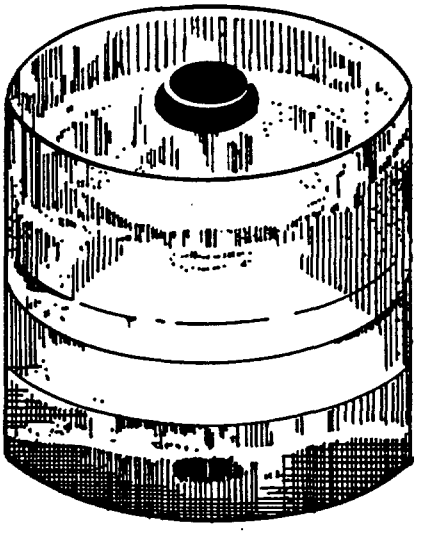
File Asbestos Sampling and Analysis

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-

PLAINTIFF'S EXHIBIT AL-986

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

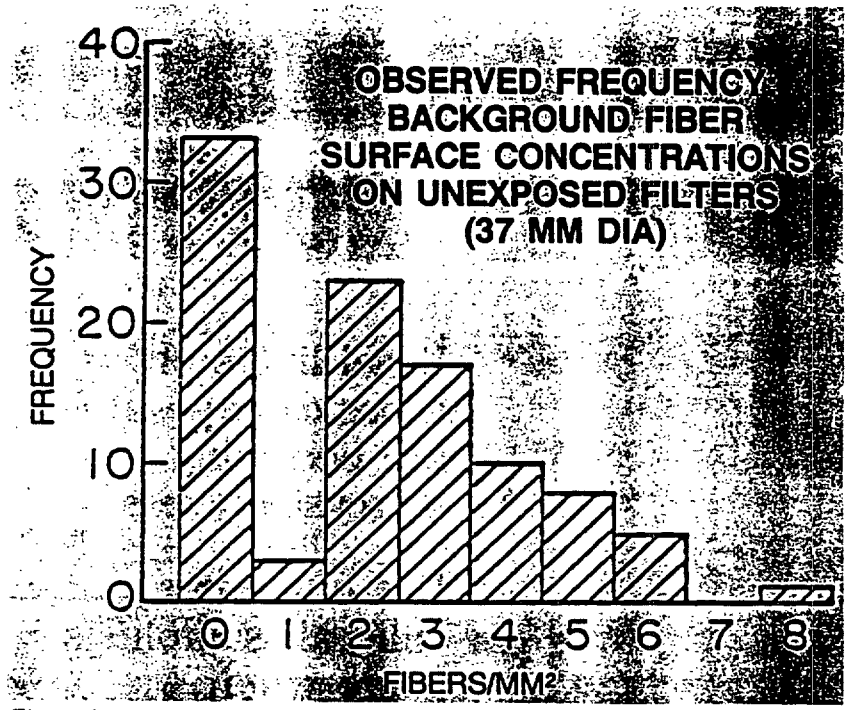


Figure 1

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.

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:

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

$$= .003$$

FROM $K_{(L.O.Q.)}$

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

$$= .012$$

Table 7

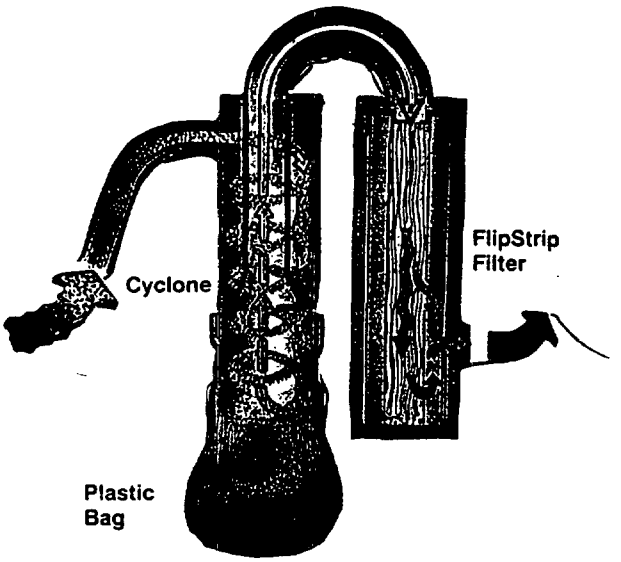
Once analytical laboratories have derived a constant LOQ, they can derive the analytical detection limit based on the volume of air sampled when the fiber count LOQ is not exceeded. The results shown here (See Table 6) for volumes varying from 100 to 5000 liters give corresponding detection limits of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

*(**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.*

Asbestos Abatement–
The Solution



EUROCLEAN has developed a unique, patented system for the safe, efficient removal of asbestos and the safe, efficient clean-up of asbestos removal equipment. The main component of the system is a combination cyclone and cleaning filter. The cyclone separates out the heavier dust particles into a replaceable, removable plastic bag.

