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DUP-1796

October 18, 1984

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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.

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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 ($\leq$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

The valuable collaboration and participation of Thomas J. Nelson in this study, and the perserverance and thoroughness of James E. Henry in doing microscopic analysis are gratefully acknowledged. Special acknowledgement is also due Robert L. Frye, C. Norman McLean, the study volunteers, and numerous other at the Kingston, Ontario site and the Potomic River site for their excellent cooperation and assistance.

The assistance of James M. Kayser, James C. Piner, James E. Henry and Susan S. Mileti in doing the workplace studies is greatefully acknowledged, as is the peer review of Edwin C. Hyatt, Earle P. Shoub, and Charles E. Billings.

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SWD/tac/3.52
Date Issued: October 18, 1984
Attachments: Table I-VI, Figure 1-8
Number of pages in this report: 21

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 3: 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 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

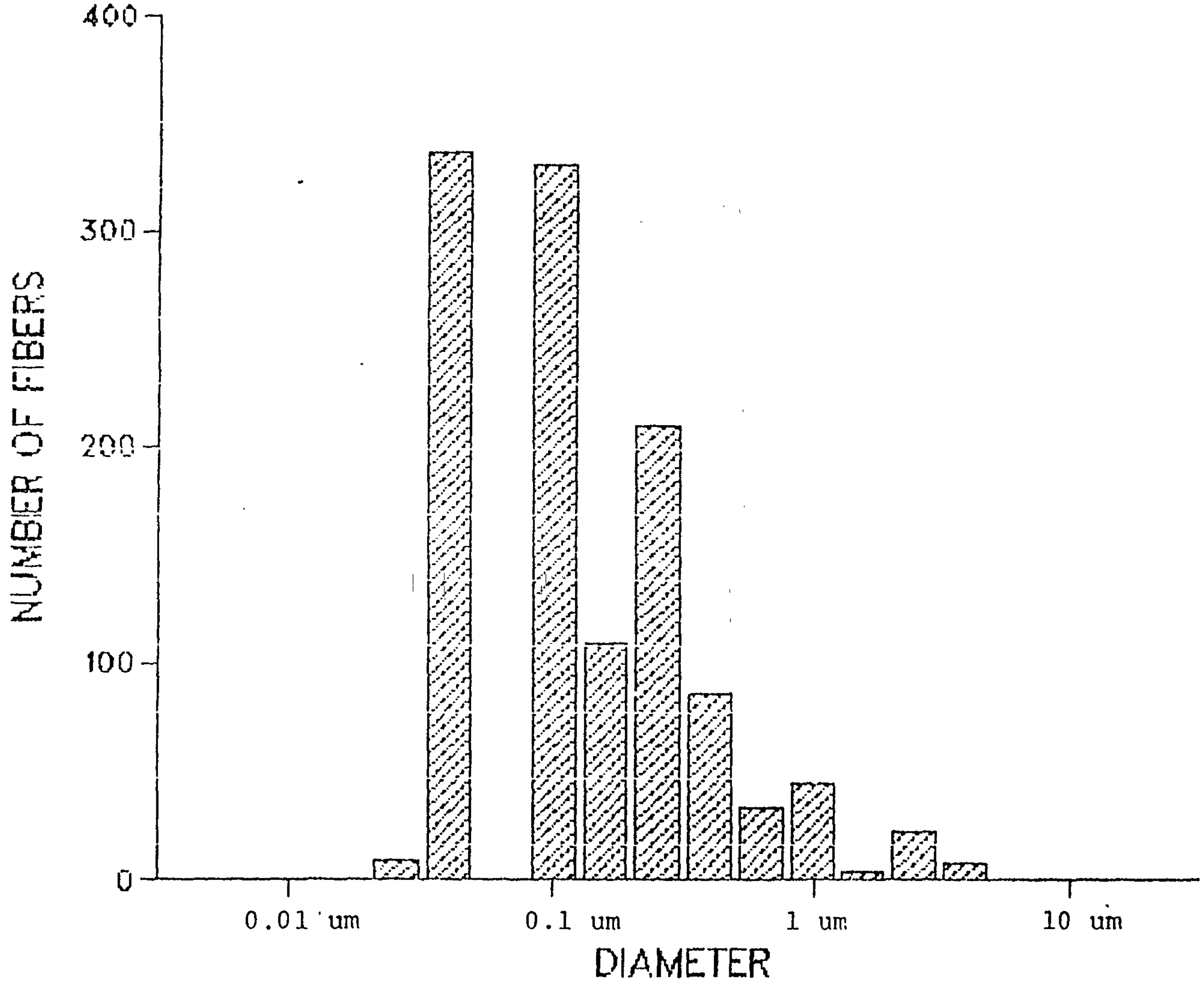


FIGURE 2 - FIBER LENGTHS

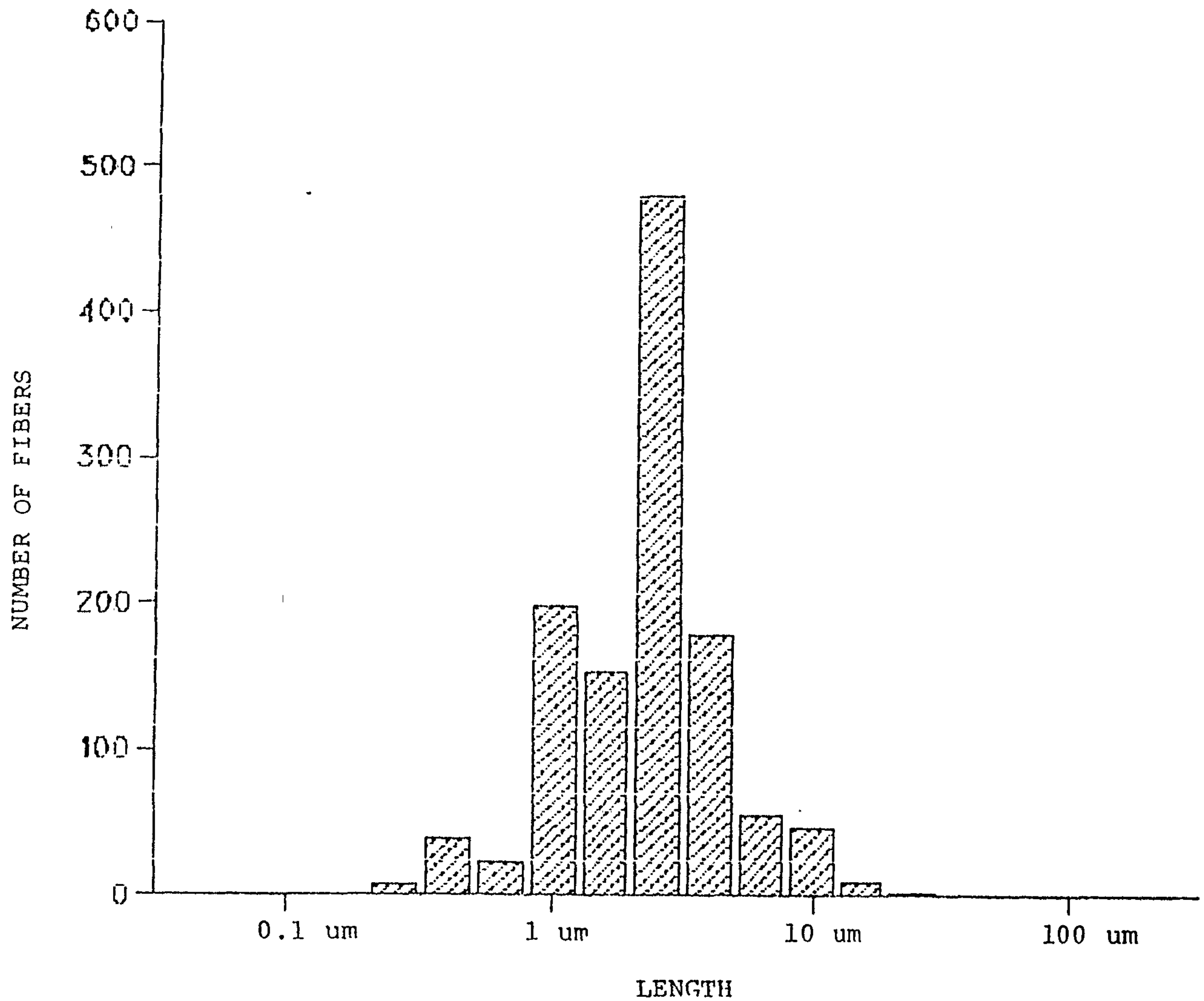
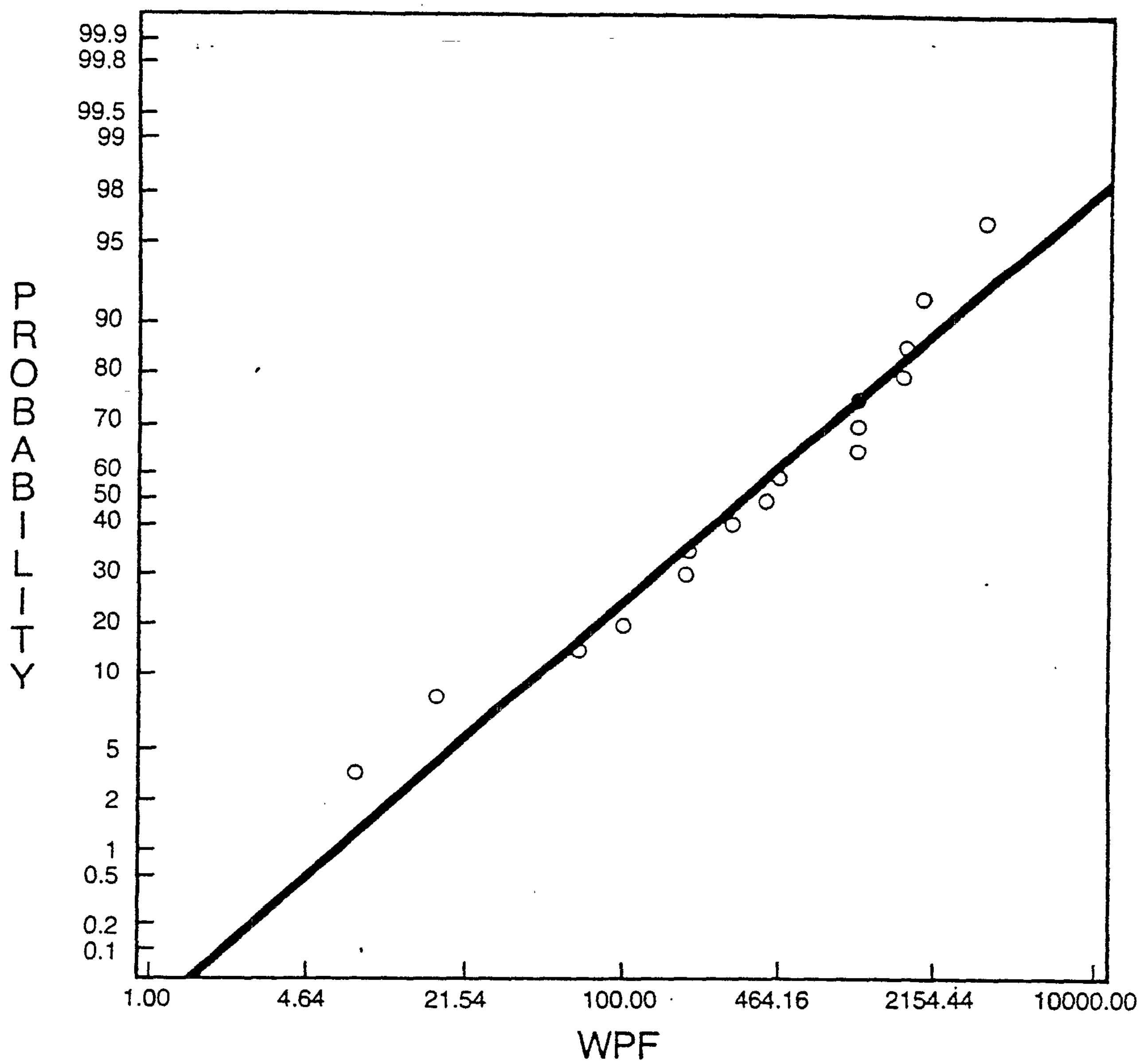


