DEVELOPMENT OF CRITERIA FOR CONTROL OF WOODWORKING OPERATION

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I. Summary and Recommendation:

By summarizing the information and observations reported here, it can be seen that:

- Adverse health effects, such as skin and/or respiratory diseases, have been confirmed to be associated with some native American soft and hardwood species.

- A higher risk of developing cancer among wood workers has been reported in the literature. The higher cancer evidence is generally associated with hardwood.

- The approximate number of production wood workers affected is 300,000.

- Regardless of production variety, the same or similar working machinery is used for similar wood working process.

- Wood dust, originated by wood working process, is emitted at high velocity by moving or spinning machinery component.

  Investigation of wood dust origination mechanism was beyond the scope of this study.

- The primary method of controlling wood dust emission is local exhaust located directly on wood working machinery or at a close distance. The local exhausts are either retrofits on older wood working machinery or a built-in type installed by the manufacturer on new wood working machinery.

- The local exhaust, located close to the emission source, seems to control wood dust relatively well - typical examples are: planers, jointers, saws, etc.) However, if for some reason the exhaust hoods are not (or cannot be) as close or designed as to break or affect dust flow patterns, visible wood dust emission was observed escaping into the work space. Typical examples: sanders, shapers, routers.

- Despite the use of existing ventilation systems, hardwood dust emission levels reported were generally found to be above the TLV standard limit of 1 mg/m^3 adopted by ACGIH (1981) namely in sanding, shaping and routering areas. Wood dust can be classified as both respirable or non-respirable. However, the majority of emissions is non-respirable (emission particle size 10 m).

- The lowest "non-hazardous" wood dust level has not been determined by NIOSH. The identification of the wood dust level, which should be achieved, apparently will result from DRDS and DSHEFS investigations presently in progress. These studies have not been completed.

- The wood working operations which appear to need improved controls are (in descending priority research need): belt sander, disc sander, hand sander, shaper, router, some types of saws.

Based on this summary, it is recommended to:

- Identify the lowest wood dust level which should be achieved.
- Develop a project investigating improvement of existing control technology, or development of new techniques where the control was identified to be poor, namely at disc sanders and belt sanders.

Final goal of this project should be:

- Development of models of wood dust origination mechanisms at selected wood working machinery.
- Development of criteria for wood dust control for selected wood working machinery.
- Proposal of design parameters for new or existing control technology.

The project proposed is attached as Appendix A.

II. Introduction

Wood has been used for several reasons, such as fuel, tools, protection, etc. During the time period, use of wood has been extended and wood became an essential part of the man's need.

Originally the work was done by hand in simple sheds; now the processes are highly mechanized and take place in large enclosed workshops. The machines used produce a great deal of very fine dust. The mechanization took place between 1920 - 1939, but expansions of emission extraction by exhaust ventilation started after World War II (Hadfield and McBeth, 1971).

Wood was always considered as harmless. Recently, however, it is known that this is not necessarily true and that the dust produced in wood working may be hazardous to the worker.

The National Institute for Occupational Safety and Health (NIOSH) has initiated an intensive investigation studying the worker's exposure to wood dust emissions. DRDS has developed a Morbidity and Mortality Study of Workers Exposed to Wood Dust project. DSHEFS is currently investigating a potential high risk due to cancer in a cohort study of automotive wood die and model workers. As a part of NIOSH's effort, DPSE has initiated a study to investigate wood dust control technology in the area of wood working operations. The purpose of this study is to review techniques used in controlling wood dust emissions and to identify areas in wood working where wood dust control technology is most needed or should be improved. The final goal is to determine wood dust control research needs and based on these needs, to develop a research project.

III. Wood Dust Exposure - Health Effects

First, there is an initial effect, resulting in contact dermatitis. Irritant compounds are most common in the sap; thus, the workers most affected are those working in the forest or in saw mill operations.

McCord (1958) lists several American wood species as having the capacity of inducing contact dermatitis, but the following species have been only confirmed: cedar, Juniperus, pine, poplar and silver spruce. A list of wood species causing contact dermatitis is shown in Table 1.

Sensitization is another health defect caused by the exposure to the wood or wood dust. The skin and respiratory system are the organs mostly affected by antigenic substances.

A number of American wood species have been listed as skin sensitizers, however, allergic contact dermatitis has been only confirmed in several

TABLE 1

AMERICAN SPECIES CAUSING CONTACT DERMATITIS (Gamble, 1979)

COMMON NAME	COMMENTS
Western red cedar	One case of allergic contact dermatitis from the wood.
Juniper, eastern red cedar	Juniper or eastern red cedar is officially recognized as cause of dermatitis in German pencil industry.
Incense cedar	2 cases reacted to thymoquinone and hydrothymoquine, but could also be irritant; officially recognized as cause of dermatitis in German pencil industry.
Port Orford cedar	Unconvincing
White cedar	Old (1926) description of dermatitis.
Pine	Relatively uncommon; sensitization has been reported mostly in non-American species.
Spruce	Possible sensitization to hydrostilbenes as often cross react with stilboestrol.
Douglas fir	3 cases with positive patch tests; 2 had previous skin disease; 2 had no exposure to dust.
Fir	8/125 patients had positive patch test. "Fir" was considered significant in 4 of the 8; needles are common irritants.
Hemlock	Positive patch test in 1/125 forest workers with dermatitis.
Poplar	1 atypical case of allergic contact dermatitis; positive patch test could be due to irritation.
Mesquite	Not commonly used wood; particularly valuable as fuel.

varieties of cedar, mesquite, pine, spruce, hemlock, fir, Douglas fir and poplar (Gamble 1979).

There are three types of respiratory diseases which may occur alone or with dermatitis:

asthma and/or rhinitis
hypersensitivity pneumonitis
chronic bronchitis

The evidence for associating wood dust with these diseases is mainly based on case reports rather than on a systematic study (Gamble, 1979). According to Gamble (1979) there are several epidemiologic studies on western red cedar, however, asthma and rhinitis have also been confirmed by bronchial challenge for redwood and oak. It is very likely that other wood dusts can also induce asthma or rhinitis. A summary of reported cases of asthma and rhinitis is shown in Table 2.

Based on recent studies, exposure to wood dust may increase risk of developing cancer among wood workers. Acheson et al. (1972); Andersen et al. (1977); Engzell et al. (1978); Hadfield et MacBeth (1971); and others, reported an excess of nasal cancer in the furniture makers exposed to hard wood. The hardwood types, mostly cited in the literature with connection of causing cancer are: oak, mahogany, beech, walnut, birch, elm, ash. These authors found no patients who worked with soft wood. In contrast, Milham (1978) associated Hodgkin's disease and other cancer increases with soft woods, namely Douglas fir. However, the workers investigated were mostly construction workers and were also exposed to another compounds. Ironside et Matthew (1975) confirmed the European study regarding the cancer in furniture workers, but also reported that some Australian saw millers and carpenters were also affected.

In 1980, the Memorial Sloan-Kettering Cancer Center (Schottenfeld et al., 1980) performed a study of cancer mortality among wood pattern makers and found a statistically significant excess of colon cancer incidence as well as greater than expected mortality from colon and bladder cancer. An excess of colorectal cancer among the wood model makers was found by a study conducted by the Michigan Cancer Foundation (Swanson, 1980). NIOSH performed a mortality study on members of the Pattern Maker's League of North America who died from 1972 - 1978. A statistically significant excess proportion of deaths due to colon cancer and leukemia among members of wood shop locals were among the findings (Robinson, et al., 1980).

TABLE 2
REPORTED CASES OF ASTHMA AND/OR RHINITIS DUE TO WOOD DUST (Gamble, 1979)
(*Native American Tree)

COMMON NAME	COMMENTS
Western red cedar,* arbor vitae	Immediate, late, and dual reactions confirmed by bronchial challenge.
Oak*	Confirmed by bronchial challenge.
Port Orford cedar*	Old report of asthma in woodworkers.
Beach apple*	Rhinitis; not widely used as found only in Everglades of Florida.
Redwood*	2 case reports with dual reaction; confirmed by bronchial challenge.
Iroko, African teak	Officially recognized in Belgium as cause of industrial asthma; chlorophorin is sensitizer for dermatitis.
Afrormosia	An exotic wood that can produce skin and respiratory irritation, asthma, and systemic symptoms.
Kejaat, African Teak	The dust causes both dermatitis and respiratory symptoms.
Rosewood, cocabolla	Many members of this genus cause allergic contact dermatitis.
Nigerian cedar, Agba	One case of possible asthma.
Orangewood	One case unconfirmed.
African mahogany	Confirmed by bronchial challenge and precipitating antibody; genus could be Swietenia; sensitizer for dermatitis identified as anthothecol.
Obeche, African whitewood	Confirmed by skin and inhalation test.
Tucuja	Native of tropical South America.
Cedar of Lebanon	Case reports of 6 workers getting asthma and rhinitis after exposure.
Ramin	Trade reports of asthma and dermatitis, case report of syndrome-like extrinsic allergic alveolitis, but inhalation challenge resulted in reduced FEV_1 and transfer factor in 6-8 hours.
African zebrawood	One case of asthma with dual reaction confirmed by bronchial challenge and immediate skin test reactivity.
Abiruana	2 case reports; 1 with an immediate reaction and 1 with dual reaction on challenge. Both had immediate positive skin tests.
Boxwood	1 case of watchmaker using sawdust to clean gold developed asthma and cough; dual response on challenge; positive skin test; native of Europe and Asia, cultivated as an ornamental in the United States.

IV. Wood Working Industry

A. Identification of establishments and wood production

A majority of industrial wood working operations is classified under the SIC Major Groups #24 and #25. (Standard Industrial Classification Manual, 1967). However, some establishments may also be found in groups of the SIC Major Groups #35, 38, 39.

The SIC Major Group #24 - Lumber and Wood Products, except furniture, includes logging camps engaged in cutting timber and pulpwood; merchant sawmills, lath mills, shingle mills, cooperage stock mills, planing mills, and plywood mills and veneer mills engaged in producing lumber and wood basic materials; and establishments engaged in manufacturing finished articles made entirely or mainly of wood or wood substitutes.

The SIC Major Group #25 - Furniture and Fixtures - includes establishments engaged in manufacturing household, office, public building, and restuarant furniture; and office and store fixtures.

