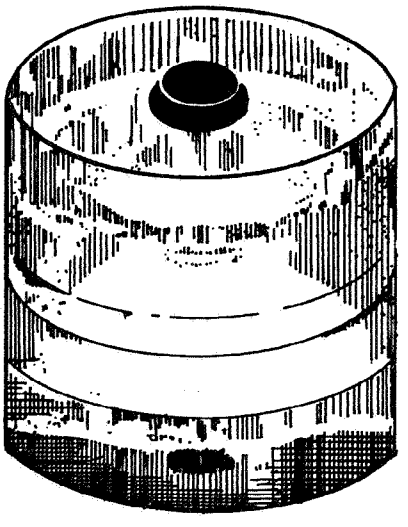
file: Asbestos Analyses (Any Subj file)

MAKING SOMETHING OUT OF NOTHING

Legal limits on asbestos exposure are becoming increasingly less.

But how are valid air samplings made when the values measured are near zero?



By Jeffrey A. Boggs

It is critical that decisions to reopen removal sites to the unprotected public are supported by statistically valid test data. Today a method for estimating low-level airborne asbestos fiber concentrations with statistical confidence, both prior to and following abatement projects, has been developed. This "Poisson" distribution method has been tested and found the best statistical model for determining both unexposed membrane filters (background levels) and sample membrane filters (exposed levels) of asbestos.

The "limits of reliable detection" for the USPHS/NIOSH methods P&CAM 239 or 7400 are the *limit of qualitative detection* (LOD) and the *limit of quantitative detection* (LOQ). Standard calculating procedures utilizing known variables—such as microscope field area, filter effective collecting area and sample air volume—provide guidelines for determining detection limits. The protocol has been simplified for laboratory analysis of low-level airborne fiber concentrations by the presently preferred NIOSH methods. Additional formulae, which determine the required air volume (Q) to "reliably detect" the filter surface fiber concentration standards (S) help laboratories and hygienists specify appropriate sampling strategies, *a priori*.

Thus, the proposed *standard* methodology offers two significant contributions for determining low-level airborne asbestos fiber concen-

trations: 1) provides point estimates based on the calculated, known "limit of detection" for any volume of air sampled, and 2) permits statistically valid "re-entry" decisions.

OSHA first regulated occupational exposures to asbestos (See Figure 2) in 1971 when it adopted a 12 f/cc limit. In June 1972, OSHA promulgated the present standard which is found at 29 CFR 1910.1001. This standard established an 8-hour TWA permissible exposure limit (PEL) of 5 f/cc (with a ceiling limit of 10 f/cc), and mandated further reduction in the PEL to 2 f/cc effective July, 1976.

In 1975, OSHA again proposed to lower the PEL from 2.0 f/cc to 0.5 f/cc and the ceiling limit from 10 f/cc to 5 f/cc. This notice of proposed rulemaking was based on then-available evidence which OSHA believed had "accumulated to warrant the designation of asbestos as a human carcinogen."

In 1982, the State of Maryland promulgated asbestos regulations that required final air testing on any large project. Areas could not be opened to the public until airborne concentrations were less than 0.1 f/cc. In November 1983, OSHA published an Emergency Temporary Standard (ETS) which mandated an immediate reduction in the PEL to 0.5 f/cc.

In June 1985, the EPA published "Guidance For Controlling Asbestos-Containing Materials in Buildings". This text is generally regarded as the latest information on asbestos hazard evaluation. Appendix M of the document recommends that if any phase-contrast microscope samples exceed 0.01 f/cc, the abatement site should be recleaned.

The Veterans Administration has specified that authorization for removal of barriers of small area asbestos removals will be authorized if the air sample is 0.005 f/cc.

These current re-occupancy standards would suggest very low and zero fiber counts in post-abatement environments. The problem, therefore, is how to handle "zero" or "near zero" data values. In industrial hygiene work, zero value levels are generally undetectable. These levels do occur, however, and there is no

