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History and evolution of warning labels for automotive friction products

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ABSTRACT

There have been claims over the years that asbestos-containing product manufacturers did not sufficiently warn end users early enough regarding the potential health hazards associated with their products (1930s–1990s). To address this issue, we compared the content of the warnings associated with asbestos-containing friction products (brakes, clutches, and gaskets) manufactured by the US automotive industries to what was expected by regulatory agencies during the time period in which an understanding of asbestos health hazards was being developed. We ended our evaluation around 1990, since asbestos-containing manufacturer supplied automotive products were functionally removed from commerce by 1985 in the United States. We assessed the warnings issued in users' manuals, technical service bulletins, product packaging materials, and labels placed on products themselves. Based on our evaluation, regulatory agencies had no guidelines regarding specific warning language for finished friction products, particularly when a product contained encapsulated asbestos fibers (i.e., modified by a bonding agent). Even today, federal regulations do not require labeling on encapsulated products when, based on professional judgment or sampling, user exposure is not expected to exceed the OSHA PEL. We concluded that, despite limited regulatory guidance, the US automotive industry provided adequate warnings with regards to its friction products.

1. Introduction

Warning signs or labels are intended to make people aware of the presence of a hazard, provide guidance as to how the hazard can be avoided, and provide information regarding the consequences of exposure to the hazard (Rousseau and Wogalter, 2006). Since the Pure Food and Drug Act of 1906, numerous federal regulations have been published which address hazard labeling of a variety of substances (e.g., food, poisons, insecticides, chemicals in general) (Ayres et al., 1998). Warning labels serve several roles. First, they allow individuals to make an informed decision before using or purchasing a product. Second, they aid in limiting exposure by providing information on how a substance or product should be handled (e.g., the need to wear rubber gloves while handling a hazardous chemical). Third, hazard warnings act as an intermediate policy between absence of regulation and more restrictive controls, such as product bans or character alterations (Viscusi, 1996). In addition to federal regulations, voluntary standards also exist for product labeling. Even though voluntary standards are not legally enforceable, they are generally offered by manufacturing associations, and often are a major factor in regulatory agency decisions. The first industry-specific voluntary standards for products other than substances such as foods, poisons, insecticides, and chemicals in general began appearing in the 1970s (Ayres et al., 1998).

Modern labeling requirements are overseen, in part, by the American National Standard Institute (ANSI) Z535 Committee on Safety Signs and Colors (ANSI, 1991). The purpose of the ANSI Z535 Committee is to "develop standards for the design, application, and use of signs, colors, and symbols intended to identify and warn against specific hazards and for other accident prevention purposes" (ANSI, 1991, p. iii). The origin of the current ANSI began with the standardization of safety colors in the American War Standard, which was developed by the War Department and approved by the American Standards Association (ASA) on July 16, 1945 (Peckham, 2006). Five subcommittees were created to update and write the following five standards: *Safety Color Code, Environmental and Facility Safety Signs, Criteria for Safety Symbols, Product Safety Signs and Labels*, and *Accident Prevention Tags*; some of these standards have been combined and updated with time (ANSI, 1991; NEMA, 2011) In 2006, a sixth subcommittee was created, *Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials* (ANSI, 2006b). Together, these six standards contain information specifying format, colors, and symbols for safety signs used in environmental and facility applications,

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in product and product literature applications, and in temporary safety tag and barricade tape applications (NEMA, 2011). The standards suggested by ANSI are not a requirement, but rather a guide to aid the manufacturer, consumer, and general public. The ANSI qualified that precautionary labels "cannot be expected to cover the complete information on the properties of a material or the complete details of its proper handling under all conditions" (ANSI, 1976, p. 7). The ANSI also stated that products that presented no hazard in normal handling or storage were not required to present a label (ANSI, 1976).

According to Wogalter et al. (2002), an effective warning label should contain four message components: (1) a word to attract attention; (2) hazard identification; (3) hazard prevention instructions; and (4) an explanation of the consequences following an exposure to the hazard.

Research conducted to evaluate warning label effectiveness can be generally divided into three categories: signal word, symbol, and text (McGrath, 2011). The ANSI identified three signal words that can be used to call for attention: danger, warning, and caution (McGrath, 2011). The description of each word is defined by the ANSI according to the perceived level of risk. 'DANGER' indicates a "hazardous situation which, if not avoided, will result in death or serious injury", 'WARNING' indicates a "hazardous situation which, if not avoided, could result in death or serious injury", and 'CAUTION' indicates "a hazardous situation which, if not avoided, could result in minor or moderate injury" (ANSI, 2007, p. 4). Although some studies have shown that perception of the three words may differ from the ANSI definitions, the ANSI recommendations can be a useful guideline. With regard to using a symbol, such as a pictorial or pictogram, interpretations of the symbol may differ based on cultural background. Lastly, text that contains an explicit warning, or those that contain specific information about the nature of the hazard, particularly those with a statement of consequences, have "improved warning label comprehension" and possible increased the perceived risk of these products (McGrath, 2011, p. 50).

Despite the expected benefits of warning labels, functionally, they may not ultimately insure protection of the user. First, the warning labels placed on products may not be read, or a user may not follow the label instructions. If that happens, the language and content of the warning would not reduce hazardous behavior or exposure risk (Viscusi, 1996). For example, research conducted on patient misinterpretation of prescription drug label instructions has shown that people with lower literacy rates have a higher rate of misunderstanding drug labels than do those with marginal or adequate literacy (Wolf et al., 2007). In a later study, Wolf et al. (2010) showed that using simplified text paired with icon labels improved warning interpretation among patients with marginal and low literacy rates. Furthermore, a warning label may be better understood by a worker if it is pointed out by a safety instructor during training (McGrath, 2011). Therefore, a warning should be viewed as a supplement to the safety program, rather than a sole substitute of it (Wogalter et al., 2006).

