THERMAL SYSTEM INSULATION (TSI) ASBESTOS-RELATED EXPOSURE

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Thermal system insulation is comprised of a variety of different products. These include pipe and block insulation, insulation muds, mastics, and cloth.

Pipe and block insulation, containing significant amounts of asbestos, have been used commercially since well before World War II. Pipe and block insulation vary in thickness and shape. Pipe insulation is usually preformed into “half rounds” that fit the diameter of the pipe being insulated. They are most commonly fastened to the pipe using wire. Their intended use requires the cutting, fitting and sealing during installation; disturbance during repair and maintenance; demolition; cleanup; and disposal of waste ACM. All these activities result in the release of asbestos fibers.

Insulators work in ships, power stations, factories and buildings, where they are required to lag boilers and pipes. A material commonly used for this application is a plaster consisting of 85 percent magnesia bonded with 15 percent amosite asbestos. The lagger fastens slabs of preformed sections around the boiler or pipe with wire, then applies a coat of wet plaster by hand, and finishes off with a coat of waterproof cement. On board ships, where temperatures are higher, the pipe sections are finished off with a covering of asbestos cloth made from chrysotile asbestos (Leathart & Sanderson, 1963).

In 1937, Standard Oil Company’s Chief Safety Inspector, Roy Bonsib, studied asbestos exposures to workers during insulation operations. While insulating a 12-inch steam line, he measured airborne concentrations as high as 23.8 million particles per cubic feet (mppcf) with an average of 12.6 mppcf. Samples taken while insulating a cracking coil accumulator resulted in an average dust concentration of 4.5 mppcf. While insulating an acid suction line, the samples resulted in an average of 0.8 mppcf. While insulating hot oil lines, the results were an average of 3.4 mppcf. While removing old insulation, the samples resulted in airborne concentrations as high as 5.9 mppcf with an average of 2.3 mppcf. While crushing scrap asbestos, by hand, and while shoveling broken-up pieces into a hopper, the airborne concentrations were 10.2 and 14.8 mppcf, respectively (Bonsib, 1937).

Fleisher et al. (1946) studied insulators in shipyards cutting insulation blocks, mixing cement (mud), and installing insulation materials. They reported exposure levels as high as 250 million particles per cubic foot (mppcf) (Fleisher, Viles, Gade, & Drinker, 1946).

Marr (1964) also studied asbestos exposures in shipyards. Aboard ships, insulators perform a great variety of installations in most compartments, especially in fire rooms and engine rooms. Marr (1964) reported dust concentrations as high as 8.0 mppcf for shipboard insulation jobs (Marr, 1964).

Balzer and Cooper (1968) collected 153 air samples during activities performed by insulators. The results were categorized by job classification, which included prefabrication, application, finishing, tearing out, mixing, and general. Sample times were from 30 minutes to three hours and the filters were replaced several times during the sampling period to avoid overloading problems. For the "application" task, the breathing zone concentrations ranged from 0.1 to 61.6 f/cc [n=45]. For the "finishing" task, the fiber concentrations ranged from 0.1 to 24.4 [n=31]. For the "tearing out" task, they reported breathing zone concentrations ranging from 0.2 to 26.3 f/cc. For the "mixing" task, they reported breathing zone concentrations ranging from 0.2 to 10.7 f/cc [n=22]. The samples reported as "general", which included cleaning up of old insulation and transporting of materials, resulted in an average concentration of 4.8 f/cc and a range of 0.1 to 22.9 f/cc [n=16] (Balzer & Cooper, 1968).

Harries (1971) studied exposure levels in Naval Dockyards including buildings and ships. Among other activities, he reported breathing zone concentrations ranging from 25 to 220 f/cc [n=20] during removal of pipe and machinery insulation in boiler rooms while the mean airborne concentration in the general atmosphere measured in boiler rooms was 171 f/cc [0.04-1062 f/cc, n=153]. The breathing zone concentrations during the application of pipe insulating materials in boiler rooms ranged from 0.1 to 68 f/cc while the mean airborne concentration in the general atmosphere measured in boiler rooms was 22.4 f/cc [1-61 f/cc, n=17]. During the removal of sprayed asbestos insulation, long running samples showed the dust concentration at the top of a ladder running up from the stripping area to the deck above to be 109 f/cc. At the top of the next ladder two decks above the stripping area, the concentration was 30 f/cc (Harries, 1971).