The FlipStrip Filter

The FlipStrip filter, a five stage cleaning filter, is an easily removable cartridge that traps the finer dust particles. Air enters through the core of the tubular FlipStrip filter and sets hanging strips in motion that agglomerate the microscopic dust particles into larger particles that work down to the bottom of the cartridge. After four more stages of filtration, the air leaving the filter is virtually clean — the outside of the filter remains clean at all times and the filter can be handled safely. The five stage filtration process of the FlipStrip filter also enhances filter capacity and efficiency.

Intended and designed for heavy industrial use, the EUROCLEAN system easily outperforms statutory requirements and meets maximum permissible hygienic levels.

Since the FlipStrip filter and the cyclone are internal components, they remain completely clean and dust-free on the outside. This means that the FlipStrip filter and the plastic bag can be changed at any time without risk of contamination and without the need to wear protective garments. In addition, the FlipStrip filter outlasts conventional micro-filters by a factor of ten times.

Euroclean

907 West Irving Park Road, Itasca, Illinois 60143
800-323-3553 (In IL 312-773-2111)

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

to LOD (N) fibers in 100 fields, where the true average count (n) is then the LOQ fibers in 100 fields. The 95 percent probability is given by one minus the sum of all event probabilities from 0 to (N-1) events.

Unfortunately, the procedure to solve for the LOQ (n) is a "trial and error" series of computations. A less burdensome evaluation can be made from the statistical tables of relative expected frequencies of the Poisson distribution. By successively summing the expected frequencies given in these tables for several LOQ (n) values by increasing LOQ (n) plus 2, plus 3, etc., one can quickly home in on the N-1 value approximately equal to .05 the 95 percent probability.

In our example, the LOD-N-4 fibers in 100 fields, the LOQ (n) was found to be 7.8 fibers in 100 fibers. Thus there is a 95 percent probability of counting less than or equal to LOD-4 fibers in a *single* 100-field count, where the true average count of LOQ is 7.8 fibers in 100 fields.

Now that we have solved for LOQ fibers in 100 fields at the 95 percent detection power, we can use the relationship shown to compute the average surface fiber concentration, S, that would yield a count of 7.8 fibers in 100 microscope fields (See Table 4). Here, S is in fibers/mm² and the count field area is in mm².

In this example, using the LOQ equals 7.8 fibers in 100 fields and the microscope field area of .006 mm², we solve for S equals 13 fibers/mm². This is now our value for the limit of quantitative detection, LOQ. It is necessary to solve for the LOQ fibers in 100 fields from the LOD fiber count which is a function of the microscope field area.

The importance of using the LOD fiber count for an individual microscope field area is inherent to the logarithmic nature of the cumulative expected frequencies of the Poisson distribution. For example, we have computed the LOD fiber count based on 6 fibers/mm², the 95 percent detection power, LOQ, and S for commonly used microscope field areas. In the case for P&CAM 239 method using a Porton Reticle with a 0.003 mm² field area, S was computed to be 16 fibers/mm² not twice the value of S

RELATIONSHIP FOR REQUIRED AIR VOLUME, Q:

$$Q = \frac{\text{(FILTER AREA) (S)}}{\text{(DETECTABLE AIRBORNE ASBESTOS CONCENTRATION)}}$$

EXAMPLE:

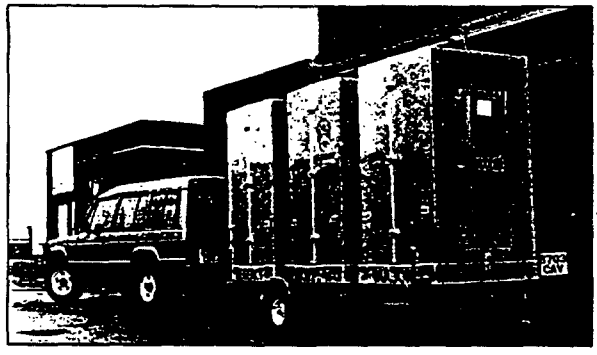
$$Q = \frac{\text{(855 SQ MM) (13 FIBERS/SQ MM) (.001 L/CC)}}{\text{.010 FIBERS/CC}}$$

