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REPORT OF WILLIAM M. EWING, CIH
RE: MR. SAMUEL INGRAM

February 5, 2020

At the request of Mr. Shane Hampton of Simmons, Hanly Conroy, I have prepared this report concerning Mr. Sam Ingram's exposure to asbestos-containing materials (ACM). I am the Technical Director of Compass Environmental, Inc. located at 1751 McCollum Parkway, Kennesaw, GA 30144. I am certified in the comprehensive practice of industrial hygiene by the American Board of Industrial Hygiene (Certificate No. CP 2627). Industrial hygiene is the field of identification, evaluation and control of occupational and environmental health hazards. I have practiced industrial hygiene for 42 years with the emphasis on asbestos exposures in facilities. I have conducted asbestos investigations in over 2000 industrial, commercial, institutional, and governmental buildings. I have measured asbestos exposures to workers in the building trades and have researched the published literature, and unpublished reports and studies, to understand the historical exposures workers experienced. I am also familiar with the standards, guidelines and regulations applicable to workers' exposure to asbestos. I have conducted sampling for asbestos and analyzed such samples over the course of my career. I was formerly the director of the Environmental Protection Agency (EPA) sponsored Asbestos Information Center at the Georgia Tech Research Institute. I was a technical advisor to the EPA during the Brake Mechanics' Education Program and was Chair of the EPA-sponsored Asbestos Brake Conference in 1987. I have published approximately 25 articles on the subject of asbestos exposure. My curriculum vitae is attached providing specific details of my qualifications, experience and publications. Compass Environmental, Inc. invoices $325 per hour for my time plus any necessary expenses.

The following case specific materials were provided and which I have relied upon in developing my opinions.

1. Deposition of Mr. Sam Ingram dated May 31, June 1 and June 23, 2016 (3 volumes);
2. Affidavit of Mr. John Specklemeyer (co-worker of Mr. Ingram at Deyer);

3. Military records for Mr. Sam Ingram (27 pages);
4. Plaintiffs' Answers to Interrogatories; and,
5. Social Security Earnings Record for Mr. Sam Ingram.

Outlined below is a summary of my understanding of Mr. Ingram's work and personal history from which I have formed opinions. Should this understanding be incorrect or be augmented, my opinions may also change.

Mr. Sam Ingram was born on November 21, 1937 in Indianapolis, IN. He grew up in Indianapolis and lived his life in Indianapolis or Clermont, IN. He attended Arsenal Technical High School in Indianapolis but left after a few months in 1951. His father worked as a mechanical engineer for Ready Mix Concrete Corporation. His mother never worked outside the home. He was the youngest of nine children.

His first job was during 1951-1953, about 2.5 years working at Turner's Pure Oil service station. It had two service bays with one lift. He began by washing cars and pumping gasoline; and after 2-3 months doing mechanical work, including brake and clutch work. He also did engine tune-ups and other work requiring replacement of gaskets. He did tire work and batteries as well. He estimated he did about 10-12 brake jobs per month during his 2.5 years working at the service station. The work was mainly on drum brakes on American brands of vehicles. He recalled American Brake Blok, Bendix, and Delco Remy brands of replacement brake linings and shoes. He removed old friction from shoes and installed new linings on shoes with rivets. He beveled the edges with a grinder. Used compressed air to blow off the dust created by the beveling. After working at Turner's about 6 months he began doing clutch replacements. He estimated he did about 2-3 clutch jobs per month during his 2.5 years at the service station. He stated he used an electric jitterbug sanding device, sandpaper, and/or a wire wheel on the two sides of the clutch plates. He stated he removed some BorgWarner clutches, and installed BorgWarner and Delco clutches. He used compressed air to clean out the bell housing and described it as filthy and dusty. He recalled using gaskets manufactured by Dana, Victor, and Delco. All replacement parts came from Kersey's auto parts store.

Mr. Sam Ingram left home and served in the U.S. Marine Corps beginning in November 1955. He completed his 16 weeks of basic training in San Diego. From here he served in Okinawa, Japan and Camp Fuji Japan. In Japan he worked as a radio operator and field wireman. He next returned to Camp Lejeune, NC and then spent 6 months aboard a ship in the Mediterranean. He did training and some cleaning aboard the ship, but no mechanical work. He was honorably discharged from the service in December 1958.

After his military service he returned to Indianapolis and went to work at the Bryant manufacturing plant. He worked as a laborer deburring metal parts, degreasing metal parts, and also bending copper tubes. These were the only jobs he did at this plant during 1959-1961. His next job for about a year in 1962 was as a track wireman for the New York Central Railroad. He replaced corroded copper wire and wood crossties alongside tracks with new material. The wire was not insulated. He held additional jobs as a milkman for Roberts Dairy and truck driver. He operated an International tractor and would haul flatbed trailers with building materials. His work included picking up loads of mostly roofing from Johns-Manville Corporation's Waukegan plant.[1] He was only at the shipping and receiving warehouse. Sometimes (about 25%) he assisted in loading the flatbed trailers using a forklift. He unloaded the flatbed trailer himself about half the time. He visited the plant to pick-up loads 2-3 times per week over about two years. He delivered these materials to construction sites and retail stores.

