AIR MOVEMENT BY INJECTOR

Thesis for the Degree of M. E.

Joseph McKibbin Newman

1936

THESIS

Injectors

Mechanical engineering

AIR MOVEMENT BY INJECTOR

Thesis for Degree of M.E.

Joseph McKibbin Newman.

1 9 3 6.

Approved
June 2 - 1936
H B Dirks

THESIS

Appreciation.

The writer takes this opportunity to express his sincere appreciation for the generous assistance and cooperation given him by the Olds Motor Works in providing facilities for the various tests necessary in obtaining the data used in this thesis.

J.M. Newman.

Introduction.

Any system of air movement where energy is imparted to an air stream of relatively low velocity through the medium of a second air stream of relatively high velocity is here considered as an injector. The variations in the design of injectors cover a wide range and probably are as numerous as the air movement problems for which they have been a solution. This is due to the fact that the air injector is simple to design, inexpensive to build, and within certain limits - easily adjusted to produce the results desired.

Many attempts have been made to definitely evaluate the relations of the elements of design of an injector by the use of empirical formulas. Many of these formulas have been published and are used by industrial ventilating engineers. It is not the objective of this discourse to discredit either the origin or use of these formulas. They have been developed by experiment - and as a rule - represent good design for most practical applications. They are statements of the practical relations of the elements of design and rarely have a fundamental aerodynamic origin.

It is the objective of this discourse to make an aerodynamic analysis of the air injector and establish a guide to its design and application.

PROCEDURE.

The subject will be dealt with in somewhat the following manner:

Part I. Analytical Development.

A. Simple Preliminary Design.................... Page 1

1. The Nozzle................................ Page 1

2. The Air Jet............................... Page 3

3. Stack Diameter............................ Page 5

4. Stack Length.............................. Page 5

5. The Test Stack............................ Page 7

B. Tests to Verify Design..................... Page 7

Part II. Theoretical Development..................... Page 12

A. Basis of Theory............................ Page 12

B. Fundamental Equations...................... Page 12

C. Friction Analysis.......................... Page 15

D. Stack Nozzle Diameter Ratio................ Page 16

E. Theoretical Summary........................ Page 18

Part III. Variations in Design..................... Page 19

A. Venturi Stacks............................. Page 20

B. Straight Stack with Deflector-Cone Nozzle.. Page 24

C. Straight Stack with Converging Nozzle and Cone Deflectors................................ Page 24

D. Stacks with Annular Ring Nozzles........... Page 27

E. Design Summary............................. Page 29

Part IV. Applications.............................. Page 30

A. General Use.................................. Page 30

B. Paint Fume Removal.......................... Page 31

C. Corrosive Fume Removal. 31

D. Incircuit Injector 32

E. General Notes on Design 32

PART I.

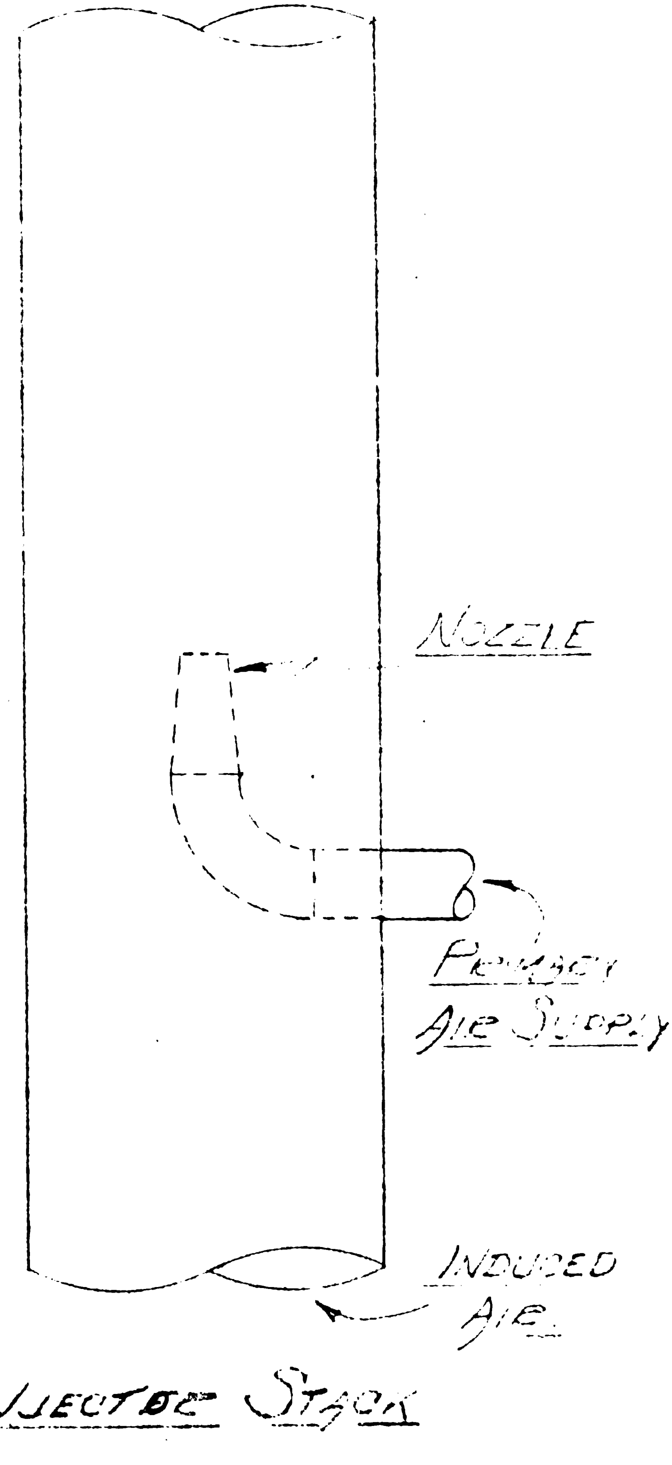
Analytical Development.

A. Simple Preliminary Design:

As a basis for discussion the writer has selected an injector stack of the simplest design - see figure 1 on the following page. Inasmuch as the primary objective of the injector is the movement of air, it is analogous to a fan. As a specific example, the centrifugal fan has two essential parts, i.e., the impeller which imparts energy to the air, and the housing which confines and directs the energized air stream. The injector stack is essentially the same. It has the nozzle for imparting energy to the air and the stack for confining and directing the energized air. If one were to assemble a fan for a specific purpose, extreme care would be taken in selecting an impeller and housing whose characteristics blended together would produce the results desired. The same care should also be taken in assembling an injector stack. The characteristics of each part should be studied and used as a guide in obtaining an efficient and balanced assembly.

1. The Nozzle:

The nozzle as the source of energy in the injector should receive first consideration. As will be apparent later in this discussion, the nozzle should produce an air jet with uniform intensity and a minimum of turbulence. With high nozzle velocities, it is also good practice to keep the approach velocity low in order to reduce the frictional resistance between the primary air supply and the nozzle. A study of the characteristics of various nozzle designs will lead to the selection of the converging orifice type



INJECTOR STACK

FIG. I

of nozzle. The writer recommends a converging orifice nozzle with an included angle of taper of 13° and an area of entrance three times the area of discharge. This gives an approach velocity of one-third the discharge velocity; it also breaks up stratification and reduces turbulence. This nozzle design and formula for its use are given in appendix I.