Laboratory and hospital furniture is included in the SIC group #3811, while barber shop furniture is in the SIC Group #3999; wooden musical instruments (piano, etc.) in the SIC Group #3931.

Wood pattern making is classified under the SIC Group #3565 - Industrial Patterns. This group includes primarily establishments engaged in manufacturing industrial patterns.

The individual wood working categories which may be considered for this study are shown in Table 3, along with the number of establishments and production worker population, as they were reported by the U.S. Dept. of Commerce, Bureau of Census 1977 and 1979.

Table 3 only includes main wood working operations, involved in wood working process. The categories, where the workers may be exposed to potentially hazardous substances other than wood dust, were not considered (for example: plywood and particle board production, etc).

The production volume of soft wood and hard wood is different with regard to the geographic localization. In the west, the industry is predominately (99% of western production) based on use of softwood lumber and sawmill stock with very little use of hard wood. The eastern part of the United States has both hard wood and soft wood - almost equally supplied.

According to the Bureau of Census (1980), the total U.S. production of lumber in 1979 was approximately 37,680 millions of board feet. Hardwood consumption represented 15% from the total lumber consumption of 46,640 board feet. Domestic hardwood species were mainly used, 2.7% from the total hardwood consumed was imported.

TABLE 3

Number of Wood Working Establishments and Production Worker Population (Bureau of Census, 1977)

Category	SI Code	Total	Establishments with 20 or more empl.	Employee's in 1000
Sawmills and Planing Mills, General	2421	7,544	1,827	155.8
Hardwood Dimension and Flooring Mills	2426	890	345	25.8
Millwork	2431	2,333	692	56.6
Wood Kitchen Cabinets	2434	2,583	510	38.7
	Total	13,350	3,374 (25% of total)	276.9
Wood Household Furniture, Except Upholstered	2511	2,982	815	124.6
Wood Household Furniture, Upholstered	2512	1,473	730	75.7
Wood Office Furniture	2521	331	119	12.8
	Total	4,786	1,664 (35% of total)	213.1
Industrial Pattern*	3565	1,002	115 (11% of total)	8.0

* According to information by Romelfanger (1982), the population of productive wood pattern makers is approximately 12,000 (union members).

There are about 21 commercial varieties of softwood and about 37 commercial hardwood comprising at least 42 softwood and 98 hardwood species used in the wood working industry. The most common used American native soft and hardwoods in the wood working industry are summarized in Table 4 and 5, respectively.

B. Environmental Data

The Occupational Safety and Health Administration (OSHA) 1976 has defined respirable dust as airborne dust in sizes capable of passing through the upper system to reach lower lung passages. Wood dust particles can be classified as respirable or non-respirable according to their size. A deep knowledge of wood dust size parameters is necessary to identify a real health hazard due to the exposure to wood dust and to determine the wood dust level which should be achieved by the control technology. Unfortunately, there is a lack of systematic studies regarding these parameters.

During past time, NIOSH has conducted several health hazard evaluations (HHE) at different wood working operations, investigating the wood dust emission levels and potential toxic exposure to wood dust. These results are summarized in Table 6.

Within the frame of the DSHEF's cohort study of automotive wood die and model makers, McCammon (1981) has recently performed measurements in several wood pattern operations, investigating the wood dust emissions in the area of shapers, routers, saws and mills. His data are shown in Table 7, along with the incomplete emission concentration data obtained for DRDS study of morbidity and mortality of workers exposed to wood dust (Morey, 1982). More data may be available after completion of both studies.

The results of industrial hygiene personal sampling of wood dust emissions reported by two major wood pattern makers (Anonymous 1973; Enright 1980) are summarized in Table 8.

Investigation of wood dust emissions at furniture industries was reported by several authors (Anderson, et al. 1977; Hounam et Williams 1974; Imbus 1979; Whitehead, et al. 1981). Their results are shown in Table 9.

The size distribution of wood dust emissions from investigation conducted at several wood working operations is shown in Table 10.

C. Control Technology

As a part of this study, MCRB/CRS team has visited several wood working operations to conduct walk-through observations of control technology. The purpose of these visits was to:

TABLE 4

COMMON NAMES AND USES OF NATIVE AMERICAN WOODS

SOFT WOOD (Bureau of Census, 1977)

Commercial Name for Lumber		Most Common Use
Cedar:	Alaska	posts, poles, boats
	Eastern red	chests, closet lining, posts
	Incense	pencils
	Northern White	posts, boxes, shingles, boats
	Southern White	
	Western Red	shakes, shingles, siding plywood
Cypress		furniture, mill work
Douglas Fir		constr. lumber, flooring, millwork, plywood
Fir:	Balsam	constr. lumber, plywood, pulp,
	Noble	boxes
	White	
Hemlock:	Eastern	constr. lumber, plywood, pulp, millwork
	Mountain	
	W. Coast	
Larch		constr. lumber, plywood, boxes, millwork
Pine:	Idaho White	constr. lumber, millwork, plywood, matches
	Jack	constr. lumber, poles
	Lodge Pole	
	Longleaf-yellow	constr. lumber, poles, piling, plywood
	Northern White	constr. lumber, siding, boats, millwork, furniture
	Norway	constr. lumber, boxes, pulp
	Ponderosa	constr. lumber, plywood, millwork, furniture, molding
	Southern Yellow	constr. lumber, plywood, poles, pulp, naval stores, flooring, boxes
	Pine Sugar	constr. lumber, millwork, boxes, lath patternmaking
Redwood:		constr. lumber, plywood, furniture cabinets
Spruce:	Eastern	constr. lumber, pulp, boxes, crates
	European	
	Sitka	constr. lumber, pulp, ladder
Tamarack		constr. lumber, pulp

TABLE 5

Common Names and Uses of Native American Woods

Hardwood (Bureau of Census, 1977)

Commercial Name for Lumber		Most Common Use
Alder		Furniture parts, pulp, firewood
Ash:	Black	
	Oregon	Handles, furniture, crates and boxes
	White	Industrial parts
Aspen		Crates, boxes, pulp, cooperage
Basswood		Crates, boxes, baskets, patternmaking, pulp
Beech		Furniture, industrial parts, boxes, flooring
Birch		Furniture, kitchen cabinets, toys, plywood and veneer, pulp, patternmaking
Box Elder		Woodenware, fuel
Buckeye		Boxes, crates, industrial parts
Butternut		Furniture
Cherry		Furniture, cabinets, wooden ware plywood
Chestnut		Furniture, posts, structural lumber, plywood
Cottonwood		Crates, boxes, pulp, core stock
Dogwood		Industrial parts
Elm:	Rock	Boxes, crates, furniture, plywood
	Soft	Furniture, bentwood frames
Gum		Furniture parts, boxes, crates
Hickory		Handles, plywood, industrial parts, furniture
Locust		Fence posts, ties, lumbers
Maple:	Hard	Furniture, flooring, plywood, handles cabinets
	Oregon	Furniture, plywood, cooperage
	Soft	
Oak:	Black	Flooring, boxes, crates, timbers, furniture.
	Red	Pallets, plywood, poles, posts, cabinet
	White	Barrels, caskets
Oregon Myrtle		Wooden Ware
Pecan		Furniture, flooring, handles
Poplar		Furniture, siding, millwork, novelties
Sycamore		Baskets, furniture, plywood, boxes
Tupelo		Furniture, plywood, boxes, crates
Walnut		Furniture, plywood, cabinets
Willow		Baskets, boxes

TABLE 6 - WOOD DUST EMISSION CONCENTRATION DATA - HHE

Reported Wood Dust Concentration Average (mg/m³)	Reported Wood Dust Concentration Range (mg/m³)	Sampling	Wood Type	Wood Working Operation	Sampling Location	Control Technology	Potential Exposure to Wood Dust*	Remark	Reference
8.60		P.T.	Not Available	Manufacturing TV and stereo cabinets	Shaper	Stationary local exhausts	Both shaper operators	Effectiveness is limited due to the wide arc through which the cutting head travel, while the stationery exhaust covers only part of this arc.	Rosensteel (1974)
0.02		P.R.			Rye Round table operater				
8.90		P.T.			Onsrud table				
0.40		P.R.			shaper operator				
2.29		P.T.	Various type	Sculpturing art class shop	Planing (inc. sanding)	No local exhausts	Concentrations of wood dust are believed to be capable of producing irritation of the upper respiratory tract.		Levy (1976)
24.18		P.T.			Planing (+cutting)				
5.04		P.T.			Sanding (+sawing)				
	4.28-6.75	P.T.			Sanding				
2.24	1.06-3.42	P.T.			Sawing				
0.86		P.T.			Sawing				
2.46		A.T.			Sampling area not identified				
	3.59-22.63	A.T. from Andersen samplers	In bulk: oak, elm, redwood, Douglas fir	Manufacturing of wood parts for variety of commerical products.	Multi-blade rip saw area	Local exhausts	Wood dust level concen- trations toxic to multi-blade saw helper and 1-man cuttoff saws and operator of router	Local exhaust at rip saw inadequate	Kominsky (1976)
	1.39-688.20	P.T.	Secondary: ash cotton wood, hickory		Multi-blade rip saw helper				
	0.47-4.40	P.R.							
0.98		P.T.	magnolia, birch,		Multi-blade rip rip saw operator				
0.39		P.R.	beech pecan, holly, maple sweet gum, walnut						
	0.83-3.47	P.T.	sycamore, willow		Large porter saw operator				
	0.13-0.44	P.R.	poplar						
4.50		P.T.	Imported: blue gum S. African black wattle		Large porter saw helper				
0.48		P.R.							
	0.91-5.05	P.T.			Cut-off saw operator				
	0.07-0.58	P.R.							