His next job was at Volkswagen Speedway as a mechanic. This facility had 12 service bays with lifts. He worked exclusively on Volkswagen (VW) vehicles. He worked here during 1965-1966 according to his Social Security records. He recalled working on brakes and clutches. He stated he did brake jobs every day, sometimes two or three. They were all drum brakes. He used compressed air to blow out the brake dust. He beveled the edges of the new brake shoes on a pedestal grinder every time. He did about two clutch jobs per week. He would remove the engine to access the clutch disk behind the flywheel. He recalled the replacement brake shoes and clutches were shipped from VW in

[1] He stated he sometimes picked up other products like asbestos cement siding and pipe. He stated sometimes he unloaded materials by hand.

Germany. Some were riveted and some were bonded brake linings. He abraded the clutch friction surfaces of the new VW clutches with sandpaper and a wire wheel. He cleaned up his work area using a broom to sweep it clean the blow the dust out of the shop with compressed air. He did not do any major engine work. Most of his work was on VW Beetles, some VW buses, and some Karmann Ghias.

He next worked at Dreyers Cycles as a mechanic during 1966-1971.[2] He worked on British Small Arms (BSA) motorcycles and other brands. He replaced brakes and clutches, rebuilt engines, and other work. He stated they used drum type brakes. He recalled BSA, Bendix, Delco, and American Brake Blok brands. He described riveting new linings onto the shoes. He stated he beveled the edges (all four edges) of each brake shoe on a grinder. This activity took 2-4 minutes per shoe. He estimated he did 2-3 brake jobs per week, sometimes more.[3] He estimated he worked on clutches about 2-3 times per week as well.[4] The BSA motorcycles clutch was a pack of 6 lined plates and 6 stainless steel plates. These were wet clutches. He recalled using BSA, Barnett, and Delco clutch parts. He used sandpaper on the friction surface of the new clutches. He recalled using Dana gaskets at this location, especially on motorcycle overhauls. There were about 25 gaskets in the engine that were replaced during each overhaul. He removed old gaskets with a putty knife, sometimes a pocketknife, and sometimes a rotating wire wheel. He estimated he did at least 100 overhauls, or about 1-2 per month. All the gaskets were precut and came as a kit. He worked about 70% on BSA motorcycles, 20% Triumph motorcycles, and 10% other motorcycles such as Honda and Yamaha.[5]

In 1971 he left Dreyers Cycles and started his own shop, Sam Ingram Cycles. He continued to work on BSA motorcycles, but also all other brands, including 10% Yamaha, some Hondas, Suzukis, Kawasakis, and about 15 Harley Davidson motorcycles. He worked on brakes of BSA motorcycles a couple of times each week. He also replaced drum brakes on Harley Davidson motorcycles about 10 times with new Harley Davidson

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[2] Per Social Security records.
[3] He also estimated he did about 5 brake jobs per month.
[4] He also estimated he did about 4-5 clutch jobs per month.
[5] He did not work on BMW motorcycles but was around another mechanic that did. He also stated he only worked on BSA motorcycles at Dreyers and other mechanics worked on the other brands.

brakes. He replaced about 1-2 Honda and Yamaha brakes each month. He used compressed air to clean out brake wear dust, often followed by wiping with a solvent soaked rag. He continued to bevel all four edges of each brake friction on a bench grinder. He recalled ECB brakes. He used original equipment brakes on Yamahas, Suzukis, and Kawasakis. He replaced clutches as well. Wet clutches were not dusty. He continued to replace gaskets associated with engine work on the motorcycles. Installed precut gaskets. He closed the shop following a shoulder injury in about 1986.

In 1986, he and his son Daniel went into professional flat track motorcycle racing. Mr. Sam Ingram sole job was pit crew. During 1989-1993 they had Hondas, Yamaha, and one Harley Davidson. He did all the maintenance work on these including tires, cables, brakes, clutches, and engine overhauls. He recalled Barnett and Delco brakes. He installed only precut gaskets.

Outside of work he maintained his personal vehicles. He changed the brakes on his own vehicles about once every year or two starting at age 16 through about 2014. He recalled American Brake Blok and Bendix brands used. He used compressed air to clean out brake wear dust. He hand sanded the new friction.[6] He also did gasket work on personal vehicles using Dana, Victor, and Delco gaskets.

Mr. Ingram was diagnosed with malignant mesothelioma in early 2016. He died on November 4, 2016.[7]

Malignant mesothelioma is almost always associated with previous exposure to asbestos, with a latency period of at least 10 years. Exposures to asbestos are expressed as a concentration of asbestos (either as fibers or structures) in air. The units are either fibers per cubic centimeter of air (f/cc) or structures per cubic centimeter of air (s/cc). An industrial hygienist refers to a significant concentration of asbestos (in the air), or a significant exposure, as one that is statistically significant above background or baseline.

[6] Bendix brake dust is HD-100.
[7] Indianapolis Star, Obituary for Sam Ingram, published March 19, 2017.

