

XV. TABLES AND FIGURE

TABLE XV-1
COMPOSITION OF SOME TYPICAL COMMERCIAL GLASS FIBERS

Glass Type	SiO2	Al2O3	CaO	MgO	Component, (% by weight)					TiO2	PbO	F2
					B2O3	Na2O	K2O	ZrO2				
(Low alkali, lime-alumina borosilicate)	54.5	14.5	22.0	-	8.5	0.5	-	-	-	-	-	-
(Soda-lime borosilicate)	65.0	4.0	14.0	3.0	5.5	8.0	0.5	-	-	-	-	-
(Soda-lime borosilicate)	59.0	4.5	16.0	5.5	3.5	11.0	0.5	-	-	-	-	-
(Soda-lime)	73.0	2.0	5.5	3.5	-	16.0	-	-	-	-	-	-
(Lime-free borosilicate)	59.5	5.0	-	-	7.0	14.5	-	4.0	8.0	-	-	2.0
(High lead silicate)	34.0	3.0	-	-	-	0.5	3.5	-	-	-	59.0	-

Other additives: Phosphorus, iron, barium, copper, cerium, tin, and beryllium oxides

Adapted from Shand [4]

TABLE XV-2

CHARACTERISTIC AND PHYSICAL PROPERTIES OF
SOME COMMERCIAL FIBROUS GLASS

Glass Type	Form	Fiber Diameter Range, μm	Density, g/cc	Refractive Index
1 (Low alkali, lime- alumina borosilicate)	Textile, mats	6 - 9.5	2.596	1.548
2 (Soda-lime boro- silicate)	Mats Textiles	10 - 15 6 - 9.5	2.540	1.541
3 (Soda-lime boro- silicate)	Wool (coarse)	7.5 - 15	2.605	1.549
4 (Soda-lime)	Packs (coarse)	115 - 250	2.465	1.512
5 (lime free boro- silicate)	Wool (fine) (ultrafine)	0.75 - 5 0.25 - 0.75	2.568	1.537
6 (High lead silicate)	Textiles	6 - 9.5	4.3	-

Adapted from Shand [4]

TABLE XV-3

CHEMICAL BINDERS, COATINGS, AND LUBRICANTS USED WITH FIBROUS GLASS

Binders	Coatings and Lubricants*
Phenol formaldehyde resin	Silicone oil
Urea formaldehyde resin	Dyes, carbon pigment
Melamine formaldehyde resin	Starch
Polyvinyl acetate	Ammonium hydroxide
Vinsol resin	Mineral oil
Urea	Vinyl silane
Epoxy resins	Methacrylate chromic chloride
	Dextrin, gelatin
	Polyvinyl alcohol (chloride)

*Comprise between 0.25 and 1.0% by weight of fiber

Adapted from Shand [4]

TABLE XV-4

OBSERVED AND EXPECTED DEATHS AMONG WHITE MALES
IN A FIBROUS GLASS PRODUCTION PLANT

Causes of Death	List Number*	Observed	Expected
Tuberculosis	001-019	0	4.69**
Malignant neoplasms	140-199	54	64.09
Digestive system	150-159	25	22.93
Respiratory system	160-164	16	20.23
Other and unspecified	140-149	13	20.93
Vascular lesions affecting central nervous system	330-334	30	32.84
Diseases of heart	400-443	163	179.86
Nonmalignant respiratory disease	470-527	25	19.96
Influenza and pneumonia	480-493	6	9.92
Other respiratory disease	470-475, 500-527	19	10.04**
Cirrhosis of liver	581	2	8.93**
Violent deaths	800-958	39	34.37
All other known causes		63	59.50
Unknown causes		0	-
Total		376	404.24

*7th Revision of International List of Diseases
and Causes of Death
**Significant at $P < 0.05$

Adapted from Bayliss et al [55]

TABLE XV-5

OBSERVED AND EXPECTED NONMALIGNANT RESPIRATORY DISEASE DEATHS (LESS
INFLUENZA AND PNEUMONIA) BASED ON TIME SINCE ONSET OF EMPLOYMENT
IN FIBROUS GLASS PRODUCTION PLANT

