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MC-87- 5

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ALTERNATIVES TO ASBESTOS

by

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Presented at the

REFINERY AND PETROCHEMICAL
PLANT MAINTENANCE CONFERENCE
February 10-13, 1987
Civic Plaza
Phoenix, Arizona

Alternatives to Asbestos

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Current government regulations on the handling and disposal of asbestos containing products are reviewed and some of the legal problems involving asbestos that have occurred are discussed. Substitute materials in the fields of insulation, fireproofing, packing and gaskets, etc. are outlined along with their pertinent properties. Possible future uses of asbestos and substitute materials are discussed.

Types of Asbestos

"Asbestos" is the general term used to describe minerals that can crystallize in the asbestiform (fiberous) variety. There is no "group of asbestos minerals"; however, the serpentine and amphibole mineral groups contain the vast majority of asbestos types. Table I lists the more common asbestos types and their approximate composition (1). Chrysotile asbestos accounts for about 95% of the world's supply (2). In 1970 Canada provided about 90% of our asbestos imports, essentially all chrysotile, while South Africa supplied most of the rest, primarily as crocidolite and amosite. United States production accounted for only about 15% of our total usage in 1970, predominantly as chrysotile.

Primary areas of use for chrysotile are as asbestos cement building products (69%), floor tile (10%), asbestos paper (7%), friction materials and gaskets (3%), and miscellaneous textiles, paints, caulk, plastics, etc. (11%). Building products include asbestos cement sheets, pipe, and fireproofing, pipe insulation, roofing felt and shingles, and molded products.

Crocidolite is used in acid resistant gasketing and packing as well as in some building products. Amosite is used in some blanket insulations and pipe coverings.

Most refineries and petrochemical plants have asbestos present in pipe and block insulation applied before 1973, valve packings and gaskets, some fireproofing products, and roofing and floor coverings. Those who run auto shops will also have brake and clutch facings of asbestos containing material.

Health Hazards

A number of health effects studies have been reported over the past 20 years on the effects of asbestos on laboratory animals and people (3, 4, 5, 6, 7). The studies have demonstrated a positive correlation between lung cancer and asbestos exposure. In addition, pulmonary fibrosis (asbestosis), mesothelioma (cancer of the lining of the lung and abdomen), and perhaps gastrointestinal cancer have developed in workers exposed to large amounts of asbestos dust (8). Unfortunately, the currently available data are often contradictory on the level of danger present in low exposure situations. The Canadian study (4) concluded that while the health risk from asbestos in buildings may not be exactly zero, it is far below risks faced every day as shown in Table II. The near panic experienced by some school boards over governmental requirements for inspection and removal has been caused by excessive publicity about occupational asbestos hazards. These exposure levels are almost never encountered in schools and other public buildings (6).

According to EPA, available data point to a linear dose-response curve for lung cancer - the more fibers you breathe in, the greater the risk. Using this model, there is no "safe threshold level". Studies of asbestos textile workers in South Carolina dispute the Canadian conclusions on the relatively low risks associated with chrysotile fibers. The EPA is using a middle range of dose-response constants in determining risks that uses data from the Canadian study at the lower risk range and data from the textile workers at the high end (5).

Cigarette smoking has been shown to greatly increase the probability of developing lung cancer in asbestos workers. A recent National Research Council study (7) estimated that smoking produced a 10 fold increase in the likelihood of developing lung cancer in low (0.002 fibers/cc) to very low (0.0001 fibers/cc) asbestos exposures (7).

The time factor is one of the major causes of data variation among researchers. Since biological effects after exposure to asbestos may take 10 to 20 years to develop, data from the 40's, 50's, and 60's must be used where levels of exposure could only be guessed at and no one wore any protective equipment. In addition, different fiber types and size distributions, which might have changed from year to year as economics and new developments dictate, would further complicate the researchers task of interpreting historical records.

An epidemiological study of 11,000 miners by J. Corbett McDonald of McGill University found very few deaths from mesothelioma. Other studies have indicated that up to 10% of workers in crocidolite mines die from mesothelioma. Unfortunately, much of the data is open to several interpretations (8).

One theory that may partly explain the discrepancies in various studies is known as the Stanton hypothesis. This theory was developed by M. F. Stanton and co-workers at the National Cancer Institute and attributes the toxicity of asbestos to their long thin dimension rather than any specific chemical property. They found that insertion of various types of fibers into the lining of the lungs of rats produced a high incidence of mesothelioma if the fibers were less than 0.25 μm in diameter and longer than 8 μm. Other researchers believe that while fiber size may be important in getting the fiber to the lung site, surface chemistry becomes the predominant factor once the fiber is lodged in the tissue (8). Additional research is needed to resolve the numerous questions about the health risks associated with exposures to asbestiform fibers.

