INDUSTRY Feature

You Can't Handle the Truth... About Final Clearance Air Sampling

By Angelo Garcia III and Thomas Laubenthal

The Environmental Information Association (EIA) held its annual conference last March in Phoenix, Arizona. There were several sessions regarding asbestos where attendees discussed the federal requirements regarding asbestos clearance air sampling. Based on those discussions the authors thought it was time to write an article on this topic to clarify many issues. This article is based on federal requirements. There are state/local programs that can have varying requirements in locations such as New York State and New York City (NYC) and others. We will look at the NYC issues later in this document.

For asbestos abatement (most often removal) the final clearance air sampling requirements for schools (K-12, public and private) are defined by the Environmental Protection Agency's (EPA) rules, Asbestos-Containing Materials in Schools (40 CFR Part 763, Subpart E, known in industry by the statute acronym as AHERA)[1]. The requirements are found in two sections of the rule

- Response Actions; §763.90 (i)
- Appendix A (to Subpart E) "Interim TEM Analytical Methods…to Determine Completion of Response Actions", *II. Mandatory Transmission Electron Microscopy Method*

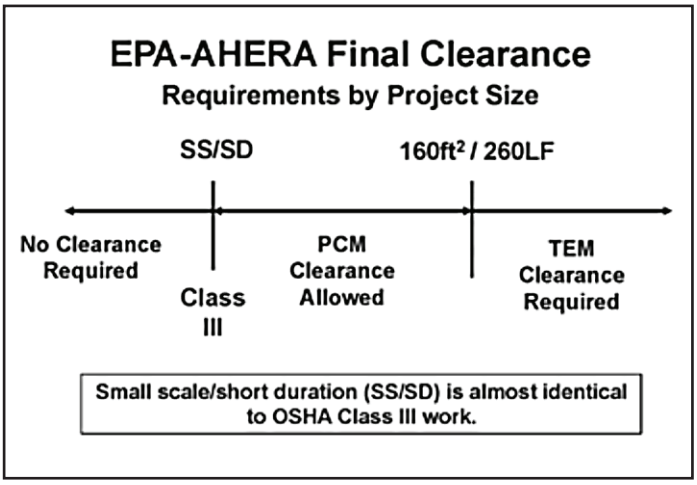
For all intents and purposes, these methods serve as the industry standard when final clearance is performed for most asbestos abatement projects, especially when areas are to be re-occupied. We'll discuss applicability issues as we go.

The AHERA regulation discusses the requirement for aggressive clearance sampling. Aggressive sampling means floors, ceilings, and walls shall be swept with the exhaust of a minimum one (1) horsepower leaf blower. Some states and specifications may also require the use of fans as described in the non-mandatory section of Appendix A.

As defined by AHERA rules, final clearance air sampling can be performed by phase contrast microscopy (PCM) methodology for projects less than or equal to 160 square feet (ft^2) or 260 linear feet (LF) by the National Institute for Occupational Safety and Health (NIOSH) method 7400, Asbestos and Other Fibers by PCM (Issue 3: 14 June 2019)[2]. For projects greater than 160 ft^2 or 260 LF clearance shall be done by the AHERA transmission electron microscopy (TEM) methods.

There are some similarities between the AHERA TEM and NIOSH 7400 methods. For example, the AHERA TEM method allows the use of either a 25-millimeter (mm) filter cassette or a 37mm filter cassette. The last time 37-mm cassettes were used was the old asbestos sampling method P&CAM 239. 37-mm cassettes

TEM Analysis (MVA Analytical)



have not been used by industry since the NIOSH 7400 method was formally published and then adopted into AHERA. For sampling, whether it is the AHERA TEM method or the NIOSH 7400 method, we use a 25-mm 3-piece cassette with 50-mm electrically conductive extension cowl cassettes. The two methods require the filter cassette to face downward (AHERA, 45 degrees downward) from the horizontal. The filter material used is mixed cellulose ester (MCE).

The AHERA TEM method does allow for the use of polycarbonate (PC) filters as well. The PC filters fell out of favor because post-sampling handling is more problematic than the MCE filters. With PC filters, if samples sent to the lab are not handled carefully, the sampled fibers can move significantly from the filter surface. This was widely described in the industry in the 1980s. Since then, only MCE filters are used outside of specialty applications.

Filter cassette to face 45 degrees downward from the horizontal.