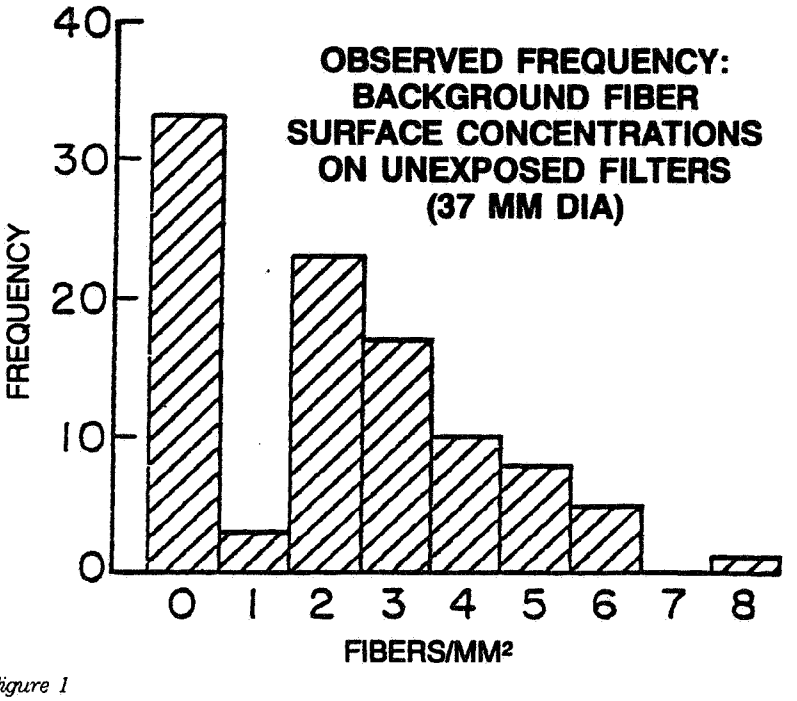


Figure 1

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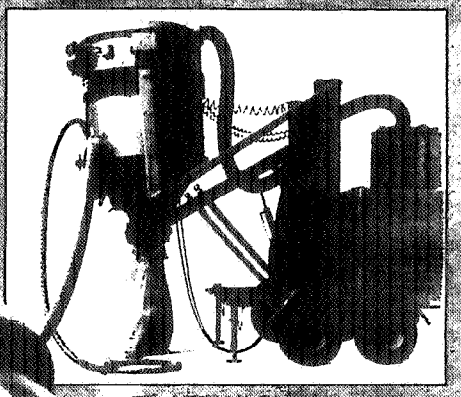

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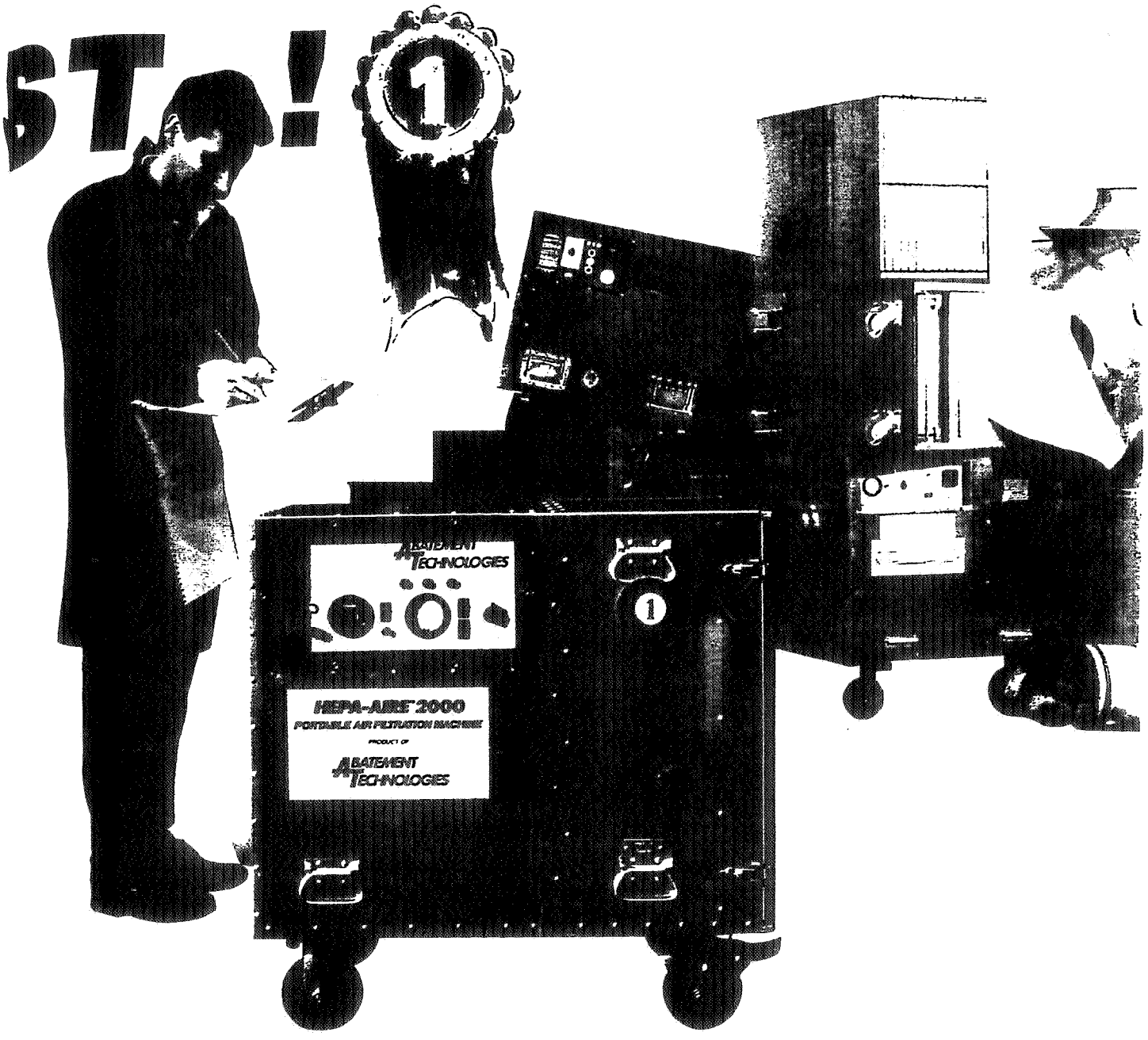