$$Q = \text{1112 LITERS}$$

Table 5

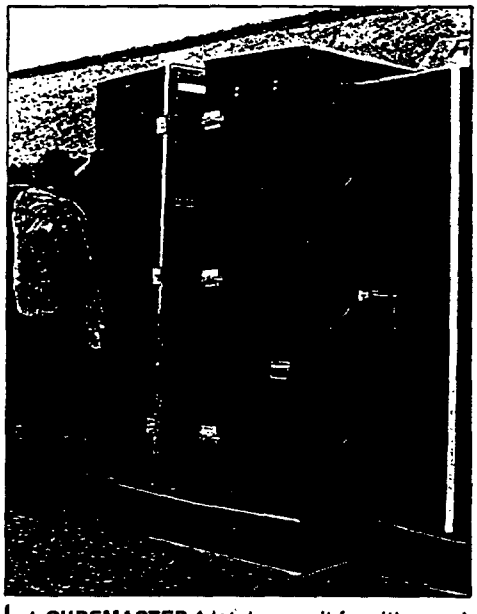
REGENCY ENVIROMASTER

BEST TECHNOLOGY AVAILABLE FOR ASBESTOS ABATEMENT

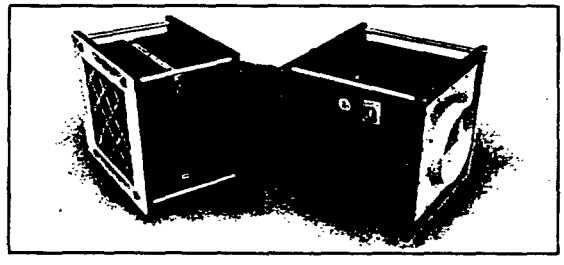


▲ **ENVIROMAJOR** A lightweight, self contained 3 cubicle airlock entry/exit unit with decontamination facilities.

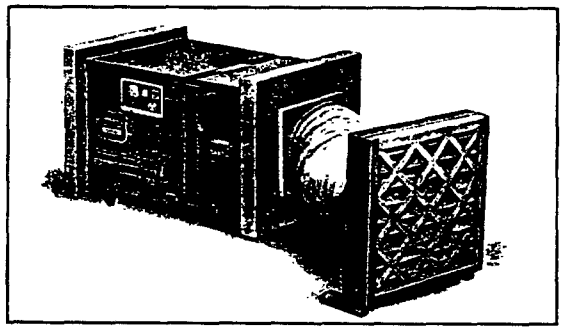
▲ **ENVIROMASTER** A compact unit offering similar facilities to the Enviromajor. Easily dismantled for transportation then assembled on site in 6 minutes.



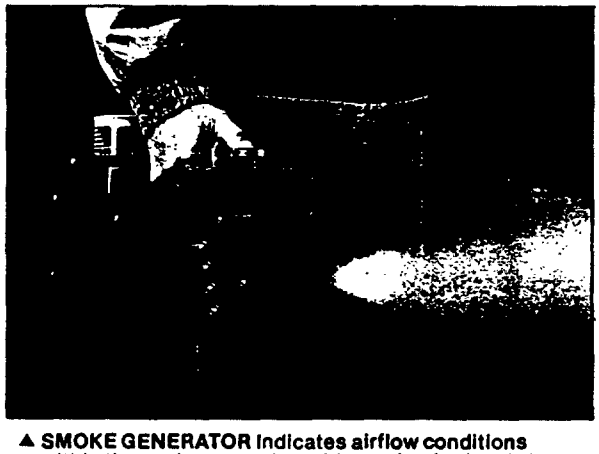
▲ **CUBEMASTER** A latch-on unit for either end of Enviromaster to expand changing area. Locker facilities can be included.



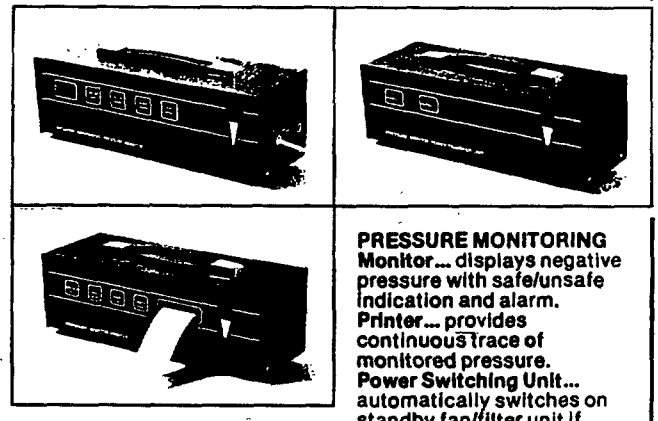
◀ **VENTMASTER AIRMOVER** Compact 2-part fan/filter system which creates negative pressure and captures airborne contamination. Suitable for airflow requirements up to 1000 CFM. Roving prefilter available for maximum versatility.



