HEALTH HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT

HETA 94-0329

Standard Steel
Burnham, Pennsylvania

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Preface

The Hazard Evaluation and Technical Assistance Branch of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene and technical assistance (TA) to federal, state, and local agencies; labor, industry, and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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SUMMARY

In July 1994, a confidential request was submitted by current employees of Standard Steel, in Burnham, Pennsylvania, to the National Institute for Occupational Safety and Health (NIOSH) for a health hazard evaluation (HHE). The requesters asked NIOSH to evaluate worker exposures to alumino-silicate fiber (hereafter referred to as refractory ceramic fiber, RCF) insulation (manufactured as Fiberfrax® by the Carborundum Company) which lines the interior of Standard Steel's industrial furnaces.

On August 22 - 23, 1994, NIOSH investigators conducted a walk-through survey of beehive heat treatment and long-car industrial furnaces and interviewed several workers. Workers expressed concern for dermal and inhalation exposures to RCF from Fiberfrax®. Subsequent activities on August 23, 1994, included observations of operations and work practices, and collection of new and after-service bulk RCF and floor soil for sample characterization.

On January 20, 1995, NIOSH investigators conducted a walk-through survey in preparation for sampling during RCF removal from a beehive furnace lid and the interior of a long car furnace. Sampling was conducted during this removal process on February 16 and 17, 1995. Area and personal air samples were collected for total dust, respirable dust, fibers, and silica. Bulk samples of Fiberfrax® were collected from the interior of the long car furnace and the beehive furnace lid for silica analysis. The RCF removal operations were supervised by Carborundum representatives, who provided a high pressure water lance to allow wet removal of the RCF.

A total of 16 time-weighted average (TWA) personal breathing zone (PBZ) and work area samples were collected and analyzed for total and respirable particulate. Six TWA PBZ respirable particulate samples from heat treatment and RCF removal tasks ranged from 0.061 to 0.37 milligrams per cubic meter of air (mg/m^3) with a mean ($\bar{x}$) of 0.17 and a standard deviation (SD) of plus or minus (±) 0.13. Respirable quartz was detected in one RCF removal sample, below the minimum quantifiable concentration. No cristobalite was detected in any of the samples. Ten TWA area total particulate samples from Heat Treatment Plant Number One (HTP#1) and RCF removal operations ranged from 0.10 to 0.52 mg/m^3 ($\bar{x}$ = 0.23, SD ± 0.14). No quartz or cristobalite was detected in any of these samples.

A total of 20 TWA PBZ samples were collected and analyzed for fibers by phase

contrast microscopy (PCM). Six samples were collected in the area surrounding HTP#1, ranging from 0.009 to 0.041 fiber per cubic centimeter of air (fiber/cc) ($\overline{X}$ = 0.024, SD ± 0.012). Fourteen samples were collected during wet method RCF removal operations, ranging from 0.55 to 3.04 fibers/cc ($\overline{X}$ = 1.44, SD ± 0.84).

One PBZ fiber sample was analyzed by transmission electron microscopy (TEM) to determine the fiber concentration and analyze fiber dimensions. Compared with the fiber concentration determined by PCM at 3.04 fibers/cc, the concentration determined by TEM was much lower, at 1.7 fibers/cc. Of 108 fibers, all had diameters less than 2.0 micrometers (μm) and lengths less than 68.0 μm. All fibers had a length to width ratio of at least 3:1. The mean fiber length was 11.9 μm (SD ± 11.3), and the mean width was 0.71 μm (SD ± 0.44).

Five bulk samples were characterized by polarized light microscopy and x-ray diffraction. No crystalline phases were detected in the fibrous portion of used (heat exposed) Fiberfrax® samples obtained from the interior of beehive and long car furnaces. The non-fibrous portions of these samples contained glass, quartz, and various oxides of iron, silica, chromium, and aluminum.

Twelve bulk samples were obtained from various depths up to 6.0 inches within heat-exposed Fiberfrax® from the interior of beehive and long car furnaces. No quartz or cristobalite were detected in any of the samples.

Standard Steel workers wearing half-mask respirators equipped with HEPA filter cartridges, safety glasses, hard hat, tyvek coveralls over work clothing, nitrile rubber gloves, and metatarsal-guarded steel-toed boots were not exposed to a health hazard from exposure to RCF.

Presently, no exposure criteria exist for RCF other than those endorsed by RCF manufacturers, users of RCF, or standards which classify RCF as an inert dust or particulate not otherwise classified (PNOC) or regulated (PNOR). Under Proposed Rules in the June 12, 1992, edition of the Federal Register, the Occupational Safety and Health Administration (OSHA) proposed a 1.0 fiber/cc standard for RCF.

In the absence of exposure criteria for RCF, Standard Steel should continue to use its 1.0 fiber/cc internal standard, which is equal to the Carborundum Recommended Exposure Guideline (REG) of 1.0 fiber/cc. This 1.0 fiber/cc limit should be employed until sufficient scientific evidence exists to determine if any other exposure limit will safeguard worker health for exposures to RCF for up to 10 hours per day, 40 hours per week, for a working lifetime.

Workers handling RCF should wear specific levels of respiratory protection (based on 1.0 fiber/cc) as outlined in the Standard Steel Safety Bulletin for refractory ceramic fibers. Company officials should monitor RCF concentrations regularly to characterize task-specific exposures to RCF. This task-specific exposure data will help Standard Steel to determine the appropriate level of respiratory protection for specific tasks. Future efforts to remove RCF should continue to utilize wet methods of removal and dust suppression to help minimize airborne dust concentrations.

The results of environmental sampling indicate that the Fiberfrax® used at Standard Steel has not converted to cristobalite. No exposures to the substances sampled were in excess of evaluation criteria for total and respirable particulate or silica.

Keywords: SIC 3296, refractory ceramic fiber, mineral fiber, dust, crystalline silica, cristobalite, furnace, beehive, long car.

INTRODUCTION

In July 1994, a confidential request was submitted by current employees of Standard Steel, in Burnham, Pennsylvania, to the National Institute for Occupational Safety and Health (NIOSH) for a health hazard evaluation (HHE). The requesters asked NIOSH to evaluate worker exposures to alumino-silicate fiber (hereafter referred to as refractory ceramic fiber, RCF) insulation (manufactured as Fiberfrax® by the Carborundum Company) which lines the interior of Standard Steel's industrial furnaces.

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On June 6, 1995, NIOSH sent Standard Steel a copy of a letter to Carborundum Company representatives of the Refractory Ceramic Fibers Coalition (RCFC). The RCFC is a research and trade organization for domestic RCF producers. The letter reported the results of air sampling by NIOSH for fibers and silica during the RCF removal from the long car furnace on February 17, 1995. The NIOSH air sampling data was used by the RCFC in its compliance with an RCF fiber concentration monitoring project administered by the Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency (EPA).

BACKGROUND

The Standard Steel plant, which employs approximately 300 workers, occupies a steel production site estimated to be 200 years old. Several open-bay buildings house heat treatment furnaces, cranes, forges, and other machinery for the manufacture of wheels and axles used in the construction of railroad cars.

Fiberfrax®, a RCF insulation product, was first patented by the Carborundum Company in 1951. Commercial production of RCF products like Fiberfrax® began in the early 1970's and has continued to grow as a substitute for asbestos insulation and use in a variety of commercial products.[1] Standard Steel lines the inside of its industrial furnaces with a veneer of Fiberfrax® to minimize thermal conductivity through the ceilings, lids, doors, and walls of the furnaces. This veneer is composed of Fiberfrax® modules (blocks of RCF approximately 2 x 2 x 1 feet).

Modules are fastened to the interior of furnaces by wires or mastic. Individual modules or complete furnace linings which exhibit overall deterioration or damage may be removed and replaced. Refractory ceramic fibers may be released during module removal, replacement, during furnace loading and unloading, or during housekeeping activities such as sweeping. Workers may use the Carborundum mastics Fiberfrax® QF-180 Blue or Topcoat™ 2600 Insulating Mix to repair damaged modules. The mastics contain water, vitreous aluminosilicate, and amorphous silicon dioxide. The Topcoat™ mix also contains aluminum silicate and hydroxyethyl cellulose.

This HHE evaluated area and PBZ concentrations of fibers and particulate associated with Heat Treatment Plant Number One (HTP#1), which is a cluster of several gas-fired, cylinder-shaped beehive furnaces in a large, open-bay. The furnaces are used to heat-treat large steel rings. The furnaces operate from 426 to 1037 degrees Celsius (°C) (800 to 1900 degrees Fahrenheit (°F)). The inside walls of the furnaces are lined with Fiberfrax® modules anchored by wires to refractory brick. The underside of cone-shaped metal furnace lids which cap the furnaces are also lined with Fiberfrax® modules, anchored by wires or mastic. Approximately five workers work intermittently in or around HTP#1 from 7:00 a.m. until 3:00 p.m., 5 days a week. The workers primarily check the operation of the furnaces, operate an overhead crane, or perform maintenance activities such as insulation or furnace repair. There is no local exhaust ventilation in HTP#1.

Typically, a furnace lid is removed from the top of a beehive furnace by an overhead rail crane and placed on the dirt floor of the bay. The crane then places a rack (which supports rings) into the furnace. The rings are tempered by heating, cooling, and reheating. The rings are cooled (quenched) as they are submerged in vats of oil or water adjacent to HTP#1. After quenching, the rings are placed into the beehive furnace for reheating, if necessary. The furnace lid is then replaced by the crane. The crane is operated remotely by a hand-held switch box which drops from the crane to a worker standing on the floor of the bay, in close proximity to the HTP#1 and the crane load.

The insulation modules in the beehive furnaces or on the underside of furnace lids become friable because of age or physical contact. Lid removal and replacement causes RCF fibers to become airborne, and when furnace lids are placed on the dirt floor of the bay, debris from the floor become airborne until settled.

This HHE also evaluated area and PBZ concentrations of fibers and particulate during RCF removal. The RCF was cut with a high pressure water lance to allow wet removal of the RCF. The removal operation took place in the Lower Ring Mill building which houses three long car furnaces, and forging and rolling operations in a large, open area. The removal took place inside and around long car furnace #8137, and in an area in which a beehive furnace lid was placed after it was transported to the Lower Ring Mill from HTP#1.