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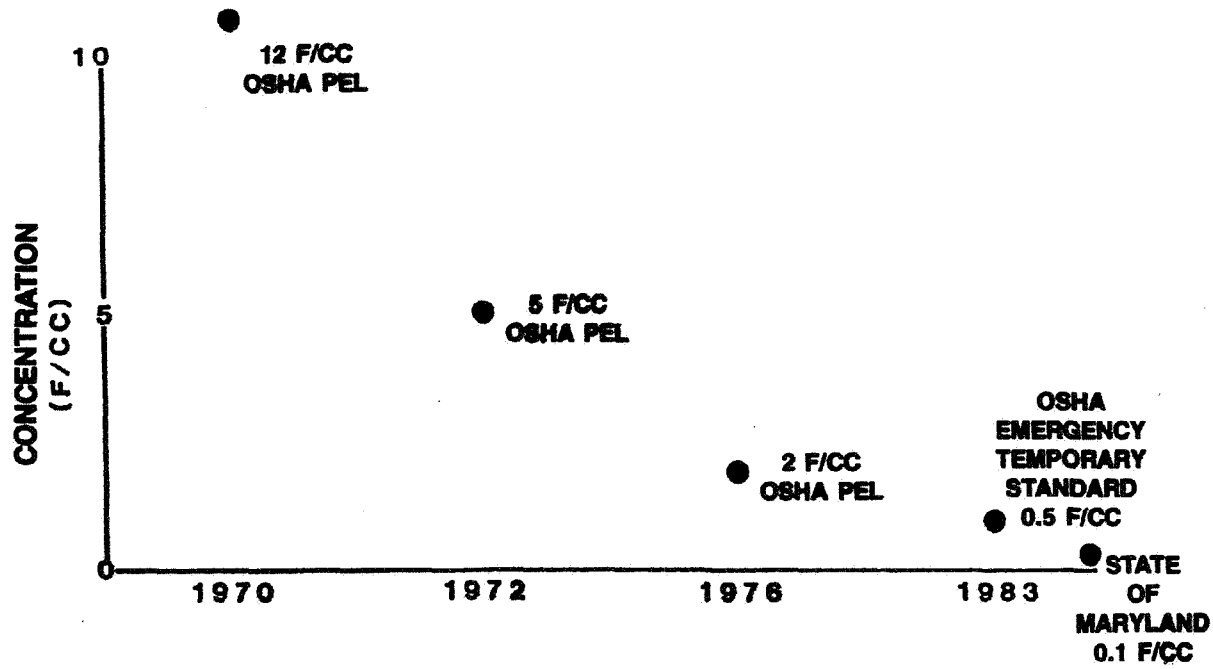


Figure 2

single accepted way to handle them.

One method is to obtain from the analytical laboratory the least amount of the contaminant which the analytical method can detect. This value is then used to determine the least detectable concentration in the amount of air sampled, and then substituted for all zero values. By resolving the proper distributional model, one can then apply the appropriate probability function, and thereby the detection power, to the analytical methods.

Methods and Results

We have accumulated data over the past several years (See Figure 1) for fiber counts on unexposed filters as a routine quality control measure for background fiber surface concentrations. The observed frequency distribution of these fiber concentrations, shown as fibers per square millimeter, was obtained from phase-contrast microscope counts using the NIOSH analytical methods P&CAM 239. Some 100 separate factory lot numbers of 37mm-diameter, cellulose-ester membrane filters have been analyzed with a microscope optical system using a Patterson-Globe graticule that has a calibrated field area of .0062 square millimeters.

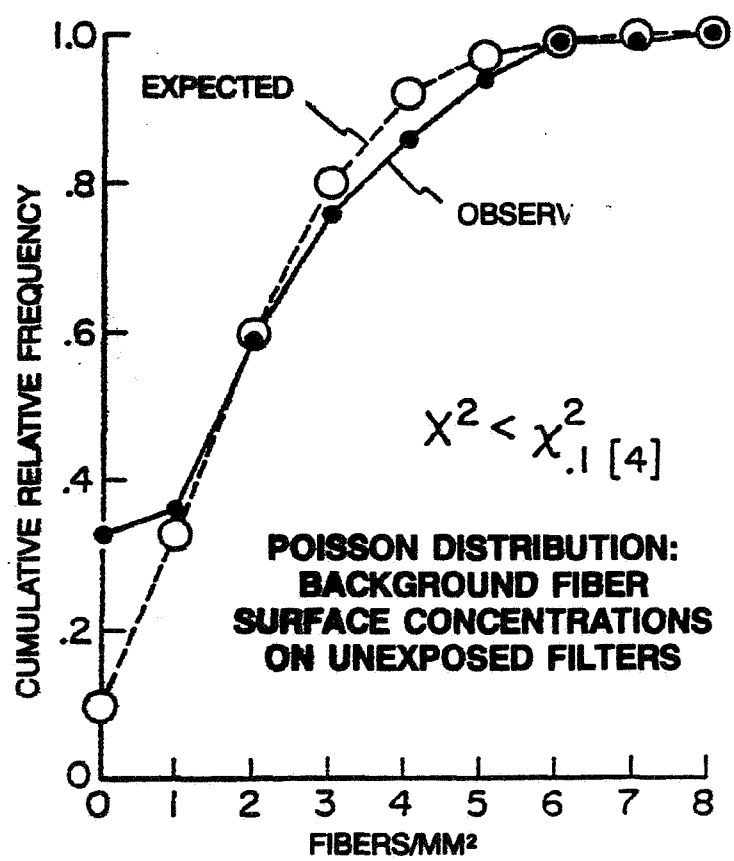


Figure 3

A striking feature of the data is the large frequency of zero concentrations, 33 percent of the total. Additionally, the clumping of 0-2 fibers/mm² results in the observed relative frequency of nearly 60 percent.