2. The Air Jet:

The air jet produced by a nozzle has characteristics which will be recognized as being of considerable importance in the jet's application to a stack injector. The American Blower Company gives a very descriptive chart on these characteristics in their book, "Air Conditioning and Engineering". This chart is given with some notes by the writer in figure II. By using it for a guide, tests were made roughly verifying the characteristics given and developing the following observations:

(A) The discharge opening of a nozzle should be very accurate in shape. For perfection, it should be smoothly machined to a true circle. Roughness or irregularity gives a distorted or one-sided jet.

(b) The included angle of the jets divergence as defined by distinct lines of force is not effected by the velocity of discharge.

(c) The stream line confines of the jet are well defined by force lines up to 15 nozzle diameters distant from the discharge. Beyond this point, turbulence, lack of confinement, and fading of force lines takes place.

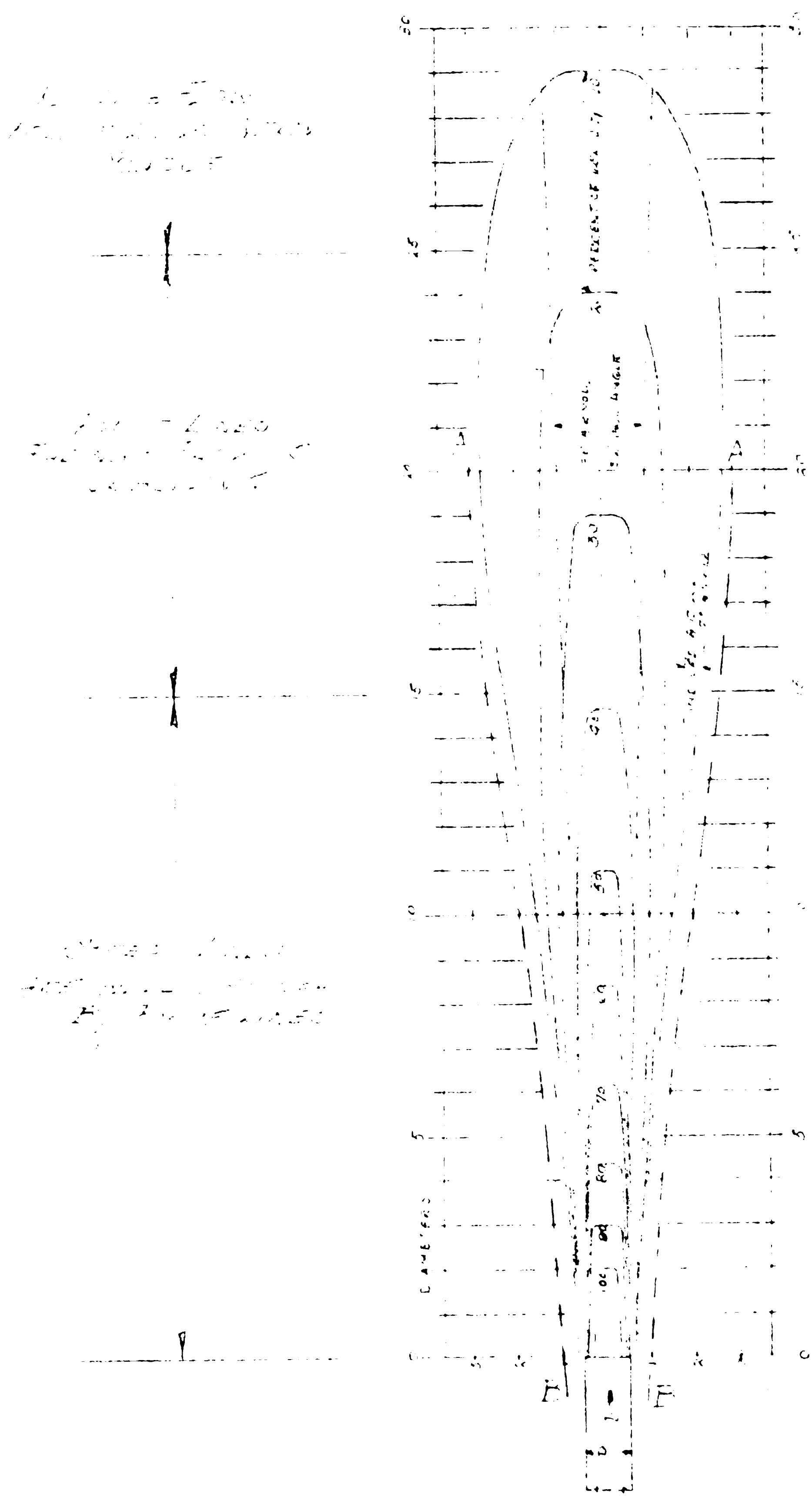


Fig. II

TAKEN FROM AMERICAN BLOWER

(d) When the air jet is projected into a smoke laden atmosphere, an induced disturbance takes place adjacent to and parallel in motion to the jet. The intensity of this motion increases as the distance from the nozzle increases. (The development and control of this characteristic is the elementary principle of the injector.)

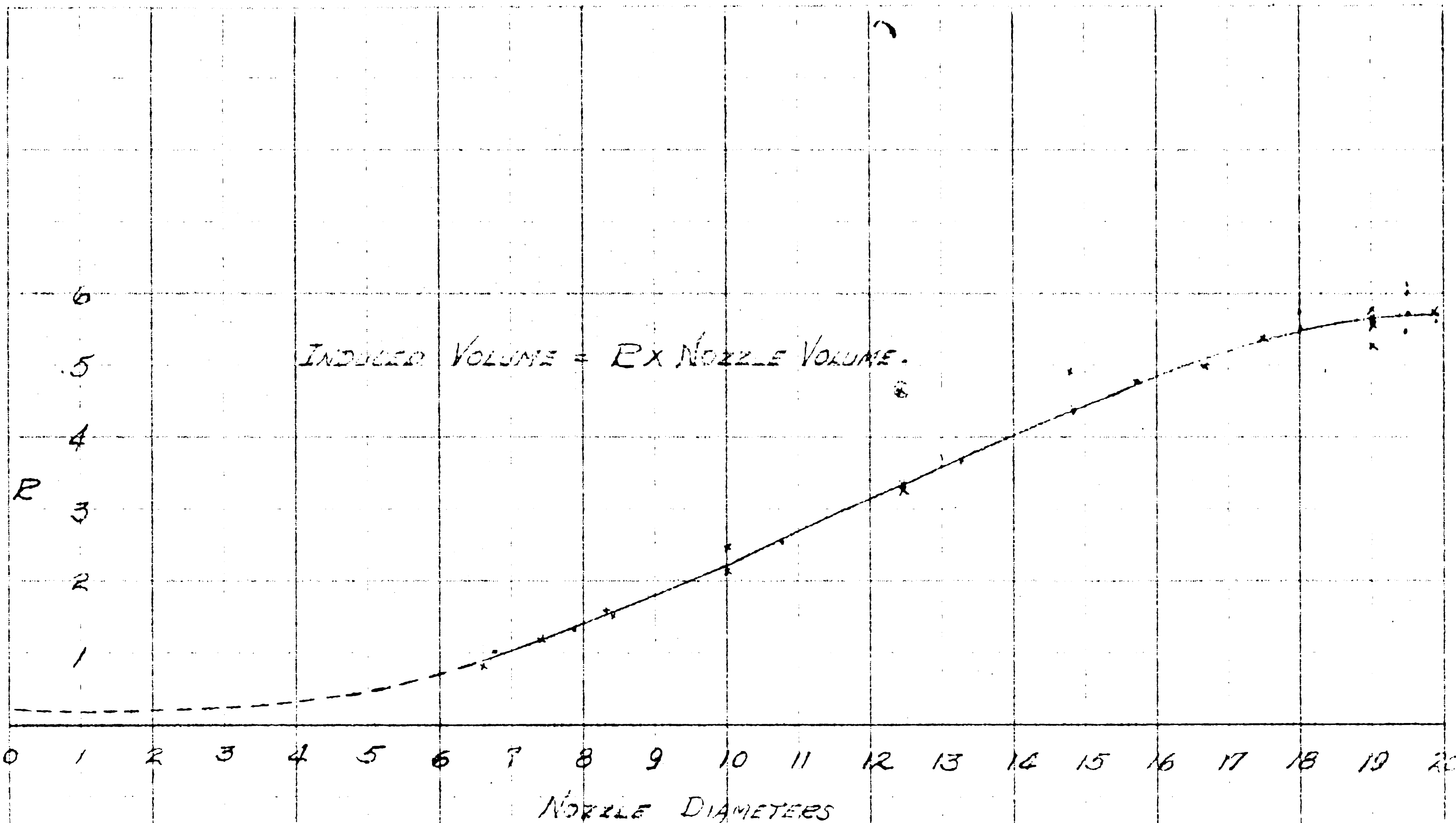
From these observations - together with figure II, relative stack dimensions can be determined. The following analogy was used by the writer in determining dimensions for a preliminary design.