A gas-fired long car furnace heats steel ingots for a period of 8 to 20 hours prior to forging. Ingots are transported by crane onto flat bed rail cars, which travel through the long car furnaces. The furnaces are approximately 160 feet long, and operate at approximately 1260 to 1371 °C (2300 to 2500 °F). The base of the furnace walls is raised approximately two feet above metal posts. A section of bare refractory brick rises above the posts, followed by seven feet of refractory bricks rising to the ceiling. Above the bare bricks, the furnace is lined with a veneer of Fiberfrax® insulation modules which are approximately one to two feet thick. The modules are anchored to the walls and ceiling of the furnace by wires. Two employees work intermittently around the long car furnaces from 7:00 a.m. until 3:00 p.m., 5 days a week. During normal operations, the workers primarily check the operation of the furnaces or perform maintenance activities such as insulation or refractory repair. There is no local exhaust ventilation in the long car furnace area. Every five years, or as required by wear of the RCF, approximately three to five workers remove and replace Fiberfrax® insulation modules from a long car furnace, over a period of 3 or more days.

OBSERVATIONS

Workers were concerned about the statement in the Fiberfrax® material safety data sheet (MSDS) which indicates that the product may present a cancer hazard based on animal health hazard studies. The MSDS also states that RCF may become more hazardous due to a potential conversion to crystalline silica after exposure to temperatures above 982 °C (1800 °F). Employees were concerned about possible health effects from past exposures to RCF, particularly during periods when personal protective equipment was not consistently used during removal of after-service Fiberfrax® insulation from the interior of furnaces. Workers were concerned that family members have been exposed to RCF attached to work clothing. Workers have worn Tyvek® suits and 3M Model 8710 dust and mist respiratory protection during the past three years.

The workers reported to NIOSH investigators that skin irritation and rashes have formed after working with Fiberfrax®. One bricklayer experienced sinus congestion and headache, while several other workers reported scratchy throats, sneezing or cough after exposure. One worker reported microscopic levels of blood in his urine (hematuria) which has not resolved over a period of months, and cannot be explained by his physicians. Another worker experienced a case of hematuria 15 years ago which resolved without treatment.

Beehive Furnace Area

Airborne RCF fibers were visible in the HTP#1 as the beehive furnace lids and hot metal rings were removed and replaced by an overhead crane. The crane operator, who stands on the ground adjacent to the furnaces, moved the crane with a hand-held control box. Fibers rose with heated air from the furnaces before settling to the floor of the area which houses the furnaces. Fresh air flows into the HTP#1 through a bank of hinged windows approximately two stories above the furnaces. Aerosolization of fibers and dust also occurred as furnace lids were lowered to contact the dirt floor of the building.

Over an eight-hour shift, crane operators, heat treatment furnace operators, bricklayers, and maintenance employees worked intermittently in the HTP#1 area. Workers wore leather or cloth gloves, coveralls, hard hat, safety glasses, and metatarsal-guarded steel-toe boots. None of the workers wore respiratory protection unless handling the RCF directly.

Occasionally, small sections of worn or abraded Fiberfrax® insulation must be cut away from a lid or furnace wall with a knife, and replaced with a section of insulation which is cut from a new Fiberfrax® module. The new insulation is fastened to the lid by a mastic. This repair process takes approximately 5 to 10 minutes. An employee who demonstrated this procedure wore a half-mask respirator fitted with high efficiency particulate air (HEPA) filter cartridges, leather gloves, and cloth work clothing.

RCF Removal

Fresh air flows into the Lower Ring Mill building through open bay doors and gaps between exterior walls and the floor of the building. Combustion products from forging and rolling processes rose by convection until capture by a bank of rooftop exhaust fans. There is no local exhaust ventilation for the removal of airborne RCF during normal or RCF removal operations.

During all RCF removal operations, workers wore half-mask respirators equipped with HEPA filter cartridges, safety glasses, hard hat, tyvek coveralls over work clothing, nitrile rubber gloves, and metatarsal-guarded steel-toed boots. The workers removed respirators, coveralls, hard hats, and gloves during their lunch period. During break periods, the workers removed respirators, gloves, and partially or completely removed the coveralls.

<u>Removal of RCF from the Beehive Furnace Lid</u>

Four workers employed by Standard Steel as bricklayers removed RCF from the underside of the beehive furnace lid during the first half of the day shift, on February 16, 1995. The cone-shaped lid was approximately 20 feet in diameter, and placed in an inverted position on the dirt floor of an open bay. One worker wetted the RCF for approximately five minutes with the water lance. A 16 horsepower pump supplied water to the lance at a pressure of 3200 pounds per square inch. After wetting the RCF, the worker used the lance to cut through and lift the RCF from the mastic and wire supports. The cutting and lifting with the water lance was not entirely effective, so two other workers manually tore the wet RCF from the lid by hand or with spades. The RCF was pushed or shoveled to the floor of the bay, or was shoveled directly into a front-end loader bucket. The fourth worker operated the loader which carried the after-service, wetted RCF into an open dumpster. The dumpster was placed in a bay next to the entrance to the long car furnaces. After working on the RCF removal for approximately three hours, the workers had a 30 minute lunch, then began the RCF removal from long car furnace #8137 for the remainder of the day shift.

RCF Removal from the Long Car Furnace

Workers removed RCF from long car furnace #8137 for the remainder of the day shift of February 16 and the entire day shift of February 17, 1995. The workers removed approximately 76 linear feet of RCF from the walls and ceiling inside the furnace. The water lance was slow to cut through and remove the RCF from the furnace walls, so the workers used the water lance as a cutting tool only. Pieces of after-service RCF modules were either removed from the walls as they were torn apart by the water lance, or partially intact blocks of RCF were removed by hand, spade, or steel bar. The RCF fell to the furnace floor, where it accumulated until it was shoveled into the front-end loader bucket. After every 15 to 30 minutes, workers rotated tasks of RCF removal, shoveling, operating the water lance, and operating the loader. The workers did not always wet the RCF thoroughly before cutting with the water lance or when removing the RCF manually, causing the dry RCF to become airborne inside and outside the long car furnace. The exposed (hot) face of the RCF was covered in most areas with a ceramic-appearing glazed coating. A Carborundum representative who was observing the removal speculated that the coating consisted of pyrolysis products emitted from metal ingots as they are heated. Immediately underneath the glazed coating, the RCF was stiff, grey, and friable. The RCF was white and less friable farther into the module.

EVALUATION CRITERIA AND TOXICOLOGY

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[2], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs)[3] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[4]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Several organizations (government agencies, a union, RCF users, and RCF manufacturers) offer exposure limits for RCF and other substances addressed in this HHE (Table I). In 1992, the Occupational Safety and Health Administration proposed a 1 fiber per cubic centimeter (fiber/cc) 8-hour TWA limit for the respirable fibers of fibrous glass, including RCF. This proposed standard was announced in the June 12, 1992, issue of the Federal Register. There are currently no OSHA PELs governing exposure to fibrous glass or RCF. Exposures to RCF are currently regulated by OSHA's standards for total and respirable inert or nuisance dusts. NIOSH is currently evaluating health effects data on RCF. Due to a lack of reported adverse health effects in epidemiologic studies, the ACGIH classifies fibrous glass as a nuisance dust, with a TLV of 10 milligrams per cubic meter of air (mg/m^3).[3,5] However, fibrous glass dust (a synthetic vitreous fiber) is currently classified as a chemical substance under study by the ACGIH.[3] The Federal Republic of Germany (FRG) classifies refractory ceramic fibers as having a positive determination of carcinogenic effects from inhalation studies. Refractory ceramic fibers are regulated under the FRG's technical exposure limits (TRK) for man-made mineral fibers.[6] Other standards for RCF or fibrous glass have been adopted or endorsed by industrial groups, including the Carborundum Company's recommended exposure guideline (REG), E. I. DuPont's acceptable exposure level (AEL), the Manville Company's workplace exposure guideline (WEG), and The Building and Construction Trades Department of the American Federation of Labor-Congress of Industrial Organizations' (AFL-CIO) endorsement of a permissible exposure limit (PEL) (Table I).[5]

Properties of Fibers

The airways of the human respiratory system branch in a series of tubes which decrease in diameter and size until they terminate as alveoli. Alveoli are thin-walled air sacs which permit the conveyance of inhaled gases into the bloodstream. Inhaled particles also deposit in the nose, pharynx, or trachea. Particles deposited in the upper airways are cleared by mucous in the air passages. Smaller particles can deposit in the lower airways. Larger particles, deposited in upper airways, are moved upward by the lung's clearance mechanisms and are swallowed or expectorated. Smaller particles, which deposit deeply within airways, are not as effectively removed.[7]

By definition, fibers have a length to diameter ratio equal to or greater than 3:1. Although fiber shape may curb deposition in deeper airways, fibers can penetrate deeply, acting aerodynamically as if spherical.[8] An equivalent spherical aerodynamic diameter can be calculated from a nominal fiber length and diameter. As the ratio of length to diameter increases, fiber length begins have an affect on fiber deposition.[7] As the fiber length to diameter ratio increases, the ratio of the nominal fiber diameter to the equivalent spherical diameter approaches a constant, which varies from 2.5 to 3.5. For example, a 20 micrometer (µm) long fiber, 1 µm in diameter, exhibits the aerodynamic properties of a 3 µm spherical particle.[8] Particles with aerodynamic diameters less than 3.5 µm may reach the deeper airways.[7] In rats, fibers with mass median aerodynamic diameters between 3 and 6 µm are capable of deposition in the alveoli at levels of one to two percent.[9]

Fiber durability may affect carcinogenic potential.[10 - 13] Fibers which preserve their structure in the lung for longer periods may have a greater carcinogenic effect on lung tissue.[10,11] For example, asbestos fibers, which are highly carcinogenic, are stable in physiologic solutions that entirely disintegrate glass fibers.[12]

Animal studies demonstrate that fibers greater than 10-15 µm in length may not be as efficiently removed from the lung by cell-mediated mechanisms.[10,14] One study reported maximum RCF removal at fiber lengths of 11-15 µm, with decreased removal as fiber length increased.[11]

In vitro (literally, “in glass,” as in “in a test tube”) studies have added data to support conclusions reached by animal (in vivo) studies that certain fiber characteristics (surface chemistry, biopersistence, fiber structure) can affect the carcinogenic potential of a fiber. It is commonly reported that during in vitro tests, longer fiber structures are more toxic than short structures.[15]