Both methods require blanks, however, that is where the similarities end. The AHERA TEM method requires three blanks: two field blanks and one laboratory (sealed) blank. The NIOSH 7400 method requires a minimum of two blanks or 10 percent of samples collected with a maximum of 10 blanks. How the blanks are handled is different as well. The AHERA TEM method laboratory (sealed) blank is not opened and kept sealed, while the field blanks are opened for 30 seconds at the entrance to the abatement area(s) and one at an ambient area. They are then closed. While the NIOSH 7400 method requires the blanks to be opened at the same time as the other cassettes (used for sampling) just prior to sampling and stored with the top covers of the cassettes that are running and remain open for the duration of sampling. These are kept in a bag or box. Many use the cassette box with the lid closed, some put field blanks zip-type bags while sampling.

Another difference is that with the AHERA TEM method we are required to use a 0.45µm MCE filter, and the NIOSH 7400 method uses a 0.8µm MCE filter. This refers to the size of the air passages in the filter material. Filter manufacturers will color code or mark the label so that the type of filter within the cassette assembly is known to the user and the laboratory.

A typical box of air sampling cassettes.
TEM filter is 0.45µm. PCM filter (white label) is 0.8µm

AHERA TEM Method Air Sampling Issues

Let's get to some of the interesting items. The AHERA TEM method is straightforward, it requires five samples taken inside the work area and 5 samples outside the work area that represent air entering the abatement site plus the three blanks (described above) for a total of 13 samples. These samples should be set for a flow rate from 1 to less than 10 liters per minute (LPM) for a total volume of air, typically, from 1200 liters (L) to 1800 L (see "Table 1" below). It would be interesting to find out how many in industry sample at less than 10 LPM (i.e., 9.9 liters per minute) versus at 10 LPM. Likely most of the industry merely samples at 10 LPM. The statistical difference between 10 LPM and the 9.9 some regulators insist upon is statistically insignificant and will affect method performance in no discernable manner. Either way, this means clearance samples will take a minimum of two hours to collect.

At the time, this method was developed it became known through research involving flow rates higher than 10 LPM could cause fibers to impact the MCE filters vertically and not horizontal to the filter surface. This makes the sample analysis, counting and identification difficult and likely biased. This is also the reason the method specifies a second MCE filter under the 0.45µm sampling filter, the 5µm diffuser (see Figure 1 below). This additional filter is placed in this manner to attempt to create an even flow across the filter surface so that the fibers impact the filter uniformly.

For the AHERA TEM method, the clearance test passes when the average concentration of the five samples from inside the work area does not exceed 70 structures per square millimeter squared (s/mm^2). See AHERA at §763.90(i)(3) for an optional clearance test based on the Z-test which compares the outside and inside air samples and the obtained blanks. This is rarely necessary. But

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TABLE 1: NUMBER OF 200 MESH EM GRID OPENINGS (0.0057MM²) THAT NEED TO BE ANALYZED TO MAINTAIN SENSITIVITY OF 0.005 STRUCTURES/CC BASED ON VOLUME AND EFFECTIVE FILTER AREA

Effective Filter Area 385 sq mm		Effective Filter Area 855 sq mm	
Volume (liters)	# of grid openings	Volume (liters)	# of grid openings
560	*24*	*1,250*	*24*
600	23	1,300	23
700	19	1,400	21
800	17	1,600	19
900	15	1,800	17
1,000	14	2,000	15
1,100	12	2,200	14
1,200	11	2,400	13
1,300	10	2,600	12
1,400	10	2,800	11
1,500	9	3,000	10
1,600	8	3,200	9
1,700	8	3,400	9
1,800	8	3,600	8
1,900	7	3,800	8
2,000	7	4,000	8
2,100	6	4,200	7
2,200	6	4,400	7
2,300	6	4,600	7
2,400	6	4,800	6
2,500	5	5,000	6
2,600	5	5,200	6
2,700	5	5,400	6
2,800	5	5,600	5
2,900	5	5,800	5
3,000	5	6,000	5
3,100	4	6,200	5
3,200	4	5,400	5
3,300	4	6,600	5
3,400	4	6,800	4
3,500	4	7,000	4
3,600	4	7,200	4
3,700	4	7,400	4
3,800	4	7,600	4

Recommended Volume Range

Recommended Volume Range

cases have occurred when contamination can exist in the air outside the work area that could cause a failure in the work area.

