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HASKELL LABORATORY

cc: C. F. Reinhardt
F. A. Bower
A. M. Kaplan

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J. R. GIBSON
CR&D
HASKELL LABORATORY

RESPIRATOR WORKPLACE PROTECTION FACTORS FOR ASBESTOS
(Haskell Laboratory Report No. 462-84; MR-5557-001)

SUMMARY AND BACKGROUND

Workplace protection factors for elastomeric and single use half-face respirators were measured during asbestos removal operations. The operations consisted of asbestos removal from a ceiling (fire proofing) and removal of pipe insulation. The use of water/surfactant solutions to spray fire proofing and insulation resulted in conditions of high humidity for indoors operations. Out-of-doors operations were also under high humidity conditions since light rain occurred on two of four days of sampling. Temperatures for both operations were in the 65-85°F range.

The respirators were used in the context of a respirator program that followed the guidance in 29 CFR 1910.134 and ANSI Z88.2 (1980) including proper respirator selection and fit testing. A total of seventeen volunteers participated in the study. One or two workplace protection factors were determined for each respirator for which the fit test had been passed.

The respirators tested were:

- One successfully fitted elastomeric facepiece respirator chosen for comfort from six respirators (MSA Comfo II and Survivair 2000 brands - small, medium and large sizes). These respirators were tested using dust, fume and mist and high efficiency filters.
- Each of three disposable respirators successfully fitted (3M 9910, 3M 8710 and American Optical R 1050).
- A successfully fitted North 7700 elastomeric facepiece respirator, chosen from the small, medium or large size facepieces.

In addition two workplace protection factor measurements were made for a self-contained breathing apparatus operated in the pressure-demand mode.

Results show that all respirators tested, reliably provide workplace protection factors of ten or greater, except the AO R1050, which reliably provides a protection factor of five or greater, based on estimates of lower 5th percentile. These results are consistent with information supplied to the OSHA asbestos record by Los Alamos National Laboratory which reported on the penetration of asbestos through respirator filter media.[1]

Results for the self-contained breathing apparatus suggest that it may not provide appreciably better protection than the two better disposable respirators and the elastomeric facepiece respirators, though it presents a considerable stress and hazard of falling because of it's weight and awkwardness. Myhre et al.[2] and Raven[3] have shown that pressure-demand respirators do not maintain positive pressure inside the facepiece when workloads are increased from rest conditions. This may explain, in part, why the pressure-demand and self-contained breathing apparatus did not provide superior protection.

PROCEDURE

Prior to testing, each person was trained in the selection and fit testing of respirators using the National Paint and Coatings Association Training Program[4]. Each was then fit tested using the saccharin fit test[4]. Fit test results are given in Table V. Respirators selected for use and vendors are listed in Table I.

Two individuals were also trained in use of a pressure-demand self-contained breathing apparatus. Fit testing was not done, as it is not required for pressure-demand equipment per the ANSI Z88.2 (1980) standard.

During sample collection, each participant was observed continually to ensure that the sample train remained intact and did not interfere with the respirator seal on the face, and to note occurrences which might have affected respirator performance, such as movement of the respirator on the face. The participants were very busy with their work activities and soon ignored the presence of the researchers.

AIR SAMPLING AND ANALYSIS

To determine the workplace protection factors, concurrent samples were taken from inside the respirator (in-mask) at nose level and outside the respirator at the lapel (lapel). Closed-face Glasrock (#1505) cassette filter holders fitted with half inch extenders and probes developed by NIOSH[5] were used for both the in-mask and lapel samples. The sample probes are specially designed to minimize the loss of particulates. The cassettes contained 0.8 um, 25mm cellulose ester filters.

The sample trains were calibrated before and after taking each sample using a mass flow meter. The mass flow meter was calibrated against a bubble flow meter at the beginning and end of the study. A flow rate of 2 Lpm was used for the in-mask samples. Lapel samples were taken at 0.5-1.0 Lpm to avoid overloading.

Samples were collected for a one- to two-hour period. Each sample represented a single wearing of the respirator.

Fiber counts were done per NIOSH method P&CAM 239[6] (phase contract microscopy), except that the triacetin/acetone mounting method was used as described in NIOSH method 7400[7]. Counting was done according to the P&CAM 239 rules (the "A" counting rules in method 7400). Five hundred fields were counted for in-mask samples to increase analytical sensitivity. All analyses were done by one counter who participates successfully in the American Industrial Hygiene Association's Proficiency Analytical Testing quality assurance program. Concentrations were calculated from the actual number of fibers counted (even if fewer than 50 fibers were counted) per the formulas in the NIOSH method.

NIOSH method P&CAM 239 reports a coefficient of variation of 0.12 which applies to lapel samples in this study. We estimate that the coefficient of variation for the in-mask samples is 0.4 at the median in-facepiece concentration and fiber count (Table III).

Transmission electron microscopic analyses were also done on selected samples to obtain data on small fiber penetration and size distribution.

All field and analytical data are retained in the MR-5557 file.

SAMPLING AND ANALYSIS METHOD VERIFICATION

In-mask sampling required use of closed-face filter cassettes. We used Glasrock #1505 25mm filter cassettes which have a unique tapered design for the outlet and a half inch extender which improves the deposition patterns[8]. To minimize sample loss, the NIOSH[5] probe was used to withdraw in-mask samples.

To eliminate possible bias, the same closed-face/probed cassette was used for both in-mask and lapel samples. To document whether concentrations determined from closed-face/probe cassette sampling differed from open-face sampling, twelve area samples were taken using both methods. Results are compared in Table II with Student's t and Variance Ratio tests[9]. The two sampling methods were found to give similar results with no significant bias or difference in precision.

RESULTS AND DISCUSSION

Transmission electron microscopic analyses were done on four lapel samples by Electron Microscopy Service Laboratories, Inc., Camden, New Jersey. The resultant distributions of fiber diameters and lengths are shown in Figures 1 and 2. Fiber diameters and lengths covered a wide range.

The overall median concentrations of fibers for in-mask and lapel samples are given in Table III. The median number of fibers counted for in-mask (500 fields counted) and lapel (≤100 field counted) samples are also given in Table III.

Cumulative distributions, geometric means, geometric standard deviations, best estimates of 5th percentiles and lists of workplace protection factors are given in Figures 3 through 8 for each respirator. The distributions of workplace protection factors were found to be approximately lognormal for all respirators studied. Therefore, logs were used for the plots, geometric means are reported as the proper measure of central tendancy and geometric standard deviations are reported as the proper measure of variability. Best estimates of 5th percentiles represent the workplace protection factors that most (95%) respirator users are expected to obtain from each respirator.

Distribution plots and geometric standard deviations include variability from the sampling and analytical method as well as from the workplace protection factors. The unavoidable inclusion of the sampling and analytical variability in the plots results in best estimates of 5th percentiles which are conservative (lower than actual). This should be considered in evaluating results.

Workplace protection factors were determined for a self-contained breathing apparatus for two individuals. Results are reported in Table IV.

Table V gives geometric means, geometric standard deviations, best estimates of the 5th percentile, and ratios of participants passing the fit test for each respirator studied. A Bonferroni(9) test for differences (p=0.05) was done and results are given in Table V. Workplace protection factors for the 3M 9910 were found to be significantly higher than those for the AO R1050. No other significant differences were found. The importance of doing a fit test is apparent from the fit test results in Table V.

The relatively low results for the AO R1050 are likely due to poorer filter efficiency for asbestos, reported by Dr. Ortiz of Los Alamos National Laboratory(1).

The unexpected comparability of the results from the 3M disposable respirators, and elastomeric facepiece respirators with both dust, mist and fume filters and high efficiency filters may be explained by several factors. First, because the filter efficiency is high (~99.9%), the limiting factor in performance of the respirators is likely face fit, not filter efficiency (except for the AO R1050 as noted above). Since the same fit test was used to select good fitting respirators for the study, comparable face fit results would be expected. In addition, the researchers noted a tendency for elastomeric respirators to slip around when some wearers' faces became wet with the water/surfactant spray. This did not occur with the disposable respirators because their fibrous material of construction clung to the skin.

It is particularly noteworthy that the workplace protection factors for the self-contained breathing apparatus were not superior to the better disposable and elastomeric respirators. Myhre[2] and Raven[3] have shown that at workloads exceeding approximately 35% of maximal aerobic capacity pressure inside the facepiece of pressure-demand type respirators does not remain positive with respect to the surrounding atmosphere. This would provide an opportunity for airborne asbestos to be drawn into the facepiece.

The volunteers who wore the self-contained breathing apparatus complained of stress and discomfort due to its weight and bulk. Movement and balance were difficult and one volunteer almost fell from a step ladder as a result. Based on their observations, the researchers believe that routine use of self-contained breathing apparatuses for asbestos removal would likely result in injuries, in view of the large amount of climbing involved. Certainly, acceptance will be much poorer than for the other respirators studied, due to discomfort which would discourage respirator use.

Transmission electron microscopic analysis results were also used to determine workplace protection factors for thin fibers (Table VI). Results for small diameter (<0.2um) fibers do not appear to differ from those for large diameter (>0.2um) fibers, for 5 um or longer lengths. Thus, results for fibers visible with the phase contrast method (>0.2um diameter) appear to be representative of those for smaller diameter fibers for the 3M 8710 and 9910, and for elastomeric respirators with dust, fume and mist and high efficiency filters.

CONCLUSIONS

1. All respirators tested provided protection against asbestos. The American Optical R1050 disposable respirator reliably provided workplace protection factors of 5 or greater. The 3M 9910, 3M 8710, and elastomeric half-face respirators with both dust, fume and mist and high efficiency filters reliably provided workplace protection factors of 10 or greater.

2. Use of higher efficiency filters did not appear to improve the workplace protector factors of the elastomeric respirators.

3. Workplace protection factor measurements for a pressure demand self-contained breathing apparatus were not significantly higher than those for the better disposable and elastomeric respirators. Comments from the test volunteers and observations indicate that acceptance of the self-contained breathing apparatus would be poorer than that of the other respirators tested. In addition, it presents a significant risk of tripping or falling, where removal work requires climbing ladders and working from scaffolding.

4. Transmission electron microscopic analyses suggest that for fibers longer than 5 um, the overall workplace penetration of small diameter (<0.2um) fibers is not higher than that of larger diameter fibers for the 3M 8710 and 3M 9910 disposable respirators nor for elastomeric respirators with dust, fume and mist or high efficiency filters.

ACKNOWLEDGEMENTS

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Report by: Stephen W. Dixon
STEPHEN W. DIXON
SECTION SUPERVISOR - INDUSTRIAL HYGIENE

Approved by: A. Michael Kaplan
A. MICHAEL KAPLAN
MANAGER - FIELD SERVICES

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Attachments: Table I-VI, Figure 1-8
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TABLE I

Respirators Studied

Respirator Name	Type	Vendor
Survivair 2000	Elastomeric (silicone rubber) with dust, fume and mist and high efficiency filters	U.S.D. Corp.
Comfo II	Elastomeric (neoprene) with dust, fume and mist and high efficiency filters	Mine Safety Appliance Co.
3M 8710	Disposable with nonadjustable staps	3M Company
3M 9910	Disposable with adjustable straps	3M Company
AO R1050	Disposable with nonadjustable straps	American Optical Company
North 7700	Elastomeric (silicone rubber) with high efficiency filters	North Company
Scott Air-Pak	Self-contained breathing apparatus, pressure-demand	Scott Aviation

TABLE II

COMPARISON OF ASBESTOS SAMPLING METHODS
(OPEN-FACE VERSUS CLOSED-FACE WITH PROBE)

Parameter	Value
Mean	2.2 fibers/mL - open face filter cassette 2.3 fibers/mL - closed face cassette with probe
Standard Deviation	0.264 fibers/mL - open face cassette 0.286 fibers/mL - closed face cassette with probe
T Statistic*	1.28
Variance Ratio**	1.17
Data	
Open-face cassette:	1.9, 1.9, 2.0, 2.1, 2.1, 2.1, 2.2, 2.2, 2.2, 2.2, 2.3, 2.9
Closed-face cassette:	2.0, 2.0, 2.0, 2.2, 2.3, 2.3, 2.3, 2.4, 2.4, 2.4, 2.5, 3.0

* 1.28 is less than a comparison t statistic of 1.78 (p=0.05). Therefore, the means do not differ significantly.

** 1.17 is less than a comparison F statistic of 2.69 (p=0.05). Therefore, the variances (precision) of the methods do not differ significantly.

TABLE III

MEDIAN ASBESTOS CONCENTRATIONS AND COUNTS FOR WORKPLACE PROTECTION FACTOR STUDY

Concentrations	
Inside Respirator	0.006 fibers/mL (8 HR. TWA $\simeq$ 0.003)*
Outside Respirator	2.6 fibers/mL (8 HR. TWA $\simeq$ 1.3)*
Counts	
Inside Filter	9 fibers
Outside Filter	130 fibers

* No more than four of eight work hours were spent doing asbestos removal. Therefore, a factor of 0.5 (4 HRS/8HRS) was applied to concentrations to estimate 8 HR TWA concentrations.

TABLE IV

WORKPLACE PROTECTION FACTORS FOR SELF-CONTAINED BREATHING APPARATUS (PRESSURE DEMAND)

Workplace Protection Factors:	400
	880

Geometric Mean: 620

TABLE V

COMPARISON OF WORKPLACE PROTECTION FACTORS FOR SEVEN RESPIRATORS

Respirator	Number of Measurements	Workplace Protection Factor Geometric Mean (Geom. S.D.)	Ratio Passing Fit Test	Lower 5th Percentile
3M 8710	18	310 (5.3)	15/17	20
3M 9910	14	580 (4.2)	14/17	55
AO R1050	7	52 (4.2)	4/6	5
Elastomeric/Dust, Fume and Mist Filter	17	240 (6.3)	Not Tested	12
Elastomeric/High Efficiency Filter	14	94 (3.0)	Surv.-14/16 MSA-1/2	16
North 7700 High Efficiency Filter	14	250 (6.9)	15/15	11
Self-Contained Breathing Apparatus	2	620	Not Tested	

*Based on a Bonferroni test[9] at a 0.05 level of significance only the 3M 9910 and AO R1050 differed.

