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FEASIBILITY OF RECIRCULATION AIR SYSTEM IN WOOD FURNITURE MANUFACTURING PLANTS

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ABSTRACT

Exposure to wood dust has long been suspected of causing a variety of adverse health effects, including dermatitis and allergic respiratory effects. To alleviate this situation, regulations covering permissible wood dust concentration limits in the furniture manufacturing industry have been revised by the Occupational Safety and Health Administration (OSHA). These revised limits imply that most of the wood furniture manufacturers must upgrade their ventilating systems, particularly those who are recirculating the exhaust air from the wood dust filters to the workplace inside the plant. This recirculation of exhaust air is a common practice during winter months, because it is more economical than pre-heating significant quantities of make-up air. However, recirculation generally raises wood dust concentration levels in the workplace beyond the presently recommended limits. In order to meet the new standards, wood furniture manufacturers are either resorting to secondary filtration or, alternatively, stopping recirculation altogether. This paper deals with the economics of both alternatives and also looks into different options currently available reducing the dust concentration in the recirculated air.

INTRODUCTION

Wood dust previously was regulated by the Occupational Safety and Health Administration (OSHA) under its nuisance standard of 15 milligrams of dust per cubic meter of air (OSHA 1989a) but recently its regulations have been revised and wood dust has been classified as a substance for which permissible exposure limits (PEL) are based on avoidance of respiratory effects (OSHA 1989b). Present regulations require wood furniture manufacturers to upgrade their ventilating systems so that no worker will be exposed to a time-weighted average (TWA) of more than 5 mg/m or a 15-minute short-term exposure limit (STEL) of 10 mg/m of wood dust for all types of soft and hard woods, except western red cedar. For western red cedar, the regulations are stricter, i.e., no worker will be exposed to its dust above TWA of 2.5 mg/m. The newly adopted dust concentration limits for wood furniture manufacturing plants pose an interesting design challenge. The potential impact of these regulations on the continued prosperity of such plants is significant, particularly in North Carolina, where furniture manufacturing ranks second only to textile manufacturing and employs more than 89,000 persons.

During a forum at the ASHRAE Annual Meeting in Vancouver (ASHRAE 1989a), a panel debated the design philosophies typical of the environmental health industry and the engineering community. Traditionally, engineers design to meet a standard while environmental health professionals employ the best available technology in order to minimize risk. Considering the furniture industry, the engineering design philosophy would typically set a goal for a ventilating system that maintains particulate matter at a concentration just below the PEL described above. On the other hand, the environmental health specialist would set the goal for the concentration level to be as low as the available technology could achieve. One area that typifies these divergent philosophies involves the recirculation of exhaust air from dust filters to the plant. Such recirculation is done during the winter because it is more economical than pre-heating significant quantities of makeup air.

Environmentally, there are two approaches in dealing with air exhausted from wood dust filters. One is to discharge the filtered air to the atmosphere instead of recirculating it to the plant, losing a significant amount of heat energy in the process but maintaining the highest possible level of environmental health safety. Another is to improve filter efficiency to its practical limit, satisfy the OSHA regulations, and continue recirculating the exhaust air in winter. This paper examines both approaches, compares the expense or savings involved, and looks at different options available if the decision is air recirculation.

WOOD DUST COLLECTION SYSTEM DESIGN

The wood dust collection system is a major component of any furniture manufacturing plant. The system not

