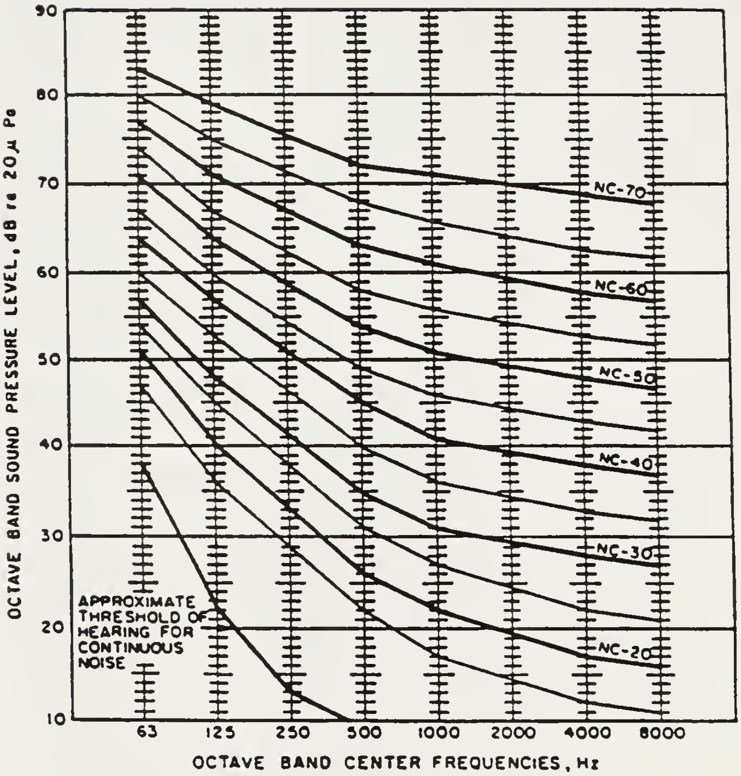


Figure 3.4.1 NC (Noise Criteria) Curves for Specifing the Design Level in Terms of the Maximum Permissible Sound Pressure Level for Each Frequency Band. Reprinted by permission from the ASHRAE Handbook --1985 Fundamentals Volume.

ADC STANDARD TEST REPORT FORM NO. ADC 14.2
SOUND TEST DATA

MFG. ______________________ OUTLET TYPE & SIZE ______________________ DATE ______________

OBSERVER ______________________

MICROPHONE ______________________ SOUND METER ______________________

CALIBRATOR ______________________ ANALYZER ______________________

RUN NO.	ΔP 25D	CFM Q_2		SCALE A	B	C	2 75 150	3 150 300	4 300 600	5 600 1200	6 1200 2400	7 2400 4800	8 4800 9600	NOTES
			BKGND L_p											
			ILG L_w				81.0	81.0	81.0	81.0	81.0	79.0	78.0	
			ILG L_p Mean											
			R.A. (Diff.)											
			L_p − dbc mean											
			− BKGND. CORR.											
			+ RA											
			L_w											
			L_p − dbc mean											
			− BKGND. CORR.											
			+ RA											
			L_w											
			L_p − dbc mean											
			− BKGND. CORR.											
			+ RA											
			L_w											
			L_p − dbc mean											
			− BKGND. CORR.											
			+ RA											
			L_w											

Supply Air Flow Form ADC III. 1.0/63-2 covering each run.

6/72

Figure.3.4.2. The ADC Sound Test Report Form.

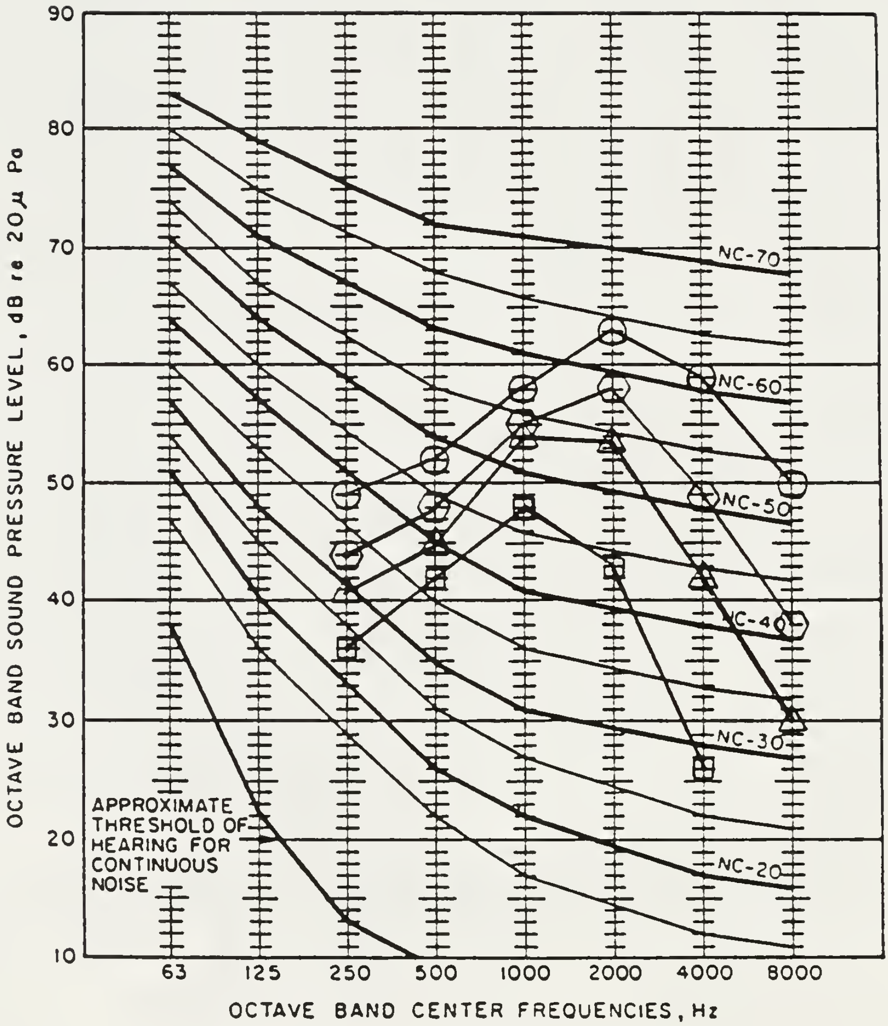


Figure 3.4.3 Example of NC graphs with experimental data sets.

3.5 ISOTHERMAL THROW-VELOCITY MEASUREMENTS

When conditioned air is delivered to a room, the air velocity at the diffuser is usually too high, and the air temperature is usually too high or too low to be comfortable to the occupants. To attain a desirable environment, it is necessary to decelerate the air, mix it with room air and distribute it evenly. Numerous studies have been performed to determine the best outlet conditions required to obtain an acceptable environment.

Studies [6] show that a majority of the occupants in an office building feel comfortable if the effective draft temperature (Θ) of the room air is kept between -3 and +2 deg F., and the air velocity kept under 70 fpm.

The effective draft temperature is a term used to describe the temperature difference that is comfortable for the human body. The effective draft temperature combines the effects of temperature difference and air velocity into a single "effective" temperature, and has been used for many comfort studies. The effective draft temperature is calculated as follow:

$$\Theta = (t_x - t_c) - a (V_x - b) \qquad (3.5.1)$$

where,

t_x is the local temperature, F°

t_c is the room average temperature, F°

V_x is the local velocity, fpm

a, b are constants with values of 0.07 and 30 repectively.

To achieve desirable climatic conditions for a room, the designer uses grilles and diffusers to slow down, mix and direct the air flow to different parts of the room. Since these devices control the comfort conditions for the occupants, it is important for the designer to know the performance characteristics of these devices before using them in an HVAC system. The manufacturers have to perform different tests on their products to report these performance data.

In the ASHRAE Handbook [6], the Air Diffusion Performance Index (ADPI) is used as an index to indicate the "goodness" of air diffusion in an occupied space. The ADPI developed by Miller and Nevins defines the percentage of locations in a room that meets the comfort conditions for the effective draft temperature and air velocity limits noted above. If the ADPI for a room is maximized (approaching 100%), it means that the most desirable condition has been achieved.

To study the relationship between air velocities and the throw distances, the ADC Throw-velocity tests are used. The throw of a diffuser is defined as the distance from the outlet device to a point in the air stream where the maximum velocity has been reduced to a selected terminal velocity. The terminal velocity commonly selected is 50 feet per minute, except for ceiling slot diffuser, for which the terminal velocity is chosen to be 100 feet per minute. The throw of a diffuser is a parameter used by designers to ensure a comfortable (high ADPI) environment. Figure 3.5.3 shows the throw of an air diffuser.

The relationship between terminal velocity and throw will depend on the position within the air stream. According to jet theory, these relationships can basically be classified in to 4 zones as described in the ASHRAE Fundamentals [4]:

Zone I is a zone in which the maximum centerline velocity of the air stream remains unchanged along the jet axis.

Zone II is a transitional zone in which the maximum air stream velocity along the jet axis is inversely proportional to the square root of the distance from the outlet.

Zone III is a zone in which the maximum air stream velocity along the jet axis is inversely proportional to the distance from the outlet.

Zone IV is a terminal zone in which the air stream velocity along the jet axis is inversely proportional to the square of the distance from the outlet.

These relationships are as shown in Figure 3.5.3. Zone III, in which the air flow is fully developed into turbulent flow, is the most significant zone because this is the longest zone and which extends into the human occupied space. Most of the performance data taken will be in this zone. In the ADC Throw-Terminal velocity graph shown in Fig 3.5.2, only zones II-IV are considered.

Mathematically, the relationship between throw and velocity for zone II-IV can be written as follows:-

For zone II, $Vx = A * (Tx)^{-\frac{1}{2}}$

For zone III, $Vx = A * (Tx)^{-1}$

For zone IV, $Vx = A * (Tx)^{-2}$

where,

Vx is the air stream velocity along the jet axis.

T_x is the throw distance.

A is a numeric constant.

These relationships, when plotted on a logarithmic scale, should be three straight lines with slopes of -1/2, -1 and -2. Therefore, the three different slope lines on the ADC Throw-velocity graph describe the theoretical relationship between air steam velocity and distance from the outlet for zone II, III and IV respectively. The data are transformed into a dimensionless form by dividing Vx by Vk, and dividing Tx by $\sqrt{Ak}$, where Vk is the discharge velocity of the outlet and Ak is an empirical area factor.

To determine how well the throw velocity characteristics of a diffuser fit the above relationship, the manufacturers need to perform the throw- terminal velocity tests as described in ADC 1062: GRD-84 [3]. Then, by plotting Vt/Vk against $T/\sqrt{Ak}$ on the ADC graph, the manufacturers can determine whether the performance data of their products fits the theoretical description. If the data fits the description well, further data may be predicted from the same graph or calculated using the same relationship. The ADC Throw Velocity Report Form is shown in Figure 3.5.2.

For the manufacturer to obtain ADC certification for their throw-velocity data, the testing has to be carried out under isothermal conditions. Throw data that are not ADC certified may or may not be performed under isothermal conditions, depending on the manufacturer.

Manual preparations of the throw-velocity graphs and report forms would again involve a tedious amount of calculation and graph plotting. By implementing the required analysis procedure into a computer program, the experimenters can confirm their results much faster. The report form and the graphs can be easily reproduced by a computer program.

