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Analysis of Design and Purchase Decision of Central Dust Collection System

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ANALYSIS OF DESIGN AND PURCHASE DECISION OF CENTRAL DUST COLLECTION SYSTEM

Strictly as per the compliance and regulations of :

Analysis of Design and Purchase Decision of Central Dust Collection System

A.I. Khan [α] & M. Y. Bhuiyan [σ]

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I. Introduction

Dust collection involves the removal or collection of solid particles from a flowing air stream, for the purpose of eliminating nuisance dust, the safety and health considerations of employees, product quality improvements and the collection of powdered products. An efficient dust collection system should be a priority for the small shop as well as the large shop, whether the material being machined is wood, plastic, or a composite. Not only this is essential for health reasons and compliance with many national and local codes but also it is good business because it saves money and helps to maintain the quality of the finished product. The harmful health effects of inhaled particulates (many of which are carcinogens) are well documented. Skin, eye, and nose problems as well as allergic reactions are frequently reported due to the dust problem [1].

Wood is one of the most common organic dusts workers' are exposed to in the furniture manufacturing industry. Studies have found that exposure can cause health effects from nasal mucosa damage, irritation and sino-nasal cancer, while deep lung deposition leads to lung cancer and impaired respiratory function. Wood machining processes such as shaping, routing and sanding particularly produce high levels of dust emission. Nevertheless, the wood exposure is influenced by the airflow field in the working area, worker inhalation rate and ventilation system, while the level of toxicity varies with the wood specie and size of dust particles. In addition, a dusty shop increases the risk of worker injury and fire, which can result in poor production, higher insurance rates and lawsuits [2]. The chunks and heavy chips of wood do not create a problem. The challenge is the extremely fine particles of dust that float in the air and land on the manufactured products, in the machinery and on the workers [3]. A dusty shop compromises the quality of the finished product: Accurate measurements and cuts are more difficult due to lack of visibility; airborne dust finds its way into finishing areas causing defects in the final product; and larger particles cling to surfaces cause scoring and other defects. Finally, dust that is not automatically collected must be collected manually as a recurring direct labor expense [1].

Revenue is dependent on safe, pleasant working conditions, minimal down time and a low cost of operation. A properly planned and designed dust collection system can certainly contribute to all of these variables to enhance the bottom line [4]. This paper is based on the study of a central dust collection system of a wood furniture industry. The dust collection system used in that industry is found inefficient and violates the rules and regulations provided by NFPA. The central dust control eliminates the unnecessary maintenance operations and hence providing the scope for the manufacturers to implement smooth production system.

II. Dust Types and Industries

Dust is being produced at different levels and they need to be indentified to enhance the collection process. Dust incidents occurred and the types of dust incidents in different industries of the world are presented in figure 1 and figure 2.

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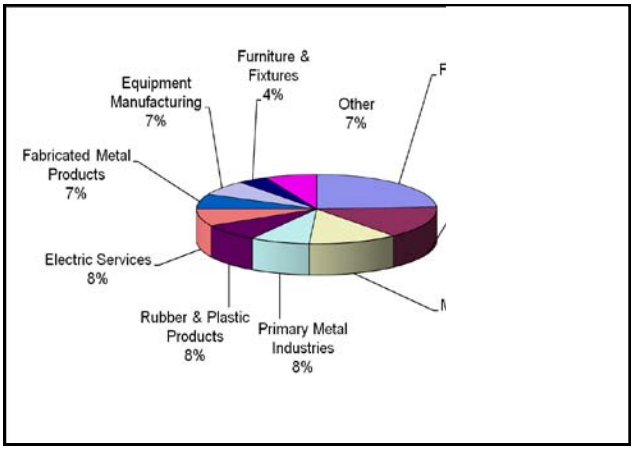


Figure 1 : Industries where dust incidents occurred (Source: CSB Report 2006-H-1)

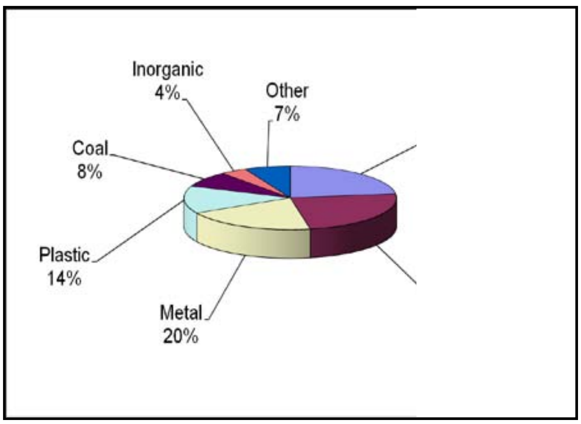


Figure 2 : Types of dust involved in incidents (Source: CSB Report 2006-H-2)

It is observed that wood dust is about 24% of the total dust incidents occurred in the world that are mostly produced in the wood furniture industries.