1.04		P.T.			Diehl rip saw				
0.73		P.R.			operator				
1.19		P.T.			Shaper operator				
0.39		P.R.			Onsund operator				
	9.65-51.04	P.T.			#63 router			Local exhausts at	
	0.31-0.82	P.R.			operator			#63 router inadequate	
1.64		P.T.			#64 router operator				
1.35		P.T.			Groover operator				
	0.60-8.00	P.T.	Various types, among them, mahogany	Wood pattern making	Pattern makers	Local Exhaust	Wood dust concen. exceeded in one of six samples	Flexible hoses of ventilation system not long enough to extend to work site	Gunter (1977)
	0.12-29.50	P.T.	Western	Shake shingle	Splitter	No	Employees in the Shake mill exposed to potentially toxic concen.	Shake mill operation	Apol (1978)
	0.01-0.36	P.R.	red cedar	production	operator	Control			
	0.17-1.74	P.T.			Deck				
	0.10-0.14	P.R.			splitters				
	5.82-30.70	P.T.			Chippers				
		P.R.							
	0.36-31.90	P.T.			Saw				
	0.05-0.83	P.R.			operator				
	0.18-0.54	P.T.			Deck saw				
	0.18-0.54	P.R.			operator				
	0.32-0.75	A.T.	Pine	Cutting logs debarking	Gang saw area	Not available	Wood dust present not toxic	Saw mill	Apol (1979)
	0.29-0.65	A.T.		trim-sawing	Trim saw area				
	0.15-0.18	A.T.		saw mill operation	Saw operator booth				
	0.26-0.45	A.T.		Planing rough	Trim saw area			Planer mill	
	0.29-0.46			sawn dimensional lumber	Planer area				

1.96-3.02	P.T.	Not Available	Cabinet Making	Cabinet maker	Local Exhausts	Employees working on stationery power wood working machinery (excluding panel saw) exposed to potentially toxic concentrations.	Machinery not identified. Exhaust air flow rates were found below rates recommended by Vent. Manual	Apol (1979a)
2.50-13.7	P.T.			Planer operator				
5.24-11.9	P.T.			Shaper operator				
24.1-50.1	P.T			Rip saw operator				
0.88-1.63	P.T.			Panel saw operator				

PT = Personal Total AT = Area Total
PR = Personal Respirable AR = Area Respirable

* based on TLV = 5 mg/m^3

TABLE 7. WOOD DUST EMISSION CONCENTRATION DATA OBTAINED BY NIOSH

Reported Wood Dust Concentration Average (mg/m^3)	Reported Wood Dust Concentration Range (mg/m^3)	Sampling	Wood Type	Wood Working Operation	Sampling Location	Control Technology	Remark	Reference
	0.093-40.1	A.T.	mahogany, birch, cherry, N. pine, cativo, maple, poplar	Wood pattern making	Shaper area	Local exhaust	Data from 2 plants	Mc Cammon (1981)
0.05		A.R.						
	0.07-52.7	A.T.	mahogany, birch, cherry cativo; N. pine, poplar		Between routers		Data from 2 plants	
	0.13-0.72	A.T.	various (1)		Milling area		Data from 2 plants	
	0.02-0.05	A.R.						
0.47		A.T.	mahogany (Honduras) birch, cherry, cativo, N. pine		Band saw area		Die model shop	
0.052		A.T.	various type (2)					
0.012		A.R.	" "		Table saw		Located in mill shop	
	0.99-4.96	A.T.	white oak	Cutting dimen-ensional lumber	Head saw (in operator booth)	Local exhaust	Saw mill operation - no identification of wood type amount cut during a testing	Morey (1982)
		A.T.	red oak					
	0.67-1.34	A.T.	poplar					
	0.66-0.92	A.T.	basswood					
		A.T.	cherry					
	1.55-2.58	A.T.	soft maple					

A.T. = Area Total
A.R. = Area respirable

(1) mahogany, poplar, sugar pine, plywood fir, maple, cativo (Impreg.^{R}), Spanish cedar, birch, pine, jelutong, cherry, Northern pine.

(2) mahogany, white pine, maple, poplar: 1949 - 1959
mahogany, poplar, cativo (Impreg.^{R}): 1960 - present.

TABLE 8: Wood Dust Emission Concentration Data - Wood Pattern Operations

Reported Wood Dust Concentration Average (mg/m^3)	Reported Wood Dust Concentration Range (mg/m^3)	Sampling	Wood Type	Wood Working Operation	Sampling Location	Control Technology	Remark	Reference
	1.9 - 3.2	P.T.	Mahogany, birch cherry, North. pine cativo (Impreg.^{R})	Wood pattern making	3-axis mill operator	Local exhaust		Anonymous (1973)
	1.0 - 5.7	P.T.			Router operator (incl.: rip sawing)			
	0.8 - 8.4	P.T.			Shaper operator & partial route-ring)			
	0.3 - 0.8	P.T.			Bench Top		Machinery not identified	
	1.9 - 14.2	P.T.			" "		Construction of basis of pine frame box	
11.0		P.T.	Mahogany, poplar	Wood pattern making	Hand sanding also planing	Not available	Samples with 20.2 and 84.2 mg/m^3 contaminated by large particles.	Enright (1980)
20.12		P.T.	sugar pine, maple,					
84.2		P.T.	plywood fir					
	0.4 - 2.5	P.T.	cativo (Impreg.^{R}) Spanish cedar, birch, pine		Sanding			
	1.9 - 26.5	P.T.	jelutong		Shaper operator and part. sawing Shaper operator	Local exhaust	Sample with 26.5 mg/m^3 contaminated by large particles.	
	0.1 - 0.4	P.T.			Omni-mill oper-tor			
	0.2 - 21.0	P.T.			Worker in crating area		Sample with 21.0 mg/m^3 contaminated by large particles.	
	0.9 - 3.4	P.T.			Router operator (and sanding)			
	0.1 - 3.6	P.T.		Model makers			Samples with 23.0 and 58.7 mg/m^3 contaminated by large particles.	
	1.3 - 23.0	P.T.		machinery not identified				
	7.4 - 58.7	P.T.						

P.T. = personal total.

TABLE 9: Wood Dust Emission Concentration Data - Furniture Industry

Reported Wood Dust Concentration Average (mg/m^3)	Range (mg/m^3)	Sampling	Wood Type	Wood Working Operation	Sampling Location	Control Technology	Remark	Reference
5.2		P.T.	Teak, oak, palisander mahogany, jokaranda beech, ramin, native masonito, pine	Furniture production	Planing (includes sawing & drilling	Not available	Average data from 8 furniture makers in Denmark	Andersen, et al. (1977)
14.3		P.T.			Machine and hand sanding			
	2.00-25.2	P.T.	Elm, beech, walnut mahogany, chipboard veneer	Furniture and chair production	Sander operator	Local exhausts	Average data from 5 furniture makers in Great Britain, machine shop well ventilated	Hounam et Williams (1974)
7.2		A.T.			Shaper area			
	1.8-10.9	P.T.			Planer operator			
	1.7-9.4	A.T.			Planer area			
	1.8-94.6	P.T.			Router operator includes: turning			
	2.5-11.3	A.T.			Router area			
	1.5-8.4	P.T.			Molder, spindle operator			
	2.0-36.3	A.T.			Molder area			
	1.0-20.1	P.T.			Band saw operator			
	0.8-100	A.T.			Band saw and circular saw area			
5.4		A.T.	Pine, maple, ash	Furniture production	Multi-blade saw area	Local exhausts	Average from 12 furniture makers in U.S.	Whitehead, et al. (1981)
1.7		A.T.	Pine		Router area (includes sander)			

38.5	A.T.	Maple		Router area (includes shaper)			
12.64	A.T.	Pine, maple, ash		Belt sander area			
8.7		Pine		Drum sander area			
13.5		Pine		Hand sanding			
6.1	from	Maple		Boge sander area			
5.3	Andersen	Maple		Edge sander area			
1.7	samplers	Pine		Sanders-not specified			
8.7-9.1	A.T.	Hard wood	Furniture production	Solem sander	Not available	Average ranges from 5 furniture plants in U.S.	Imbus (1979)
5.1-5.4	A.T.			Mold sander			
7.6-8.1	A.T.			Automatic brush sander			
14.2-16.5	A.T.			Automatic polisher			
2.3-2.7	A.T.			Hand sanding			
0.9-2.3	A.T.			Routers			
0.6-2.1	A.T.			Band saws			
2.9-3.6	A.T.			Lathes			
4.3-4.7	A.T.			Tenoner			
0.8-0.9	A.T.			Rip saw			
1.1-2.7	A.T.			Molders			
2.3-4.4	A.T.			Shapers			

P.T. - Personal Total
A.T. - Area Total

TABLE 10

Data on the Aerodynamic Particle Size Weight Distribution
% of Sample Weight on Stage

Location	Wood Type	Cut-off diameter								Remarks	Reference
		22.5 µm	14.1 µm	5.5 µm	3.2 µm	2.0 µm	1.2 µm		Filter		
Belt Sander	Pine	77	11.5	5.5	2.5	0.75	0.75		1.8	Samples positioned on machines as close as possible to worker's breathing zone	Whitehead, et al., 1981
	Ash	72	15.0	8.0	2.0	0.50	--		0.5		
	Maple	69.5	15.5	11.0	3.5	1.00	0.30		0.5		
Drum Sander	Pine	54.5	18.5	12.5	3.0	2.5	2.0		6.0	Averaged from 12 furniture makers	
Edge Sander	Maple	73.5	15.0	7.5	2.0	--	--		2.0	Local exhausts generally on machinary except hand sanding (no control)	
Boge Sander	Maple	72.0	19.5	8.0	1.5	--	--		--		
Sanders (not identified)	Pine	65.0	17.5	12.0	--	--	--		--		
Hand Sanding	Pine	68.0	21.5	7.5	1.5	0.5	0.5		--		
Router-Sander	Pine	76.0	17.5	6.0	--	--	--		--		
Router-Shaper	Maple	86.0	9.0	3.5	0.5	1.0	0.5		0.5		
Multi-blade saw	Maple	79.5	11.0	5.5	2.0	--	--		--		
			9.2 µm	5.35 µm	2.95 µm	1.53 µm	0.92 µm	0.54 µm	Filter		
Multi-blade saw	Various Type (1)		84	7	3	2	2	1.5	1	Manufacturing of wood parts for variety of commercial products. Local exhaust on machinery. Average from 3 measurements.	Kominsky (1976)
		10 µm	7 µm	4.7 µm	3.3 µm	2.1 µm	1.1 µm	0.65 µm	0.43 µm		
Milling (center shop area)	Cherry cativo, Northern pine, birch, mahogany	5	31.5	17	8	7	5	6	20.5	Wood die model shop	McCammon (1981)
Shaper Room (center)		22	19.5	9.5	6	6	4	5	27.5	"	"
Milling	Various type (2)	47.5	20	--	6	7	5	4.5	10	Mill Shop	
		21.0	18	14	8	8.5	8	5.5	16	Mini mill shop	

		13.7 µm	4.2 µm	1.5 µm	1.5 µm		
Saw	Elm,	40	47	8	5	Average from 5 furniture	Hounam et Williams
Router	beech	35	50	7	8	makers in Great Britain.	(1974)
Planer	walnut	32	50	8	8	Reference: Hounam and	
Sander	mahogany	30	48	10	11	Williams, (1979).	
Spindler		38	44	10	8		

(1) In bulk: redwood, oak, elm, Douglas fir
Secondary: ash, cottonwood, hickory, magnolia, birch, beech, pecan, holly, maple, sweet gum, sycamore, walnut, willow, poplar.
Imported: blue gum (Eucalyptus), S. African black wattle.