Fred Venables, Industrial Hygienist at Exxon Baton Rouge, reported the results of air samples for asbestos that he collected at a turnaround on October 8-9, 1974 (Venable, 1974) . Three personal breathing zone samples collected during the removal by one of Exxon's insulators of the material covering an 8-inch hot line on overhead pipebands resulted in PCM fiber concentrations of 15, 58, and 78 f/cc. The insulator was wearing a half-mask air-purifying respirator. Personal breathing zone samples collected during the removal of asbestos insulation from the exterior of the reactor vessel by a contractor's insulator were 203 and 255 f/cc. Venables observed that it was difficult, if not impossible, to suppress the dust by prior wetting methods by water hoses since pipe insulation, in particular, is covered with waterproof paper, which must be removed before water can reach the insulation material. This problem is further complicated due to working at a high elevation. Venables noted that large quantities of insulations removed and the wire mesh support of the asbestos cement contributed to the dustiness of the contractor's job. Venables further noted that Exxon was in violation of regulations concerning providing protective clothing, laundering contaminated clothing, etc. that are required to protect employees and family members from asbestos exposure.

Fontaine and Trayer (1975) measured exposures levels to workers in a steam power plant during a routine maintenance outage. Eight-hour time-weighted average (TWA) exposures ranged from non-detectable levels to 5.9 f/cc for asbestos workers (insulators). For laborers, the TWA airborne concentrations ranged from non-detectable levels to 3.7 f/cc. Peak concentrations were as high as 24.6 f/cc for insulators and 21.5 f/cc for laborers (Fontaine & Trayer, 1975).

The U.S. Maritime Administration commissioned a study to measure the exposure levels to the ships' personnel performing routine maintenance and repair operations. The study was conducted by IIT Research Institute covering the period from February 1, 1978 through November 1, 1978. Bystander/area air samples during pipe lagging repair (i.e., removal and replacement) resulted in airborne fiber concentrations up to 0.87 f/cc. Bystander/area air samples during pipe repair operations (i.e., lagging removal and dismantling of pipe systems) resulted in concentrations up to 1.14 f/cc. Clean-up after piping or lagging repair with a broom ranged resulted in concentrations up to 3.4 f/cc. Bystander/area air samples during clean-up after lagging repairs resulted in concentrations up 3.3 f/cc (Jones, 1981).

Insulation "mud" is a term applied to the cementitious materials typically applied to block, pipe, and cloth as a wet "mud" to fill in cracks and holes as well as provide a hard exterior for the insulation. It is made by grinding up scrap block or pipe insulation or purchasing it as a separate product. The dry "mud", with a consistency somewhat like Portland cement or flour, was traditionally poured into a bucket, on the floor, or in some other container and then mixed with water to the proper consistency. Mud is used at butt joints on pipe insulation to fill voids, for making pipe elbows and tees, and as a coating over the asbestos cloth or canvas exterior. It was typically troweled on or hand-applied to the surface. Spillage was common which required sweeping or scraping to remove the residue.

Leathart and Sanderson (1963) measured airborne dust concentrations of asbestos during mixing of water with powdered magnesia/asbestos plaster. The mixing process lasted approximately five to 15 minutes and was repeated every two to four hours. They used a thermal precipitator to collect the air samples and analyzed the samples for only fibrous particles between five and 50 microns in length. The results were approximately 255 particles per cubic centimeter. In addition, they found measurable fiber concentrations 20 yards from the mixing box about 60 minutes after the mixing had ceased (Leathart & Sanderson, 1963).

Harries et al. (1971) measured asbestos concentrations generated during the removal of mud (pouring out) from its container and the mixing of it with water. They reported breathing zone concentrations ranging from 48 to 470 f/cc (pouring out) and 24 to 579 f/cc (mixing). General area concentrations measured during these activities ranged from 48 to 328 (pouring) and 53 to 377 f/cc (mixing) (Harries, 1971).