FIG. 2 SAMPLE THROW-TERMINAL VELOCITY GRAPH FOR A PRODUCT SERIES

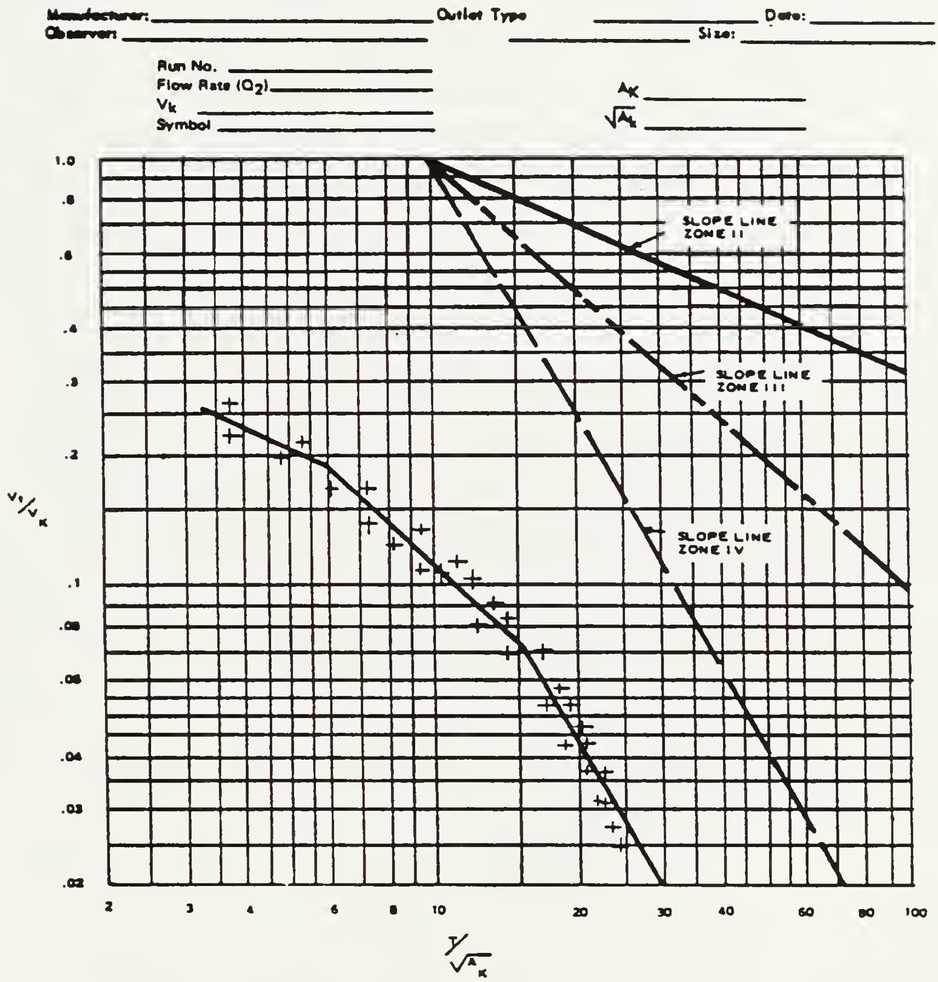
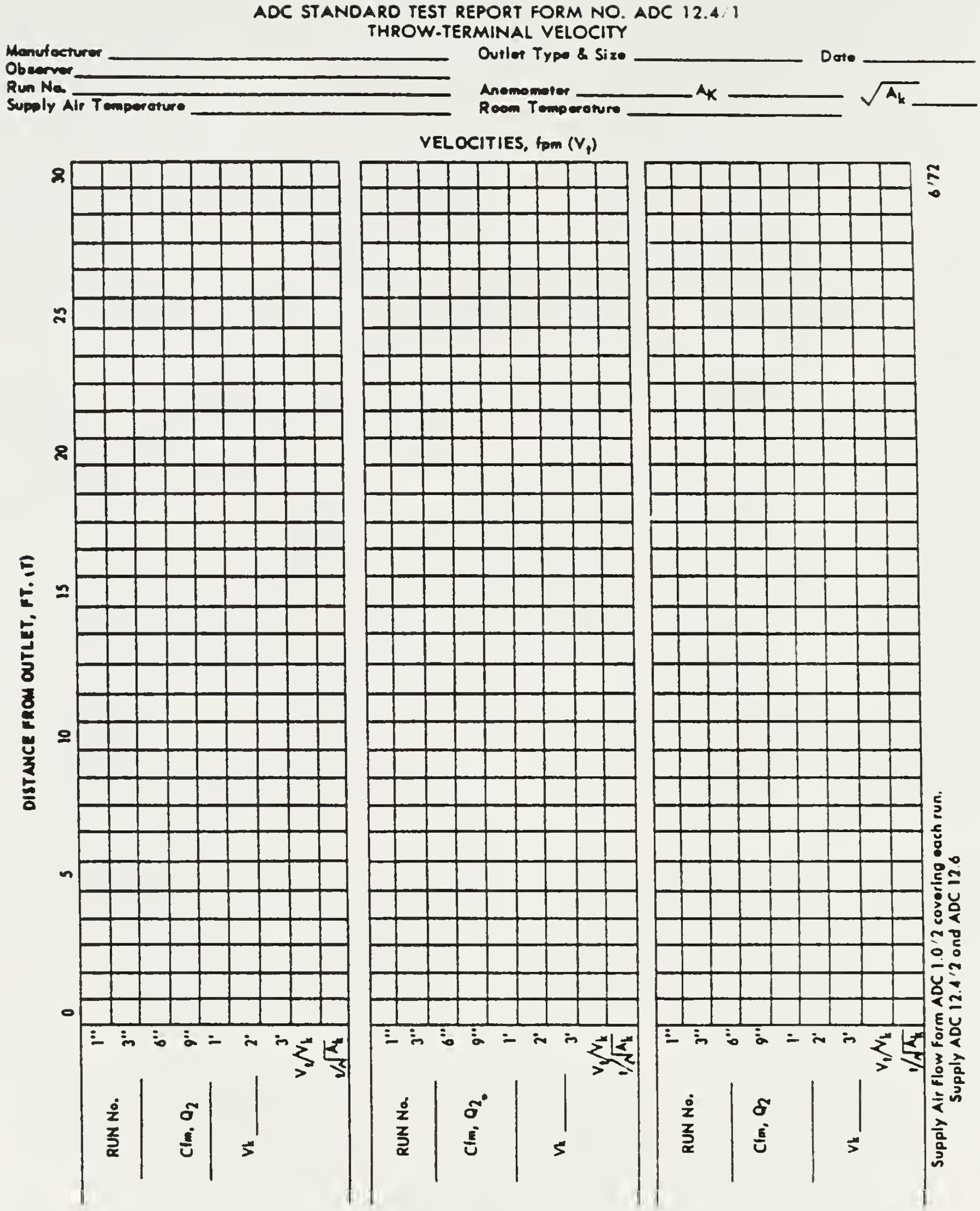


Figure.3.5.1 ADC Throw Velocity Graphs.



ADC STANDARD TEST REPORT FORM NO. ADC 12.4/1
THROW-TERMINAL VELOCITY

Manufacturer ______ Outlet Type & Size ______ Date ______
Observer ______
Run No. ______ Anemometer ______ A_K ______ $\sqrt{A_k}$ ______
Supply Air Temperature ______ Room Temperature ______

VELOCITIES, fpm (V_t)

DISTANCE FROM OUTLET, FT. (T)

0 5 10 15 20 25 30

1" 3" 6" 9" 1' 2' 3' V_t/V_k $T/\sqrt{A_k}$

RUN No. Cfm, Q_2 Vk ______

6'72

Supply Air Flow Form ADC 1.0/2 covering each run.
Supply ADC 12.4/2 and ADC 12.6

Figure 3.5.2 The ADC Throw Velocity Report Form.

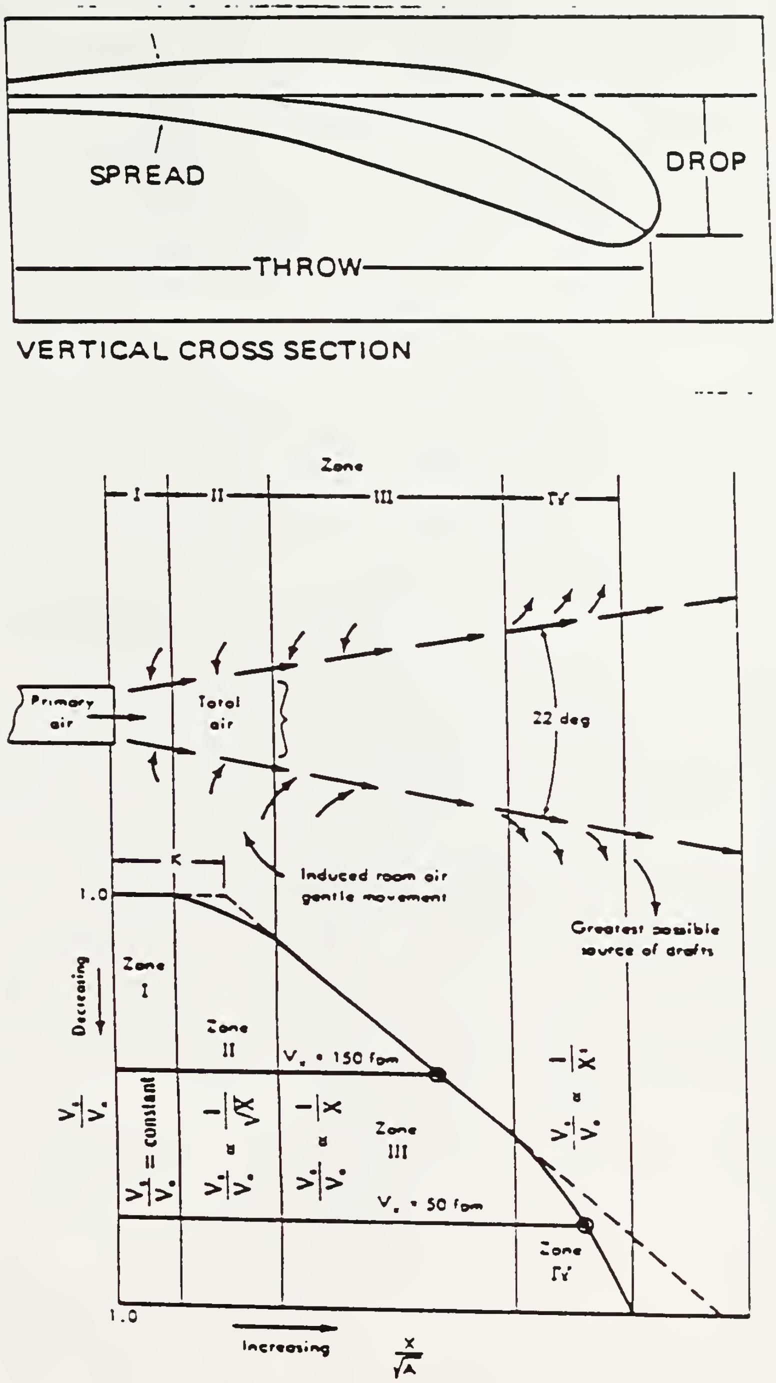


Figure 3.5.3 The Throw-Velocity Relationsionships.

3.6 AREA FACTOR CALCULATIONS

The area factor of a diffuser is a charateristic of the device being tested and the measuring instruments. As defined in both the ADC test code 1062 GRD-84 [3] and 1062R4 [1], the area factor of a device is an empirical factor which may be used to determine the outlet air flow rate of a diffuser as actually installed. This area factor (Ak), when multiplied by an average velocity (Vk) measured in a prescribed way (described in ADC 1062R4) with a prescribed instrument, will give the air outlet volumetric flow rate (CFM = Ak * Vk). The procedures for these area factor tests are described in detail in the ADC test codes and will not be discussed here.

The area factor is a characteristic of the type of diffuser tested and the type of measuring device used. To ensure that the experimental data are consistent, the ADC has chosen the Alnor Velometer, Model 3002-G or Model 6000P with the 6070 probe as the standard measuring instrument for the area factor tests. The manufacturers also need to prescribe the technique of measurements (probe position, angle, etc.). in their test reports. The ADC Area Factor Report Form is shown in Figure 3.6.1.

Experimentally, the area factor is expected to be a function of size only, and should be independent of the air flow rate through the device. The area factor is also indirectly related to the sound power level produced by the diffuser. The ADC area factor test is used to verify these relationships.

The procedure for the Area Factor experiment is easily implemented into a computer program. The computer checks if the area factor data are within the tolerances set by the ADC. The program will prompt the user to repeat the experiments if the data exceeds the allowable tolerances. The computer program also produces the related forms and graphs automatically.

ADC STANDARD TEST REPORT FORM NO. ADC 11.0

AREA FACTOR A_K

FOR AIR OUTLETS AND AIR INLETS

MANUFACTURER:	OUTLET/INLET TYPE & SIZE:	DATE:
OBSERVER:	NECK AREA:	
FLOW METER EQUIPMENT:	ANEMOMETER TYPE & SERIAL NUMBER:	

RUN NO.	READINGS							CALCULATIONS				
	ΔP_1 (FLOW METER)	ANEMOMETER — (V_K)					ΔP_{2SD} STATIC PRESSURE	Q_2 FLOW CFM	NECK VEL.	NECK V.P.	TOTAL PRESS.	AREA FACTOR (A_K)
		1	2	3	4	AVE.						
											AVERAGE	

IN THE SPACE TO THE RIGHT, MAKE A DIMENSIONED SKETCH OF PLAN AND ELEVATION OF THE RELATIVE LOCATIONS OF UNIT AND PROBE.

Figure 3.6.1 The ADC Area Factor Report Form.

CHAPTER 4

4.0 REGRESSION ANALYSIS FOR DATA

To produce a catalog of performance data for diffusers and mixing boxes, the manufacturer will have to present a lot of information. The best and most accurate way for the manufacturer to publish catalog data is to provide results of actual testing on their devices. However, since testing is expensive and time consuming, it is impossible to perform tests on each and every products over all ranges of use. Therefore, manufacturers have to find an alternate way to predict the performance data of their products.

Previous experimental work [9] has shown that it is possible to correlate the experimental data for diffusers and mixing boxes by means of mathematical models. The manufacturer must collect test data and try to fit this model. If the experimental data set fits the model reasonably well, the manufacturer can then use this model to predict the performance data of his products.

To determine the coefficients of fit for the mathematical model, it is necessary to do a statistical analysis on the data sets. In this case, a multiple linear regression technique is used. The number of data sets and laboratory tests required depends on how well the data fits the model.

If the data sets do not fit the mathematical model well, more data sets need to be collected to eliminate the possibility of error. If the data sets still do not correlate well, it may be necessary to select a different mathematical model to fit the data sets, or the actual test data over the full range of variables may have to be reported.

The multiple regression analysis procedure is quite complicated and tedious to carry out manually. It involves the formulation of a regression matrix, finding the inverse matrix, and calculating various parameters to determine the "goodness of fit" for the data sets. This process is sometimes long and repetitive, but is well formulated and can be followed easily.

Before computers became readily available, the regression analysis was usually performed using graphical techniques. To correlate the data sets, the experimenter has to plot a series of graphs, and try to determine the "best fit" lines visually. Although the graphical technique is easily applied manually, it requires a lot of time, effort and good human judgment.

Since computers can perform a large number of calculations in a relatively short time, it is much more efficient to implement the regression procedure in a computer program and let the computer do all the "number crunching". The experimenter can then focus more time on analyzing the results and decision making. The graphical analysis method will be discussed briefly in the following section. The computer method will be discussed in Chapter 5.

4.1 GRAPHICAL METHOD

Since multiple regression procedures are too tedious to perform manually, the data correlation process has conventionally been done by graphical techniques. The graphical method involves breaking down complicated regression procedures into several manageable parts. For example, if a set of data relating air flow rate (CFM), pressure drop (DP) and diameter (D) is to be analyzed, they would first have to be plotted on a graph as shown in Fig. 4.1.1 Note that there are two independent variables (DP & D) and one dependent variable (CFM). In Fig. 4.1.1, the pressure drop is plotted against air flow rate for various diameters. By drawing the "best fit" parallel lines through the data set with the same size, a series of parallel lines are obtained.

Assume that data sets for sizes 4", 6" and 8" are available, but that catalog data for sizes 5" and 7" are also needed. The following graphical technique is used to obtain the performance data for 5" and 7" devices.

First, a suitable parameter which relates two of the independent variables (CFM and D) is selected. In this case the parameter is chosen to be the velocity (1000 fpm). The 1000 fpm velocity is chosen arbitrarily, but is a suitable choice. The air flow rate of the device for each size can be calculated readily by multiplying the velocity with the device's area. These data points, having area and air flow rate as variables, are plotted on the same graph. The "best line" through these new data points is then constructed. This line is then the "1000 fpm" line. For the 7" device, the corresponding air flow rate for a velocity of 1000 fpm can be calculated and this provides a reference point (P) on the velocity line. Since the "size" lines run parallel to each other, the 7" line has the same slope as the other lines and passes through the reference point (P). The line for the 5" size is plotted in the same fashion, and all data for the catalog are read from these "best fit" lines.

This graphical technique is really a "sequential" multiple linear regression and requires much time and effort, and is not as accurate as a true multiple regression technique.