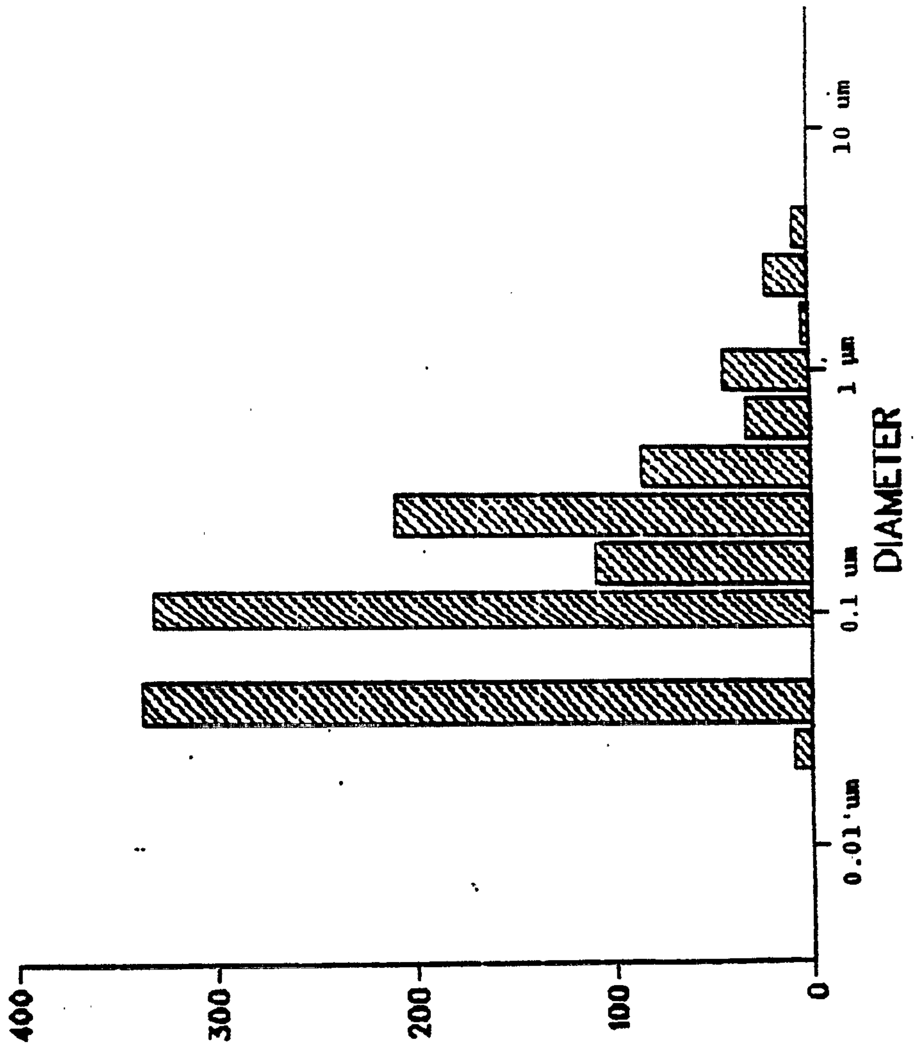
TABLE VI

WORKPLACE PROTECTION FACTORS FROM TRANSMISSION ELECTRON MICROSCOPIC ANALYSES

Respirator	Workplace Protection Factor: Fibers Exceeding 0.2 um Diameter and 5 um Length*	Workplace Protection Factor: All Diameter Fibers Exceeding 5 um Length
3M 8710	330	120
3M 9910	47	41
Survivair 2000 with Dust, Mist and Fume Filter	28	29
Survivair 2000 with High Efficiency Filter	21	19

*Those which would be counted by the standard phase contrast microscopy method.

FIGURE 1 - FIBER DIAMETERS



DUP 0933735

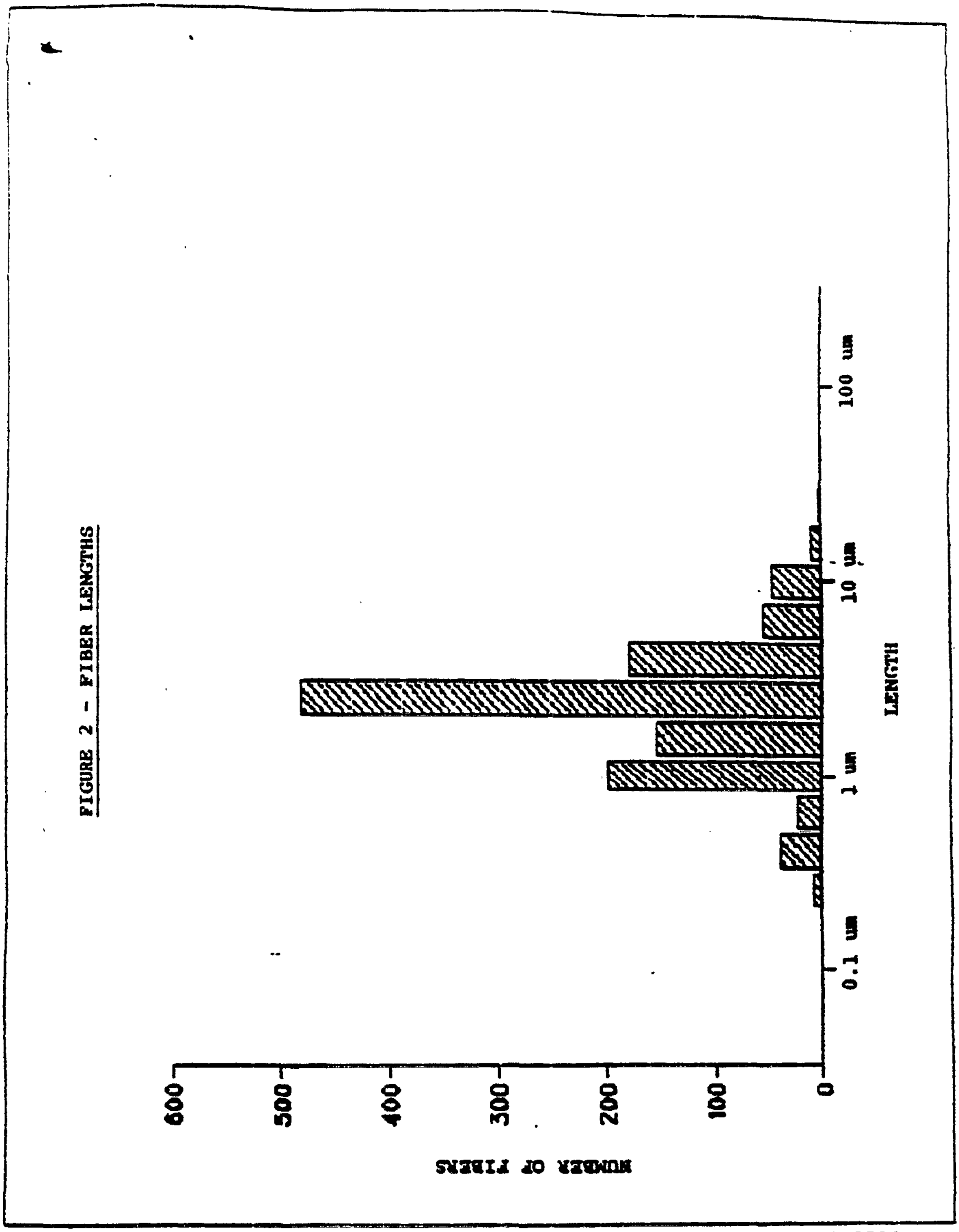
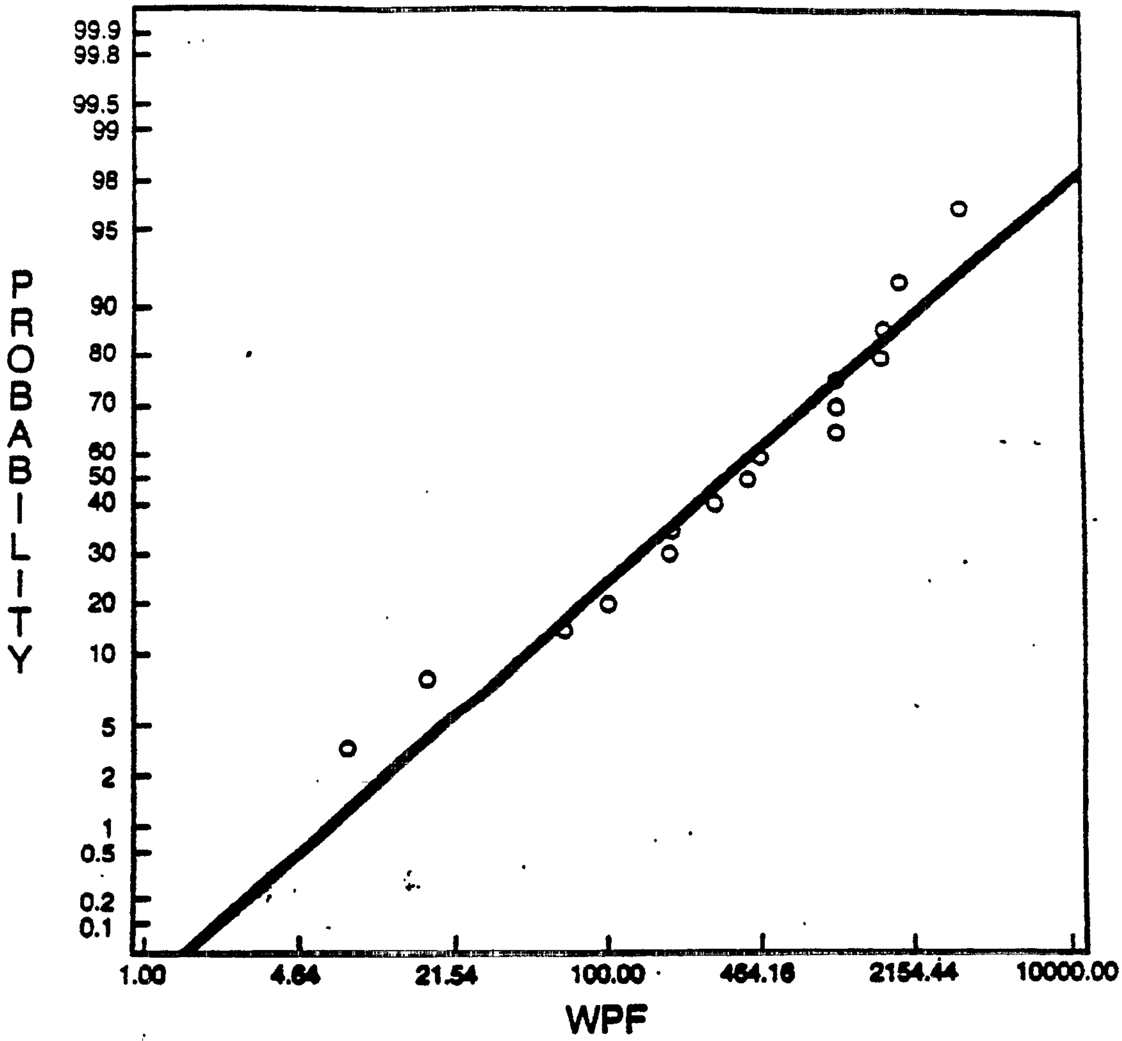


FIGURE 2 - FIBER LENGTHS

Figure 3 – Workplace Protection Factors for 3M 8710 Respirator

Cumulative Distribution: (Lognormal)



Geometric Mean: 310

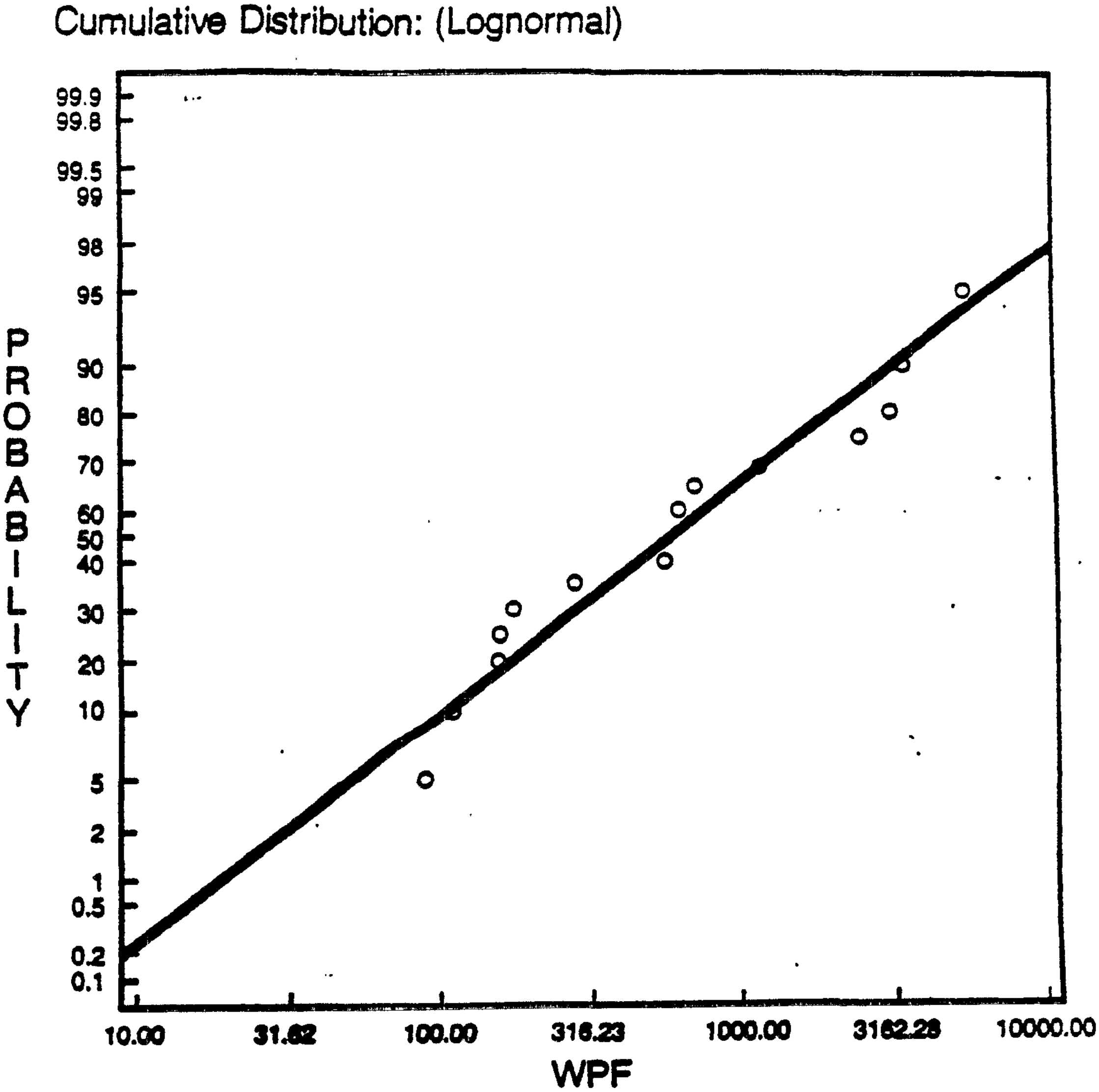
DUP 0933737

Geometric Standard Deviation: 5.3

Best Estimate of 5th Percentile: 20

Data: 7.4, 15, 61, 110, 110, 180, 200, 310, 400, 420, 430, 1000, 1000, 1100, 1500, 1600, 1800, 3200