III. Study of Present Condition

Conventional dust collectors use the fabric bag and flexible hose pipe. It consists of a blower with a larger hose inlet, similar to the old Hoover designs but on a larger scale, with a tube or duct, usually about four inches in diameter, carrying dust and debris to the blower, then from the blower into a bag or bin where the dirt and dust is deposited. The conventional dust collection system of a furniture industry is presented in figure 3.

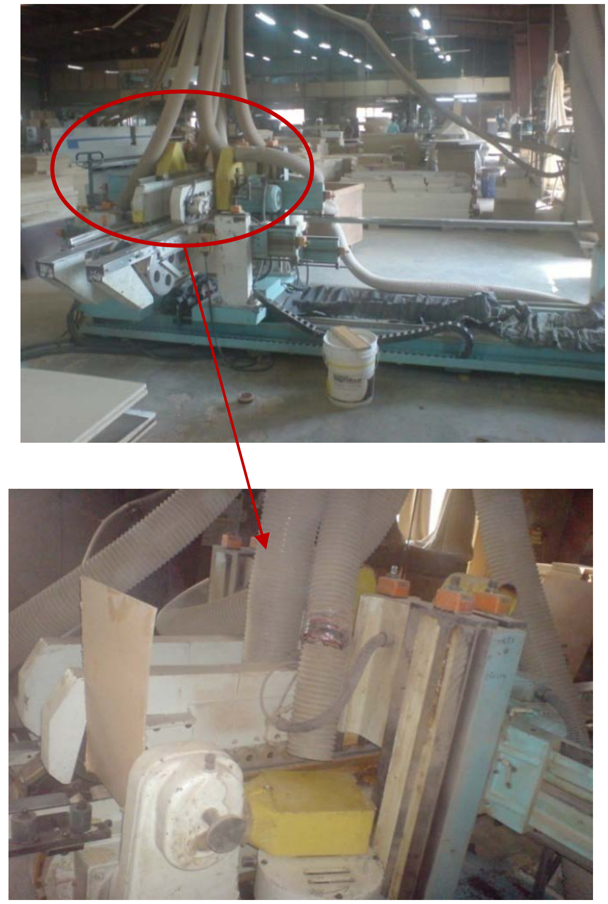


Figure 3 : Photographic view of conventional dust collection system

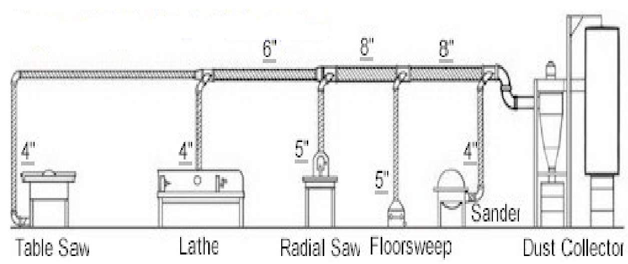


Figure 4 : Diagram of typical dust collection system [8]

Dust collection design can be complicated, here are a few simply steps to design an effective and efficient dust collection system.

IV. Design of Central Dust Collection System

The dust collection design for furniture industries requires a solid understanding of dust flow, piping arrangement and layout design. It is necessary to centralize the dust collection system to avoid the complicacy of individual piping system and exhaust fan or blower. Before starting the design of Dust Collection System it will need a floor plan of shop area including the following:

Global Journal of Researches in Engineering (G) Volume XIII Issue I Version I Year 2013

1. Location of dust producing machines: indicate size & location of dust pickups on each machine.
2. Desired location of dust collector unit.
3. Floor to joist measurement.
4. Any obstructions that would interfere with the run of the duct.

a) Design Methodology

Design parameters of the central dust collection system are illustrated based on schematic diagram (Figure 4).

i. *Type of duct velocity*

Table 1 : Duct velocity in the branches and main [5]

Type of Dust	Velocity in Branches	Velocity in Main
Metalworking Dust	4500 FPM	4000 FPM
Woodworking Dust	4000 FPM	3500 FPM
Other Light Dust	4000 FPM	3500 FPM

ii. *Determining the size of each branch*

There are several ways to determine the diameter of the branches.