These results indicate that background fibers concentrations might be adequately described by the Poisson distribution. The Poisson distributional model also seems appropriate based on the low mean value of 2.3 fibers/mm² with a high coefficient of variation of 87 percent. The purpose of fitting a Poisson distribution to numbers of rare events is to test whether the events occur independently with respect to each other. If they do, they will follow the Poisson distribution.

We have tested this observed distribution as well as the observed frequency distribution of re-occupancy sample fiber concentrations against the expected Poisson frequencies and evaluated the comparison by the Chi-Square test for goodness of fit. The plot of cumulative, relative observed and expected frequencies of fibers concentrations (f/mm²) from unexposed filters shows good agreement throughout the range of measured values (See Figure 3).

The shape of the Poisson expected frequency curve is completely defined by the mean of the observed values. The Chi-Square test value was less than the Chi-Square critical value at 10 percent with four degrees of freedom and by interpolation was actually less than the critical value at 30 percent. This significant agreement, therefore, supports our hypothesis that the observed fiber concentrations of unexposed filters are Poisson distributed.

Having adequately described the Poisson distribution of background fiber concentrations, we have randomly selected 100 re-occupancy samples and plotted the observed frequency distribution for fiber concentrations in fiber/mm² (See Figure 4). Not too surprisingly, as predicted from these presumed clean air environments, there is a relatively high frequency of low, 0-3 fibers/mm², concentrations accounting for more than 20 percent of the distribution with more than 50 percent being less than 8 fibers/mm².

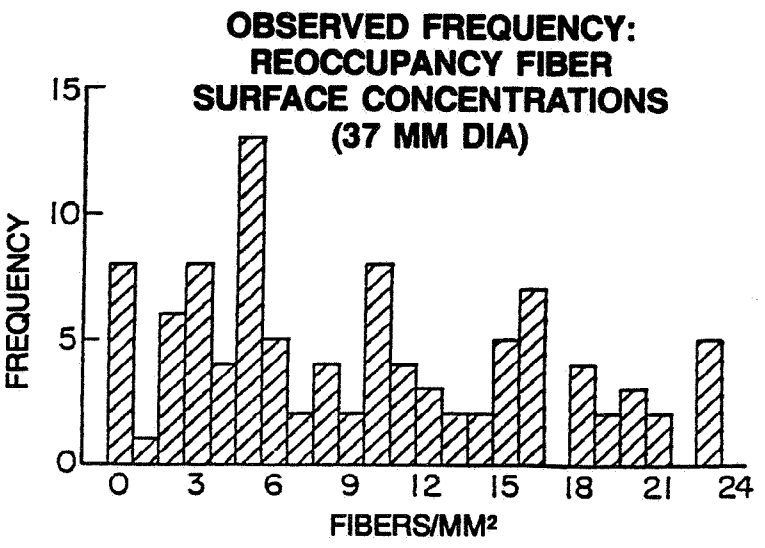


Figure 4

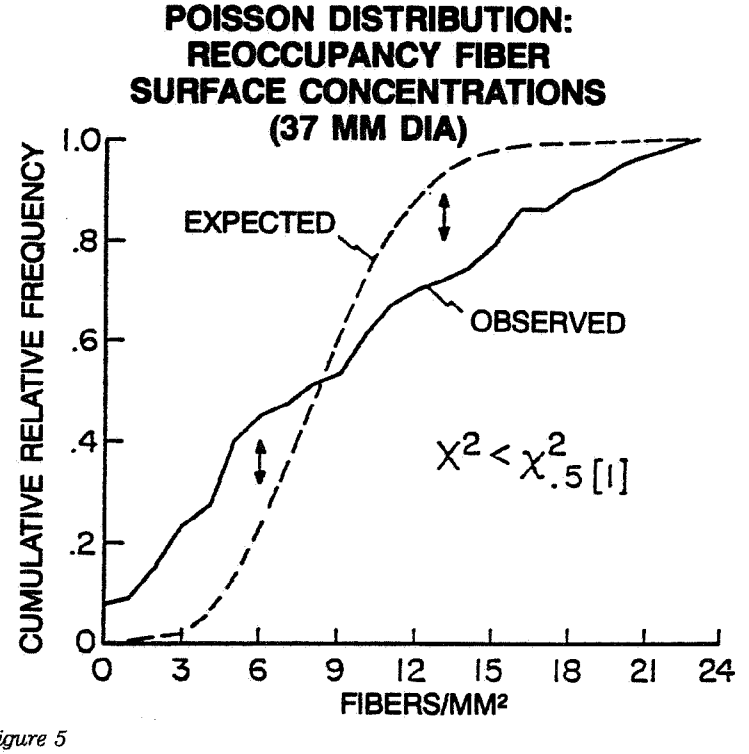


Figure 5

The observed mean for this data set was 8.8 fibers/mm² with a coefficient of variation of 76 percent. These sample concentrations are measured from filtered volumes of 1000-1500 liters and have not been corrected for background fiber concentrations. With such a high coefficient of variation and a relatively low *total* fiber concentration, we felt this observed frequency distribution might also be Poisson distributed.