Interval Since Onset of Employment (Years)	Observed	Expected
5 to 9	0	0.53
10 to 19	9	2.90
20 to 29	10	6.11
30 or more	0	0.50
After 5 or more years	19	10.04*
After 10 or more years	19	9.51**

*Significant at $P < 0.05$

**Significant at $P < 0.01$

Adapted from Bayliss et al [55]

TABLE XV-6

RESPIRATORY DISEASE AND RELATED DEATHS FROM CASES
AND MATCHED CONTROLS BY EXPOSURE ASSESSMENTS

No Deaths from Respiratory Diseases	Deaths from Respiratory Diseases		Total
	Potentially Exposed	Not Potentially Exposed	
Not potentially exposed	9	38	47
Potentially exposed	0	2	2
Total	9	40	49

Chi-square = 3.27 (.05 < P < .10)

Adapted from Bayliss et al [55]

TABLE XV-7

NUMBER OF RATS SHOWING CHANGES IN MESOTHELIAL CELLS
AFTER INTRAPLEURAL INOCULATIONS

Cell Change	Exposure Material	
	Fine Glass Fiber (Code 100)	Coarse Glass Fiber (Code 110)
No hyperplasia	1	12
Occasional hyperplasia	3	5
Focal hyperplasia	12	11
Generalized hyperplasia	4	4
Marked hyperplasia	7	0
Suspicion of malignancy	1	0
Mesothelioma	4	0
	<u>32</u>	<u>32</u>

Adapted from Wagner et al [71]

TABLE XV-8

PERCENTAGE OF RATS DEVELOPING MESOTHELIOMAS
AFTER INTRAPLEURAL INOCULATION OF VARIOUS MATERIALS

Material	Percentage of Rats* With Mesotheliomas
SFA chrysolite	66
UICC crocidolite	61
UICC amosite	36
UICC anthophyllite	36
UICC chrysotile (Canadian)	30
UICC chrysotile (Rhodesian)	19
Glass fiber code 100 (Fine)	12
Ceramic fiber	10
Glass powder	3
Glass fiber code 110 (Coarse)	0

*Each group consisted of 96 rats, 48 of each sex.

Adapted from Wagner et al [71]

TABLE XV-9

PROBABILITY OF PLEURAL SARCOMAS IN RATS WITH DIFFERENT
DIMENSIONS OF FIBROUS GLASS AFTER INTRAPLEURAL
ADMINISTRATION OF A 40-MG DOSE

Predominant Dimensions of Fiber*		Probability (%)
Diameter, μm	Length, μm	
0.5 - 1.5	<64	85.3
0.5 - 2.5	<64	73.9
0.5 - 2.5	8-64 and <64	71.2
0.5 - 8	<64	69.3
0.5 - 8	8-64 and <64	64.4
2.5 - 8	8-64 and <64	21.5
2.5 - 8	8-64 and <64	19.4
1.5 - 4.0	<64	14.3
4.0 - 8.0	4-8 and 8-64	8.3
0.5 - 4.0	1.8	8.1
>4.0	<8	6.7
>4	4-64	5.9
>4	4-64	5.7
4.8	8-64	5.5
1.5 - 4	4.64	4.5
0.5 - 1.5	>8	0
8.0	<64	0

*More complete representation of dimensions can be found in the original paper.

Adapted from Stanton et al [76]

TABLE XV-10

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions, μm Diameter Length	Exposure Variables	Effects
HUMANS-OCCUPATIONAL			
Mungo [42]	-	64 particles/ml, 2 to 4-year exposure	Skin and upper respiratory tract irritation
<u>Studies in the Same Plant</u>			
a) Wright [44]	2 - 10 median 6	0.93 - 13.3 mg/cu m 0.09-0.32 mppcf (3.2-11.2 particles/cu m), up to 32 years of exposure	Roentgenographic examination showed no distinctive markings
b) Utidjian [46]	-	232 male fibrous glass production workers	Pulmonary function tests showed no decrement
c) Utidjian and de Treville [47]	-	2028 male fibrous glass production workers	Roentgenographic examination showed no distinctive patterns
d) Nasr et al [51]	-	20 deceased fibrous glass production workers, 16 to 32 years of exposure	Post mortem comparison of deceased urban dwellers and fibrous glass production workers showed no significant differences
e) Gross et al [50]	-		