There are several statistical tests used to make this determination, and such a determination is required for air sampling following an asbestos response action in a school building to comply with the Asbestos Hazard Emergency Response Act (AHERA) regulations. To be able to state there is a significant exposure to asbestos, and not due to chance alone, the exposure usually needs to be about 5-10 times the background level.[8]

The background level, usually referred to as the ambient level, is what is found from sampling the outdoor air. Many different numbers have been reported depending on how the measurements were done, dust/fibers included in the analyses, and location of the samples. Analyses by National Institute for Occupational Safety and Health (NIOSH) method 7400 uses the light microscope (phase-contrast) with results expressed in f/cc. Analyses by transmission electron microscopy (TEM) have results normally expressed as s/cc, but may also be expressed as f/cc. A structure can be a fiber, bundle of fibers, cluster of fibers, or a matrix with fiber(s) protruding.

Mr. Sam Ingram was repeatedly exposed to asbestos from friction products starting in about 1951 through 1953 and again during 1965 through about 1986. These exposures resulted from his mechanical work with brakes, clutches, and gaskets. Mr. Ingram used compressed air associated with much of his brake and clutch work. He used a grinder to bevel the edges of brake friction. He relined some brake shoes. He sanded clutch friction faces, and some brake friction.

Published studies in the scientific literature repeatedly demonstrate that significant airborne asbestos exposures occur when performing brake work where compressed air is used to clean out the brake assembly. (**Figure 1.**) Selikoff and Lee reported a range of exposures of 0.4 – 29.4 fibers per cubic centimeter (f/cc) when blowing dust out of brake drums.[9] Additional data demonstrate that even though the concentration in the brake wear dust may be only one percent or less, peak concentrations of 87 f/cc can occur during

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[8] Keyes, D.L. and J. Chesson, *A Guide to Monitoring Airborne Asbestos in Buildings*, Environmental Sciences, Inc., Tucson, AZ, 1989, p. 63.
[9] Selikoff, I.J. and D.H.K. Lee, *Asbestos and Disease*, Academic Press, New York, p. 115 (1978).

blowing the dust out of brake assemblies with compressed air.[10,11,12] Some brake wear dust collects in the brake drum and on the brake components as the brake lining wears down. When this dust is subject to the force of compressed air, the dust disperses into the air and is inhaled by the mechanic and others in the area.[13] This entrainment of the dust is recognized as a source of asbestos exposure among vehicle mechanics, and even sweeping of the dust has been shown to cause exposures in the range of less than 0.1 to 1.7 f/cc.[14,15] These exposures have been shown to pose a health risk to workers.[16,17]

Table 1 lists the specific ranges of exposure measured by some researchers investigating exposure during the specific activities of brake work. The data presented below include measurements taken on the person doing the actual work and measurements taken in the area while another person is doing the work.

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[10] Lorimer, W.V., et al., "Asbestos Exposure of Brake Repair Workers in the United States," *The Mt. Sinai J. of Med.*, Vol. 43, No. 3, pp. 207-218 (may-June 1976).
[11] Rohl, A.N., "Asbestos Exposure During Brake Lining Maintenance and Repair," *Environ. Res.*, Vol. 12, pp. 110-128 (1976).
[12] Plato, N., et al., "An Index of Past Asbestos Exposure as Applied to Car and Bus Mechanics," *Ann. Occup. Hyg.*, Vol. 39, No. 4, pp. 441-454 (1995).
[13] Rodelsperger, K., et al, "Asbestos Dust Exposure During Brake Repair," *Amer. J. Ind. Med.*, Vol. 10, pp. 63-72 (1986).
[14] Occupational Safety and Health Administration (OSHA), "Asbestos-Automotive Brake and Clutch Repair Work, Safety and Health Information Bulletin," Washington, DC, July 26, 2006 (Available at www.osha.gov/dts/shib/shib072606.html)
[15] Kauppinen, T., and K. Korhonen, "Exposure to Asbestos during Brake Maintenance of Automotive Vehicle by Different Methods," *Amer. Ind. Hyg. Assoc. J.*, Vol. 48, pp. 499-504 (1987).
[16] Lemen, R.A., "Asbestos in Brakes: Exposure and Risk of Disease," *Amer. J. Ind. Med.*, Vol. 45, pp. 229-237 (2004).
[17] Lloyd, J.W., "Current Intelligence Bulletin 5: Asbestos Exposure During Servicing of Motor Vehicle Brake and Clutch Assemblies," DHHS(NIOSH) Publication Number 78-127, August 8, 1975 [available at http://www.cdc.gov/niosh/docs/1970/78127_5.html], accessed November 4, 2014.

Table 1. Asbestos Measurements Reported During Brake Maintenance and Repair

Mt. Sinai data[18]

Blowing dust (auto brake drums) Area (n=5)	0.4 – 4.8 f/cc
Blowing dust (auto brake drums) Personal (n=4)	6.6 – 29.8 f/cc
Grinding used truck brake linings Area (n=2)	0.2 – 1.7 f/cc
Grinding used truck brake linings Personal (n=10)	1.7 – 7.0 f/cc
Beveling new brake Area (n=4)	0.3 – 0.6 f/cc
Beveling new brake Personal (n=5)	26.3 – 72.0 f/cc
Riveting new brake linings (n=2)	1.9 – 2.0 f/cc
Sweeping floor around grinder (n=1)	3.6 f/cc