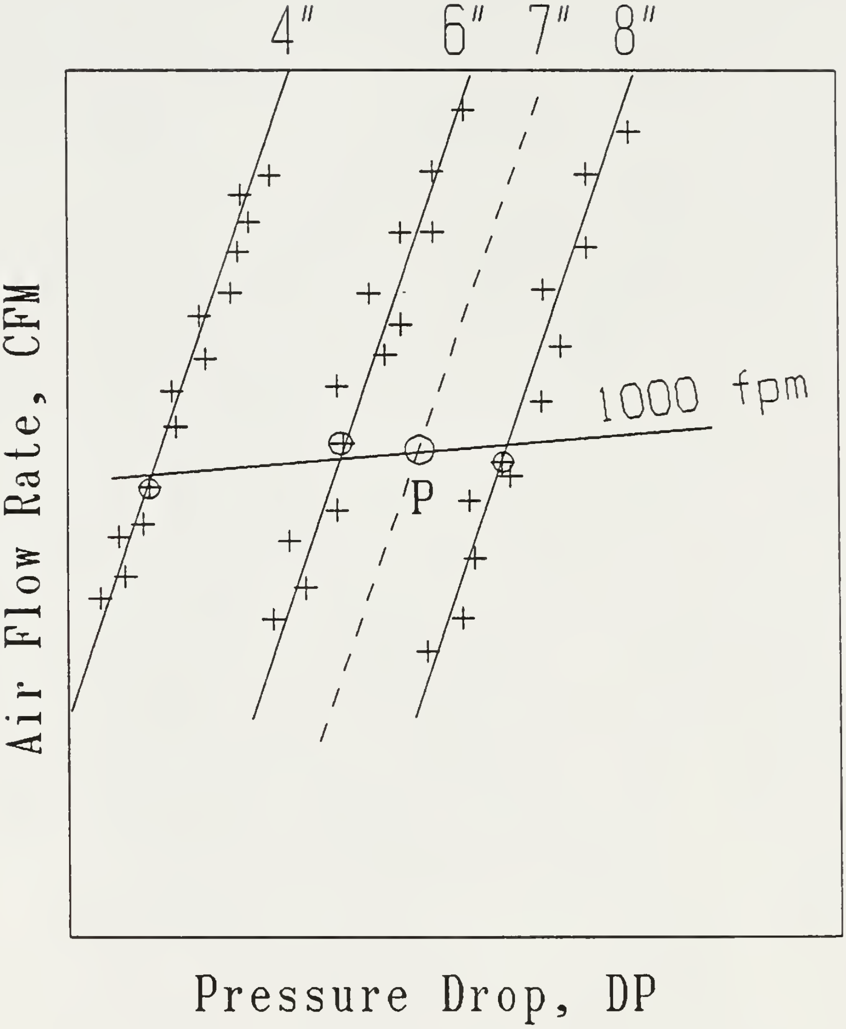


Figure 4.1.1 Example for the Graphical Regression Method.

CHAPTER 5

COMPUTER IMPLEMENTATION

The process of data collection and analysis for the various ADC tests is currently performed manually. However, since the procedures are well defined, they can be emulated by a computer program. Computer analysis of the data set is not only faster but also more efficient. Since it is possible to observe the results of data analysis in a relatively short time, the experimenters can actually observe immediately if the data sets fit the model well. They can also decide much more quickly if the number of data sets are sufficient. The computer programs can also generate the test forms and related graphs automatically. All this information can also be saved and retrieved for later use.

The computer operations on the company meter calibration test and device air flow measurement test are found in Appendices B.1 and B.2 respectively. The computer programs will prompt the user to input experimental data and then compute the calibration curve or air flow measurement graph on the screen almost instantaneously. The experimenters can check their work quickly to see if the data sets are within the allowable limits. If the data sets are good, the computer program will store the data set so that the standardized ADC forms and graphs can be reproduced at any convenient moment.

The computer operations for the Area Factor Test are found in Appendix B.3. The computer program will accept experimental data, check the tolerances, and calculate the area factor for the device. The related ADC test forms can also be easily generated.

The computer operations for generating the Throw-Velocity forms and graphs are found in Appendices B.4 and B.5. The computer programs will accept the experimental data, calculate the results and plot the Throw-Velocity curve on the screen. The user can then decide if the data sets can be described by the equations described in Chapter 3.5. If the results are satisfactory, the computer program will proceed to evaluate the fitting constants for the equations. The equations are used later to generate the catalog data.

The computer operations on the sound test is found in Appendix B.7. The computer program will accept experimental sound pressure data from the user, calculate the background correction factors, and checks if the data sets meet the tolerances set by ADC. If the results are satisfactory, the computer will convert the sound pressure level data into noise criteria, and plot them on an NC graph. The computer program can also be used to generate the respective ADC test forms and graphs.

The computer operations described in Appendices B.6, B.8 and B.10 are used to correlate the experimental data sets. As described in chapter 4, a graphical method is conventionally used to determine the relationships between various parameters. The graphical method, although easier to apply manually, is difficult to implement on a computer program. The graphical technique requires a lot of human judgment, and therefore there is much room for error. Furthermore, since the graphical regression procedure is done sequentially, it is less accurate and it is difficult to make alterations because it involves too much manual work.

The full scale mathematical multiple regression procedure, which takes into account the influence of all the independent variables simultaneously, is a better method of analysis. By employing the multiple regression procedure, a lot of other important statistical parameters can also be determined. Some of those parameters are the regression coefficient, confidence interval, etc. These parameters are very useful for the experimenters to determine how well the data fits the mathematical model. The computer can also present the data sets in graphical format for visual verification, and the residual error of estimate can also be calculated and plotted.

The multiple regression procedure can be found in many statistical text books. For the program developed in this thesis, the statistical formulae are adapted from statistic books by Allen L. Edwards [7] [8], and the results of using these formulae has been checked against a commercial statistical package.

If the relationships between the various parameters can be described by the mathematical models as described in Chapter 3, then the computer procedures found in Appendix B.9 can be used to generate the catalog data. The computer procedures can also be used as an "electronic catalog" to predict the performance data for any combinations of parameters for a device.

Appendix B of this thesis is a "Users Manual" for the computer programs developed in this thesis. It describes the computer program operations in detail, and includes various examples of the computer generated ADC forms and graphs.

CHAPTER 6

CONCLUSIONS & RECOMMENDATIONS

The first four chapters of this thesis describe the procedures and theories used for the experimental testing and data analysis of air diffusers and mixing boxes. A good understanding of the procedures and analysis is necessary for the development of efficient computer programs to emulate these processes.

In this thesis, a computer program has been developed to automate the data analysis process for the testing of air diffusers and mixing boxes. The program is designed to accept experimental data interactively from the user or read data from user created data files. The program will then complete the necessary calculations and produce the related ADC report forms and graphs on the screen. The computer program can also displays lists of temporary results, plots and figures. These intermediate results may be used interactively by the user to decide if the results are appropriate. If the results are satisfactory, the programs can be used to prepare hard copies of the results. Also included in the computer program is a multiple regression routine. The user may use this regression routine to determine the relationships between the data sets, instead of the conventional graphical method. If suitable relationships between the data sets are found, the computer program may be used to generate catalog data.

In conclusion, the program developed does an excellent job of reproducing the ADC test forms and graphs, accelerates the data analysis process and provides a convenient way for the user to determine the relationships between experimental data sets by the use of a regression routine. Once these relationships are determined, they can be used to generate the catalog of performance data for the diffusers and mixing boxes. Since the whole process (from experimental data to calculated catalog data) is much faster and involves a minimum of human effort, it is a convenient and labor saving tool to use during the testing and certification of diffusers and mixing boxes.

PROGRAM LIMITATIONS AND RECOMMENDATIONS FOR FURTHER STUDIES

To produce the catalog data, the computer program assumes that the data relating air flow rate, size and pressure drop can be represented by a certain set of mathematical equations. However, this assumption is not necessarily always true for all types of diffusers. For example, the throw distance for a ceiling slot diffuser may be a function of slot width and number of slots, but neither of these variables are included in the mathematical model. Further study would be needed to determine if it is possible to include these kind of relationships into the computer program.

The computer program developed is unable to recognize and eliminate bad data sets (data sets which do not fit the mathematical model used). For the case of one dependent variable and two independent variables, the computer program can present the data in graphical form and the user may be able to discover the bad data sets visually, and discard them manually. However, for analysis which involves more than two independent variables, there is no easy way to display the results. Data rejection then would have to be based on statistical means. Statistical limits like Chauvenet's criterion [7] can be used in a computer program and is worth further investigation.

The ADC has about 18 different standard test forms. In this thesis only eight test forms are discussed. Although some of these test forms require much manual effort (for example, ADC 12.4/2, Throw pattern diagram), many of them can be also be generated by computers.

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APPENDICES

A.1 GETTING STARTED

The computer programs in this thesis are developed using the MICROSOFT QUICKBASIC COMPILER version 4.0. The QuickBasic software is selected for the ease of programming and BASIC's good graphics capability. Should a syntax error occur during execution of the ADC program, the QuickBasic help menu will be a useful reference.

The computer programs require a CGA graphics adapter. It has been tested on a Hewlett Packard Vectra AT compatible with a CGA card and a monochrome monitor using MS DOS 3.20.

The computer programs use the B disk drive extensively for data input and output. If a B drive is not present, DOS will prompt the user to insert the B disk in drive A, and then proceed normally. The ADC programs also allow the user to change the default search path.

All the computer programs are executable files and can be invoked independently. To get instruction on the contents of a disk, run the batch file "STARTADC.BAT". This batch file is available on the all the main program disks. To execute the batch file, the user should type <STARTADC> to activate the program from DOS.

The user is prompted to respond from a menu most of the time. The screen display will pause automatically after an important output (tables, graphs, etc). The user simply hits the RETURN key or SPACE BAR to continue execution of the program.

The DOShell routine included in the ADC programs allow the user to issue any standard MS-DOS command. To use this option, the user needs to ensure that a copy of COMMAND.COM is made available to the computer. For users who run the ADC program on a hard drive, they need to supply the path where the COMMAND.COM file can be found.

A.2 STANDARD FORMAT

To provide better file management, the ADC program will automatically write the data files to a separate sub directeory on the B: drive using default file extensions. For example, files that are generated using 'MAIN1' will be grouped under the specification:

'B:\MA1DAT\filename.MA1',

Data files for 'MAIN2' will have the specification:

'B:\MA2DAT\filename.MA2'

To set up the data disk for the ADC program, the user can use the SETUPB.BAT batch file in the program disk to creat the default sub-directories automatically.

For the program instructions give in APPENDIX A2, the following notations are used:

BOLD FACE Indicates a key word or option.

< > A word or number enclosed in this bracket indicates that it is a user response. Usually, the user types it on the keyboard and hits the RETURN/ENTER key.

The contents in a box are a reproduction of the information shown on the computer monitor.

A.3 COMMON COMMANDS & ERRORS

The following commands are common through all the ADC programs:

QUIT / RETURN

The QUIT option allows the user to terminate the ADC program normally. The RETURN option however, will return the user to the previous menu. For example, if the user chooses the GET data option in the MAIN1 opening menu, he will go into the GET data sub-menu. If he wants to terminate the program, he has to first choose RETURN from the GET data sub-menu to get back to the opening menu, and then select the QUIT option to end the program.

DOShell

The DOShell option allows the user to check the files available on the data disk. Actually, the DOShell option allows the user to utilize any standard MS-DOS commands like DIR, COPY, CD, etc. The user has to type the word EXIT to return to the ADC program.

Although the ADC programs are designed carefully to avoid most common user errors, it is impossible to eliminate them completely. The following are the most common errors found:

FILE NOT FOUND

This indicates the user has supplied a file name that is not present on disk. Usually, this means that the user has input a wrong filename, or has misspelled the filename.

DIVSION BY ZERO

The statistical subroutine uses complicated matrix inversion techniques to derive the curve fitting constants. If a file with bad data is encountered this error may occur.

If an error forces the user to abandon the program, the user can simply restart the program again. The data files created should be still intact. However, a regular backup of the data disk is strongly recommended.

B.1 COMPANY METER CALIBRATION

MAIN1 is used for taking data necessary for the calibration of company flow meter. The program will complete the required calculations, generate the ADC forms, and plot the calibration curve. On execution of the program, the following menu is available:

```
This is the company meter calibration menu

        1) DOShell to check file
        2) QUIT this session
        3) GET data
        4) COMPany flow meter calibration
        5) PRINT data

Your Choice   ?
```

Opening Menu for MAIN1

These different options are described as follows:-

DOShell and QUIT

These options were explained earlier as in Appendix A.3.

GET data

The GET data option is used to obtain data sets for calibration of the company flow meter. This option can either accept experimental data directly, or extract the data set from data files on disk.

Within the GET data routine the following options are available:

Input **Preliminary** data

This option allow allows the user to record the preliminary data for the experiment. Information such as device type, device number, barometric pressure and room temperature can be saved to a data file for later use.

ADC & COMP meter measurements

This option is used to record the experimental data of pressure drop and temperature. After the experiment has been completed, the user will be prompted to save the experimental data to a disk file for later use.

READ data from disk

This option is used to extract experimental data from disk files. The procedure to extract data is explained in Example 1.

COMPany meter calibration

This option is used to complete the necessary calculations for the company meter calibration. The program also plots the calibration curves for the company meter and reports the calibration constants.

PRINT data

This option is used to print out the ADC test forms for the company meter calibration.

The program flow chart is shown in Figure B.1.1.

****

EXAMPLE 1

Example of how a data file may be generated.

1) Select the **GET** data menu. The program will prompt the user for the calibration constants for the ADC flow meter. Then the following menu will be available:-

```
        This is the get data Menu

          1) Input PREliminary data
          2) ADC & COMP meter measurements
          3) READ data from disk
          4) RETURN to calibration

        Your choice ?
```

Get data menu for MAIN1.

Select <1> to input the preliminary data for the device.

Select <2> to input experimental data. The program will prompt for the required items individually. After the data collection is completed, the program will return to the **GET** data menu.

Select <4> to return to the opening menu.

2) Select the **COMP**any flow meter calibration to begin calculations and to display the calibration graph on screen. After the program is done, the program will return to the opening menu.

3) Select the **PRINT** data option to print out the ADC report forms.

4) Use **QUIT** to terminate the program.

The program flow chart is shown in Figure B.1.1

Example of how data may be extracted from disk file.

1) Select the **GET** data option from the opening menu. The program will prompt for the calibration constants. For this example, enter A as <50.0> and B as <0.5> .

2) Select <3> from the **Get data** menu. The following menu will be available:-

```
This is the read data menu

     1) Use DOShell to check file
     2) RETURN to get data menu
     3) READ data for comp. meter calibration
     4) Read Preliminary data

Your choice  ?
```

Read data menu for MAIN1

Within this sub-menu;

Select <3> to read the data file. For this example enter <COMCALI1>.