TABLE XV-10 (CONTINUED)

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions, μ m Diameter Length	Exposure Variables	Effects
HUMANS (CONTINUED)			
f) Bayliss et al [55]	Median 1.8 28	0.08 fibers/cc dust 0.3 mg/cu m	Slight excess risk of death from "normal- inant respiratory diseases"
	1 - 3	Case-control study of 49 cases of respiratory related deaths	Increased risk of death from malignant respi- ratory disease with exposure to small-diameter fibers (0.05 < p < 0.10)
Hill et al [52]	75% < 4 34% < 2	Total dust, 0.4 to 12.7 mg/cu m in breathing zones; respirable size dust, 1.0 to 4.8 fibers/ml	No differences between exposed workers and controls
Enterline and Henderson [54]	-	416 retired workers 65 years of age or older	Slight excess of death in 276 normal retirees due to "diseases of respiratory system" and "all other heart diseases"

TABLE XV-10 (CONTINUED)

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions, μm Diameter Length	Exposure Variables	Effects
HUMANS (CONTINUED)			
Murphy [40]	-	Several months of exposure	Dry cough, shortness of breath, bronchiectasis of the right lung
Heisel and Mitchell [27]	17.7 - 18.1	Patch tests	Small isolated erythematous papules
Heisel and Hunt [28]	>5.3		Transient mechanical skin irritation
	<4.6		No skin irritation
McKenna et al [29]	-	126 workers in hot humid manufacturing operation	Skin irritation, paronychia, folliculitis of the feet
Erwin [24]	-	120 workers	All had mild skin irritation, 9 had persistent eczematoid dermatitis

TABLE XV-10 (CONTINUED)

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions, μm Diameter Length	Exposure Variables	Effects
HUMANS (CONTINUED)			
Longley and Jones [36]	-	Woman worker 1 day/wk for 8 to 9 mon	Itching of skin, acute conjunctivitis, keratitis with sterile corneal abscess
Milby and Wolf [16]		Summary of occupational diseases attributed to fibrous glass in California, 1960-62	691 cases, 38 due to respiratory tract irri- tation, 653 due to skin irritation
ANIMAL EXPERIMENTS			
Davis [70]	0.05	10 mg, ip, mice	Large granulomas, fibrosis
	0.05	10 mg, ip, mice	Small granulomas
	3.5	10 mg, ip, mice	Large granulomas, fibrosis
	3.5	10 mg, ip, mice	Small granulomas
Gross et al [58]	0.5	100 mg/cu m, 24 mon of inhalation, rats, hamster	Accumulation of dust filled macrophages in rats; no fibrosis

TABLE XV-10 (CONTINUED)

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions, μm Diameter Length	Exposure Variables	Effects
ANIMALS (CONTINUED)			
Stanton et al [76]	0.5 - 1.5 >64	40 mg intrapleural administration	Pleural sarcomas occurring with a prob- ability up to 85%
Botham and Holt [59]	<1 <20	"High" single exposure, guinea pigs	Many fibers cleared within 1 wk, red blood cells migrated from capillaries, intracellular fibers coated with ironcontaining material
Wagner et al [71]	<0.12 1.7 with 2%>20	20 mg intrapleural,	Mesotheliomas in 12% no
	1.8 22	Rats	No mesotheliomas
Pott et al [68,69]	50%<0.2 50%<11	2 mg, 10, 50 mg ip, rats	Tumor rates of 24, 53, 71%
	50%<1 50%<28	20 mg, rats, ip	Tumor rate of 37%

TABLE XV-10 (CONTINUED)