Figure 3 – Workplace Protection Factors for 3M 8710 Respirator

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

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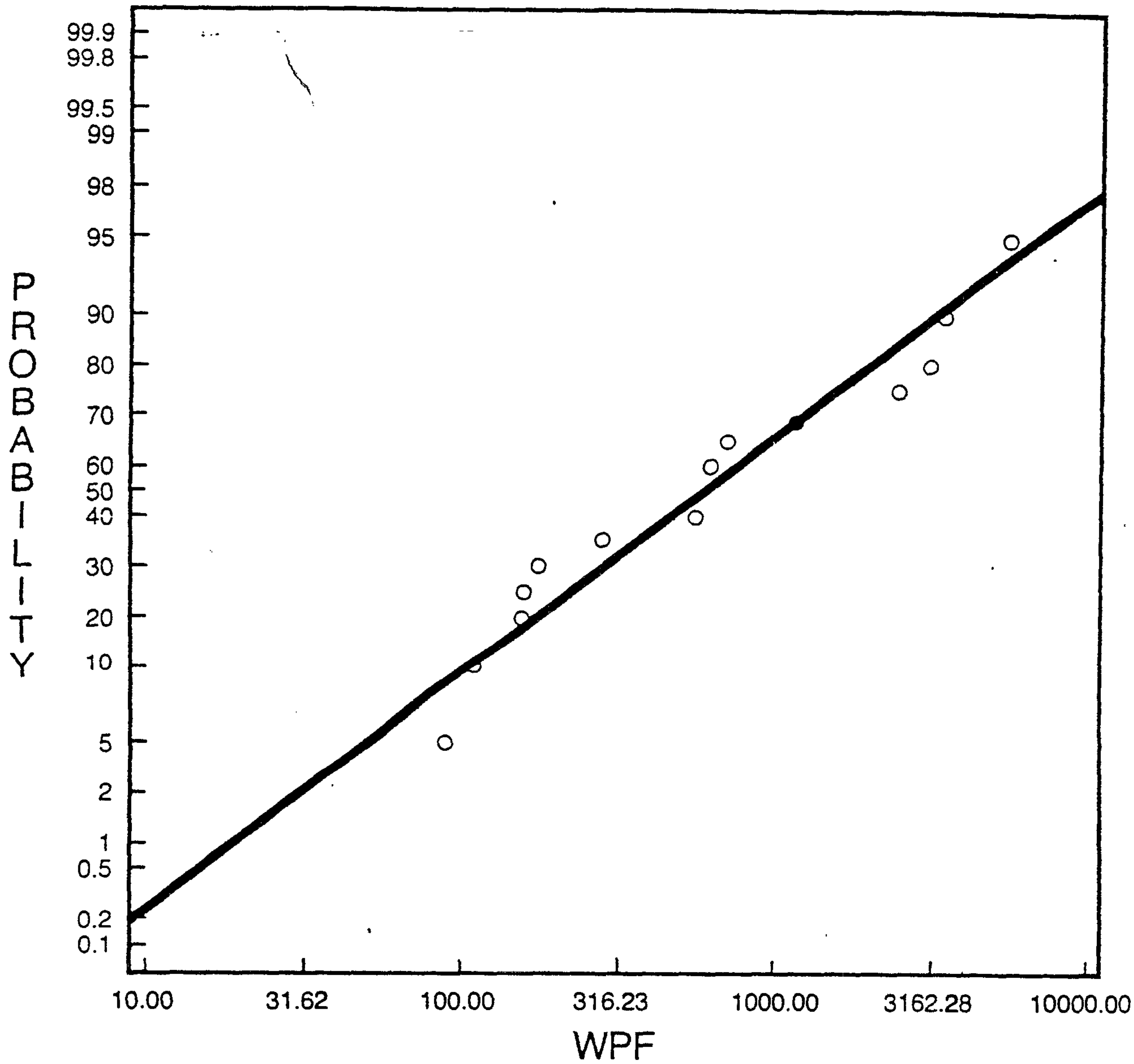
Figure 4 – Workplace Protection Factors for 3M 9910 Respirator