Again, we have plotted (See Figure 5) the observed and expected cumulative frequencies of the fiber concentrations in fibers/mm². We wished to evaluate the low-level concentration

portion of the curve—comparable to the previously shown background fiber concentration distribution—separately from the higher concentration portion from 9 to 23 fibers/mm². For the purpose of Chi-Square testing for fit of the two curves we therefore chose to have just one degree of freedom.

Under these testing conditions the Chi-Square measured value was less than the critical value at 50 percent. Thus we now have two separate tests of significant agreement with the Poisson distributional model using both unexposed and exposed filter fiber concentrations. These results provide the proper statistical framework from which we can evaluate the limits of qualitative detection (LOD) as well as the limits of quantitative detection (LOQ).

Limits of Detection

We have chosen the 95th percentile of the observed, Poisson distributed, unexposed filter fiber concentration for the limit of

LIMITS OF QUALITATIVE DETECTION (L.O.D.)
UNEXPOSED FILTER CONCENTRATIONS
(FIBERS/SQ. MM)

	A.M.A.	N.I.O.S.H.
MEAN	2.3	2.5
STD. DEV.	2.0	1.5
+3 S.D.	—	7.0[b]
POISSON	6.0[a]	

(a) ESTIMATED L.O.D. METHOD 7400
(b) PROPOSED L.O.D.

Table 1

FUNCTIONAL RELATIONSHIP FOR FIBER COUNT L.O.D.:

L.O.D. = (MICROSCOPE AREA) (FIBERS/SQ. MM) (100 FIELDS)

EXAMPLE:

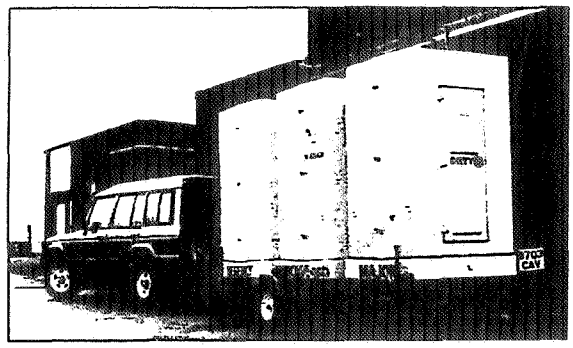
L.O.D. = (.006 SQ. MM) ($\frac{6 \text{ FIBERS}}{\text{SQ. MM}}$) (100)

L.O.D. = 3.6 FIBERS IN 100 FIELDS

Table 2

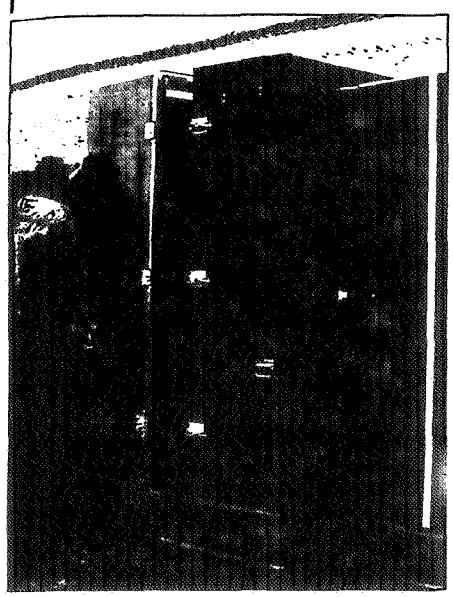
REGENCY ENVIROMASTER

BEST TECHNOLOGY AVAILABLE FOR ASBESTOS ABATEMENT

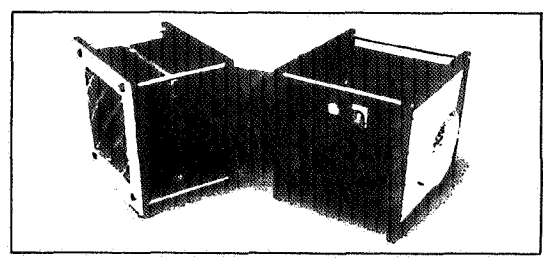


▲ **ENVIROMAJOR** A lightweight, self contained 3 cubicle airlock entry/exit unit with decontamination facilities.

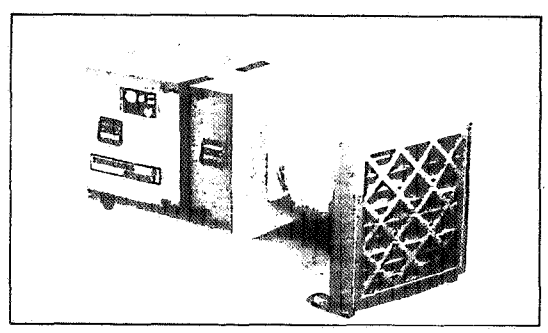
▲ **ENVIROMASTER** A compact unit offering similar facilities to the Enviromajor. Easily dismantled for transportation then assembled on site in 6 minutes.