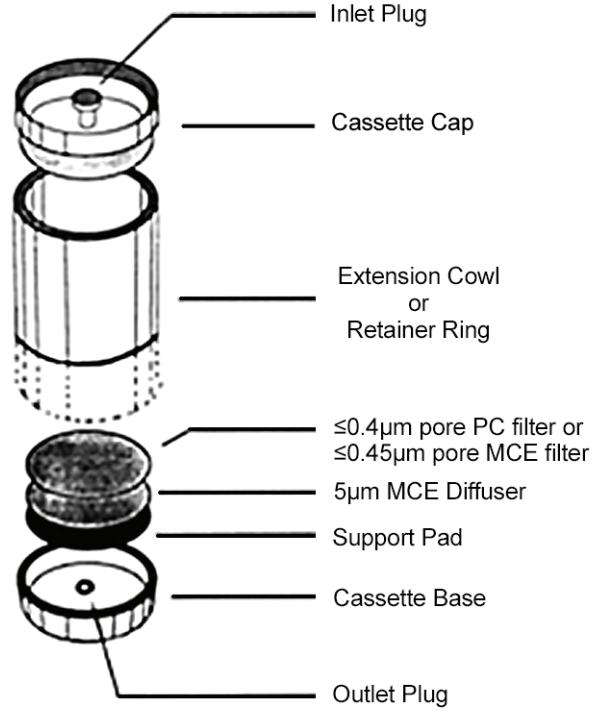
NIOSH 7400 Method Sampling Issues

The NIOSH 7400 method for final clearance has differences than what is prescribed for TEM. For schools, when PCM is allowed, it's five samples inside the work area. Clearance is based on each sample being less than or equal to a limit of quantitation (LOQ) for PCM of 0.01 fibers per cubic centimeter (f/cc). This concept of LOQ is not a concept understood by many that use the NIOSH 7400 method. In the NIOSH 7400 method, this issue is addressed as follows in section, "Sampling," number 4 on page 4. It utilizes the formula below to determine the amount of time needed to achieve the fiber density, E, for optimum filter loading. So, the minimum density the method allows is 100 fibers per square millimeter (the LOQ). The Ac is the collection area for a 25-mm cassette which is 385 square millimeters (mm^2). The Q is the sampling flow rate in LPM. We'll use 16 LPM which is the maximum flowrate allowed by the NIOSH 7400 method. The L is the concentration of fibers in the air. We are looking to achieve clearance at 0.01 f/cc. So, if you plug these numbers into the formula below you will get a time of 240.6 minutes, which means the sample would have to run for a little over 4 hours at 16 liters per minute. This would yield a total sampling volume of 3,850 L.

$$t = \frac{A_c * E}{Q * L * 10^3}$$

As another example, if your pump or calibrated rotometer can only achieve 15 LPM, then you would have to increase the sampling time to 256.7 minutes which is just short of 4 hours and 15 minutes at 16 LPM. The lower the flow rate, the longer time it will take to meet sample volume requirements.

Figure 1: Sampling Cassette Configuration



Airbox High-Performance Air Sampler

APPENDIX E: EQUIVALENT LIMITS OF DETECTION AND QUANTITATION

Fiber density on filter* (Fibers per 100 fields)	Fiber density on filter* (Fibers /mm²)	Fiber concentration in air, f/cc (400-L air sample)	Fiber concentration in air, f/cc (1000-L air sample)
200	255	0.25	0.10
100	127	0.125	0.05
LOQ 80	102	0.10	0.04
50	64	0.0625	0.025
25	32	0.03	0.0125
20	25	0.025	0.010
10	12.7	0.0125	0.005
8	10.2	0.010	0.004
LOD 5.5	7	0.00675	0.0027

*Assumes 385 mm² effective filter collection area, and field area = 0.00785 mm², for relatively "clean" (little particulate aside from fibers) filters

NIOSH 7400
Method Volume Issues

Many believe or have been misled to believe that NIOSH 7400 method sampling is the same as AHERA TEM method sampling in terms of sampling volume. This is not the case. A NIOSH 7400 method sample volume meeting AHERA TEM method clearance requirements is not at 1200 L. To do so is outside of the NIOSH 7400 method requirements for this purpose.