The adequacy of warnings has become a significant issue in personal injury and product liability litigation in the United States (Wogalter et al., 2006). The purpose of this review and analysis is to determine when and how warning labels associated with finished automotive friction products were first developed, and how they changed or expanded over time, and to examine what factors influenced their evolution. Based on our review of the available literature, there is no published manuscript that has specifically reviewed or evaluated warning labels on automotive friction products such as brakes and clutches. We evaluated these warnings in conjunction with the state-of-the-art knowledge of asbestos science, as well as with relevant legal and regulatory guideline development. The history of asbestos use in US automotive friction products, US regulatory guidelines with regards to asbestos and such products, and the development of the science associated with asbestos toxicity are well documented.

2. Method

A search for documents containing information on asbestos toxicology as it relates to friction products and the requirements for warning relevant employees and consumers of potential exposure and adverse health effects was conducted. Reference materials evaluated in this study included: (1) toxicological data from peer-reviewed published literature, conference abstracts, and meeting proceedings; (2) warning standards and guidelines described in textbooks, peer-reviewed published literature, industry publications, government documents; (3) regulatory guidelines presented in government documents; (4) examples of labels from friction products; and (5) various types of lawsuits mentioned in law reviews and legal meeting proceedings. Multiple databases and search engines (e.g., PUBMED, Web of Science, Medline, Lexis–Nexis) and public and university libraries were searched to identify relevant books and peer-reviewed literature. Regulatory-related information was identified and collected primarily from government and professional organization websites, as well as from books, reports, and other literature published by these organizations, such as the *Federal Register*. For the collection of actual warnings and labels for friction- and automotive-specific products, such as clutches and brakes, we reviewed corporate documents, service manuals, user manuals, technical service bulletins (TSBs), Material Safety Data Sheets (MSDSs), and package labels.

Results were reported chronologically. Each of the time periods included information on key asbestos-related scientific literature, suggestions or requirements for labeling set forth by professional organizations, advisory agencies, or the federal government, and examples of pertinent warning labels issued by automotive manufacturers.

3. Results

3.1. Part I: Regulatory requirements for asbestos-containing products, prior to the establishment of OSHA

3.1.1. 1930s and 1940s: No governmental regulation; initial development of guidelines

During the 20th century, the understanding of the toxicity and potency of asbestos fibers steadily increased. The first death of a worker that was alleged from inhalation exposure to asbestos was reported in 1900 and the event is commonly referred to as the "Montague Murray Case" (Merewether and Price, 1930, p. A3). Shortly thereafter, although not as a result of this case report, animal experiments were conducted by Professor J.M. Beattie, which revealed that inhaling asbestos dust correlated with a mild degree of fibrosis in animals (Merewether and Price, 1930). In 1930, Merewether and Price conducted a study of workers in a textile, as well as a brake and clutch lining manufacturing setting in the United Kingdom. The authors concluded that the duration of exposure to asbestos dust and the type of work activity performed at the plant correlated with increasing risk of incidence of pulmonary fibrosis (Merewether and Price, 1930). This was basically the first time the term asbestosis was used to describe a unique disease due to exposure to asbestos; rather than simply a pneumoconiosis. Prior to this, it was difficult to know whether breathing difficulties were due to exposure to silica dust, dusts in general, pneumonia, tuberculosis, or other risk factors.

In 1938, Dreessen et al. evaluated the incidence of asbestosis in workers in the asbestos textile industry. Similar to Merewether

and Price, they concluded that both the type of work activity and the duration of exposure contributed to asbestosis development. Because asbestosis was found only in dust concentrations exceeding 5 million particles per cubic foot (mppcf) and was not found at lower concentrations, the investigators concluded that 5 mppcf "may be regarded tentatively as the threshold value for asbestos-dust exposure until better data are available" (Dreessen et al., 1938, p. 91). Subsequently, several states adopted this value (Air Hygiene Foundation, 1941; OSBH, 1945; State of California. Department of Industrial Relations, 1945), followed in 1946 by the American Conference of Governmental Industrial Hygienists (ACGIH), which assigned a Maximum Allowable Concentration (MAC) value of 5 mppcf to asbestos (ACGIH, 1946).

The value identified by ACGIH was a recommendation for non-encapsulated asbestos fibers less than 5 μm in length and having an aspect ratio of 3:1. Similar to other cohorts studied in this era, Dreessen et al. (1938) and Merewether and Price (1930) measured the exposures in factories in which workers handled raw asbestos fibers. In contrast to these raw fibers or friable products, the chrysotile asbestos fibers found in finished automotive brakes and clutches are encapsulated via phenolic resins or other bonding agents. Once the asbestos fibers are encapsulated, the majority of fibers in the product are prevented from becoming airborne even when manipulated (Langer, 2003). Furthermore, encapsulation often changes the size of the fiber/resin complex, primarily reducing the capacity of fibers to become airborne, and therefore logically resulting in a decreased hazard to workers (Langer, 2003).

3.1.2. 1950s and 1960s: First involvement by federal agencies

Official US governmental regulation of occupational exposure to asbestos began in the 1950s with the 1951 Walsh–Healey Contract Act (U.S. Congress - 74th, 1936; USDL, 1951). This Act required that contractors and manufacturers follow standard employment rules, including those for health and safety, when under contract by the US government. The goals of the Act included ensuring the safety and well-being of workers and their families, and mitigating the cost of accidents in terms of money and human resources. To this end, with regards to "atmospheric impurities," the Act accepted the exposure guideline recommended by the ACGIH in 1946 for "allowable concentrations" of airborne asbestos (USDL, 1951, p. 21). Asbestos was listed as a mineral dust, with a suggested MAC of 5 mppcf (USDL, 1951, p. 22).