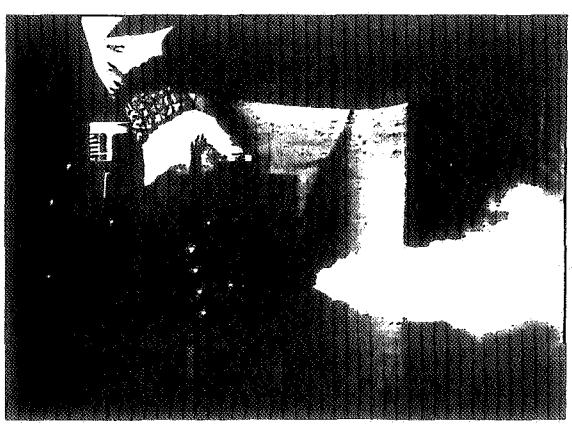
▲ **CUBEMASTER** A latch-on unit for either end of Enviromaster to expand changing area. Locker facilities can be included.



◀ **VENTMASTER AIRMOVER** Compact 2-part fan/filter system which creates negative pressure and captures airborne contamination. Suitable for airflow requirements up to 1000 CFM. Roving prefilter available for maximum versatility.



◀ **TORCHCROSS AIRMOVER** A single unit fan/filter with the same function as Ventmaster but for airflows up to 3000 CFM. Shown with roving prefilter.



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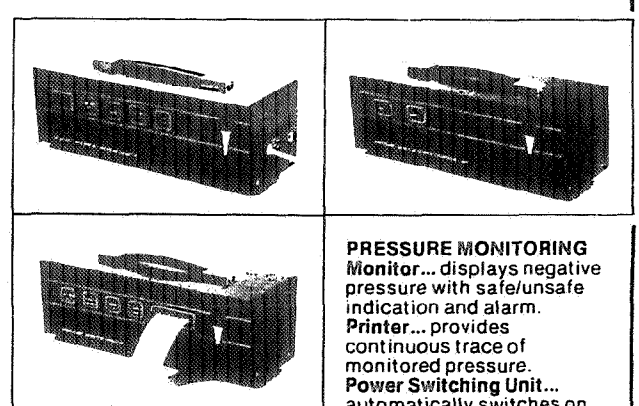

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qualitative detection, LOD. From our data set (See Table 1), in fact, the 95–99 percentile occured at the surface concentration of 6 fibers/mm². Such clumping is a result of the limited classes available from the counting of either whole or half fibers only.

The comparison of our data set with the results obtained by the NIOSH Division of Physical Science and Engineering shows good agreement. There is no significant difference between the means of the two data sets. However, the proposed LOD of 6 fibers/mm² is based on the tested Poisson model. The normally distributed mean plus three standard deviations (or 99th percentile) has been given by NIOSH as the estimated LOD for Method 7400.

The fiber count LOD in fiber/100 fields (See Table 2) is a function of the microscope field area for counting (mm²) and the 95th fractile value for the distribution of background fiber surface concentrations for unexposed filters, or the LOD in fibers/mm².

For example, for our laboratory using a microscope with a count field area of 0.006 mm², the fiber count LOD is four fibers in 100 fields. There are two conclusions which can result from the comparison of the fiber count LOD to a measured fiber count that exceeds the fiber count LOD: With regard to quality control, any filter lot from which representative filters have a measured fiber count greater than four fibers in 100 fields (LOD) should be discarded. Also, four fibers in a 100-field count is the minimum total count that must be obtained from any exposed filter sample before concluding the exposed filter has a significantly greater surface concentration of fibers than an unexposed filter. (This may not always be the case as shown earlier.)

We now have the tools necessary for estimating a sufficient surface fiber concentration to yield a specified power of counting at least the fiber count LOD of fibers in 100 fields, for a given set of measurement conditions (See Table 3). First, we assume a distribution of *many* 100-field fiber counts is adequately described by the Poisson distribution. Next, we can solve for the 95th cumulative probability on counting less than or equal

"DETECTION POWER" (PROBABILITY) FOR LIMIT OF QUANTITATIVE DETECTION (L.O.Q.)

POISSON DISTRIBUTED CUMULATIVE PROBABILITY OF COUNTING L.O.D. AT THE 95 PERCENT DETECTION POWER:

$$\Pr(\leq \text{L.O.D.}) = 1 - \sum_{i=0}^{(n-1)} \frac{n^i e^{-n}}{i!}$$

E.G.

$\Pr(\leq \text{L.O.D.}) = 1 - .05 = \text{L.O.Q.}$

L.O.D. = 4 FIBERS IN 100 FIELDS

L.O.Q. = 7.8 FIBERS IN 100 FIELDS

Table 3

FUNCTIONAL RELATIONSHIP FOR AVERAGE SURFACE FIBER CONCENTRATIONS, S:

$$S = \frac{\text{L.O.Q. (FIBERS AT 95\% POWER)}}{\text{(MICROSCOPE FIELD AREA) (100 FIELDS)}}$$

EXAMPLE:

$$S = \frac{\text{7.8 FIBERS IN 100 FIELDS}}{\text{(.006 SQ. MM) (100)}}$$

$$S = \text{13.0 FIBERS/SQ. MM}$$

Table 4

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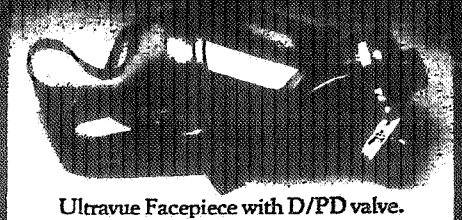

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for a .006 mm² field area. The value of S for Method 7400, where the microscope field area equals 0.00785 mm², was computed to be 12 fibers/mm².