3. Stack Diameter:

Figure II indicates that the maximum diameter of the jet defined by distinct lines of force is $5\frac{1}{2}$ nozzle diameters. Assuming that a stack larger than this ratio would act as an encumbrance on the air stream thru turbulence and friction, the writer chose $5\frac{1}{2}$ nozzle diameters for the test design. Subsequent tests proved this ratio to be a little too high. See Part II-D.

4. Stack Length:

It was observed that an induced motion parallel to the jet existed. Inasmuch as it is the development of this characteristic that we are primarily interested in, tests were made to determine the amount of the induced volume at varying points along the axis of the jet. The lines on figure II marked A-B were arbitrarily drawn to establish the diameters of imaginary circles. Circles were established at points as indicated, the air volume determined, and the results plotted in terms of the nozzle volume. See figure III. From this study, a stack length of 20m nozzle diameters was established. As will be shown later, this length is insufficient. See discussion under B-1.



DISTANCE FROM NOZZLE AT WHICH VOLUME WAS MEASURED.

FIGURE III

5. Test Stack:

Figure IV shows the test stack. That portion shown in dotted lines indicates the portion added for test purposes. The bell-mouth entranse gives a minimum entrance loss and is the basis for calculations. The length shown was developed by tests. The nozzle was made detachable with the idea of varying the nozzle sizes and studying nozzle-stack diameter ratios. .

B. Tests to Verify Design:

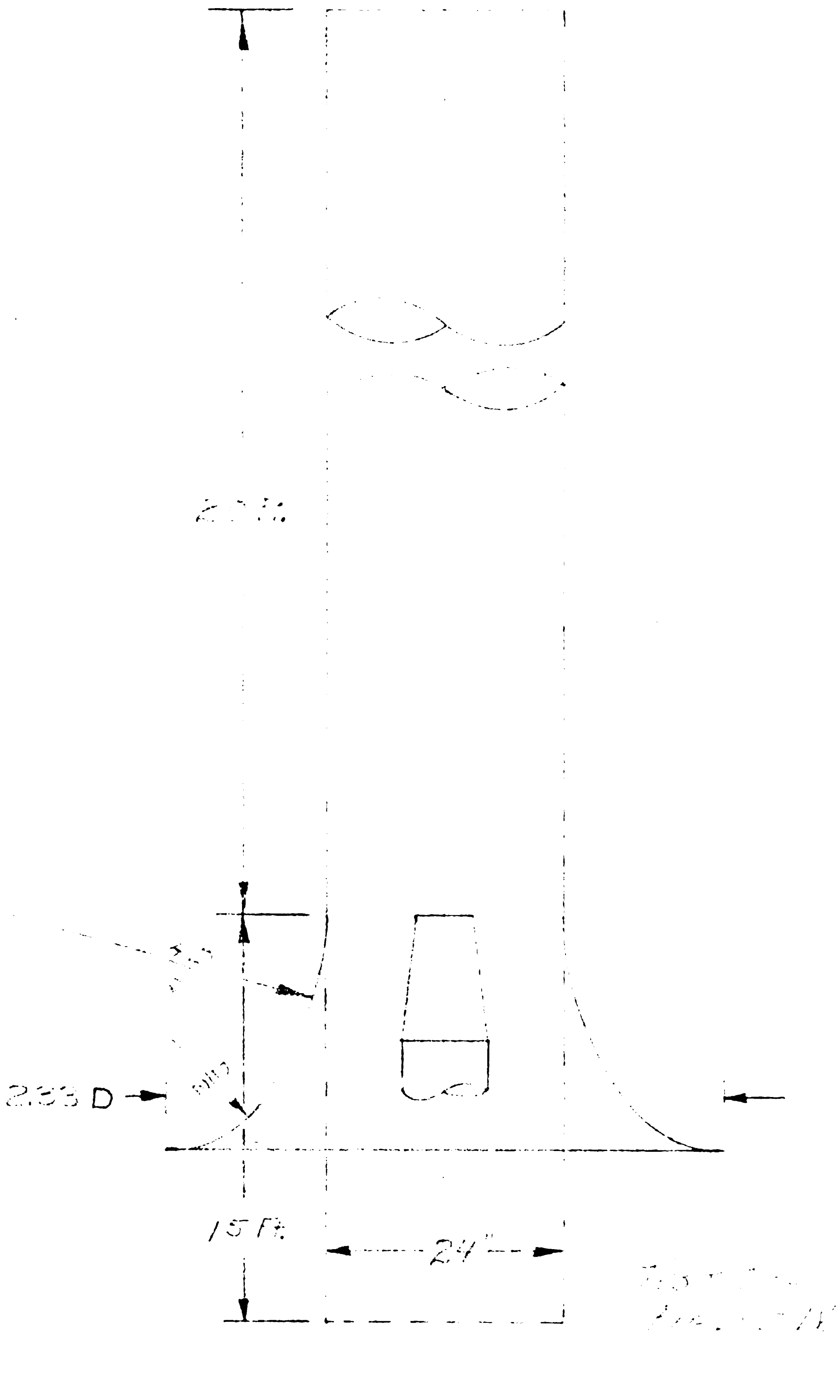
The following tests were made and the results were recorded. Many of the tests were repeated as many as twenty times under varying conditions of nozzle sizes, primary air pressures, and entrance and discharge resistanses. The results given are either the average or a specimen, as indicated.