We need to make clear some of the limitations of PCM and the NIOSH 7400 method. The NIOSH 7400 method is a personal air sampling method designed for exposure assessments of workers to determine compliance with established OSHA permissible exposure limits. It was never written for nor intended for use in sampling in low fiber level environments such as sampling in hallways outside of work areas during removal activities or for final clearance air sampling. When AHERA was being written and PCM was to be allowed, Dr. Paul Baron (NIOSH) made a few changes to the method to allow for PCM clearance[5]. This included allowing flow rates up to 16 LPM and the NIOSH 7400 method "page 4" reference used above about the 3,000-10,000 liters sampling to achieve quantifiable loadings. Let's make it clear, the limit of detection (LOD) does not equal the limit of quantitation (LOQ). There are many places to find formal definitions of these terms, but simply; detection (LOD) is when a method can detect an analyte above a background value, quantitation (LOQ) is the point at which sampling is sufficient to provide reproducible results, or statistical significance. In the NIOSH 7400 method we are given a LOD of 7 f/mm² (5.5 fibers in 100 fields) and a range of 100-1300 f/mm². 100 f/mm² is our LOQ (78.5 fiber in 100 fields) and this number is essentially rounded to 80 by NIOSH.

This graphic (Appendix E, above) was added to demonstrate LOD and LOQ. The sample volumes you see on this chart are for personal air sampling, not outside of work areas or final clearance air sampling. The method was never evaluated for the low fiber counts we encounter in these environments.

Further, we do not sample by NIOSH 7400 method for clearance air sampling to meet minimum air volumes such as the LOD or other values found within the method. It seems that some find on the first page of the method, such as:

Sampling: VOL-MIN*: 400 L @ 0.1 fiber/cc

Applicability: The quantitative working range is 0.04 to 0.5 fiber/cc for a 1000-L air sample.

The volumes seen here apply to personal air sampling, not NIOSH 7400 method clearance air sampling.

The statistical basis for the NIOSH 7400 method is from years of air sampling in industrial environments where asbestos products were being produced. This means very high asbestos fiber counts and high fiber loading on filter surfaces. Not the raft of "other fibers" we see today that are not asbestos such as cellulose, fibrous glass and many others. The reader should consult the reference section (starting on page 16) of the NIOSH 7400 method for papers on this history.

Any sampling method is about reproducibility. What this means is the ability to reproduce data if one were to recount a slide one had previously counted or that of a trained coworker. Are the results statistically similar? That is the goal of quality control (QC) analysis. There are statistical limits within methods that are acceptable or those one should attempt to achieve with ongoing statistical analysis of PCM counts.

On the first page of the method in the section "Accuracy" the reader will find "RANGE STUDIED: 80 to 100 fibers counted." This is effectively where the method has statistical relevance and known reproducibility. What do we see with our air sampling outside of work areas and clearance very commonly? Far less than this range. In most cases many are fortunate to find more than a dozen fibers with relatively clean clearance samples. This fiber loading is significantly outside of the expectations of the method.

Further on method accuracy from the last section, "Calculations and Reporting of Results," page 10, #24:

Report intra- and interlaboratory relative standard deviations with each set of results. NOTE: Precision depends on the total number of fibers counted [1,24]. Relative standard deviation is documented in references [1,24-25] for fiber counts up to 100 fibers in 100 graticule fields. **Comparability of interlaboratory results is discussed below. As a first ap-**

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proximation, use 213 percent above and 49 percent below the count as the upper and lower confidence limits for fiber counts greater than 20 (see Figure 1, below).