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

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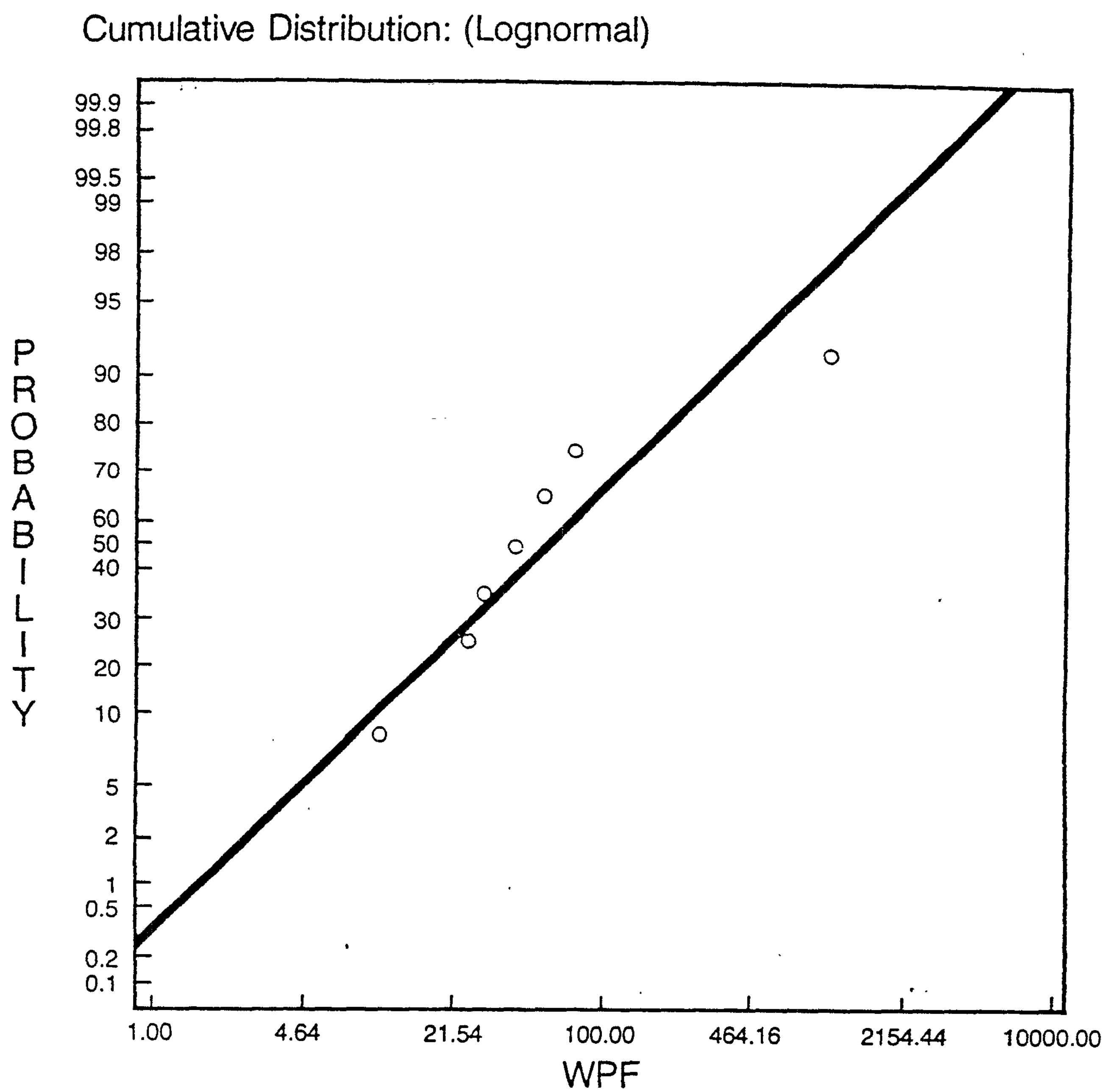
Figure 5 – Workplace Protection Factors for AO R1050 Respirator