Select <4> to read the preliminary data for the company meter. For this example, enter <PRELIUM1>.

Select <2> to return to the **GET** data menu.

Now, the program should display the Get data menu

Select <2> from the **GET** data menu to return to the opening menu.

3) Select the **COMP**any meter calibration option.

4) Select the **PRINT** data option to print out the data.

5) Use **QUIT** to terminate the program.

The sample output is shown in Figure B.1.2.

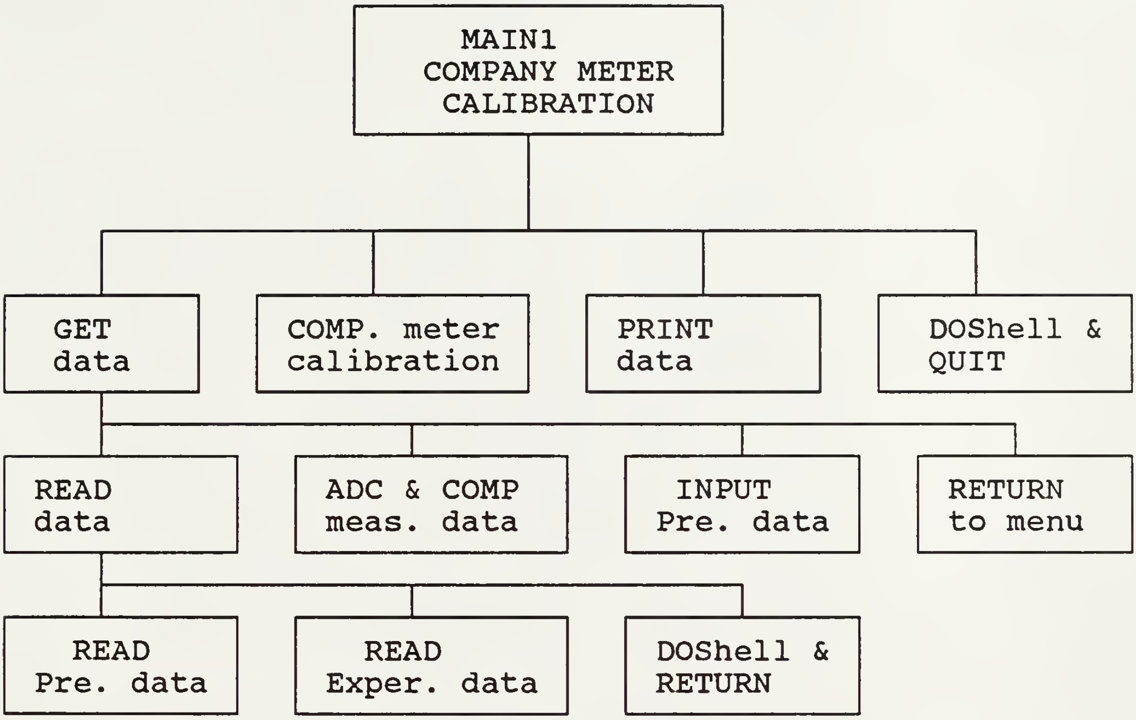

Figure B.1.1 Flow Chart For The ADC Company
Flow Meter Calibration program.

ADC AIR FLOW CALIBRATION SHEET NO: 1
FORM NO : ADC 1.0/1

ADC METER # 12 COMPANY METER # 12
MANUFACTURER : Tit
OBSERVER : KL JG
AMBIENT TEMP : 60 (°F)
BAROMETRIC PRESSURE : 14.7 (inHg)
DATE : 11-08-80
Norminal area : .545 ft²

REFERENCE DENSITY : 0.075 lbm/ft3
Q.075 FROM CALIBRATION CHART
AIR DENSITY FROM ASHRAE HANDBOOK

DATA ANALYSIS FOR THE ADC METER

RUN	dp1	ps1	-	Pabs	D.B.	W.B.	e1	RAT	Q.075	Q1
	(inH2O)			(inHg)	(F)	(F)			(CFM)	(CFM)
1	0.89	1.09	0.08	14.78	89.5	69.5	0.034	1.5	47.17	69.59
2	0.58	0.71	0.05	14.75	84.5	69.5	0.035	1.5	38.08	55.84
3	0.44	0.55	0.04	14.74	84.5	69.5	0.035	1.5	33.17	48.65
4	0.52	0.60	0.04	14.74	84.5	69.5	0.035	1.5	36.06	52.89

DATA ANALYSIS FOR THE COMPANY FLOW METER

RUN	dp2	ps2	-	Pabs	D.B.	W.B.	e2	e1/e2	Q2	es/e2	dp2sd
	(inH2O)			(inHg)	(F)	(F)			(CFM)		(inH2O)
1	0.89	1.09	0.08	14.78	89.5	69.5	0.034	1.00	69.59	2.18	1.94
2	0.58	0.71	0.05	14.75	84.5	69.5	0.035	1.00	55.84	2.15	1.25
3	0.44	0.55	0.04	14.74	84.5	69.5	0.035	1.00	48.65	2.15	0.95
4	0.52	0.60	0.04	14.74	84.5	69.5	0.035	1.00	52.89	2.15	1.12

Figure B.1.2 Sample ADC Air Flow Calibration Sheet.

B.2 AIR FLOW MEASUREMENTS

MAIN2 is used for taking air flow measurement data for the device. The program will complete the required calculations, generate the ADC forms, and plot the related graphs. The format of this program is very similar to MAIN1. On execution of the program, the following menu is available:

```
This is the air flow measurements menu

   1) DOShell to check file
   2) QUIT this session
   3) GET data
   4) COMPany/terminal device calculation
   5) PRINT data

Your Choice   ?
```

Opening Menu for MAIN2

The different options are described as follows:

DOShell and QUIT

These options are the same as explained earlier.

GET data

The **GET** data option is used to obtain the device air flow measurements data. This option can be used to input experimental data directly, or it can be used to extract data sets from data files created earlier from disk.

Within the GET data routine the following options are available:

Input **Preliminary** data

This option allow allows the user to record the preliminary data for the experiment. Information such as device type, device number, barometric pressure and room temperature can be saved to a data file for later use.

COMP & TER.DEVICE measurements

This option is used to record the experimental data of pressure drop and temperature. After the experiment has been completed, the user will be prompted to save the experimental data to a disk file for later use.

READ data from disk

This option is used to extract experimental data from disk files. The procedure to extract data is explained in Example 2.

COMPany/terminal device calculation

This option is used to complete the necessary calculations for the device air flow measurements. The program also displays the related graphs for the tested device and report its fitting constants.

PRINT data

This option is used to print out the ADC test forms for the device air flow measurements.

The program flow chart is shown in Figure B.2.1.

****

EXAMPLE 2

Example of how a data file may be generated.

1) Select the **GET** data menu. The program will prompt the user for the calibration constants for the company flow meter. Then the following menu is available:-

```
        This is the get data Menu

          1) Input PREliminary data
          2) COMP & TER.DEVICE measurements
          3) READ data from disk
          4) RETURN to calibration

        Your choice ?
```

Get data menu for MAIN2.

Select <1> to input the preliminary data for the device.

Select <2> to input experimental data. The program will prompt for the required items individually. After the data is completed, the program will return to the **GET** data menu.

Select <4> to return to the opening menu.

2) Select the **COMP**any flow meter calibration to begin calculations and display the related graphs. The program will prompt the user if he wishes to save the calculated data for later use. This data is used to perform a regression analysis later to determine the relationship between air flow rates, pressure drop and area. After the program is done, the program will return to the opening menu.

3) Select the **PRINT** data option to print out the ADC report forms.

4) Use **QUIT** to terminate the program.

Example of how data may be extracted from disk file.

1) Select the **GET** data option from the opening menu. The program will prompt for the calibration constants for the company flow meter. For this example, enter A as <50.0> and B as <0.5> .

2) Select <3> from the **Get data** menu. The following menu will be available:-

```
This is the read data menu

    1) Use DOShell to check file
    2) RETURN to get data menu
    3) READ data for air flow measurements
    4) Read PREliminary data

Your choice  ?
```

Read data menu for MAIN2

Within this sub-menu;

Select <3> to read the data file. For this example enter <TER1>.

Select <4> to read the preliminary data for the company meter. For this example, enter <PRETER1>.

Select <2> to return to the **GET** data menu.

Now, the program should display the Get data menu.

Select <2> from the **GET** data menu to return to the opening menu.

3) Select the **COMP**any meter calibration option. When the program prompts for the user to save the data, enter <n> for not saving the data set.

4) Select the **PRINT** data option to print out the data.

5) Use **QUIT** to terminate the program.

The sample output is shown in Figure B.2.2.

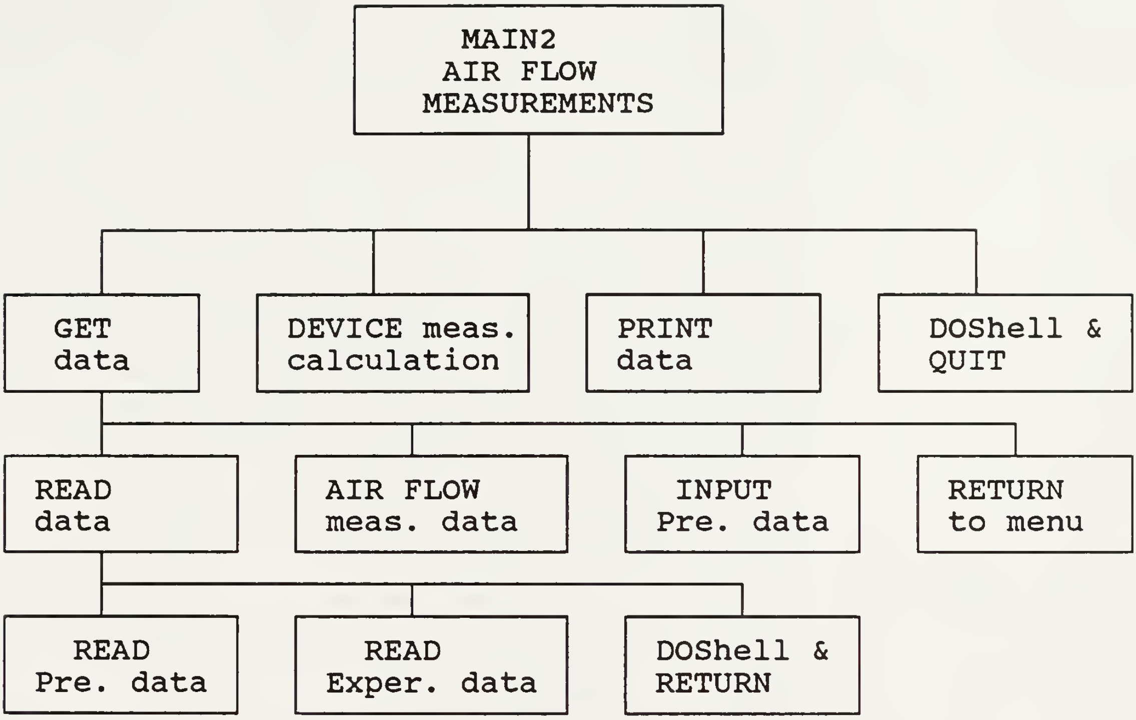

Figure B.2.1 Flow Chart for The ADC Air Flow Measurement Calculations Program.

ADC AIR FLOW MEASUREMENT SHEET NO: 2
FORM NO : ADC 1.0/2

COMP METER # 1 TER. DEVICE # 2
MANUFACTURER : Tit
OBSERVER : KL JG
AMBIENT TEMP : 65 (°F)
BAROMETRIC PRESSURE : 14.7 (inHg)
DATE : 11-08-80
NORMINAL AREA : .545 (ft^2)

REFERENCE DENSITY : 0.075 lbm/ft3
Q.075 FROM CALIBRATED CHART
AIR DENSITY FROM ASHRAE HANDBOOK

DATA ANALYSIS FOR THE COMPANY METER MEASUREMENT

RUN	dp1	ps1	-	Pabs	D.B.	W.B.	e1	RAT	Q.075	Q1
	(inH2O)		-	(inHg)	(F)	(F)			(CFM)	(CFM)
1	0.89	1.09	0.08	14.78	89.50	69.50	0.034	1.5	47.17	69.59
2	0.58	0.71	0.05	14.75	84.50	69.50	0.035	1.5	38.08	55.84
3	0.44	0.55	0.04	14.74	84.50	69.50	0.035	1.5	33.17	48.65
4	0.52	0.60	0.04	14.74	84.50	69.50	0.035	1.5	36.06	52.89

DATA ANALYSIS FOR THE TERMINAL DEVICE MEASUREMENTS

RUN	dp2	*	Pabs	D.B.	W.B.	e2	e1/e2	Q2	es/e2	dp2sd
	(inH2O)	*	(inHg)	(F)	(F)			(CFM)		(inH2O)
1	0.89	0.07	14.77	89.50	69.50	0.03	1.001	69.66	2.18	1.94
2	0.58	0.04	14.74	84.50	69.50	0.03	1.001	55.87	2.15	1.25
3	0.44	0.03	14.73	84.50	69.50	0.03	1.001	48.68	2.15	0.95
4	0.52	0.04	14.74	84.50	69.50	0.03	1.000	52.91	2.15	1.12

Figure B.2.2 Sample ADC Air Flow Measurement Sheet.

B.3 AREA FACTOR CALCULATIONS

MAIN3 is used for taking data for the Area factor measurement experiments and calculations. The program completes the necessary calculations and produces the related ADC forms. When MAIN3 is executed, the following menu is available:

```
This is the Area Factor Calculation Menu

      1) Use DOShell to check files
      2) QUIT this session
      3) RUN experiment
      4) SAVE data to disk
      5) READ data from disk
      6) PRINT the data

Your choice  ?
```

Opening Menu for MAIN3

These options are described as follows:

DOShell and QUIT

These options are the same as explained earlier.

RUN experiment

This option is used to read experimental data and complete the required calculations. The program also checks the correctness of the velocity data (ADC CODE states that the individual velocities must not vary more than 10% from the average velocity).

SAVE data to disk

This option allows the user to save the experimental data to a disk file for later use.

READ data from disk

This option allows the user to extract experimental information from a disk file.

PRINT the data files

This option allows the user to view the data file on the screen and obtain a hard copy. The program will plot the graphs of pressure drop against area factor to ensure that these parameters are not related.