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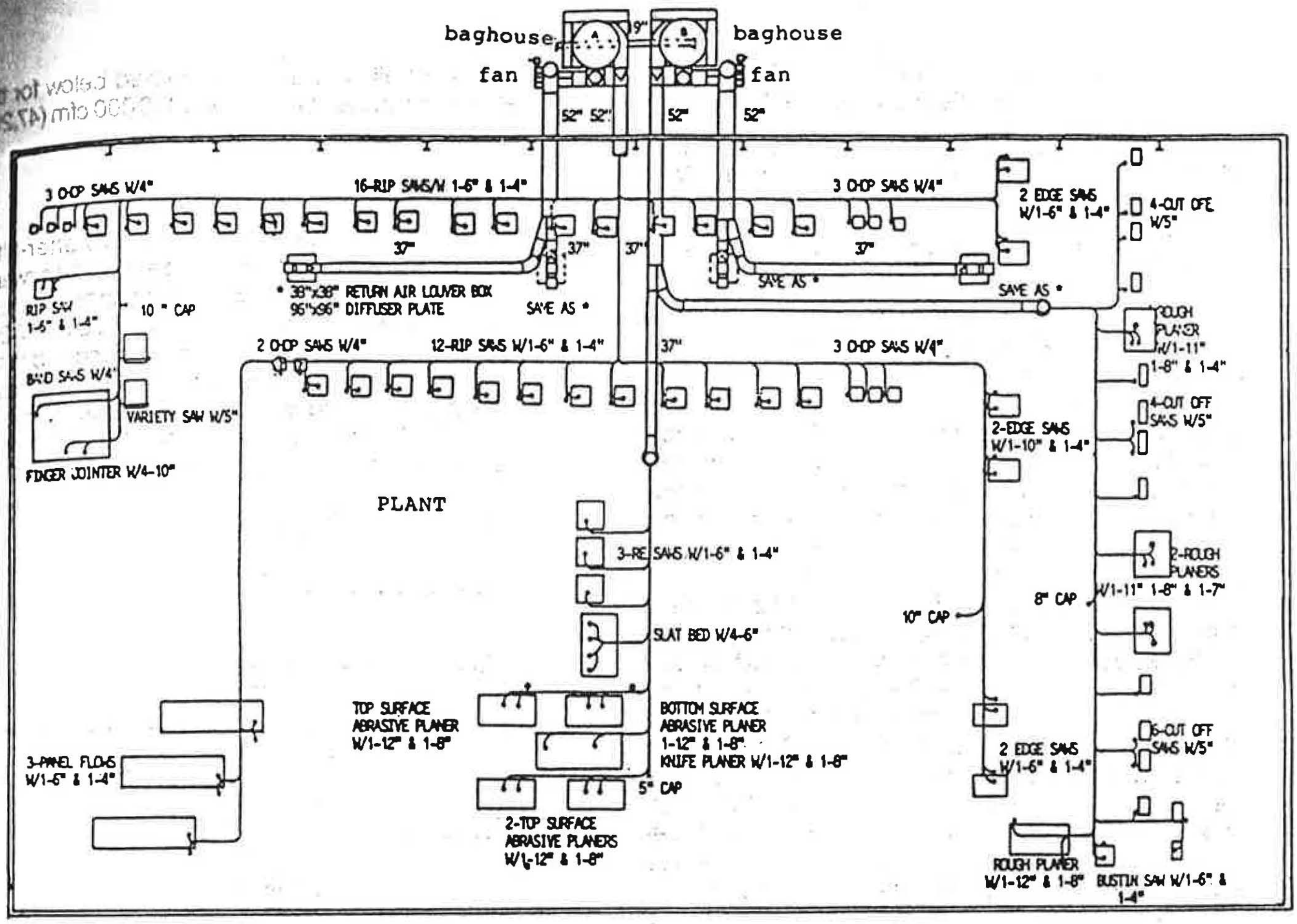

***Figure 1** Layout of a typical wood furniture manufacturing plant fitted with recirculation air system*

only removes excess waste from the machine area but it also reduces air pollution inside the plant (Singh et al. 1988). The traditional dust collection system includes hoods and/or machine connections that keep the machines from clogging and, to a lesser degree, minimize the dust breathed by the machine operator. The dust is piped through a series of ducts and fans to a high-efficiency filter. During warm weather, the air discharged from the filters is exhausted to the atmosphere. As the cold weather of winter approaches, the damper positions are changed and the air is returned to the plant floor. Figure 1 shows the layout of a typical wood furniture manufacturing plant fitted with a recirculation air system. The practice of returning or recirculating air, which is fairly typical in the industry, was adopted in the late 1970s when energy saving was becoming a national concern. However, the system design can incorporate either a nonrecirculation strategy or a recirculation strategy. Both strategies are discussed for a typical furniture manufacturing plant using hard or soft woods (excluding western red cedar) with an airflow of 100,000 cfm (47,200 L/s).