Man-made Mineral Fibers and Refractory Ceramic Fibers

Synthetic, or man-made mineral fibers (MMMF), also referred to as man-made vitreous fibers (MMVF), commonly refer to amorphous glass fibers made from molten slag, rock, or glass. Four general classifications of MMMF exist; slag wools, rock wools, glass, and ceramic wools and filaments. Unlike asbestos, MMMFs are amorphous, commonly have a larger diameter and fracture in a transverse plane (asbestos fibers fracture longitudinally, producing a large number of finer fibrils). Refractory ceramic fiber products such as Fiberfrax® are part of the MMMF family, specifically a vitreous wool which is produced by melting a combination of alumina (Al_2O_3) and silicon dioxide (SiO_2) in approximately equal proportions, or by melting kaolin clay together with several trace ingredients. This molten mixture is made into fibers by blowing an air stream on the molten material or by directing the material into a series of spinning wheels. The fibers are collected directly as bulk fiber, or made into a blanket by a needling process. Advances in production have allowed manipulation of fiber length, diameter, physical form, and chemical composition to meet specialized needs and applications. Refractory ceramic fibers are generally used for high temperature applications and are made into a wide range of product forms including bulk, blanket, modular block, paper, board, textile, cement, and moldable, preformed, or fabricated shapes.[1,16 - 18]

Animal and In Vitro Studies

Animal studies have generally dosed animals with fibers by inhalation, or injection/implantation. Fibers have generally been instilled by injection/implantation by the following routes; intrapleural (adjacent to the pleura of the lung), intratracheal (in the trachea), and intraperitoneal (in the lining of the abdominal cavity).[1]

One of a few in vitro studies of RCF indicate that although fiber length affects cytotoxicity, this association is not consistent for RCF. Higher levels of cellular activity were observed for RCF fibers in vitro than were expected in vivo.[15]

Tumor production has been observed to increase from the injection of RCF.[1,15] The carcinogenic potential of RCF by intraperitoneal inoculation has been reported by a number of animal studies, with a much more pronounced carcinogenic effect of Fiberfrax® RCF by this route of exposure than by intratracheal instillation or inhalation.[15] A study which compared the effect of intrapleural instillation between glass fibers and

RCF in rats and hamsters showed a higher sustained dose-dependant pleural mesothelial cell proliferation for RCF. This proliferation effect was particularly higher for hamsters, which led the authors to conclude that species-specific differences may explain differences in the incidence of mesotheliomas during long-term rodent inhalation studies.[19] Fiber size influences dose to the lung. Specific types of fibers combined with specific production processes make certain types of fibers more likely to be of respirable size, therefore potentially increasing dose. Refractory ceramic fibers and certain specialty glass fibers are more likely to be of respirable size, followed by rock wool, slag wool, and glass wool. Glass filaments are not likely to be of respirable size due to production processes.[20]

The number of studies which have exposed animals to RCF by inhalation have increased since the 1970's, with varying results. Significant tumor production has been observed by inhalation of RCF and asbestos when these fibers have been used as positive controls by inhalation. RCF has produced more tumors in hamsters than asbestos, but fewer tumors in rats than asbestos.[15] The results of inhalation studies have varied widely (and significantly in some comparisons) in the number and type of tumors or mesotheliomas observed and incidence of tumor production by species. Some of these differences are thought to be a function of differences in dose or fiber structure (such as fiber diameter) as well as species specificity.[15]

Researchers have generally concluded that while the chemical composition of a fiber may not greatly affect its carcinogenic potential, it does affect the durability of the fiber. The durability of a fiber is its resistance to dissolution by physiologic solutions.[1] Fiber durability may affect carcinogenic potential since a fiber probably must persist for a non-specific but sometimes lengthy period to elicit a negative physiologic response.[1,10] Certain chemical components such as aluminum may decrease fiber dissolution.[20] The separate contributions of various fiber parameters (surface area, surface morphology, oxidants production, rod or fibrillar structure)[15,20] or biopersistence (dissolution, disintegration, elimination, or migration through the body)[1,15] must be determined before the significance of fiber durability on overall bioactivity can be estimated. In vitro and in vivo studies have demonstrated that refractory ceramic fibers are more durable than fibers of mineral wool[1], which are more durable than glass fibers.[13] Refractory ceramic fibers do not undergo dissolution as readily as glass fibers (under laboratory conditions)[13] or mineral wools[1] and are not as readily cleared from the lungs.[11] Experiments indicate that the rate of RCF removal from the lung is markedly slower than for glass fibers.[11]

Several animal studies have been contracted by the RCFC[16] and the Thermal Insulation Manufacturers Association (TIMA).[5] One multidose inhalation study sought to research the effects of inhalation of four RCF fiber types (kaolin, high purity, zirconia, and heated kaolin) on rats and hamsters. The fibers were carefully prepared to maximize lung burden with the respirable, fibrous component of RCF. Rats exposed to all four types of RCF at 200 fibers/cc (determined to be a maximum tolerated dose by the researchers) developed significant increases in lung tumors, and insignificant increases in mesotheliomas.[21]

In addition, animal studies cited in the Federal Register Proposed Rules for Refractory Ceramic Fibers under Nonmalignant Respiratory Disease and Carcinogenicity,[5] and those cited in the IARC Monographs on the Evaluation of Carcinogenic Risks to Humans for Man-made Mineral Fibers[22] have indicated that RCF can cause non-malignant respiratory effects in animals, including alveolar lipoproteinosis, and pulmonary fibrosis. The IARC evaluation of RCF also determined that there was sufficient evidence for the carcinogenicity of RCF in experimental animals.[22]

Intra-pleural or intra-peritoneal fiber injection studies of RCF in animals have produced tumors. Refractory ceramic fibers have produced carcinogenic effects in animals, including malignant pulmonary neoplasms and mesotheliomas by several routes of administration.[5,21] These animal studies provide evidence that humans may be at risk for carcinogenic or non-malignant respiratory effects.[5]

Epidemiological Studies

Bricklayers and welders employed at the Heppenstall Company, in Pittsburgh, Pennsylvania, filed a NIOSH HHE request in 1977 due to skin and throat irritation during handling of Fiberfrax® insulation.[23] Throat irritation occurred principally during Fiberfrax® installation. The investigators concluded that published literature on the toxicity of RCF was scarce. At the time, an early inhalation study[21] (in 1956) which exposed rats to RCF concluded that RCF was like an inert dust. The only data the investigators obtained was in a Technical Information Bulletin provided by the Carborundum Company. In the bulletin, Carborundum reported that Fiberfrax® irritated skin and mucous membranes, and that the insulation was inert by the oral route of exposure. The irritation could occur from mechanical contact with the insulation. Carborundum determined these health effects from an independent laboratory which was contracted to determine the toxicology of Fiberfrax® by animal testing. The bulletin did not mention specific animal studies. The bulletin suggested that Fiberfrax® be categorized as a nuisance particulate. The NIOSH investigators advised Heppenstall to minimize worker exposures to airborne Fiberfrax® since health effects data from long term exposures were not available. The investigators recommended that personal protective clothing which minimizes skin contact be worn, and that a suitable dust mask be worn as Fiberfrax® is installed.[23]

To maintain compliance with the OSHA Hazard Communications Standard, a recent edition of the MSDS produced by Carborundum for Fiberfrax® warns of a possible cancer hazard by inhalation, with the hazard dependent upon duration and level of exposure. The MSDS further states that although ingestion is unlikely, ingestion of Fiberfrax® in sufficient quantities may cause gastrointestinal disturbances. Skin exposures may result in irritation, inflammation, and rash. The abrasive action of the fibers may cause damage to the outer surface of the eye. Inhalation may cause upper respiratory tract irritation, and pre-existing medical conditions such as bronchial hyper-reactivity and chronic bronchial or lung disease may be aggravated. The MSDS states that existing toxicology and epidemiology data for RCF is still preliminary, and at the time the MSDS was printed, no known published reports demonstrate negative outcomes for workers exposed to RCF. Epidemiology studies are ongoing. According to the MSDS, preliminary evidence indicates no evidence of fibrotic lung disease or lung disease among those who have never smoked exists, based on evidence obtained from employees exposed to RCF in RCF manufacturing facilities. According to the MSDS, decreases in some measures of pulmonary function in exposed populations are not significant. Pleural plaques observed in small numbers of employees with long duration employment were not regarded as pre-cancerous, were not associated with a measurable effect on lung function, and may have several occupational and non-occupational causes.[24]

IARC studies and literature reviews indicate that no data were available on the carcinogenicity of RCF to humans. Overall, RCF's were grouped as 2B, meaning possibly carcinogenic to humans.[22]

No epidemiological studies have completely evaluated the risks of developing lung cancer or mesothelioma in RCF manufacturing or user industry populations. Health affects observed from mineral wool, fibrous glass, or asbestos studies are not completely suggestive of health effects from RCF exposures, because physical characteristics affecting the carcinogenic potentials of these fibers (rate of dissolution and fiber dimension) may not be comparable.[11] Fiber dimension is particularly evident in a comparison of RCF to asbestos, as the median diameter of asbestos fibers is much smaller than RCF. Asbestos fibers split longitudinally into fibrils of decreasing diameter, while RCF tends to break transversely into shorter lengths of the same diameter. Thus asbestos, which is more durable than RCF, may also be inhaled more deeply within the lungs, resulting in both a larger effective dose to target tissues deep in the lung and a greater likelihood the dose will remain in the lung to elicit long-term injury.[1]

Under the authority of the Toxic Substances Control Act, the EPA issued a Testing Consent Order for Refractory Ceramic Fibers which plans for at least five years of workplace exposure level monitoring for RCF. Members of the RCFC will perform the monitoring, specifically the Carborundum Company, Premier Refractories and Chemicals, Inc., and Thermal Ceramics, Inc.[16] In the monitoring project plan, the RCFC cite nine human epidemiology presentations or papers related to RCF which have been sponsored by RCF producers.[16]

A Carborundum Company publication cited a 1986 to 1989 morbidity study which indicated that decreased pulmonary function, dry cough, and breathlessness among a study population of 650 european RCF industry workers was not attributed to RCF exposure. A 1986 Carborundum x-ray study of 214 current RCF plant workers determined that the results were consistent with x-rays from factory workers with no known RCF exposures.[21,25]