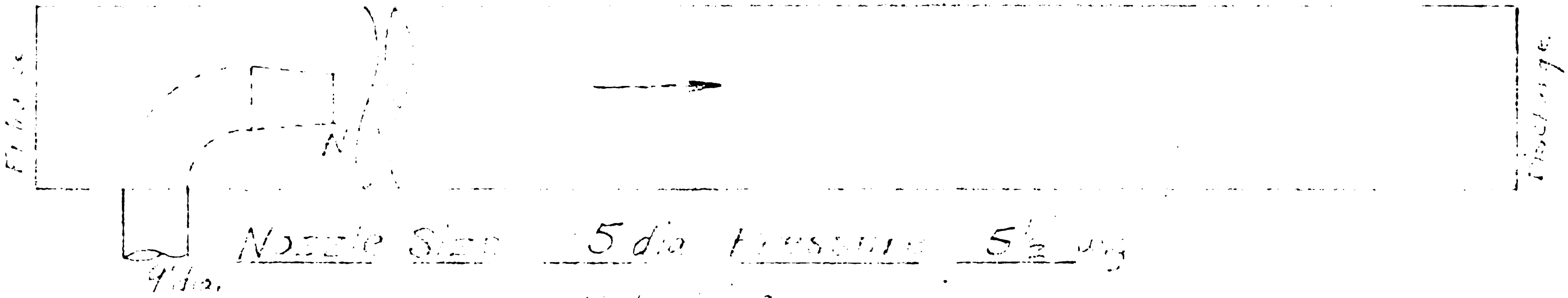
1. To determine the minimum length of stack necessary for maximum efficiency.

This test was run for nozzle sizes of 2", 3", 4", 5", and 6" diameter. The pressures on the nozzles varied from 2" water gauge on the 2" nozzle and 1" water gauge to 6" water gauge on the 6" nozzle. Figure V. shows a specimen test with a 5" diameter nozzle under 5" w.g., pressure. It was found that maximum entrance volume resulted when the stack was 40 nozzle diameters in length. This length was verified for the other nozzles at various pressures. It will be observed that at this distanse the cross-section of the discharge becomes practically uniform - indicating a minimum of stratification.

2. To determine the nature of the confined jet:

The results of this test are shown in figure VI. An attempt was made to apply this study to each nozzle size; however, the 5" diameter and


2.33 D
15 Ft.
24"



Nozzle Size 5 dia Pressure 5½ [illegible]

Velocity Pressures

Pt.	Distance from N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	.45	[illegible]	.50	.51	.57	.31	.45	.37	.35	.24	.24	.35
[illegible]		.45	.46	.48	.5	.51	[illegible]	.46	[illegible]	.43	.34	.38	.37
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	.55	.51	.47	[illegible]	.44	.42	.41	.40
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.5[illegible]	.57	[illegible]	.45	.43	[illegible]	.41
[illegible]		[illegible]	[illegible]	.60	[illegible]	[illegible]	.66	.60	[illegible]	.45	.45	.42	.45
[illegible]		.72	[illegible]	.70	[illegible]	[illegible]	[illegible]	[illegible]	.57	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	.72	.41	.45	[illegible]	[illegible]	[illegible]	.48	[illegible]	[illegible]	.42
[illegible]		1.5	[illegible]	.71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.41
A.		.71	.65	.51	[illegible]	[illegible]	.56	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
Av. [illegible]		[illegible]	[illegible]	.3	.4	.25		.1	.2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Test [illegible]

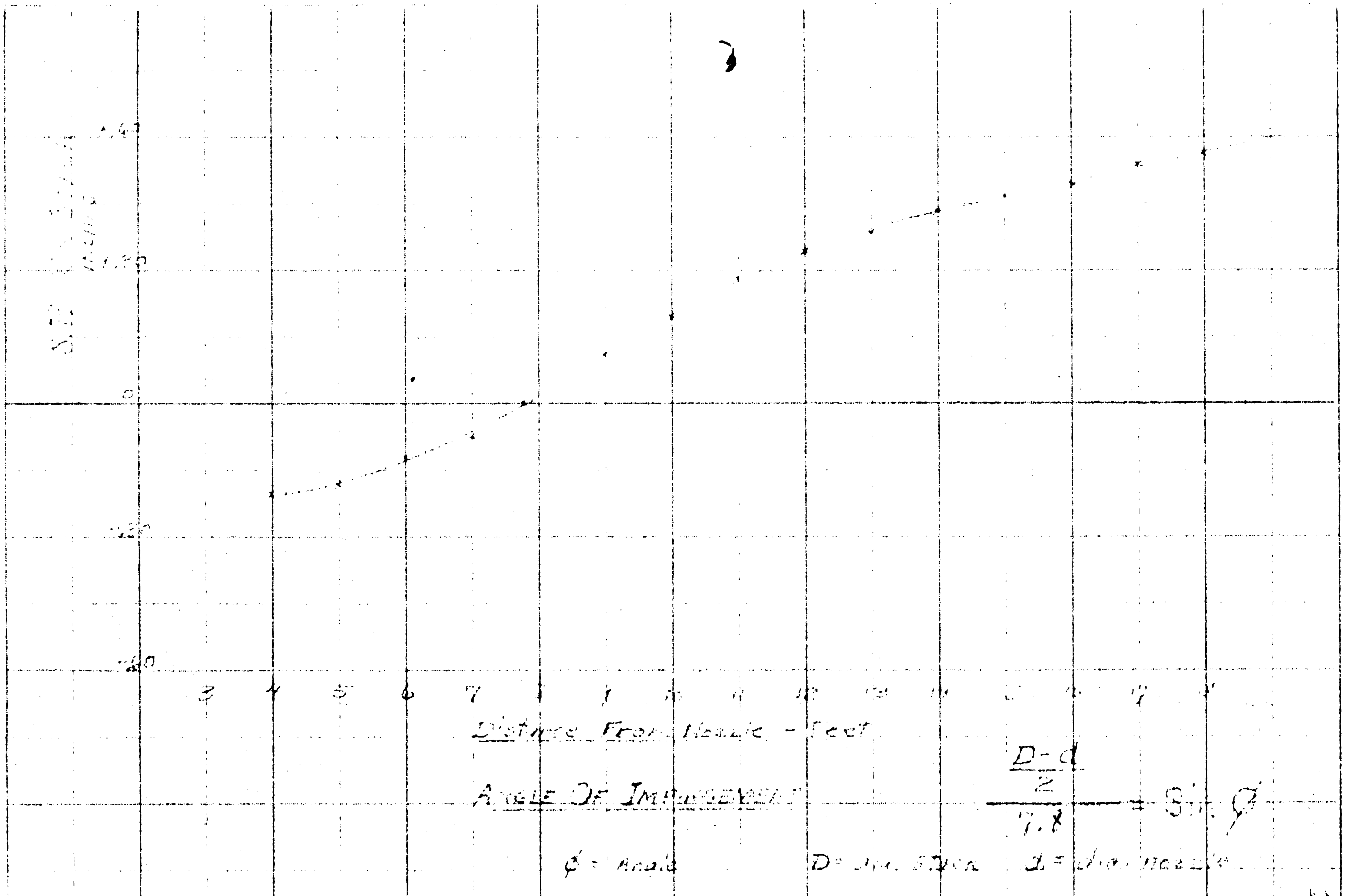

0
3
4
5
6
7
Distance From Nozzle - Feet
Angle Of Impingement
$\frac{\frac{D-d}{2}}{7.8} = \sin \phi$
ϕ = Angle

Fig. VI.

and 6" diameter nozzles were the only successful tests. By way of explanation - the writer suggests that the nozzles - smaller than 5" diameter could not completely fill a stack of 24" diameter. This theory is based on the maximum defined jet diameter as determined by the previous study of a jet. Figure VI. gives the results of a test on a 5" diameter nozzle at 5" w.g.,pressure.

3. Determine the effect of varying the stack-nozzle diameter ratio as indicated by the efficiency of the equipment.

This test is discussed in part II.

PART II.

Theoretical Development.