Having computed the values for LOD and LOQ concentrations, look again at the cumulative observed and expected frequency distribution for re-occupancy sample fiber surface concentrations (See Figure 5). The vertical arrows indicate the LOD and LOQ fiber concentrations of 6 and 13 fibers/mm², respectively. As can be seen, we have observed sample concentrations less than or equal to LOD at a frequency of 45 percent and less than or equal to LOQ at at frequency of 72 percent. It appears, therefore, we have chosen the appropriate distributional model and confidence limits under the condition of low-level airborne concentrations.

The relationship for the required air volume Q, in liters, to detect a given concentration level, such as a re-occupancy standard, is computed by the effective collection area of the filter used, times the fiber surface concentration LOQ equals S, divided by a given concentration we wish to detect (See Table 5). In this example, we are using P&CAM 239, i.e., a 37mm-diameter filter and S equals 13 fibers/mm², where we must be able to detect the typical re-occupancy limit of 0.01 fibers/cc. The computed required voume of air, Q, is 1112 liters.

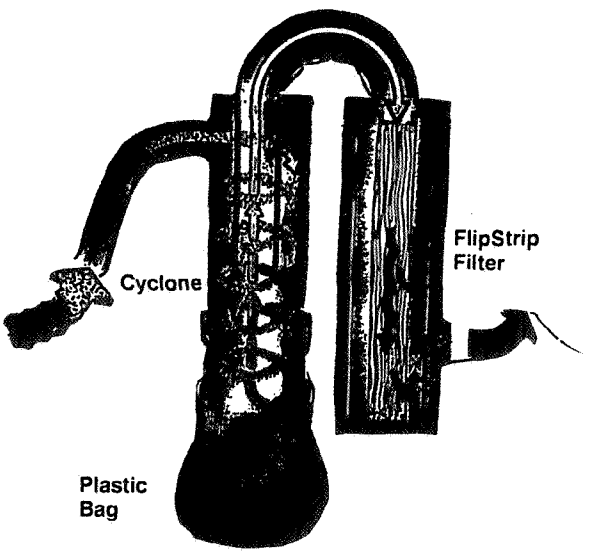
Those familiar with the EPA guidance for the limit of reliable quantification of 0.01 fibers/cc using P&CAM 239 method will recognize that this Q of 1112 liters is somewhat lower than

LIMITS OF QUANTIFIABLE DETECTION (L.O.Q.) FROM K (L.O.Q.)

VOLUME (LITERS)	FIBERS/CC
100	0.111
500	<0.022
1000	<0.011
2000	<0.006
5000	<0.002

Table 6

Asbestos Abatement–
The Solution



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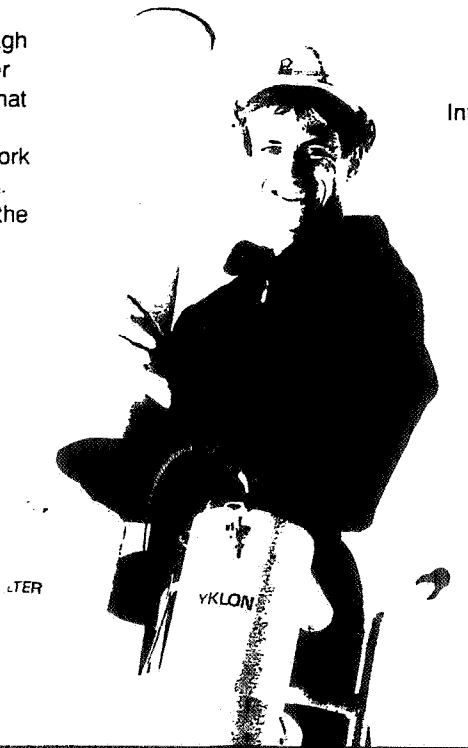

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the 1500 liter specification where 10 fibers must be counted in 100 fields. Our result, however, permits the "detection limit" of 0.01 f/cc to be used when 1112 liters have been sampled and fewer than eight fibers are counted in 100 fields.

Conclusions

We have shown how to compute the required volume Q to detect a given airborne fiber concentration. However, analytical laboratories do not usually control the volume sampled for individual analysis. As such, we have algebraically solved for the detection limit based on the volume of air sampled given as a constant K. This computation uses the same features as the relationship for Q, i.e., the effective filter area times the LOQ, surface fiber concentration as known. However, this method solves for the concentration of airborne fibers/cc as a function of the volume sampled.

Here, we show for our own laboratory, that K equals 11.12 fibers/cc divided by the dimension less value of the volume sampled. Somewhat obviously, if we divided K by the required volume Q to detect the previously shown re-occupancy limit, we solve for 0.01 fibers/cc.

Once analytical laboratories have derived a constant LOQ, they can derive the analytical detection limit based on the volume of air sampled when the fiber count LOQ is not exceeded. The results shown here (See Table 6) for volumes varying from 100 to 5000 liters give corresponding detection limits of 0.12 to 0.002 fibers/cc.