As a result of some of the research conducted in the early 1960s, concerns over the risk of asbestos related diseases among end-users were raised. For example, Thomson et al. (1963) performed autopsies of the general population in Cape Town, South Africa, to better understand the impact of airborne asbestos fibers on urban dwellers. The investigators raised concerns regarding various sources of asbestos exposures, including break wear debris (i.e., brake dust), noting that brake wear debris could have been a significant source of asbestos in urban air, although the researchers noted that the inhaled fibers were "not in amounts sufficient to produce pulmonary lesions or disability" (Thomson et al., 1963, p. 81). Shortly thereafter, Dr. Irving Selikoff reported on the relationship between asbestos exposure and the increased incidence of lung and pleural cancers in insulation workers (Selikoff et al., 1964). In part, because of the Selikoff studies and increased awareness about the importance of latency, concern grew that the 5 mppcf asbestos occupational guideline published by ACGIH was no longer adequate for protecting workers.

In 1965, at the Conference on the Biological Effects of Asbestos, the 5 mppcf limit recommended by Dreessen et al. was called "inadequate to give complete working-lifetime protection against all forms of asbestos" (Corn, 1986, p. 517). Following the conference, in 1968, ACGIH recommended lowering the threshold limit value (TLV), regardless of fiber type, to 12 fibers per cubic centimeter (f/cc) (the prior limit of 5 mmpcf was roughly equal to 30 f/cc) (ACGIH, 1968). This value was adopted by the Walsh–Healey Act in 1969 (OSHA, 1972). The reduced exposure limit was based on an understanding that not only miners and millers were exposed to asbestos fibers, but also textile weavers, carpenters, insulators, pipe laggers, dockers, rubber compounders, and others (ACGIH, 1968). In 1970, ACGIH recommended lowering the asbestos TLV further, to 5 f/cc (Hosey, 1970).

Several studies occurred in the late 1960s and early 1970s that expanded the state of knowledge of asbestos with regards to exposure to friction products specifically. These investigators concluded that the quantity of asbestos fibers and the length of those fibers released from brake lining was generally considered to be too low to constitute a public health or occupational health hazard (Anderson et al., 1973; Hickish and Knight, 1970; Jacko et al., 1973; Lynch and Ayer, 1968). Hickish and Knight (1970), for example, were the first to measure a daily time weighted average (TWA) exposure for brake repair workers. Their work was initiated because, at the time, there was little known about the exposure concentrations resulting from maintaining passenger vehicle brakes, and businesses were trending towards introducing a work flow system where one individual would potentially be engaged almost entirely in brake servicing. Hickish and Knight reported that "exposure to asbestos during brake maintenance is not as severe as was anticipated," and that the personal exposure samples collected during car servicing were below the Hygiene Standard of 100 fiber-year/cm^3 for 50 years (Hickish and Knight, 1970, p. 20). In addition, Boillat and Lob (1973) conducted an epidemiological study in which the incidence of asbestosis in workers assembling brake linings was evaluated; the authors noted that exposure and risk of disease in this population had never been examined as of the time of their study. The authors concluded that the recommended American health workers exposure limit of 5–10 fibers/cm^3 for a quarter of an hour, five times a day, was not likely to be surpassed in this population, and that the risk of asbestosis appeared small (Boillat and Lob, 1973).

3.1.2.1. Contemporaneous labeling of encapsulated materials: non-friction examples. Prior to 1970s, there were no requirements for labeling asbestos-containing products, and we found no examples of any brake, clutch, or gasket warning labels in existence during this time period. However, requirements for warnings on other types of consumer products had been evolving for the prior decades and these guidelines may have influenced the content of future labels on friction products.

In 1932, Senator Hiram Bingham of Connecticut introduced a bill into Congress calling for labeling of certain chemical products. Following this bill, a committee from the chemical industry met with the Surgeon General of the U.S. Public Health Service to evaluate the matter further (Murphy, 1953). Thus evolved the voluntary "Surgeon General's Agreement," adopted by the U.S. chemical industry in 1934–1935. Under this agreement, the texts of the precautionary labels used on specific products were agreed upon and made part of the executive agreements. However, the Manufacturing Chemists' Association (MCA) replaced the Surgeon General in 1952 in overseeing the use of precautionary labels on certain products (MCA, 1961).

In 1944, the MCA organized the Labels and Precautionary Information Committee (LAPI), a group composed of technical and legal personnel for the purpose of examining labeling (Murphy, 1953; Unknown, 1945). The first guide developed by the LAPI Committee was published in 1945 by the MCA, and was titled "A Guide for the Preparation of Warning Labels for Hazardous Chemicals," or "Manual L-1" (Murphy, 1953). According to this document, although employee education regarding chemical hazards should remain the direct responsibility of employers, manufacturers

should also affix labels on hazardous chemical containers with precautionary statements and "instructions stated as simply and briefly as circumstances permit" (Unknown, 1945, p. 992). According to the guide, the following general principles should be considered prior to the preparation of the precautionary label: statements should be brief and simple, uniformity of labels should be considered for different products, and precautionary statements should be used only when necessary, since "indiscriminate use will tend to destroy [the label's] value" (Unknown, 1945, p. 992). The guide also stated that the following subject matters should be considered for inclusion when preparing a chemical label: (1) chemical name, (2) signal word designating degree of hazard, (3) affirmation statement of hazard, (4) instruction in case of accident (Fig. 1).

Since its first publication in 1945, Manual L-1 was revised six times, and was ultimately reorganized into the American National Standard (ANSI Z129) in 1976 (ACS and ANSI, 2006a).