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



▲ **SMOKE GENERATOR** Indicates airflow conditions within the work area and provides a simple visual check to prove effective tent sealing.



PRESSURE MONITORING
Monitor... displays negative pressure with safe/unsafe indication and alarm.
Printer... provides continuous trace of monitored pressure.
Power Switching Unit... automatically switches on standby fan/filter unit if pressure becomes unsafe.

REGENCY ENVIROMASTER INC.
P.O. Box 3541, West Chester, Pennsylvania 19382.
Telephone: (215) 344 0637. Toll Free 1-800 USA ENVI

REGENCY ENVIROMASTER

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.)

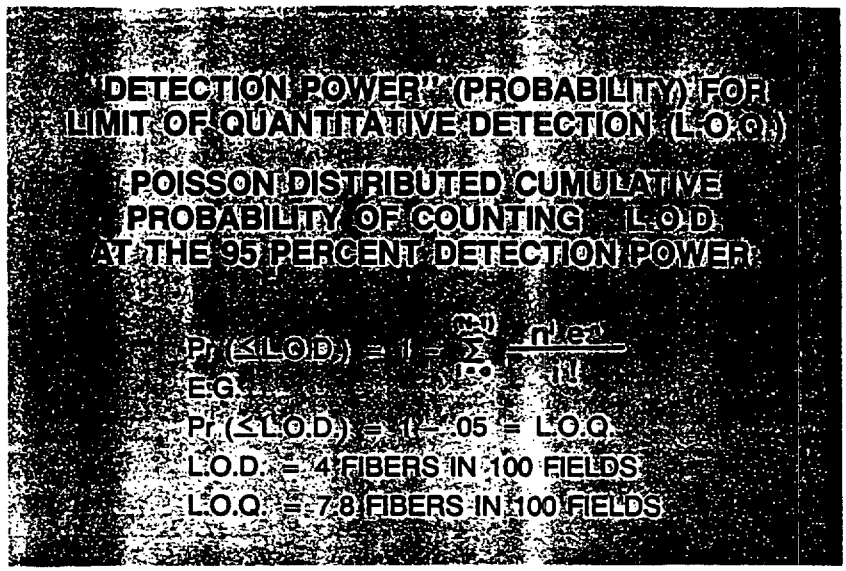


Table 3

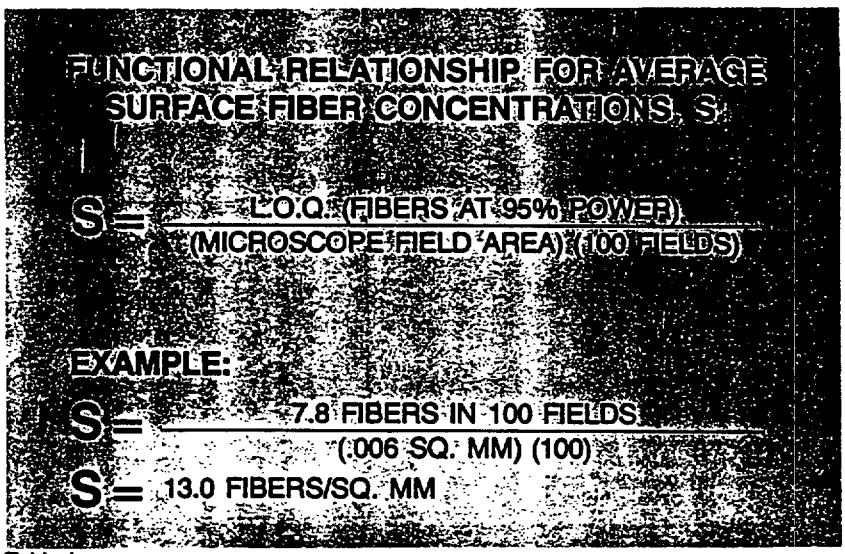


Table 4

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

BEST BY TE

...HEPA-AIRE® 2000

ASBESTOS FILTRATION MACHINE

D.O.P. LEAKAGE
(penetration at 0.5 μ D.O.P.)

☑ **HEPA-AIRE 2000 –**
tested over 30 times better than the competition*

CFM OUTPUT

☑ **HEPA-AIRE 2000 –**
tested over 20% better than the competition*

*** Results of H2000A compared to average results of 5 competitive brands.**

HEPA-AIRE 2000... BLOWS THE DOORS OFF THE COMPETITION

We knew our engineers had developed an outstanding product, and now the experts agree. In recent tests conducted by professional independent testing services the new HEPA-AIRE 2000 Model H2000A was the hands down winner when evaluated against five leading competitive brands. In fact, it wasn't even close. HEPA-AIRE 2000 blew the doors off the competition! For example, HEPA-AIRE 2000 tested up to 60 times better against D.O.P. smoke penetration.