In the early to mid-1970s, after the OSHA standard to control exposure to asbestos dust was promulgated, pre-mixed mud already containing water, was manufactured which while it reduced the dust created during mixing, it did not reduce the dust during cleanup or removal.

Longo et al. (2007) performed a work practice study involving applying insulation to an Ideal Arco Number 4 Series Boiler and during the subsequent removal of the insulation on the same boiler. Personal and area air samples were collected during the application of the first coat, second coat, and final coat of 7M asbestos mixed with water. Personal and area air sampling were subsequently collected during the removal of the previously applied asbestos insulation from a round series cast iron boiler. Air sampling was also conducted during clean-up activities following the application of the insulation as well as the removal of the insulation. The personal and area air sampling results are summarized as follows:

Application of Insulation (All Coats)

- Personal (n = 16): 0.38 to 7.2 f/cc [mean = 2.4 f/cc]
- Area (n = 16): 0.41 to 5.1 f/cc [median = 1.9 f/cc]

Boiler Insulation Removal

- Personal (n = 8): 1.3 to 4.3 f/cc [mean = 2.7 f/cc]
- Area (n = 8): 0.46 to 3.2 f/cc [median = 1.7 f/cc]

Cleanup Activities Following Both Application and Removal

- Personal (n = 8): 2.3 to 4.5 f/cc [mean = 3.2 f/cc]
- Area (n = 8): 0.47 to 3.5 f/cc [mean = 1.4 f/cc]

(Longo, Hatfield, Mount, & Ewing, 2007)

Mastics, sometimes called glue, are usually comprised of a tarry substance. The major fiber releases occur whenever the dry mastic is disturbed by sanding, cutting, or beating on as well as during clean-up of spills and debris.

Foster Fibrous Adhesive, such as Foster 81-27 and 81-93, is a sodium silicate-based adhesive for lagging asbestos cloth on high temperature insulation. It was also used to adhere dense thermal insulation, such as calcium silicate, 85% magnesia, amosite, asbestos block, and asbestos felt to itself and to non-porous surfaces (Amchem Products, Inc., 1975).

Millette (2003) conducted a series of workplace reconstruction experiments to determine if asbestos fibers were released when Fibrous Adhesive 81-27 was disturbed and to measure the exposure concentrations generated. He spread the Fibrous Adhesive 81-27 containing approximately 30% asbestos (by volume) on a piece of aluminum sheet, onto a denim cloth, and on a piece of wood with cheese cloth embedded in the initial layer. Air sampling was conducted while sanding and scraping the fibrous adhesive from the aluminum sheet, scraping/brushing the adhesive from the denim while wet, and chiseling/hammering the fibrous adhesive from the wood substrate. The results were as follows:

- Sanding/scraping dried fibrous adhesive (aluminum substrate): 0.17-0.27 f/cc (by PCM) and 1.2-4.1 s/cc (by TEM)
- Scraping/brushing fibrous adhesive (wet denim substrate): 0.32 f/cc (by PCM) and 0.16 s/cc (by TEM)
- Chiseling/hammering (wood substrate): 10.8 f/cc to overloaded (by PCM) and 111.4 s/cc to overloaded (by TEM)

(Millette, 2003)

Paustenbach et al. (2004) conducted a simulation study of four asbestos-containing products – a coating, two mastics, and an adhesive. The products were reported to be representative of various classes of products that have been used historically, were tested to determine the airborne concentration of asbestos fibers released during five different activities – application, spill cleanup, sanding, removal, and sweep cleaning. Each activity was performed for 30 minutes. Personal [n=172] and area [n=280] air samples were collected during the tests, and each was analyzed for total fiber concentrations using PCM and for asbestos fiber count using TEM. The authors reported that the calculated TWAs using hypothetical work scenarios ranged from 0.03 to 0.009 fibers/cc (Paustenbach, Sage, Bono, & Mowat, 2004).