Additionally, in 1960, the Federal Hazardous Substance Labeling Act (FHSA) was promulgated to regulate the distribution and sale of packages of hazardous substances intended or suitable for household use (Scriba, 1961). The Act was meant to protect users, including children, from serious illness or death caused by ingesting, inhaling, or absorbing a hazardous substance (Scriba, 1961). 'Hazardous substances' were defined as substances or mixtures that were toxic or corrosive, or an irritant, strong sensitizer, flammable, or capable of generating pressure, if such a substance may cause potential personal injury or substantial illness during, or as a result of, foreseeable handling or use (Scriba, 1961). The Act defined 'label' as a "written, printed or graphic matter upon the immediate container of any substance" (Scriba, 1961, p. 373). The FHSA was amended by the Child Protection Act of 1966 (U.S. Congress - 89th, 1966).

3.2. Part II: Evolution of warning labels following the promulgation of OSHA

3.2.1. Early 1970s: Establishment of regulations associated with warnings and labeling

In 1971, OSHA promulgated a permissible exposure limit (PEL) for asbestos based on ACGIH's proposed TLV of 12 f/cc. The PEL also reflected the Federal standard promulgated under the Walsh–Healey Act in 1969 (OSHA, 1971). A year later, in 1972, OSHA lowered the PEL to 5 f/cc, a value previously recommended by ACGIH in 1970 (Hosey, 1970, OSHA, 1972).

Despite the reduction of the asbestos standard by more than 50% in less than 2 years, and even with the increased scientific knowledge that developed between the late 1950s and the 1960s, as of the 1970s, no agency or scientific body recommended applying a warning label for products in which asbestos fibers had been modified by a bonding agent or other material, so that "during any reasonable foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits . will be released" (OSHA, 1972, p. 11321). These encapsulated products included brakes, gaskets, floor tiles, and other products made with phenolic resins.

1. Chemical name.
2. "Signal word" (DANGER—WARNING—CAUTION) designating degree of hazard (Column A, Schedule 3).
3. Affirmative statement of "hazard" (Column B, Schedule 3).
4. "Precautionary measures" covering actions to be followed or avoided (Column C, Schedule 3).
5. Instructions in case of accident, where advisable (Column D, Schedule 3).

Fig. 1. Subject matter to be included on a chemical label (Unknown, 1945)

Nonetheless, in the early 1970s, although not required, some automotive manufacturers began placing warning labels on their replacement brake and clutch products. Several representative warnings are shown in Figs. 1–4. The earliest friction material-related warning that we identified from an automotive original equipment manufacturer was from a 1973 Chrysler Service Manual (Fig. 2). The text advised that proper equipment and ventilation should be used during resurfacing of brake shoes in order to minimize exposure to asbestos dust. The warning stated that asbestos dust can be "detrimental to health" (Fig. 2). This warning could be applied to most substances that create dust when manipulated.

Additionally, a warning label appeared on Bendix brake boxes in 1973 and cautioned against inhaling asbestos fibers (Fig. 3). Although the warning label did not provide specific instructions to the user, it advised that inhaling asbestos dust "may cause serious bodily harm" (Fig. 3). Such broad or generic warning labels were common during the late 1960s and early 1970s for a host of products, including neat industrial chemicals, various poisons, insecticides, and household substances.

3.2.1.1. Other factors to consider; the labeling of non-friction products. While no organization was making recommendations specifically for labeling asbestos-containing consumer products such as brakes, clutches, and gaskets in the 1970s, the development of contemporaneous guidelines for other consumer products, poisons, and chemicals may have influenced the automotive industry as it developed its own warnings.

For example, according to the ANSI, specific language on precautionary labels may differ depending on the degree of hazard posed by the chemical (ANSI, 1976). One of the most detailed warnings recommendations for containers and wrappers was consistent with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) recommendations, which have been in effect in some various forms since 1910. As of 1972, the requirements for labeling pesticides was highly detailed (U.S. Congress - 92nd, 1972b). Other examples include The Poison Prevention Packaging Act (PPPA) that was enacted in 1970 and required that household substances be packaged and labeled in a way that would protect children from serious personal injury or illness (CPSC, 2008) and the Consumer Product Safety Act (CPSA) that was enacted in 1972 to develop uniform safety standards for consumer products.

Motor vehicles and motor vehicle equipment were not considered to be consumer products, and thus were not directly regulated by these Acts and guidelines (U.S. Congress - 92nd, 1972a). However, the wording on the two asbestos warnings previously shown in Figs. 2 and 3 seems to be appropriate and in line with many of the label requirements of the time period for other toxic materials. For example, although the recommendations provided by the ANSI were not required and were not written specifically for asbestos or the automotive industry, the representative Bendix brake box warning label (Fig. 3), while succinct, included most of the components suggested by ANSI, such as a proper signal word, statement of hazard, and a precautionary measure.

For comparison purposes with regards to level of detail, we evaluated example warning labels associated with chemicals known to be highly toxic. As previously described, the sixth edition of the Manual L-1 was published in 1961. This document classified vapor chemicals into three separate categories: rapidly toxic or

"CAUTION: When resurfacing brake shoes follow manufacturing recommendations for proper use of their equipment. Whatever equipment is used, ensure that proper ventilation is provided to remove asbestos dust, which can be detrimental to health."

Fig. 2. Warning text from a 1973 Chrysler Service Manual (Chrysler, 1973)

CAUTION: CONTAINS ASBESTOS FIBERS.
AVOID CREATING DUST. BREATHING ASBESTOS
DUST MAY CAUSE SERIOUS BODILY HARM.

Fig. 3. Warning text from a 1973 Bendix brake box (Bendix, 1973).

CHLOROFORM

WARNING! VAPOR HARMFUL

Use only with adequate ventilation.
Avoid breathing vapor.
Avoid prolonged or repeated contact with skin.
Do not take internally.

Fig. 4. Example chloroform warning label (MCA, 1961).

extremely irritating, hazardous from prolonged or repeated exposures, or physiologically inert. The Manual contained warning labels for chloroform (Fig. 4) and trichloroethylene (Fig. 5), both known central nervous system depressants that can potentially be fatal at doses above the TLV (Gosselin et al., 1984; MCA, 1961). Similar to the Bendix brake box label (Fig. 3), these labels were brief and concise, with appropriate signal words, statements of hazard, and precautionary measures.