An ongoing study (1987 - present) of employees in the RCF industry has been conducted by the University of Cincinnati College of Medicine.[5,25] The study reported 8 (11%) of 70 employees with over 20 years since first employment in a RCF production job had pleural changes. Not all of these workers were exposed to the RCF for all of 20 years. Of 29 workers who were exposed to RCF for all of 20 or more years, 6 (21%) had pleural changes. Among 686 current and former production workers, a total of 23 (3.4%) had pleural changes. Of these 23, 21 (91%) of the pleural changes were classified as pleural plaques, and 2 were pleural thickening. Of the 23 employees, 22 worked in two plants with long histories of RCF manufacturing, starting in 1953 and 1970.[26,27] The authors concluded that the "association between pleural plaques and time since first RCF production job is statistically significant and remains so after adjustment for known asbestos exposure."[27] A nested case-control study confirmed that a "plausible" time period existed between development of plaques on "historical films" and RCF exposure, and that asbestos "did not account for the observed association between RCF exposure and pleural plaques."[28] Adjusted odds from a multiple logistic regression of the data were "significantly increased for workers with greater than 20 years time since first RCF production job and for workers with greater than 20 years duration employment in an RCF production job."[27] No excess risk of lung cancer or mortality was indicated in this cohort, and respiratory symptoms were similar to those observed in other dust-exposed working populations.[21,28] However, if plaques continue to be observed as observation of this cohort continues, it "would appear that RCF has a significant enough biological durability to induce changes along the parietal pleura."[27]

A study of asbestos workers with pleural plaques has demonstrated that those workers had significantly higher death rates from lung cancer, mesothelioma, and asbestosis than did workers without pleural plaques. It did not appear, however, that the plaques became pleural mesothelioma, nor did lung cancer occur distinctly in the regions of the plaques.[5] Prior to the University of Cincinnati study, pleural plaques were almost exclusively associated with asbestos exposure.[21,27]

Exposure limits for asbestos, which range from 0.1 to 0.25 fibers/cc are generally lower than the RCF exposure limits (0.1 to 1.0 fiber/cc) currently recommended by manufacturers or users of RCF (Table I).[2,3,4,5,6] Some manufacturer or user limits are more protective than the 1.0 fiber/cc PEL proposed by OSHA in 1992 for RCF and fibrous glass.[5] In the absence of standards for RCF, several user industries have applied the OSHA 0.2 fiber/cc TWA and 1.0 fiber/cc 30-minute excursion PEL for asbestos to RCF as an interim, internal exposure standard.[29]

Conversion of Refractory Ceramic Fibers to Cristobalite

Exposure to crystalline silica as quartz and cristobalite has been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lung. The fibrosis is characterized by nodules in the lung. Evidence suggests that crystalline silica is a potential occupational carcinogen.[30,31] Silicosis may form after 30 to 40 years of low occupational exposures, or after 4 to 8 years of high exposure. Acute silicosis may occur after one to three years of heavy exposure.[32] Smoking or respiratory infection can hasten the generation of the disease.[33] Exposure limits for quartz and cristobalite are shown in Table I.

Some forms of crystalline silica, including crystalline quartz, can undergo conversion to cristobalite after heating.[33] Similarly, RCF may undergo chemical conversions which form cristobalite when RCF is heated in industrial furnaces. Conversion to mullite (an aluminum-silicate) can occur rapidly. Conversion to cristobalite can require two weeks of sustained heat at conversion temperatures.[34] A study of RCF in furnaces estimated that RCF may convert to cristobalite at 920 °C (1688 °F). This study found that cristobalite was formed in diminishing quantities from the hot face of the insulation to the outermost four inch layer.[35] Samples of RCF collected from furnaces have contained from 15 to 20% cristobalite after exposure to temperatures ranging from 270 to 1350°C (500 to 2550 °F), for 100 to 470 hours.[35] Another study estimated conversion to cristobalite at temperatures of 1000 °C (1742 °F),[36] to 1150 °C (2012 °F).[34] One study suggests that the alumino-silicate RCF products, Kaowool® and Fiberfrax®, may require sustained heat from days to weeks to covert chemically. These products converted to mullite within hours. Fiberfrax® further converted to cristobalite. The authors of the study suggest that titanium, sodium and potassium oxides in the Fiberfrax® may have a role in the conversion of mullite in the Fiberfrax® to cristobalite.[37]

Total and Respirable Particulate

Deposition of excessive amounts of particulate in mucous membranes may result in unpleasant deposits in the eyes and nose, or mechanical injury to the membranes.[38] RCF can be irritating to the eyes, skin, and throat[39] and contains approximately 50% unfiberized particles as manufactured.[25] Since OSHA has no PEL for RCF, exposures to RCF are limited by OSHA total particulate or respirable particulate standards under the terminology of “nuisance dusts” or “particulates not otherwise regulated” (PNOR)[4]. This standard, however, is not adequate to protect workers’ substances that have carcinogenic or other toxic effects.

SAMPLING METHODS

Bulk samples were collected on August 23, 1994, and February 17, 1995. Full period (full shift) or consecutive, partial-period samples were collected on February 16 and 17, 1995, in the HTP#1 and RCF removal areas. Samples were positioned in the personal breathing zone (PBZ) of workers, or located in fixed positions as area samples.

Samples were collected for total dust, respirable dust, or RCF.

A total of 20 PBZ samples of RCF were collected on 25 millimeter (mm) diameter, 0.8 micrometer (µm) pore size, mixed cellulose ester (MCE) filters, housed in three-piece electrically conductive filter holders with extensions. Each filter holder was connected by flexible tubing to a portable sampling pump. Sixteen samples were taken at a flow rate of 1.0 liter per minute (lpm). During RCF removal operations on February 16, 1995, four PBZ samples were collected at 1.7 lpm. The RCF samples were analyzed by phase-contrast microscopy (PCM) to determine fiber concentrations per square millimeter (f/mm^2) of filter by NIOSH analytical method 7400.[40] Fiber concentrations were determined using criteria set by NIOSH method 7400 'B' counting rules. A quarter section of PBZ RCF sample #25 was sent to Clayton Environmental Consultants, of Kennesaw, Georgia, for analysis by transmission electron microscopy (TEM) to determine the fiber concentration per mm^2 of filter and fiber dimensions by guidelines listed in the RCF Monitoring Project Quality Assurance Project Plan.[41]

A total of 7 area samples of total particulate were collected onto pre-weighed, 37 mm diameter, 5.0 micrometer µm pore size, poly-vinyl chloride (PVC) filters, housed in polystyrene closed-faced filter cassettes. Each cassette was connected by flexible tubing to a portable sampling pump operated at a flow rate of 1.0 lpm. Each sample was analyzed for total mass by NIOSH analytical method 0500.[42] Each sample was also analyzed for quartz and cristobalite using x-ray diffraction (XRD) by NIOSH analytical method 7500.[43]

A total of 6 PBZ samples of respirable particulate were collected through 10-mm nylon cyclones onto pre-weighed, 37 millimeter (mm) diameter, 5.0 micrometer (µm) pore size, poly-vinyl chloride (PVC) filters, housed in polystyrene filter cassettes. Each cyclone was connected by flexible tubing to a portable sampling pump operated at a flow rate of 1.7 lpm. Each sample was analyzed by gravimetric analysis for respirable mass by NIOSH analytical method 0600.[44] Each sample was analyzed using XRD for quartz and cristobalite by NIOSH analytical method 7500.[43]

On August 23, 1994, two bulk samples of unused Fiberfrax® blanket and module, one sample of dirt from the floor of the HTP#1 beehive furnace area, and two samples of heat exposed Fiberfrax® from long car furnace interiors were collected. These samples were characterized by polarized light microscopy (PLM) on an Olympus microscope at magnifications of 100 and 200X. The samples were also characterized for silica by NIOSH analytical method 7500.[43] Twelve bulk samples of Fiberfrax® blanket or modules were collected on February 17, 1995. The samples were analyzed for quartz and cristobalite content by NIOSH analytical method 7500.[43] An optical examination was also performed to confirm the results of the XRD analysis.

RESULTS

Results of the environmental monitoring are listed in Tables II through XI, and illustrated by Figures 1 and 2. Minimum detectable concentrations (MDC) and minimum quantifiable concentrations (MQC) are noted in the tables if the limits of detection (LOD) and limits of quantification (LOQ) for a particular analytical method were reported. The MDC is based on the LOD, which is the quantity of analyte which can be detected with acceptable precision above a mean blank signal. The MQC is based on the LOQ, which is the smallest quantity of analyte that can be quantifed with an acceptable level of precision. The MDC and MQC are calculated by dividing each respective LOD and LOQ by a sampling volume appropriate for a sample or set of samples.

During February 16 and 17, 1995, four full-shift area concentrations of total particulate were measured at a height of four to six feet, near the outside walls of four beehive furnaces. The TWA concentrations ranged from 0.10 to 0.34 mg/m^3, with an average ($\bar{x}$) concentration of 0.19 mg/m^3, and a standard deviation (SD) of plus or minus (±) 0.11 mg/m^3. No quartz or cristobalite was detected in any of these area samples (Table II).

During February 16, 1995, three full-shift area concentrations of total particulate were measured at a height of 4 to 5 feet, and approximately 15 feet in front and to the left and right sides of the beehive furnace lid RCF removal operation. The TWA concentrations ranged from 0.16 to 0.20 mg/m^3 ($\bar{x}$ = 0.17, SD ± 0.02). No quartz or cristobalite was detected in any of these area samples (Table II).

During February 17, 1995, three full-shift area concentrations of total particulate were measured at a height of 4 to 5 feet, approximately midway between the entrance of Long Car Furnace #8137 and a dumpster containing after-service RCF. Inside the furnace, after-service RCF was shoveled into a front-end loader bucket, then the loader transported the RCF out of the furnace, past the area air samplers, and emptied the RCF into the dumpster. The TWA concentrations of total particulate ranged from 0.10 to 0.52 mg/m^3 ($\bar{x}$ = 0.34, SD ± 0.22). No quartz or cristobalite was detected in any of these area samples (Table II).

During February 16 and 17, 1995, six full-shift personal concentrations of RCF were measured during Work Leader, RCO Checker/Crane Operator, and Furnace Operator tasks in the area surrounding HTP#1. These TWA concentrations were between the MQC and MDC for the samples. Therefore, the concentrations are estimates which range from 0.009 to 0.041 fiber/cc ($\bar{x}$ = 0.024, SD ± 0.011) (Table III).

During February 17, 1995, three full-shift personal concentrations of respirable particulate were measured during Work Leader, RCO Checker/Crane Operator, and Furnace Operator tasks in the area surrounding the beehive furnaces in HTP#1. The

TWA concentrations ranged from 0.061 to 0.13 mg/m^3 ($\bar{x}$ = 0.094, SD ± 0.035). No quartz or cristobalite was detected in any of these personal samples (Table IV).