Figure 4 – Workplace Protection Factors for 3M 9910 Respirator



Geometric Mean: 580

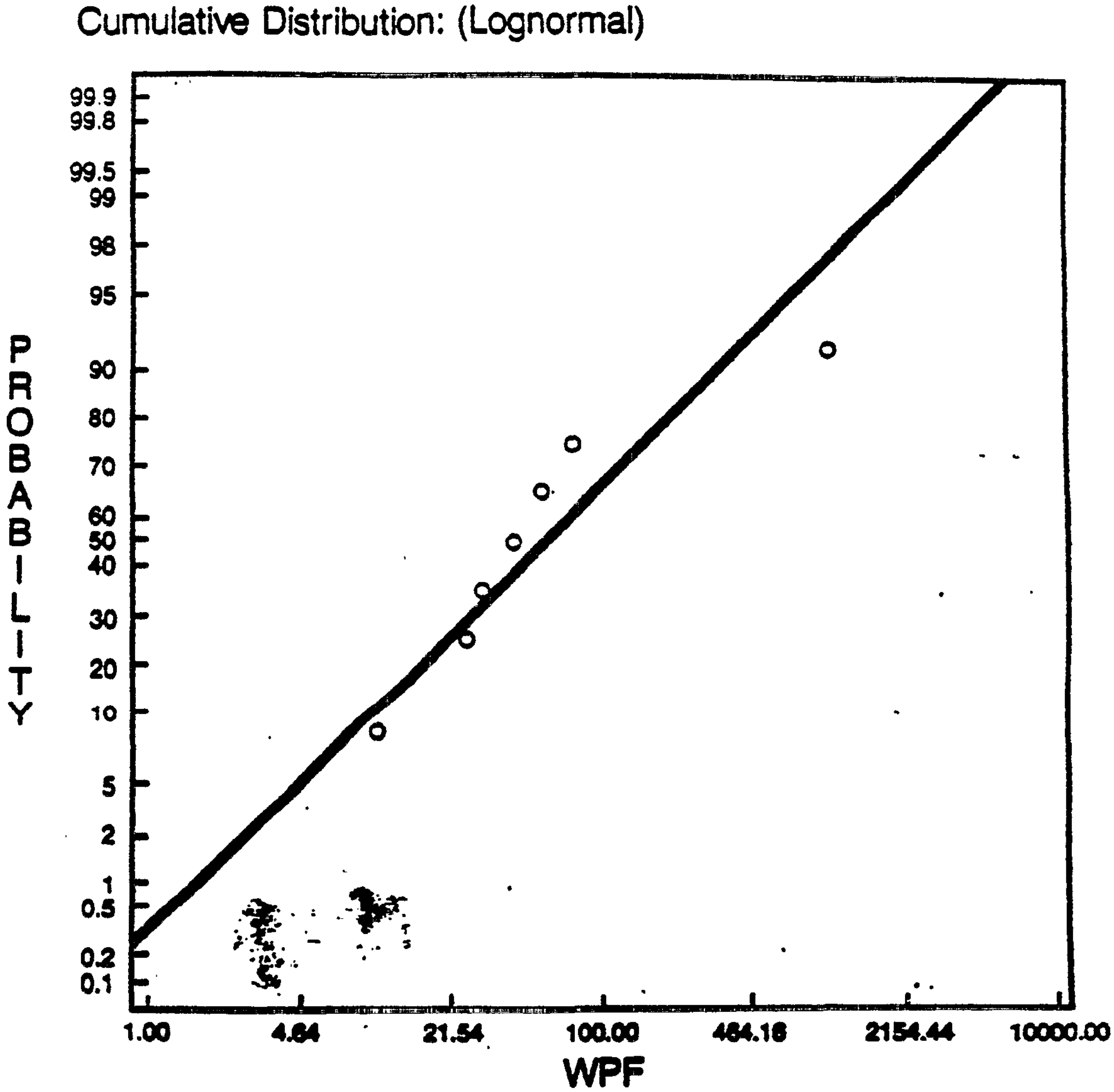
DUP 0933738

Geometric Standard Deviation: 4.2

Best Estimate of 5th Percentile: 55

Data: 94, 110, 150, 150, 170, 280, 550, 630, 710, 1300, 2400, 3000, 3700, 5600

Figure 5 – Workplace Protection Factors for AO R1050 Respirator



Geometric Mean: 52

Geometric Standard Deviation: 4.2

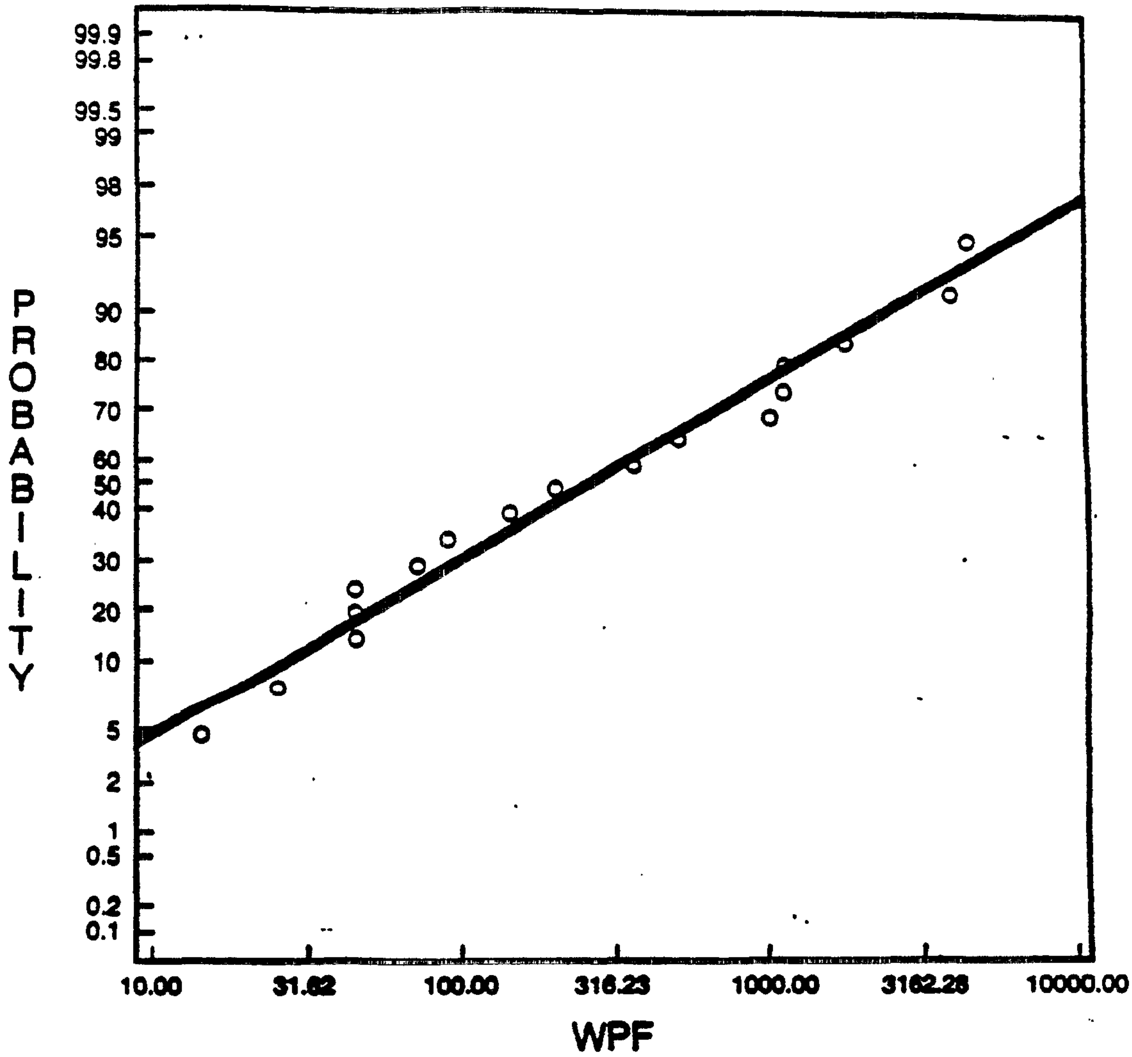
Best Estimate of 5th Percentile: 5

Data: 9.7, 26, 28, 38, 52, 75, 970

DUP 0933739

Figure 6 – Workplace Protection Factors for Survivair 2000 and MSA Comfo® Halfmask Respirators with Dust, Fume and Mist Filters

Cumulative Distribution: (Lognormal)



Geometric Mean: 240

DUP 0933740

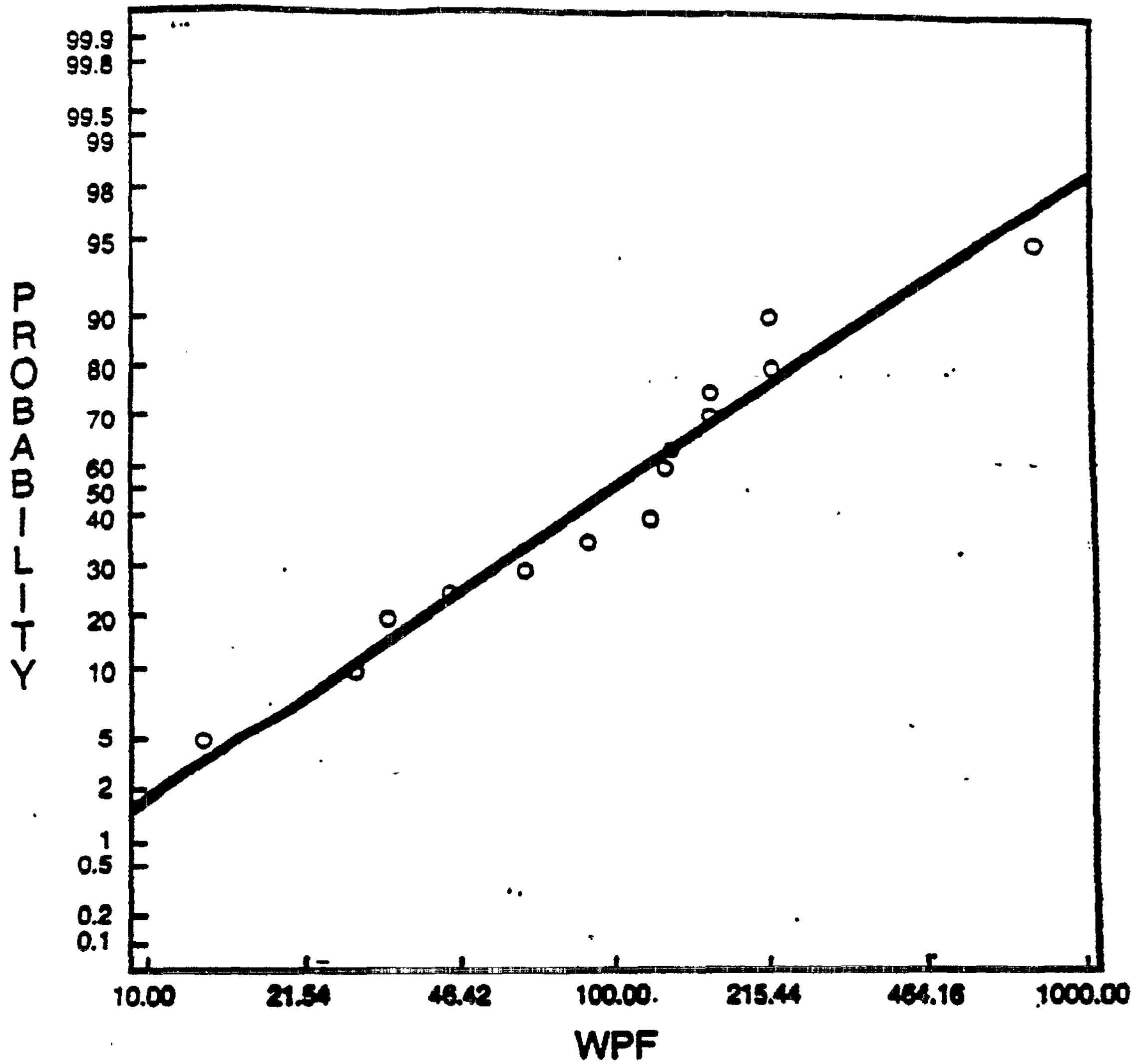
Geometric Standard Deviation: 6.3

Best Estimate of 5th Percentile: 12

Data: 15, 24, 45, 46, 47, 74, 88, 140, 190, 370, 480, 1000, 1100, 1100, 1800, 4100, 4200

Figure 7 – Workplace Protection Factors for Survivair 2000 and MSA Comfo® Halfmask Respirators with High Efficiency Filters

Cumulative Distribution: (Lognormal)



Geometric Mean: 94

DUP 0933741

Geometric Standard Deviation: 3.0

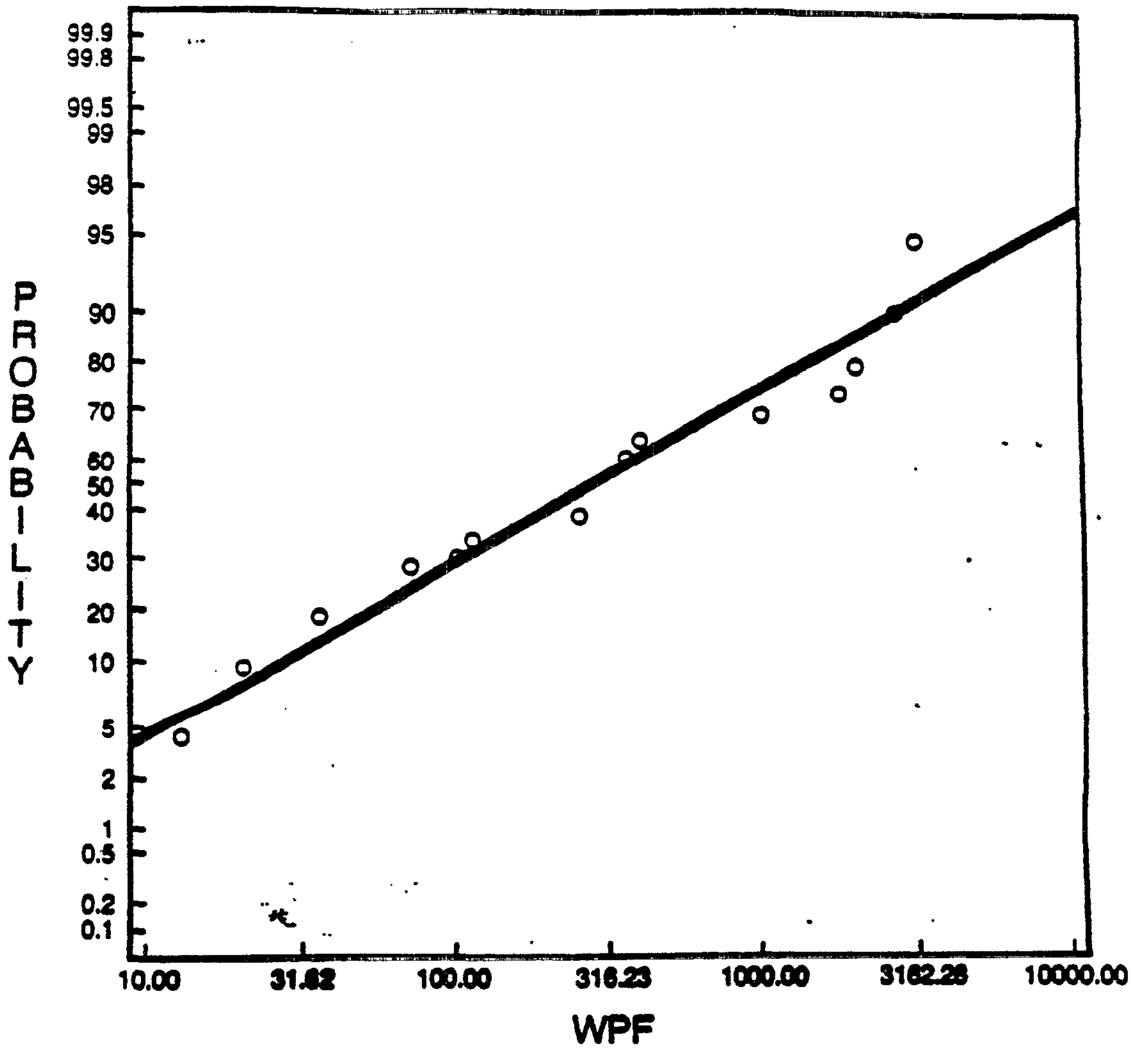
Best Estimate of 5th Percentile: 16

Data: 12, 28, 32, 42, 65, 85, 110, 120, 140, 160, 160, 220, 220, 780, 7900*

*Removed from plot analysis, as an outlier.

Figure 8 – Workplace Protection Factors for North 7700 Halfmask Respirators with High Efficiency Filters

Cumulative Distribution: (Lognormal)



Geometric Mean: 250

DUP 0933742

Geometric Standard Deviation: 6.9

Best Estimate of 5th Percentile: 11

Data: 12, 20, 36, 60, 74, 110, 260, 350, 400, 1000, 1900, 2000, 2400, 3100

RESPIRATOR WORKPLACE PROTECTION FACTORS FOR ASBESTOS

SUMMARY AND BACKGROUND

Workplace protection factors for elastomeric and single use half-face respirators were measured during asbestos removal operations. The operations consisted of asbestos removal from a ceiling (fire proofing) and removal of pipe insulation. Copious use of water/surfactant solutions to spray fire proofing and insulation resulted in conditions of high humidity for in-doors operations. Out-of-doors operations were also under high humidity conditions since light rain occurred on two of four days of out-of-doors sampling. Temperatures for both operations were in the 65-85°F range.

The respirators were used in the context of a respirator program that followed the guidance in 29 CFR 1910.134 and ANSI Z88.2 (1980) including proper respirator selection and fit testing. A total of seventeen volunteers participated in the study. One or two workplace protection factors were determined for each respirator for which the fit test had been passed.