(2) Mahogany, poplar, sugar pine, plywood fir, maple, cativo (Impreg.[R]), Spanish cedar, birch, pine jelutong.

- Acquire practical up-dated knowledge of the control technology presently used at wood working operations.

- Identify areas of wood working operations where control technology is needed or needs to be improved.

- Familiarize with different type of wood working process.

All visits were informative and strictly related to the control technology. No industrial hygiene measurements or data were taken, no worker was questioned about health conditions.

A list of the wood working operations visited is shown in Table 11 along with the wood type generally used for processing.

During these visits, it has been observed that the same or similar wood working machinery is used for the similar wood working process. Therefore, the reported findings from the observations will be based on the wood working machinery type.

Typical wood working machinery observed was: different types of radial table saws, band saws, rip saws, routers, disc and belt sanders, drum sanders, shapers, tenoners, molders, lathes, drills. Some machinery had an automatic lumber feeding, at some machinery, the lumber is fed manually.

Table saw:

All circular table saws were controlled by a ventilation system, which is recommended by the Industrial Ventilation Manual (1980) and shown in Figure 1. The upper part of the blade (working part above the table) was covered with a protective guard, which - in some cases, was also ventilated. At some operations a strip of flexible material was attached to the machinery covering the open space between the table and lower hood. When the hood was operating, this strip, due to suction, was firmly pressed to the machinery, decreasing the open area. This innovative adjustment served as to increase the control velocity of the lower hood and to diminish the wood dust release from this space.

A special modification of the ventilation system was observed on the circular saw for cutting off narrow slats. The blade was fully covered, leaving only a narrow opening on the top of the blade. This cover was ventilated.

Rip saws:

This type of saw also had the protective guide, located above the blade. The cover was connected to the ventilation system. When the rip saw was provided with an automatic feeding for transportation of the wood, the feeding system was also controlled by the hood located

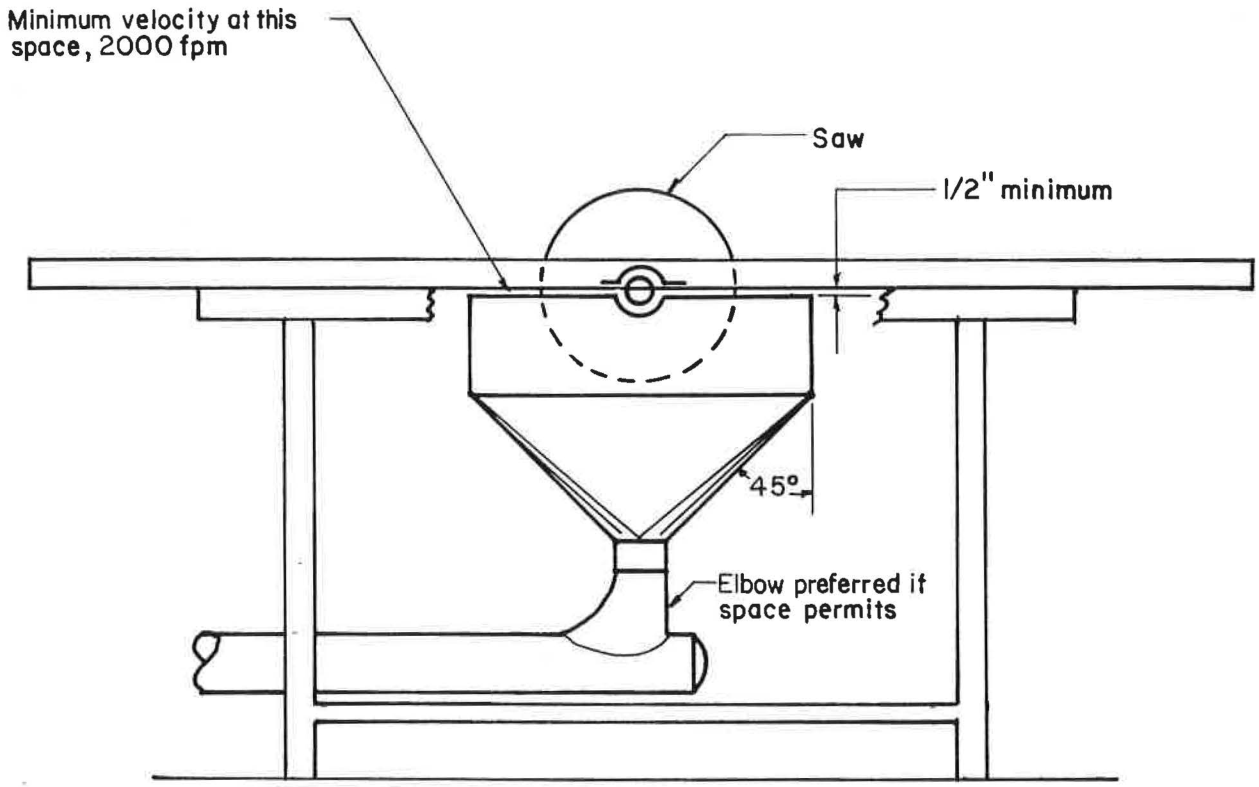
TABLE 11

List of Woodworking Operations Visited
and Wood Type Used

Small Wood Pattern Maker,	#1	Mahogany, sugar pine
	#2	Pine, mahogany
Large Wood Pattern Maker,	#1	Cativo (Impregnated[R]), mahogany (Honduras) birch, cherry, white pine
	#2	Mahogany, poplar, cativo (Impregnated[R]) (before 1960: mahogany (Honduras, Philippine), maple, poplar, white pine)
	#3	Mahogany, poplar, sugar pine, plywood fir, maple, cativo (Impregnated[R]), Spanish cedar, birch, Jelutong, cherry, northern pine
Wood furniture maker,	#1	Walnut, red oak, sycamore
	#2	Oak, walnut, gum
Hardwood Floor Manufacturer		Oak, hickory, maple, birch, ash

FIGURE 1

Table Saw (ACGIH, 1980)



underneath the transportation system in the neighborhood of the saw. At one operation, a collector with an outlet on the side of the multi-blade rip saw, was located underneath the transportation chain. A small hood, located close to the outlet, controlled the dust from this collector.

Band Saws:

The ventilation systems at all band saws observed were installed underneath the blade slot, as it is indicated in Figure 2. Only one innovation of this system was observed at a wood pattern maker. The table blade slot incorporated several 1/8" diameter holes to increase the collection area of the hood, which is normally limited by the slot opening. This plant also plans to install a suction nozzle above the table at the rear of the saw blade to collect the wood dust from the saw teeth.

Emission Observations:

Local exhaust systems, located above or under the saws were generally working adequately - only a few visible emissions (if any) were observed. Rather, splinters or very large particles were observed. The above described collector on multi-blade rip saw did not work properly because the hood was not physically attached to the collector outlet. The band saw with the multi-hole blade slot was not operating during the visit. However, according to plant information, this modification did improve the hood collection.

Planers:

According to their use, the planers may have one or more planing components. The spinning head was usually controlled by an open face hood located above the head. In the case of a multiple-head planer, each head was ventilated separately or one hood controlled several heads. As an example, 3-head planer observed at one of the furniture makers, was controlled by a system of two hoods - one controlled two heads located above the planer table, while the second hood, located under the table, controlled the head processing the bottom of the lumber. The typical example of the ventilation system controlling each head separately is shown in Figure 3.

Emission Observation:

The control technology installed at this type of wood working machinery appeared to work properly and efficiently. There were no or very few emissions observed. Occasionally, very large particles (splinters) were thrown off.

FIGURE 2

Band Saw (ACGIH, 1980)

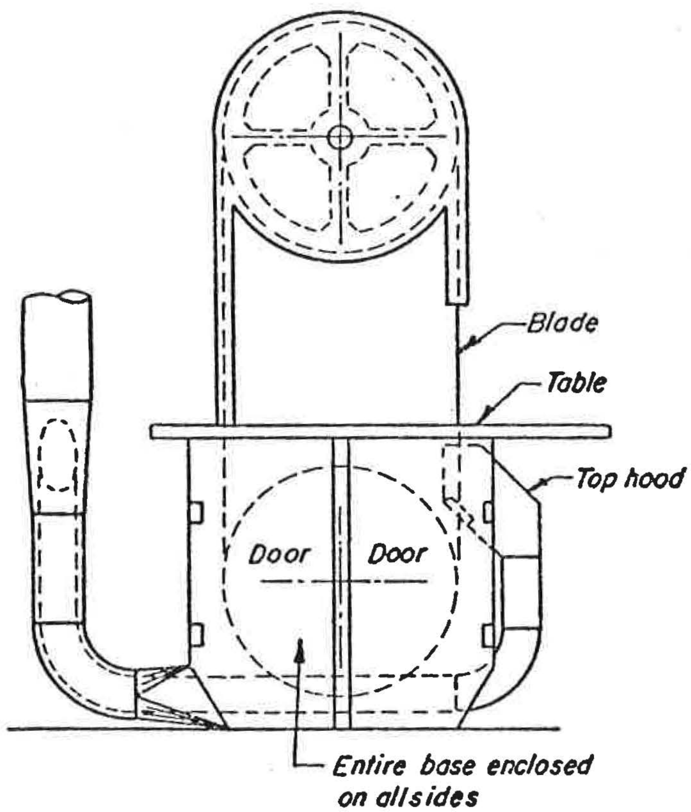
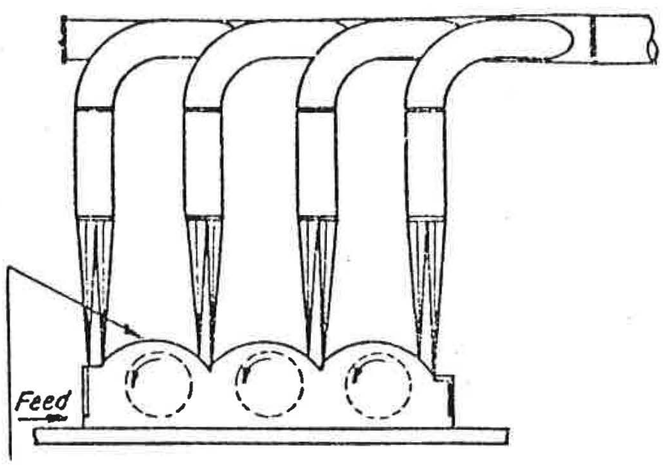


FIGURE 3

Multi-head Planer



Jointers:

All jointers observed were controlled by a local exhaust hood located underneath the machine head, as it is indicated in Figure 4. There was no additional innovation of the installed control technology observed.