Trucks & Buses – Kauppinen data

Opening of brakes (n=25)	<0.1 – 1.9 f/cc	mean = 0.4 f/cc
Cleaning brake by brushing (n=8)	0.1 – 4.5 f/cc	mean = 1.3 f/cc
Cleaning brake with damp cloth (n=3)	1.1 – 3.3 f/cc	mean = 1.9 f/cc
Cleaning brakes by washing (n=6)	<0.1 – 0.2 f/cc	mean = 0.1 f/cc
Punching rivets into linings (n=12)	<0.1 – 1.6 f/cc	mean = 0.7 f/cc
Grinding brake linings (n=5) on machine – no exhaust	0.3 – 125 f/cc	mean = 56 f/cc
Grinding brake linings (n=30) On machine – with exhaust	0.1 – 5.9 f/cc	mean = 1.5 f/cc
Beveling edges of brake with file (n=7)	0.1 – 0.9 f/cc	mean = 0.4 f/cc
Assembling of brakes (n=9)	<0.1 – 0.4 f/cc	mean = 0.2 f/cc
Sweeping floor of garage (n=4)	<0.1 – 1.7 f/cc	mean = 0.6 f/cc

Passenger cars – Kauppinen data

Opening and brushing drum brakes (n=4)	0.3 – 0.6 f/cc	mean = 0.4 f/cc
Compressed air cleaning drum brakes (n=9)	<0.1 – 8.2 f/cc	mean = 1.5 f/cc
Comp. air cleaning with exhaust (n=5)	<0.1 – 0.2 f/cc	mean = 0.1 f/cc
Changing disc brakes (no clean) (n=10)	<0.1 - <0.1 f/cc	mean = <0.1 f/cc
Change clutch linings (n=3)	<0.1 – 0.1 f/cc	mean = <0.1 f/cc

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[18] Rohl, Rohl, A.N., "Asbestos Exposure During Brake Lining Maintenance and Repair," *Environ. Res.*, Vol. 12, pp. 110-128 tables 3 & 4 (1976).

Rodelsperger Data[19]

76 German Shops	Passenger Cars	Trucks/Buses
	Average Fiber Dose (fibers>5 micrometers per cc-minute)	
Blowing out (n=5,8)	4.7	5.3
Dry Brushing (n=6,1)	4.0	9.3
Riveting (n=0,7)	-	9.0
Grinding by hand (n=5,0)	3.9	-
Machine grinding (n=10,4)	3.9	9.9
Turning truck drum linings(n=0,21)	-	8.6
Combinations (n=14,5)	3.8	4.4

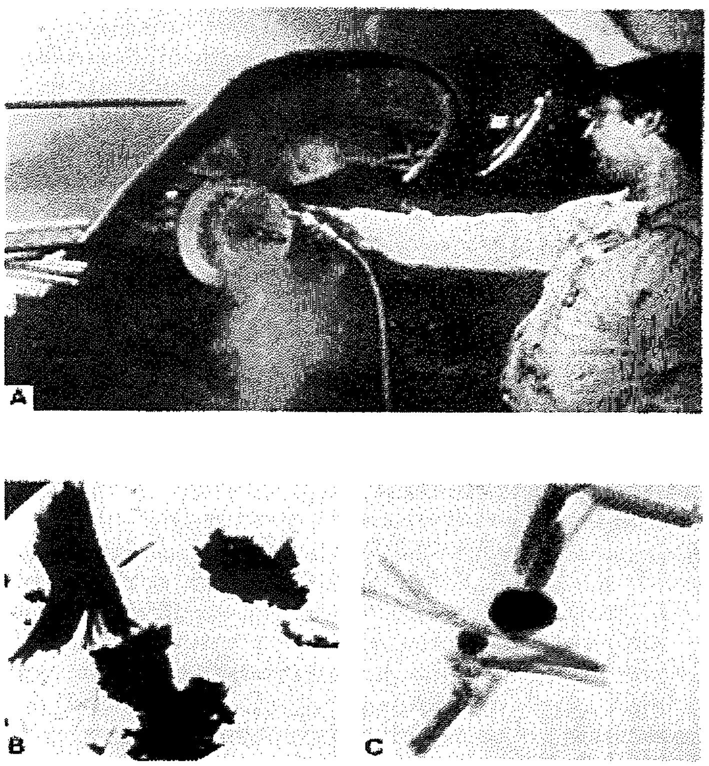

Figure 1. Blowing brake dust from a drum brake using compressed air and electron micrographs of the same brake dust

[19] In this study the exposures were normalized by converting exposure measurements in f/cc to dose measurements in f/cc per minute. For example, a measurement of 10 f/cc for a 3-minute sample during blow out would be converted to 3.3 f/cc-minute. To compare the dose number to an 8-hour PEL of 0.1 f/cc the PEL is recalculated as 0.1 f/cc times 480 minutes, or 48 f/cc-min.

The National Institute for Occupational Safety and Health (NIOSH) undertook a study to evaluate mechanics' exposures to asbestos during brake work at 11 service centers in the Cincinnati area.[20] Their report provides a brief history of the development and use of friction materials for vehicle braking applications. Six of the 11 facilities service automobiles and performed 2-45 brake jobs per week at about 65 minutes per vehicle. Four facilities did 5-45 brakes jobs per week on automobiles and trucks. One facility only did truck brake servicing. They conducted personal and area air sampling following Physical and Chemical Analysis Method (P&CAM) 239 except for some short-term samples where they used a flowrate of about 10 liters per minute. A subset of samples was analyzed by transmission electron microscopy (TEM). The methods for cleaning the brake wear dust varied from compressed air blow-out, compressed air/solvent mist wash off, dry brushing, wet brushing, squirt bottle, and HEPA[21] filtered vacuum method. There was no brake arcing, beveling, grinding, or sanding conducted.