The respirators tested were:

- One successfully fitted elastomeric facepiece respirator chosen for comfort from the two brands (MSA Comfo II and Survivair 2000 - 3 sizes each). These respirators were tested with type F (dust, fume and mist) and type H (high efficiency) filters.

- Each of the three disposable respirators successfully fitted (3M 9910, 3M 8710 and American Optical R 1050).

- One successfully fitted (of three sizes) North 7700 elastomeric facepiece respirator.

In addition two workplace protection factor measurements were made for a self-contained breathing apparatus operated in the pressure-demand mode.

Results showed that all respirators tested reliably provided workplace protection factors of ten or greater except the AO R1050 which reliably provided a protection factor of five or greater. Results for the self-contained breathing apparatus suggest that it may not provide appreciably better protection than the better disposable and elastomeric facepiece respirators, though it puts considerable more physical stress on the wearer due to its weight and bulk.

PROCEDURE

Prior to testing, each person was trained in the selection and fit testing of respirators using the National Paint and Coatings Association Training Program[1]. Each was then fit tested using the saccharin fit test[1]. Respirators selected for use by participants are listed above and in Table I.

Two individuals were also trained in use of a pressure-demand self-contained breathing apparatus, for which two workplace protection factor measurements were made. Fit testing was not done, as it is not required in the ANSI Z88.2 (1980) standard.

During sample collection, each participant was observed continually to ensure that the sample train remained intact and did not interfere with the respirator seal on the face, and to note occurances which might have affected respirator performance, such as movement of the respirator on the face. The participants were very busy with their work activities and soon ignored the presence of the researchers.

AIR SAMPLING AND ANALYSIS

To determine the workplace protection factors, concurrent samples were taken from inside the respirator (in-mask) at nose level and outside the respirator at the lapel. Closed-face Glasrock (#1505) cassette filter holders fitted with half inch extenders and probes developed by NIOSH[2] were used for both the inside and outside samples. The sample probes are specially designed to minimize the loss of particulates. The cassettes contained 0.8 um, 25mm cellulose ester filters.

The sample trains were calibrated before and after each sample using a mass flow meter. The mass flow meter was calibrated against a bubble flow meter at the beginning and end of the study. A flow rate of 2 Lpm was used for the inside samples. Outside samples were taken at 0.5-1.0 Lpm to avoid overloading.

Samples were collected for a one to two hour period. This duration was chosen based on expected fiber levels. Each sample represented a single wearing of the respirator.

Fiber counts were done per NIOSH procedures 7400[3] (phase contract microscopy) using the "A" counting rules. Five hundred fields were counted for in-mask samples to increase analytical sensitivity. All analyses were done by one counter who participates successfully in the American Industrial Hygiene Associations Proficiency Analytical Testing quality assurance program. Concentrations were calculated from the actual number of fibers counted (even if fewer than 50 fibers were counted) per the formulas in the NIOSH method.

NIOSH method 7400 reports a coefficient of variation of 0.12 which applies to lapel samples in this study. We estimate that the coefficient of variation for the in-mask samples is 0.4 at the median in-facepiece concentration and fiber count (Table III).

SAMPLING AND ANALYSIS METHOD VERIFICATION

In-mask sampling required use of closed-face filter cassettes. The Glassrock #1505 25mm filter cassettes used have a unique tapered design for the outlet and a half inch extender which improves the deposition patterns(4). It was also necessary to probe the respirator to withdraw the in-mask sample. The NIOSH probe(2) was used to minimize sample loss.

To eliminate possible bias, the same closed-face/probed cassette was used for both in-mask and lapel samples. To document whether concentrations determined from closed-face/probe cassette sampling differed from open-face sampling, twelve area samples were taken using both methods. Results are compared in Table II with Student's t and Variance Ratio tests. The two sampling methods were found to give similar results with no significant bias or difference in precision.

RESULTS AND DISCUSSION

Transmission electron microscopic analyses were made on four lapel samples to document the distribution of fiber diameters and lengths. Distributions are shown in Figures 1 and 2. Fiber diameters and lengths covered a wide range.

The overall median concentrations of fibers for in-mask and lapel samples are given in Table III. The median number of fibers counted for in-mask (500 fields counted) and lapel (≤100 field counted) samples are also given in Table III.

Cumulative distributions, geometric means, geometric standard deviations, best estimates of 5th percentiles and lists of workplace protection factors are given in Figures 3 through 8 for all respirators. The distributions of workplace protection factors were found to be approximately lognormal for all respirators studied. Therefore, logs were used for the plots, geometric means are reported as the proper measure of central tendancy and geometric standard deviations are reported as the proper measure of variability. Distribution plots and geometric standard deviations include variability from the sampling and analytical method as well as from the workplace protection factors. This should be considered in evaluating results.

Best estimates of 5th percentiles represent the workplace protection factors that most (95%) respirator users are expected to obtain from each respirator. The unavoidable inclusion of the sampling and analytical variability in the plots results in best estimates of 5th percentiles which are conservative (lower than actual).

Workplace protection factors were determined for a self-contained breathing apparatus for two individuals. Results are reported in Table IV.

Table V gives geometric means and standard deviations for all respirators studied. A Bonferroni[5] test for differences ($p=0.05$) was done and results are given in Table V. Workplace protection factors for the 3M 9910 were found to be significantly higher than those for the AO R1050. No other significant differences were found. The researchers noted a tendency for elastomeric respirators to slip around when some wearers' faces became wet with the water/surfactant spray. This did not occur with the disposable respirators because their fibrous material of construction clung to the skin. This may explain the unanticipated comparability of the results for the 3M disposable respirators and the elastomeric respirators. The relatively low results for the AO R1050 are likely due to poorer filter efficiency for asbestos, reported by Dr. Ortis of Los Alamos National Laboratory[6].

It is particularly noteworthy that the workplace protection factors for the self-contained breathing apparatus were not superior to the better disposable and elastomeric respirators. The volunteers who wore the self-contained breathing apparatus complained of stress and discomfort due to its weight and bulk. Movement and balance were difficult and one volunteer almost fell from a step ladder as a result. Based on their observations, the researchers believe that routine use of self-contained breathing apparatuses for asbestos removal would likely result in injuries, in view of the large amount of climbing involved. Certainly, acceptance will be much poorer than for the other respirators studied, due to discomfort which would discourage respirator use.

Transmission electron microscopic analyses were done on in-mask and lapel samples. Resultant workplace protection factors are reported in Table VI. Results for small diameter (<0.2um) fibers do not appear to differ from those for large (≥0.2um) diameter fibers, for 5 um or longer lengths. Thus, results for fibers visible with the phase contrast method (≥0.2um diameter) appear to be representative of those for smaller diameter fibers (>5 um length) for the 3M 8710 and 9910, and for elastomeric respirators with type F and H filters.

CONCLUSIONS

1. All respirators tested provided protection against asbestos. The American Optical R1050 disposable respirator reliably provided workplace protection factors of 5 or greater. The 3M 9910, 3M 8710, and elastomeric half-face respirators with both Type F and Type H filters reliable provided workplace protection factors of 10 or greater.

2. Use of higher efficiency (type H) filters did not appear to improve the workplace protector factors of the elastomeric respirators.

3. Workplace protection factor measurements for a pressure demand self-contained breathing apparatus were not significantly higher than those for the better disposable and elastomeric respirators. Comments from the test volunteers and observations indicate that acceptance and safety of the self-contained breathing apparatus will be poorer than that of the other respirators tested.

4. Transmission electron microscopic analyses indicate that overall workplace penetration of small diameter (<0.2um) fibers (longer than 5 um) is not discernibly higher than that of larger diameter fibers for the 3M 8710 and 3M 9910 disposable respirators nor for elastomeric respirators with Type F or H filters.

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1. "Guide to Respirator Fit Testing" (1981), National Paint and Coating Association, Washington, D.C.

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3. National Institute for Occupational Safety and Health, Method 7400, February 15, 1984.

4. Adams, M. J. et al, "Cassette Extenders: Effects on Chrysotile Fiber Deposition and Concentration Measurements", Presented at the American Industrial Conference, May 24, 1983.

5. Snedecor, G. W. and W. G. Cochran: Statistical Methods, 7th Ed., Iowa State University Press, Ames, Iowa (1980).

6. Orits, L. W. et al: "Interim Report: Penetration of Respirator Filters by an Asbestos Aerosol." May 2, 1984 (Los Alamos National Laboratory).

TABLE I

Respirators Studied

Respirator Name	Type	Vendor
Survivair 2000	Elastomeric (silicone rubber) with type H and with type F filters	U.S.D. Corp.
Comfo II	Elastomeric (neoprene) with type H and with type F filters	Mine Safety Appliance Co.
3M 8710	Disposable with nonadjustable staps	3M Company
3M 9910	Disposable with adjustable straps	3M Company
AO R1050	Disposable with nonadjustable straps	American Optical Company
North 7700	Elastomeric (silicone rubber) with type H filter	North Company
Scott Air-Pak	Self-contained breathing apparatus	Scott Aviation

DUP 0933761

TABLE II

COMPARISON OF ASBESTOS SAMPLING METHODS
(OPEN-FACE VERSUS CLOSED-FACE WITH PROBE)

Parameter	Value
Mean	2.2 fibers/mL - open face filter cassette 2.3 fibers/mL - closed face cassette with probe
Standard Deviation	0.264 fibers/mL - open face cassette 0.286 fibers/mL - closed face cassette with probe
T Statistic*	1.28
Variance Ratio**	1.17
Data	
Open-face cassette:	1.9, 1.9, 2.0, 2.1, 2.1, 2.1, 2.2, 2.2, 2.2, 2.2, 2.3, 2.9
Closed-face cassette:	2.0, 2.0, 2.0, 2.2, 2.3, 2.3, 2.3, 2.4, 2.4, 2.4, 2.5, 3.0

* 1.28 is less than a comparison t statistic of 1.78 ($p=0.05$). Therefore, the means do not differ significantly.

** 1.17 is less than a comparison F statistic of 2.69 ($p=0.05$). Therefore, the variances (precision) of the methods do not differ significantly.

DUP 0933762

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TABLE III

MEDIAN ASBESTOS CONCENTRATIONS AND COUNTS FOR WORKPLACE PROTECTION FACTOR STUDY

Concentrations	
Inside Respirator	0.006 fibers/mL (8 HR. TWA $\simeq$ 0.003)
Outside Respirator	2.6 fibers/mL (8 HR. TWA $\simeq$ 1.3)
Counts	
Inside Filter	9 fibers
Outside Filter	130 fibers

DUP 0933763

TABLE IV

WORKPLACE PROTECTION FACTORS FOR
SELF-CONTAINED BREATHING APPARATUS (PRESSURE DEMAND)

Data: 400
880

Geometric Mean: 620

TABLE V

COMPARISON OF WORKPLACE PROTECTION FACTORS FOR SEVEN RESPIRATORS

Respirator	Number of WPF	Workplace Protection Factor Geometric Mean (Geom. S.D.)	Significant Differences*
3M 8710	18	310 (5.3)	
3M 9910	14	580 (4.2)	Higher than R1050
AO R1050	7	52 (4.2)	Lower than 3M 9910
Elastomeric/ Type F Filter	17	240 (6.3)	
Elastomeric/ Type H Filter	14	94 (3.0)	
North 7700 Type F Filter	14	250 (6.9)	
Self-Contained Breathing Apparatus	2	620	

*Based on a Bonferroni test[5] at a 0.05 level of significance, only the 3M 9910 and AO R1050 differed.

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TABLE VI

WORKPLACE PROTECTION FACTORS
FROM TRANSMISSION ELECTRON MICROSCOPIC ANALYSES

Respirator	Workplace Protection Factor: Fibers Exceeding 0.2 um Diameter and 5 um Length*	Workplace Protection Factor: All Diameter Fibers Exceeding 5 um Length
3M 8710	330	120
3M 9910	47	41
Survivair 2000 with Type F Filter	28	29
Survivair 2000 with Type H Filter	21	19

*Those which would be counted by the standard phase contrast microscopy method.

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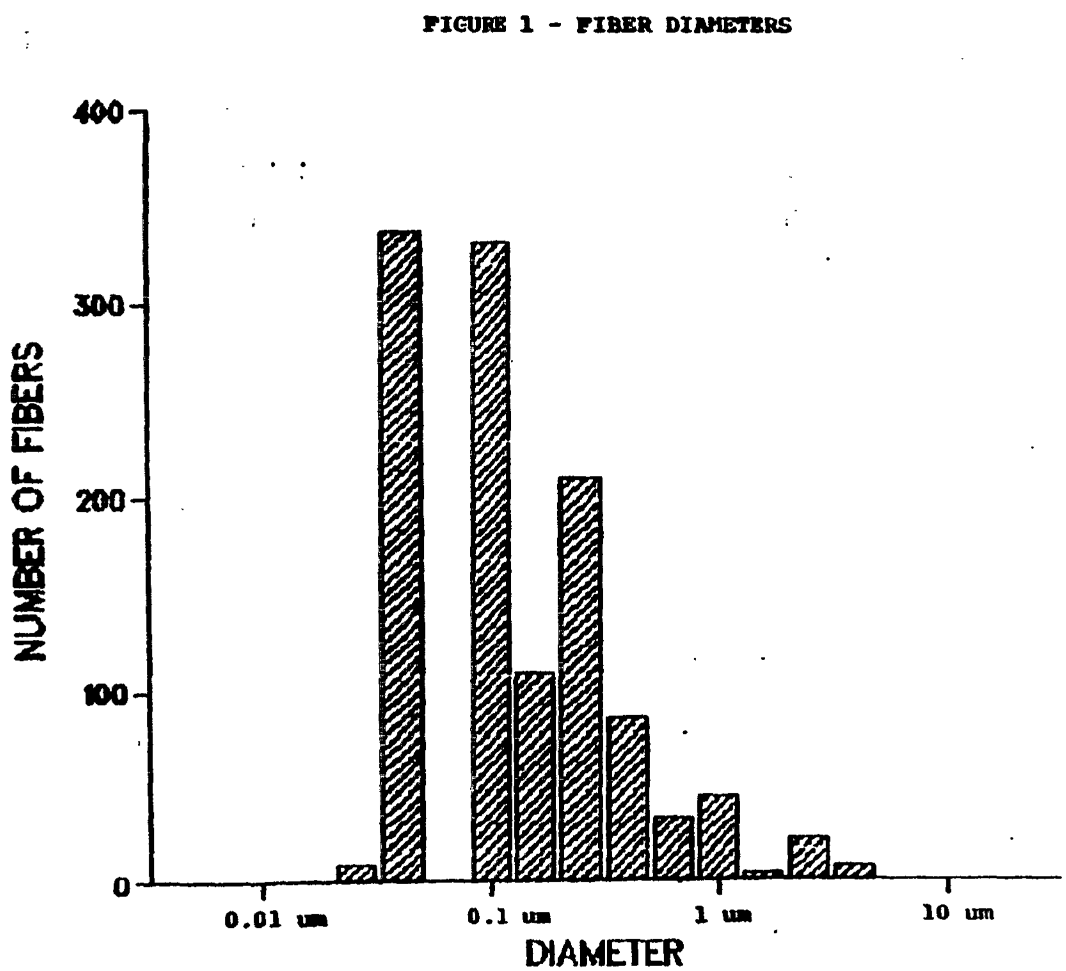
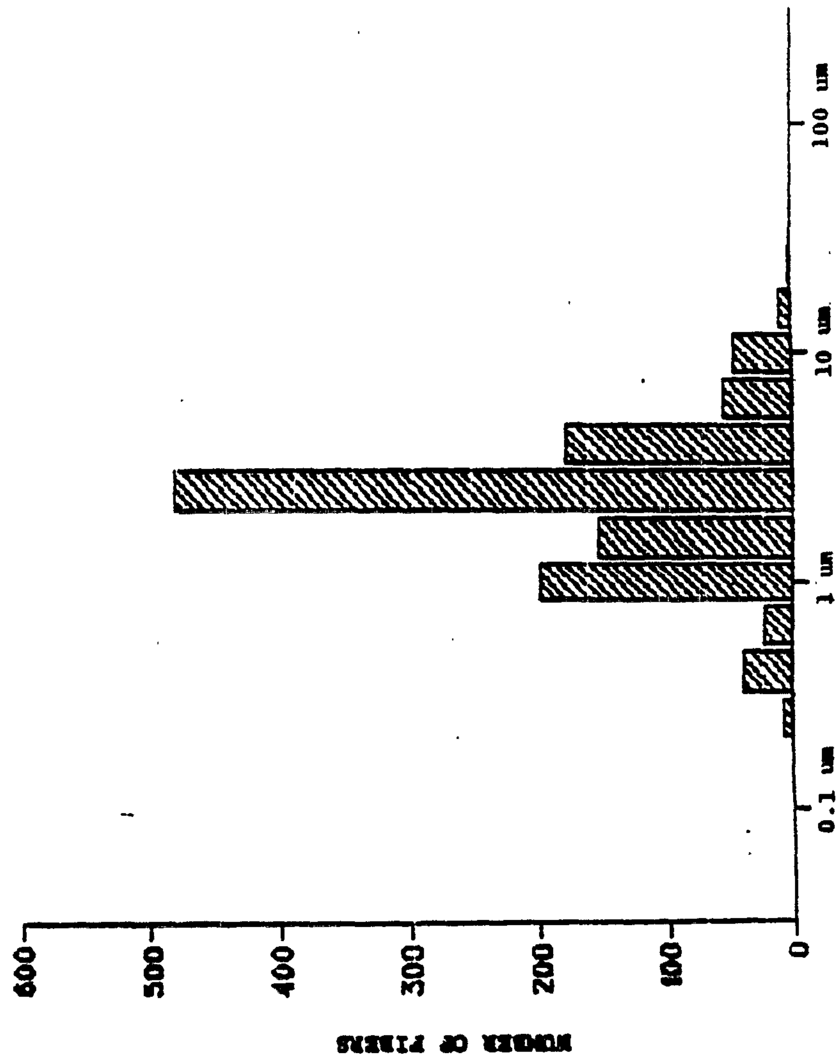