Emission observed:

This was a clean operation - no visible wood dust emissions were observed except some splinters thrown off by the spinning component.

Unfortunately, there were few jointers operating during the visit.

Molders:

There was a variety of molder types observed. Generally, each molder incorporated a number of heads which were controlled separately by an open face hood shaped around the spinning component. A combination of a four-head molder with planer was used at one of the furniture makers. Each head of the molder was controlled. The rough planer, located at the lumber feed end of the machinery did not have a hood, while the fine planer located at the opposite end of the machine was ventilated by a hood positioned underneath the molder table. An innovation, installed in addition to the existing ventilation system by the plant management was observed at a four head molder-tenoner. Besides the usual local exhaust ventilation at all spinning heads, an additional small open face hood was installed aside the machine between the main head and the worker. This small hood controlled the emissions eventually released through the face opening of the existing local exhaust at the main head.

Emission observation:

At this type of the operation, the local exhausts seemed to work adequately - there were generally no problems with the emissions. Only a small amount of visible wood dust was observed. Rather, splinters and very large particles were observed to be emitted at the uncontrolled rough planer combined with the 4 head molder. The above described additional installation of the hood at the molder-tenoner contributed significantly to the diminishing of the wood dust emission not controlled by the main head local exhaust.

Shapers:

Typical shaping machines observed consisted of two spinning heads. Each head was controlled by a plain open hood, which was located on the table behind the head. The opening of the hood was either fixed or adjustable via a movable hood wall. A typical installation of the local exhaust is shown in Figure 5.

FIGURE 4

Jointer (ACGIH, 1980)

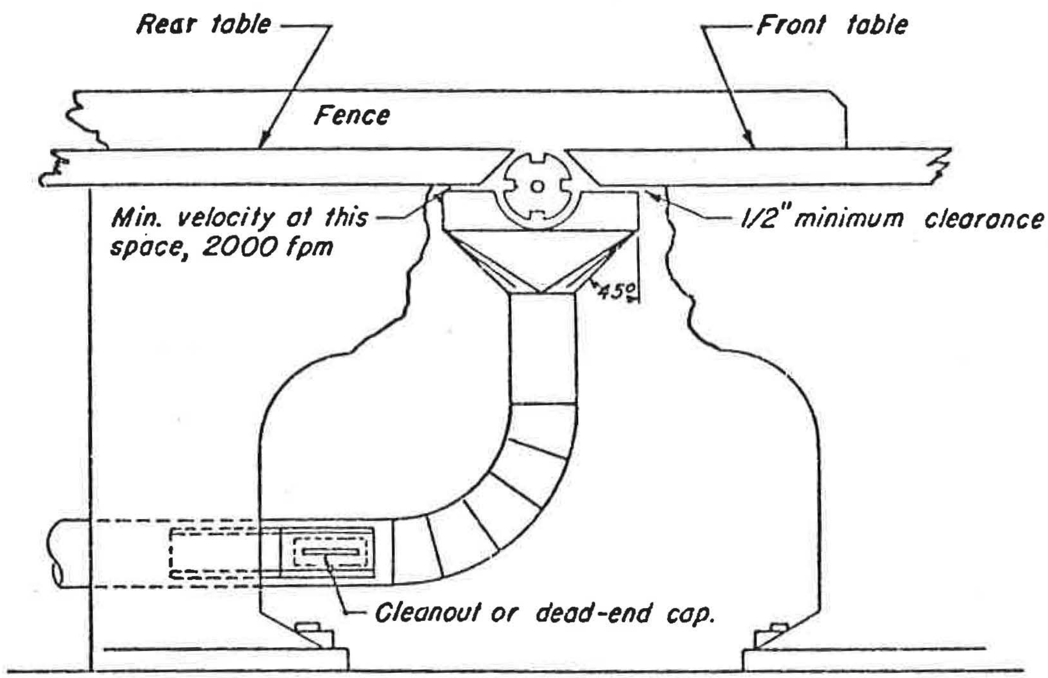
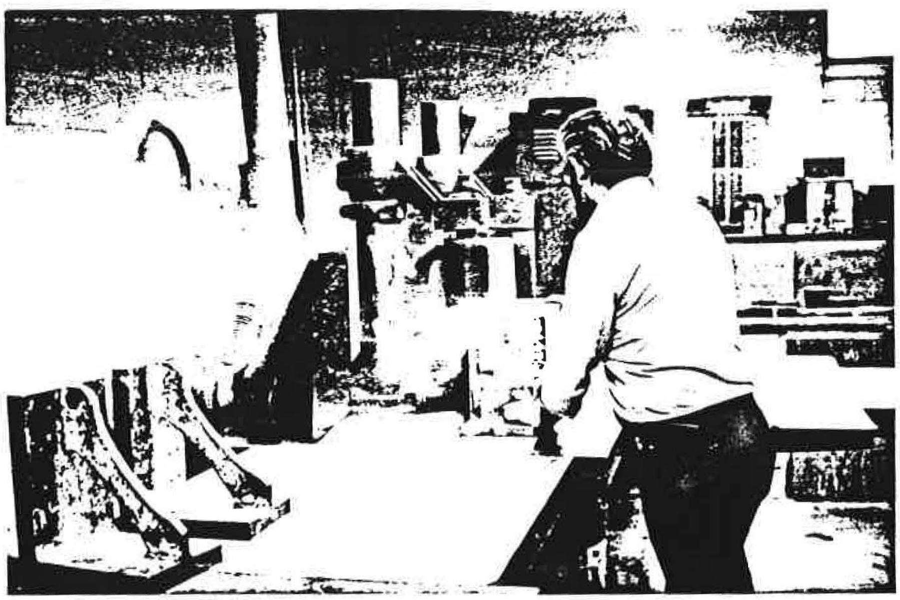


FIGURE 5

Shaper in Operation
(Courtesy of C. McCammon)



A combination of fixed and movable hoods was also observed. Between the shaper heads, a fixed plain hood was attached at the rear edge of the table. At both outer sides of the hoods, movable open hoods were situated on the table.

A quasi push-pull ventilation system was installed at one of the wood pattern model shops. This system consisted of two fixed hoods located behind the shaper heads, as described above. The push ventilation system was suspended from the ceiling behind the worker above his head. The push air flow was directed toward the exhaust hoods.

A combination of two hoods was observed at a round table shaper. The opening of a small movable hood, located at the upper part of the spinning head, was positioned close to the working head area. The second hood - open face - was located at the periphery of the table.

Emission observation:

The typical hood system located at the dual shapers does not seem to work properly and adequately. Visible emissions were discharged into the work place and not collected by the hood, apparently due to insufficient air flow rate. The combination of fixed and movable hoods was not very effective either. The push-pull ventilation was not seen operating during the visit.

An emission problem at the round table shaper was reported by the plant personnel. Both hoods are incapable of controlling wood dust emissions due to the wide arc through which the head travels.

Mills:

Three types of ventilation systems were observed controlling large milling machines:

A ventilation system consisting of a system of flexible hoses located above the working table and behind it.

A local exhaust which was directly built-in in the spinning head of the mill. This system was factory-installed.

A combination of push-pull ventilation with a booth-type hood was observed. The milling machine was situated at the front edge of the booth provided with a pulling system. The push ventilation consisted of two flexible hoses, suspended from the ceiling in front of the mill. The air flow was directed toward the booth opening. Two plastic walls situated in front of the mill secluded the system from the other shop space and helped to direct the push air flow.

Emission observation:

No problems with the emissions have been identified at this machinery.

Routers:

The technology, usually controlling router operations consisted of two open face hoods located behind the heads on the router table. These hoods were connected via a flexible hose to the ventilation system. A typical installation of such hoods is shown in Figure 6. The hoods were movable in horizontal direction so that they could be located as close to the router as possible. However, hood adjustment only in the vertical direction was also observed. At some installations, the hoods were combined with a slot or open face hood, which was situated at the rear end of the router table.

Another combination of two hood systems was observed at one furniture maker: A small hood was fixed to the router head and connected to the ventilation system via a flexible hose. Another - open face - hood was located at a side of the router table. The above described flexible hose was generally connected to the head hood, however, at some routering process, the operator disconnected the flexible hose and positioned it on the router table to improve the dust collection. An innovative system of push-pull ventilation installation was observed at one wood pattern shop. The pull system consisted of two open face hoods located at the rear end of the router table. The push system was a movable narrow slot hood located on the router table.

The small hand routers were generally not controlled.

Emission observation:

Visible emission of fine wood dust was observed at all router's operations, namely, with the control technology being fixed to the router's head. The hood located at the side of the table did not seem to be very effective, due to a farther distance between the hood and the emission source. A shape of some local exhaust hood, shown in Figure 7, seemed to contribute to the lower collection capability of the hood due to a sudden change of the wood dust direction.

The router controlled by the push-pull ventilation system was not operating during the visit.