A. Basis for Theory - See Test Stack - Figure IV.

Tests were made by use of the section shown in dotted lines. This was necessary for making reasonably accurate measurements. For theoretical analysis the stack must take the form shown in heavy lines. The conditions to be taken into consideration in the analysis are as follows:

1. The bell-mouth entrance offers a minimum of resistance. It forms a basis from which all development must be in the form of increased entrance resistance.
2. The full discharge length is essential for complete mixing of the two air streams as indicated by tests already discussed.
3. All losses in the primary air stream previous to the discharge opening of the nozzle are considered as part of the primary air supply system and not part of the injector stack.

B. Fundamental Equations:

As previously mentioned, the fundamental action of the injector is the transfer of energy from an air stream of relatively high velocity to another air stream of relatively low velocity. Expressing this action in the form of an equation, we have

$$E_N = E_D + E_F \qquad (1)$$

where

E_N = energy of the nozzle.

E_D = energy of the air stream at discharge.

E_F = energy absorbed by friction.

If this equation were expressed in terms of the mass-energy equation where

$$E = \frac{1}{2} MV^2 \qquad (2)$$

it would read as follows:

$$\frac{1}{2} M_N V_N^2 = \frac{1}{2} M_D V_D^2 + E_F \qquad (3)$$

where

M = mass of primary air

V_N = velocity of discharge in feet per second.

M_D = mass of secondary air plus primary air at discharge.

V_D = velocity of combined primary and secondary at discharge in feet per second.

E_F = energy consumed by friction.

Inasmuch as M_D consists of the two masses, primary and secondary air, equation number three (3) can be further expanded to

$$\frac{1}{2} M_N V_N^2 = \frac{1}{2} M_N V_D^2 + \frac{1}{2} M_S V_D^2 + E_F \qquad (4)$$

where

M_S = mass of secondary air.

Stating MV^2 in terms of air volumes and velocities the equation becomes

$$\frac{1}{2} \cdot \frac{Q_N \cdot w \cdot V_N}{2g} = \frac{1}{2} \cdot \frac{Q_N \cdot w \cdot V_D}{2g} + \frac{1}{2} \cdot \frac{Q_S \cdot w \cdot V_D}{2g} + E_F \qquad (5)$$

where

Q = quantity of air in cubic feet per second

g = acceleration due to gravity in feet per second 32.2

w = weight of air per cubic foot.

E_F being a constant determined by experiment and varying for different values of Q and V - equation #5 can be cancelled out to show a more direct functional relation between the variables V and Q. The equation becomes after clearing

$$Q_N \cdot V_N = V_D \left(Q_N + Q_S \right) + F \qquad (6)$$

"F" being the new constant for friction.

From this relation observe the following:

Assume the value of the equation remains constant.

1. If Q_N varies
    a. V_N varies indirectly.
    b. V_N varies directly.
    c. Q_S varies indirectly.
    d. F varies directly.

2. If V_N varies
    a. V_2 varies indirectly.
    b. Q_N varies indirectly.
    c. Q_S varies directly.
    d. F varies indirectly.

Let it be observed that the amount of energy available for use on the secondary air is dependent on the amount used in moving the primary air. In other words - the smaller the volume of primary air the greater the possibility of high efficiency in terms of energy applied. Following this logic - the efficiency of the energy transfer depends on the amount of available energy which can be expressed as

$$E_a = \frac{Q_s}{Q_N + Q_s} \cdot E_N - E_F \qquad (7)$$

where E_a = available energy.

C. Friction Analysis:

This leads us to the necessity of holding E_F to a minimum. Friction can be classified as one of two forms, either internal or external. Internal friction is considered as those losses in energy transfer due to the characteristics of the equipment which can be controlled - to a very great extent by care in design. External friction consists of the physical requirements of the application which are controlable only to a small degree. It is the same friction a fan would have to work against if it were applied to the same job. For the sake of making clear the effect of design on the amount of energy lost by friction of either classification - both classes are enumerated below.

Internal Friction:

1. Poorly shaped nozzles can give a one-sided jet, spending energy in a non-effective blast-turbulence, and friction against the stack walls.
2. Improperly proportioned stack-nozzle diameters can spend energy in turbulence, skin friction, or excessive secondary velocity. See Section D.
3. Improperly installed nozzles (out of line or loose) develop the same troubles with friction as noted in #1.
4. All duct work should be smooth and stream-line.

External Friction:

1. Elbows, tees, canopies, booths, etc.,
2. High velocities, restrictions, etc.
3. Excessive lengths of entrance and discharge ducts.

4. Leaks in joints and seams.

5. Sprinkler lines inside stacks, etc.

Internal friction cannot be evaluated except by test. External friction can be evaluated in terms of velocity head or static pressure. When known in terms of static pressure the energy consumed can be calculated by use of the equation

$$E_F = (Q \times P \times .0865) \text{ foot pounds per second.} \quad (8)$$

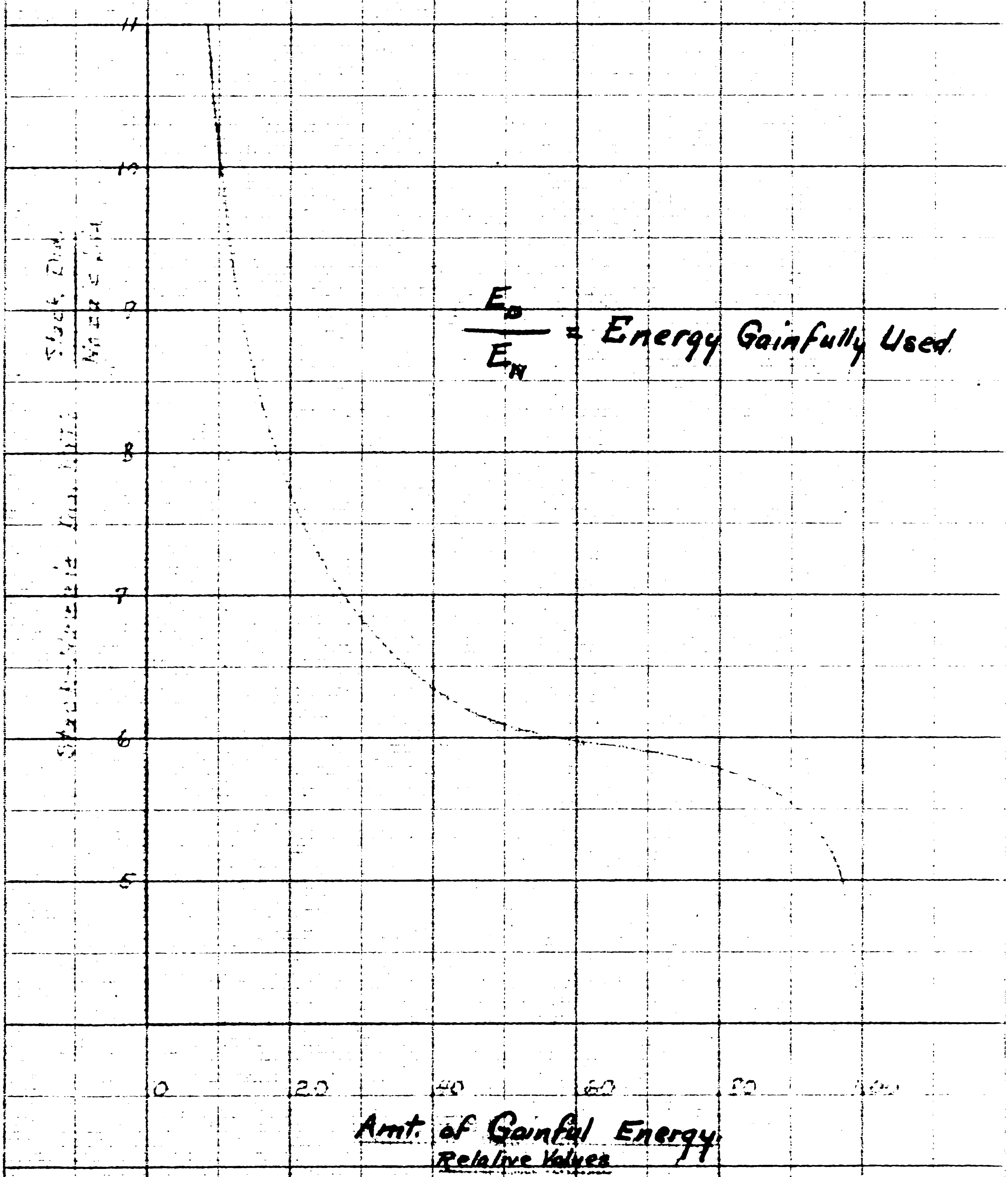
where

P = static pressure in inches w.g. .0865 = foot pounds per second required to move one cubic foot of air per second against one inch pressure water gauge.