During February 16, 1995, two full-shift and two consecutive partial-period personal concentrations of RCF were measured during RCF removal tasks by bricklayers at both the beehive furnace lid and long car furnace #8137 in the Lower Ring Mill. Full-shift, TWA concentrations calculated from full-period or consecutive, partial-period measurements ranged from 0.55 to 1.74 fibers/cc ($\bar{x}$ = 0.97, SD ± 0.67) (Table V).

During February 17, 1995, ten partial-period personal concentrations of RCF were measured during Bricklayer RCF removal tasks at long car furnace #8137 in the Lower Ring Mill. Full-shift, TWA concentrations calculated from consecutive, partial-period measurements ranged from 0.82 to 1.55 fibers/cc ($\bar{x}$ = 1.30, SD ± 0.42) (Table VI). One of the partial-period concentrations used in calculating the full-shift TWA concentration of 0.82 fibers/cc is below its respective MQC. Thus, the full-shift concentration of 0.82 fibers/cc was estimated by using one unquantifiable measurement and two quantifiable measurements.

During February 17, 1995, three full-shift personal concentrations of respirable particulate were measured during Bricklayer RCF removal tasks at long car furnace #8137 in the Lower Ring Mill. The TWA concentrations ranged from 0.076 to 0.37 mg/m^3 ($\bar{x}$ = 0.24, SD ± 0.15). Respirable quartz was detected in one sample. This concentration of respirable quartz (0.031 mg/m^3) was below the minimum quantifiable concentration. No cristobalite was detected in any of these samples (Table VII).

The concentration of RCF (3.04 fibers/cc) from personal sample #25 in Table VI was determined by counting fibers on the sample filter by phase contrast microscopy (PCM). Clayton Environmental Consultants used transmission electron microscopy (TEM) to count and measure dimensions of a sample of fibers on a quarter of the filter from sample #25. Using the TEM data, the concentration of RCF was measured at 1.70 fibers/cc (Table VIII). One hundred and eight fiber dimensions from the TEM analysis are listed in Table IX. All 108 fibers had diameters less than or equal to 2.0 micrometers (µm) and lengths less than or equal to 68.0 µm. All fibers had a length to width ratio of at least 3:1. The mean fiber length was 11.9 µm (SD ± 11.93 µm) and the average width was 0.71 µm (SD ± 0.44 µm). The geometric mean length was 8.0 µm and the geometric mean width was 0.57 µm (Figure 1). Sixty-nine percent of the fibers were less than 3.0 µm in diameter and greater than 5.0 µm in length. Thirty-nine percent of the fibers were less than 3.0 µm in diameter and greater than 10.0 µm in length (Figure 2).

The analysis of bulk samples collected on August 23, 1994, found no crystalline phases in samples of unused Fiberfrax® blanket and module. Debris from the floor of the Beehive Furnace area contained quartz, non-crystalline fibers, and a variety of relatively inert oxides of iron, silica, chromium, and aluminum. Non-fibrous sections of heat-exposed Fiberfrax® from Beehive Furnace #3 contained quartz, glass, and a variety of relatively inert oxides of iron, silica, chromium, and aluminum. The fibrous section contained no crystalline phases. Non-fibrous sections of heat-exposed Fiberfrax® from a long car furnace contained quartz, glass, and a variety of relatively inert oxides of iron, silica, chromium, and aluminum. The fibrous section contained no crystalline phases. No cristobalite was detected in any of these bulk samples (Table X).

The analysis of bulk samples of heat-exposed RCF collected from the wall in the middle of long car furnace #8147 and the wall at the far ends and middle of long car furnace #8137 on February 16, 1995, (prior to RCF removal) found no quartz or cristobalite in both fibrous and non-fibrous samples from the surface of the insulation up to a depth of 6.0 inches within the insulation. Bulk samples of heat-exposed RCF collected from the beehive furnace lid on February 17, 1995, (after partial RCF removal) contained no quartz or cristobalite from 0.75 up to 2.25 inches into the insulation. A sample of heat-exposed RCF from a wall in an in-service beehive furnace contained no quartz or cristobalite approximately 0.75 inches into the insulation (Table XI).

DISCUSSION

Refractory Ceramic Fibers

Disease in animals from RCF exposure does not provide conclusive evidence that the same disease will develop in humans, due to differences between human and animal physiology, differences in dose from laboratory to workplace, and the duration, route, and history of exposure.

Refractory ceramic fibers do not undergo dissolution as readily as glass fibers under laboratory conditions[13], and are not as readily cleared from the lungs[11], thus the increased durability of RCF relative to the other forms of MMMF may have a significant function in determining if RCF is more or less likely to produce carcinogenic or non-malignant disease in the future.

The current epidemiologic evidence in support of any standard for exposure to RCF is weak due to several factors:

- Based on epidemiological studies of asbestos exposed workers, it may be too early for epidemiological studies of RCF workers to detect chronic diseases such as respiratory tract cancer and mesothelioma. Studies of asbestos workers have demonstrated that the latency period (the time between exposure to a substance and the onset of disease) for mesotheliomas can be as long as 45 years and is routinely between 20 and 40 years.[5]

- Although exposure controls mandated by the OSHA Act of 1970 have probably lowered worker exposures to RCF, RCF was not considered especially harmful, except as an inert dust, as late as 1977.[23] Exposures to RCF have probably decreased since 1977, after scientific evidence from animal studies indicated RCF is a potential carcinogen.

- Only a small percentage of workers have been continuously exposed to RCF for a period of 20 or more years.[5]

Efforts to document current exposures to RCF, and the maintenance of detailed records of RCF exposures throughout the working lifetime of several worker cohorts will help occupational health professionals to estimate an exposure standard for RCF in the future. In the interim, researchers seem to be divided as to whether or not RCF should be limited at 0.1, 0.2, or 1.0 fiber/cc, depending upon their interpretation of current research and how they relate the research to the known health effects of asbestos or MMMFs.

Currently, Standard Steel limits exposure to RCF according to guidelines issued in a Standard Steel Safety Bulletin for Ceramic Fiber dated February 2, 1993. The bulletin lists work practices and personal protection for fabrication, installation, and removal operations for RCF materials. Many of these guidelines are based on recommendations listed in the Fiberfrax® MSDS, which follows a recommended exposure guideline of 1.0 fiber/cc. The respiratory protection guidelines in use at Standard Steel are also consistent with recommendations in the Fiberfrax® MSDS.

Exposures at Standard Steel

One of many studies of RCF exposures in RCF production plants has cited mean partial-period (task length) fiber concentrations ranging from 0.01 - 3.4 fibers/cc.[45] Other partial-period estimates are 0.01 to 6.4 fibers/cc (averaging 0.62 fiber/cc) for manufacture, and 0.01 to 24.73 fibers/cc (averaging 1.24 fibers/cc) for end use.[5] Measurements of partial-period RCF concentrations at six refineries and two chemical plants determined that the geometric mean (GM) RCF exposures outside of an enclosed space typically were less than 0.2 fiber/cc. Exposures during inspections, minor repairs, erecting scaffolding, and refractory repairs ranged from 0.007 to 0.34 fiber/cc. During welding tasks, these ranged from 0.003 to 17 fibers/cc, with a GM of 0.39 fiber/cc. RCF removal tasks ranged from 0.059 to 17 fibers/cc, with waste handling ranging from 0.009 to 0.05 fiber/cc. Installation tasks ranged from 0.024 to 2.6 fibers/cc. Based on the study at the refineries and two chemical plants, workers repairing RCF or handling pieces of RCF debris from floors during housekeeping activities are likely to be exposed during partial-period sampling between 0.1 fiber/cc and 1 fiber/cc. As workers install new RCF, it is likely that partial-period exposures will be above 0.1 fiber/cc and may reach 2.6 fibers/cc. During dry removal of after-service RCF without ventilation controls, partial-period exposures may reach 17 fibers/cc.[29]

Quantifiable personal TWA concentrations of RCF (analyzed by PCM) during this evaluation at Standard Steel ranged from 0.55 to 3.04 fibers/cc. Personal fiber exposures in the area surrounding HTP#1 ranged from 0.009 to 0.041 fiber/cc. These concentrations were below quantifiable limits (see Table III). None of the six samples from this area (collected over a two-day period) were above 1.0 fiber/cc. One of three full-shift personal airborne RCF concentrations measured during RCF removal from a beehive furnace lid and a long car furnace exceeded 1.0 fiber/cc. The exposure range was 0.55 to 1.74 fibers/cc. Two of three full-shift personal airborne RCF exposures measured during RCF removal from long car furnace #8137 exceeded 1.0 fiber/cc. The exposure range was 0.82 to 1.55 fibers/cc.

Results of the laboratory analysis of the RCF samples by phase contrast microscopy (PCM) indicated that some of the samples had low fiber counts because the majority of the particulate collected was non-fibrous. Many fibers present on many of the samples were not counted because they fell outside of the ‘B’ counting rules criteria (fibers were longer than 5 µm and less than 3 µm). As other researchers have found with asbestos and RCF counting by TEM and PCM, the two methods determine TWA concentrations which are quite different.[29] The concentration for sample #25 by PCM was 3.04 fibers/cc (Table VI), while the concentration by TEM was 1.70 fibers/cc (Table VIII).

Workers were concerned that the Fiberfrax® MSDS states that the product may present a cancer hazard and this warning was not present on MSDS sheets that were distributed in the past. By warning of a cancer hazard, Carborundum is complying with the OSHA Hazard Communications Standard, which requires a manufacturer to consider all available scientific evidence concerning the hazardous effects of a product. No testing is required and the evaluation may be based solely on information currently available in the scientific literature. For health hazards including carcinogenicity, the evidence must be statistically significant, and based on at least one positive study. According to OSHA’s standard, all materials found to be carcinogens or potential carcinogens by IARC (RCF is rated 2B, possibly carcinogenic) must be labeled as such in the MSDS sheet.[4]

Two workers were concerned that exposure to Fiberfrax® insulation may be have caused hematuria. Hematuria has many etiologies. A physician should be contacted for further evaluation to determine the source of the hematuria.

Until an exposure limit is available from OSHA, NIOSH, ACGIH, or other organization which is recognized by occupational health professionals for setting occupational or environmental exposure standards, it is prudent to maintain exposures to RCF at 1.0 fiber/cc or less, through the use of engineering controls, personal protective equipment, and good work practices.