With regards to warning-related legal developments, the landmark 1973 asbestos lawsuit *Borel v. Fibreboard Paper Products Corporation*, et al. resulted in a substantial verdict for Texas insulation worker Clarence Borel, against 10 asbestos manufacturers per a ruling by the U.S. Court of Appeals, Fifth Circuit (Borel v. Fibreboard Paper Prod. Corp. 493 F.2d 1076, 1973). This product liability case involved an asbestos manufacturer's duty to warn industrial insulation workers of dangers associated with using asbestos. Mr. Borel alleged that he had contracted mesothelioma as a result of his exposure to the defendants' products during his 33 year career in the industry. To our knowledge, this instance of litigation was the first time that asbestos-containing product manufacturers were held liable for warning end product users about the potential dangers of their products (Borel v. Fibreboard Paper Prod. Corp. 493 F.2d 1076, 1973; Johns-Manville, Undated). Although none of these defendants were automobile or friction product manufacturers, the case likely had an impact on the future of labeling development and use for all asbestos-containing product manufacturers.

3.2.2. Mid to late 1970s: Sampling of auto mechanics and evolution of warnings and labels

With the exception of the study published by Boillat and Lob (1973), prior to 1975 there were no epidemiological studies conducted characterizing asbestos-related diseases in brake mechanics.

It wasn't until Mt. Sinai researchers suggested a possible increased risk of developing an asbestos related disease in auto mechanics that further epidemiological and exposure studies were conducted to better understand this possible risk (Lorimer et al., 1976). The researchers reported that both the TWAs and the peak levels indicated "significant asbestos exposure." However, they noted that the findings of their study could not be "generalized to all brake maintenance workers" (Lorimer et al., 1976, p. 217). The researchers also concluded that asbestos disease "will be present" among brake repair workers, and thus "appropriate control measures should be urgently instituted" (Lorimer et al., 1976, p. 217). The meaning of "will be present" is unclear as to whether they recognized that lung cancer and mesothelioma would be present in this cohort whether or not they had any exposure to asbestos due to work with brakes.

Based on data collected, although the number of samples collected were limited, a letter was issued in the NIOSH Current Intelligence Bulletin (CIB) to all US industrial hygienists by William J. Lloyd, the director of Office of Occupational Heath Surveillance and Biometrics (Lloyd, 1975). In a July meeting, he alerted those active in occupational medicine, as well as NIOSH staff, about the limited state of understanding that existed regarding asbestos exposure in motor vehicle brake and clutch mechanics (Lloyd, 1975). Mr. Lloyd's letter suggested that more work should be conducted in order to determine any correlation between brake mechanical work and possible adverse health effects (NIOSH, 1975).

According to Mr. Lloyd's letter, potential exposure to asbestos among brake servicing personnel had not been extensively studied. Even so, the letter included interim procedures recommended by NIOSH to minimize dust exposures during brake and clutch work. Specifically, the letter recommended (without force of law) that entrances to areas in which brake and clutch repairs were performed should have an asbestos warning sign posted that would provide the following information: (1) caution against inhaling dust; (2) advice for assigning and wearing protective equipment; and (3) warning that asbestos dust may cause cancer and asbestosis (Fig. 6).

The letter also contained information on removing brake dust, as well as which cleaning methods should be avoided, such as compressed air or dry brushing. The letter recommended that an industrial type vacuum cleaner or a water soaked rag be used in order to reduce exposure to dust (Lloyd, 1975).

Simultaneously, the automotive industry began developing and including warnings in its technical bulletins and service manuals consistent with the NIOSH CIB recommendations for premises warnings. For example, in 1975, a warning cautioning against using compressed air during brake work appeared in the Ford Technical Service Bulletin (Ford Motor Company, 1975). The label advised that brake assemblies should be cleaned only with a vacuum cleaner "suitable for use with asbestos fibers" (Fig. 7).

Over time, more information appeared on warning labels. In 1976, for example, the Small Car Brake Service Manual (Fig. 8) published by Delco Moraine Division of General Motors, contained language that was more extensive than what had been used previously, although the overall content remained the same. The added language presented clearer instructions to avoid creating

TETRACHLOROETHYLENE (PERCHLOROETHYLENE)
***Same label as* TRICHLOROETHYLENE**

TRICHLOROETHYLENE

WARNING! VAPOR HARMFUL

Use only with adequate ventilation.
Avoid prolonged or repeated breathing of vapor.
Avoid prolonged or repeated contact with skin.
Do not take internally.

Fig. 5. Example trichloroethylene warning label (MCA, 1961).

Asbestos
Dust Hazard
Avoid Breathing Dust
Wear Assigned Protective Equipment
Do Not Remain in Area Unless Your Work Requires It
Breathing Asbestos Dust May Cause Asbestosis and Cancer

Fig. 6. Asbestos warning sign that appeared in the NIOSH Current Intelligence Bulletin 5, issued on August 8, 1975, to alert auto mechanics of the possible hazard of working with brakes. The bulletin was titled "Asbestos Asbestos exposure during servicing of motor vehicle brake and clutch assemblies" (Lloyd, 1975).

CAUTION: Dust and dirt conditions present on wheel brake assemblies and rotors and drums, may contain asbestos fibers that can represent a potential health hazard when made airborne by cleaning with compressed air.

All wheel brake assemblies should therefore be cleaned only with a vacuum cleaner suitable for use with asbestos fibers. This type of vacuum cleaner is available through the Rotunda Dealer Equipment Catalog. Dust and dirt from the vacuum cleaner should be disposed of in a manner that prevents dust exposure.

