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IBIS INTERNATIONAL, INC.
DESIGN STANDARDS
FOR DUCTING OF EQUIPMENT

INTRODUCTION

This bulletin will assist in the design and modification of ducting used to connect IBIS equipment to machinery or areas requiring process air filtration, dust pick up, or material conveying. This bulletin is an overview of design considerations and standards used when designing ducting for use with our equipment. It is not a replacement for a text on the fundamentals of high air velocity duct design and pneumatic conveyance of material. Additional reference material include: SMACNA Design Manual, Industrial Ventilation Manual and the Nuclear Air Cleaning Handbook.

SYSTEM TYPES

Process air, exhaust, and material conveying are the three types of systems, which will be discussed. Many processes require the use of air for one purpose of another. In many instances this air is contaminated by the process and needs to be transported to a central point to be filtered before being released back into the atmosphere. An exhaust type system also transports polluted air from various areas to a central location for filtration.

This system differs from the process air system in that the air being polluted is not actually being used in the manufacturing process, it is used only to gather and transport the pollutants to a central point for filtration. In these systems the ratio of weight of pollutant transported to weight of air needed to transport it is very low (.1 and below).

Systems in which the ratio of weight of material to weight of air is above .1 are considered to be material conveying systems. For fan powered systems a maximum ratio of weight of material to weight of air is 1:1. Material conveying systems differ from process air exhaust systems because the material being conveyed causes friction in addition to that of air alone.

For systems in which the weight of material to weight of air is .1 or below, the friction for air alone can be used for design. For higher ratios, a certain percentage resistance above that of air alone must be factored in.

DESIGN

Many things must be known to properly design and size a fan powered air filtration or conveying system. Air velocity and quantity must first be determined and then a duct system and fan must be chosen. The fan selection not only includes type but also motor size.

The quantity, or volume per unit time, of air required to move a specific weight of material, capture the particles in a certain area, or needed for a process is largely decided by empirical testing. For fan conveying systems, a ratio of one pound of air per pound of material to be conveyed is the maximum. This ratio has much to do with the pressure and power required to convey the material. Figures for quantity of air needed to run certain equipment are supplied by IBIS or by your equipment's manufacturer.

When designing duct to convey particulate laden air, velocity is the most governing factor. Velocity will be given in feet traveled per minute (denoted by fpm or ft/min). The duct size, fan size, and fan type is determined by the velocity needed to convey a material, the amount of air needed to convey the material, and the distance which the material is to conveyed. The system must be designed to move the particulate laden air at a velocity which does not allow the particulate to fall out of the air stream and clog the duct. The velocity required to "float" the particulate is a function of the particulate's size, shape, and specific weight. Air velocity is determined by the cross-sectional area of the duct, the fan capacity, and the fans ability to overcome friction caused by the air and particulate moving through the duct. Pulp fiber/fluff and other similar material should be conveyed at 3500 to 4500 fpm. Velocities for other commonly conveyed material are given in table 1. Note: cubic meters per hour is a common metric volume with normal velocities in the range of 18 to 23 meters per second.

Air quantity through a duct with a specific cross-sectional area can be calculated by the following formula:

$$Q=VA$$

Where : V=Velocity, fpm (m/sec.)
Q=Quantity, cfm (m^3/hr).
A=Cross-sectional area, ft^3 (m^2).

Friction can be defined as the resistance to movement or flow caused by two substances rubbing or interacting together. We will be mainly concerned with the friction generated by the air and material interacting with the duct walls. The resistance present is dependant on the velocity of air and amount of conveyed material present. In fan powered systems the resistance is generally given in the form of pressure loss per unit length of pipe. Since pressure losses are generally low, the loss is expressed in inches of water (mm H_2O). Various tables and charts are available for friction or pressure values for straight pipe and fittings. Although tables are handy for determining pressure losses, a ductulator will make things easier.

Ductulators, available from most HVAC suppliers are very useful when determining friction losses in a duct system. Contact IBIS for your ductulator.

The material being conveyed causes resistance above that of air alone. This extra friction depends on many things, but there is a general rule of thumb to follow in determining it. This extra resistance can be expressed as a percentage of the resistance caused by the air alone. In general, this percentage equals the ratio of weight of material to weight of air multiplied by 50%. For most fiber conveying systems, the resistance of air alone is adequate for design purposes.