Geometric Mean: 52

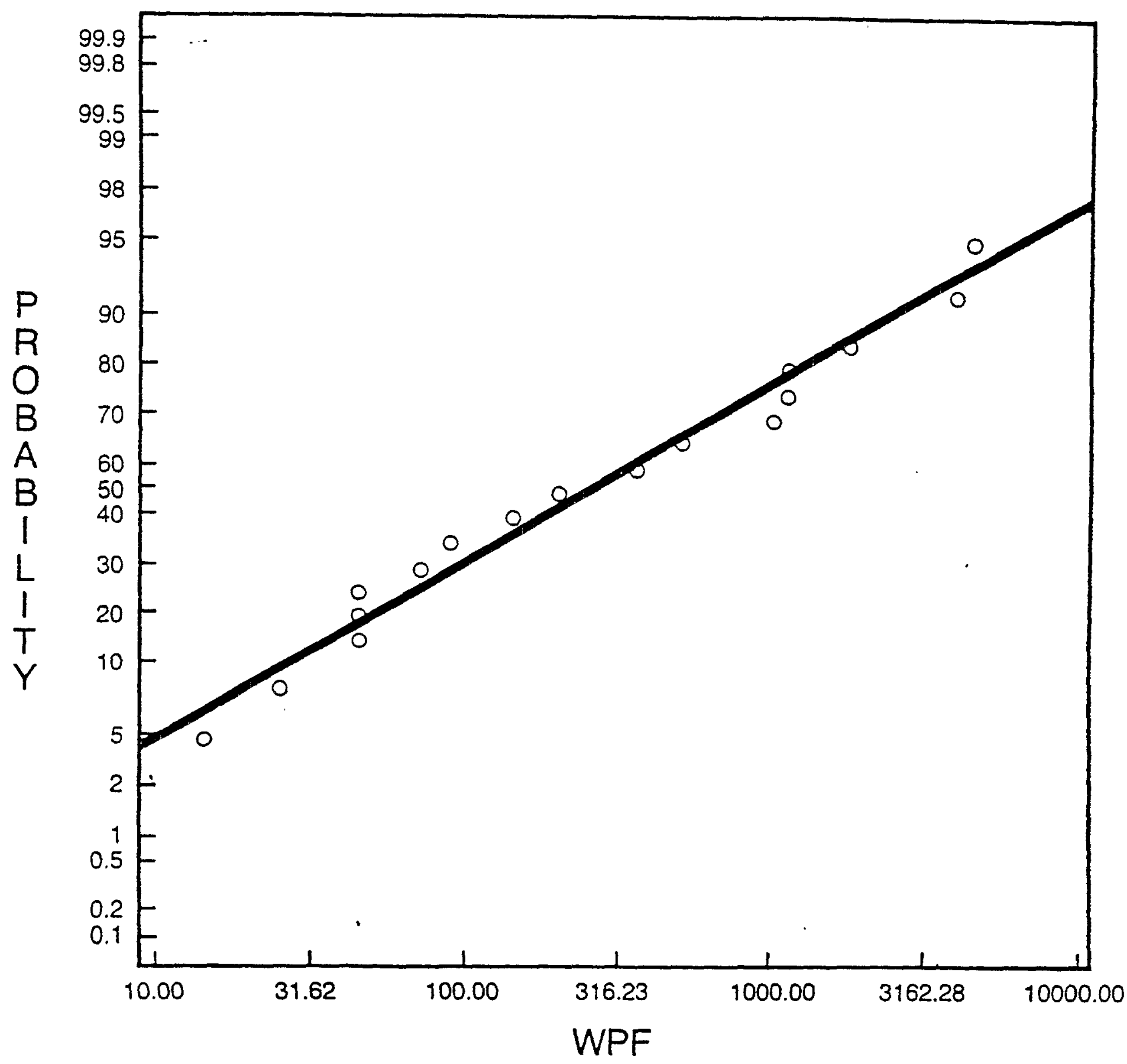
Geometric Standard Deviation: 4.2

Best Estimate of 5th Percentile: 5

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

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

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