1. If the machine has a factory installed collar, the manufacturer has determined that the machine needs that size branch under normal circumstances.
2. If the machine has a metric diameter outlet, is to be converted into inches, and rounded off to the nearest inch.
3. If the outlet is rectangular it is needed to determine the equivalent round diameter.
4. If the branch is smaller than 3" diameter then a reducer can be used near the machinery to increase the branch to 3". In this case the CFM for 3" can be 195 CFM.

Depending on the size and operation, it is general practice to use 4" diameter pipe for Table Saw and Lathe, 5" diameter for Radial Saw and 6" diameter for Large Lathe Machine used in wood processing [8].

iii. *Determining diameter of main duct*

The velocity of air in a ventilation duct can be expressed in:

$$v_m = q_m / A_m = 4\, q_m / (\pi\, d_m^2).$$

Where,

v_m = *air velocity (FPM),*

q_m = *air flow (CFM),*

d_m = *diameter of the duct (in).*

Like as for $d_m=3$ *inch,* $v_m=3500$ *FPM the* q_m = $(3500 \times 12 \times 3.1416 \times 3^2)/4=$ *approximately 170 CFM.*

The 4" branch run from the Table Saw until it joins with the branch 4" from the Lathe. At this point main starts and it needed to increase the pipe to handle the combined CFM (350+350=700). Using the CFM Chart 1 looking up 700 CFM under the appropriate velocity (3500 FPM in the main for wood dust), where the corresponding diameter (6") is viewed. The 6" pipe in the main from the Lathe section joins with the branch of the Radial Saw and similar for other lines.

Charts : The following charts are the basic determinants of different parameters required

- CFM requirements for diameter at specified velocity
- Static Pressure based on 100' of Pipe
- Elbow to Straight Pipe Conversion

Chart 1 : CFM requirements for diameter at specified velocity			
Diameter	3500 FPM	4000 FPM	4500 FPM
3"	170	195	220
4"	300	350	390
5"	475	550	610
6"	700	785	880
7"	950	1100	1200
8"	1200	1400	1570
9"	1550	1800	1990
10"	1900	2200	2450
12"	2800	3175	3600
14"	3800	4300	4800
Chart 2 : Static Pressure based on 100 ft of Pipe			
Diameter	3500 FPM	4000 FPM	4500 FPM
3"	7.5	10.0	12.0
4"	5.5	7.0	8.5
5"	4.2	5.5	6.5
6"	3.5	4.5	5.5
7"	2.8	3.8	4.5
8"	2.4	3.2	3.8
9"	2.0	2.8	3.4
10"	1.8	2.4	3.0
12"	1.2	2.0	2.5
14"	1.3	1.6	2.0

Chart 3 : Elbow to Straight Pipe Conversion		
Diameter	90° Elbow 1.5 Diameter Rad.	45° Elbow 1.5 Diameter Rad.
3"	5'	2.5'
4"	6'	3'
5"	9'	4.5'
6"	12'	6'
7"	12'	6.5'
8"	15'	7.5'
9"	17.5'	8.75'
10"	20'	10'
12"	25'	12.5'
14"	30'	15'

iv. *Figure System Resistance (SP)*

The total static pressure is different types of pressure heads added together. They are entry loss, dirty filter loss, static pressure of the worst branch duct, static pressure of the main duct and static pressure of the return duct.