The program flow chart is shown in Figure B.3.1.

****

EXAMPLE 3

Example of how to generate an output file.

1) Select the **RUN** menu. The program will prompt the user for various information about the device manufacturer, device type, etc. The sample input screen is as shown below:

```
   ADC STANDARD TEST REPORT FORM NO. ADC 11.0
                 AREA FACTORS
         FOR AIR OUTLETS AND AIR INLETS

 Manufacturer                          :?
 Outlet/Inlet type & size              :?
 Date                                  :?
 Observer                              :?
 Neck area                             :?
 Flow meter equipment                  :?
 Anemometer type & serial number       :?
```

Sample input screen 1 for MAIN3

After the user has input all the required information, the program will prompt for experimental data. A second input screen will be available. This input screen 2 is shown as follows:

RUN#	dp1 (Flow Meter)	ANEMOMETER_(Vk) 1	2	3	4	ave	dp2sd static press.

RUN# ?

Sample input screen 2 for MAIN3

The user has to provide the following information :-

i) RUN# : The experiment number

ii) dp1 : The pressure drop across the company flow meter.

iii) ANEMOMETER_(Vk): The velocity readings obtained at different locations of the air outlet.

iv) dp2sd : The static pressure drop across the device.

v) q2 : The air flow rate through the device.

The program calculates the average velocity and informs the user if the data are within allowable limits. After the data taking procedure is completed, the program will return to the opening menu.

2) Select the **SAVE** option to store the data collected to a disk file.

3) Select the **PRINT** option to print out the data. This option also allows the user to graph pressure drop against area factor. The goodness of fit is also calculated. The user can also change the scale of the graphs.

4) Use **QUIT** to terminate the program.

Example of how a data file may be extracted from disk file.

1) Select the **READ** option to read the data file. For this example, use <AF1> as the data file name.

2) Select the **PRINT** data option to print out the data.

3) Select **QUIT** to terminate the program.

A sample output file is shown in Figure B.3.2.

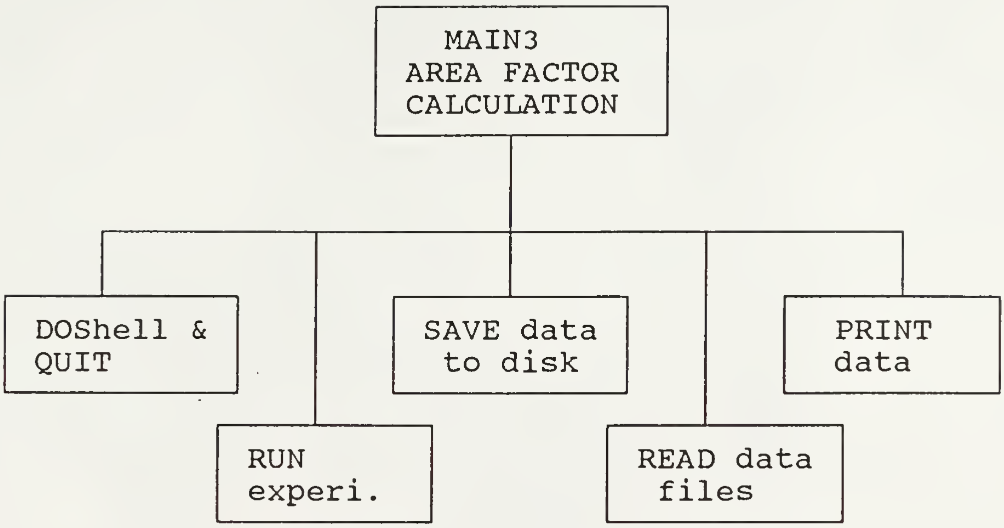

Figure B.3.1 Flow Chart for The Area Factor Calculation program.

ADC STANDARD TEST REPORT FORM NO. ADC 11.0
AREA FACTORS
FOR AIR OUTLETS AND AIR INLETS.

Manufacturer:	: S & S
Outlet/Inlet type & size	: 2 in T X H
Date	: 11-08-88
Observer	: SHIM
Neck are	: .545
Flow meter equipment	: ------
Anemometer type & serial number	: ------

READINGS

RUN #	dp1 (Flow Meter)	ANEMOMETER ___(VK) 1	2	3	4	ave	dp2sd static press.
13	0.890	2050	2050	2050	2050	2050	0.397
14	0.580	1750	1750	1750	1750	1750	0.261
15	0.440	1475	1475	1475	1475	1475	0.207
16	0.270	1200	1200	1200	1200	1200	0.125

CALCULATIONS

RUN#	Q2 CFM	NECK VEL.	NECK V.P.	TOTAL PRESSURE	AREA FACTOR (AK)
13	969	1778	0.197	0.594	0.473
14	782	1435	0.128	0.389	0.447
15	681	1250	0.097	0.304	0.462
16	534	980	0.060	0.185	0.445
				AVERAGE Ak =	0.457

Figure B.3.2 Sample Output Data for The Area Factor Calculation program.

B.4 THROW-VELOCITY EXPERIMENTS

MAIN4 is used for taking experimental data for the Throw-Velocity measurements. It also completes the necessary calculations and produces the related ADC report forms. On execution of the program, the following menu is available:

```
This is the Throw-Velocity Calculation menu

        1) DOShell to check files
        2) QUIT this session
        3) RUN experiment
        4) READ data from disk
        5) PRINT the data

Your choice  ?
```

Opening menu for MAIN4

The options are described below:

DOShell and QUIT

These options are the same as described earlier.

RUN experiment

This option is used to read the experimental data sets. The data includes the distances from outlet, outlet velocities, and locations of the readings. The user supplies the measured velocity and the program will calculate the rest of the parameters and save them on a disk file. After the experiments are completed, the program will return to the opening menu.

READ data from disk

This option is used to extract information from disk files.

PRINT the data

This option is used to print out the general information about the device tested and the related Throw-Velocity graphs.

The program flow chart is shown in Figure B.4.1.

****

EXAMPLE 4

For this example, four example data files are used. The names of the files are : INFOR1.MA4, RUN1.MA4, RUN2.MA4, RUN3.MA4.

Example of how a data file may be generated.

1) Select the **RUN** experiment option. The program will prompt the user for various information about the device. The sample input screen is as shown below:

ADC STANDARD TEST REPORT FORM
NO.ADC A.12.4/1
THROW-TERMINAL VELOCITY

Manufacturer	:?
Outlet/ type & size	:?
Date	:?
Observers	:?
Anemometer type & serial number	:?
Neck area	:?
Supply air temperature	:?
Room temperature	:?

Sample input screen for MAIN4

After the data input is completed, the program will prompt the user for a filename to save the data. For this example, enter <INFOR1>. Then the program will prompt for the number of experiments to run. For each run, the user has to input the run number, air flow rate, the velocity, and description of outlet. After these steps, the input screen shown in the next page is available. The user has to provide the following data:

i) Distance from outlet (feet): This is the distance from the outlet where the local velocity is taken.

ii) Vt (fpm) : This is the local velocity in feet per minute.

iii) Located at (inches) : This is the distance from ceiling at where the reading is obtained. For a sidewall diffuser, this is the vertical distance between the ceiling and the location where the reading is obtained.

The program will request the user to enter data in the input "window" at the bottom of the screen. The user simply inputs a negative distance to terminate the experiment. The program will compute the rest of the parameters and saves them for later use. After the experiment the program will return to the opening menu.

```
Distance       Vt          Located       Vt/Vn       t/SQRT(An)
 from          fpm           at
outlet (t)                 (inches)
---------------------------------------------------------------




---------------------------------------------------------------
RUN NO :                  Q2 cfm :
Vk     :                  Vc     :
```

```
Distance from outlet, t?
```

Enter a negative distance to terminate readings.

Sample input screen for MAIN4.

2) Select the **PRINT** data option to print out the data files. The following menu is available:-

```
                PRINT DATA

   1) Print general information about device
   2) Print experimental data for different runs
   3) Return to main menu

                Your choice ?
```

Print data menu for MAIN4

Select <1>. When the program prompts for the file name, input <INFOR1>.

Select <2>. When the program prompts for the file name, input <RUN1>.

Select <3> to return to the opening menu.

3) Use **QUIT** to terminate the program.

Example of how data may be extracted from a disk file.

1) Select the **READ** data option to extract information from file. The following menu is available:

```
                 READ DATA FROM DISK

   1) Read general information about device
   2) Read experimental data for different runs
   3) Return to main menu

                 Your choice ?
```

Read data menu for MAIN4

Select <1>. When the program prompts for the filename, enter <INFOR1>.

Select <2>. When the program prompts for the file name, enter <RUN1>.

Select <3> to return to the opening menu.

2) Select the **PRINT** option to print out the data.

3) Use **QUIT** to terminate the program

A sample data output is shown in Figure B.4.2

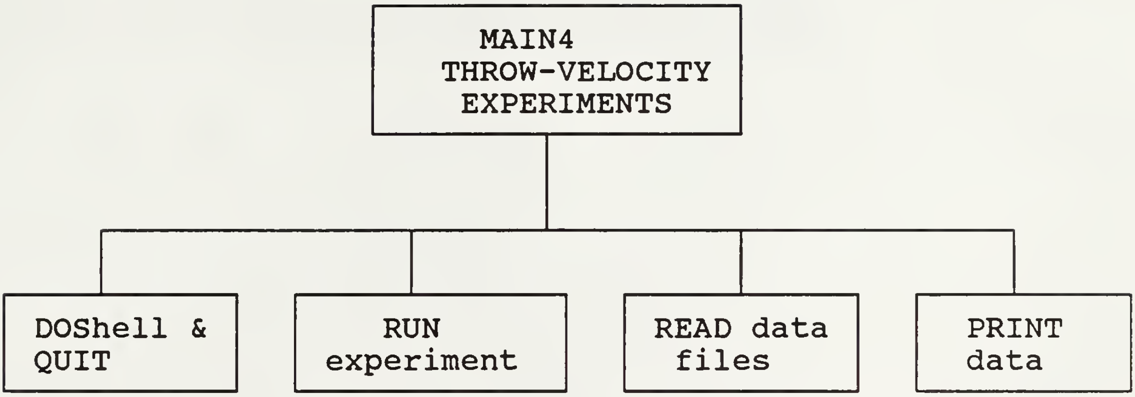

Figure B.4.1 Flow Chart for The Throw-Velocity Experiments Program.

ADC STANDARD TEST REPORT FORM NO. A.12.4 / 1
THROW-TERMINAL VELOCITY

Manufacturer	: S & S
Outlet/ type & size	: 2 X H
Date	: 30-8-88
Observer	: SHIM
Anemometer type & serial number	: 3455
An = 0.545	√An = .7382411
Supply air temperature	: 60
Room temperature	: 60

RUNO : 25 Q2 cfm: 873
Vk : 1525 Vc : 0 4-WAY

Distance from outlet (t)	Vt fpm	Located at (inches)	Vt/Vn	t/SQRT(An)
2	510	1	0.334	2.71
3	390	1	0.256	4.06
5	270	1	0.177	6.77
7	200	3	0.131	9.48
9	150	3	0.098	12.19
11	140	3	0.092	14.90
13	110	3	0.072	17.61
15	90	3	0.059	20.32
17	80	3	0.052	23.03
19	80	3	0.052	25.74

Figure B.4.2 Sample Output Data for The Throw-Velocity Experiment Program.

B.5 THROW-VELOCITY GRAPHS

MAIN5 is used to plot the Throw-Velocity graphs using experimental data sets obtained in MAIN4. The program can be used to plot experimental throw velocity data using air flow rate or size as the second independent variable. The program will request the user to position the three different slope lines manually, and plots the lines on the throw-velocity graph with the data sets. When the program is executed the following menu is available:

```
This is sub-program MAIN5. MAIN5 is used to plot
the throw-velocity graph using data from ADC test
form 12.4/1 Throw velocity measurements and calcu-
lation.

      1) Use DOShell to check data files
      2) QUIT this session
      3) PLOT T-Velocity graphs for different CFM
      4) PLOT T-Velocity graphs for different SIZE

Your selection ?
```

Opening menu 1 for MAIN5

The different options are explained below:

DOShell and QUIT

These options are the same as described earlier.

PLOT T-Velocity graph for different **CFM**

This option is used to plot the experimental data for a single size, using air flow rate as the second independent variable.

PLOT T-Velocity graph for different **SIZES**

This option is used to plot the experimental data using size as the second independent variable.

The user is required to run option 3 first to generate the data files used by option 4. These options will be explained in detail.

When option 3 is selected from the main menu, the following sub-menu will be available:

```
This part of the program is used to plot the Throw-
Velocity graphs.  The maximum number of data sets
that can be plotted is 3.

    1) Use DOShell to check data files
    2) RETURN to  main menu
    3) INPUT/PRINT Preliminary information
    4) READ data files for plotting graphs.
    5) PLOT the graph

Your selection  ?
```

Opening menu 2 for MAIN5

The different options are described as follows:

DOShell and RETURN

These options are the same as described earlier.

INPUT/PRINT Preliminary data.

This option allows the user to create the heading for the Throw-Velocity graph.

READ data files for plotting graphs.

This option is used to input the data sets necessary to plot the Throw-Velocity graphs. The user will be prompted for the number of files to be used and the file names. The user can plot up to three data files on one graph.

PLOT the graphs

This option is used to plot the Throw-Velocity graph. The user has the option of plotting the data points only or to include the three specified slope lines. To position the three slope lines, the user will have to specify the locations of the end points of the lines. The user will start working with the (-1) slope line, then the (-½) line, and finally, the (-2) slope line.

The data sets will be plotted each time with the slope lines.

The program flow chart is shown in Figure B.5.1.

****

EXAMPLE 5

Example of how to plot the Throw-velocity graph for different CFM

This example will use the three data files created earlier with MAIN4. They are named RUN1.MA4, RUN2.MA4 and RUN3.MA4 respectively. A preliminary information file called INFOR1.MA5 is also used.

To generate the Throw-Velocity graphs for these data files follow the following steps:

1) Select the **INPUT/PRINT** option and type in <INFOR1> when the program prompts for a file name. The user can then print out the data sheet. The program will return to the opening menu.

2) Select the **READ** option to input the data file for plotting the graph. When the program prompts for the number of data file to read, answer <3>. When the program prompts for the names of the files, type in <RUN1>, <RUN2> and <RUN3> respectively. After the data input is completed, the program will return to the opening menu.