Current Government Regulations

On January 29, 1986, the EPA published a proposal (9) with several alternatives for a new rule under the Toxic Substance and Control Act that would immediately ban the use of asbestos in asbestos-cement pipe and consumption. Other asbestos containing products as well as mining and importing asbestos would be phased out over a 5 to 10 year period as alternative materials are developed.

Written comments will be submitted to the EPA and public hearings will be held in 1986 to determine the feasibility and effectiveness of the various alternatives to the proposed rule and its effect on the general welfare. Manufacturers and some users of asbestos products will be seeking continued asbestos usage in specific products and areas. Environmental and health groups will try to get elimination of all areas of asbestos use. A final decision on the EPA proposal is not expected before June or July of 1987 according to Dr. D. Dull, Deputy Director of the EPA (10). The final version may be quite different from the proposal issued in January 1986.

The federal Occupational Safety and Health Administration (OSHA) recently reduced the permissible exposure level in the workplace from two fibers per cc to 0.2 fibers per cc. OSHA's "action level" for asbestos, the exposure level at which employers must provide protective gear and monitor air quality, is now 0.1 fiber per cc. EPA estimates that about 2500 deaths over a 15-year period would result from asbestos exposure if they did not act. About 1900 of those lives could be saved with a ban plus phaseout. If OSHA strictly enforces its 0.2 fiber per cc limit, asbestos related deaths are estimated to drop to about 1300. According to the EPA, the proposed ban would save an additional 1000 lives. Caution must be used when applying single risk assessment numbers. They are guidelines that generally contain numerous uncertainties. Often, the range and likelihood of predicted outcomes are not stated in the risk communication, leading to a higher perception of risk and a corresponding emotional response. Comparisons with everyday risks help to place risk factor estimates in a proper perspective.

Handling Procedures

Current OSHA requirements cover the entire removal procedure from planning, permit requirements, protective clothing, respirators, air locks, shower rooms, sealing off techniques, wet removal, and reinsulating or fireproofing (11, 12, 13, 14). The major items are worker protection and isolation of the work area so asbestos isn't tracked or blown into unprotected areas. Air monitors and techniques such as glove bags and thorough water soaking of the material before removal are also critical factors. Proper planning and attention to detail in designing and constructing the decontamination areas are other important controls that must be considered.

Disposal of the asbestos containing material is regulated typically by federal, state, and local laws. Burial in heavy plastic bags is the usual method of disposal since it is generally the most cost-effective treatment.

Encapsulation, usually with a flexible waterbased sealant that is sprayed over the material and traps all the particles, may be advisable for asbestos containment under special situations. Encapsulation is often a good control for granular, cementitous material, or where asbestos-containing material is extremely difficult or impossible to remove.

Legal Problems

The EPA assessed a $24,000 fine against three schools in New Hampshire in March 1984 for failure to comply with EPA rules concerning asbestos in schools. The District of Columbia filed a $400 million lawsuit in December 1984 against asbestos manufacturers and distributors to recoup the cost of removing asbestos from city buildings. In January 1985, Fairfax County, Virginia, announced it will spend $5-6 million to remove asbestos from three public buildings, even though it says air levels are not hazardous (8). New Jersey's highest court has upheld the award of punitive damages against the Manville Corporation (Johns-Manville Corp.) in a case where the company was shown to be liable for a worker's asbestos-related injury. A similar case involving a carpenter exposed to asbestos is currently pending before the Georgia supreme court (15). It is estimated that 16,000 claims were filed against Manville before it declared bankruptcy in 1982 and that number has now swelled to over 50,000. Class action suits have been brought against virtually all manufacturers and distributors. In a landmark case, the U.S. District Court of the Eastern District of Texas has permitted a $130 million settlement in a class action lawsuit brought by a group of former asbestos workers (16). Damages per claimant will range from $75,000 to $650,000.

The American Institute of Architects is staging a grass-roots campaign to have government agencies separate asbestos removal from the rest of their contracts. The AIA's position is that all major liability insurance carriers exclude coverage for asbestos related work, and many architects cannot bid on certain projects due to a lack of liability coverage (17).

The U.S. Court of Appeals for the 4th Circuit has ruled that a former pipefitter who developed a lung disease may sue asbestos manufacturers for damages without identifying the specific product or manufacturer. This decision allows recovery even when the worker relies only on witnesses and circumstantial evidence. This ruling may result in an additional 5,000 cases per year being filed (18).