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions μ m Diameter Length	Exposure Variables	Effects
ANIMALS (CONTINUED)			
Kuschnier and Wright [64]	<1	3-25 mg in 2 to 6 guinea pigs	No fibrosis, alveoli filled with macrophages
	<1	Intratracheal exposure	Interstitial fibrosis at 1 yr
	<0.3	<5	No fibrosis
	<0.3	>10	Interstitial fibrosis
	2	<10(12%>10)	Some fibrosis
	2	>10	Interstitial fibrosis
Schepers and DeLahant [56]	6	0.143-0.146 mg/cu m, 1.4 to 2.2 mppcf, 20 mon to glass wool followed by 20 mon to glass cotton, guinea pigs and rats, no controls	Epithelial hyperplasia, cellular desquamation in smaller bronchioles, hyperplasia of parenchymal pulmonary lymph nodes

TABLE XV-10 (CONTINUED)

FIBROUS GLASS EXPOSURE AND EFFECTS

Author	Fiber Dimensions, μm Diameter Length	Exposure Variables	Effects
ANIMALS (CONTINUED)			
Wenzel et al [61]	3	5-8 Single 50-mg intratracheal injection in rats	Bronchial wall lesions, hyperplasia of bronchiolar mucous membrane, chronic bronchitis, peribron- chiolar hyperplasia of lymphatic tissue
	30	30-100 Single 50-mg intratracheal injection in rats	Chronic bronchitis, stenosis of bronchial lumen with hyperplasia of peribronchial lymphatic tissue, atrophic emphysema, atelectasis

TABLE XV-11

DUST CONCENTRATIONS AND DIMENSIONS IN FIBROUS GLASS
PRODUCTION PLANT

Sampling Position	Respirable Dust (fibers/cc) Mean	Range	Total Dust (mg/cu m) Mean	Range
Operators' Breathing Zones				
Edge trimming				
Take-off position	2.3	1.1-4.8	11.6	10.0-12.7
Feed position	1.3	1.1-1.5		
Batch splitting operator	1.4	1.0-2.0	7.1	7.0-7.2
Navyboard sander operator	2.0	2.0	0.6	0.4-0.7
Emptying extractor sander	5.5	5.5		
2 Ft Below Operators' Breathing Zones				
Edge trimming				
Bench level	10.4	10.0-10.7	185	185
2 ft from dust course horizontally	-	-	30	26-33
Batch splitting				
Bench level	3.4	3.4	-	-
Fiber Dimensions				
Diameter (μm)	(%)	Length (μm)	(%)	
0.5	11	> 12	80	
1.5	33	> 25	70	
2.5	14	> 50	50	
3.5	17	> 100	18	
4.5	12			
5.5	5			
> 5.5	9			

Adapted from Hill et al [52]

TABLE XV-12

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Centrifugal-forming glass wool building insulation (4 plants)	Dement [5]	0.08	54	Diameter <10 μ m	1.44	39
Centrifugal-forming glass wool appliance insulation (2 plants)		0.05	35	"	0.81	17
Glass wool pipe insulation formation (3 plants)		0.10	16	"	1.74	19
Scrap reclamation-glass pouring wools (4 plants)		0.07	26	"	1.44	19
Flame attenuated forming-glass insulating wools (2 plants)		0.37	16	"	0.69	17
Other manufacturing operations - product fab, pack, etc. 3 plants (mg/cu m); 4 plants (f/ml)		0.08	26	"	0.63	41

TABLE XV-12 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Centrifugal-forming glass wool (6 plants)	Konzen [87].	0.15	63	Total fiber count	1.66	59
Centrifugal-formed glass wool packing and fab		0.16	246	"	2.02	259
Scrap reclamation-glass pouring wools		0.11	37	"	1.09	37
Bonded glass mat formation (an attenuation of textile bushing fiber)	Konzen [87]	0.22	18	Total fiber count	1.12	13
Flame-attenuated glass wool formation includes wools with nominal fiber diameters of 1-4 μ m		0.38	8	"	1.33	35
Continuous glass textile fiber formation		0.20	6	"	2.99	18

TABLE XV-12 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Glass textile yarn fabrication	Konzen [87]	0.37	205	Total fiber count	1.19	228
Stable (carded) glass fiber formation (1 plant)		0.35	2	"	5.49	10
Stable fiber fabrication (1 plant)		0.20	1	"	2.25	7
Glass wool insulation manufacture (method of formation not specified) (4 plants)	Johnson et al [85]	0.37	*	Total fiber count	0.32	*
Continuous glass textile fiber formation (1 plant)		0.20	*	"	0.06	*
Glass textile fiber - spinning and twisting		0.33	*	"	0.16	*
Glass textile fiber - waste recovery		0.33	*	"	0.11	*