The NIOSH report found that two of the four peak samples, collected during compressed air blow-out of the brakes were over the Occupational Safety and Health Administration (OSHA) Short Term Excursion Level (STEL) in place at the time (10 f/cc for 15 minutes). The 8-hour, time-weighted average (TWA) exposures were all below the then current OSHA 8-hour TWA Permissible Exposure Limit (PEL) of 2 f/cc. When the 8-hour TWA values were compared to the then NIOSH Recommended Permissible Exposure Limit (RPEL) of 0.1 f/cc there were 8 of 13 exposures over this level. All of the peak exposures exceeded the NIOSH STEL RPEL of 0.5 f/cc in place at the time. They also found that the exposures were consistent among the mechanics in the shop, even among those not working on the brake replacements.

The TEM analyses found that 80-90% of the fibers detected by TEM were less than 5 micrometers in length and therefore not counted by the optical method. They found that the geometric mean length for chrysotile fibers was 1.70 micrometers and a geometric mean width of 0.15 micrometers.

[20] Roberts, D.R. and R.D. Zumwalde, Assessment of Asbestos Exposure to Mechanics performing Brake Service Operations, NIOSH, Cincinnati, OH, April 27, 1981.
[21] HEPA = high efficiency particulate air

On December 1-2, 1976 Bell Laboratories conducted sampling at three garages in the Miami area.[22] Each of these garages performed preventive maintenance inspections of the brakes on ½ or ¾ ton service vans. When necessary new brake shoes were installed. Personal air sampling following P&CAM 239 was in a range of 0.16 – 0.24 fibers greater than 5 micrometers per cubic centimeter (f/cc) with an additional three samples too heavy to count due to overloading. Four area samples and one outside ambient air sample were submitted for electron microscopy analyses looking only at fibers greater than 5 micrometers in length. One inside sample was 0.24 f/cc and the remaining were below the limit of detection.

Paik & Lee evaluated exposures at two automobile maintenance shops during the 1980s.[23] **Table 2** summarizes their findings.

Table 2. Airborne Fiber Concentrations During Brake Servicing

Process	No. Samples	Geometric Mean (f/cc)	Range (f/cc)
Grinding Brake Lining	16	0.28	0.04 – 2.51
Assembling Brake Lining	7	0.40	0.03 – 3.04
Changing Brake Lining	8	0.02	0.01 – 0.13
Brushing Brake Lining	12	0.26	0.08 – 0.62
Cleaning with Compressed Air	5	4.26	0.11 – 7.28
Brake Lining Test	3	0.06	0.04 – 0.09

The brake shoes that Mr. Ingram worked with were likely asbestos-containing throughout his career, and when working on personal vehicles until at least the late 1980s. At this point the brake shoes began shifting over to non-asbestos alternatives. Semi-metallic brake pads for disk brakes were widely used during the 1970s, and later. The asbestos-

[22] Kenny, G.D., Bell Telephone Laboratories, Asbestos Exposures During Brake Changes, March 30, 1977.
[23] Paik, N.W. and Y.H. Lee, "Characterization of Worker Exposure to Airborne Asbestos in Asbestos Industry," *Korean Ind. Hyg. Assoc. J.*, Vol. 1, No. 2, November 1991, pp. 144-153.

containing brakes used by Mr. Ingram likely contained approximately 40-50 percent chrysotile asbestos.[24,25]

Mr. Ingram was exposed to significant concentrations of asbestos when he performed brake beveling (chamfering) of new brake friction material. Exposures of up to 125 f/cc have been reported during grinding of friction (on truck brakes) with no local exhaust. Published sources indicate that beveling of brake materials results in a range of exposure of 26.3 – 72.0 f/cc. In a study using Carlisle brake blocks the beveling produced exposures in a range of 69 – 241 f/cc.[26] Similar conclusions were reached in the study by Falgout.[27] In eight tests of brake grinding he found an average of 465.1 f/cc per gram of brake material ground. He also found that only 3 of 113 asbestos structures would be seen by the phase contrast microscope. The hand sanding of the friction surfaces (brakes and clutches) would also produce elevated exposures, but not in the range of grinding or beveling. One study measured personal exposures during the hand sanding activity in a range of 2.4 - 7.2 f/cc (n=5, with PCME of 2.1 - 2.4 f.cc).[28]

Mr. Ingram was also exposed as a bystander to the work performed by others at times. Researchers from Mt. Sinai School of Medicine in New York evaluated exposures during automotive and truck brake repair at a repair shop during the 1970s.[29] They looked at the exposures to fibers during blow-out of brake drums, at various distances from the work, and after time had elapsed from the work. **Tables 3** and **4** summarize these results.