NONRECIRCULATION STRATEGY

If a nonrecirculation strategy is adopted, then 100,000 cfm (47,200 L/s) of air being drawn from the workplace and discharged to the atmosphere has to be recouped from outside. This outside makeup air in winter months is cold and needs pre-heating to maintain the desired warmth inside the plant. As an example, the location of a typical plant is assumed to be Greensboro, NC, and winter months are taken as October through April. The average outdoor bin temperatures during this period for this location, as found from the standard weather data charts (DOAF 1978), are:

Shift	Shift Hours	Average Outdoor Temperature
A	01 to 08 hours	42.60°F (5.89°C)
B	09 to 16 hours	54.55°F (12.53°C)
C	17 to 24 hours	47.88°F (8.82°C)

Further, it is assumed that the indoor temperature desired is 70°F (21.11°C).

Heating Load

The sensible heating load with respect to make-up air (ASHRAE 1989b) is given by:

$$h_s = 1.1\, Q(T_i - T_o)$$

where

h_s = sensible heat required for make-up air, Btu/h
Q = volume flow rate, cfm
T_i = temperature of inside air, °F
T_o = temperature of outside air, °F

Shift B It has been found (AFMA 1987) that most of the furniture manufacturing plants operate during shift B only.

Q during shift B = (1.1)(100,000)(70−54.55)
= 1.6995 MBtu/h (497.95 kW)

The operating period of the plant is assumed to be 2500 hours per year or 1458 hours for winter (October through April).

Q for winter = (1.6995 MBtu/h)(1458 hours)
= 2478 MBtu/winter (2614.29 GJ/winter)

Heating Cost (Wood Dust as Fuel) Assuming a calorific value of 7450 Btu/lb (17,358.5 kJ/kg) and a combustion efficiency of 0.5 for wood dust, the amount of wood dust needed per winter works out as 332.6 short tons (301.67 Mg). The furniture plant may generate this much wood dust within the facility or may procure it partly from the market. The cost of wood dust has been ascertained to be nearly $10 per short ton; hence, the cost of procuring wood dust would be $3326 per winter.

Heating Cost (Other Fuels) Assuming the cost of natural gas to be $3.5/MBtu, the total cost for the gas as fuel would be $8673 per winter. Cost of Oil No. 6 as fuel at the rate of $4 per MBtu would be $9912 per winter. Similarly, the cost of electricity for heating at the rate of $0.06/kWh or $17.60/MBtu would be $43,613 per winter. Comparing the costs of different fuels as calculated above, it is seen that the use of sawdust is least expensive. However, the amount of $3326 per winter is only the primary cost of fuel. Associated with this are the costs of transportation, storage, and handling of wood dust and the cost of installing an air pre-heat system. In view of the above, the annual cost has been estimated to be $7000. Further, at certain plant locations, the problem of availability of the sawdust could be serious if the plant is not self-sufficient in this fuel resource. It should also be noted that, if it is not possible to put any additional load on the present boilers, installation of a new boiler of nearly 50 hp capacity would also be required.

Other Shifts The cost of pre-heating the make-up air calculated above pertains to shift B only. Corresponding cost for shift A or shift C can be determined approximately by assuming it to be linearly proportional to the shift-wise difference in average temperature of inside and outside air. With this assumption we get the approximate cost of pre-heating make-up air as $12,500 per winter for shift A and $10,000 per winter for shift C.

RECIRCULATION STRATEGY

If a strategy of recirculating the air discharged from the wood dust filters is adopted, the filtration efficiency has to be improved to meet the OSHA regulations or to be even better.