D. Stack-Nozzle Diameter Ratio:

In Part I - Tests, a reference was made in regard to a test for determining the proper stack-nozzle diameter ratio. The discussion and results of this test were differed to this later treatment due to the fact that their understanding should be founded on the foregoing theoretical development. The results are shown as figure VII. The curve shows the percent of primary air energy actually consumed in air movement. Stating the curve in the form of an equation

$$\frac{E_D}{E_N} = \text{Nozzle Ratio Efficiency.} \quad (9)$$



$\frac{E_D}{E_N}$ = Energy Gainfully Used
11
10
9
8
7
6
5
0
20
40
60
80
100
Amt. of Gainful Energy
Relative Values

Fig. VII

E. Theoretical Summary:

As can be observed in equation #6, the successful injector depends on the balance developed by the designer for the relation between five variables. In order to properly design an injector for a specific application, each of the variables must be evaluated in terms of the conditions set up by the application. If this is followed out in a logical sequence - the design is simple and definite. A plan of logical procedure is here given.

1. Determine the velocity of the secondary air and figure the necessary stack diameter to handle the volume required.
2. Determine the energy required to move the secondary air at the velocity selected - use equation #2.
3. Determine the additional energy required for overcoming approach resistance or friction.
4. Select the volumetric ratio of primary to secondary air.
5. Determine the energy required to move the combined volume of secondary and primary air at the velocity established in #1. Use equation B-2.
6. Determine the energy necessary for overcoming friction in the stack. This value can be assumed to be from 2% to 5% of the energy at the nozzle.
7. By use of the sum of items 3, 5, and 6, and the primary air volume the area and pressure of the nozzle can be determined. For this - use either the calculations of appendix I together with equation #6 - or the chart given in appendix II.

The overall efficiency can be figured by dividing the sum of items #2 and #3 by the power input.

PART III.

Variations in Design.

The foregoing has dealt entirely with what has been referred to as a simple design. An attempt was made to show the fundamentals of this method of air movement. As will be shown in the following discussion, this method has been used in several different stack designs; however, the fundimental principle remains the same and the fundimental equation given as B-6 on page 14 holds true for each design. This equation was used by the writer in some 100 tests and found to be consistent. There are four fundamental deviations from the simple stack design. Each of these are given in the following discussion; however, the writer feels safe in stating that an increase of efficiency, by any one of them, of over 5% would be unusual and excessive.

The test stack with the bell-mounthed entrance (figure IV) eliminates all the resistance of approach. This leaves the throat and discharge end as the only remaining parts that might be improved. It was stated previously that the friction in a well designed stack might run as high as 5% on the discharge. Following this line of reasoning, it might be said that all that could be expected of any improved stack would be a possible increase of 5% in efficiency - speaking of available energy only.

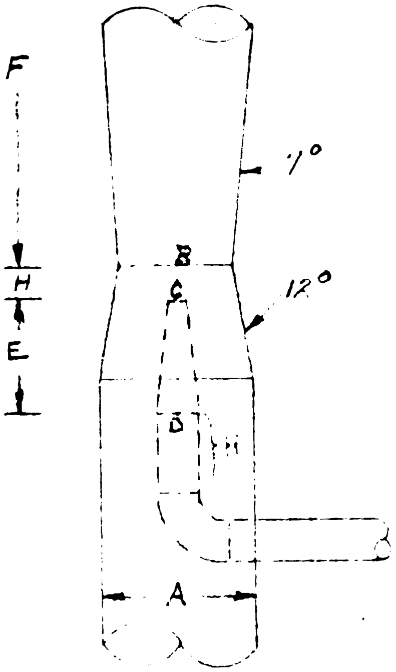
A. Venturi Stack:

Figures VIII, IX, and X show venturi designs of more or less empirical origin. This type was used by one of our largest industrial ventilation engineering and contracting firms for a number of years. It was claimed to be the most efficient of all stack designs; however, they admit now that it never showed an advantage of over 5% over other designs. Their claims contended their increased efficiency was due to reduced discharge resistance - and increased efficiency of energy transfer by high throat velocity. The reduced discharge resistance is admitted. By use of the venturi it is possible - under ideal conditions - to reduce this resistance to a negative quantity - actually creating a slight suction on the throat. The contention for high throat velocity seems rather unfounded as it, in itself, requires a greater amount of energy than if a lower velocity were used.

Physically the stack has several characteristics noteworthy of mention.

1. Its design appears difficult; however, it is simple, as adjustments are always provided to compensate for errors in design. See note on figure IX.
2. It is expensive to fabricate as many different patterns are necessary.
3. The small throat makes the upper portion inaccessible for cleaning or maintenance.