Full-shift total particulate concentrations for all personal and area samples ranged from 0.10 to 0.52 mg/m^3, below the OSHA and ACGIH standards of 15 and 10 mg/m^3 respectively. Full-shift respirable particulate concentrations for all personal samples ranged from 0.061 to 0.37 mg/m^3, below the OSHA and ACGIH criteria of 5 and 3 mg/m^3 respectively. Although these concentrations were well below the OSHA and ACGIH criteria, total or respirable particulate should not be considered useful standards to determine if workers are exposed to a health hazard if the mass of the particulate contains RCF. These total and respirable particulate samples were collected primarily to determine if RCF removal presented a likely occupational exposure to cristobalite by heat conversion of RCF.

CONCLUSIONS/RECOMMENDATIONS

Presently, no exposure criteria exist for RCF other than those endorsed by manufacturers or users of RCF, or standards which classify RCF as an inert dust or particulate not otherwise classified (PNOC) or regulated (PNOR). Under Proposed Rules in a June 12, 1992, edition of the Federal Register, the Occupational Safety and Health Administration proposed a 1.0 fiber/cc standard for RCF.

The results of the air sampling and bulk sampling data indicate that the Fiberfrax® used at Standard Steel has not converted to cristobalite. The Fiberfrax® may not reach high enough temperatures for long enough periods to allow conversion, or the chemical composition of the fibers may have affected the probability of conversion. None of the air samples collected exceeded any of the existing exposure criteria for quartz, cristobalite, total dust, or respirable dust.

Guidelines regarding work practices and protective equipment in the Standard Steel Safety Bulletin for Ceramic Fiber dated February 2, 1993, should continue to be followed to minimize worker exposures to RCF. For those situations where local exhaust cannot be used to effectively control exposures to fibers, or as an interim measure until local exhaust is installed, protective equipment should be used to minimize exposures to RCF. Workers may wear goggles with half-mask respirators or a full-facepiece respirator to reduce eye irritation from airborne fibers.

Company officials should monitor RCF concentrations regularly to characterize task-specific exposures to RCF. This task-specific exposure data will help Standard Steel in determining the level of respiratory protection which is appropriate for specific tasks.

Future efforts to remove RCF should continue to utilize wet methods of removal and dust suppression to help minimize airborne dust concentrations.

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1. Standard Steel
2. The Carborundum Company - Fibers Division
3. OSHA, Region III
4. U.S. Environmental Protection Agency
5. Requestors

This report will serve to close-out this health hazard evaluation at Standard Steel, Burnham, Pennsylvania. For the purpose of informing affected employees, copies of this report should be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I
Comparison of Air Concentration Standards for Particulate, Selected Fibers, Quartz, and Cristobalite
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

	Total Particulate (mg/m^3)	Respirable Particulate (mg/m^3)	Asbestos Fibers (f/cc)	Fibrous Glass	Ceramic Fibers (f/cc)	Respirable Quartz (mg/m^3)	Total Quartz (mg/m^3)	Respirable Cristobalite (mg/m^3)	Total Cristobalite (mg/m^3)
OSHA PEL	15	5	0.2[1]	None[2]	None[3]	0.1	0.3	0.05	0.15
NIOSH REL	None	None	0.1[4]	3 f/cc[5]	None[6]	0.05	None	0.05	None
ACGIH TLV	10[7]	3[8]	0.2[9]	(10 mg/m^3)[10]	None[10]	0.1	None	0.05	None
DFG TRK	None	6	0.25[11]	1 f/cc[12]	1[13]	0.15	None	0.15	None
Carborundum REG	ND[14]	ND	ND	ND	1	ND	ND	ND	ND
E.I. duPont AEL	ND	ND	ND	2	0.5	ND	ND	ND	ND
Manville WEG	ND	ND	ND	ND	1	ND	ND	ND	ND
AFL-CIO PEL	ND	ND	ND	1	0.1	ND	ND	ND	ND

[1]For fibers 5 micrometers and longer, with a length to diameter ratio of at least 3 to 1.
[2]1 glass fiber/cc proposed in the June 12, 1992, edition of the Federal Register.
[3]1 ceramic fiber/cc proposed in the June 12, 1992, edition of the Federal Register.
[4]For a 100 minute, time-weighted average (TWA), 400 liter air sample (fibers greater than 5 micrometers long).
[5]For fibers less than or equal to 3.5 micrometers in diameter and greater than or equal to 10 micrometers long, or 5 mg/m^3 TWA (total fibrous glass).
[6]NIOSH commented in the June 12, 1992, Federal Register that a 0.2 fibers/cc standard may be necessary to protect workers from the development of lung caner.
[7]Total dust containing no asbestos and less than 1% crystalline silica.
[8]Adopted by the ACGIH in 1995 - 1996, for respirable dust containing no asbestos and less than 1% crystalline silica.
[9]Fibers greater than 5 micrometers in length with an aspect ratio equal to or greater than 3:1.
[10]The 1995-1996 edition of the ACGIH TLV and BEI booklet lists Fibrous glass dust (Synthetic Vitreous Fibers) as Chemical Substances and Other Issues Under Study.
[11]Chrysotile asbestos (length greater than 5 and diameter less than 3 micrometers, with an aspect ratio greater than 3:1.)
[12]For non-mobile existing installations (until 12/31/94), and processes not subject to very high fiber concentrations, spray insulation processes, or removal of fibers subject to heat.
[13]If not exposed to heat.
[14]Not Determined.

TABLE II
Area Sample Time-Weighted Average (TWA) Concentrations
of Total Particulate, Quartz, and Cristobalite
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Sample Location	Sample Period	Sample Number	Sample Volume (liters)	TWA Concentration (mg/m^3)								
				Total Particulate			Quartz			Cristobalite		
				Sample	MQC[1]	MDC[2]	Sample	MQC	MDC	Sample	MQC	MDC
February 16, 1995												
Next to Beehive Furnace #7	0730 - 1355	4425	385	0.34	NR[3]	0.052	ND[4]	0.078	0.026	ND	0.078	0.039
Next to Beehive Furnace #1	0735 - 1356	4431	381	0.18	NR	0.052	ND	0.079	0.026	ND	0.079	0.039
RCF removal from Beehive Lid	0952 - 1400	4420	248	0.20	NR	0.081	ND	0.12	0.040	ND	0.12	0.060
	0952 - 1400	4426	248	0.16	NR	0.081	ND	0.12	0.040	ND	0.12	0.060
	0952 - 1400	4432	248	0.16	NR	0.081	ND	0.12	0.040	ND	0.12	0.060

[1]Minimum Quantifiable Concentration.
2Minimum Detectable Concentration.
[3]Not Reported.
[4]Not Detected.

TABLE II - Continued
Area Sample Time-Weighted Average (TWA) Concentrations of Total Particulate, Quartz, and Cristobalite
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Sample Location	Sample Period	Sample Number	Sample Volume (liters)	TWA Concentration (mg/m^3)								
				Total Particulate			Total Quartz			Total Cristobalite		
				Sample	MQC[1]	MDC[2]	Sample	MQC	MDC	Sample	MQC	MDC
February 17, 1995												
Next to Beehive Furnace #1	0700 - 1347	4412	407	0.12	NR[3]	0.049	ND[4]	0.074	0.025	ND	0.074	0.037
Next to Beehive Furnace #6	0703 - 1347	4417	407	0.10	NR	0.049	ND	0.074	0.025	ND	0.074	0.037
Between RCF Dumpster and entrance to Long Car Furnace #8137 during RCF removal	0738 - 1400	4418	382	0.10	NR	0.052	ND	0.079	0.026	ND	0.079	0.039
	0740 - 1400	4413	380	0.39	NR	0.053	ND	0.079	0.026	ND	0.079	0.039
	0741 - 1400	4419	381	0.52	NR	0.052	ND	0.079	0.026	ND	0.079	0.039
Analytical Limits of Quantification (LOQ) and Limits of Detection (LOD)												
LOQ (mg/Sample)				NR			0.03			0.03		
LOD (mg/Sample)				0.02			0.01			0.015		
Occupational Exposure Standards (mg/m^3)												
NIOSH REL				None			None			None		
OSHA PEL				15			None			0.15		
ACGIH TLV				10			None			None		

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3]Not Reported.
[4]Not Detected.

TABLE III
Personal Sample Time-Weighted Average (TWA) Concentrations
of Refractory Ceramic Fibers
Heat Treatment Beehive Furnace Area
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description / Classification	Sample Period	Sample Number	Sample Volume (liters)	Fiber Density per Sample (fibers/mm^2)	Total Fibers per sample	TWA Concentration (fibers/cc)		
						Sample	MQC[1]	MDC[2]
February 16, 1995								
Work Leader	0714 - 1354	12	390	[29][3]	11,165	[0.029]	0.099	0.0069
RCO Checker	0721 - 1353	11	392	[25]	9,625	[0.025]	0.098	0.0069
Furnace Operator	0718 - 1354	9	386	[25]	9,625	[0.025]	0.10	0.0070
February 17, 1995								
Work Leader	0721 - 1345	14	384	[41]	15,785	[0.041]	0.10	0.0070
RCO Checker / Crane Operator	0705 - 1346	15	401	[14]	5,390	[0.013]	0.096	0.0067
Furnace Operator	0706 - 1330	22	384	[9]	3,465	[0.009]	0.10	0.0070
Analytical Limit of Quantification (LOQ) and Limit of Detection (LOD)								
LOQ (fibers/mm^2) per Sample				100				
LOD (fibers/mm^2) per Sample				7				
Occupational Exposure Standards (fibers/cc)								
NIOSH REL						0.2[4]		
OSHA PEL						1.0[5]		
ACGIH TLV						None[6]		

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3][ ] = Value is between the MQC and MDC.
[4]NIOSH commented in the June 12, 1992, Federal Register that a 0.2 fibers/cc standard may be necessary to protect workers from the development of lung cancer.
[5]1 ceramic fiber/cc proposed in the June 12, 1992, edition of the Federal Register.
[6]The 1995-1996 edition of the ACGIH TLV and BEI booklet lists Fibrous glass dust (Synthetic Vitreous Fibers)under Chemical Substances and Other Issues Under Study.