Improved Filtration Alternatives

Two alternatives that are considered effective in improving the filtration efficiency to the required standard are:

1. Addition of an after-filter (secondary baghouse) to the existing baghouse system with new fans and new connecting ductwork.
2. Addition of flat, removable basket type filters to an extended return air duct.

The above two alternatives are discussed below for the typical plant having an airflow rate of 100,000 cfm (47,200 L/s).

Alternative No. 1

Figure 2 shows the addition of a new after-filter (secondary baghouse) and two new clean air backward-inclined fans (50,000 cfm or 23,600 L/s capacity each) and connecting ductwork to the existing 100,000 cfm (47,200 L/s) baghouse to improve the filtration efficiency up to the required limits. With this arrangement, the static pressure requirement of the wood dust collection system will go up by 4 in. or 10.16 mm (water gauge) requiring 433 bhp in place of the existing 343 bhp, i.e., an additional 90 bhp.

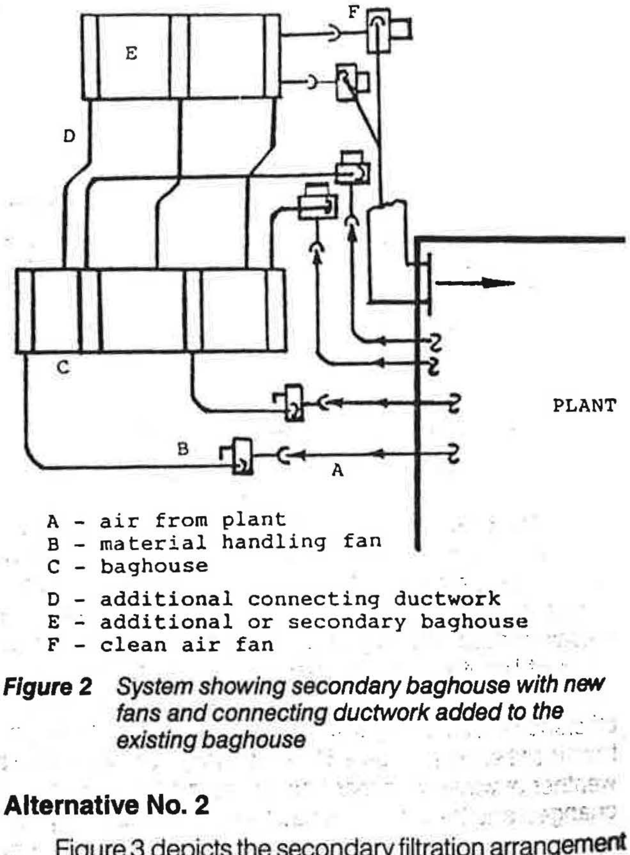

Figure 2 *System showing secondary baghouse with new fans and connecting ductwork added to the existing baghouse*

Alternative No. 2

Figure 3 depicts the secondary filtration arrangement in which flat, removable, basket-type filters are shown fitted onto the extension of the existing ductwork handling 100,000 cfm (47,200 L/s). The extension is nearly 200 feet (60.96 m) long. With this arrangement, the static pressure requirement of the wood dust collection system goes up by 1 in. or 2.54 mm (water gauge) requiring 372 bhp in place of the existing 343 bhp, i.e., an additional 29 bhp. However, no new fans are required. Figure 4 shows the extended duct with flat basket-type filters along with typical dimensions of the facility being considered.

COMPARISON OF IMPROVED FILTRATION ALTERNATIVES

Initial Cost

The initial cost of the retrofit, including installation, has been estimated to be $163,000 for the first alternative and $36,000 for the second alternative.