Typical uses of asbestos cloth include welding (fire) blankets, pipe (TSI) covering, pipe wrap, clothing, and tapes among others. TSI requires an outer covering to protect the insulation materials. Often, this material was an asbestos cloth similar to canvas. Cloth was wrapped around insulated pipe or was the final “skin” over large surface areas and would typically be covered with mud and then painted.

Hatfield and Longo (2001) measured asbestos fiber concentrations during the cutting and handling of asbestos cloth. The work activity consisted of cutting four pieces of asbestos cloth from a roll of the material. The roll of cloth was approximately eight feet long. The cloth was handled while cutting and after cutting, the pieces of cloth were removed and handled for two minutes. PLM analysis of the cloth indicated it consisted of an approximate mixture of 75% chrysotile and 25% cellulose. The breathing zone fiber concentration during cutting and handling the asbestos cloth ranged from 5.9 to 6.9 f/cc with a median concentration of 6.3 f/cc [n=4]. The area concentrations ranged from 0.91 to 1.86 f/cc with a median concentration of 1.4 f/cc [n=4]. Additionally, the clothing worn by the worker was highly contaminated by the asbestos released from the asbestos cloth (Hatfield & Longo, 2001).

Harries (1971) studied the asbestos fiber concentrations generated from asbestos cloth when shipyard workers fitted it over pipe lagging and ripping it. Concentrations during ripping contaminated cloth ranged from 5.5 to 43 f/cc with a mean concentration of 20 f/cc [n=12]. Concentrations during ripping cloth (untreated) ranged from 0.3 to 16.5 f/cc with a median concentration of 7 f/cc [n=5] (Harries, 1971).

Johns-Manville and Owens-Corning were in the process of developing asbestos-free calcium silicates in or around 1972 (Lester Divisions - Standards Engineering - Materials & Processes - M. Dorfman, 1972). Field testing of asbestos free Kaylo (calcium silicate) began around June of 1972 (Summer, 1972).

Asbestos-free calcium silicate insulation became available in the market around 1973 (Stanley, 1972; Unrich, 1973; Textile Fibers, 1973). Although new asbestos free insulation products were reported to have satisfactory thermal and chemical properties, Union Carbide reported that the characteristics of asbestos free insulation products were unknown when exposed to fire. In 1973, Union Carbide began running fire tests on the new asbestos-free calcium silicate material (Powell, 1973).

The U.S. EPA, through its National Emission Standards for Hazardous Air Pollutants (NESHAPS) rules banned the use of asbestos in TSI in 1975. This ban included the following:

- Installation of wet-applied and pre-formed (molded) asbestos pipe insulation.
- Installation of pre-formed (molded) asbestos block insulation on boilers and hot water tanks.

(EPA, 1975)

Based on relevant scientific literature, asbestos exposures during activities associated with TSI are summarized in Table 1.

Insulators using asbestos materials to insulate systesm aboard ships were routinely exposed to asbestos. These systems were especially prevalent in fire rooms and engine rooms. Reported dust concentrations were recorded as high as 8.0 mppcf for shipboard insulation jobs .