Any repairs done on brake linings, pads, rotors and drums, should be done using properly exhaust ventilated equipment

Fig. 7. Warning text from the 1975 Ford Technical Service Bulletin, Number 99 (Ford Motor Company, 1975).

WARNING. WHEN SERVICING WHEEL BRAKE PARTS, DO NOT CREATE DUST BY GRINDING OR SANDING BRAKE LININGS OR BY CLEANING WHEEL BRAKE PARTS WITH A DRY BRUSH OR WITH COMPRESSED AIR. (A WATER DAMPENED CLOTH OR A SUITABLE VACUUM CLEANER SHOULD BE USED.) MANY WHEEL BRAKE PARTS CONTAIN ASBESTOS FIBERS WHICH CAN BECOME AIRBORNE IF DUST IS CREATED DURING SERVICING. BREATHING DUST CONTAINING ASBESTOS FIBERS MAY CAUSE SERIOUS BODILY HARM.

Fig. 8. Warning text from the 1976 Small Car Brake Service Manual published by General Motors Delco Moraine Division (Delco, 1976).

dust during wheel servicing, and also suggested alternative cleaning methods (Delco, 1976).

There was some variability in the content and extensiveness of warnings information in the auto industry in the 1970s, because no standard warning language existed. For example, text that appeared in the General Motors 1976 Small Car Brake manual noted that breathing dust may cause harm (Fig. 8) (Delco, 1976). Another example similar to previously discussed warning labels, and in line with contemporary recommendations, is the 1977 Chevrolet manual (Fig. 9) that encouraged using proper cleaning techniques. Specifically, this manual emphasized that brake lining grinding, sanding, or cleaning using a dry brush or compressed air should be avoided. Furthermore, the warning stated that a wet, rather than dry, cleaning technique should be used (Chevrolet, 1977).

3.2.3. 1980s–1990s: Expanding knowledge of the hazards of asbestos and continued limited concern about the health hazards of brake dust

In 1983, OSHA issued an emergency temporary standard (ETS) that lowered the PEL to 0.5 f/cc for airborne asbestos. According to the *Federal Register*, OSHA derived a dose–response relationship and estimated that an ETS of 0.5 f/cc would reduce the mortality caused by occupational exposure to asbestos (OSHA, 1983). Some of the studies used by OSHA to support this change included Finkelstein et al. (1983), Dement et al. (1983), and Henderson and Enterline (1979). Using data collected from workers at an asbestos-cement factory, Finkelstein and others were able to analyze

Warning: When servicing wheel brake parts do not create dust by grinding or sanding brake linings or by cleaning wheel brake parts with a dry brush or with compressed air. (A water dampened cloth should be used.) Many wheel brake parts contain asbestos fibers which can become airborne if dust is created during servicing. Breathing dust containing asbestos fibers may cause serious bodily harm.

Fig. 9. Warning text from a 1977 Chevrolet Service Manual. The information was printed on the first pages of both the hydraulic and air brakes sections (Chevrolet, 1977).

individual exposure history and generate an exposure–response relationship for asbestos-associated malignancies (Finkelstein, 1983). Dement et al. (1983) performed a retrospective mortality study among chrysotile asbestos workers that estimated worker exposure associated with textile processes. Lastly, Henderson and Enterline (1979) proposed a dose–response relationship for respiratory cancer using information collected from workers employed by a US asbestos company.

Initially, because of many comments and concerns that were submitted after OSHA recommended the 0.5 f/cc ETS, the limit was not promulgated as a final rule. Most of the comments submitted by industry, as well as by senators and congressmen, argued that the PEL of 0.5 f/cc was not feasible from an economic or engineering standpoint. Furthermore, representatives of the maritime and construction industries asked that a ruling more suitable to their unique workplace be established (Martonik et al., 2001). However, in 1986, after the review of existing and newly published epidemiological studies and a subsequent risk assessment, OSHA ruled to lower the existing PEL of 2 f/cc, not to the proposed ETS of 0.5 f/cc, but to 0.2 f/cc instead. According to OSHA, work published by Dement, Henderson and Enterline, Finkelstein and Seidman, and Nicholson and Selikoff showed that the current PEL of the time (2 f/cc), was "inadequate" for protecting workers against the risk from lung cancer and mesothelioma, as was the previously proposed 0.5 f/cc (OSHA, 1986, p. 22619, 22644). They further noted that, according to their risk assessment, a PEL to 0.2 f/cc was "reasonably necessary to reduce the cancer mortality risk from exposure to asbestos" (OSHA, 1986, p. 22647). Specifically, OSHA's risk assessment showed that lowering the PEL from 2 f/cc to 0.2 f/cc "reduce[d] the asbestos related cancer mortality risk from lifetime exposure from 64 deaths per 1000 workers to 6.7 deaths per 1000 workers," which corresponded to a 90% reduction in the risk; whereas lowering to 0.5 f/cc would only reduce the number of deaths to 17 in 1000 (OSHA, 1986, p. 22647). Additionally, the Supreme Court had ruled that occupational exposure requirements could be imposed up to the limit of what was technologically achievable. Accordingly, OSHA conducted a technological feasibility study that showed that 0.2 f/cc was "the lowest level that [could] feasibly be attained in operations in workplaces in both general industry and construction" (OSHA, 1986, p. 22648).

Warnings were discussed in the 1986 *Federal Register*. The regulation indicated that signs and labels should be placed on each regulated area, or temporarily regulated area, "where occupational exposures could exceed the PEL" (OSHA, 1986, p. 22698). However, two exceptions to the standard existed: no warning label or MSDS was required in situations in which: (1) asbestos fibers "have been modified by a bonding agent, coating, binder, or other material," and the manufacturer could demonstrate that during "any reasonably foreseeable use (including handling, storage, disposal, processing, or transportation) employee exposure will remain below the action level;" and (2) the concentration of asbestos in a product was less than 0.1% (OSHA, 1986, p. 22698–22699). As had been true for many years, this exemption was intended for items such as brakes, floor tiles, and similar products that contained encapsulated asbestos.