4
2



VENTILATION

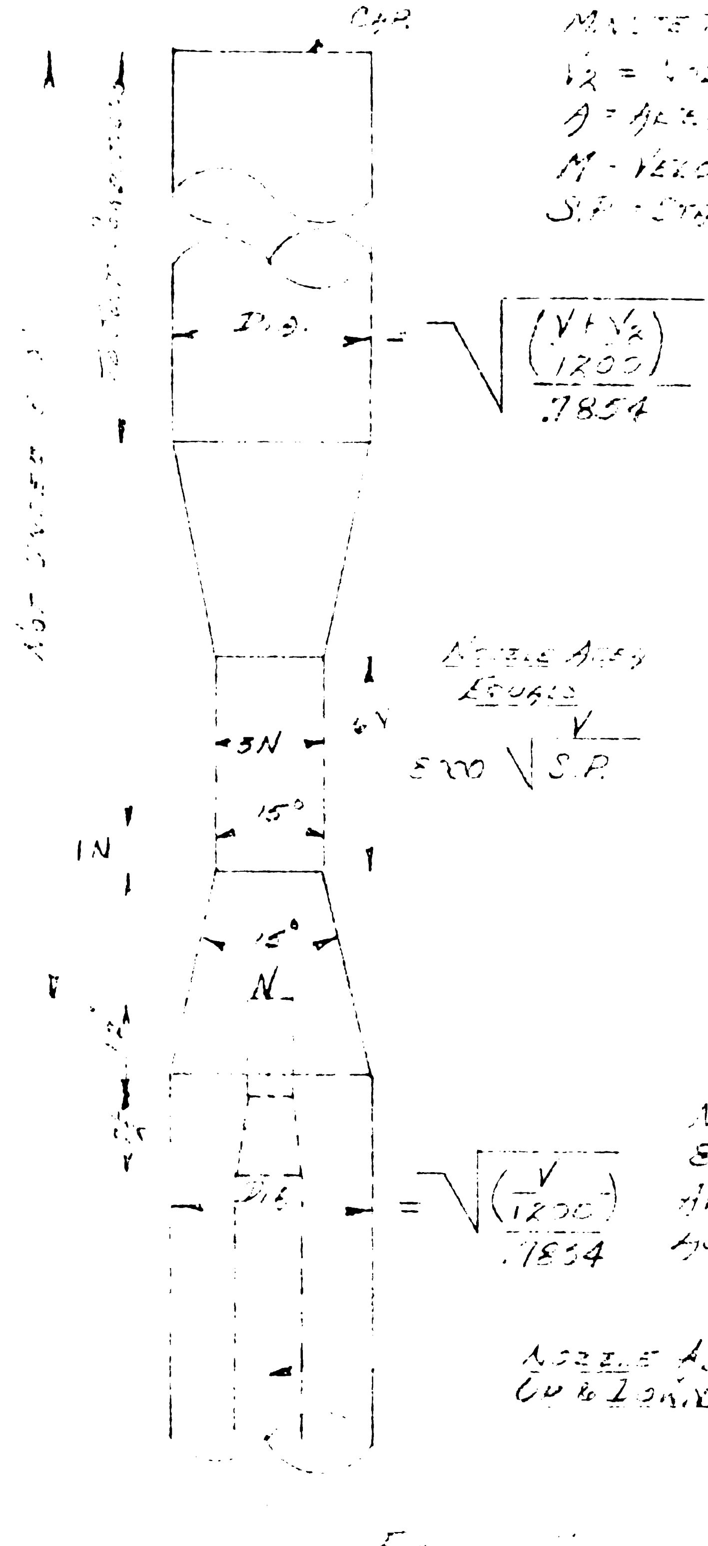
Spray Booths

A = 100% for Velocities of 1500 To 2000
B = 50% of Area - A
C = 7% " " "
D = .5% " " "
E = 66% " Dia. "
F = 500% " " "
G = 25% " " "
H = Variable
Pressure @ C = 5 × Pressure @ A
But never less than 5" W.G.
Use 6" W.G. for Safety

Note

VENTURI STACK
FIGURE IX

V = [illegible]
M[illegible] TO BE HANDLED
V_2 = NOZZLE VOLUME = AM
A = AREA IN SQ. FT.
M - VELOCITY - FT./MINUTE
S.P. - STATIC PRESSURE [illegible]



STACK DIA AT BASE	NOZZLE DIA - N
15"	4
18"	4
24	5"
27"	5"
30"	5"
33"	6"
36"	6"
42"	7
48"	[illegible]

NOTE
8000 FT/MIN NOZZLE VEL. [illegible]
AVERAGE CONDITIONS [illegible]
[illegible]

NOZZLE ADJUSTMENT
[illegible] ONLY 3"

B. Straight Stack with Deflector-Cone Nozzle.

Figure XI shows a straight stack design with a deflector-cone nozzle. The objective of this type of nozzle is to obtain an immediate mixing of the two air streams and thereby shorten the necessary length of the stack. It is the opinion of the writer than an attempt in this direction is false economy. Changing the diverging angle of the jet, changing the course or direction of the jet, or changing the course of the secondary air stream involves restrictions or interference which produce friction. The savings accomplished by shortening the stack would not pay for very much energy consumed by friction when figured over the anticipated life of the equipment. It could also be expected that this type of nozzle would have a greater action than other nozzle designs in blasting intrained pigment against the walls of the stack.

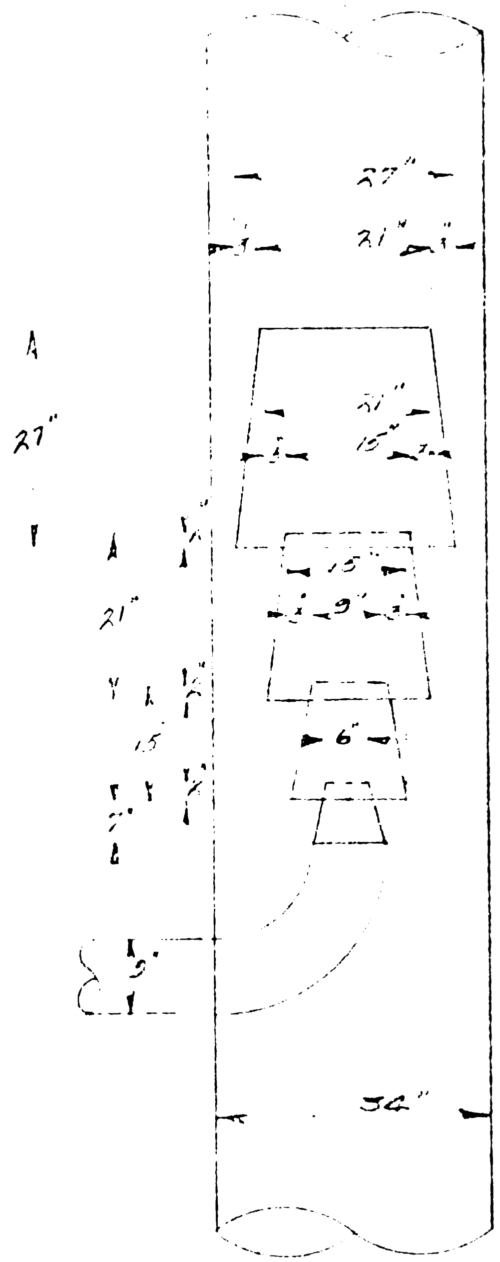
C. Straight Stack with Converging Nozzle and Cone-Deflectors:

Figure XII shows another design intended to shorten the stack. This design is patterned after the Schutte-Koerting draft boosters. The idea is good when applied to stack-nozzle diameter ratios greater than 5½. The Schutte-Koerting designs were for use in large diameter chimneys with small high pressure nozzles. The application of this idea to air movement within the scope as here discussed could be criticized in the same manner as followed in discussing the design of figure XI. Actual experience by the writer has proved the criticisms to be true and not a matter of opinion.

[illegible]

[illegible]

[illegible] II



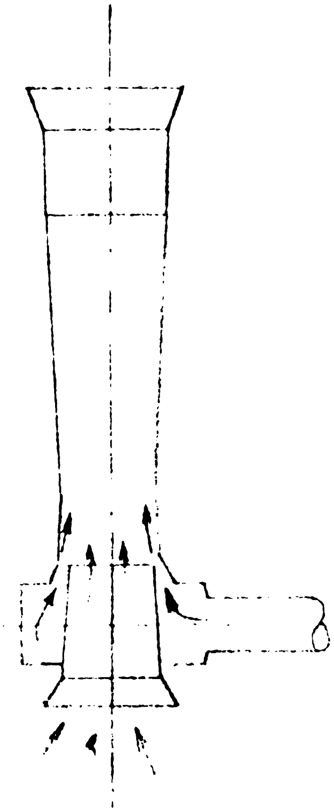
[illegible]
[illegible] and Cone De[illegible]
Figure VII

D. Stacks with Annular Ring Nozzles:

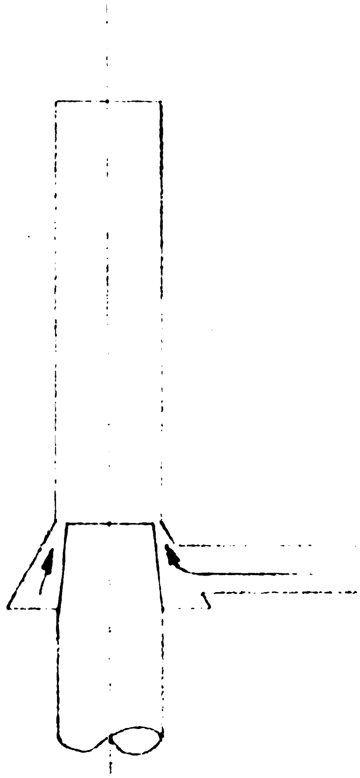
Figures XIII and XIV show the latest developments in nozzles for an injector stack. This design probably has more arguments in its favor than any other deviation from the simple stack design. Figure XIV is the later development and is now being used very successfully. The principal points of construction are the protective skin for the stack - formed by the primary air, the shorter required stack design, the low pressure primary air, and the ease of cleaning and maintenance.