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[24] Environmental Protection Agency, "Asbestos: A Review of Selected Literature through 1973 Relating to Environmental Exposures and Health Effects," Publication No. EPA-560/2-76-001, EPA Office of Toxic Substances, Washington, DC (January 1976), p. 28.
[25] "Brake Linings: Goodbye Asbestos, Hello Semi-mets, Glass and Plastics," *Brake and Front End*, May 1985, pp. 29-37.
[26] Millette, J.R., "Beveling Carlisle Truck Brakes," Report of a study to Simmons Cooper, August 25, 2009.
[27] Falgout, D.A., "Environmental Release of Asbestos from Commercial Product Shaping," EPA Publication No. 600/S2-85/066, August 1985.
[28] Materials Analytical Services, Inc., "Opening of Brake Box and Hand Sanding of Brake Shoes," Report dated February 16, 2004.
[29] Rohl, A.N., et al. (1976).

Table 3. Exposures at Distance during drum brake blowout

Operation	Distance (ft.)	N	Fiber Concentration (f/cc) Mean	Fiber Concentration (f/cc) Range
Blowout of	3 - 5	4	16.0	6.6 - 29.8
brake drums with	5 - 10	3	3.3	2.0 - 4.2
compressed air	10 - 20	2	2.6	0.4 - 4.8

Table 4. Exposures at distances during and following brake drum blowout

	Distance (ft.)	Time lapse (min.)	Fiber Concentration (f/cc)
Background samples	10	0	0.3
taken at varying	20	0	0.8
distance and lapsed	12	5	0.2
times, after brake	50	5	0.1
drum blowing	65	7	0.1
	75	14	0.1

Researchers from Ford published data they collected in the late 1960s.[30] The point of the research was to evaluate a novel control device against the usual method of blowing out brake dust. They also measured the concentration of fibers in an adjacent repair bay to simulate the exposures of mechanics working nearby. They found 0.84 - 5.35 f/cc (n=2) for the mechanics doing the blowouts, and 0.16 - 0.52 f/cc (n=2) in the adjacent repair bay. These measurements were collected over a one-hour period.

The same researchers from Ford repeated this work to evaluate truck brake servicing during the late 1960s.[31] During a 3-hour period a mechanic serviced truck brakes that included the use of compressed air. His measured exposure was reported as 7.09 f/cc during this work. The measured concentration during the same 3-hour period in the adjacent service bay was 0.28 f/cc, and in two bays away it was 0.17 f/cc.

Mr. Ingram was exposed to asbestos when handling the old brake shoes and unpacking the new shoes. In a study sponsored by Ford, GM and Chrysler, researchers measured

[30] Knight, K.L. and D.E. Hickish, "Investigations into Alternative Forms of Control for Dust Generated During the Cleaning of Brake Assemblies and Drums," *Annals of Occup. Hyg.*, Vol. 13, 1970, pp.37-39.
[31] Knight, K.L. and D.E. Hickish, "Exposure to Asbestos During Brake Maintenance," *Annals of Occup. Hyg.*, Vol. 13, 1970, pp. 17-21.

exposures when packing and unpacking asbestos-containing brake shoes and pads to estimate the exposures parts suppliers would have encountered when handling brake shoes. They reported the average airborne 30-minute asbestos concentration of 0.086 – 0.368 f/cc when unpacking and repacking brake pads; and 0.021 – 0.126 f/cc when unpacking and repacking brake shoes.[32]

Mr. Ingram performed clutch replacements on vehicles, including motorcycles. An article by Cohen and Van Orden summarized a study sponsored by the Borg Warner Corporation to estimate vehicle mechanics' exposure to asbestos from clutch removal.[33] The authors reported a range of exposures of 0.015 – 0.13 f/cc during this work. In this study the clean out the bell housing was not done. This activity would result in additional exposures. It would be expected that Mr. Ingram's past exposures when performing clutch replacements would be consistent with the Cohen and Van Orden data, with additional peak exposures during clean out of the clutch wear dust from the bell housings. It would not be expected to have any significant increase in asbestos exposure when removing a wet clutch from a motorcycle clutch basket. Mr. Ingram also handled many clutches. A study was performed to estimate exposures from handling clutch boxes.[34] They reported 15 minute and 60-minute exposures in a range of 0.006 - 0.37 f/cc (0.004 - 0.70 s/cc) for handling clutch boxes. This is consistent with the findings of sampling conducted by Ford during unpacking of pressure plates and opening clutch plate boxes.[35] They reported a range of 0.05 – 0.30 f/cc.

Mr. Ingram was exposed to asbestos at times when he replaced asbestos-containing gaskets on vehicles. Some gaskets were cork or rubber and resulted in no excess exposure. Other gaskets may have been completely covered with a layer of soft metal

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[32] Madl, A.K., et al., "Exposure to Chrysotile Asbestos Associated with Unpacking and Repacking Boxes of Automotive Brake Pads and Shoes," *Ann. Occup. Hyg.* Vol. 52, No. 6, 2008, pp. 463-479.
[33] Cohen, H.J. and D. R. Van Order, "Asbestos Exposures of Mechanics Performing Clutch Service on Motor Vehicles, *J. Occup. And Environ. Hyg.*, Vol. 5, No. 3, 2008, pp. 148-156.
[34] Jiang, G.C.T., et al., "A Study of Airborne Chrysotile Concentrations Associated with Handling, Unpacking, and Repacking Boxes of Automotive Clutch Discs," *Reg. Tox. and Pharm.* 51 (2008), pp. 87-97.
[35] Francis, Mark R., Letter Report to C.J. Augey, Industrial Hygiene Asbestos Study – Clutch Assembly Area, May 14, 1979.