Even though OSHA continued to exempt encapsulated products from asbestos labeling requirements, warnings were still provided in automobile service manuals as a precaution. For example, according to the language in the 1985 Buick Service Manual, (Fig. 10), it was recommended that brake lining grinding or sanding should be avoided, along with using compressed air. Furthermore, this manual specified that a water dampened cloth or specialized equipment should be used to clean brake parts (Buick, 1985).

In 1994, the asbestos PEL was lowered to the current (as of 2013) value of 0.1 f/cc as an 8-h TWA (OSHA, 1994). Again, even

CAUTION: When servicing wheel brake parts, do not create dust by grinding, sanding brake linings, or by cleaning wheel brake parts with a dry brush or with compressed air. Many wheel brake parts contain asbestos fibers which can become airborne if dust is created during servicing. Breathing dust containing asbestos fibers may cause serious bodily harm. A water dampened cloth or water based solution should be used to remove any dust on brake parts. Equipment is commercially available to perform this washing function. These wet methods will prevent asbestos fibers from becoming airborne.

Fig. 10. Warning text from a 1985 Buick Chassis Service Manual, Volume I. The information was printed on the first page of the General Brakes Section (Buick, 1985).

before this action, the automotive industry proactively warned mechanics of the potential hazards of asbestos exposure. Warnings had generally been added to documents and products that were associated with brakes after the 1975 NIOSH CIB, even though the asbestos was encapsulated and the vast majority of asbestos in brakes was converted to forsterite or a similar breakdown products during the braking process (Anderson et al., 1973; Jacko et al., 1973; Lynch and Ayer, 1968). Exposures to asbestos during the grinding process presented a possibility for significant short term exposure, but the duration of exposure was generally thought to be too short to pose a health hazard. This conclusion was supported by various industrial hygiene surveys conducted between 1975 and 2002 (Paustenbach et al., 2004). Later, Weir et al. (2001) concluded that grinding and drilling asbestos-containing brake pads "do not pose an important source of exposure to respirable asbestos fibers" (Weir and Meraz, 2001, p. 11490). The analysis of samples collected during a NIOSH survey from 1982, for example, revealed that TWA concentrations for raw material mixers, machine finishers, drillers, and slab cutters were below 2 f/cc, the OSHA PEL at that time (Zey and Klemme, 1982).

Nonetheless, even though warnings were not necessary according to OSHA regulations and exposures were expected to be below the PEL, from 1975 to the present, the automotive industry included warnings statements regarding the brake replacement. There was no standardized warning statement used across the automotive brake manufacturing industry during the 1990s (which would be passed to the original equipment manufacturers), but the one shown in Fig. 11 was fairly typical of the era. Interestingly, this particular warning recommended that non-asbestos replacement parts should be used whenever possible (Ford Motor Company, 1993).

4. Discussion

Our analysis indicates that the US automotive industry was proactive with respect to issuing warning labels on finished friction products in response to the growing concern regarding the occupational health hazards posed by asbestos. At the time, such warnings were issued absent any conclusive evidence that these products exposed mechanics to harmful levels of asbestos (even later studies repeatedly failed to show evidence of harm to the mechanics from such fibers). Thus, there were no regulatory requirements for labeling or warnings and, accordingly, such warnings were not legally necessary. The inclusion of these warnings was, based on our research, due to increased societal expectations regarding labeling of many different consumer products, as well as the increase in asbestos-related litigation.

WARNING: DO NOT INHALE DUST FROM BRAKES, CLUTCHES OR ASSOCIATED COMPONENTS. INHALATION OF DUST CONTAINING ASBESTOS FIBERS CAN BE INJURIOUS TO YOUR HEALTH AND COULD CAUSE CANCER OR ASBESTOSIS. COMPRESSED AIR OR BRUSHES MUST NOT BE USED TO CLEAN BRAKES, BRAKE DRUMS, CLUTCHES AND ASSOCIATED COMPONENTS. A VACUUM CLEANER EQUIPPED FOR THIS PURPOSE SHOULD BE CAREFULLY USED TO REMOVE ANY DUST. ADHERENT DUST SHOULD BE REMOVED WITH A DAMP RAG. ANY DUST SHOULD BE CONTAINED IN A SEALED AND LABELED BAG FOR DISPOSAL. WEAR AN APPROVED HIGH EFFICIENCY CARTRIDGE OR AIR LINE RESPIRATOR AND USE EXTRA CAUTION TO AVOID BREATHING THIS DUST. USE NON-ASBESTOS REPLACEMENT PARTS WHENEVER POSSIBLE.

Fig. 11. Warning text from a February 20, 1993 Ford Technical Service Bulletin. The information was printed in the Light Truck Shop Manual Section, specifically under the 4-Wheel Anti-Lock Brake Section (Ford Motor Company, 1993).

In 1986, the US EPA published a controversial document entitled *Guidance for Preventing Asbestos Disease among Auto Mechanics* (also known as the "Gold Book"). It was controversial, in part, because it was the first time that EPA chose to offer guidance regarding possible occupational exposures, even though they had no mandate to be involved in this arena (one which was under the purview of OSHA). Throughout the pamphlet, the US EPA makes statements regarding mesothelioma and brake mechanics (USEPA, 1986). However, the document utilized out-dated case reports, and disregarded the relevant epidemiological literature. For example, the US EPA neglected to include three case-control studies that were published in the 1980s (McDonald and McDonald, 1980; Spirtas et al., 1985; Teta et al., 1983), and these studies uniformly concluded that brake mechanics were not at an increased risk of developing an asbestos-related disease (Wong, 2001). The *Gold Book* also failed to note at least six different studies published between the late 1960s and early 1970s that found virtually no asbestos fibers in brake dust (Anderson et al., 1973; Hickish and Knight, 1970; Jacko et al., 1973; Lynch and Ayer, 1968).