We show here (See Table 7) in the two computations the type of error that results from calculating the airborne asbestos fiber concentration when the LOQ fiber count is not known. This is not a worst-case situation but rather, unfortunately, a condition that arises quite often for samples submitted for re-occupancy.

In the upper calculation there were two fibers in 100 fields measured, a value even lower than the LOD, for a sample volume of 960 liters. This is essentially an 8-hour TWA at 2 liters/min. Were the laboratory to release the result of 0.003 fibers/cc, the area would be improperly cleared for re-entry of the unprotected public when the limit of detection is actually 0.012 fibers/cc. This, again, is a moderate problem when compared to a fiber count of zero whose detection limit is still 0.012 fibers/cc—but without this LOQ relationship the analytical laboratory has no quantitative estimate for the airborne fiber concentration. The value is not truly zero but rather the concentration was undetectable.

MAGNITUDE OF ERRORS ENCOUNTERED WITH LOW FIBER CONCENTRATIONS:

CONDITIONS: 37 MM DIA. FILTER
.006 SQ MM FIELD AREA
960 LITERS
2 FIBERS IN 100 FIELDS

BY CALCULATION:

$$\text{FIBERS/CC} = \frac{(2/100\ \text{FIBERS})\ (855\ \text{SQ. MM})}{(.006\ \text{SQ. MM})\ (960\ \text{LITERS})\ (1000\ \text{CC/L})}$$

$$= .003$$

$$\text{FROM K}_{(\text{L.O.Q.})}$$

$$\text{FIBERS/CC} = \frac{11.12\ \text{FIBERS/CC}}{960}$$

$$= .012$$

Table 7

***(About the Author:** Jeffrey Boggs is an analytical consultant with Aerosol Monitoring & Analysis, Inc., Hunt Valley, Md. Also contributing to this article were M.J. Cirri and B.E. Lippy of the same laboratory, and N.A. Leidel of the federal Center for Disease Control, Atlanta, Ga.*

NO SUPPLIES... NO WORK. IT'S THAT SIMPLE!

When removing asbestos, lack of supplies is more than just an inconvience. It's crucial to the safety of your crew. Being short one Respirator means you have one less worker to do the job!

At AAA Arts, we know what Asbestos Abatement means to you, we understand your priorities and can provide you with a full line of abatement supplies, products you can rely on: Nilfisk, Pullman Holt, Sensidyne, Staplex, Willson, Neoterik Abatement Technologies and more. Our staff knows your work depends on our supplies . . . It's that simple.

In NJ 609-854-2114 — Elsewhere 1-800-852-ARTS

AAA ARTS

Post Office Box 208, Collingswood, NJ 08108

Supplies and Equipment For Asbestos Abatement

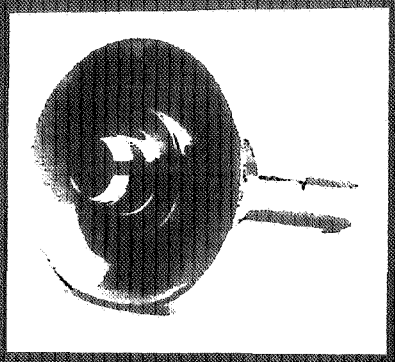
What makes Nilfisk the leader for asbestos removal?

Innovation.

Nilfisk's vacuums and vacuum accessories are always one step ahead of your asbestos removal problems. Introducing the Asbestos Bulk Sampler, a Nilfisk innovation that allows you, for the first time, to take dust-free samples of asbestos safely and easily. Used with our new compact Back Vac, the Bulk Sampler becomes a total sampling system. Because you wear the vacuum on your back, you can conveniently take samples almost anywhere.

Versatility.

Only Nilfisk has a full product line of asbestos-removal vacuums. You get exactly the right solution for your asbestos problems, from collection systems for asbestos dust to removal systems for sprayed-on asbestos insulation. We even have hand-tool systems to control the dust created when pipe covering and lagging are removed.



New Bulk Sampler eliminates contamination dangers! Nilfisk's new Bulk Sampler lets you take asbestos samples quickly and safely without releasing potentially dangerous fibers into the surrounding air.
Nilfisk makes it easy to take samples. The unit is light and portable. And so safe that no protective clothing is required. Used with our new compact Back Vac, the Bulk Sampler gives you a total sampling system. Because you wear the vacuum on your back, you can take samples almost anywhere.

Efficiency.

Nilfisk's HEPA and ULPA filters trap up to 99.9995% of all fibers—even those as small as 0.12 microns—meeting or exceeding OSHA and EPA requirements. And to keep your vacuum working efficiently, only Nilfisk has the exclusive shaker handle that allows you to purge the filter without opening the vacuum.

Reputation.

Nilfisk is known worldwide as the leader in dust collection and asbestos removal. In fact, more asbestos abatement contractors rely on Nilfisk vacuums than any other brand. We build our vacuums ourselves. Make our own motors. Even test them beyond the limit! So you can be assured of years of reliable service. We've been dust collection specialists since 1910. For more information, contact Nilfisk of America, Inc., 300 Technology Drive, Malvern, PA 19355. Or call **1-800-NILFISK.**

NILFISK

Dust Collection Specialists Since 1910.