Lathes and drills:

This type of machinery observed was not controlled. An installation of an open face hood attached to a movable mechanical arm is planned at one wood pattern making shop.

FIGURE 6

Router Ventilation System
(Courtesy of C. McCammon)

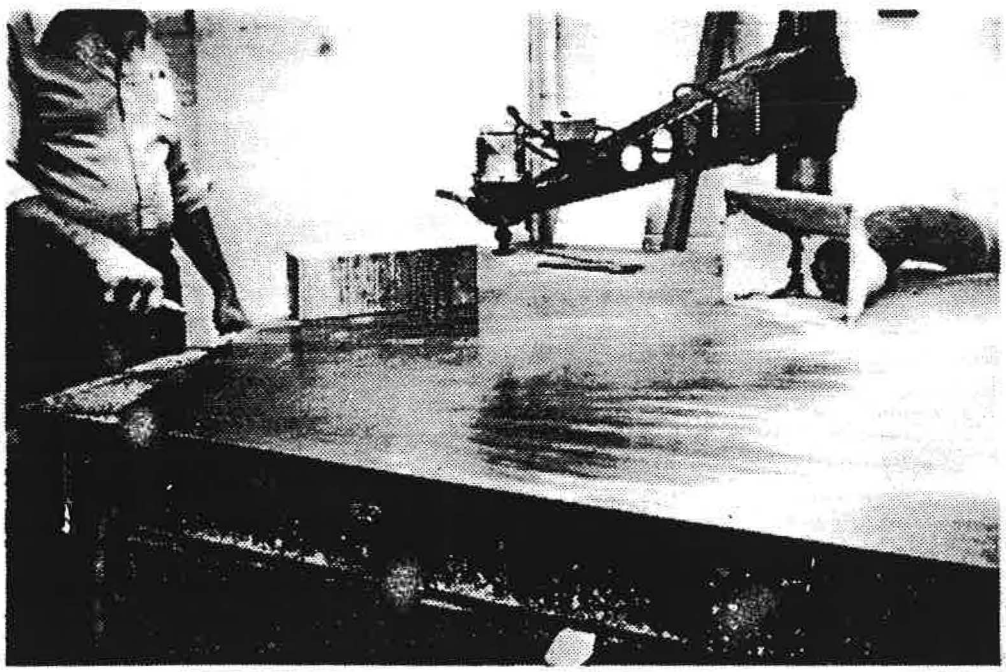
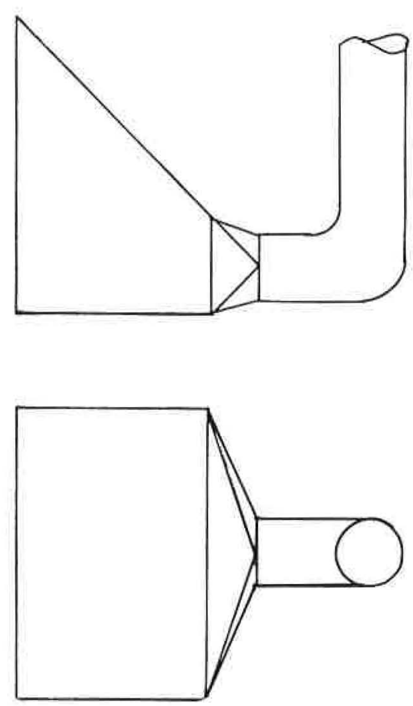


FIGURE 7
Hood Shape Found at Some Routers



Sanders:

There was a variety of sanding machines, however, two basic types could be recognized: spinning sanders and belt sanders.

Disc sanders:

Disc sanders were generally controlled by a hood positioned under the sander table. Above the table, the sanding wheel was provided with a protective cover at the rear side of the wheel. A guard around the wheel periphery was hinged to the protective cover. A typical installation of the local exhaust at the disc sander is shown in Figure 8.

At some operations, the protective guard was also connected with the ventilation system so that a system of two hoods controlled the wood dust emission.

An innovative installation of the local exhaust was reported by one wood pattern maker during the visit. An additional "shoe-hood" is planned to be located at the sander table level perpendicularly to the spinning direction. The hood should collect the dust above the working table produced by the spinning wheel. This innovation was installed after our visit. As reported by the user, the hood is not working properly and did not reduce wood dust emission, as expected. It will be replaced by another type of hood, parameters of which are in the process of investigation.

Another type of sander was a vertical drum sander (spindle sander), which was controlled by a hood, situated under the table. The hood opening is around the whole drum periphery enabling an up and down vertical movement of drum while spinning.

Belt sanders:

The wood is sanded or polished by a contact with an endless sanding belt. For sanding, the wood is fed manually or automatically into the machine or the sanding belt is pressed toward the wood which is located next to the belt on a working table (edge sanders). The exhaust hoods were generally located at both ends of the belt, controlling the dust carried by the belt. A typical installation of the ventilation system at the horizontal belt sander is shown in Figure 9.

At some operations, the hood was provided with a side hinged door, which could be opened to accommodate a lumber piece longer than the operating length of the belt.

At some operations, an additional smaller hood was installed above the area where the lumber is processed, as indicated in Figure 9.

FIGURE 8

Disc Sander Ventilation System (ACGIH, 1980)

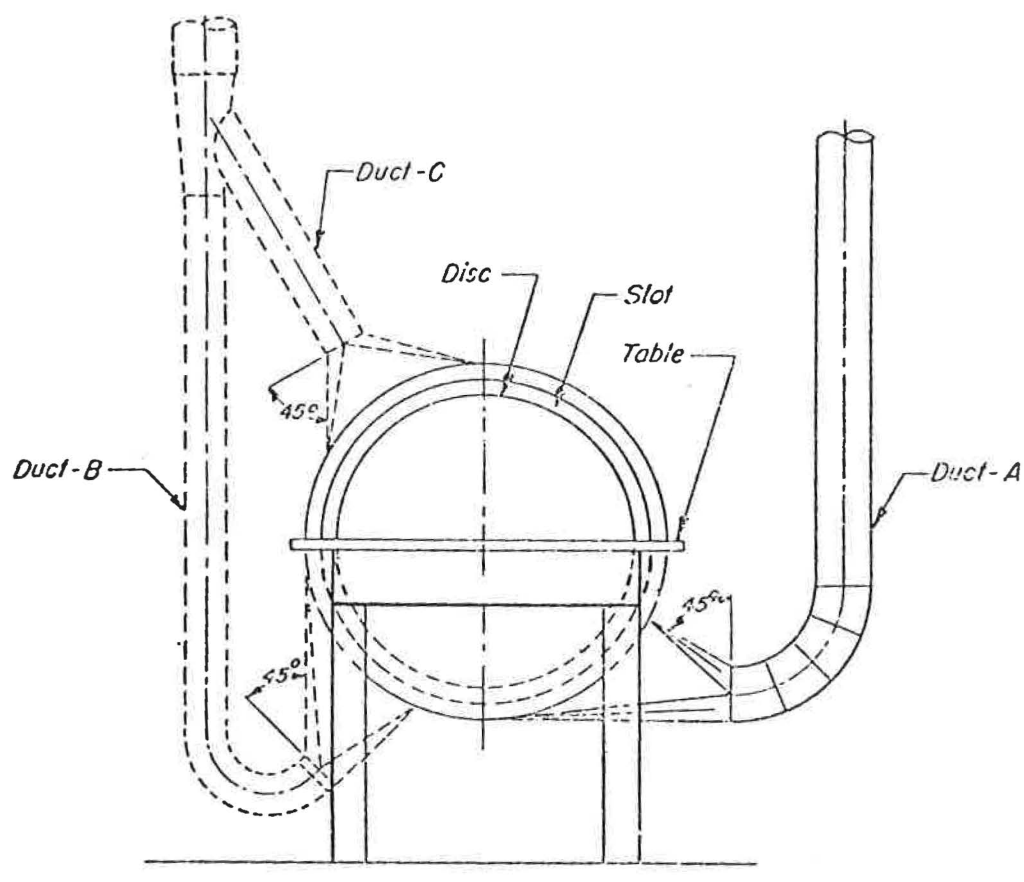
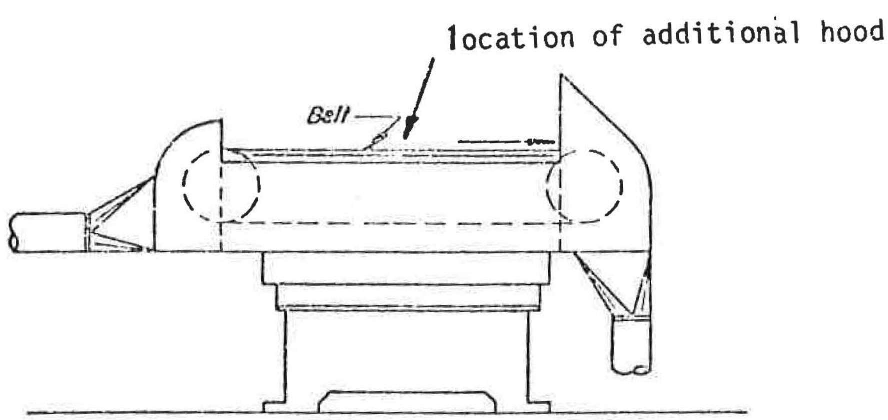


FIGURE 9

Horizontal Belt Sander (ACGIH, 1980)



The belt sander having the automatic feeding system was also equipped with a ventilation system, controlling the dust from this feeding system. When the feeding system consisted from a number of narrow belts, small slot hoods were located between each belt. A typical example was a large polisher with a factory-installed ventilation system in one of the furniture shops. In addition, the plant installed a movable hood directly above the polishing area.

A one-piece feeding belt was generally controlled by a hood located under the transportation belt. Typical example was a wide belt vertical sander. Two vertically positioned belt grinders were controlled by the slot hoods at the operation ends. The feed belt was provided with the open face hood located under the belt. The whole system was completely closed by an enclosure.

A modification of belt sander - as a drum sander - is shown in Figure 10. As it is seen from the figure, the whole system was enclosed in a hood, except the opening at the end of the belt. Above this grinding opening, an open face hood was located.