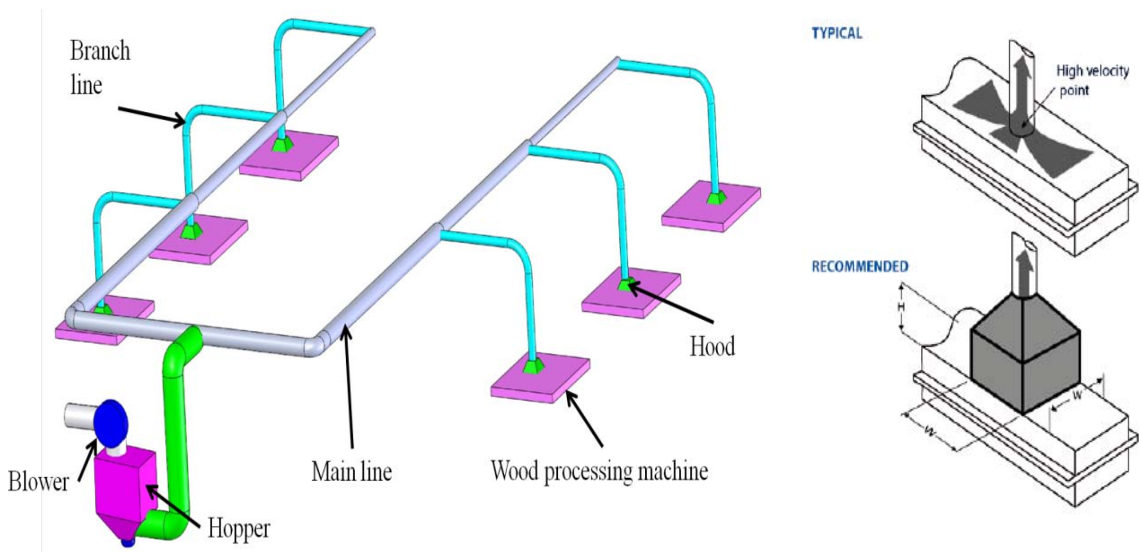
1. There are more complicated ways to figure the entry loss of the dust collection system, but normally it is usually equals a loss of 1" water gauge. (1" as a constant)
2. If the system has filters, a 2" loss is needed to be added.
3. The worst branch means the branch with the greatest resistance. The branch with the greatest resistance is usually smaller diameter with the most lineal footage of pipe elbows. Static pressure of worst branch and main duct can be calculated by using the following Chart 2. Chart 2 is based on 100 feet of pipe; therefore it is required to convert all elbows to an equivalent of pipe. To convert 90° and 45° elbows to equivalent feet of pipe the Elbow to Straight Pipe Conversion Chart is useful. When figuring the feet of pipe the lateral type branches are of greater importance. Flexhose has a lot of resistance depending on the amount of bends included in the installation. For this reason it is required to keep hose a minimum. Multiplying the length of flexhose on the worst branch by 3 for equivalent length of straight pipe was taken.

a. *Determining Static Pressure of Worst Branch*

For this particular diagram (figure 4), the worst branch is 4" Table Saw which is 20' long along with 2 - 90° elbows, 2 - 45° elbows and 5' flexhose.

Description - 4" Diameter	Equivalent to Straight Pipe
Straight Pipe	20'
2 - 90° elbows	12'
2 - 45° elbows	6'
5' flexhose (3x)	15'
Total equivalent straight pipe after conversions	53'

*Therefore, Static Pressure in the worst branch = (53/100)*7(Chart 2) = 3.71" W.G.*



(a) (b)

Figure 5 : (a) Layout of improved central dust collection system, (b) Recommended hood design

b. *Static Pressure in MAIN DUCT 6" and 8"*

For this particular diagram (figure 4), Lathe to Radial Saw distance is 20' and Radial Saw to dust collector distance is 25' with 2 - 90° elbows. The static pressure of the Main Duct is done the same way, except you figure it out for each diameter in the Main, starting farthest away and working toward the collector.

Description - 6" Diameter	Equivalent to Straight Pipe
Straight Pipe	20'
Total equivalent straight	20'
Description - 8" Diameter	Equivalent to Straight Pipe
Straight Pipe	25'
2 - 90° elbows	30'
Total equivalent straight	55'

Static Pressure in 6" Diameter Main= (20/100) * 3.5 (Chart 2) = 0.7" W.G. and similarly Static Pressure in 8" Diameter Main = 1.3" W.G.

Total Static Pressure = 1" + 2" + 3.71" + .70" + 1.3" = 8.71" of Water Gauge

Therefore the system should provide a minimum static pressure capability of 8.71 inches of W.G. and discharge of 1250 CFM for this particular case of central dust collection system (figure 4). To accomplish this, a blower can be used.

of central dust collection system (figure 4). To accomplish this, a blower can be used.