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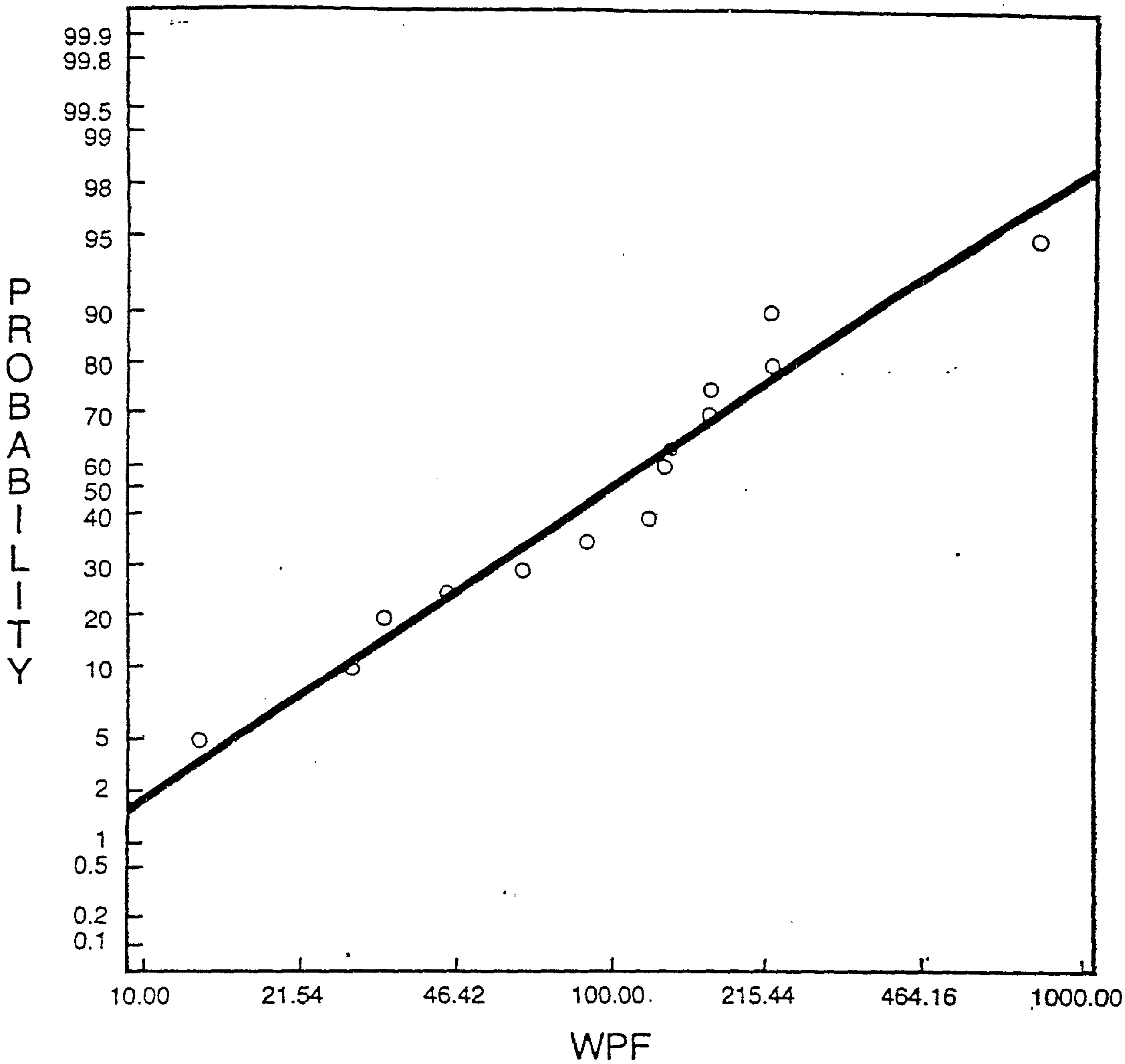
Figure 7 - Workplace Protection Factors for Survivair 2000 and MSA Comfo® Halfmask Respirators with High Efficiency Filters

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.