FIGURE 1 - FIBER DIAMETERS
NUMBER OF FIBERS
400
300
200
100
0
0.01 um
0.1 um
1 um
10 um
DIAMETER

DUP 0933767

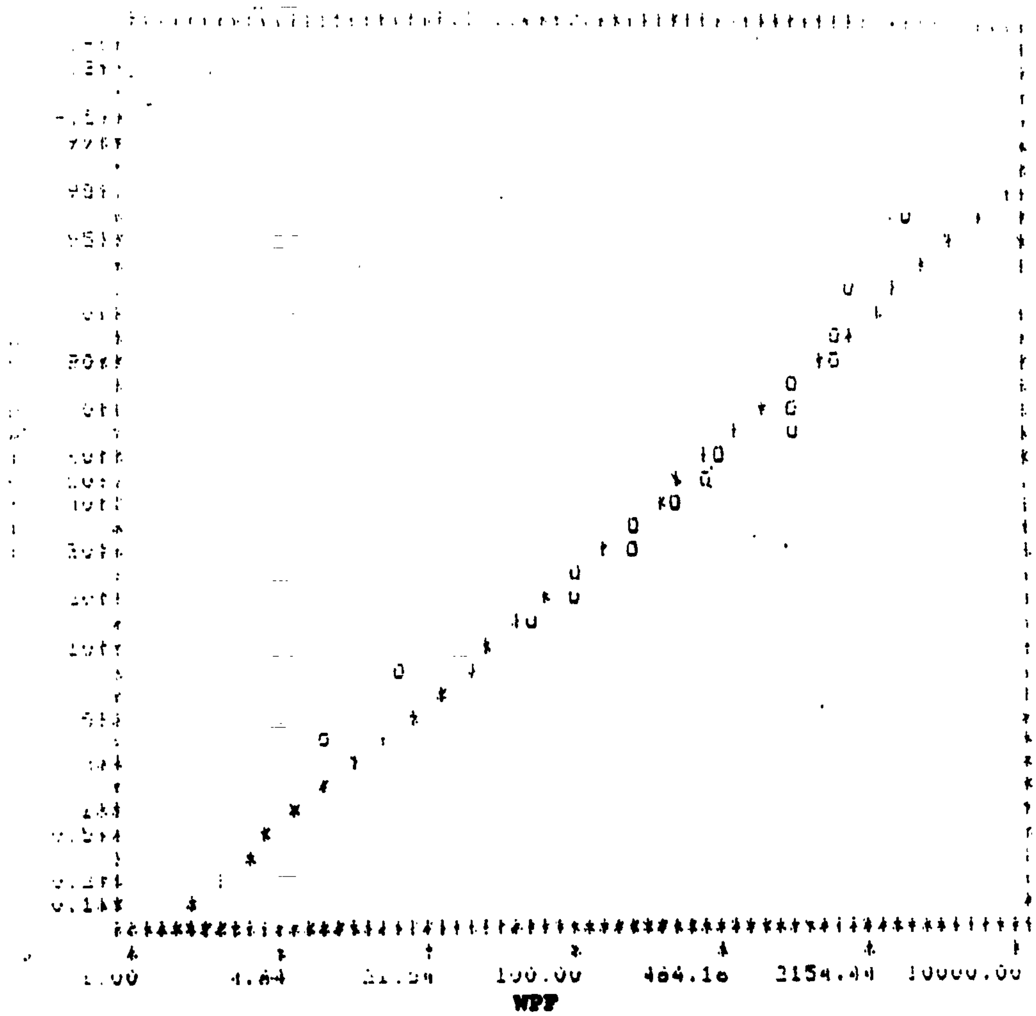
FIGURE 2 - FIBER LENGTHS



DUP 0933768

FIGURE 3 - WORKPLACE PROTECTION FACTORS FOR 3M 8710 RESPIRATOR

CUMULATIVE DISTRIBUTION: (LOGNORMAL)



GEOMETRIC MEAN: 310

GEOMETRIC STANDARD DEVIATION: 5.3

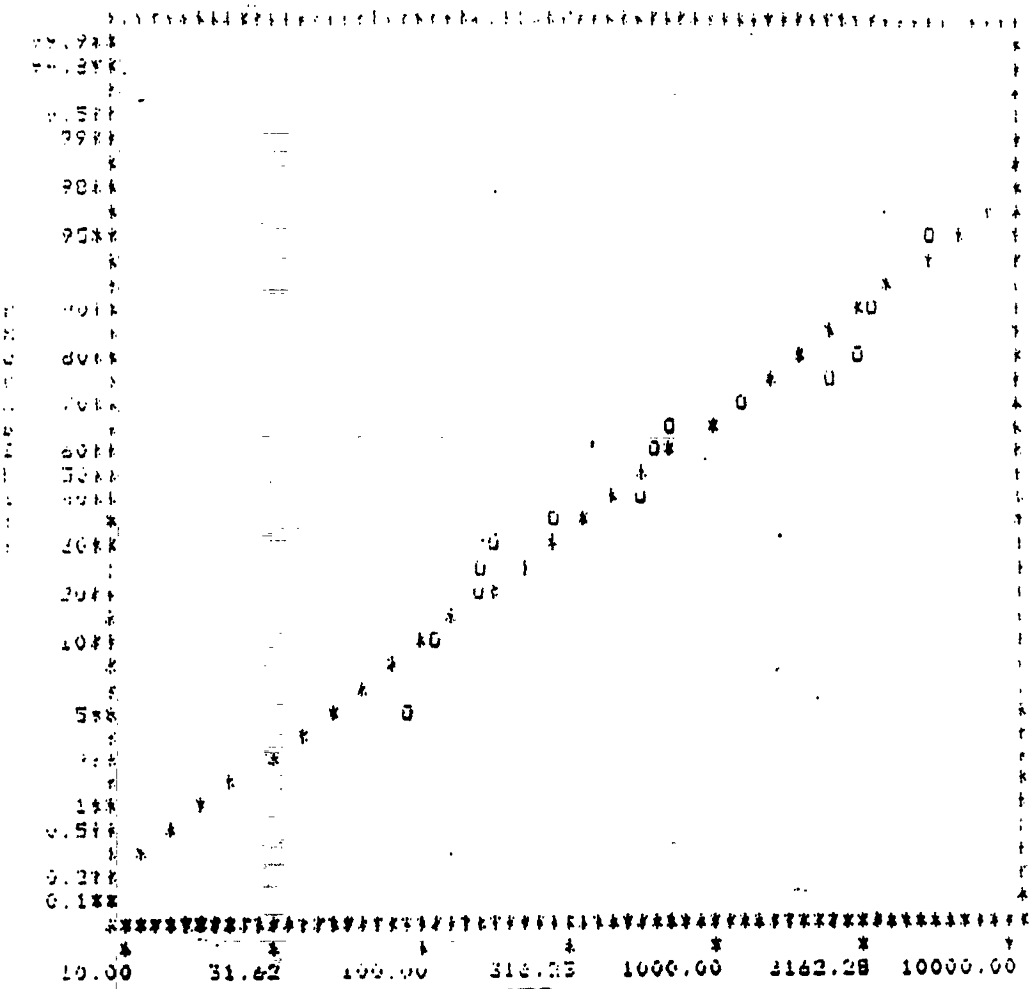
BEST ESTIMATE OF 5TH PERCENTILE: 20

DATA: 7.4, 15, 61, 110, 110, 180, 200, 310, 400, 420, 430, 1000, 1000, 1100, 1500, 1600, 1800, 3200

DUP 0933769

FIGURE 4 - WORKPLACE PROTECTION FACTORS FOR 3M 9910 RESPIRATOR

CUMULATIVE DISTRIBUTION: (LOGNORMAL)



GEOMETRIC MEAN: 580

GEOMETRIC STANDARD DEVIATION: 4.2

BEST ESTIMATE OF 5TH PERCENTILE: 55

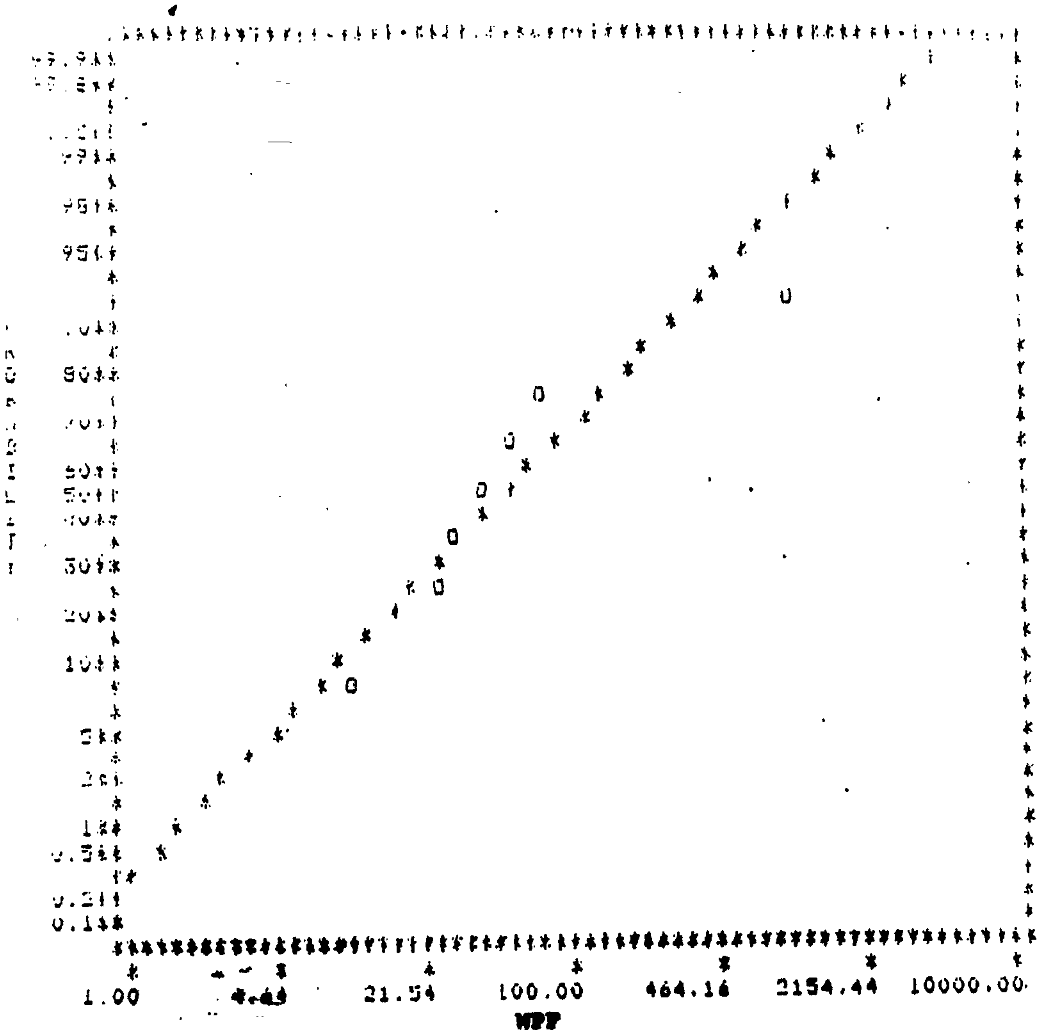
DATA: 94, 110, 150, 150, 170, 280, 550, 630, 710, 1300, 2400, 3000, 3700, 5600

DUP 0933770

DU 036328

FIGURE 5 - WORKPLACE PROTECTION FACTORS FOR AO R1050 RESPIRATOR

CUMULATIVE DISTRIBUTION: (LOGNORMAL)



GEOMETRIC MEAN: 52

GEOMETRIC STANDARD DEVIATION: 4.2

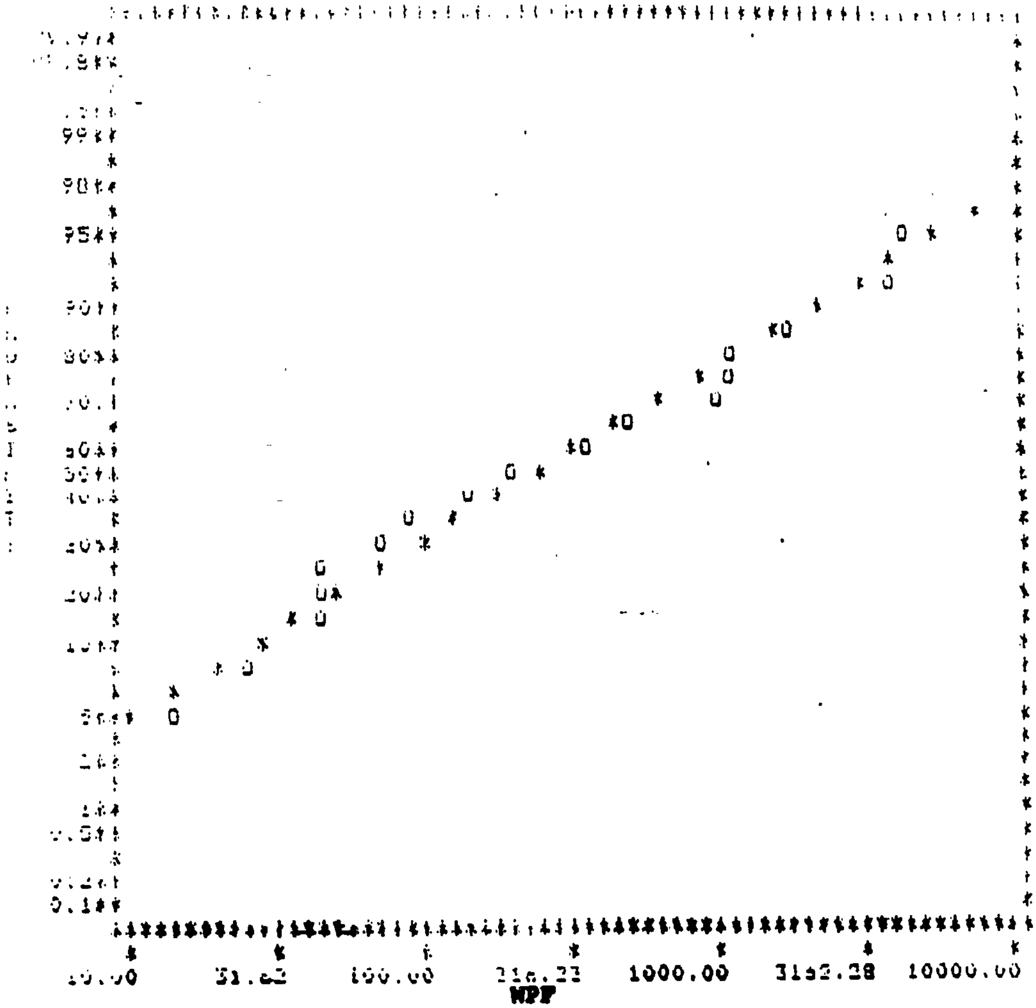
BEST ESTIMATE OF 5TH PERCENTILE: 5

DATA: 9.7, 26, 28, 38, 52, 75, 970

DUP 0933771

FIGURE 6 - WORKPLACE PROTECTION FACTORS FOR SURVIVAIR 2000 AND MSA COMFO HALFMASK RESPIRATORS WITH TYPE F FILTERS

CUMULATIVE DISTRIBUTION: (LOGNORMAL)