V. Improved Design

The layout of improved design is illustrated in figure 5 (a). This layout is based on the visited furniture industry. There are six wood processing machines; 2 Lathes, 2 Table Saws, 1 Radial Saw and 1 Large Lathe. The diameters of the branches are different as per the recommended values mentioned earlier. The pipes required for improved dust control should be spiral steel pipe (figure 6) which ensures better functionality of the system rather than hose pipe. Dust builds up more easily on the hose's ridged inside surface than on the smooth metal duct. The internal resistance of flexhose is more than twice of the smooth metal duct. The system's exhaust fan may not be large enough to provide the speed necessary to overcome this additional airflow resistance and the result is low air velocity that causes dust to drop out of the air and plug the ducts [6]. But using a spiral steel pipe which is curved inside is beneficial because dust can't be easily clogged on it.

The dust being produced by the source is required to be sucked by the hood. Figure 5 (b) provides the features of the typical and recommended hood design. Improved design of hood provides more surface area which can collect dust particulates from a greater area surrounding the source. The tapered shape of hood enables easier suction of dust particles into the duct.

Another improvement of the central dust collection system is to incorporate a hopper. It provides better control on the dust collection. It also offers the automation of dust collection by using an airlock and tipping valve. The hopper is shown in the layout of the central dust collection system as presented in figure 5 (a). There must be a filter inside the hopper to separate dust particles from the air stream. It protects the blower from the damage of blades. It is highly recommended to use some other provisions to remove fine dust coming from the shop floor and sources.

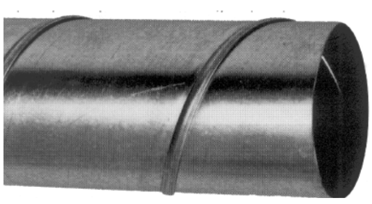


Figure 6 : Spiral steel pipe

VI. Discussion

Dust can severely impair the performance of the wood processing system by accumulating on fans, motors, vents, ducts and shutters and can cause these components perform poorly or to fail completely. These production issues were dealt to solve on the model presented on this paper. The overview of the analysis resulted in the need for better flow and maintenance of the dust [7].

It is the agreement of the researchers, engineers and industry specialists who have observed the dusty environment in different industrial environment i.e. furniture, metal, mining etc. that to achieve workplace safety plastic pipes should be avoided to collect dust particles. In the US National Fire Protection Association (NFPA)'s 2002 edition, Chap.8/8.2.2.2.1.2 has a regulation about wood dust collection, "Nonconductive ducts such as PVC pipes shall not be permitted". Some of the reasoning is as follows [8]:

- Static sparks can develop internally or externally can eventually ignite combustible mixtures inside or outside the pipe, can be extended objects other than wood dust mixtures.
- In a risky environment, static pipes arcing can confuse and injure personnel along with reducing the accuracy of the processing operation.
- Plastic pipes are not designed for pneumatic conveying. So, an efficient dust collection is difficult with them.

Metal pipe is used because it provides substantially better performance and proper fittings are readily available. If the design of duct includes air handling ductwork and fittings then it will deliver substantially more air out of the tool where it is needed.

The large heavy particles thrown out by the cutting heads or wheels have such a high speed that their trajectories cannot be altered by a vacuum system regardless of its velocity [1]. In addition hoods should be placed as close to the source of dust contamination as possible since the effectiveness of an exhaust hood decreases very rapidly as it is moved away from the source. The recommended metal dust hood can improve the efficiency of the system.

To maximize the benefits of a good dust collection system, the collected dust must be disposed of in an effective manner. The dust handling capacity should be greater than the maximum collection rate in order to prevent storage in the hopper. Pneumatic conveying is one method to transport the dust to a controlled location given the right climate and control system.

VII. Conclusion

The proposed design is based on the international standard for airborne particulate exposure and control and sufficient technical information is provided to apply it in the shop floor setting of a furniture industry. Although the initial cost of the improved design is higher than the conventional one but in terms of life cycle operation and considering other factors the improved design is more economical.

This paper presents a better understanding of the involved parameters considering cost and availability machine layout on production floor. The recommendations provided here will put a lot more benefit for the industries considering safety and better control of core manufacturing expertise.

Many industries use vacuum line for various processes. In that case the same vacuum pump can be used to create suction of the dust collection instead of using a separate blower. The fittings such as elbows, bends should be properly designed so that there is less pressure drop. There should be no leakage in the pipe line and joints that can make the whole system inefficient.

VIII. Acknowledgment

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