TABLE XV-12 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Plant A - Glass wool (personal)	Corn et al [93]					
Flame attenuated fiber rollup		0.12	4	Total fiber count	3.5	4
Rigid duct manufacture		0.07	3	"	2.3	3
Filter packer		0.10	10	"	4.8	1
Bond mat rollup		0.12	2	"	2.1	2
Scrap reclamation		0.08	2	"	3.4	2
Mold and pipe manufacture		0.12	4	"	3.6	4
Wool plant selector packer		0.12	4	"	3.1	4

TABLE XV-12 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Plant A - glass wool (environmental)	Corn et al [93]					
Acoustic tile plant		0.11	3	Total fiber count	1.2	3
Flexible duct formation		0.12	3	"	2.0	2
Filter fiber formation		0.13	4	"	3.0	4
Bonded mat plant		0.06	2	"	0.7	2
Textile mat formation		0.17	4	"	2.3	4
Scrap reconditioning		0.13	2	"	3.2	2
Warehouse		0.06	2	"	1.5	2
Flame attenuated fiber formation		0.07	2	"	1.3	2
Wool plant - hot end		0.09	4	"	2.3	4

TABLE XV-12 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Plant B - glass wool and textile fiber (personnel)	Corn et al [93]					
Fiber formation, winding		0.07	6	Total fiber count	2.6	6
Hot fiber handling - chopped, bonded mat		0.15	3	"	1.0	3
Hot fiber handling - helix formation		0.76	2	"	2.4	2
Microfiber formation - cold end		0.17	3	"	0.6	3
Microfiber fleting and leaching		0.74	3	"	0.9	4
Filter tube manufacture - socking station		2.40	2	"	2.8	4
Filter tube manufacture - saw operator		1.39	2	"	1.2	2

TABLE XV-12 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - PRIMARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Plant B - (environmental)						
Textile fiber roving, weaving, chopped strand manufacture		0.09	5	"	1.1	5
Bonded mat, helix formation		0.05	3	"	0.7	3
Microfiber formation - hot end		0.04	1	"	0.1	1
Chopped mat formation		0.02	2	"	0.2	2
Filter tube formation		0.15	2	"	0.7	2
Bonded mat formation		0.03	2	"	0.5	2

*Not reported

Adapted from Schneider and Pifer [6]

TABLE XV-13

OCCUPATIONAL EXPOSURE SUMMARY - SECONDARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for Inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Fibrous glass reinforced plastics Plant A Spray-up	Dement [5]	0.07	7	<10 μ m	2.23	7
Flashing removal & finish		0.03	3	"	3.55	3
Non-corrosive products plants several using spray-up, filament winding and hand layup; data not differentiated by job codes	Konzen [87]	0.12	38	Total fiber count	3.49	43
Plant C Molded glass reinforced plastic products finishing and trimming (personal)	Corn et al [93]	0.15	5	"	3.9	5

TABLE XV-13 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - SECONDARY MANUFACTURERS

Exposure	Source	Mean Fiber Concentrations (fiber/cc)	No. of Samples	Basis for inclusion in Fiber Count	Mean Total Dust Concentration (mg/cu m)	No. of Samples
Plant C (environmental)	Corn et al [93]					
Mat cutting		0.17	4	"	3.3	3
Large reform area		0.17	4	"	1.3	4
Small preform area		0.14	4	"	2.4	4
Panel department		0.09	8	"	2.6	8
Custom molding		0.16	8	"	2.2	8

Adapted from Schneider and Pifer [6]