GEOMETRIC MEAN: 240

GEOMETRIC STANDARD DEVIATION: 6.3

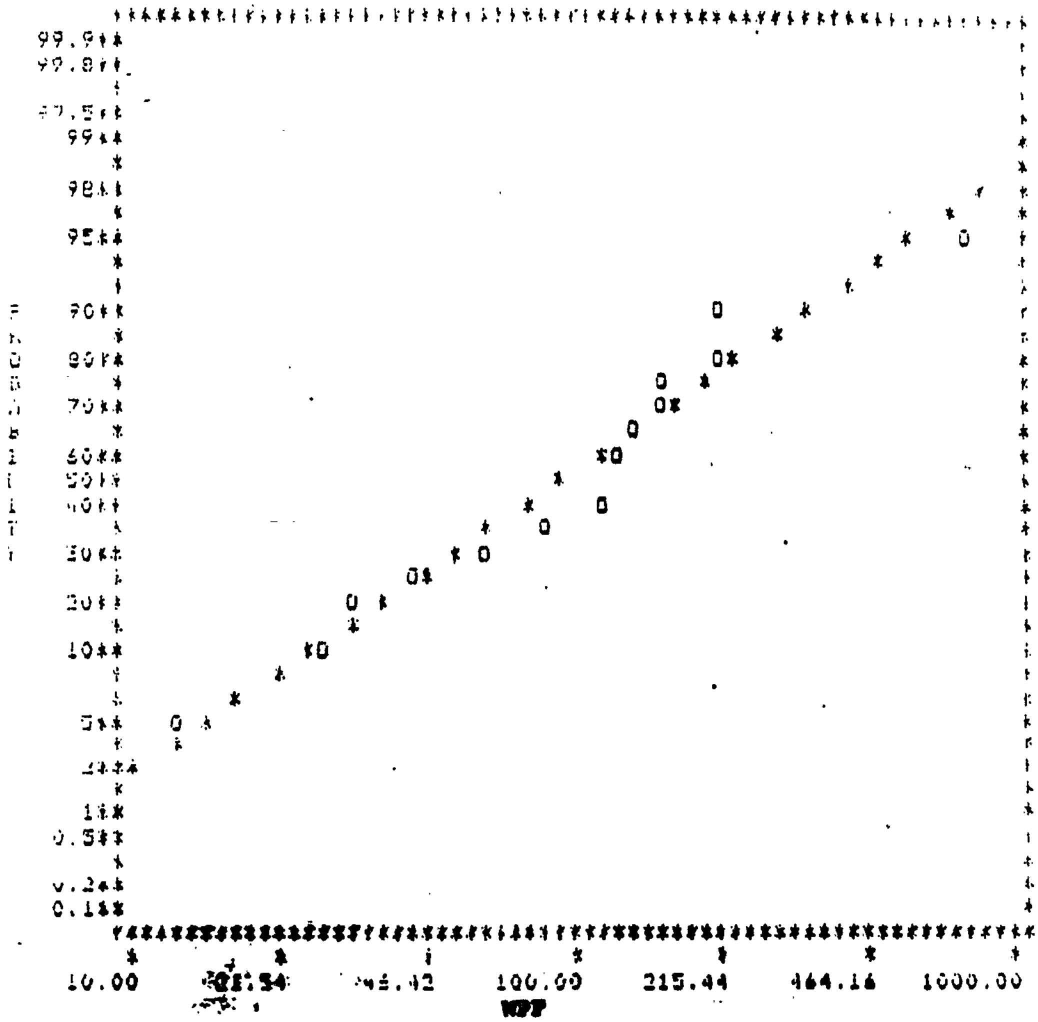
BEST ESTIMATE OF 5TH PERCENTILE: 12

DATA: 15, 24, 45, 46, 47, 74, 88, 140, 190, 370, 480, 1000, 1100, 1100,1800, 4100, 4200

DUP 0933772

FIGURE 7 - WORKPLACE PROTECTION FACTORS FOR SURVIVAIR 2000 AND MSA COMFO HALFMASK RESPIRATORS WITH TYPE H FILTERS

CUMULATIVE DISTRIBUTION: (LOGNORMAL)



GEOMETRIC MEAN: 94

GEOMETRIC STANDARD DEVIATION: 3.0

BEST ESTIMATE OF 5TH PERCENTILE: 16

DATA: 12, 28, 32, 42, 65, 85, 110, 120, 140, 160, 160, 220, 220, 780, 7900*

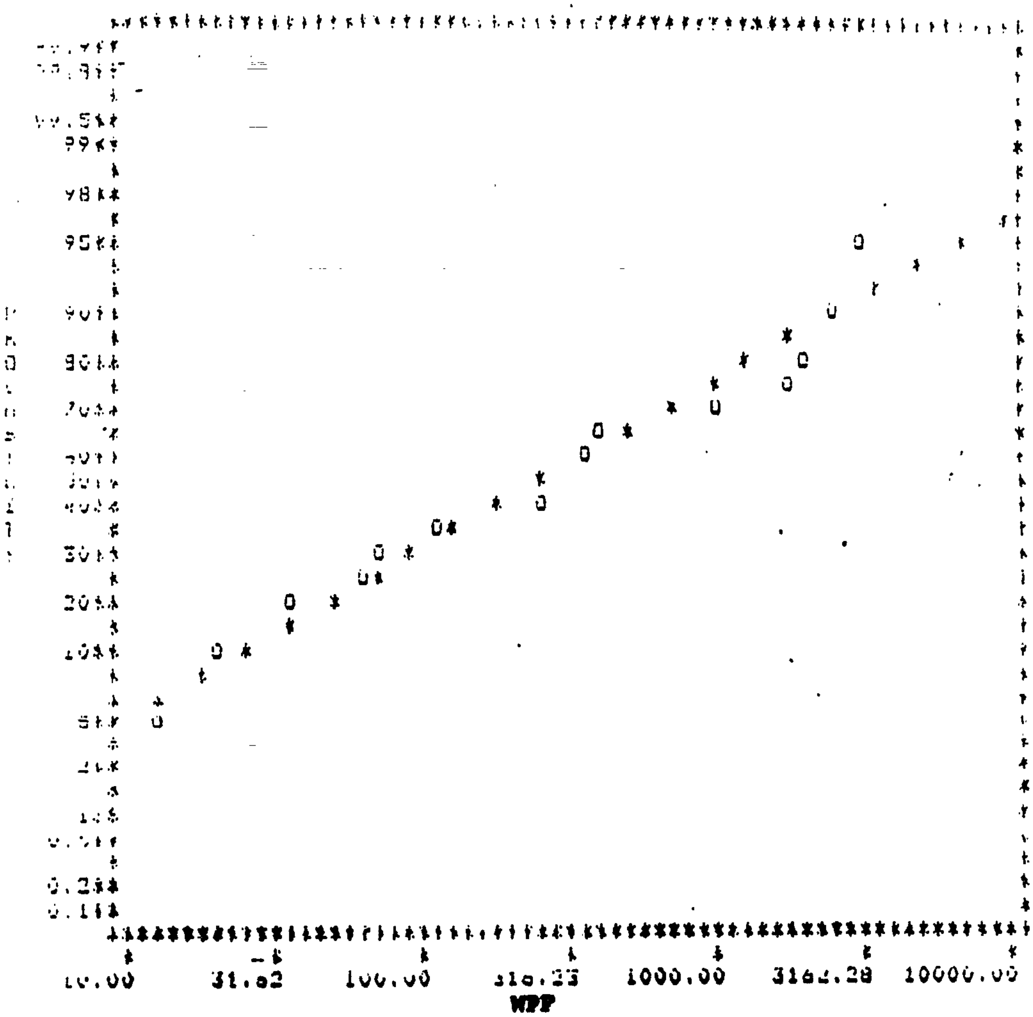
*Removed from plot analysis, as an outlier.

DUP 0933773

DU 036331

FIGURE 8 - WORKPLACE PROTECTION FACTORS FOR NORTH 7700 HALFMASK RESPIRATORS WITH TYPE H FILTERS

CUMULATIVE DISTRIBUTION: (LOGNORMAL)



GEOMETRIC MEAN: 250

GEOMETRIC STANDARD DEVIATION: 6.9

BEST ESTIMATE OF 5TH PERCENTILE: 11

DATA: 12, 20, 36, 60, 74, 110, 260, 350, 400, 1000, 1900, 2000, 2400, 3100

DUP 0933774

TO: Robertson Egerts

FROM: BURFORD W. CULPEPPER, M.D.
Employee Relations Dept.
Medical Division N–11400
E. I. du Pont de Nemours & Co.
Wilmington, Delaware 19898
Phone: 77–45226

Edward A Gaensler
Prof. of Surg & Physiology
Boston Univ. School Med

Gary R. Epler
Chair. Dept Med
New Eng Baptist Hosp.
Asso. Prof. Med
Boston Univ.

Bill Weiss
Prof. Med. Hahnemann
230 N. Broad St.
Philly 19102 215-448-8291.

Raymond Murphy
Shattuck Hosp.
Boston

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DU 036335

Hilton Lowenstein
617-522-8110
Union Carbide

Jn vs Joe,

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Court permits punitive asbestos damages

Ruling is first in N.J. on product linked to ills

Associated Press

TRENTON, N.J. — Punitive damages can be collected from suppliers of asbestos, as well as compensatory damages for health problems linked to the substance, under an appeals court ruling Tuesday that is the first of its kind in New Jersey.

The decision by the Appellate Division of Superior Court, which affects state law in areas other than asbestos cases, said punitive damages can be collected in so-called "strict liability" cases involving the defectiveness of a product.

If the ruling remains intact through possible appeals to higher courts, former asbestos worker James Fischer and his wife will be allowed to collect a penalty payment of $300,000 from Johns-Manville Corp. and Bell Asbestos Mines Ltd.

The couple, who lived in Plainfield but have since moved out of state, also have been awarded a total of $91,000 in compensatory damages for Fischer's asbestos-related health problems, court records show.

The ailments stemmed from exposure to the mineral fiber supplied by Johns-Manville and Bell while Fischer worked at an Asbestos Ltd. plant in Millington 46 years ago, according to the court records.

The Fischers "based their punitive damage claim on the contention that (Johns-Manville and Bell) knew of these hazards as early as the 1930s and made a conscious effort to withhold this information from the public," Judge Sylvia B. Pressler said in her opinion for the three-member appeals panel.

A Superior Court jury previously awarded the punitive damages to the Fischers. Johns-Manville and Bell then appealed.

The firms claimed that punitive damages are not allowed in product liability actions and, if they are, the Fischers did not prove the two firms' actions were "outrageous," according to the court records.

"We considered both these contentions and reject them both," Pressler wrote.

The Manville Corp., of which Johns-Manville is a wholly owned subsidiary, filed for protection under federal bankruptcy laws in 1982. The company, the nation's major asbestos manufacturer, was in no immediate danger of default, but its executives said the cumulative impact of lawsuits related to the effects of the substance placed the firm in financial danger.

DUP 0933779

DU 036337

COMPENSATION FOR DEATH FROM ASBESTOS

WILLIAM G. JOHNSON and EDWARD HELER*

This paper analyzes the adequacy and equity of compensation to the survivors of 560 men who died between 1967 and 1977 from workplace exposure to asbestos. Data were gathered in interviews with the men's widows, who received compensation primarily from workers' compensation, social insurance, private pensions, and tort awards and settlements. The results show that compensation was neither adequate in amount, when compared to income losses, nor equitably distributed among survivors. The authors use their findings to evaluate one of the recent bills before Congress that would institute a federal system of compensation for asbestos-related deaths.

Asbestos kills between 8,500 and 10,000 workers each year.[1] Widespread dissatisfaction with existing means of compensating the survivors of these workers has led to proposals for a federal statute to govern compensation for asbestos-related and similar occupational illness. The leading proposal in 1983, H.R. 3175, was to replace state workers' compensation coverage for asbestos-related illness with federal benefits and to prohibit product-liability suits by workers. This proposal represents an important change in compensation legislation, because its provisions can be extended to govern compensation for other occupational diseases. But any such proposal should be based on accurate information about the defects of the current forms of compensation.

This paper provides information, gathered in interviews with 560 survivors, on the adequacy and equity of the benefits currently paid to the survivors of workers killed by asbestos. It is one of the first studies of compensation for occupational illness and, to our knowledge, is only the second modern study of the consequences of work-related deaths.[2]

*William Johnson is Professor of Economics at the Maxwell School and a Senior Research Associate of the Health Studies Program, both at Syracuse University. Edward Heler is Lecturer at the School of Public and Environmental Affairs, Indiana University Northwest, and Research Associate of the Health Studies Program. This paper is an extension of research completed in conjunction with the Mt. Sinai School of Medicine. Irving Selikoff provided invaluable guidance during that study, and Donald Spatz was a major contributor to its success. Helpful comments on the paper were provided by John F. Burton, Jr., Michael Goldberg, James Lambrinos, and Paul Weiler. Nelson Parder and Mark Miller created the computer programs used in the analysis, and Barbara Clee and Virginia Rapant provided clerical assistance.

[1] William J. Nicholson et al., "Cancer from Occupational Asbestos Exposures: Projections 1980-2000," in *Banbury Report 9: Quantification of Occupational Cancer* (Cold Spring Harbor, N.Y.: Cold Spring Laboratory, 1981).

[2] The only previous study of survivor benefits is Cheit's of 200 widows of workers killed in 1958 and 200 widows of workers killed in 1956. None of the workers died from occupational illness. See Earl F. Cheit, *Injury and Recovery in the Course of Employment* (New York: Wiley, 1961), chaps. 4 and 5.

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0019-7939/84/3704 $01.00

Data

This analysis is based on data collected as part of a study of 995 asbestos-related deaths that occurred between 1967 and 1977 among members of the International Association of Heat and Frost Insulators and Asbestos Workers, AFL-CIO and CLC.[1] As part of that study, 792 survivors from the United States and Canada were interviewed in 1980 to determine the economic consequences of the deaths.[2] We excluded interviews with Canadian citizens from the present analysis because of the differences between the Canadian and U.S. compensation systems. We also excluded interviews with survivors other than the deceased's widow and interviews with widows whose husbands died after the expected end of their work life. Remaining after these exclusions were interviews with 560 widows.