TABLE 1 Float velocities for various materials

Material	Approx. Wieght Per cu. Ft. Lbs.	Average velocity to convey (FPM)	Suction to pick-up (inches of water)
Ashes, coal	30	5500	3
Beans	28	6000	4
Buffing		3700	2 ½
Cement	100	7000	5
Cork	14	3000	1 ½
Corn, cobs	25	5500	2 ½
Corn, ear	56	6000	4 ½
Corn, shelled	45	5500	3 ½
Cotton, dry	5	3500	2
Grinding dust	30	4500	2
Lime, hydrated	30	5500	3
Malt	35	4800	3
Mineral wool	12	3500	2
Paper cuttings	20	5000	3
Rags, dry	30	4000	2 ½
Sawdust, dry	12	3500	2 ½
Shavings, light	9	3500	2 ½
Shavings, heavy	24	4000	3
Wheat	46	6000	4
Wool, dry	5	3500	2

Pressure loss due to acceleration of the material being conveyed needs also to be added to the total. A relatively simple formula for determining this loss follows:

$$Fq=2.25\ Rp$$

Where: Fq=Pressure loss due to acceleration, inches of water
R=Ratio, lb of material per lb of air
p=Velocity pressure inches
$p=(V/4500)^2$

The power required to move a certain weight of air with a specific fan can be found by reviewing the fan curve provided for the fan by the manufacturer. When material is added the poser requirements go up. A good rule of thumb is to add a percentage more hp than suggested by the fan curve, this percentage can be found by multiplying the ratio of 1 lb material to l lb air by 25%.

If you are more familiar with the metric system of measurement the following conversion factors will be useful:

Length:	1 foot (ft) = 3.048×10^{-1} meters (m)
Area:	1 square foot (ft^2) = 9.29×10^{-1} square meters (m^2)
Volume:	1 cubic foot (ft^3) = 2.832×10^{-2} cubic meters (m^3)
Quantity:	1 cubic foot per minute (ft^3/min) (cfm) = 1.68 cubic meters per hour (m^3/hr)
Velocity:	1 foot per minute (ft/min) = .005 meters per second (m/s)
Pressure:	1 pound per square inch (1 lb/in^2) (psi) = 7.031×10^2 kilograms per square meter (kgs/m^2)
	1 inch water column = 25.4 millimeters water column

EXAMPLES

To illustrate the use of the principals and techniques forwarded earlier two examples follow:

Problem 1: Duct work and fan sizes need to be determined for connecting drum filter to a diaper machine. This requires duct for process air filtration. Please refer to figure #1 on page 5.

GIVEN:

*Diaper machine requires 6000 cfm @ -6" water static pressure. (10,080 m^3/hr @ 152mm H_2O)

*3% of cellulose fiber entering forming chamber goes through forming screen.

*Diaper machine makes 400 diapers per minute with a pad weight of 50 grams.

SOLUTION:

The amount of fiber transported per minute is 400 diapers/min x 50g/diaper x .0205 lb/g x 3% = <u>12.3 lb/min</u> 6000 cfm air = 450 lb/min air. This means that the material to air ratio is .027. In this case friction and power requirements for air alone can be used since the ratio is below 0.1. The proper transport velocity for cellulosic fiber is about 4000 fpm. Using the equation for velocity on page two, 6000 cfm at 4000 fpm requires 1.5 sq ft cross-sectional duct. The closest duct size is 16" dia and corresponds to a final velocity of <u>4299 fpm</u>, well within design standards.

The pressure losses are as follows:

6" needed at forming chamber
1.62" for (2) 90 deg 1.5D elbows (table IV)
<u>3.3" for 220' of 16" dia duct (table III)</u>
10.92" total

In this case size the fan for 6000 cfm at 12” water static. Any chance of moving too much air can be alleviated by adding a slide gate type damper in the 16” line to create artificial resistance. IBIS oversized the fan and motor slightly in case more air is required. Use special care when selecting the main system fan.