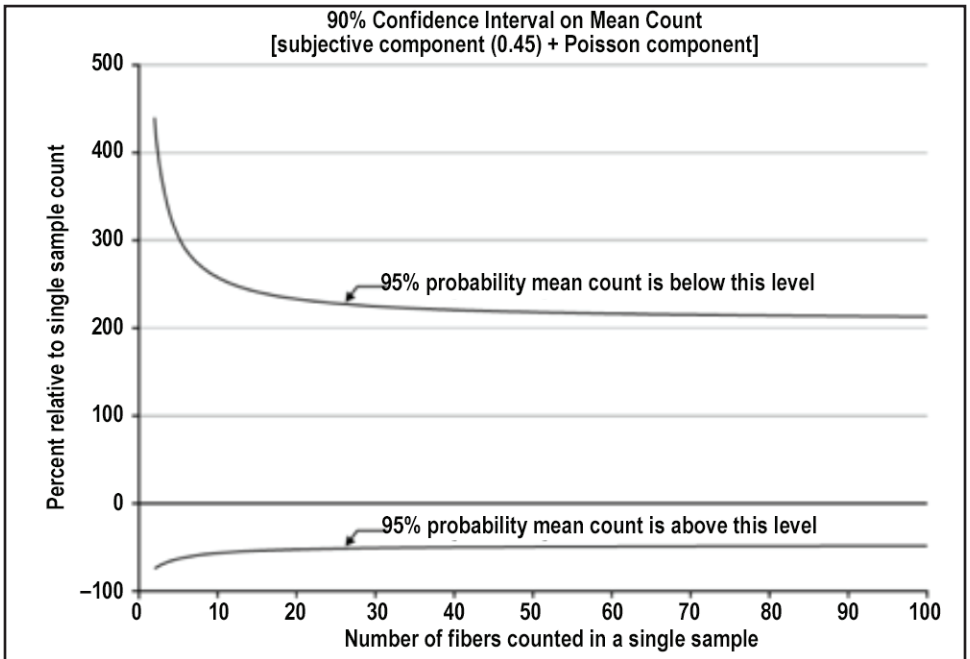


Figure 1. Interlaboratory precision of fiber counts

So, to start with, how many readers here report intra-and interlaboratory relative standard deviations (or as CV, coefficient of variation) with each set of results? Likely fewer than most would know. This is a method requirement.

Then, as few likely generate this data we are supposed to use **"213 percent above and 49 percent below the count as the upper and lower confidence limits for fiber counts greater than 20"** as a starting point for statistical reporting. So, if you reported a NIOSH 7400 method clearance sample as 8 fibers counted in 100 fields and a result of 0.009 f/cc, then what does that really mean statistically? The variability is out of control, and we have not even counted enough fibers to claim we're anywhere near method accuracy.

AHERA TEM Method Advantage Over NIOSH 7400 Method

So why all of this? NIOSH 7400 method clearance is statistically indefensible in most cases. We don't count enough fibers most of the time and most have no control of their data from method-required statistical analysis. Historically, PCM-based methods are all that we had for asbestos air sampling. The methods were written for fiber rich environments, not the low fiber counts we encounter in most cases with NIOSH 7400 clearance air sampling. The AHERA TEM procedures and clearance level is the only method designed for final clearance air sampling after asbestos abatement.

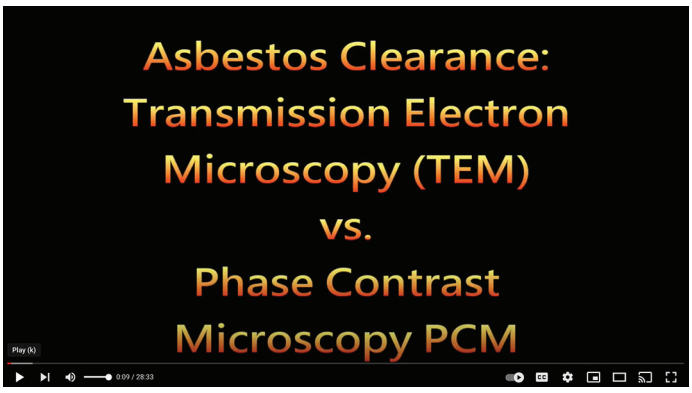
The NIOSH 7400 method clearance value for PCM of 0.01 f/cc is the same as reporting 10,000 f/M^3. That's not any better than reporting an order of magnitude below the 8-hour TWA OSHA PEL of 0.1 f/cc. That's a lot of potential asbestos still in the air. The clearance value for the AHERA TEM method of 70 s/mm^2 is effectively being about the theoretical background count in mixed cellulose ester (MCE) filters at the time the method was written. That result in net effect is closer to a zero-exposure standard.

The other problem with the NIOSH 7400 method is that all fibers meeting method criteria are counted, not just asbestos fibers. Under the AHERA TEM method asbestos fibers/structures are only counted in the analysis meeting method criteria for size, and those much smaller than can be determined by the NIOSH 7400 method. Therefore, the AHERA TEM method should be used for all final clearance air sampling prior to re-occupancy with the realization that the NIOSH 7400 method may be necessary for small jobs with tight timeframes.

This is Not a New Discussion

In March 2015, EIA published a revision to the EPA's 1985 document Guidance for Controlling Asbestos-Containing Materials in Buildings (EPA 560/5-85-024, known as the Purple Book). This nationally peer-reviewed document was re-titled "Managing Asbestos in Buildings: A Guide for Owners and Managers."[4] In Chapter 5 (on page 88), the AHERA method is enumerated including the use of 3000 L to meet NIOSH 7400 requirements for LOQ sampling.