3) Select the **PLOT** option to plot the graph. The following menu should be available:

```
This is the Graphic menu....

  1) Show data sets only
  2) Show -1 slope line
  3) Show -1/2 & -1 slope line
  4) Show all slope line
  5) Return to main menu

Your Choice  ?
```

Graphic Menu for MAIN5

Choose option <1> to display all the data sets. Three data sets, represented by circles, triangles and squares, will appear on the screen.

Use option <2> to draw the -1 slope line. The user will be prompted for the point selected. This is the point where the -1 slope line will pass through. The program uses this point to determine the position of the -1 slope line relative to the data points. For this example, first enter the coordinates as <10,0.1>. This line will be displayed on the screen. To move the line, return to the graphic menu and reenter the co-ordinate again. This time, enter the co-ordinate as <10,0.145>. The line shown on the screen should pass through most of the data points. The user can change the position of the line by selecting a different co-ordinates.

After the -1 slope line is positioned, use option <3> to draw the -½ slope line. This time the program will prompt the user for the "left end point". This is the X co-ordinate of the point where the -½ slope line will intersect the -1 slope line. The program does not request a Y coordinate because it will be determined automatically (based on the fact that these two lines intersect). The position of the -½ slope line can be changed in a similar manner to that of the -1 slope line. For this example, use the left end point as <5>.

After both the -½ and -1 slope line are drawn, use option <4> to draw the -2 slope line. The program will prompt for the "right end point". Again, this the X coordinate of the point where the -2 slope line will be drawn. For this example, use the right end point as <20>.

Use option <5> to leave the graphics menu. The program will report the curve fitting constants for the device for zones 2-4. This information is later used to generate catalog data for the diffuser.

4) Select **QUIT** to terminate the program.

A sample of the Throw velocity graph for different air flow rates is shown in Figure B.5.2.

****

EXAMPLE 5

Example of how to plot the Throw-Velocity graphs for different sizes.

1) Select the **SIZES** option from the opening menu.

2) When the program prompts for the number of sizes to plot, enter <3> for three sizes. The program will then prompt for the file names. For this example enter <SIZE1>, <SIZE2> and <SIZE3> respectively.

3) When the program has collected all the necessary data, the following menu will appear:

```
This is the Graphic menu....

   1) Show all the slope lines
   2) Show all the data points
   3) Select -1 slope line
   4) Select -1/2 & -1 slope line
   5) Select all slope line
   6) Return to main menu

Your Choice  ?
```

Graphic Menu for MAIN5

Select <1> to see the three different slope lines for the data sets. The program will proceed to report the curve fitting constants.

Select <2> to plot all the data points.

Select options <3>-<5> to draw different sets of slope lines. These options operate exactly like the graphic options <2>-<4> as described in the previous example.

Select <6> to return to the opening menu.

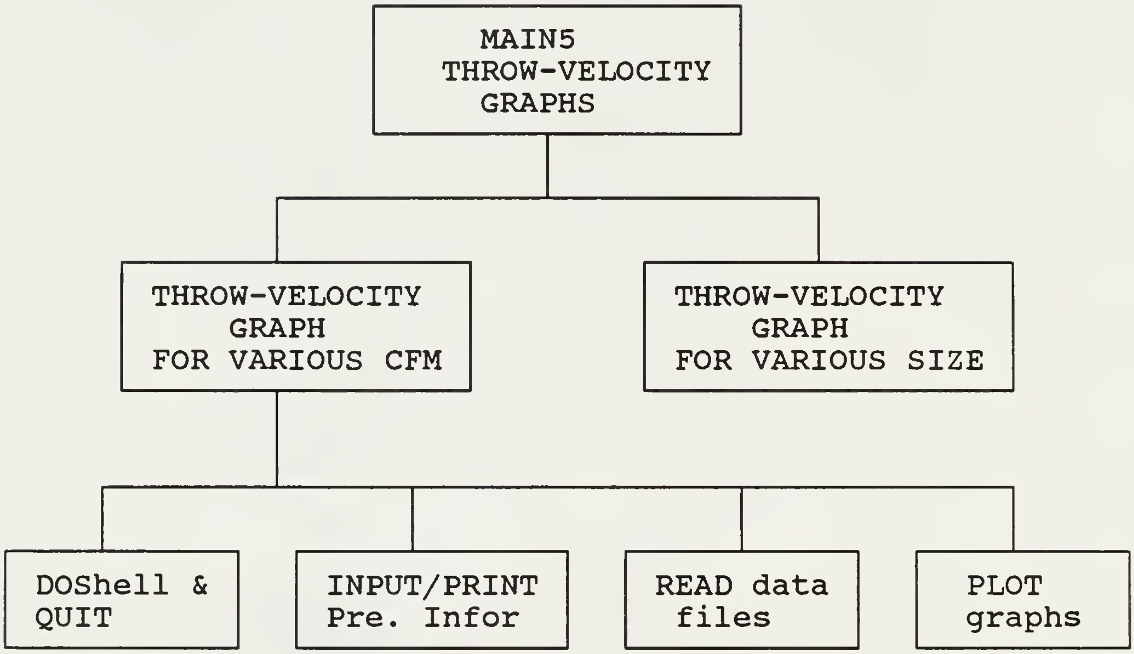

Figure B.5.1 Flow Chart for The Throw-Velocity Graphs Program.

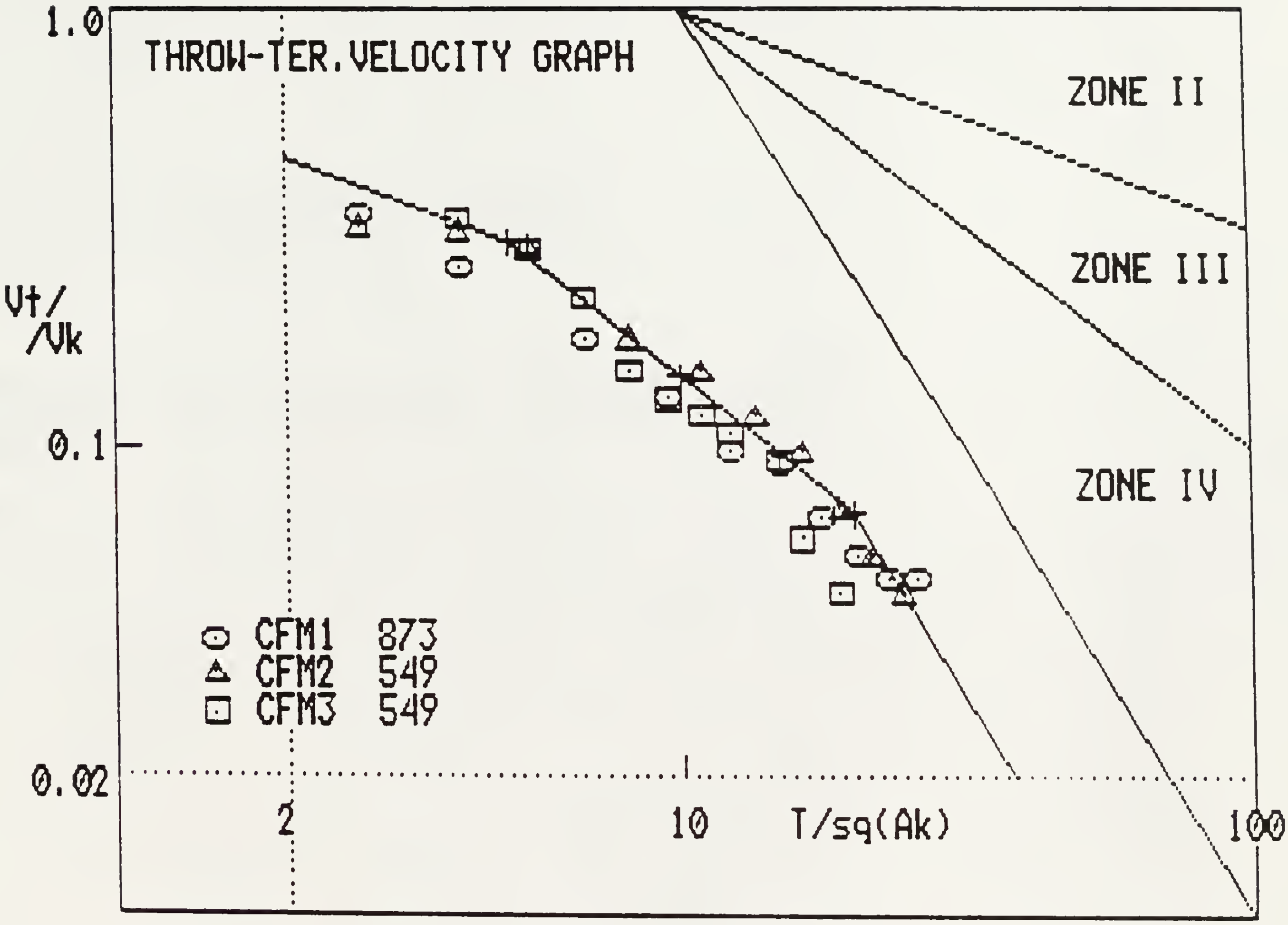

Figure B.5.2 Sample Throw-Velocity Graph.

B.6 CONSTRUCTING DATA FILES FOR STATISTICAL ANALYSIS

MAIN6 is a subprogram used to combine data files generated in MAIN2.BAS. The newly constructed data file is used for the multiple regression analysis. When the program is started the following menu is available:

```
This is subprogram MAIN6.  MAIN6 is used to cons-
truct a new data file for the multiple linear reg-
ression routine to determine the relationship between
air flow rates, pressure drop and area using the data
obtained in MAIN2.

      1) Use DOShell to check files
      2) QUIT this session
      3) FORM data files for regression analysis
      4) BEGIN regression analysis

Your choice   ?
```

Opening menu for MAIN6

DOShell and QUIT

These options are the same as described earlier.

FORM data files for regression analysis

This option is used to combine various data files generated by the MAIN2 subroutine into a single file. This data file is used by the regression subroutine. The program will prompt the user for the output file name and the input file name(s), write the results, and then return to the opening menu.

BEGIN regression analysis

This option is used for statistical analysis, and will be described in APPENDIX B.10.

The program flow chart is shown in Figure B.6.1.

****

EXAMPLE 6

The following is an example on how MAIN6 may be used:

<TABLE1.MA2>, as prepared in APP. B.2, will be used as the input file and <REG.EX1> will be used as the output file.

1) Select the **FORM** data file option. When the program prompts for the name of the output file, enter <REG.EX1>. When the program prompts for the number of files and file names to combine, enter <1> and <TABLE1> respectively. After the data file is constructed, the program will return to the opening menu. If the user returns to DOS at this point, a file named <REG.EX1> will be available in the B: disk under the MA6DAT directory.

2) Select the **BEGIN** option to do regression analysis on the data.

3) Select **QUIT** to terminate the program.

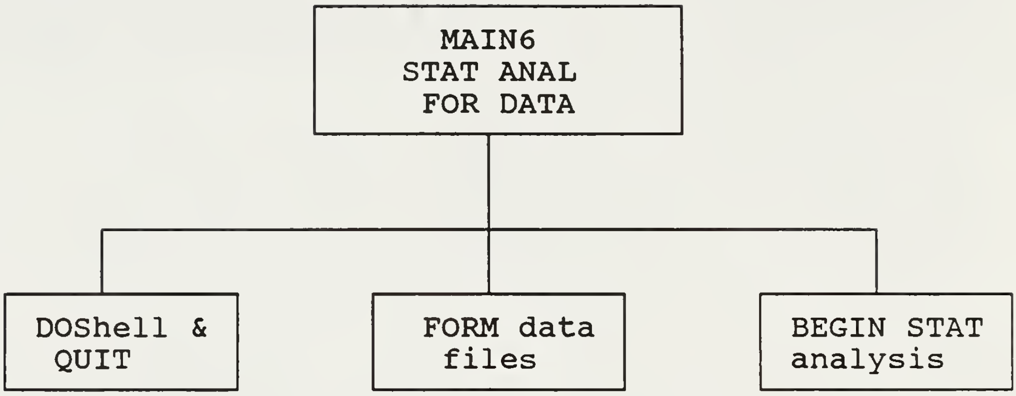

Figure B.6.1 Flow Chart for MAIN6.

B.7 SOUND TEST DATA FORMS AND NC CURVES

MAIN7 is used to produce the Sound Test data forms and plot the related NC curves. Some experimental sound pressure level data which are very close to the background sound pressure level may not satisfy the tolerances limits established by the ADC. The computer program will automatically sort out these bad data points, and omit them when plotting the NC curves. When MAIN7 is executed, the following menu is available:

```
MAIN7  is used to produce the SOUND
TEST DATA FORM. Here is the Menu:

      1)DOShell to check files
      2)QUIT this session
      3)RUN experiment
      4)READ data files from disk
      5)PRINT the ADC data forms
      6)Plot the NC curves

Your choice?
```

Opening menu for MAIN7

The different menu choices are described below:

DOShell AND QUIT

These options are as described earlier.

RUN experiment

The **RUN** menu is used to record laboratory sound data. The program will prompt the user to supply all the necessary information and store them for later use. The user will be prompted to supply the name of two data files. One is used for storing information on the NC reports form, and the other is used for storing information for plotting the NC curves. After confirmation of these data file names, the program will begin to prompt for the experimental data. Simply answer the questions on the screen until the MAIN7 opening menu appears again.

READ data files from disk

The ADC program has the ability to retrieve data files that were created earlier. The program will prompt the user for a file name, confirm it and return to the MAIN7 opening menu.

PRINT the ADC data forms.

After the user finishes supplying data either from the RUN or READ menu, the information can be printed. The program will first display the data on the screen. The user can also get a hard copy of the results. After the printing is done the program will return to the MAIN8.BAS menu.

PLOT the NC curves

This option is used to plot the NC curves. Before the graph is plotted, the program will prompt the user to input the heading for the graphs and then the name of the data file for plotting. The data file name should be the same as in the **RUN** option.

The program flow chart is shown in Figure B.7.1.

****

EXAMPLE 7

Example on how NC report forms and NC graphs are generated.

1) Select the **RUN** option to begin recording data of the NC experiment. The program will prompt for the required information individually. After the user has supplied all the necessary data the program will prompt the user to save the data to a file. Then the program returns to the opening menu.

2) Select the **PLOT** graph option to plot the NC graph. A more detailed explanation on how to use this option is given in the example for extracting data from a disk file.

3) Select **QUIT** to terminate the program.

Example of how to extract data from disk file.