So, why buy the rest when you can have the best? Call or write today for more information about the HEPA-AIRE 2000 or for the name of your local Abatement Technologies distributor.

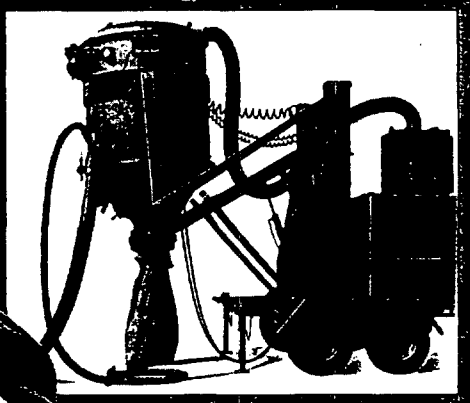
HEPA-AIRE 2000 – the state-of-the-art in asbestos air filtration products. Now available in 3 models . . .

- **H2000A – 2 speed full feature electric**
- **H2000C – 2 speed contractors electric**
- **H2000P – variable speed air driven model**

ADVANCED PRODUCTS FOR THE ASBESTOS REMOVAL INDUSTRY

KICK ASBESTOS

...you outwork the competition, ...outbid the competition!



When you go into bidding with a 60% reduction in labor and material costs, you've got one big competitive edge! And an opportunity for greater profits.

The HEPA VAC automated vacuum system reduces bag handling from 5 or more workers to 2. Cuts bag use by 75%. Why? Because wet or dry asbestos is moved, not by muscle, but by a vacuum hose up to 1000 ft. long at the rate of 9-18 tons/hr.

Certified HEPA air filtration assures system will meet or exceed OSHA and EPA safety regs. From pick up to bagging, fibers are captured in a fully enclosed, negative pressure system.

The HEPA VAC never leaves the site, working continuously until the job is done. And John Deere diesel engine, quality construction and proven design means the job gets done faster and more safely than the old-fashioned manual way. A faster job. A safer job. A better job. A less expensive job. Bring on the competition!

Vacuum Engineering Corporation

3374 West Hopkins Street
Milwaukee, Wisconsin 53216
414/444-4010

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*
POISSON	6.0*	

(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

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.