TABLE IV

Personal Sample Time-Weighted Average (TWA) Concentrations
of Respirable Particulate, Quartz, and Cristobalite
Heat Treatment Beehive Furnace Area

Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description / Classification	Sample Period	Sample Number	Sample Volume (liters)	TWA Concentration (mg/m^3)								
				Respirable Particulate			Respirable Quartz			Respirable Cristobalite		
				Sample	MQC[1]	MDC[2]	Sample	MQC	MDC	Sample	MQC	MDC
February 17, 1995												
Work Leader	0721 - 1345	4423	652.8	0.092	NR[3]	0.031	ND[4]	0.046	0.015	ND	0.046	0.023
RCO Checker/Crane Operator	0705 - 1346	4421	681.7	0.13	NR	0.029	ND	0.044	0.015	ND	0.044	0.022
Furnace Operator	0706 - 1330	4428	652.8	0.061	NR	0.031	ND	0.046	0.015	ND	0.046	0.023
Analytical Limits of Quantification (LOQ) Limits of Detection (LOD)												
LOQ (mg/Sample)				NR			0.03			0.03		
LOD (mg/Sample)				0.02			0.01			0.015		
Occupational Exposure Standards (mg/m^3)												
NIOSH REL				None			0.1			0.05		
OSHA PEL				5			0.05			0.05		
ACGIH TLV				3			0.1			0.05		

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3]Not Reported.
[4]Not Detected.

TABLE V
Personal Sample Time-Weighted Average (TWA) Concentrations of Refractory Ceramic Fibers
Heat Treatment Beehive Furnace Lid and Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Fiber Counts by Phase Contrast Microscopy (PCM)
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description/ Classification	Sample Period	Sample Number	Sample Volume (liters)	Fiber Density (fibers/mm^2) per Sample	Total Fibers per Sample	TWA Concentration (fibers/cc)		
						Sample(s)	MQC[1]	MDC[2]
February 16, 1995								
Bricklayer #1	0944 - 1345	8	409.7	662	254,870	0.62	0.094	0.0066
Bricklayer #2	0946 - 1349	4	413.1	594	228,690	0.55	0.093	0.0065
Bricklayer #3	0945 - 1030	6	76.5	415	159,775	2.01	0.50	0.035
	1217 - 1349	3	156.4	655	252,175	1.61	0.25	0.017
Bricklayer #3 (all samples)	0945 - 1349		232.9			1.74	0.33	0.018
Analytical Limit of Quantification (LOQ) Limit of Detection (LOD)								
LOQ (fibers/mm^2) per Sample				100				
LOD (fibers/mm^2) per Sample				7				
Occupational Exposure Standards (fibers/cc)								
NIOSH REL						0.2[3]		
OSHA PEL						1.0[4]		
ACGIH TLV						None[5]		

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3]NIOSH commented in the June 12, 1992, Federal Register that a 0.2 fibers/cc standard may be necessary to protect workers from the development of lung cancer.
[4]1 ceramic fiber/cc proposed in the June 12, 1992, edition of the Federal Register.
[5]The 1995-1996 edition of the ACGIH TLV and BEI booklet lists Fibrous glass dust (Synthetic Vitreous Fibers) under Chemical Substances and Other Issues Under Study.

TABLE VI
Personal Sample Time-Weighted Average (TWA) Concentrations of Refractory Ceramic Fibers
Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Fiber Counts by Phase Contrast Microscopy (PCM)
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description/ Classification	Sample Period	Sample Number	Sample Volume (liters)	Fiber Density (fibers/mm^2) per Sample	Total Fibers per Sample	TWA Concentration (fibers/cc)		
						Sample(s)	MQC[1]	MDC[2]
February 17, 1995								
Bricklayer #1	0738 - 0831	32	53	[87][3]	33,495	[0.63][4]	0.73	0.051
	0831 - 0957	28	86	356	137,060	1.59	0.45	0.031
	0957 - 1401	18	244	377	145,145	0.59	0.16	0.011
Bricklayer #1 (all Samples)	0738 - 1401		383			[0.82][5]	0.30	0.021
Bricklayer #2	0731 - 0829	33	58	179	68,915	1.19	0.66	0.046
	0829 - 0957	21	88	404	155,540	1.77	0.44	0.031
	0957 - 1147	26	110	255	98,175	0.89	0.35	0.025
	1147 - 1351	1	124	688	264,880	2.14	0.31	0.022
Bricklayer #2 (all Samples)	0731 - 1351		380			1.55	0.41	0.029
Bricklayer #3	0727 - 0827	25	60	474	182,490	3.04	0.64	0.045
	0827 - 1002	20	95	697	268,345	2.82	0.41	0.028
	1002 - 1406	23	244	411	158,235	0.65	0.16	0.011
Bricklayer #3 (all Samples)	0727 - 1406		399			1.53	0.29	0.020

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3][ ] = Value is below the LOQ.
[4][ ] = Value is between the MDC and the MQC.
[5]Value is an estimate.

TABLE VI - Continued
Personal Sample Time-Weighted Average (TWA) Concentrations of Refractory Ceramic Fibers
Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Fiber Counts by Phase Contrast Microscopy (PCM)
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description/ Classification	Sample Period	Sample Number	Sample Volume (liters)	Fiber Density (fibers/mm^2) per Sample	Total Fibers per Sample	TWA Concentration (fibers/cc)		
						Sample(s)	MQC[1]	MDC[2]
Analytical Limit of Quantification (LOQ) and Limit of Detection (LOD)								
LOQ (fibers/mm^2) per Sample				100				
LOD (fibers/mm^2) per Sample				7				
Occupational Exposure Standards (fibers/cc)								
NIOSH REL						0.2[3]		
OSHA PEL						1.0[4]		
ACGIH TLV						None[5]		

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3]NIOSH commented in the June 12, 1992, Federal Register that a 0.2 fibers/cc standard may be necessary to protect workers from the development of lung cancer.
[4]1 ceramic fiber/cc proposed in the June 12, 1992, edition of the Federal Register.
[5]The 1995-1996 edition of the ACGIH TLV and BEI booklet lists Fibrous glass dust (Synthetic Vitreous Fibers) under Chemical Substances and Other Issues Under Study.

TABLE VII
Personal Sample Time-Weighted Average (TWA) Concentrations
of Respirable Particulate, Quartz, and Cristobalite
Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Fiber Counts by Phase Contrast Microscopy (PCM)
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description/ Classification	Sample Period	Sample Number	Sample Volume (liters)	TWA Concentration (mg/m^3)								
				Respirable Particulate			Respirable Quartz			Respirable Cristobalite		
				Sample	MQC[1]	MDC[2]	Sample	MQC	MDC	Sample	MQC	MDC
February 17, 1995												
Bricklayer #1	0734 - 1401	5128	658	0.076	NR[3]	0.030	ND[4]	0.046	0.015	ND	0.046	0.023
Bricklayer #2	0732 - 1351	4415	644	0.28	NR	0.031	ND	0.047	0.016	ND	0.047	0.023
Bricklayer #3	0721 - 1406	4427	678	0.37	NR	0.029	[0.031][5]	0.044	0.015	ND	0.044	0.022
Analytical Limits of Quantification (LOQ) and Limits of Detection (LOD)												
LOQ (mg/Sample)				NR			0.03			0.03		
LOD (mg/Sample)				0.02			0.01			0.015		
Occupational Exposure Standards (mg/m^3)												
NIOSH REL				None			0.1			0.05		
OSHA PEL				5			0.05			0.05		
ACGIH TLV				3			0.1			0.05		

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3]Not Reported.
[4]Not Detected.
[5][ ] = Value is between the MDC and the MQC.

TABLE VIII
Personal Sample Time-Weighted Average (TWA) Concentration of Refractory Ceramic Fiber
Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Sample #25 Fiber Count by Transmission Electron Microscopy (TEM)
Grid Opening Size: 0.013 mm^2
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Job Description/ Classification	Sample Period	Sample Number	Sample Volume (liters)	Openings Examined	Fibers Counted	Fiber Density (fibers/mm^2)	Total Fibers per Sample	TWA Concentration (fibers/cc)		
								Sample	MQC[1]	MDC[2]
February 17, 1995										
Bricklayer #3	0727 - 0827	25	60	25	84	258	99,508	1.7	NR[3]	0.020
Analytical Limit of Quantification (LOQ) and Limit of Detection (LOD)										
LOQ (fibers/mm^2)						NR				
LOD (fibers/mm^2)						3.1				
Occupational Exposure Standards (fibers/cc)										
NIOSH REL							0.2[4]			
OSHA PEL							1.0[5]			
ACGIH TLV							None[6]			

[1]Minimum Quantifiable Concentration.
[2]Minimum Detectable Concentration.
[3]Not Reported.
[4]NIOSH commented in the June 12, 1992, Federal Register that a 0.2 fibers/cc standard may be necessary to protect workers from the development of lung cancer.
[5]1 ceramic fiber/cc proposed in the June 12, 1992, edition of the Federal Register.
[6]The 1995-1996 edition of the ACGIH TLV and BEI booklet lists Fibrous glass dust (Synthetic Vitreous Fibers) under Chemical Substances and Other Issues Under Study.

TABLE IX
Personal Sample Refractory Ceramic Fiber Dimensions
Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Sample #25 Fiber Dimension Analysis by Transmission Electron Microscopy (TEM)
Grid Opening Size: 0.013 mm^2
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Structure Number	Length (μm)	Width (μm)	Structure Number	Length (μm)	Width (μm)	Structure Number	Length (μm)	Width (μm)	Structure Number	Length (μm)	Width (μm)
1	1.9	0.33	17*	9.7	0.8	33	10	0.27	49	4	0.27
2*	33	1	18	8.7	0.27	34*	15	0.8	50	13	1.3
3	27	0.67	19	6.7	0.33	35	1.3	0.33	51	17	0.8
4*	68	1	20	11	1.2	36*	6.7	0.2	52*	8.7	1
5	47	1	21	13	0.4	37	1.3	0.13	53	3.3	0.13
6	21	1	22	28	0.53	38	2.7	0.27	54	5.3	0.67
7	5.3	0.13	23*	6.7	0.4	39	27	0.27	55*	15	1.3
8*	33	1.3	24	8.7	1.3	40	3	0.4	56*	13	0.47
9*	13	1.3	25	7.3	0.47	41	4	0.27	57	1.3	0.2
10	7.3	0.67	26	1.5	0.13	42	8.7	1	58	9.3	0.67
11	50	1	27	6.7	0.27	43*	47	1	59*	4	0.27
12*	3.3	0.47	28	1.5	0.27	44	10	1.3	60*	18	1.3
13*	20	1.7	29	5.3	0.87	45*	4.7	0.2	61	3.1	0.8
14	6	0.27	30*	35	1.7	46*	18	1.3	62*	4	0.8
15*	6.7	0.87	31	3	0.47	47*	19	1	63*	4.3	0.33
16	2.7	0.67	32	6.7	0.67	48*	52	1	64	5.3	0.4

*Half fiber.