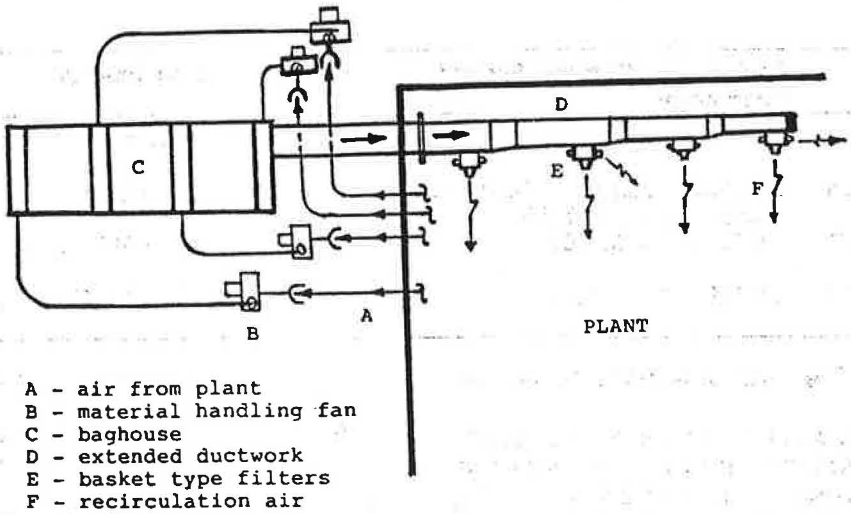

Figure 3 *System showing flat removable basket-type filters fitted onto the extension of the existing ductwork*

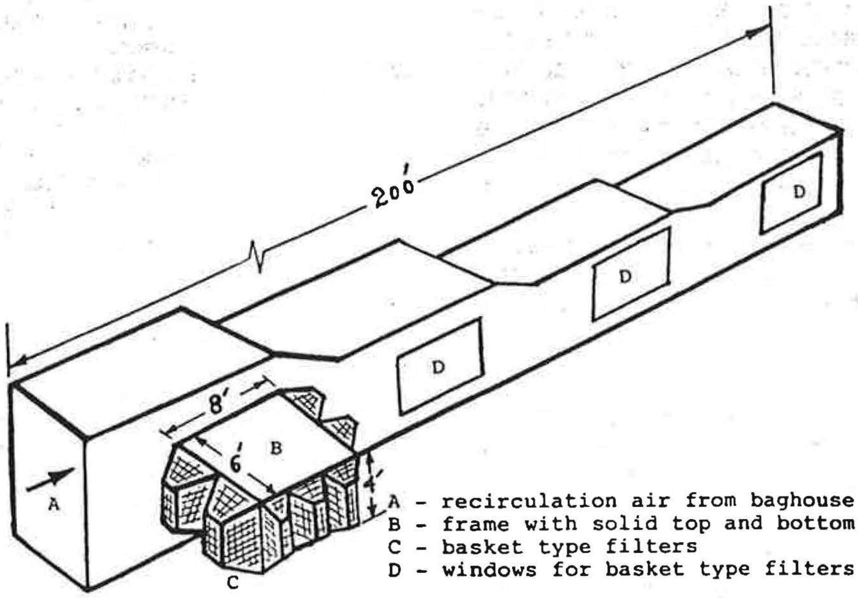

Figure 4 *Pictorial view of flat removable-type filters with typical dimensions*

Maintenance of Filters

Maintenance of the additional after-filter in the case of alternative No. 1 would be relatively low, since it would be self-cleaning and operate automatically in conjunction with the existing system. The flat basket-type filters in the second alternative, however, are not automatically cleaned, and they would need to be changed every three months for a single-shift operation. Therefore, there would be a recurring maintenance cost in the form of replacement of filter media. For estimating purposes, it is best to assume that the filter media could not be reused. This recurring charge would be nearly $6000 per year for the filter media. Labor cost for change out of the media would be approximately $1500 per year, bringing the total recurring charge to $7500 per year.

Cost of Electrical Energy

Assuming the operating period of the plant to be 2500 hours per year and $0.06/kWh as the rate of electricity, the approximate operational cost for additional electrical power comes to $10 000 per year for first alternative and $3250 for the second alternative.