In addition to the problems of health-related lawsuits, and the limitations on liability insurance coverage, some building owners are finding that insurance companies are closing the door on loans for commercial buildings containing asbestos (19). The ban by the insurers includes both the purchase of buildings for their own portfolios and financing for outside investors. Since there is an excess of office space in many cities, tenants have a choice of where to rent and may move if they perceive the possibility of future lawsuits in buildings containing asbestos. If many tenants leave, the lender may have to foreclose on a building that is unmarketable. In addition, they may be stuck with a big asbestos removal job.

Substitutes for Asbestos

Ceramic fiber, mineral wool, and fiberglass are the primary replacements for asbestos in insulating products. There are a variety of ceramic fibers made from relatively pure starting materials that will resist temperatures from 2000°F to nearly 3000°F (20). In the area of pipe and block insulation, essentially all materials made after 1973 are asbestos free. Before that time, typical calcium silicate based insulations contained 10% to 15% asbestos for improved flexural strength. Both fiberglass and organic fibers, e.g.

dacron, nylon, cotton, have been used as additives to improve the flexural strength of calcium silicate based insulation. Fireproofing materials, particularly the sprayed-on type, substituted fiberglass or ceramic fiber for asbestos to improve coherence after exposure to a fire. Generally, fiberglass and mineral wool based pipe and block insulations did not use asbestos since they exhibited excellent flexural and impact strength without it.

Gasket and packing manufacturers have historically used asbestos for temperature and chemical resistance. Replacement materials for compressed sheet gaskets have included Aramid, acrylics, flexible graphite, PTFE, reinforced cellulose, and glass fibers and inorganic fillers, e.g. clay, and traditional elastomeric binders such as SBR, Buna N, and EPDM. Table III lists the properties of some substitute fibers. A typical compressed asbestos sheet has 80% asbestos, 10%-15% elastomeric binder and the balance in inorganic fillers. An Aramid fiber sheet may have 5% to 15% Armid fiber, 20%-25% elastomeric binder, and the balance clay or other inorganic fillers (21). Glass fiber based sheets have similar percentages of binder and fillers. The lower percentage of fiber makes these non-asbestos sheets much more dependent on the integrity of the matrix.

PTFE based materials provide excellent chemical resistance to 500°F and are available in a variety of forms. The mineral filled and expanded forms of PTFE overcome, to a large extent, the cold flow problems usually encountered with PTFE.

Flexible graphite appears to be one of the best replacement materials for asbestos in gaskets and packings (22). Fire tests indicate this material will pass stringent requirements for safety in the event of fires. Successful use of flexible graphite in both steam and hydrocarbon service to 1200°F has been demonstrated. Frequently, metal inserts are added to flexible graphite to improve handling and cutting characteristics. Failures of flexible graphite have occurred when the material was exposed to temperatures of 1000°F or more in oxidizing atmospheres or in strong mineral acids at elevated temperatures.

The use of spiral-wound gaskets has increased in refineries and petrochemical plants over the past 10 years. The asbestos filler is being replaced with PTFE, flexible graphite, and mica/graphite composites, often with improved performance levels. Sealing characteristics are significantly better with PTFE and flexible graphite than with the asbestos filled spiral wound gaskets.

Ceramic fiber filled spiral wound gaskets have good chemical and temperature resistance and are currently one of the best substitutes for crocidolite (blue) asbestos in hot nitric acid. Unfortunately, the ceramic fillers are expensive and higher in permeability, thus requiring critical flange designs and assembly.

Mica/graphite is competitive in price to asbestos sheet and when properly formulated, is equal to or better than asbestos in most properties. One refinery has reported using mica/graphite spiral wound gaskets in 1400°F flue gas and 1100°F hydrocarbons with excellent results during 18 months of service.

Another substitute for asbestos gaskets for use at temperatures below 350°F is reinforced cellulose (23). The reinforced cellulose fiber has excellent crush resistance, good torque retention, and good stability and sealability. Above 350°F the aramid fiber and flexible graphite are the primary candidates.

The consensus of the speakers at the Valve Manufacturers Association Seminar on asbestos substitutes in Houston on August 6 and 7, 1986, was that flexible graphite would be the packing of choice in virtually every application. In some cases, end rings of a higher tensile strength material may have to be used to prevent extrusion of the flexible graphite. Flexible graphite can be obtained in a variety of densities, the lower densities being softer and better suited to repairing old equipment where the original dimensions have changed.