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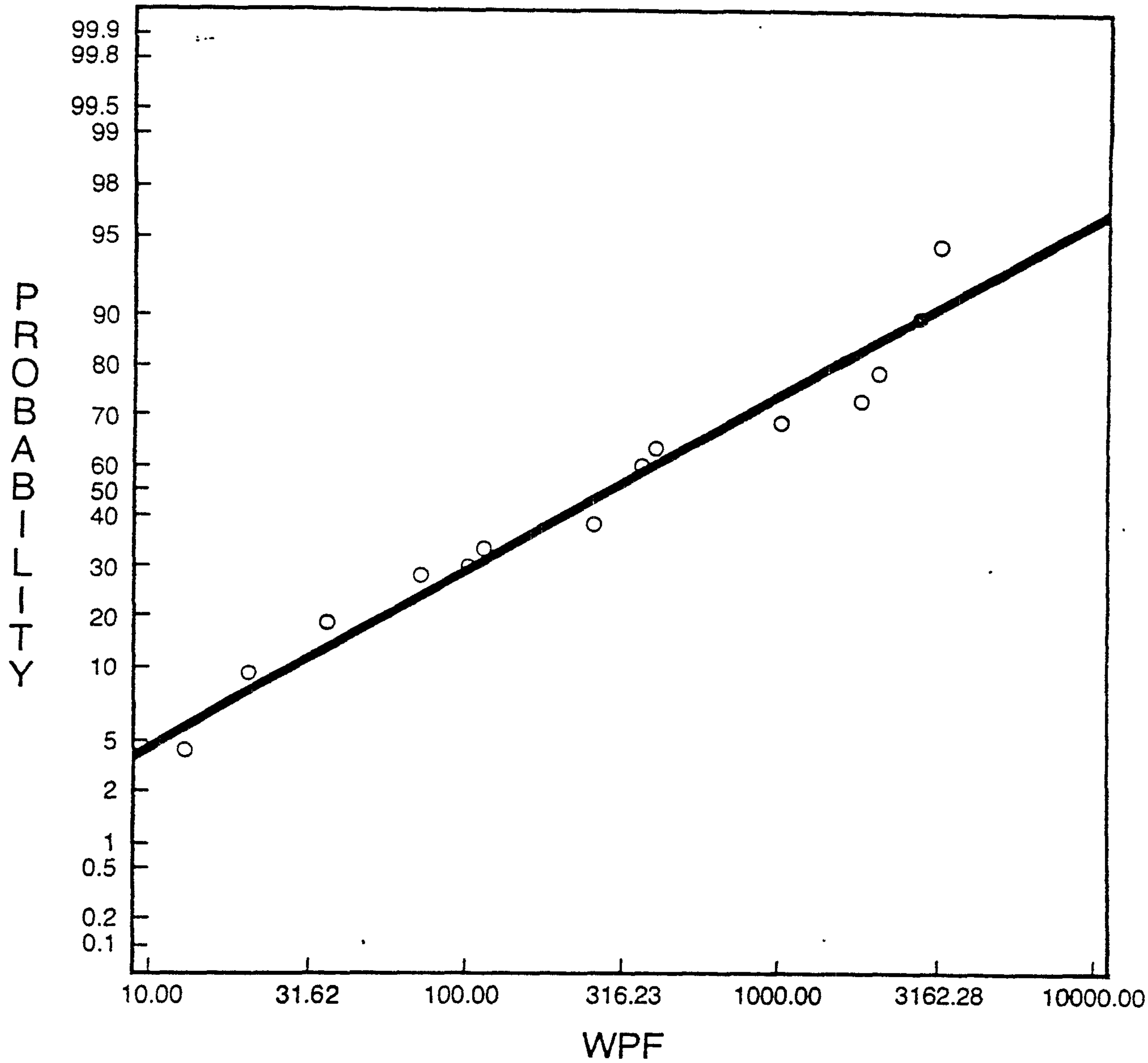
Figure 8 – Workplace Protection Factors for North 7700 Halfmask Respirators with High Efficiency Filters

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

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