Interview questions probing the economic consequences of the deaths focused on the cash income and later compensatory payments received by the widows. Queries about the amount and source of cash incomes were only for the year 1979, to minimize recall error, but questions about lump-sum payments from workers' compensation and tort settlements asked about all years 1967-79.[3] We can assume that recall error in reports of lump-sum payments is low because the events surrounding the payment awards (such as court suits and workers' compensation agency rulings) are so significant to the survivors.[4]

The annual income losses of survivors were calculated from the time of death to the end of the worker's expected work life. Because our most accurate data on compensation payments are those for 1979, we emphasize the results for 249 widows whose husbands' expected work lives extended at least to 1979, and we present only limited results for the 311 survivors of men whose work lives were expected to end before 1979.

Methods

To measure loss replacement in this analysis, we used the ratio of compensation benefits to the survivor's net losses. The net loss is the portion of the deceased's wages that the survivors would probably have consumed had he lived, namely, his wage income minus federal income taxes, FICA taxes, and the income he himself would have consumed had he lived.[5] We could not calculate costs for medical care or other expenses borne by the survivors on the deceased's behalf. Finally, we assumed that losses ended in the last year of the deceased's expected work life,[6] and we therefore do not include in the analysis the loss of retirement benefits caused by the interruption of the work life.

We estimate death-related payments as the sum of cash benefits in any year plus the estimated income in that year from a

[1] Irving J. Selikoff, ed., *Disability Compensation for Asbestos-Associated Disease in the United States* (New York: Environmental Sciences Laboratory, Mt. Sinai School of Medicine, 1982).

[2] The interviews were conducted as part of a research project at the Mt. Sinai School of Medicine. For a detailed description of the interviews, see Peter Barth, "Compensation for Asbestos-Associated Disease: A Survey of Asbestos Insulation Workers in the United States and Canada," in Selikoff, *Disability Compensation*, pp. 215-94.

[3] Workers' compensation benefits may be paid in a one-time lump sum or as a series of equal amounts over time. When survivors are awarded benefits in installments, they often receive a lump sum equal to the sum of installments due from the time of the deceased's death to the date the claim is settled. Retroactive payments are converted to equivalent installments in this study. The term "lump sum" signifies a one-time lump sum award or settlement.

[4] A comparison of survivors' survey responses with their husbands' workers' compensation records in one state supports this assumption. See Donald Spatz, "Workers' Compensation Experience Among Three Groups of Asbestos-Exposed Workers in New Jersey," in Selikoff, *Disability Compensation*, p. 302.

[5] Hourly wage rates for each year were obtained from the collective bargaining agreements of each worker's union local. Wage income was estimated as the product of wage rates and average hours worked each year by members of the insulation workers' union. Hours data are from a communication from Carday Associates, Inc., Landover, Maryland, May 18, 1982. For details on the loss-estimation methodology, see William G. Johnson and Edward Heler, "The Costs of Asbestos-Associated Disease and Death," *Milbank Memorial Fund Quarterly, Health and Society*, Vol. 61, No. 2 (Spring 1983), pp. 177-94.

[6] The expected work life of each worker was obtained from Shirley J. Smith, "New Worklife Estimates Reflect Changing Profile of Labor Force," *Monthly Labor Review*, Vol. 105, No. 3 (March 1982), pp. 15-20.

previous lump-sum payment. We derive estimates of income from a lump-sum payment in the following manner. The lump-sum payment minus attorneys' fees is treated as financial capital.[9] In each year following the death, the net loss for that year is deducted from capital, and interest income on the balance for that year is added to capital. This procedure is repeated until the capital is exhausted. Our method does not adjust for wage differentials that may be paid for the risk of exposure to asbestos.[10] Barth's study of asbestos-related differentials suggests that, if such premiums exist, they are small.[11]

Standards of Adequacy

The preceding method for comparing benefit payments to losses will tell us how individuals are compensated under the present system of benefits, but an evaluation of current plans and proposed changes requires that we also know how the present system is supposed to operate. What standards of adequate compensation have been developed to date?

The present approach to compensation relies upon workers' compensation plans and tort suits in common law. Our evaluation focuses primarily on payments from these "occupational illness" programs, but to be complete, we also include social insurance and private pension benefits in the analysis.

The conventional wisdom is that workers' compensation benefits should equal two-thirds of the deceased worker's wages in one or more years prior to death.[12] The rationale for the two-thirds standard is ambiguous, but its general acceptance among policymakers makes it an important criterion to use in comparing compensation schemes.

In principle, common-law damage awards should equal the sum of wage loss, medical costs, and compensation for pain and suffering. The objective of the common law is to return successful litigants to the state of well-being they would have enjoyed had their spouses not died. Since our estimates equal only wage income losses, our replacement ratios for tort awards are higher than the true ratios. As a standard of adequacy for our results, we use a replacement ratio equal to one.

Another important measure of adequacy is the proportion of survivors who receive benefits. Workers' compensation laws promise universal coverage for work-related deaths. In theory, therefore, all the survivors studied here were eligible for workers' compensation. Common law requires that each plaintiff prove his or her eligibility, however, and elements of proof vary among jurisdictions and involve issues of fact about which we do not have information. We therefore cannot define a general standard for common-law coverage of the survivors.

The standards that we have defined here approximate only the most general objectives of the current forms of compensation. Our inability to be more precise reflects the variation among workers' compensation laws and the confusion that surrounds the purposes of the current system of compensation programs.

Three sets of results are presented in this study. The first evaluates the adequacy and equity of benefit payments in 1979 for 249 widows whose husbands' expected work life extended to that year. The second set of results provides information about 311 survivors of workers who, had they lived, would have been retired in 1979. Two hundred forty of the 311 widows received some form of compensation during 1979. Their losses are compared to estimated payments from workers' compensation and tort awards for the period from the time of the death to 1979. We then compare these last results to those for the 249 widows of

---

[9] The survey data indicate that attorney fees averaged 39 percent of the awards. Interest was calculated using rates on U.S. Treasury Bonds.

[10] Robert S. Smith, "Compensating Wage Differentials and Public Policy: A Review," *Industrial and Labor Relations Review*, Vol. 32, No. 3 (April 1979), pp. 339-52.

[11] Peter Barth, "Wage Premiums for Risk of Asbestos Workers," in Selikoff, *Disability Compensation*, pp. 557-67.

[12] The National Commission on State Workers' Compensation Laws recommended that "wage loss be replaced at the rate of 66⅔% subject to a maximum benefit of 200 percent of the prevailing State average weekly wage." See *Research Report of the Interdepartmental Workers' Compensation Task Force*, Vol. 1 (Washington, D.C.: GPO, June 1979), p. 19.

DUP 0933783

DU 036340

Table 1. The Replacement of the Net Losses of Widows Who Received Benefits in 1979, by Source of Benefit.[a]

Source	*Number of Widows*	*Net Loss in 1979*	*Workers' Compensation Benefits as a Percentage of Loss*	*Tort Benefits as a Percentage of Loss*	*Social Insurance and Private Pensions as a Percentage of Loss*	*Total Benefit as a Percentage of Loss*	*Uncompensated Loss*[b]
Workers' Compensation Only	10	$14,079	36.2	0.0	0.0	36.2	$8,754
Workers' Compensation, Social Insurance, and Pensions	10	15,439	44.7	0.0	25.0	72.6	4,350
Tort Only	4	13,561	0.0	100.0	0.0	100.0	0
Tort, Social Insurance, and Pensions	8	13,804	0.0	100.0	37.6	137.2	(−5,350)
Workers' Compensation, Tort, Social Insurance, and Pensions	1	15,279	58.4	76.6	11.5	146.5	(−7,102)
Social Insurance and Pensions Only	73	13,967	0.0	0.0	28.5	28.5	9,838
All Sources	124	13,968	0.0[c]	0.0[d]	24.3	36.0	8,811

[a]Rows and columns may not add to the totals because all loss and benefit values and percentages are medians.
[b]Negative values represent the median amount of overcompensation.
[c]Median = zero; mean = 17.1 percent.
[d]Median = zero; mean = 9.8 percent.

workers whose expected work lives extended to 1979. The final set of results compares the adequacy and equity of current benefits with the benefits that would be supplied under H.R. 3175, a 1983 bill before Congress that would create a federal compensation system for the victims of exposure to asbestos and other toxic substances.

The Adequacy and Equity of Compensation Payments

Our most accurate data are for the 249 widows whose husbands' expected work lives extended to 1979. During 1979, these widows lost $3,401,094. Of the 249, 125 widows were not compensated for their losses; the other 124 widows received $777,637 in benefits. Workers' compensation paid $217,085 (or 28 percent of that total); imputed income from tort awards and settlements paid $123,924 (15.7 percent); private pensions paid $185,148 (23.6 percent); and social insurance (primarily social security) paid $228,072 (29.4 percent). The ratios of benefits to losses by source of benefits are described in Table 1.

Workers' Compensation

As shown in column 3 of the table, among widows whose only source of income in 1979 was workers' compensation, that benefit replaced 36.2 percent of their losses. Among widows who received additional payments from other sources, 44.7 percent to 58.4 percent of their net losses were replaced by workers' compensation. Payment of less than net losses to survivors is difficult to rationalize. Disincentive effects were not a concern in these cases. By deducting taxes from our loss estimates, we avoid comparing nontaxable benefits to before-tax wages. One can argue, however, that workers' compensation should be evaluated against the two-thirds standard rather than some absolute measure of adequacy.

Because these results represent net losses in the year that is a median of six years after the worker's death, they cannot be directly evaluated by the two-thirds standard (the ratio of benefits at the time of the award to gross wages prior to death). Instead, we perform the following calculation, which approximates that kind of evaluation. Since workers' compensation benefits are usually paid in installments of equal amounts, benefits in 1979, for most survivors, should have been equal to the annual amount awarded after the worker's death. We evaluate the two-thirds standard, therefore, by comparing 1979 benefits to the deceased's wages in the year of his death. The median ratio of benefits to gross wages prior to death is 29 percent.[13]

These results show that whether we consider the 1979 data or the two-thirds standard, worker's compensation payments are not adequate. This conclusion is reinforced by the fact that our results are based on data for only those widows who received such payments. When the losses of widows who did not receive workers' compensation are also included in the analysis, the replacement ratios are substantially lower.

Only 39 (16 percent) of the 249 widows received workers' compensation payments in 1979. A larger number of widows had received payments before 1979, but these payments had ended. Of the 249 widows, 125 filed workers' compensation claims; two of those were denied their claims, 15 had cases pending in 1979, and 108 had received an award or settlement by the time of the interviews. Of those 108, 46 were awarded lump sums, and 62, installment payments.[14] If all these beneficiaries are considered, 43 percent of the widows received workers' compensation death benefits at some time between the death of their husbands and the year 1979.

Only 39 of the original 108 recipients were still receiving payments in 1979. All but two of the 46 lump-sum payments were consumed by losses before 1979, and 25 of the 62 benefits paid in installments had ended before 1979. The exhaustion of worker's compensation benefits before losses end has also been observed among workers disabled by accidental injuries. Studies show that, generally, the shorter the period of loss, the higher the rate of replacement by workers' compensation.[15]

In sum, the results show that the standard of universal coverage is not nearly met. Whether the failure is that of workers' compensation schemes or other influences is not clear. Most of the widows who filed claims received payments, but only one-half of the widows filed. An analysis of the reasons for this low rate of filing is therefore critical to evaluating the adequacy of coverage, but such an analysis is beyond the scope of this study.

Tort Awards

Workers' compensation laws typically bar workers from suing their employer for work-related injuries or illnesses. The exceptions to these "exclusive remedy" provisions are the following: intentional torts, employer deceit, and situations in which a third party (such as an asbestos producer), who is sued by the worker, sues the worker's employer. Workers can sue producers of hazardous substances without sacrificing their workers' compensation claims. Although many workers have adopted this strategy in recent years, only one survivor in our study received income from both sources during 1979. Interestingly, this widow was the best compensated of those studied.

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[13] There are 36 widows for whom this estimate could be made

[14] Data on the outcome of two claims were missing

[15] William G. Johnson, Paul R. Cullinan, and William P. Curington, "The Adequacy of Workers' Compensation Benefits," and Richard Ginnold, "A Follow-up Study of Permanent Disability Cases Under Wisconsin Workers' Compensation," both in *Research Report of the Interdepartmental Workers' Compensation Task Force*, Vol. 6 (Washington, D.C.: GPO, June 1979), pp. 113 and 89, respectively.

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Tort income replaced all the losses of 11 of the other 12 widows who received tort income in 1979.[16] The common law, therefore, satisfies its standard of adequacy. The adequacy of compensation does vary, however, with the time at which benefits and losses are compared.

All these 12 widows, except for one whose imputed income was less than her net loss in 1979, had capital left to invest at the end of that year. In the following year, eight of the 11 tort recipients received an imputed income sufficient to replace their 1980 losses. The other three widows would have exhausted their tort award capital during 1980. The pattern of the gradual exhaustion of lump sum awards is one that deserves more attention as an important part of the adequacy of compensation.

The replacement ratios for tort income in 1979 do not reflect the losses of unsuccessful plaintiffs or of survivors whose lump sum was consumed before 1979. Of 44 widows who filed tort suits, 26 received an award or a settlement. Only 13 of the 26 (Table 1) received income in 1979 from their tort suit. Unfortunately, the data on tort suits are incomplete. Six widows said their suit was successful but did not report benefits, and twelve suits were undecided at the time of interview. It is clear, however, that few suits were filed. As in the case of failure to file workers' compensation claims, the reasons for this behavior are not clear. The low rates of filing for tort and workers' compensation do not support the suggestion sometimes made that workers substitute tort claims for workers' compensation. These results imply that other influences are responsible for the low rate of filing.

Private Pensions and Social Insurance

Social insurance and private pensions are retirement schemes that also protect against loss resulting from death. The fact that these plans are the only source of income for most (59 percent) of the widows studied here is further evidence of the failure of both workers' compensation plans and the common law. Benefits from these two sources typically replaced less than 30 percent of losses (Table 1). Widows who combined these benefits with payments from other sources, however, were the only ones whose compensation exceeded their losses.

The amount of social insurance benefits varies with the time at which they are measured. Eligibility for social security survivors' benefits is conditional on whether there are any dependent children in the home or on the age of the widow. Widows receive no benefits between the time their children come of legal age and the time the widows reach retirement age. The data on private pensions do not separate retirement from survivors' benefits.

None of the 249 widows received public assistance.[17] Instead, they presumably used income such as proceeds from life insurance, their own wages, savings, and assistance from relatives to maintain consumption above poverty levels.

Equity in the Distribution of Benefits

We assume that benefits are equitably distributed if the proportion of benefits to losses is the same for each survivor. The mean replacement ratio for those who received payments is 59.7 percent, but as shown in the figure, the distribution about the mean is skewed toward below-average levels of replacement. Approximately 55 percent of the recipients are able to replace less than 40 percent of their loss. The inequity is even more extreme if we include in the distribution the 125 widows who were not compensated.

We can better understand the true impact of these inequities if we also consider the size distribution of losses. The

[16] The finding of replacement ratios no greater than 100 percent is dictated by our assumption that the amount of tort income consumed in any year is not greater than the net loss.

[17] This result parallels earlier findings that few disabled workers resort to public assistance. Vroman found that only one in six seriously injured beneficiaries of workers' compensation in New York City received public assistance or benefits from private charity. Wayne Vroman, "Serious Injuries, Workmen's Compensation and Public Assistance in New York City," in *Supplemental Studies for the National Commission on State Workmen's Compensation Laws*, Vol II (Washington, D.C.: GPO, 1973), p. 69.