Mr. Dana Brown did a video regarding the LOQ issue and why NIOSH 7400 method is not the best choice for clearance, you can see it at https://youtu.be/jNw9MNTc1IE.



This article's co-author Angelo Garcia III previously posted a blog on his page calling for AHERA TEM method to be utilized for asbestos-containing floor tiles and mastic removals based on that

blog post the "**Asbestos Floor Tile Debate**", was published in the August 2017 issue of **Healthy Indoors Magazine,** which found that the NIOSH 7400 method is not able to detect the type of fibers (these fibers are typically less than 5 µm) found in these materials because of the known small fiber sizes generated by floor tile removal work.

Whether AHERA-based work or asbestos abatement where re-occupancy will occur, the surest way to make sure an area is ready to be given back to the public to be free of asbestos as practicable by current sampling methods, the most reliable method for clearance would only be the AHERA TEM method.

NYC Problems

This issue becomes even murkier with a long-established NYC regulation, "Title 15," Subchapter D[6], "Air and Bulk Sampling, Monitoring and Analysis," at § 1-42 Monitoring Requirements:

Area Samples for Analysis by	Minimum Volume	Flow Rate
PCM 25 mm	560	5 to 15 litres/min.
TEM 25 mm	560	1 to 10 litres/min.
TEM 27 mm	1,250	1 to 10 liters/min.

We find this a baffling list of sample volumes for the 25 mm cassettes. 560 liters has absolutely no relevance to the NIOSH 7400 method. That value is the minimum air volume for an AHERA TEM method air sample, not a NIOSH 7400 sample.

Further, at 560 liters the TEM laboratory must analyze 24 grid openings by regulation. The recommended range from the regulation is 1200-1800 L. That is what we should be using, it's an industry standard and it is how laboratories have priced their analysis. To count 24 grid openings, they are going to have to bump up the price significantly for that analysis. As for 560 L for a PCM air sample, while it might be allowed, it is flawed, it is less stringent than federal AHERA requirements and would not stand scrutiny if deposed in a civil or federal regulatory case. The fiber loading requirements for sampling as defined by the NIOSH 7400 method would never be met with this volume in any case in the experience of the authors.

Then from Title 15, § 1-43 Post-Abatement Clearance Air Monitoring.

Area Samples for Analysis by	Minimum Volume	Flow Rate
PCM	1,800 Liters	5 to 15 litres/min.
TEM	1,250 Litres	1 to 10 liters/min.

This volume of air for PCM air sampling does not meet the NIOSH 7400 method requirements as described above. Not less than 3000 L should be obtained for this purpose. We must wonder who made these decisions for sampling volumes and based on what scholarship? NYC is not the only entity with flawed air sampling requirements in their regulations. There are others that also have requirements outside of established federal methodologies. Our hope that the reader of this paper might better understand that just because something is allowed does not mean it is within the scope of established methods and would protect your liability and that of your clients.

*This Industry Feature was co-authored by asbestos experts **Angelo Garcia III**, principal and industrial hygienist at Future Environment Designs Inc. in Syosset, New York, and **Thomas Laubenthal**, owner of TGL Consulting Inc. in Fort Lauderdale, Florida. Dana Brown of Time's Dark Captains in Hurst, Texas, was a contributing author. You can reach Angelo by email at angelo3@futureenv.com or his website at https://www.futureenv.com. Tom can be reached by email at tglconsulting@att.net or his Linkedin at https://www.linkedin.com/in/tom-laubenthal-772857/.*

Footnotes:

1. https://www.govinfo.gov/content/pkg/CFR-2011-title40-vol31/pdf/CFR-2011-title40-vol31-part763-subpartE.pdf
2. https://www.cdc.gov/niosh/nmam/pdf/7400.pdf
3. https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1101AppA
4. https://eia-usa.org/Purple_Book
5. Laubenthal, personal communications with Dr. Paul Baron (NIOSH), Mr. Michael Beard (EPA) in that era (both have passed away) and more recently with Dr. Martin Harper (NIOSH, retired).
6. https://www1.nyc.gov/assets/dep/downloads/pdf/air/asbestos/asbestos-rules-regulations-title-15.pdf