(e.g., copper) effectively encasing the asbestos fibers within. Asbestos-containing gaskets that were removed would have likely resulted in some exposure. Asbestos-containing gaskets were used for cylinder head applications, intake manifolds, and exhaust manifolds, among other locations in the engine.[36] New compressed sheet gaskets for hot surfaces began changing over to asbestos-free in the late 1980s. However, in-place gaskets that were installed into engines on hot surfaces and exhaust systems prior to that time were usually asbestos-containing. Exposures to asbestos-containing vehicle gaskets would be highly variable depending, among other factors, how easily the gasket released from the surface and how vigorous the flange cleaning procedure. It would also depend on the technique used to remove the in-place asbestos-containing gaskets.

Industrial hygiene sampling has been conducted over the years to measure exposures to asbestos when working with compressed sheet gaskets containing asbestos. A sheet gasket forms a seal between two non-moving surfaces to prevent the leakage of a liquid or a gas. In place and undisturbed the asbestos in the gasket is not released from the materials. However, when the gaskets are removed, cut, drilled, sawed, sanded, or in other ways abraded asbestos fibers are released. The historical data is largely focused on asbestos gasket manufacturing operations, and exposures from work with asbestos gaskets used on pipes, valves, pumps, and similar equipment.

In one study conducted by the U.S. Navy where 14 samples were collected in the breathing zone of workers during the removal of gaskets using a hand scraper they found a range of exposures from less than 0.06 fibers (greater and 5 micrometers in length) per cubic centimeter (f/cc) to 0.39 f/cc with an average of 0.13 f/cc.[37] A published article by industrial hygienists from Chevron Corporation found an exposure range of 0.11 – 0.33 f/cc when removing sheet gaskets using dry scraping and brushing.[38] Millette et al. also

[36] Zeitz, J.E., "What Will Replace Asbestos Gaskets?", *Diesel & Gas Turbine Progress*, July 1980.
[37] Ibid., p. 41.
[38] Cheng, R.T. and H.J. McDermott, "Exposure to Asbestos from Asbestos Gaskets," *Appl. Occup. Environ. Hyg.* 6(7), 1991, pp. 588-591.

found a significant increase in exposures to asbestos when performing maintenance operations on asbestos gaskets.[39]

McKinnery and Moore published their findings from work with asbestos gaskets.[40] Based on 23 personal samples they found a range of 0.05 – 0.44 f/cc for gasket removal and installation using light microscopy for analysis. The numbers increase dramatically to 0.86 – 18.45 asbestos structures per cubic centimeter (s/cc) when the analysis is performed by transmission electron microscopy (TEM). The electron microscope is capable of seeing the shorter and thinner asbestos fibers not detected by the light microscope.

In 1976, Briggs & Stratton conducted industrial hygiene sampling to measure the exposure of workers handling asbestos-containing head gaskets for small engines.[41] The results were in a range from less than 0.073 to 2.6 f/cc. More recently measurements have been conducted on mechanics doing work with engine and/or exhaust system gaskets. Boelter, et al. collected 30-minute measurements during "Gasket-related work" that included anything from handling metal parts, wiping down parts, to scraping compressed sheet gaskets. The results were reported in a range of 0.044 - 0.413 f/cc by phase-contrast microscopy (PCM) using NIOSH method 7400; and 0.044 - 0.413 f/cc by transmission electron microscopy (TEM) using NIOSH method 7402.[42] The authors stated, "Removed and replaced gasket materials positive for asbestos ranged from 3% to 85% chrysotile." Unfortunately, the article did not disclose to what extent non-asbestos-containing gaskets were involved in the work for which the air samples described above were collected. However, the study authors did disclose this information in a paper presented at the 2005

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[39] Millette, J.R., et al., "Releasability of Asbestos Fibers From Asbestos-Containing Gaskets," *EIA Technical J.*, Fall 1995, pp. 10-15.
[40] McKinnery, W.N. and R.W. Moore, "Evaluation of Airborne Asbestos Fiber Levels During Removal and Installation of Valve Gaskets and Packing," *Amer. Ind. Hyg. Assoc. J.* (53), 1992, pp. 531-532.
[41] Letter report from Jack E. Peterson, Ph.D. to A.T. Dirksmeyer of Briggs & Stratton dated May 3, 1976.
[42] Boelter, F. W., et al., "Heavy Equipment Maintenance Exposure Assessment: Using a Time-Activity Model to Estimate Surrogate Values for Replacement of Missing Data," J Occup. Environ. Hyg., July 2007, pp. 525-537 (Table IV).

American Industrial Hygiene Conference. Twenty-two (22) of the 62 gaskets contained asbestos, or 35 percent.[43]

A study by Liukonen, L.R. and F.W. Weir measured exposures to fibers during work with gaskets associated with disassembly of a medium duty diesel engine.[44] They reported 14 personal sampling results analyzed by NIOSH 7400 in a range of 0.017 - <0.120 f/cc. Unfortunately, the only personal sample collected during the "buffing of head gasket surface" was not analyzed since the "sample overloaded with particulate." The bulk sample analyses of the gaskets found that 28 of the 33 gaskets handled in this study contained 5 - 70% chrysotile asbestos.