Several studies published in the last decade have shown that asbestos exposures associated with automotive work are low (Blake et al., 2003, 2008; Boelter and Spencer, 2003; Boelter et al., 2007, Cohen and Van Orden, 2008; Finley et al., 2007; Jiang et al., 2008; Madl et al., 2008, 2009; Paustenbach et al., 2003, Richter et al., 2009; RJ Lee Group Inc., 2004). In addition, numerous epidemiological studies have been conducted examining the incidence of asbestos-related health effects in vehicle mechanics between 1975 and the present (Agudo et al., 2000; Butnor et al., 2002; Goodman et al., 2004; Hansen and Meersohn, 2003; Hessel et al., 2004; McDonald and McDonald, 1980; Milham and Ossiander, 2001; NIOSH, 2002; Olsen and Jensen, 1987; Rake et al., 2009; Rolland et al., 2010; Spirtas et al., 1994, Spirtas et al., 1985; Teschke et al., 1997; Teta et al., 1983; Welch et al., 2005; Woitowitz and Rodelsperger, 1994; Wong, 2001). These studies have consistently found no increased risk of any asbestos-related disease in auto mechanics.

Beyond these, NIOSH currently maintains the National Occupational Mortality Surveillance (NOMS) database on its website, which tracks associations between cause-specific mortality and occupation and industry (NIOSH, 2011). According to the NOMS data, there is no evidence of an increased risk of mortality from cancer of the pleura among "vehicle and mobile equipment mechanics and repairers" (NIOSH, 2011). As a result of several discrepancies identified in the original US EPA document, a revised *Gold Book* was published in March, 2007, entitled *Current Best Practices for Preventing Asbestos Exposure among Brake and Clutch Repair Workers*. This document explained the engineering controls and proper cleaning methods that should be used during brake and clutch repair (USEPA, 2007).

Currently (as of 2013), the occupational standard for asbestos does not require that a warning label be placed on finished friction products. Specifically, the 1994 *Federal Register* states that no label is required on products to which "asbestos fibers have been modified by a bonding agent, coating binder, or other materials, provided that the manufacturer can demonstrate that during any reasonably foreseeable use, handling, storage, disposal, processing,

or transportation, no airborne concentration of asbestos fibers in excess of the permissible exposure limit and/or excursion limit will be released" (OSHA, 1994, p. 41089 and 41090). Similarly, the 2013 California Code of Regulations, specifically states that requirements for labels and MSDSs do not apply when asbestos fibers have been modified by a bonding agent or other material, and that during all reasonably foreseeable uses, the airborne concentrations of asbestos fibers will not be in excess of the TWA permissible exposure level (OSHA, 2013). According to the current California OSHA Title 8, warning signs should be displayed near areas that are known to, or presumed to, contain asbestos fibers (OSHA, 2013). Based on that document, the language on the warning sign should include the following text:

DANGER ASBESTOS
MAY CAUSE CANCER
CAUSES DAMAGE TO LUNGS
AUTHORIZED PERSONNEL ONLY

In addition, when protective clothing and respirators are required, signage should include the text "WEAR RESPIRATORS AND PROTECTIVE CLOTHING IN THIS AREA." The usefulness of such broad warnings is unclear. However, these requirements are specifically for premises signs; no warnings or labels are required for brake, clutch, or automotive gasket packaging or users manuals.

There have been suggestions that the information placed on the warning labels by the automotive industry during the pre-1990s were insufficient (Egilman and Howe, 2007; Egilman and Billings, 2005). However, based on our research, such broad claims are unfounded based on what was, and is, known regarding asbestos toxicity and the epidemiology of automotive mechanics.

Beyond the fact that exposures of mechanics to asbestos were not determined to pose a significant hazard, it was recognized by numerous researchers over the past 20 years that warnings might not serve their intended purpose, if too much information were to be included, or if too many warnings were issued for products which did not pose an appreciable hazard. For example, based on a literature review conducted by Frantz et al (1999), overuse of warning labels on a product can potentially produce unwanted consequences on the user's safety. Empirical studies, for example, have shown that users only process certain sections of the information on a warning label, rather than all of the information. These findings indicate that even if large quantities of information about the plausible health hazards had been placed on the warning labels, the user may not necessarily have received any additional benefits. Further, these researches noted that overusing warning labels may have a negative effect on user compliance. The authors reported that as the number of warning labels increases, especially on products which posed low risks, users are more likely to disregard the labeling information (Frantz et al., 1999). The Food and Drug Administration (FDA) and the Consumer Product Safety Commission (CPCS) both advise that overusing safety messages weakens the effectiveness of information, and, in turn, does not produce the desired warning effect on the user (Sala et al., 2011).

Our historical review indicates that the warning labels set forth by the automotive brake and clutch manufacturers were thorough and appropriate for their time. Despite the lack of regulations and requirements and the paucity and inconsistency of reports of the risk of asbestos-related disease in auto mechanics, the language on these warning labels provided end users with information regarding product content, proper use, and possible health hazards associated with the product. Furthermore, the automotive industry warned against exposure to asbestos from brake and clutch repair, despite the mounting scientific evidence that did not support the association between such exposures and an increased risk of developing mesothelioma, lung cancer, or other asbestos-related disease among auto mechanics.

Conflict of interest

All of the work associated with writing this manuscript was conducted without outside financial support from any automotive or truck manufacturer or any group associated with brakes, automobiles or trucks. Cardno ChemRisk has conducted a number of studies and has published nearly 20 papers on the hazards posed by asbestos in brakes over the past 15 years. The firm also has had numerous clients who have been involved in litigation involving asbestos. At least one of the authors has served as an expert witness on asbestos in the courtroom who was retained by automobile, truck or bus manufacturers.

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