Table 1: Asbestos Exposure from TSI Activities

Year	Activity	Concentration	Role
1937	Insulating 12-inch steam line (Bonsib, 1937)	23.8 mppcf [maximum] 12.6 mppcf [mean]	Direct
1937	Removing insulation during dismantling a 4" tar line (Bonsib, 1937)	5.9 mppcf [maximum] 2.3 mppcf [mean]	Direct
1937	Insulating cracking coil accumulator (Bonsib, 1937)	4.5 mppcf [mean]	Direct
1937	Insulating acid suction line (Bonsib, 1937)	0.8 mppcf [mean]	Direct
1937	Insulating cracking coil hot oil lines (Bonsib, 1937)	3.4 mppcf	Direct
1937	Crushing scrap asbestos insulation by hand (Bonsib, 1937)	10.2 mppcf	Direct
1937	Shoveling broken pieces of scrap asbestos insulation (Bonsib, 1937)	14.8 mppcf	Direct
1963	Mixing magnesia/asbestos plaster (Leathart & Sanderson, 1963)	255 particles/cc	Direct
1968	Applying insulation materials by fitting, hammering, or carving, and attaching to the surface by wiring or gluing (Balzer & Cooper, 1968)	0.1-61.6 f/cc [n=45] 6.4 f/cc [mean] 1.4 f/cc [median]	Direct
1968	Finishing i.e., coating materials with asbestos containing cements, resins, asbestos cloth, or petroleum-based sealers (Balzer & Cooper, 1968)	0.1-24.4 f/cc [n=31] 2.7 f/cc [mean] 0.8 f/cc [median]	Direct
1968	Tearing out old or unusable materials in the process of insulating or reinsulating (Balzer & Cooper, 1968)	0.2-26.3 f/cc [n=17] 8.9 f/cc [mean] 4.9 f/cc [median]	Direct
1968	Mixing mineral wool, asbestos, fibrous glass, and cements or glues separately or in combination in buckets or troughs (Balzer & Cooper, 1968)	0.2-10.7 f/cc [n=22] 2.6 f/cc [mean] 1.4 f/cc [median]	Direct
1968	Cleaning up of old insulation and/or transporting material (Balzer & Cooper, 1968)	0.1-22.9 f/cc [n=16] 4.8 f/cc [mean] 0.8 f/cc [median]	Direct

Table 1: Asbestos Exposure from TSI Activities

Year	Activity	Concentration	Role
1971	Removal of pipe and machinery insulation in boiler rooms (Harries, 1971)	25-220 f/cc [n=20] 97 f/cc [mean]	Direct
1971	Area concentration in boiler rooms during removal of pipe and machinery insulation (Harries, 1971)	0.04-1062 f/cc [n=153] 171 f/cc [mean]	Bystander
1971	Application of pipe insulating materials in boiler rooms (Harries, 1971)	0.1-68 f/cc [n=14] 16.8 f/cc [mean]	Direct
1971	Area concentration in boiler rooms during application of pipe and machinery insulation (Harries, 1971)	1-61 f/cc [n=17] 22.4 f/cc [mean]	Bystander
1971	Fitting asbestos cloth over pipe lagging (Harries, 1971)	0.3-43 f/cc [n=7] 22 f/cc [mean]	Direct
1971	Mixing asbestos “plastic mix” with water in bucket (Harries, 1971)	24-579 f/cc [n=12] 256 f/cc [mean]	Direct
1971	Area concentration during mixing asbestos “plastic mix” with water in bucket (Harries, 1971)	53-377.4 f/cc [n=3] 167 f/cc [mean]	Bystander
1971	Area concentration during “blowing down” asbestos debris (Harries, 1971)	140-932 f/cc [n=7] 489 f/cc [mean]	Bystander
1971	Area concentration during sweeping and bagging amosite debris (Harries, 1971)	76.3-1191 f/cc [n=10] 564 f/cc [mean]	Bystander
1971	One deck above removal of sprayed asbestos insulation (Harries, 1971)	109 f/cc	Bystander
1971	Two decks above removal of sprayed asbestos insulation (Harries, 1971)	30 f/cc	Bystander
1975	Laborer working near asbestos worker(s) (Fontaine & Trayer, 1975)	ND-3.7 f/cc [TWA, n=9] 21.5 f/cc [maximum]	Bystander
1978	Pipe lagging repair – removal and replacement (Jones, 1981)	ND – 0.87 [n=7]	Bystander
1978	Pipe repair operations – lagging removal and dismantling pipe systems (Jones, 1981)	0.35 – 1.14 f/cc [n=4]	Bystander

Table 1: Asbestos Exposure from TSI Activities Continued

Year	Activity	Concentration	Role
1978	Clean-up after lagging repair (Jones, 1981)	ND – 3.3 f/cc [n=6]	Bystander
1978	Clean-up from piping repair (Jones, 1981)	0.11 – 1.92 f/cc [n=5]	Bystander

mppcf = Million particles per cubic feet
f/cc = Fibers per cubic centimeter
ND = None detected
TWA= 8-hour time-weighted average

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