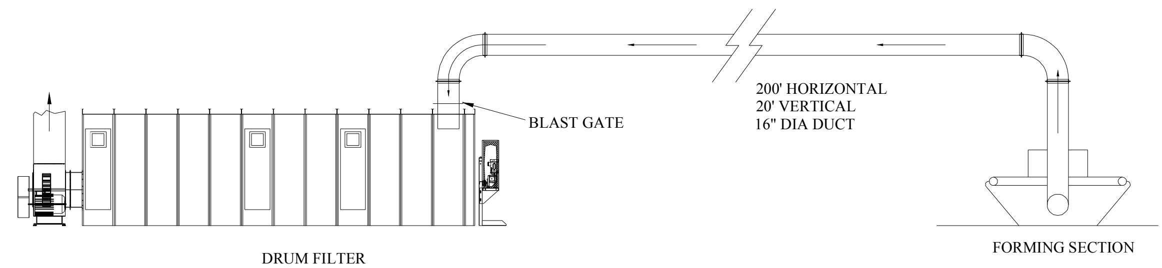

FIGURE 1 PROBLEM 1

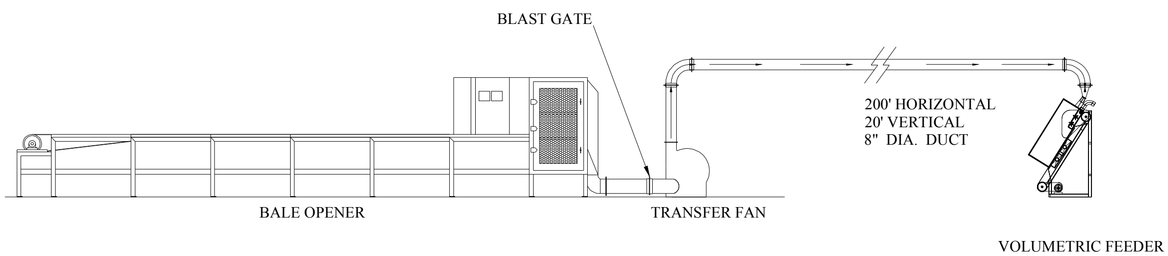

FIGURE 2 PROBLEM 2

Problem 2: Duct work and fan sizes need to be determined for conveying cellulosic fiber from a bale opener to a volumetric feeder placed near a manner mill 200 ft away. Please refer to figure #2.

GIVEN:

*Bale Opener requires 1500 cfm @ -2” water static pressure to capture opened fluff.

*Bale Opener opens 3000 lb fluff/hour.

SOLUTION:

The amount of fiber transported per minute is 3000 lb/hr x 1/60 hr/min = <u>50 lb/min.</u> 1500 cfm air = 112 lb air/min. This means that the material to air ratio is .44. In this case friction and power requirements will be above that for air alone. The proper transport velocity for cellulosic fiber is about 4000 fpm. Therefore 1500 cfm at 4000 fpm requires .375 sq ft cross-sectional duct. The closest duct size is 8” dia and corresponds to a final velocity of <u>4299 fpm</u>, well within design standards.

The pressure losses for air lone are as follows:

0.9” for (2) 90 deg 1.5D elbows
0.225” for (1) 45 deg 1.5D elbow
6.6” for 220’ if 16” dia duct
7.73” friction in duct

Pressure loss due to material being conveyed:

7.73” (air friction) x .44 (air to material ratio) x 50% = 1.70”

Pressure loss due to acceleration of material being conveyed:

2.25 x .44 (air to material ratio) x .91” (velocity pressure) = .90”

Total pressure loss to overcome = 10.33”

Power required:

For a particular fan the extra power required above that for air alone would be .44 (material to air ratio) x 25% = 11%

In this case size the fan for 1500 cfm at 11” water static. Any chance of moving too much air can be alleviated by adding a slide gate type damper in the 8” line to create artificial resistance. IBIS oversized the fan and motor slightly in case more air is required.

CONSTRUCTION DESIGN

MATERIAL:

(1) Straight smooth duct should be made from galvanized steel with a minimum thickness of:

22 gage for up to 8” diameter duct (.0299”)
20 gage for over 8” to 18” diameter duct (0.359”)
18 gage for over 18” to 30” diameter duct (0.478”)
16 gage for over 30” diameter duct (.0598”)

*If spiral duct is used, one lighter gage may be used. eg: If 20 ga for duct use 22 ga for spiral.

*If the metal is thinner than specified, the duct may collapse. If thicker, it will cost more than necessary.

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Allowable Negative Pressures in Round Spiral Duct

The following table lists the recommended *metal gage* and *reinforcing* for various negative pressures in different diamenters of round spiral duct. The negative pressures listed are working pressures with a safety factor of 3 included.

TABLE I:

Diameter	MAXIMUM NEGATIVE PRESSURE 0"-10" W.G.	10"-20" W.G.	20"-30" W.G.	30"-40" W.G.
3-7	26 Ga.	26 Ga.	26 Ga.	26 Ga.
8	26	26	26	24
9-12	24	24	22	22
13-15	24	22	22	20
16-18	22	20	20	18
19-22	22	18	18	18 w/Fl.* or 16
24-26	20	18	18 w/Fl.* or 16	18 w/AR** 6'c/c or 16 w/Fl.*
28-34	18	18 w/Fl.* or 16	18 w/AR** 6'c/c or 16 w/Fl.*	18 w/AR** 4'c/c or 16 w/Fl.*
36-42	18 w/Fl.* or 16	18 w/AR** 6'c/c or 16 w/Fl.*	18 w/AR** 4'c/c or 16 w/Fl.*	16 w/Fl.*
44-50	18 w/AR** 6'c/c or 16	18 w/AR** 4'c/c or 16 w/Fl.*	16 w/Fl.*	16 w/AR** 6'c/c
52-60	18 w/AR** 6'c/c or 16 w/Fl.*	18 w/AR** 4'c/c or 16 w/Fl.*	16 w/AR** 6'c/c	16 w/AR** 6'c/c

*Maximum Length of Duct Section = 12' (With Angle Ring Flanges)
**Angle Ring Reinforcement