Cost Comparison

The initial cost of procurement and installation of the retrofit equipment is higher for the first alternative by about $127,000. The electrical operational cost is also higher by nearly $6750 per year. However, the maintenance cost of secondary or additional filters is higher for the second alternative by approximately $7500 per year. Comparing these costs, it is seen that the first alternative is very expensive and is not likely to appeal to owners of wood furniture manufacturing plants.

DISCUSSION AND CONCLUSION

From the above cost comparison, it is apparent that, if the recirculation strategy is adopted, the second alternative (addition of basket-type filters) would probably be the choice of most of the plant owners. However, the final decision to adopt or discard this strategy would depend on how it compares with the other strategy, i.e., the non-

Cost Item	Recirculation Strategy (Second Alternative)	Nonrecirculation Strategy
Initial Cost	$36,000	No initial cost, assuming that the additional air pre-heat load can be put on existing boilers.
Annual Cost (Shift B only)	$7500 (filter change) + $3250 (extra operating cost) = $10,750	$7000 (air pre-heating)
Annual Cost (Shifts B & C only)	$10,750 × 2 = $21,500	$7000 + $10,000 = $17,000 (air pre-heating)
Annual Cost (Shifts A, B, & C)	$10,750 × 3 = $32,250	$7000 + $10,000 + $12,500 = $29,500 (air pre-heating)

recirculation strategy. The costs involved in both strategies are listed above.

From the costs listed above, it is observed that the nonrecirculation strategy is more economical. This observation may or may not be valid if an auxiliary boiler of 50 hp capacity has to be installed if the existing boilers cannot take up the additional air pre-heating load. However, even in the latter situation, the total initial cost and the total annual cost for both strategies would be on the same order. Thus, for the typical plant studied as an example, it appears advisable to select the nonrecirculation strategy, which has the added advantage of a cleaner environment inside the plant. This discussion, however, leads to the conclusion that, for each wood furniture manufacturing facility, the parameters affecting the choice of strategies/options may be different. A cost analysis on the pattern suggested above may be done, taking account of the parameters specific to a particular facility in order to make the right choice.

REFERENCES

AFMA. 1987. "Survey of wood furniture manufacturing units—Dust collection system survey forms." Survey conducted by American Furniture Manufacturing Association in collaboration with Architectural Engineering Department, North Carolina A&T State University, Greensboro.

ASHRAE. 1989a. "Emerging legal issues in indoor air quality." American Society of Heating, Refrigerating, and Air-Conditioning Engineers Annual Meeting, Vancouver, BC, Canada.

ASHRAE. 1989b. *ASHRAE handbook—1989 fundamentals.* Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

DOAF. 1978. *Engineering weather data—facility design and planning.* Department of the Air Force (USA).

OSHA. 1989a. "Air contaminants—rules and regulations." *Federal Register,* Vol. 54, No. 12 (Jan.), p. 2528. Occupational Safety and Health Administration.

OSHA. 1989b. "Air contaminants—permissible exposure limits." *Title 29, Code of Federal Regulations,* Part 1910.1000, pp. 76-78. U.S. Department of Labor.

Singh, H.; Rojeski, P., Jr.; and Kapur, A. 1988. "Energy-conserving design concepts in wood dust collection system." *Proceedings of the Intersociety Energy Conversion Engineering Conference,* Denver, Colorado, Paper No. 889060, pp. 81-85.

BIBLIOGRAPHY

NIOSH. 1987. U.S. Department of Health and Human Services *Health effects of exposure to wood dust—a summary of literature.* Washington, DC: U.S. Department of Health and Human Services, National Institute of Occupational Safety and Health Administration.

Rojeski, P., Jr.; Singh, H.; and Kapur, A. 1988. "Energy efficient dust collection in North Carolina's furniture industry." Report prepared for North Carolina Alternative Energy Corporation, Research Triangle Park, NC.