Other packing materials include carbon/graphite yarn, glass fibers, ceramic fibers, and Polybenzamidazole (PBI). None of these products seem to have the overall combination of properties found in flexible graphite as shown in Table III.

In friction materials, e.g. brake and clutch linings, nothing seems to work quite as well as asbestos. Ceramic, glass, metal, and some organic fibers, e.g. Kevlar, are commonly used as replacements (30% to 60%) for the asbestos. Knowledgeable industry specialists indicate that some asbestos is apt to be used in friction materials through the decade (25).

Structural asbestos/cement pipe and sheet products have been replaced by plastic compounds, resin/fiberglass composites, and ceramic shapes. Most of the organic items do not have the thermal stability of the original asbestos/cement products. However, they typically have improved chemical and/or mechanical properties. Building items such as roofing felt, floor tile, and insulating board are apt to use fiberglass to replace the asbestos previously used.

Future Expectations

The VMA seminar on asbestos substitutes revealed that a number of manufacturers and users plan to "sit tight" for a while and not jump into production or use of alternative materials. While the EPA statements and proposal would appear to eliminate any future use of asbestos, the upcoming public hearings and the attitudes of some foreign governments toward the acceptability of some types and uses of asbestos may result in a less than complete ban on asbestos in the final regulation due in June 1987. The question of cost effectiveness in eliminating all asbestos is a very complex one. Many members of the European Economic Community differentiate between chrysotile asbestos and the amphibole types with regard to public safety. Health-related data can be confusing and in a few cases not very convincing, even to members of the occupational health profession.

There seems to be little doubt that asbestos-based insulation, fireproofing, asbestos/cement products, roofing felts and shingles, floor tile, and asbestos clothing will be banned completely. The case for gasketing, packing, and friction products is less clear. It is possible that some items will be allowed because the substitutes are not able to meet specific physical requirements.

The question of potential health hazards with ceramic fiber has not been answered. It is known that after exposure to temperatures of 1600°F or higher, ceramic fiber undergoes a partial conversion to cristobalite, a form of crystalline silica that can cause silicosis, a respiratory disease (24). The effect of breathing ceramic fibers on the health of rats and hamsters is being studied at Los Alamos by Dr. D. Smith who started his studies in 1979. It is anticipated that the study will be completed in 1986. A second health study in Edinburgh, Scotland, known as the Davis study is currently underway. A possible complication in these studies arises from the fact that the Davis studies are funded by the British Asbestos Research Council while the Los Alamos study is funded by a trade organization which includes manufacturers of man-made fibers (24).

The technical advantages of using ceramic fiber instead of hard refractory products to line furnaces are sufficient to warrant their continued use, even though the concern for silicosis requires extensive safety precautions in installation and repair work. Some studies on the health of workers who handle ceramic fiber are underway but results and conclusions are not expected before the end of the decade. One technological development that will reduce health risks has been the trend to longer fibers with larger diameters. A generally agreed upon principle is that a larger diameter fiber poses a significantly lower threat to health than a thin fiber of the same substance.

References

1. Campbell, W. J., et al, "Selected Silicate Minerals and their Asbestiform Varieties," Information Circular No. 8751, U.S. Dept. of Interior, Bureau of Mines, 1977.

2. May, T. C. and Lewis, R. W., "Asbestos," Bureau of Mines Bulletin 650, 1970, U.S. Dept. of the Interior.

3. Asbestos - Final Report of the Advisory Committee, HMSO, London, England, 1979.

4. Report of the Royal Commission on Matters of Health and Safety Arising From the Use of Asbestos in Ontario, OMGS, Toronto, Ontario, 1984.

5. Jager, S. "Banning Asbestos, A Clear Case of Danger," Engineering Times Vol. 8, July 1986.

6. Ellis, W. and Lieff, M., "Asbestos in Buildings," ASTM Standardization News, p. 44-47, June 1985.

7. National Research Council: Asbestiform Fibers, Nonoccupational Health Risks, Washington, D.C., National Academy Press, 1984.

8. Zurer, P.S., "Asbestos, The Fiber That's Panicking America," C and EN, p. 28-41, March 4, 1985.

9. "Asbestos; Proposed Mining and Import Restrictions and Proposed Manufacturing Importation and Processing Prohibitions," Federal Register, Vol. 51, No. 19, January 29, 1986.

10. Dull, D., Address to Asbestos Substitute Gasket and Packing Materials Seminar, Valve Manufacturers' Association of America, Intercontinental Hotel, Houston, Texas, August 6, 1986.