This example uses the sample experimental data stored in two disk files named NCRUN1.MA7 (for report forms) and NCCV1.MA7 (for NC graph plotting).

To print out the forms and graphs, use the following steps.

1) Select the **READ** data option. When the program prompts for the report file name, enter <NCRUN1>. Then the program will return to the main menu.

2) Select the **PRINT** option to print out the report form. The report form is shown in Figure B.7.2. After the report form is completed the program will return to the main menu.

3) Select the **PLOT** option to plot the NC graph. The program will prompt to see if the user wants to input headings for the graph. For this example, answer <n> for no headings. The program will then prompt for the file name for NC graph data. Enter <NCCV1> to plot the graph. The graph is shown in Figure B.7.3. After the graph is completed, the program will return to the main menu.

4) Select the **QUIT** option to terminate the program.

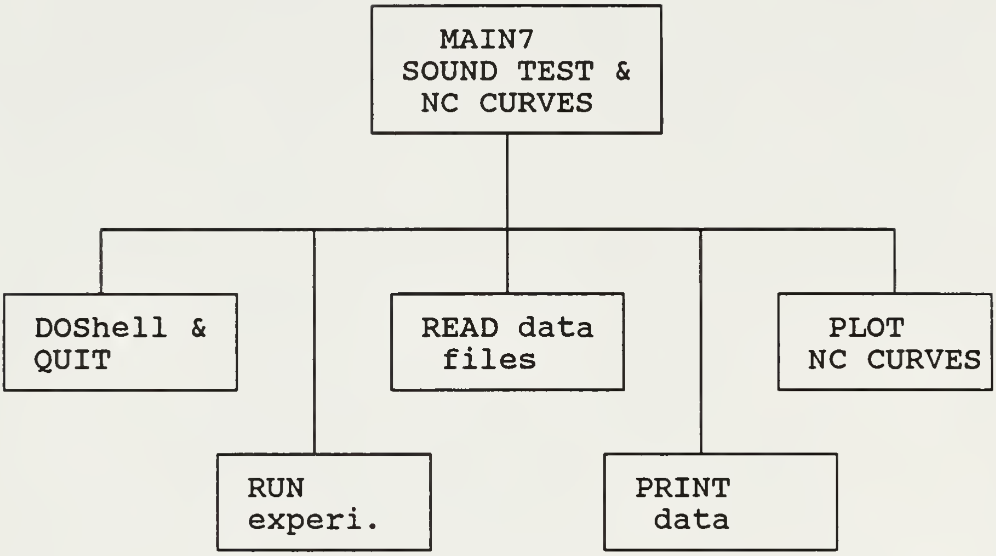

Figure B.7.1 Flow Chart for The Sound Tests and NC Curves Program.

ADC STANDARD TEST REPORT FORM NO.ADC 14.2
SOUND TEST DATA

Manufacturer	: Titus
Observer	: KL JG
Outlet type & size	: 10 in T X H
Date	: 8-20-80
Microphone	: Sridhar
Calibrator	: Shim
Sound Meter	: A010
Analyzer	: Shim

	SCALE A	B	C	2 125	3 250	4 500	5 1000	6 2000	7 4000	8 8000
BKGND LP	*	*	*	32.0	19.0	19.0	11.0	8.0	6.5	6.0
ILG Lw	83.0	85.0	86.5	81.0	81.0	81.0	81.0	81.0	79.0	78.0
ILG Lpm	*	*	*	67.0	72.5	73.5	73.5	72.0	68.0	61.5
R.A. (Diff)	*	*	*	14.0	8.5	7.5	7.5	9.0	11.0	16.5
FOR RUN # 13		Q2(cfm) =		969	Dp2sd	=	.15			
Lp dbc	57.0	56.5	58.0	41.0	40.5	44.0	50.0	54.5	47.5	33.0
-Bkg corr	*	*	*	0.5	0.0	0.0	0.0	0.0	0.0	0.0
+R.A.	*	*	*	14.0	8.5	7.5	7.5	9.0	11.0	16.5
Lw	*	*	*	54.5	49.0	51.5	57.5	63.5	58.5	49.5
FOR RUN # 14		Q2(cfm) =		782	Dp2sd	=	.14			
Lp dbc	52.5	52.0	55.0	36.0	35.0	40.0	47.5	48.5	37.5	21.0
-Bkg corr	*	*	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+R.A.	*	*	*	14.0	8.5	7.5	7.5	9.0	11.0	16.5
Lw	*	*	*	0.0	43.5	47.5	55.0	57.5	48.5	37.5
FOR RUN # 15		Q2(cfm) =		681	Dp2sd	=	.13			
Lp dbc	49.5	49.0	54.0	33.0	32.5	37.5	46.0	44.5	31.0	14.0
-Bkg corr	*	*	*	0.0	0.0	0.0	0.0	0.0	0.0	0.5
+R.A.	*	*	*	14.0	8.5	7.5	7.5	9.0	11.0	16.5
Lw	*	*	*	0.0	41.0	45.0	53.5	53.5	42.0	30.0
FOR RUN # 16		Q2(cfm) =		534	Dp2sd	=	.12			
Lp dbc	41.5	42.5	50.0	30.0	28.0	34.0	40.0	33.5	15.5	6.5
-Bkg corr	*	*	*	0.0	0.5	0.0	0.0	0.0	0.5	0.0
+R.A.	*	*	*	14.0	8.5	7.5	7.5	9.0	11.0	16.5
Lw	*	*	*	0.0	36.0	41.5	47.5	42.5	26.0	0.0

** NOTE * A ZERO IN THE Lw CALCULATION INDICATE THAT THE DATA SET IS NO GOOD, AND WILL BE OMITTED IN THE NC CURVE PLOTTING AND ANALYSIS

Figure B.7.2 Sample NC data Report Form.

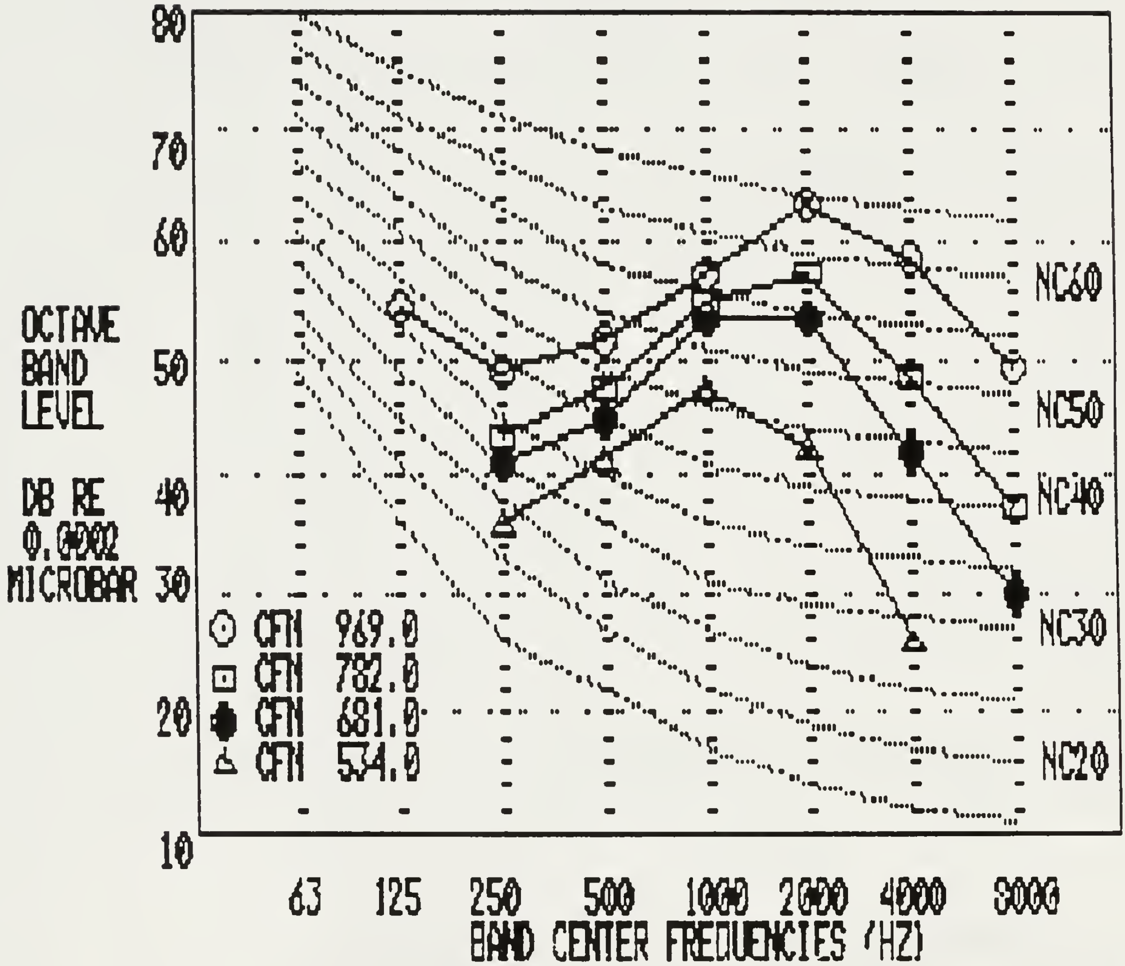

Figure B.7.3 Sample NC graphs.

B.8 STATISTICAL ANALYSIS FOR THE NC DATA

MAIN8 is used to sort out the NC data files. It is also used to access the multiple regression subroutine. The regression analysis can be used to determine the relationships between various parameters for the ADC SOUND tests. By executing MAIN8, the following menu should be available:

```
This is sub program MAIN8. MAIN8 is used to deter-
mine the relationship between NC, area, pressure
drop and CFM for different bands

      1) Use DOShell to check files
      2) QUIT this session
      3) CREATE data files for STAT analysis
      4) BEGIN STAT analysis

Your Choice ?
```

Opening menu for MAIN8

The different menu choices are described below:

DOShell AND QUIT

These options are the same as described earlier.

CREATE data files for STAT analysis

This option uses the NC graph data files created in MAIN7.BAS. It will sort out the data points corresponding to each octave band and generate 7 new data files (one data file for each band) for use by the regression subroutine. The program will prompt for the number of data files to be used, and their names respectively. After the files are completed, the program will return to the main menu.

BEGIN STAT analysis

This option is used for statistical analysis, and will be described later.

The program flow chart is shown in Figure B.8.1.

****

EXAMPLE 8

The following is an example on how MAIN8 may be used to do statistical analysis for the NC data :-

The user must provide the names of the NC graph data file(s) generated in MAIN7. For this example, the related data file is NCCV1.MA7.

1) Select the **CREATE** data file option.

2) When the program prompts for the number of data files to use, enter <1>. When the program prompts for the name of the data file, enter <NCCV1.MA7>. After the program confirms the response, it will generate the files automatically and the following message will be seen:

```
THE FILES THAT ARE GENERATED FOR STATISTICAL ANALYSIS
ARE AS FOLLOWS:-

        B:\MA8DAT\BAND2.MA8
        B:\MA8DAT\BAND3.MA8
        B:\MA8DAT\BAND4.MA8
        B:\MA8DAT\BAND5.MA8
        B:\MA8DAT\BAND6.MA8
        B:\MA8DAT\BAND7.MA8
        B:\MA8DAT\BAND8.MA8

PLEASE NOTE THEM, YOU WILL NEED THEM FOR LATER USE
```

After this, the program will return to the main menu.

3) The user may select the **BEGIN** STAT analysis option to perform a multiple regression analysis on the data files.

4) Use **QUIT** to terminate the program.

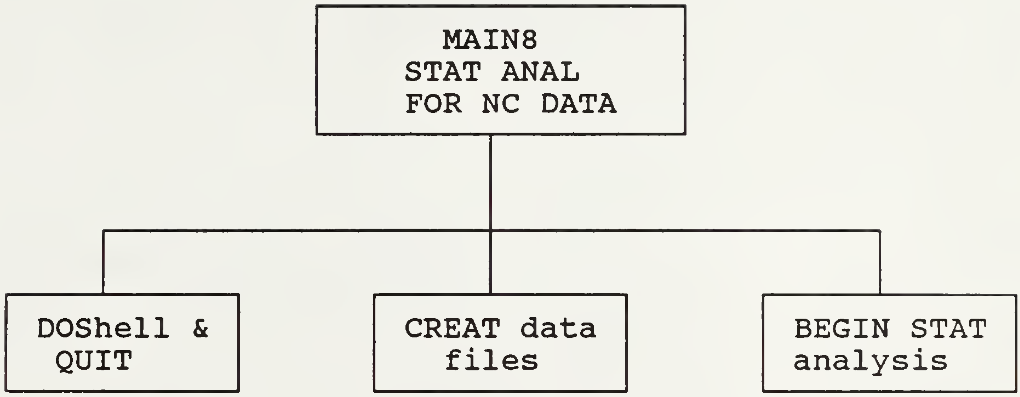

Figure B.8.1 Flow Chart for MAIN8.

B.9 GENERATING THE CATALOG DATA

MAIN9 is used to generate the catalog data described in this thesis. The user is required to supply the results from the statistical analysis routine performed earlier. The information required is presented below:

To correlate the air flow rate, static pressure drop and area, the user needs to supply the values of C1, C2 and C3 as described by the following equation.

$$LN(cfm) = C1 * LN(dpsd) + C2 * LN(Ak) + C3$$

To correlate the noise criteria, pressure drop, air flow rate and area, the user needs to supply the values of C4, C5, C6 and C7 as described by the following equation.

$$NC = C4 * LN(dpsd) + C5 * LN(cfm) + C6 * LN(Ak) + C7$$

To calculate the throw distances corresponding to the terminal velocities of 150 fpm, 100 fpm and 50 fpm, the user needs to supply the values of K2, K3 and K4 as described by the following equations.

$$(Vt/Vk) = K2 * (T/\sqrt{Ak})\hat{}-\tfrac{1}{2} \quad \text{for Zone II}$$
$$(Vt/Vk) = K3 * (T/\sqrt{Ak})\hat{}-1 \quad \text{for Zone III}$$
$$(Vt/Vk) = K4 * (T/\sqrt{Ak})\hat{}-2 \quad \text{for Zone IV}$$

The input parameters for this program are the sizes (nominal areas) and the neck velocities. The program will calculate the velocity pressure (VP), total pressure drop (TP), air flow rate (CFM), Noise Criteria (NC) and the throw distances (T) corresponding to the three specified terminal velocities. The following is a summary of these relationships:

INPUT PARAMETERS		CALCULATED PARAMETERS	
C1-C7	(Fitting constants)	DPSD	(Static press. drop)
K2-K4	(Fitting constants)	TP	(Total press. drop)
Vn	(Neck velocities)	CFM	(Air flow rates)
Ak	(Area Factor)	NC	(Noise Criteria)
		T	(Throw distance)

When MAIN9 is invoked, the following menu is available:

```
MAIN9 is used to generate the Catalog Performance
data for diffusers

      1) Use DOShell to check files
      2) QUIT this session
      3) INPUT catalog information
      4) READ data files
      5) PRINT catalog data

Your Selection  ?
```

Opening menu for MAIN9.