TABLE XV-14

OCCUPATIONAL EXPOSURE SUMMARY - FINE FIBER PRODUCERS AND USERS

Exposure	Data Source	Mean Fiber Concentrations		Mean Total Dust Concentration	
		(fiber/cc)	No. of Samples	(mg/cu m)	No. of Samples
Fine fiber manufacturers	Dement [5]				
Plant 1					
Production and bulk handling		1.0 (0.1-1.7)	5	0.4 (0.1-.1.)	5
Plant 2					
Production and bulk handling		9.7 (0.9-33.6)	54	0.7 (0.2-2.0)	25
Fabrication and finishing		5.3 (0.3-14.3)	24	0.3 (0.1-0.7)	13
High efficiency filter and cryogenic paper manufacture	Dement [5]				
Plant 1					
Fiber mixing		5.8 (4.7-6.9)	2	*	
Trimming/folding		1.9 (1.6-2.1)	2	*	
Plant 2					
Fiber blending		21.9 (8.9-44.1)	3	*	
Fiber trimming		10.6	1	*	

TABLE XV-14 (CONTINUED)

OCCUPATIONAL EXPOSURE SUMMARY - FINE FIBER PRODUCERS AND USERS

Exposure	Data Source	Mean Fiber Concentrations		Mean Total Dust Concentration	
		(fiber/cc)	No. of Samples	(mg/cu m)	No. of Samples
Aircraft Insulations manufacture	Dement [5]				
Plant 1					
Bulk fiber handling		1.2 (0.4-3.1)	13	0.6 (0.2-1.4)	8
Fabrication and finishing		0.8 (0.2-4.4)	15	0.4 (0.4-0.9)	10
Plant 2					
Bulk fiber handling		14.1 (3.2-24.4)	3	*	
Fabrication and finishing		2.1	1	*	

*Not taken

Adapted from Schneider and Pifer [6]

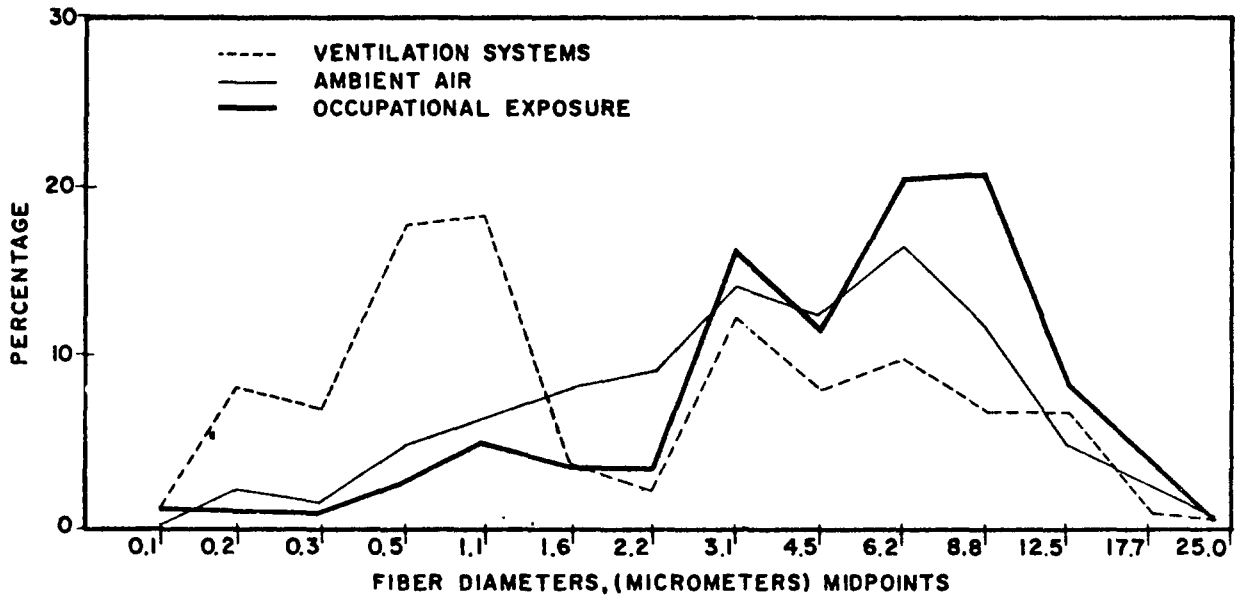


FIGURE XV-1

GLASS FIBER DISTRIBUTION BY DIAMETER
FOR THREE TYPES OF SOURCES

Adapted from reference 91