The hand sanders were generally not controlled. A hand sander with a factory built-in vacuuming system is being used by one wood pattern maker. A significant reduction of wood dust emission was reported by the user.

Emission observations:

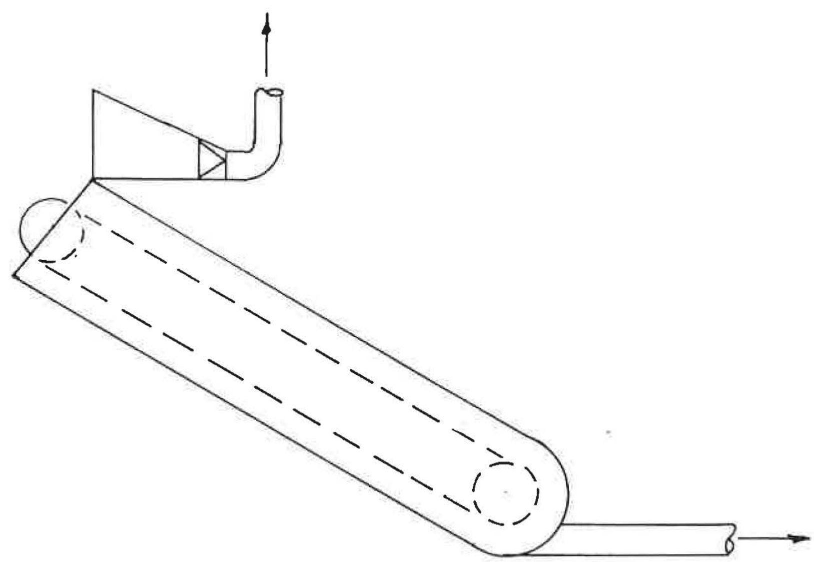
The control technology used at the sanders, or polishers, did not seem to work properly. Visible emission of wood dust into the work place was observed at disc sanders. The belt sanders appear to have an even bigger problem with the wood dust discharge; namely, the sanders where large pieces of the lumber are polished. The hoods located at the ends of the sanding belts did not seem to handle the wood dust produced.

Evidently, the hoods were not capable of controlling emissions produced at the center of the belt, due to the farther distance between the hood and emission source. The hood shape, frequently used, (see Figure 7) apparently contributed to the decrease of the hood efficiency. The additional hood, installed above the working area by the plants, seemed not to solve this problem. Some ventilation systems controlling emissions from feed belts were found inadequate and the installation of the additional hood did not appear to help. Typical example was the large polisher with the factory installed ventilation system.

However, the wide vertical belt sander had the factory installed wood dust control completely covered in the enclosure, along with the sanding belt and rollers. This ventilation seemed to be working effectively, because no visible emissions were observed at this machine.

FIGURE 10

Sketch of Drum-Belt Sander



As it has been mentioned above, hand sanders were generally not controlled and emissions produced by these sanders were released into the workplace.

V. Discussion

As it has been indicated above, wood dust can be classified as both respirable or non-respirable, according to its size.

OSHA has no permissible exposure limit for wood dust as such. The limits for inert or nuisance dust are normally applied. The current federal limits for nuisance particulates, presumably including wood dust, is 15 mg/m^3 for the total and 5 mg/m^3 for the respirable fraction, expressed as TWA concentration for up to an 8-hour work shift in a 40-hour week.

The TWA concentration adopted by the ACGIH (1981) is 1 mg/m^3 for certain hard woods (as beech and oak), while for soft wood, (non-allergic) is 5 mg/m^3. The concentration for short term exposure limit (TLV-STEL) is 10 mg/m^3 for soft wood; No STEL-limit for hardwood has been established.

The Canadian province of British Columbia has a standard for allergic wood dust of 2.5 mg/m^3 (APOL 1978).

An interesting suggestion for recommendation of wood dust exposure limits was published by Hanslian and Kadlec (1964). The authors recommended, based on the content of toxic substances, that the wood can be divided into three levels of toxicity:

- Low level (oak, beech, maple, ash, etc.)
- High level (mahogany, birch, pine)
- Allergenic (yew, mansania).

The limits of exposure recommmended for these groups were 10, 5 and 1 mg/m^3, respectively.

In their HHE's, the NIOSH's investigators generally used a former standard of 5 mg/m^3 for the identification of potential toxic exposure to wood dust. However, if the TWA-standard of 1 mg/m^3 adopted by ACGIH (1981) would be considered, the potential toxic exposure ratio would be much higher than reported in HHE's (see Table 6).

Since the level of exposure necessary to cause serious disease is not well defined, it would seem prudent to maintain levels of wood dust at as low a level as possible.

As it is obvious from Table 6-9, the reported data regarding wood dust emission levels vary widely. This variation could be caused by several parameters. In the first place, intensity and volume of work performed on wood working machinery, frequency, machinery type and ratio of machinery use to hand working, will mainly affect the results in personal sampling. The wood material processed, the wood dust size and its particle size distribution, will contribute to the variation of both personal and area sampling. At last, but not least - the ventilation system condition and efficiency will play a major role in the collected data variation. Unfortunately, these parameters were not generally reported and, therefore, it may be difficult to specify any details from the information shown in the above tables.

However, a major conclusion could be drawn from these data. The results from the area and personal sampling obtained at several furniture makers (Table 9) indicate that a higher concentration of wood dust emitted can be generally found at sanders, shapers and routers compared to other types of wood working machinery. Local exhausts were reported to be mainly used. A similar conclusion could be found in Table 8, where the concentration data obtained from personal sampling at two major wood pattern makers are shown. The data appear to offer greater potential for generating dust in hand sanding, shaping and routering area, compared to the milling, crating, or other activity. Some extensive concentrations found in some operator's personal samples should be, however, ascribed to the very large wood particles found in the sample, as noted by one of the authors (Enright, 1980). It should be again reminded, that most of the wood working machinery was controlled by local exhausts.

These findings are consistent with the results from the measurements conducted by NIOSH's investigators, as shown in Table 7. A higher concentration of wood dust was found in the shaper and router area compared to the milling and sawing area. It follows from this table that the local exhausts were controlling the wood working machinery under investigation. A majority of HHE investigations, shown in Table 6, indicate and confirm that sanders, routers, and shapers, tend to produce higher amounts of wood dust than the other types of the wood working machinery.

Sometimes high wood dust levels were reported at machinery, where low levels would normally be expected. In these cases, however, an inadequate ventilation system was generally reported being used. A typical example may be a very high wood dust concentration range of 1.4 - 688 mg/m^3 obtained from personal sampling on the multi-blade rip saw helper, compared to the significantly lower dust concentration found in personal samples of other saw operators, as shown in Table 6 (Kominsky, 1976).

The mass concentration of wood dust is not the only dust parameter which should be considered for evaluation. The size, and size distribution of wood dust, is also very important because it may provide different health effects and different control practices. The small airborne wood dust particles are swept into the respiratory tract during inhalation and may be deposited there, giving a rise to undesirable biological effects and different control practices. The large dust particles are incapable of entering the respiratory tract; however, the increased potential for ingestion of these particles should not be ignored.

Despite the scarcity of data concerning the mean size and size distribution, it can be presumed from Table 10, that the prevailing concentration of wood dust particles is in the range of 10 m or above, which seems to be consistent with the findings in Tables 6-9.

Regardless of different cut-off diameters of reported data, it could be seen from this table, that the size distribution tends to change favorably toward smaller particles produced by sanders.

Based on the observation, wood dust, originated by wood working process, is emitted at high velocity by moving or spinning machinery component. In some cases, the particles are carried in teeth or other profiled surfaces of the moving component and then thrown off later. A typical example may be the band saw.

The primary method of controlling wood dust is with local exhausts. The exhaust hoods are located as close as possible to the emission source, either on the wood working machinery itself, or at a close distance from the machine. Both ways were observed.

Reported air flow rates of some local controls are shown in Table 12, and compared with the air flow rates, recommended by the ACGIH Industrial Ventilation Manual (1980). According to the manual . . . "the recommended exhaust volumes are for average-sized wood working machines and are based on many years of experience. It must be noted that some modern high speed or extra large machines will produce such a large volume of waste that greater exhaust volumes must be used . . . ."

As it is seen from Table 12, the majority of the reported flow rates are in compliance, or higher than recommended by the manual. However, despite the recommended, or higher flow rate volumes used, visible wood dust emission was observed at disc and belt sanders, routers, and shapers, while no emission problems were found at planers, jointers, and saws.

This may suggest that increase of exhaust volume may not be sufficient for reducing wood dust emission to the TLV-level recommended by ACGIH (1981), and that a new design or redesign of existing local exhausts may be required. Apparently, the exhausts close to the emission source (or well designed exhausts) seem to be adequate and to control wood dust relatively well. However, when for some reason, the hood is not as close, or designed as to break or affect dust flow pattern, or collect the dust stuck to the moving components, visible wood dust

TABLE 12

Reported Local Control Air Flow Rates at Some Wood Working Machinery

	Flow Rate (ft^3/ min)			
	Reported by User			Recommended
Wood Working Machinery	A	B	C	by ACGIH (1980)
Disc sander, 12"			400	350
Disc sander, 12" - 18"			600	440
Disc sander, 20"	505			550
Disc sander, 18" - 26"			900	550
Disc sander, 24"	700	480		550
Double end disc sander, 30"	1635			700
Edge belt sander (belt 6" - 9")			600/900*	350/550*
Edge belt sander (belt 9" - 14")			900/1200*	440/800*
Polisher, (belt 6")			900/900*	350/440*
Polisher, (belt 7")			1250/1250*	350/350*
Polisher, (belt 8")			1500/1500*	350/350*
Router	990	1100/1700+	600	350/800
Shaper	1550	1800++		440/1400
Band saw (3/4" blade)	1170	310/400	900	700
Jointer (size not specified)	1083			800
Jointer (knife length 6")		350	400	350
Jointer (knife length 6" - 12")			600	440
Jointer (knife length 12" - 24")			900	550
Planer, single, 18" knives		770		785
Planer, single, 26" - 32" knives			1500	1400
Planer, double, 32" - 38" knives			1900/1570**	1800/1400**
Radial Saw (14")			900	350
Table cut off saw (12")			400/700	350
Table circular saw (12")			400/700	350

* - tail end/head end data

** - top/bottom data

\+ - push-pull system (push system = 390 ft^3/min)

++ - push-pull system (push system = 900 ft^3/min)

A. Large wood pattern maker, #2

B. Large wood pattern maker, #1

C. Wood furniture maker, #2

emission was observed escaping into workroom space. Typical examples are routers, shapers, and sanders. At the latter, excessive emissions were observed in some cases. This observation is consistent and in very good correlation with the wood dust levels reported in the literature (see Tables 6-9).