These different options are explained as follows:

DOShell and QUIT

These options are the same as described before.

INPUT catalog information

This option is used to select the input parameters. The program requires the user to supply the constants C1-C7, and constants K2-K4. The user can select up to five different neck velocities, and up to seven different device sizes. The program calculates the rest of the parameters, and saves the results to a data file specified by the user.

READ data files

This option is used to extract the catalog data information calculated earlier.

PRINT data files

This option is used to print out the catalog data.

The program flow chart is shown in Figure B.9.1

****
EXAMPLE 9

Example of how a catalog data file may be created.

1) Select the **INPUT** data option from the main menu.

2) The program will prompt the user to supply all the required information. The user may chooses up to five different neck velocities and up to seven different device sizes. The program will then prompt the user to save this information to a data file. For this example, type in the following information:

file name	: <CATEX1>		
chart title	: <CEILING DIFFUSERS>		
model	: <S & S TXH>		
constants	: C1 = <100.0>	C2 = <1.0>	C3 = <1.0>
	C4 = <2.0>	C5 = <3.0>	C6 = <4.0>
	C7 = <0.01>	K2 = <1.0>	K3 = <2.0>
	K4 = <0.6>		
neck velocities	: Vn(1) = <700.0>	Vn(2) = <800.0>	
	Vn(3) = <1000.0>	Vn(4) = <1200.0>	
	Vn(5) = <1400.0>		
number of sizes	: <1>		
size (inches)	: <4>		
nominal area	: <0.545>		

3) Use the **PRINT** data file option to print out the data file.

4) Use **QUIT** to terminate the program.

The sample output file is shown in Figure B.9.2.

Example of how a catalog data file may be printed.

1) Select the **READ** data option. When the program prompts for the data file name, enter <CATALOG>.

2) Select the **PRINT** data option to print out the catalog data.

3) Use **QUIT** to terminate the program.

The sample catalog data obtained from the <CATALOG> data file is shown in Figure B.9.3.

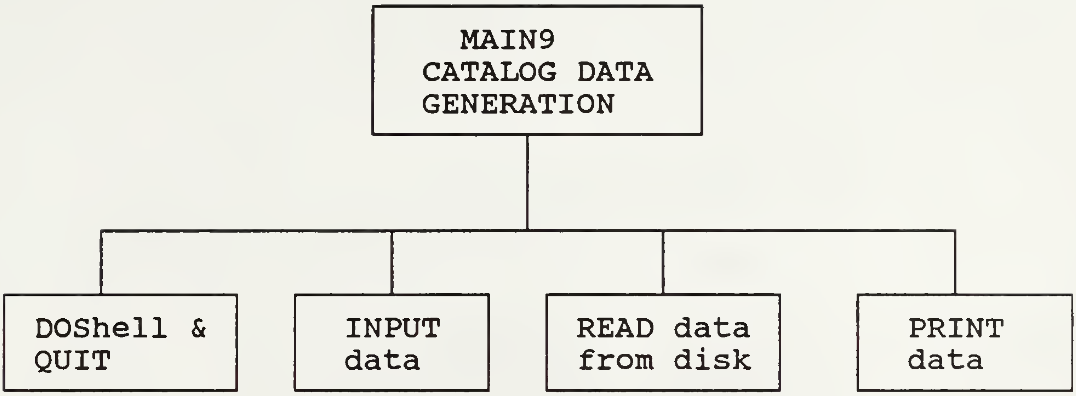

Figure B.9.1 Flow Chart for The Catalog Data Generating Program.

CEILING DIFFUSSERS
S & S TXH

DuctSize (inches)	Neck Vel. FPM	700.0	800.0	1000.0	1200.0	1400.0
	VP. Inches WG	0.031	0.040	0.062	0.090	0.122
4	TP. Inches WG CFM NC Throw. Ft	1.088 381.5 16 1* 2* 2	1.098 436.0 16 1* 2* 2	1.123 545.0 17 1* 2* 3	1.153 654.0 17 2* 2* 3	1.187 763.0 18 2* 2* 3

Notes:
1) Throw values are given for terminal velocity of 150, 100 and 50 fpm.
2) Test in accordance with the ADC Test Code 1062 R4.

Figure B.9.2 Sample catalog data from file CATEX1.

CEILING DIFFUSERS
Model TXH

DuctSize	Neck Vel. FPM	700.0	800.0	1000.0	1200.0	1400.0
(inches)	VP. Inches WG	0.031	0.040	0.063	0.090	0.123
4	TP. Inches WG CFM NC Throw. Ft	0.026 60.0 10 2* 3* 5	0.035 70.0 15 2* 3* 6	0.058 90.0 24 3* 4* 7	0.079 105.0 29 3* 5* 7	0.103 120.0 33 4* 5* 8
5	TP. Inches WG CFM NC Throw. Ft	0.033 95.0 14 2* 3* 6	0.044 110.0 19 2* 4* 7	0.066 135.0 26 3* 5* 8	0.099 165.0 32 4* 6* 9	0.131 190.0 37 4* 6*10
6	TP. Inches WG CFM NC Throw. Ft	0.044 140.0 18 3* 4* 8	0.058 160.0 22 3* 4* 9	0.090 200.0 29 4* 5*10	0.124 235.0 34 4* 7*11	0.170 275.0 39 5* 8*12
7	TP. Inches WG CFM NC Throw. Ft	0.041 190.0 20 3* 5* 9	0.052 215.0 24 3* 5*10	0.083 270.0 31 4* 6*12	0.116 320.0 37 5* 8*13	0.160 375.0 42 6* 9*14

Notes:
1) Throw values are given for terminal velocity of 150, 100 and 50 fpm.
2) Test in accordance with the ADC Test Code 1062 R4.

Figure B.9.3 Sample catalog data from file CATALOG.

B.10 THE STATISTICAL ANALYSIS ROUTINE.

This subprogram can be used to perform a multiple least square regression analysis for up to a maximum of four independent variables and one dependent variable. The user can use the data sets as they are, or convert them into logarithmic scale for regression analysis. When the program is invoked, the following menu is available:

```
REGRESSION SUBPROGRAM

This program will perform a multiple least-
square regression analysis on up to four
independent variables for one set of data.
Return to main menu for a different analysis!

      1) Use DOShell to check file
      2) RETURN to main menu
      3) READ data from disk
      4) START STAT analysis
      5) PRINT out the stat data
      6) LOOK at the residual plot

Your selection ?
```

Opening menu for the statistical routine.

DOShell AND RETURN

These options are just like the DOShell and QUIT commands as described before.

READ data from disk

The statistical routine always reads its data from a data file. The User will have to provide the name of the data file and its DOS search path before proceeding. The program will prompt the user for the types of data to be used (normal or logarithmic), and the name(s) of the variable. After the data input is completed, the program will return to the opening menu.

START STAT analysis

This option will perform the necessary statistical calculations to determine the best possible fitting coefficients for the data set. It also calculates and reports various statistical parameters for the data set. After these computations are completed, the program will return to the opening menu.

PRINT out the STAT data

This option is used to print out the statistical data. The user has the options of either viewing the data on the screen or getting a hard copy of the results.

LOOK at the residual plot.

This option is used to plot out the residual of the independent parameter with respect to each of the independent parameters.

****

EXAMPLE

In this example, the following data set will be used. The data set has 3 independent variables (X1, X2 & X3), and one dependent variable (Y):-

Y	X1	X2	X3
3	4	1	8
2	1	2	1
5	8	3	9
7	7	4	3
4	2	5	5
7	5	10	3
7	8	6	4
4	3	7	7
9	7	8	9
5	8	10	4

Number of data sets = 10

Sample data sets

These data sets have been written to a file called

REGRESS.EX1. To do a multiple regression on this data, the following steps are used:

1) Select the READ data option from the opening menu. When the program prompts for the file name, type <REGRESS.EX1>. Then the following menu is available:

```
Data file name : REGRESS.EX1
No of variables : 3
No of data set : 10

Please declare the data type of the variables

       1) No modification
       2) Use normal log scale (LOG 10)
       3) Use natural log scale (LOG e)

Data type for X( 1 ) =      ?
```

Data declaration Screen.

Select data type <1> for X1, X2, X3 and Y. When the program prompts for the variable names, use <X1>, <X2>, <X3> and <Y> respectively. The program will return to the opening menu.

2) Select the **START** STAT analysis option. When the computations are done, the program will return to the opening menu.

3) Select the **LOOK** at residual plot option to view the residual of Y with respect to X1, X2 and X3.

4) Use the **PRINT** option to print out the data and results. The data sheets and results are shown in Figure B.10.2 and Figure B.10.3.

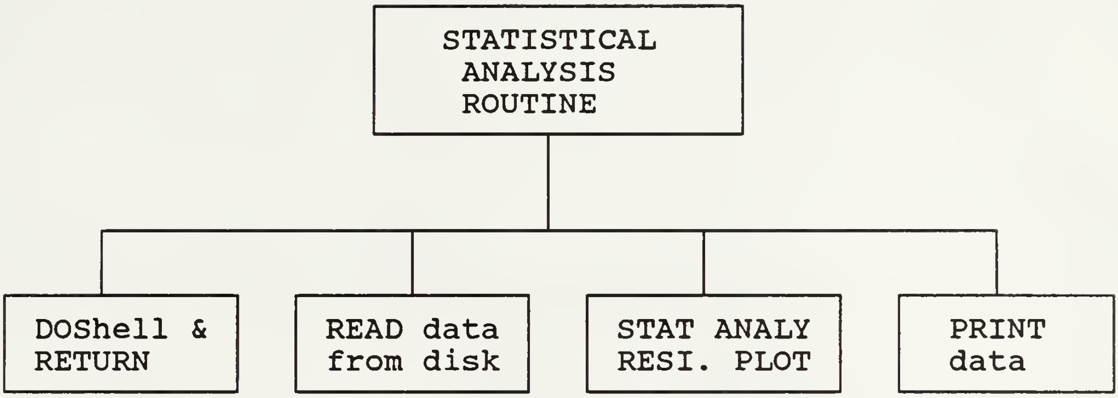

Figure B.10.1 Flow Chart for The Statistical Routine.

```
MULTIPLE LINEAR REGRESSION PROGRAM WITH STATISTICAL ANALYSIS
WRITTEN BY P.L.MILLER, 7/20/84   REVISED BY K.S.SHIM 7/14/88

              EXAMPLE1

THESE DATA ARE TAKEN FROM FILE regress.ex1

THE FORM OF THE FITTED EQUATION IS:

 y = B0 + B1 * x1 + B2 * x2+ B3 * x3

DEGREES OF FREEDOM;
    MODEL =  3
    ERROR =  6
    TOTAL =  9


R-SQUARE =  .6105153
 R-SQUARE =  .4157729    ADJUSTED FOR DF

 F VALUE 3.13499      (DF = 3 AND 6 )

 THE STD DEVIATION OF THE DEPENDENT VARIABLE ABOUT THE
 REGRESSION LINE IS

 S =  1.653144
```

PARAMETER	MULTIPLIER ESTIMATE	STD ERROR OF ESTIMATE	F-VALUE
	0.1233D+01	0.1658E+01	0.5526E+00
x1	0.4420D+00	0.2325E+00	0.3613E+01
x2	0.2652D+00	0.1895E+00	0.1959E+01
x3	0.4518D-01	0.2098E+00	0.4638E-01

```
  DF = 1 AND  6

DATE: 02-03-1989
TIME: 13:10:37
```

Figure B.10.3 Sample data output from the Statistical Routine.

EXAMPLE1

INPUT, CALCULATED, AND RESIDUAL DATA
FROM FILE regress.ex1

DATA SET	INPUT DATA				CALCULATED	
NN	x1	x2	x3	y	y'	RESIDUAL
1	0.4000E+01	0.1000E+01	0.8000E+01	0.3000E+01	0.3628E+01	-.6276E+00
2	0.1000E+01	0.2000E+01	0.1000E+01	0.2000E+01	0.2250E+01	-.2503E+00
3	0.8000E+01	0.3000E+01	0.9000E+01	0.5000E+01	0.5971E+01	-.9713E+00
4	0.7000E+01	0.4000E+01	0.3000E+01	0.7000E+01	0.5523E+01	0.1477E+01
5	0.2000E+01	0.5000E+01	0.5000E+01	0.4000E+01	0.3669E+01	0.3314E+00
6	0.5000E+01	0.1000E+02	0.3000E+01	0.7000E+01	0.6230E+01	0.7698E+00
7	0.8000E+01	0.6000E+01	0.4000E+01	0.7000E+01	0.6541E+01	0.4592E+00
8	0.3000E+01	0.7000E+01	0.7000E+01	0.4000E+01	0.4731E+01	-.7313E+00
9	0.7000E+01	0.8000E+01	0.9000E+01	0.9000E+01	0.6855E+01	0.2145E+01
10	0.8000E+01	0.1000E+02	0.4000E+01	0.5000E+01	0.7602E+01	-.2602E+01

DATE: 02-03-1989
TIME: 13:10:41

Figure B.10.2 Sample data output from the Statistical Routine.

COMPUTER PROGRAMS TO CORRELATE TEST DATA FOR AIR DIFFUSION DEVICES

By

KON SU SHIM

B.S. , Kansas State University, 1987.

AN ABSTRACT OF A THESIS

Submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Mechanical Engineering

Kansas State University,
Manhattan, Kansas

1989

ABSTRACT

In this thesis, computer programs are developed to help the manufacturers generate the required Air Diffusion Council forms and graphs necessary for the certification of air diffusers and mixing boxes. These programs include company flow meter calibrations, air flow measurement calculations, the throw-velocity calculations and graphs, and the sound test data calculations and the NC graphs. A multiple regression analysis procedure is used to correlate the experimental data, replacing the conventional graphical method. The computer program also allows the user to generate catalogs of performance data for diffusers and mixing boxes.