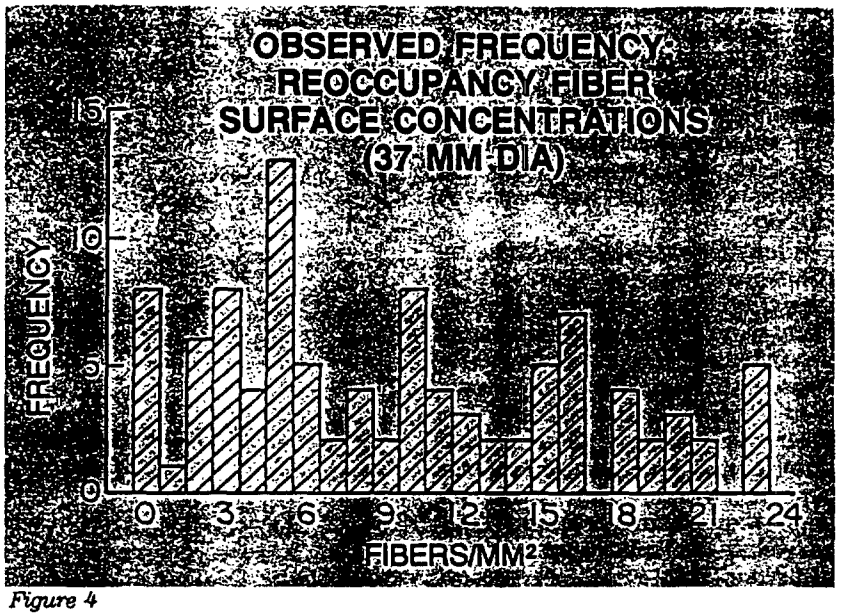


Figure 4

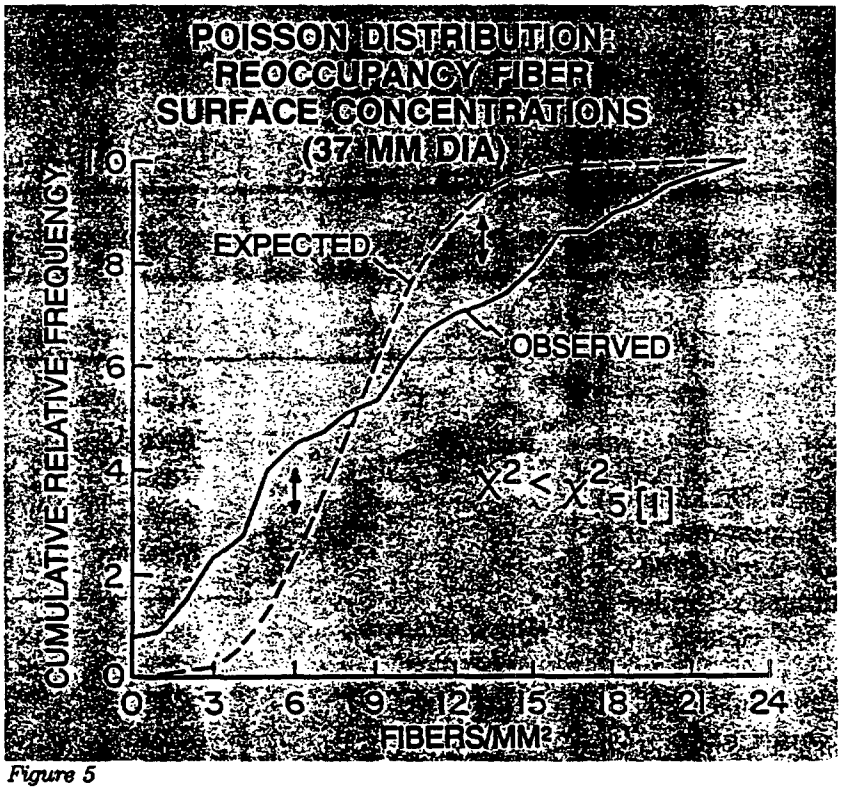


Figure 5

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

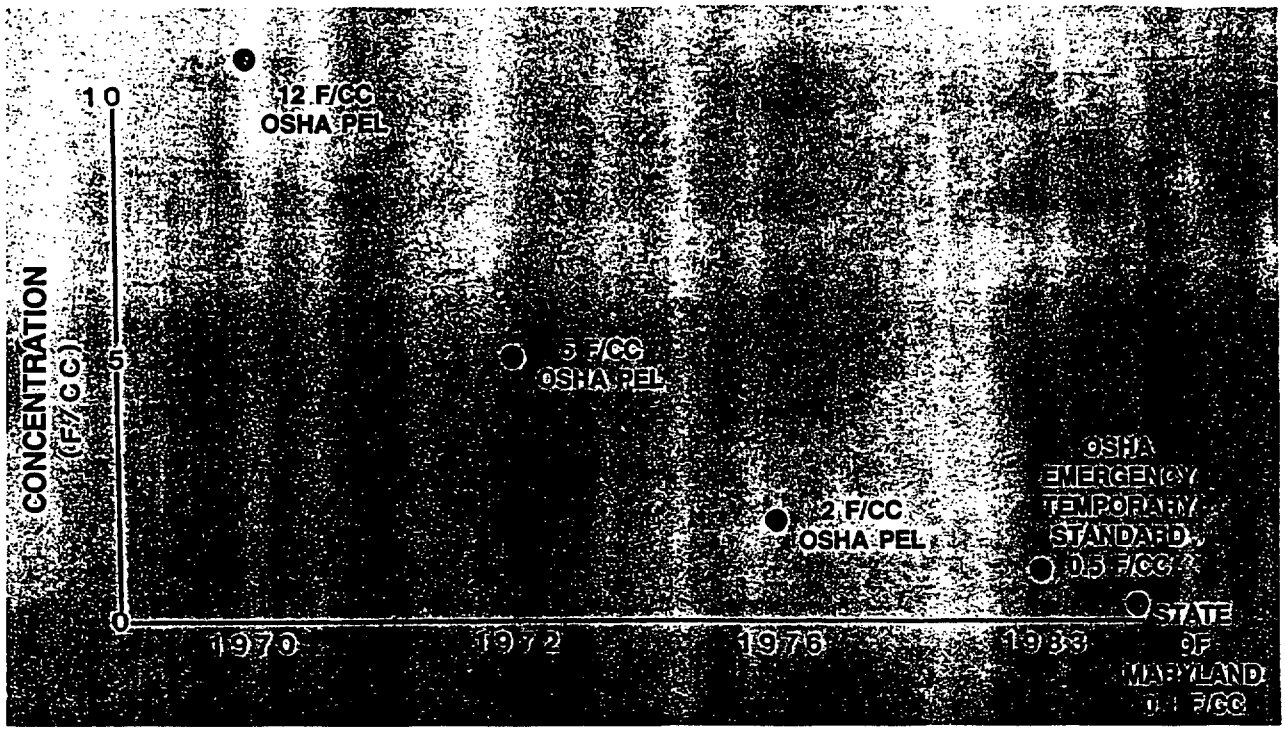


Figure 2

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 is 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.