One has to notice, however, that the Industrial Ventilation Manual does not include exact hood design and that the shape of the observed controls were simliar only to those schematically shown in the manual. In some cases, only the flow rate data without a hood diagram are recommended by the manual. Therefore, a comparison between the recommended and reported air flow rate data is difficult and may not be fully suitable to account for success or failure to adequately control.

The airborne wood particles, emitted into the work place, are usually controlled by general ventilation. During the visits, a variety of general ventilation was observed - from natural ventilation to the forced make-up air system, generally found at large operations.

The larger operations were also found to be cleaner than the smaller ones. The large operations seem to be favorably inclined toward an improvement of their existing control technology. For example, some innovative additional controls were installed by the plant to the existing ventilation system. The maintenance of the ventilation system is on a higher level here than at small operations. A concentration of wood working machinery in one spot secluded from the other work room space was observed at a large wood pattern shop, so was the exclusion of eating in the work room. Such activities may not often be possible or feasible for smaller shops.

The newer wood working machinery was equipped with ventilation systems installed by the manufacturer; older machinery is provided with retro-fits, sometimes designed by local designers.

As it is obvious from Table 11, the majority of wood used at observed operations was a variety of hard wood - this is consistent with the information about the use, shown in Tables 4 and 5.

The parameters for the selection of the SIC groups for identification of the production worker population include:

- major use of hard wood

- use of wood working machinery which appear to need improvement of control.

Based on these parameters, the total number of the workers affected may be approximately 300,000, considering all SIC #25 groups, shown in Table 3, and including the SIC groups: 2426, 2434 and 3565.

ACGIH: Industrial Ventilation, 16th Ed., Committee on Industrial Ventilation, Lansing, MI 1980.

ACGIH: TLV's -Threshold Limit Values for Chemical Substances in Workroom Air. Adopted by ACGIH for 1981.

Acheson, E.D.; R.H. Cowdell and E. Rang: Adenocarcinoma of the Nasal Cavity and Sinuses in England and Wales. Br. J. Ind. Med. 29:21-30, 1972.

Andersen, H.C.; I. Andersen, J. Solgaard: Nasal Cancers, Symptoms and Upper Airway Function in Woodmakers. Brit. J. Ind. Med. 34, 201-207, 1977.

Anonymous: Body Engineering Product Engineering, Die Model and Plastic's Shops. Industrial Hygiene Air Monitoring Data, 1973.

Apol, A.G.: Health Hazard Evaluation #76-79, 80-543. Weyerhaeuser Co., Longview, WA. U.S. DHEW, CDC, NIOSH, Cincinnati, 1978.

Apol, A.G.: Health Hazard Evaluation #78-97-559. Homestake Forest Products, Spearfish, SD. U.S. DHEW, CDC, NIOSH, Cincinnati, OH 1979.

Apol, A.G.: Health Hazard Evaluation #78-92-571. North Park Millwork, LTD., Colorado Springs, CO. U.S. DHEW, CDC, NIOSH, Cincinnati, OH 1979a.

1977 Census of Manufacturers: SIC Major Groups #24, #25 and Group #3565. U.S. Dept. of Commerce, Bureau of Census, 1981.

Engzell, V., A. Englund, and P. Westerholm: Nasal Cancer Associated with Occupational Exposure to Organic Dust. Acta Otolaryngol 86:437-442, 1978.

Enright, J.C.: Total Particulate, Gases and Vapors (General) Nitrosamines, Formaldehyde, Miscellaneous, Report No. 8043-R. Fisher Body Division Centeral Engineering Facility, Warren, MI 1980.

Gamble, J.F.: Adverse Health Effects of Exposure to Native American Wood. Presented at the 39th Annual AMA Congress on Occupational Health, Chapel Hill, NC, 1979.

Gunter, B.J.: Health Hazard Evaluation Determination, #77-104-446. Arapahoe Pattern Comp., Englewood, CO. U.S. DHEW, CDC, NIOSH, Cincinnati, OH 1977.

Hadfield, E.H., R.G. MacBeth: Adenocarcinoma of Ethnoids in Furniture Workers. Ann. Otol. 80, 699-703, 1971.

Hanslian, L., K. Kadlec: Timber and Timber Dust, Pracov. Lek 16(6) 276-282, 1964.

Hounam, R.F., J. Williams: Levels of Airborne Dust in Furniture Making Factories in the High Wycombe Area. Br. J. Ind. Medicine, 31, 1-9, 1974.

Imbus, H.R.: Written communication from Burlington Industries, Greensboro, N.C. to J. Warrick, 1978. Information concerning the development of the criteria document and recommended health standards for wood dust.

Ironside, P., J. Matthews: Adenocarcinoma of the Nose and Paranasal Sinuses in Wood Workers in the State of Victoria, Australia. Cancer, 36: 1115-1121, 1975.

Kominsky, J.R.: Health Hazard Evaluation Determination #75-19-276. Masonite Corp. Evendale, OH. U.S. DHEW, CDC, NIOSH, Cincinnati, OH 1976.

Levy, B.S.B.: Health Hazard Evaluation Determination #75-12-321. Cooper Union Schoole of Art, NY, NY. U.S. DHEW, CDC, NIOSH, Cincinnati, OH 1976.

Lumber Production and Mill Stocks, 1977. U.S. Dept. of Commerce, Bureau of Census.

Lumber Production and Mill Stocks, 1979. U.S. Dept. of Commerce, Bureau of Census, 1980.

McCammon, C.S.: NIOSH, DSHEFS, personal letter, 1981.

McCord, C.P.: The Toxic Properties of Some Timber Woods. Ind. Med. Surgery, 27:202, 1958.

Milham, S.: Mortality Experience of the AFL-CIO United Brotherhoood of Carpenters and Jointers of America, 1969-1970 and 1972-1973. NIOSH Technical Report, DHEW (NIOSH) Publication #78-152, 1978.

Morey, P.R.: NIOSH, DRDS personal letter, 1982.

U.S. Dept. of Labor, OSHA, 1976
OSHA Safety and Health Standards (29 CFR 1910)

Robinson, C., R.J. Waxweiler and C.S. McCammon: Pattern and Model Makers, Proportionate Mortality 1972-1978. Am. J. Ind. Med. 1:59-165, 1980.

Romelfanger, C.: personal communication 1982.

Rosenstell, R.E.: Health Hazard Evaluation Determination #73-178-158. Magnavox Company of Tennessee, Andrew, NC. U.S. DHEW, CDC, NIOSH, Cincinnati, OH 1974.

Schottenfeld, D., M. Warshauer, A.G. Zauber, J.G. Meikle, R.M. Payne, and J.F. Haas: Study of Cancer Mortality and Incidence in Wood Shop Workers of the General Motors Coporation. Memorial Sloan-Kettering Cancer Center. 1980.

Standard Industrial Classification Manual 1967. Office of Statistical Standards.

Swanson, M.: Incidence of Cancer Among Wood Workers in Seven General Motors Corp. Plants Located in Metropolitan Detroit: An Exploratory Analysis. 1980.

Whitehead, L.W., T. Freund and L.L. Hahn: Suspended dust concentrations and size distributions, and qualitative analysis of inorganic particles, from wood working operations. Amer. Ind. Hyg. Assoc. J. 42:61 461-467, 1981.

Appendix A.

DEVELOPMENT OF CRITERIA FOR WOOD DUST CONTROL TECHNOLOGY

It has been documented that exposure to wood or wood dust may cause some diseases. Numerous publications report about respiratory or skin diseases due to the wood dust. Besides that, a higher risk due to cancer has been reported in literature. An excess of adenocarcinoma of the paranasal sinuses was observed in furniture workers in England. A study of cancer mortality in wood workers revealed an increased risk of colorectal cancer among the wood workers. Recently, NIOSH/DSHEFS team reported about a statistically significant excess proportion of death due to colon cancer and to leukemia observed among members of the predominately wood shop locals. Although the studies regarding the mortality due to the cancer have not been completed, there is a strong indication of the excess of risk due to the cancer among the workers exposed to the wood dust.

A primary method to control wood dust emission is an exhaust located directly on wood working machinery or at a close distance. A MCRB/CRS team has recently conducted walk-through observations of wood dust control technology at operations of different wood working processes.

Preliminary results of these observations indicate that:

- The same type of wood working machinery is used at different wood working processes.
- Wood dust originated by wood working process, is emitted at high velocity by moving or spinning machinery components.

Ventilation systems located close to the emission source seems to control wood dust relatively well (e.g. at saws, planers, etc). However, if for some reason the control is not as close as to break or affect dust flow patterns, visible wood dust emission was observed escaping into the room space. Typical examples are routers, shapers, and sanders.

To overcome this problem, and to increase protection of the workers against potential carcinogenic agents, it is suggested to investigate the improvement of existing technology, where the control was found to be poor, namely at sanders. Final goal of the project will be:

- development of model of wood dust origination mechanism at disc and belt sanders.
- development of criteria for wood dust control for specific wood working machinery.
- design parameter proposal for new or existing control technology.

A main part of the experimental work shall be conducted in the DPSE laboratory on ventilation equipment, available in DPSE, and on specific wood working machinery, to be rented.

It is suggested to contact the wood working machinery manufacturing industry for cooperation. However, some cooperation with wood working operations shall be required to verify the laboratory results.

The proposed project is based on preliminary information from wood working studies conducted by DSHEFS and DRDS and on investigations conducted by MCRB for the Particulate Control Research project. The investigations conducted by other Divisions have not been completed and, therefore, the level of wood dust, which must be achieved, has not been identified. Such information should be known before initiation of the described research effort. Presently, the TLV for soft wood (not allergenic) is 5 mg/m^3, while 1 mg/m^3 for hardwood has been adopted by ACGIH 1981.