TABLE J: SIZES AND GAGES OF SPIRAL DUCT

NOMINAL DIAMETER (Inches)	CROSS SECTION AREA (Sq. Ft.)	METAL GAGE STD.	METAL GAGE MAX.	WEIGHT Lb./Ft. STD. GA.	WEIGHT Lb./Ft. MAX. GA.	NOMINAL DIAMETER (Inches)	CROSS SECTION AREA (Sq. Ft.)	METAL GAGE STD.	METAL GAGE MAX.	WEIGHT Lb./Ft. STD. GA.	WEIGHT Lb./Ft. MAX. GA.
3	.047	26	18	.9	2.0	24	3.14	24	16	7.8	20.0
4	.08	26	18	1.1	2.6	26	3.70	24	16	8.4	21.7
5	.13	26	18	1.4	3.2	28	4.28	22	16	11.1	23.4
6	.19	26	16	1.5	5.0	30	4.92	22	16	11.9	25.0
7	.26	26	16	1.8	5.8	32	5.60	22	16	12.7	26.7
8	.35	26	16	2.1	6.7	34	6.30	22	16	13.5	28.4
9	.44	26	16	2.4	7.5	36	7.10	22	16	14.2	30.0
10	.54	26	16	2.6	8.3	38	7.87	20	16	17.7	31.7
11	.66	26	16	2.8	9.2	40	8.72	20	16	18.6	33.4
12	.79	26	16	3.0	10.0	42	9.62	20	16	19.5	35.0
13	.92	26	16	3.3	10.8	44	10.55	20	16	20.5	36.7
14	1.06	26	16	3.5	11.7	46	11.52	20	16	21.4	38.4
15	1.23	24	16	4.8	12.5	48	12.55	20	16	22.3	40.1
16	1.40	24	16	5.1	13.4	50	13.61	20	16	23.3	41.7
17	1.58	24	20	5.4	7.8	52	14.75	18	16	36.2	43.4
18	1.77	24	16	5.7	15.0	54	15.90	18	16	37.6	45.1
19	1.97	24	20	6.1	8.7	56	17.10	18	16	38.9	46.7
20	2.19	24	16	6.4	16.7	58	18.35	18	16	40.3	48.4
21	2.41	24	20	6.7	9.6	60	19.64	18	16	41.7	50.1
22	2.64	24	16	7.0	18.4						

Certain Intermediate Sizes Available on Special Order.

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(2) Elbows, transitions, and taps should be a minimum of same gauge as straight lengths of equal diameter.

(3) Because flexible duct causes more resistance than regular duct, flexible piping should be used only when necessary. A non-collapsible type should be used and kept to a minimum.

CONSTRUCTION:

(1) Longitudinal joints of ducts should be lapped and riveted or spot welded on 3” centers maximum. Double lock and spiral seams may also be used.

(2) Girth joints of duct should be made with the inner lap in the direction of air flow, with 1” lap for diameters to 19” and 1-1/4” lap for diameters above 19”.

(3) Van stone & angle ring connections are preferred.

(4) All joints and connections must be dust tight. Any holes left in the duct will allow fine dust to escape from the system.

(5) Elbows and angles need to have a centerline radius of at least two pipe diameters when possible. For elbows of less than 6” diameter, use five piece construction. For elbows of greater than 6” diameter, use seven piece construction. Ling radius elbows (4.0 x Diameter) may be required for some scrap/trim systems.

(6) Rectangular ducts should be used only when clearance prevents use of round duct. Rectangular ducts must be as square as possible. Weight of metal, lap, and other construction details should be equal to round duct construction whose diameter equals the longest side.

SYSTEM DETAILS:

(1) Use straight through weather caps unless otherwise specified. Do not screen the outlet.

(2) When possible transitions should be tapered 5” long for every 1” change in diameter.

(3) All branches into the main duct line should enter at the large end of transition and at an angle no greater than 45 degrees.

(4) Provide dead-end caps within 6” from last branch of all mains and sub-mains.

(5) Provide dust tight access openings or cleanouts every 20 ft and near each elbow angle or transition. (Contact IBIS for cleanouts & dampers/blast gates).

(6) Support the duct in such a manner that it transmits no load to the equipment it is connected to, even if the duct is plugged with material. Intervals between supports should be 12 ft minimum.

(7) Provide 6” clearance minimum between duct and ceiling, walls, or floors.

(8) Blast gates for adjustment of system should have a means of locking once they are set. Butterfly type dampers cannot be used.

(9) Fire dampers, explosion vents, etc., should be installed in accordance with national and local fire ordinances.

BRIEF EXTRACTS ARE ATTACHED FROM SMACNA, NUCLEAR AIR CLEANING HANDBOOK, INDUSTRIAL VENTILATION MANUAL, ETC.