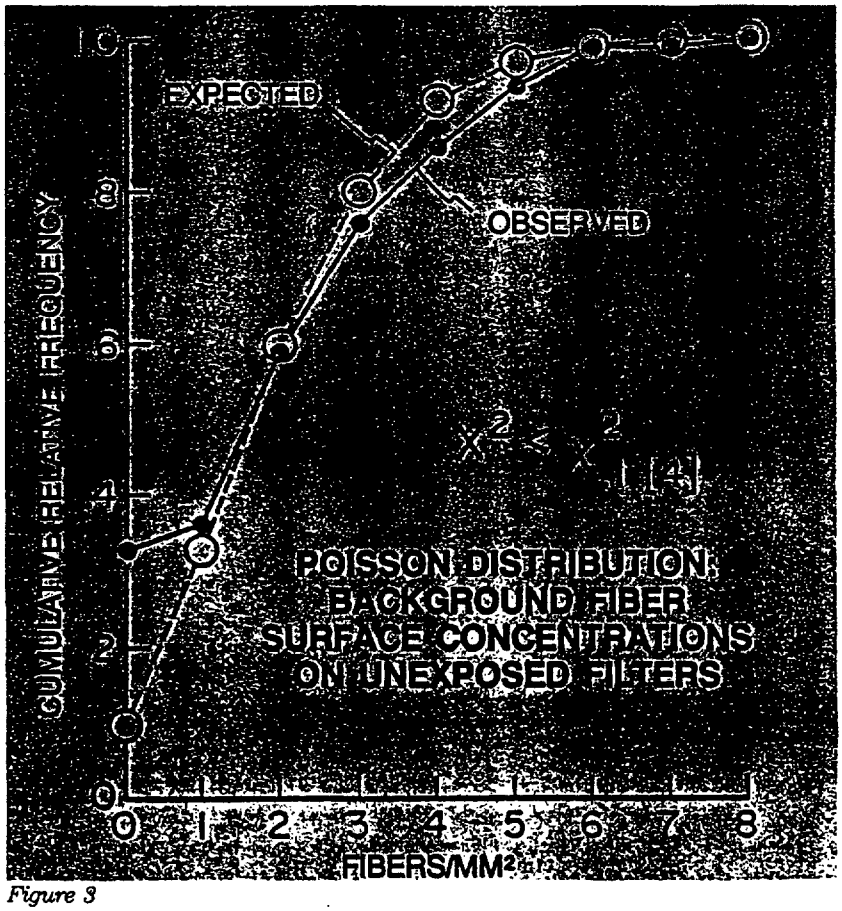


Figure 3

ABATEMENT TECHNOLOGIES

3305 Breckinridge Blvd. • Suite 118 • Duluth, GA 30136 • 404-925-2761 • FAX 1-404-381-7454

AIR FILTRATION • WATER FILTRATION • GLOVE BAGS • ADHESIVES • SURFACTANTS • SIGNS • LABELS

BREATHING ROOM

With the new Duo-Flo™ and Duo-Twin™ Pressure Demand Respirators from MSA, you can enter, exit and move station to station in asbestos work areas without an air-line.*

When you remove asbestos for a living, you know what a hassle it can be to have an air-line hose trail you around. It's there wherever you go, in whatever you do. Well not anymore.

MSA's new Duo-Flo and Duo-Twin Pressure Demand Respirators,* featuring Ultravue* or Duo-Twin Facepieces with unique D/PD "switchable" exhalation valve, allow you to easily disconnect from your air-line and still breathe freely. It's like having more breathing room to work with, without more air-line to worry about.