11. Ewing, W. M. and Spain, W. H., "Getting to the Very Fiber of Industrial Asbestos Removal," Occupational Health and Safety, p. 29-68, June 1984.

12. Federal Register Vol. 49, No. 67, April 5, 1984 (13658-65), "National Emission Standards for Hazardous Air Pollutants; Amendments to Asbestos Standard" (Final Rule).

13. Ibid, Vol. 47, No. 103, May 27, 1982 (23360-89), "Friable Asbestos Containing Materials in Schools; Identification and Notification" (Final Rule).

14. Ibid, Vol. 48, April 10, 1984 (51085-114), "U.S. Dept. of Labor (OSHA), Occupational Exposure to Asbestos" (Proposed Rule).

15. "Asbestos Action," p. 67, Engineering News Record, August 7, 1986.

16. "Class Action Lawsuit," p. 30, Insulation Guide, June/July 1986.

17. "Liability Insurance," p. 28, Insulation Guide June/July 1986.

18. "Damage Judgements," p. 28, Insulation Guide, June/July 1986.

19. "Asbestos in Buildings Scaring Lenders Away," Engineering News Record, p. 10, July 10, 1986.

20. Crowley, M. S., "New Developments in Refractory Linings," NPRA paper No. MC83-9, presented at the Refinery and Petrochemical Plant Maintenance Conference, Anaheim, Ca., February 8-11, 1983.

21. Thomas, S. F. and McKillop, G. R., "Substitute Materials to Replace Asbestos in Refinery Service Gaskets and Packings," Oil and Gas Journal, p. 47-51, May 26, 1986.

22. Petrunich, P. S., "Flexible Graphite Non-Asbestos Valve Packing," and "Flexible Graphite Non-Asbestos Gasketing Material," Asbestos Substitute Gasket and Packing Materials Seminar, Valve Manufacturers' Association, Houston, Texas, August 6-7, 1986.

23. Kaufmann, J. C. "Better Gaskets Without Asbestos," Machine Design, p. 67-70, July 10, 1986.

24. "Refractory Ceramic Fibers, A Product Report," Insulation Guide, p. 24-27, July/August 1985.

25. Scott, S. W., "Asbestos Substitutes in Friction Applications," Design News, p. 44-50, March 26, 1984.

Table I

Asbestiform Minerals

Mineral Group	Variety	Formula
Serpentine	chrysotile (white)	$Mg_6Si_4O_{10}(OH)_8$
Amphibole	crocidolite (blue)	$Na_2Fe_3^{2+}Fe_2^{3+}Si_8O_{22}(OH,F)_2$
	amosite (brown)	$(MgFe^{2+})_7Si_8O_{22}(OH)_2$
	tremolite-actinolite	$Ca_2(MgFe^{2+})_5Si_8O_{22}(OH)_2$
	anthophyllite	$(MgFe^{2+})_7Si_8O_{22}(OH,F)_2$

Table II

Risks of Death by Cause - 1980
(Death rate per 100,000 population/year)

Cause of Fatality	
Accidents[a]	
Motor vehicles (traffic)	22.5
Falls	7.7
Drowning	3.4
Miscellaneous	2.9
Fire	3.1
Poisoning	1.9
Suffocation	2.2
Aircraft	0.7
Motor vehicles (non-traffic)	0.6
Firearms	0.3
Disease[b]	
Cardiovascular diseases	337.2
Cancer	165.3
Pneumonia	19.7
Diabetes	12.0
Asbestos Disease from Building Exposure	
U.K. Advisory Committee on Asbestos (50 years)[c]	0.007-0.24
Royal Commission on Asbestos Estimate (10 years)	0.029

Sources: [a]Canada Safety Council, Accident Fatalities, Canada 1980 (Ottawa: The Council, 1982), Table 2, p. 5.
[b]Ibid., Table 19, p. 24
[c]Adapted from: U.K. Advisory Committee on Asbestos. Asbestos - Volume 1: Final Report of the Advisory Committee (London: Her Majesty's Stationery Office, 1979), Table 22, p. 62.

Table III

Properties of Packing Materials for Use Above 450°F

Property	Carbon Pitch	Flexible Graphite	Glass E	Glass S	Misc. PBI*	Misc. Ceramic
Temperature Limitation	1200°F	1200°F	1000°F	1500°F	1000°F	2200°F
Pressure Limitation	1000 psi	2500 psi	1000 psi	2500 psi	2500 psi	1000 psi
pH range	0-14	0-14	4-8	3-10	2-11	3-10

*Polybenzidazol (Celanese Corporation)