The only criticisms on this stack are directed against the designer's claims for higher efficiency. If the efficiency of the stack is figured on the basis of the whole system, including the primary air fan and motor - the contentions could fall beyond criticism. If the contention is limited to the stack alone - it is poorly founded. To bear out this point the writer has prepared a graph shown in appendix #II. This graph is based on calculations only - but it shows the increase of available energy by increased primary air pressures. It will be observed that the amount of available kenetic energy in the primary air, with the primary air volume constant, is directly proportional to the primary air pressure. This is true regardless the design of the nozzle.

However, this attack on the contended efficiency of the annular-ring-venturi stack should be modified. The overall efficiency is the important consideration in the long run. This design, although possibly of low efficiency as a unit, has several characteristics which - when balanced in ultimate results - place



Annular Ring-Venturi Stack
Figure XIV



Annular Ring Straight Stack
Figure XIII

it in the opinion of the writer as the best of current practical design. To support this opinion the following points are enumerated:

1. The stack is simple to design.
2. It is relatively more expensive to build.
3. It is convenient to clean.
4. It requires a greater volume but lower pressure primary air. This results in a greater efficiency of primary air supply.
5. The venturi stack reduces stack back pressures.

Design Summary:

To summarize the merits of the various stack designs the writer has chosen to construct a chart which is given as figure XV. The qualifications of each stack are given as the opinion of the writer; they are the result of personal experience, experiences of others, and ordinary deduction and study. No stack could be designed ideal for all applications. Each stack has some one outstanding characteristic which may make it ideal for a specific application. An attempt has been made to bring out the chief characteristics of each design and pick out the one stack design which - in the opinion of the writer - would be most satisfactorily used for the average applications.

Figure	Name	Stack Efficiency	Design	Shop Work	Cost		Cleaning
					Labor	Material	
IIV IX X	Venturi	Good	Many Details	Intricate	High	Average	Hard
XI	Straight Stack Cone-Nozzle	Low	Minimum Detail	Simple	Low	Low	Easy but plenty
XII	Straight Stack Cone Deflector	Low	Many Details	Intricate	High	High	Hard and plenty
XIII	Straight Stack Annular R.	Good	Minimum in Detail	Simple	Low	Average	Easy
XIV	Venturi Annular R.	High	Average in Detail	Simple	Average	Average	Easy
IV	Test Stack	Good	Minimum Detail	Simple	Low	Low	Easy

Relative Merits of Stack Designs
Figure XV.

PART IV.

Application.

A. General Use:

All problems of air handling can be solved more efficiently and more economically than by use of the injector, when considered from the power standpoint alone. The use of the injector should be the result of careful deliberation on all the circumstances influencing the application. Relatively speaking, the injector is low in first cost but costly to operate. Keeping this thought in mind its use will generally fall in one of the following applications:

1. Increase draw of furnace stack for periodic operation.
2. Remove smoke or steam from process operations when use is only occasional.
3. Remove corrosive fumes from process operations.
4. Remove fumes and fog from spray painting operations.
5. Handling air where space will not permit the installation of a direct operating fan.
6. Handling air where the investment in a direct operating fan is prohibitive when compared to using a high pressure low volume blower that may be on hand.

Statements have been made to the effect that an injector stack should never be used in a position where the jet motion is not up. The impression seems to be prevalent that the success of the injector largely depends on a natural draft action. The writer takes the liberty of correcting this impression. Tests have proved that the advantage realized by use of the natural draft created in a sheet metal stack (except where heated air is handled) is very small and not dependable. The writer advises the use of the injector in any position advantageous to the application, providing sufficient length of straight stack is available for proper approach and discharge conditions. Less friction is encountered if the injector is located near the discharge when long runs are necessary. Whether the injector or a fan is used, provision for replacement air is necessary.

B. Paint Fume Removal:

The injector stack has worked very satisfactory in removing pigment or varnish laden fumes from paint spraying operations. There is equipment on the market now that works on this application more efficiently and economically than the injector. The air is drawn through a scrubber and filter, thence into a fan and discharged to the atmosphere. It is high in first cost but low in cleaning and power costs. If a job is to be short in life and will not require excessive cleaning, the injector will probably figure out to be the best investment.

C. Corrosive Fume Removal:

This type of application is a very good example of an air handling job where the injector is most successful. The parts of the equipment coming in contact with the fumes are standard gauge sheet metal, easily treated for corrosive resistance. The fan can be standard design and not risk the necessity of frequent replacement. The injector figures to be the most advisable investment for this application when compared with the cost of a fan of special material or special treatment.

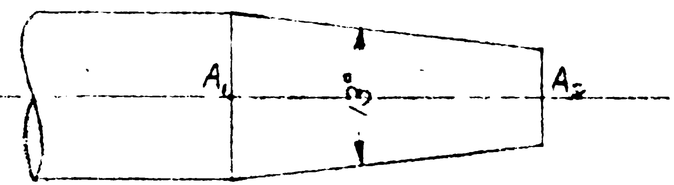
D. Incircuit Injector Fan:

Many applications of the injector stack require the movement of air that is relatively clean and would not be detrimental to the fan. In cases of this nature - the fan may be connected somewhat as shown in figure XVI. This arrangement saves the energy lost in handling the primary air and increases the overall efficiency considerably.

E. General Notes on Design:

Although the injector normally would not be used for back pressures as high as would be the case with a fan, the same precautions in design must be followed. Losses due to poor design are more costly with an injector than with a fan - due to the share of energy necessary for conveying away the primary air. Some items not to be overlooked are as follows:

1. Plan the duct velocities low to avoid unnecessary friction, 1,200 to 1,500 feet velocity.
2. Plan all hoods, elbows, tees, branches, and canopies for a minimum of resistance.
3. Plan all systems with a means of replacing the air exhausted.
4. Take the primary air from outside to avoid heat loss. This does not apply to air incircuit hook-up.
5. Locate the nozzle in a straight run of pipe - at least four pipe diameters from any elbow and have sufficient stack to give at least 50 nozzle diameters before a discharge elbow is encountered.



A = Area $\qquad A_1 = 3A_2$

$$Q = 1096.5 \times C \times A_2 \times \sqrt{\frac{P}{W}} \times \sqrt{\frac{1}{1-(A_2/A_1)^2}}$$

Where:

Q = Discharge in C.F.M.

C = Coefficient of Discharge (.961)

A_2 = Area of Orifice in Square Ft.

A_1 = Area of Pipe in Square Ft.

P = Pressure Producing Flow in Inches W.G.

W = Weight of Air per Cu. Ft.

Appendix I.

[redacted]

[redacted]