TABLE IX - Continued
Personal Sample Refractory Ceramic Fiber Dimensions
Long Car Furnace #8137
Refractory Ceramic Fiber Removal
Sample #25 Fiber Dimension Analysis by Transmission Electron Microscopy (TEM)
Grid Opening Size: 0.013 mm^2
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Structure Number	Length (μm)	Width (μm)		Structure Number	Length (μm)	Width (μm)		Structure Number	Length (μm)	Width (μm)		Structure Number	Length (μm)	Width (μm)
65*	17	0.67		76	15	1.3		87	4	0.13		98	4	0.47
66	6	0.47		77*	20	0.2		88*	15	0.33		99	12	0.87
67*	7.3	0.67		78*	4	0.67		89	20	1.7		100*	8.7	0.53
68	7	0.67		79*	4	0.73		90	4.7	0.87		101*	20	0.87
69*	4.3	0.13		80	1.7	0.27		91*	5.3	0.67		102*	2.7	0.87
70*	6.7	1.2		81	3	0.8		92*	11	0.67		103*	12	0.93
71*	13	0.67		82*	27	2		93*	5.3	0.27		104	4	0.27
72	13	1		83*	12	1.3		94*	18	0.27		105	7.3	0.8
73	3.3	0.67		84	19	1.7		95	10	1.2		106*	13	0.47
74*	4	0.2		85	10	1		96*	13	0.67		107*	23	1.7
75	0.87	0.13		86	1.7	0.2		97	5.7	0.53		108*	5.3	0.87

*Half fiber.

TABLE X
Bulk Sample Characterization by
Polarized Light Microscopy (PLM) and X-ray Diffraction (XRD)
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Sample Description	Sample Location	Sample Number	Sample Comment	Description	
				PLM	XRD
August 23, 1994					
Unused Fiberfrax® Blanket	From manufacturer	B1	Blanket is used to seal lid of Beehive Furnaces.	No crystalline phases detected.	No crystalline phases detected.
Unused Fiberfrax® Module	From manufacturer	B2	Modules used to line furnace interior.	No crystalline phases detected.	No crystalline phases detected.
Debris	Floor, Beehive Furnace Area	B3[1]	Collected between both rows of Beehive Furnaces.	Fibers not crystalline. Non-fibrous phases: Glass, Quartz, Opaques	Quartz, oxides of iron, silica, chromium, aluminum
Heat exposed Fiberfrax® from interior of furnace	Beehive Furnace #3	B4a	Fibrous portion of sample B4.	No crystalline phases detected.	No crystalline phases detected.
		B4b[1]	Non-fibrous portion of sample B4.	Glass, quartz, opaques.	Quartz, oxides of iron, silica, chromium, aluminum
	Long Car Furnace bottom	B5a	Fibrous portion of sample B4.	No crystalline phases detected.	No crystalline phases detected.
		B5b[1]	Non-fibrous portion of sample B4.	Glass, guartz, opaques	Quartz, oxides of iron, silica, chromium, aluminum

[1]Non-fibrous particles were not small (several micrometers or up to sand-sized). No conversion to cristobalite detected.

TABLE XI
Bulk Sample Characterization
by X-ray Diffraction (XRD)
Percent Crystalline Silica Analysis for Quartz and Cristobalite
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Sample Description	Sample Location	Sample Number	Core Depth inward from insulation surface (inches)	Sample Comment	Percent Composition	
					Quartz	Cristobalite
February 16, 1995						
Heat exposed Fiberfrax® Blanket	Wall, 80 feet into Long Car Furnace #8147	CB-01a	< 0.5	Non-Fibrous High Density	ND[1]	ND
		CB-01b	< 0.5	Fibrous	ND	ND
Heat exposed Fiberfrax® Module	Wall, 80 feet into Long Car Furnace #8147	NB-01a	< 0.5	Non-Fibrous High Density	ND	ND
		NB-01b	0.5 - 1.5	Fibrous	ND	ND
		NB-02	2.25	Fibrous	ND	ND
Heat exposed Fiberfrax® Module, prior to insulation removal	Wall, 160 feet into Long Car Furnace #8137	FB-01a	< 0.5	Non-Fibrous High Density	ND	ND
		FB-01b	0.5 - 3.0	Fibrous	ND	ND
		FB-02a	3.0 - 4.5	Fibrous	ND	ND
		FB-02b	4.5 - 6.0	Fibrous	ND	ND

[1]Not Detected.

TABLE XI - Continued
Bulk Sample Characterization
by X-ray Diffraction (XRD)
Percent Crystalline Silica Analysis for Quartz and Cristobalite
Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Sample Description	Sample Location	Sample Number	Core Depth inward from insulation surface (inches)	Sample Comment	Percent Composition	
					Quartz	Cristobalite
Heat exposed Fiberfrax® Module, prior to insulation removal	Wall, 120 feet into Long Car Furnace #8137	MB-01a	< 0.5	Non-Fibrous High Density	ND[1]	ND
		MB-01b	0.5 - 3.0	Fibrous	ND	ND
		MB-02a	3.0 - 4.5	Fibrous	ND	ND
		MB-02b	4.5 - 6.0	Fibrous	ND	ND
Heat exposed Fiberfrax® Module, prior to insulation removal	Wall, 80 feet into Long Car Furnace #8137	BB-01a	< 0.5	Non-fibrous High Density	ND	ND
		BB-01b	0.5 - 3.0	Fibrous	ND	ND
		BB-02	4.5	Fibrous	ND	ND
February 17, 1995						
Heat exposed Fiberfrax® Module	Wall, top of Beehive Furnace	HB-01	0.75	Fibrous	ND	ND
	Lid, Beehive Furnace	HB-02	0.75	Fibrous	ND	ND
		HB-03	2.25	Fibrous	ND	ND
Analytical Limits of Quantification (LOQ) and Limits of Detection (LOD)						
LOQ (% in bulk 2 milligram portion)					1.5	1.5
LOD (% in bulk 2 milligram portion)					0.75	0.75

[1]Not Detected.

FIGURE 1

Standard Steel
Burnham, Pennsylvania
HETA 94-0329

Fiber Count by Dimension

Sample #25 Fiber Dimension Analysis by TEM Total Fibers: 108

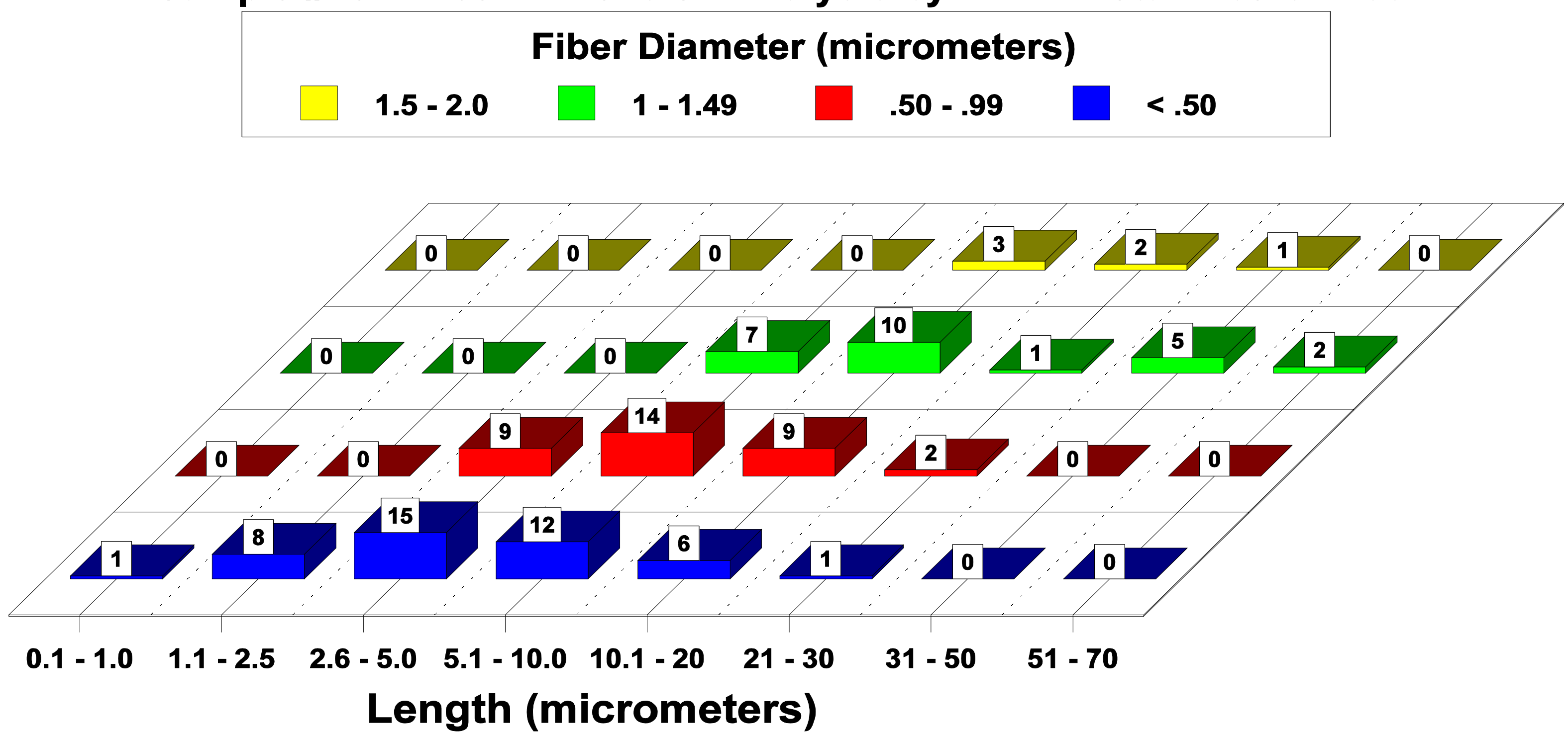

FIGURE 2

Standard Steel
Burnham, Pennsylvania
HETA 94-0329