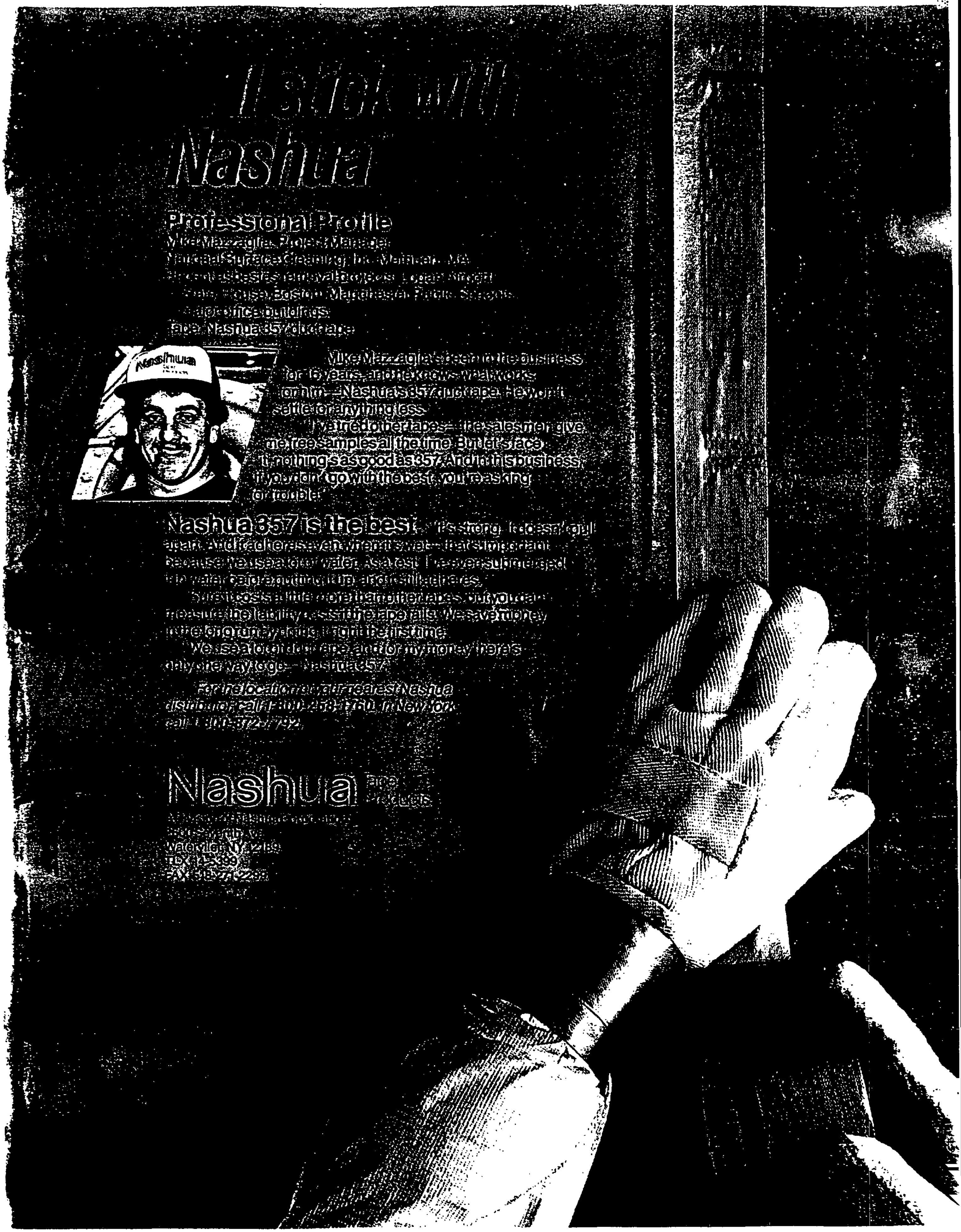
The Duo-Flo and Duo-Twin Pressure Demand Respirators meet EPA guidelines, are fully approved by NIOSH, and are completely retrofittable from MSA's current straight Pressure Demand and Duo-Flo Pressure Demand Respirators.

For more information on the new Duo-Flo and Duo-Twin Pressure Demand Respirators, or any of MSA's full line of asbestos abatement products, call 1-800-MSA-2222. Or write MSA, P.O. Box 426, Pittsburgh, PA 15230.

Ultravue Facepiece with D/PD valve.

MSA

*This device is NIOSH approved for entry, egress and moving station to station in the air-purifying "HEPA Filter" mode of operation.



I stick with Nashua
Professional Profile
Mike Mazzaglia, Project Manager
Tape: Nashua 357 duct tape
Mike Mazzaglia's been in the business for 15 years, and he knows what works for him — Nashua's 357 duct tape. He won't settle for anything less.
"I've tried other tapes — the salesmen give me free samples all the time. But let's face it, nothing's as good as 357. And in this business, if you don't go with the best, you're asking for trouble."
Nashua 357 is the best. "It's strong. It doesn't pull apart. And it adheres even when it's wet — that's important because we use a lot of water.
Sure it costs a little more than other tapes, but you can't measure the liability costs if the tape fails. We save money in the long run by doing it right the first time.
We use a lot of duct tape, and for my money there's only one way to go — Nashua 357."
For the location of your nearest Nashua distributor call 1-800-258-1760. In New York call 1-800-872-7792.
Nashua Tape Products
Watervliet, NY 12189
TLX 14-5399