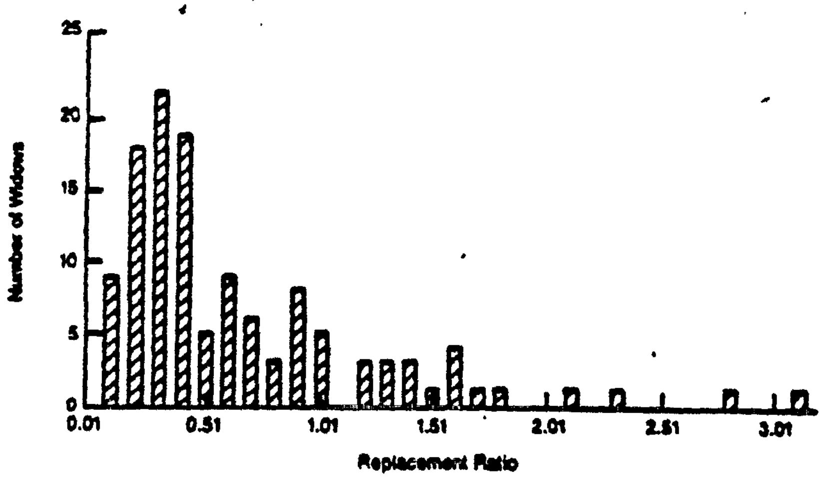

Figure 1. Distribution of Replacement Ratios of Widows Who Received Benefits in 1979 and Whose Husbands' Work Life Included 1979.

results in Table 2 show that a large proportion of above-average ratios occur in cases in which losses are low. Most low-loss cases are those in which the deceased's work life was expected to end in 1979. Our estimates of losses equal zero at the end of the work life, and widows who received compensation payments for the entire year, therefore, have high replacement ratios.

The inequities in the distribution of benefits also reflect variations in the eligibility rules under workers' compensation plans, tort laws, and social insurance. In a pattern familiar to students of compensation programs, replacement ratios are higher for those with payments from several sources than for those who rely on a single source. Some of the variation in workers' compensation benefits occurs because of differences in benefits among different states. These differences also cause inequities in payments to injured workers.[18]

The fact that compensation payments may continue after our estimates of losses equal zero means that estimates based on a single work-life year (Table 1) could be lower than the true ratios.[19] Data on compensation payments in 1979 to widows whose husbands' work lives ended before 1979 provide additional information on the bias of single-year estimates.

Compensation Payments During Retirement Years

Although our analysis does not consider losses of retirement benefits, data on the 311 widows whose husbands' work lives were

[18] John F. Burton, Jr., and Wayne Vroman, "A Report on Permanent Partial Disabilities Under Worker's Compensation," in *Research Report of the Interdepartmental Workers' Compensation Task Force*, Vol. 6, pp. 67-70

[19] Payments are limited to an absolute duration or are payable to the widow for life or until remarriage. These criteria do not refer to the year in which the worker would be expected to leave the work force had he lived. The New York benefit, for example, is defined as equal to two-thirds of the worker's wage (wage income prior to death), but in 1982 the benefit could not be less than $30 per week or more than $215 per week. Survivors' benefits terminate upon remarriage, at which time a lump sum equal to two years of benefits is paid. See U.S. Department of Labor, *State Workers' Compensation Laws* (Washington, D.C.: GPO, January 1982), p. 11.

Table 2. The Distribution of Benefit Adequacy, by Net Loss, Among Widows Who Received Benefits in 1979.

Net Wage Loss	*Number of Widows*	*Benefits as a Percentage of Loss*†
$0 - $2,999	4	252.6
3,000 - 5,999	6	123.3
6,000 - 8,999	4	76.8
9,000 - 11,999	13	36.2
12,000 - 14,999	70	31.6
15,000 - 17,999	24	32.2
18,000 and Over	3	31.8
Total	124	

†All percentage values are medians.

expected to end before 1979 do provide information on the effect of post-work-life benefits on the replacement of losses. We assume that workers' compensation benefits in 1979 for 240 widows who received benefits equaled the annual amount paid since the time of their husbands' death. Annual income from lump-sum payments was calculated from the time of death to 1979 in the manner described in the methods section. The ratios of the sum of benefits (from the time of death to 1979) to the sum of losses (annual losses equal zero after the expected end of the work life) are presented in Table 3. The time distribution of social insurance and pension benefits cannot be approximated, so replacement ratios are estimated only for the occupational-illness programs.

Since the two cohorts of widows differ in age and average losses, a comparison of the ratios in Table 3 with those in Table 1 only approximates the effect of post-work-life benefits on the adequacy of compensation. The replacement ratios for workers' compensation in Table 3 (column 3) differ from those in Table 1, being higher in some categories and lower in others. In no category, however, do the ratios exceed 41 percent of the losses. All the replacement ratios for tort awards (column 4 in Table 3) are lower than those for the cohort having a work life that was expected to include 1979. The results for post-work-life benefits thus do not substantially alter the conclusions that were drawn from the more accurate data on the single year 1979.

Summary. The results of this study describe a compensation system that pays only 36 percent of the losses of the 124 widows who received compensation in 1979. Payments are not distributed equitably, although one of the causes of this inequity is the failure of widows to claim benefits. Those who succeed in common-law suits receive the most compensation, whereas workers' compensation plans fail both the two-thirds standard and the promise of universal coverage.

These failures are not limited to compensating deaths from occupational illness. Cheit's conclusions about the survivors of death by workplace injury are similar to the findings here. Cheit concluded, for example, that in 37 of 51 states in 1956, workers' compensation replaced 40 percent or less of the estimated losses caused by occupational death.[28] Our estimates are from 36 to 45 percent for most workers' compensation recipients. Cheit also described the problem mentioned earlier of widows who receive no social security benefits between the time their dependents leave home and the time they themselves retire.[29]

[28] Cheit, *Injury and Recovery,* p. 116.
[29] Ibid., p. 129.

Table 3. The Replacement of Net Losses, by Source of Benefits for Widows Who Received Benefits in 1979 and Whose Husbands' Work-Life Expectancy Ended Before 1979.[a]

Source	*Number of Widows*	*Total Net Wage Loss*	*Benefits as a Percentage of Loss*	*Tort Benefits as a Percentage of Loss*
Workers' Compensation Only	24	$53,074	40.9	0.0
Workers' Compensation, Social Insurance, and Pensions	54	50,386	33.8	0.0
Tort Only	11	44,361	0.0	63.4
Tort, Social Insurance, and Private Pensions	9	55,387	0.0	17.2
Workers' Compensation, Tort, Social Insurance, and Private Pensions	4	46,561	15.3	43.1
Social Insurance and Pensions Only	138	40,707	—[b]	—[b]
All Sources	240	43,052	0.0[c]	0.0[d]

[a]Rows and columns may not add to totals because all loss and benefit values and percentages are medians.
[b]Replacement ratios could not be calculated for social insurance and pensions.
[c]Median = 0.0, mean = 18.2.
[d]Median = 0.0, mean = 45.9.

These similarities in findings are surprising because Cheit's data are nearly 30 years old. One would expect to find many changes in the structure of benefits and in benefit adequacy between the 1950s and 1979, but the only important differences are in the adequacy of tort awards. Our results show that tort awards replaced 76.6 to 100 percent of net losses in 1979 and from 17 to 63.4 percent over a longer period, whereas Cheit found that in 1956 tort awards replaced only 9 to 18.5 percent of losses.[illegible] The higher replacement ratios found in our study may be the result of the recent liberalization in the application of product-liability law in occupational illness.

It is important to caution against generalizing our results to deaths occurring after 1977, since which time workers' compensation benefits have increased and coverage of occupational illness has expanded. In general, however, once benefits are awarded, they are still not indexed for inflation, and any expansion in coverage since 1977 has been small. A review of the 1979 workers' compensation laws, for example, found that the laws "deliberately limit the number of cases, especially of the chronic, long term (and probably costly) variety, which are admitted into the system."[illegible]

Another reason for caution is that the survivors studied here may have had more success in obtaining compensation than other survivors during the years 1967–77. The survivors' husbands belonged to a well-organized national labor union and had expert information on the relationship between their illnesses and asbestos at the workplace. On the other hand, the court decisions that expanded producers' liability for asbestos occurred after most of these workers had died.[illegible] Because these influences are contradictory, the extent to

[illegible]Ibid., p. 115.

[illegible]Lloyd W. Larson, "Analysis of Current Laws Reflecting Worker Benefits for Occupational Diseases," research report to the Assistant Secretary for Planning, Evaluation, and Research, U.S. Department of Labor, contract no. ASPER/PUR-78/4386/A (Washington, D.C.: USDOL, May 1979), p. 12.

[illegible]Richard A. Epstein, "Manville: The Bankruptcy of Product Liability Law," in *Regulation: AEI Journal on Government and Society,* Vol. 6, No. 5 (September-October 1982), pp. 14–46.

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which our results represent compensation for more recent deaths is unknown.

Evaluation of Proposed Programs

Three bills were introduced in the 97th Congress to provide compensation for asbestos-associated disease and death.[28] With the adjournment of the 97th Congress, those bills expired. A toxic-substances compensation bill, H.R. 3175, was then introduced in the 98th Congress by Congressman George Miller of California.[29]

Evaluation of H.R. 3175 is important because it could become the model for compensating victims of all occupational illnesses. It promises no-fault coverage of losses resulting from exposure to asbestos or other toxic substances that could be designated for coverage at a later date. The bill prohibits workers from suing employers or producers who purchase insurance in amounts to be set by the U.S. Secretary of Labor. Employers and producers can choose whether or not to purchase their own insurance, subject to the provisions of the bill. Claims are to be administered by the Office of Workers' Compensation of the U.S. Department of Labor. Death benefits are to be paid in a lump sum equal to "the product of 80 percent of the average manufacturing weekly wage for the month in which the death occurred, or 80 percent of the national construction average weekly wage for the month in which the death occurred ... multiplied by 260."[30]

In order to evaluate the potential adequacy and equity of compensation under the proposed legislation, we applied the benefit formula of H.R. 3175 to data for each of the 560 widows in the study cohort. Using the methods described earlier, we converted the lump sum to an annual income stream, and we assumed that all the widows would receive benefits. Table 4 presents the ratios of benefits to losses from the time of death to the expected end of the work life.

The results show that H.R. 3175 would substantially increase the adequacy of compensation beyond that provided by workers' compensation and the common law. They also demonstrate that the payment of a lump sum not related to individual losses discriminates against survivors with relatively large losses. If H.R. 3175 benefits had been paid to the 560 survivors studied here, 80.5 percent (the median) of their losses would have been reimbursed. This is a higher percentage of widows' losses than are our estimates for the small number of widows who received payments in 1979. The most important improvement over the current compensation system, however, is the payment of benefits to widows who would not be paid at all under the current system.

The improvement that we estimate from the Miller bill depends on the assumption of universal coverage. Experience with workers' compensation, on which the bill is modeled, warns that our assumption may be too optimistic. The failure of workers' compensation to provide universal coverage points to the need for statutory provisions for objective monitoring of the performance of compensation plans and for more research on the low rates of filing by eligible claimants.

In addition, the Miller bill's reliance on lump-sum payments deserves further scrutiny. The settlement of claims by one-time lump-sum payments has been repeatedly attacked as inequitable.[31] The use

[28] Millicent Fenwick, *H.R. 5224: Asbestos Health Hazards Compensation Act*, 97th Cong., 1st sess. (Washington, D.C.: GPO, December 16, 1981); Gary L. Hart, *S. 1643: Asbestos Health Hazards Compensation Act of 1981*, 97th Cong., 1st sess. (Washington, D.C.: GPO, September 9, 1981); and George Miller, *H.R. 5735, Occupational Health Hazards Compensation Act of 1982*, 97th Cong., 2d sess. (Washington, D.C.: GPO, March 4, 1982).

[29] U.S. Congress, House. *A Bill to Provide for the Compensation of Individuals Who Are Disabled as a Result of Occupational Exposure to Toxic Substances, to Regularize the Fair, Adequate, and Equitable Compensation of Certain Occupational Disease Victims, and For Other Purposes. H.R. 3175*, 98th Cong., 1st sess. (Washington, D.C.: GPO, 1983), discussion draft, § 3(16).

[30] Ibid. The construction wage is the basis for benefits for construction workers. All other benefits are based on the manufacturing wage.

[31] Ronald Conley and John Noble, "Workers' Compensation Reform: Challenge for the 80's," in *Research Report of the Interdepartmental Workers' Compensation Task Force*, Vol. 1, p. 78.

Table 4. Estimated H.R. 3175 Benefits Based on Net Losses from the Time of Death to the Expected End of the Spouse's Work Life, for All Widows Surviving in 1979.

Net Loss	*Number of Widows*	*Replacement Ratio* *Mean*	*Median*
$ 3,490 - 14,999	36	4.661	4.000
15,000 - 24,999	65	2.452	2.500
25,000 - 34,999	83	1.602	1.600
35,000 - 44,999	48	1.246	1.250
45,000 - 54,999	43	0.990	1.000
55,000 - 64,999	36	0.831	0.800
65,000 - 74,999	22	0.682	0.700
75,000 - 84,999	31	0.616	0.600
85,000 - 94,999	33	0.597	0.600
95,000 - 104,999	22	0.475	0.500
105,000 - 114,999	16	0.456	0.500
115,000 - 144,999	30	0.415	0.400
145,000 - 174,999	26	0.327	0.300
175,000 - 204,999	19	0.242	0.200
205,000 - 234,999	14	0.236	0.200
235,000 - 284,999	14	0.207	0.200
285,000 - 334,999	16	0.190	0.200
335,000 - 404,999	8	0.188	0.200
405,000 and Over	9	0.100	0.100
Total	600	1.106	0.800

of this form of payment as a "reform" of the compensation system would merely perpetuate (and perhaps exacerbate) a fundamental problem with the existing workers' compensation and tort awards. Survivors with relatively small losses are overcompensated, but those with above-average losses receive less than 50 percent of their loss (see Table 4). Most of the difference in losses is caused by differences in expected work lives.

Because of the long latency period of asbestos disease, death typically occurs in middle age (53 in this cohort), and the period of loss to survivors is short (ten years). If the principles of the Miller bill are applied to diseases that cause death at younger ages, the adequacy of compensation would be substantially lower than the results in Table 4.

The introduction of no-fault statutes at a time when common-law damages are becoming a significant cost to employers parallels the history of the early years of workers' compensation legislation.[illegible] Some scholars believe that the common law compensates victims inequitably and that the social costs of litigation outweigh the social benefits obtained from common-law incentives.[illegible] The Miller bill eliminates the workers' compensation and tort remedies but nonetheless follows the workers' compensation model. Some studies of the adequacy of workers' compensation suggest that workers' compensation laws do not match the adequacy of contemporary common-law remedies;[illegible] they also question the wisdom of diluting the incentives for risk minimization that are provided by the common law.[illegible]

The dispute over common-law versus workers' compensation remedies will not soon be resolved. The uncertainty surrounding the performance of these alternatives and the history of workers' compensation suggest that the elimination

[illegible]James L. Croyle, "Industrial Accident Liability Policy of the Early Twentieth Century," *Journal of Legal Studies*, Vol. 7, No. 2 (June 1978), pp. 279 - 98.

[illegible]Jeffrey O'Connell, *The Injury Industry* (Urbana: University of Illinois Press, 1971).

[illegible]Robert Ashford and William G. Johnson, "Negligence vs. Strict Liability: The Workers' Compensation Example," *Seton Hall Law Review*, Vol. 12, No. 4 (August 1982), pp. 738 - 66.

[illegible]James R. Chelius, *Workplace Safety and Health: The Role of Workers' Compensation* (Washington, D.C.: American Enterprise Institute for Public Policy Research, 1977).

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of workers' right to sue could be a serious mistake. Much of the current pressure for reform comes from the recent flood of asbestos-related litigation. But unless proposed compensation schemes include strong incentives for evaluating and improving their performance, the right to sue could be the only reason for change.

Conclusion

The implications of this study are more general than our conclusions regarding asbestos workers. The results demonstrate that those who benefit from the production and use of commodities, such as the producers and users of asbestos, have not paid the full cost of the commodities. They have, in effect, been subsidized by the workers who have died and by their survivors. Whether one wishes to measure social goals in terms of economic efficiency, morality, or some common-sense definition of what is just, compensation that fails to pay even the net loss to the survivors of dead workers is grossly inadequate.

Date: 2/27/85

To: ~~B. W. CULPEPPER~~ ER
N-11400

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~~AEB~~

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Polymer Products Department — M-5525

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