A study by Paustenbach, et al. measured exposures during work involving exhaust systems on 15 General Motors, Chrysler and Ford automobiles built during 1953-1970 and one automobile built in 1946.[45] Compressed sheet gaskets were associated with exhaust systems of these vehicles. Some of the gaskets were asbestos-containing and some were not. Of the asbestos-containing gaskets, bulk sample analyses by x-ray diffraction were reported to be in a range of 9.5 - 80.1% chrysotile. All of the 16 vehicles had exhaust manifold gaskets. During the removal of 12 of these exhaust systems the researchers chose not to remove these exhaust manifold gaskets. For the other four vehicles that the exhaust manifold gaskets were removed only two contained asbestos. No wire brushing was used to remove the residual gasket material from these two flanges. The researchers collected a total of 35 personal samples; excluded 5 personal samples that were overloaded with particulate, excluded 7 samples collected when working on exhaust systems known to have no asbestos components; leaving 23 samples that were analyzed. The article reported 0.006 - 0.066 f/cc (am=0.022 f/cc) for these samples by PCM and 0.0005 - 0.105 f/cc (am = 0.013 f/cc) for these samples by TEM.

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[43] Boelter, F.W., et al, "Airborne Asbestos Fiber Exposure Assessment of Heavy Equipment Mechanics," American Industrial Hygiene Conference (presentation), Anaheim, CA, 2005.
[44] Liukonen, L.R. and F. W. Weir, "Asbestos Exposure from Gaskets during Disassembly of a Medium Duty Diesel Engine, " Reg. Tox. Pharm. Vol. 41, 2005, pp. 113-121.
[45] Paustenbach, D.J., et al., "Chrysotile Asbestos Exposure Associated with Removal of Automobile Exhaust Systems (ca. 1945-1975) by Mechanics: Results of a Simulation Study," J. Exposure Sci. Environ. Epi., Vol. 16, 2006, pp. 156-171.

A study by Blake, et al. examined exposures during "the partial disassembly of engines and the removal of gaskets remnants from engine receiving surfaces and loose parts."[46] It also examined "engine reassembly" and "installation of new asbestos-containing gaskets." The work was done on three automobiles (1974 Chevrolet Malibu, 1978 Chevrolet pickup truck, and a Ford Thunderbird). In describing the work practices followed it was stated, "To aid in the gasket and other residue removal process, the mechanic sprayed the parts with a non-chlorine containing solvent dispersed from an aerosol spray can, Aerosol Systems, Inc., P/N TM 3506." It was further stated, "Loose parts, such as engine heads and manifolds, were next immersed into a water bath cleaner, a product of Safety Kleen, and washed using an Arm and Hammer brand Aqua Works Cold Cleaning Solution, before being burnished using a rotary 1-in. knot type wire end brush, NAPA service tools Part Number (P/N) 2312." A total of 6 personal samples were collected on the mechanic during the three engine disassemblies (one on the left shoulder and one on the right shoulder during each engine disassembly work). The range for these 6 samples was 0.007 - 0.027 f/cc as analyzed by PCM NIOSH 7400. The TEM by NIOSH 7402 results were not provided in the article, with only the asbestos fiber ratio reported. A total of 6 of the 9 compressed sheet gaskets involved in this study were found to be asbestos-containing in the range of 14 - 75% chrysotile. Three of the 9 (33%) were not asbestos containing. Measurements during the installation of new gaskets did not detect asbestos fibers in the four personal samples by NIOSH method 7402. The article concluded this was "due to the gasket being precut and sprayed with an adhesive sealant."

It is my opinion that Mr. Ingram's exposure to asbestos resulting from his gasket work was in the range of <0.01 - 1.0 f/cc, with a likely geometric mean (average) of about 0.1 f/cc for a 15-minute period.

Mr. Ingram likely had some exposure to asbestos associated with his loading and unloading of his flat bed delivery truck with certain products from the Johns Manville plant/warehouse in Waukegan, IL. Mr. Ingram was exposed to asbestos dust from

[46] Blake, C.L., et al., "Assessment of Airborne Asbestos Exposure during the Servicing and Handling of Automobile Asbestos-containing Gaskets," Reg. Tox. Pharm. Vol. 45, 2006, pp. 214-222.

asbestos cement pipe. In 1977, the Asbestos Cement Pipe Producers Association conducted a study to measure exposures during various activities with asbestos cement pipe.[47,48] They reported when loading and unloading asbestos cement pipe (n=4) the exposures were less than the detection limit (<0.01 f/cc) to 0.03 f/cc.

I hold the opinions expressed herein to a reasonable degree of scientific certainty.

This report prepared by: William M. Ewing
William M. Ewing, CIH

Date: February 5, 2020

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[47] Noble, W.M., et al., of Equitable Environmental Health, Inc. "Asbestos Exposures During the Cutting and Machining of Asbestos Cement Pipe," Report to The Asbestos Cement Pipe Producers Association, Arlington, VA, March 16, 1977.
[48] Equitable Environmental Health, Inc. "Dust Exposures During the Cutting and Machining of Asbestos Cement Pipe, Additional Studies" Report to The Asbestos Cement Pipe Producers Association, Arlington, VA, December 15, 1977.