IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
BEAUMONT DIVISION

MASTER ASBESTOS FILE	§	MASTER DOCKET NOS. 1:90MC1000
	§	1:90MC2000

PITTSBURGH CORNING CORPORATION'S AMENDED
ANSWERS TO PLAINTIFFS' MASTER SET OF INTERROGATORIES

GENERAL OBJECTION

This Defendant manufactured an asbestos thermal insulation product, UNIBESTOS, from July 1, 1962 to on or about February 1, 1972. Unless otherwise stated in response to specific interrogatories, the responses herein shall be limited to such product and time period. This Defendant objects to providing responses for any other period of time on the grounds that such additional information sought is irrelevant, immaterial, not calculated to lead to the discovery of admissible evidence, and furthermore, could be burdensome, expensive and harassing to comply with.

This Defendant also relabeled and sold mastics, a few of which contained a small amount of asbestos fibers used as a binder, as an accessory product for use principally with this Defendant's low temperature nonasbestos-containing insulation

PLAINTIFF'S
EXHIBIT
U210

product. Said fibers were bound in a bituminous and/or resinous binder, and were exempt from the asbestos controls of the Consumer Products Safety Commission 16 C.F.R. § 1304.3(c).

The mineral asbestos may be found in a wide variety of product forms, including ceiling tiles, floor tiles, gaskets, gloves, mastics, protective aprons, protective matting, etc. This Defendant objects generally to these interrogatories and requests as vague, overly broad, irrelevant, immaterial and not reasonably calculated to lead to the discovery of admissible evidence so far as they relate or refer to unidentified asbestos-containing products or materials and will limit its responses as stated above.

This Defendant states that there never existed a predecessor corporation with respect to this Defendant. While this Defendant purchased on June 30, 1962 selected assets from Union Rubber & Asbestos Co., it did not purchase that company; that company continued to operate as a separate company for years and to sell other products and was not a predecessor corporation of this Defendant. Further, Defendant states that its responses to any interrogatory or request herein relate only to this Defendant and are not to be construed to imply the existence of a predecessor corporation.

REQUEST FOR ADMISSIONS

1. You are now in the business of manufacturing, selling or distributing products containing asbestos.

RESPONSE: Deny.

2. You have been in the past in the business of manufacturing, selling or distributing products containing asbestos.

(a) This was true during a part of the time between 1940 and 1972.

RESPONSE: Admit to the extent that this Defendant was engaged in the asbestos thermal insulation product business only from July 1, 1962 to about February 1, 1972. However, with regard to the mastic product this Defendant objects as that information is irrelevant and not calculated to lead to admissible evidence.

(b) Between 1940 and 1972, your products were sold or distributed in Texas.

RESPONSE: Admit to the extent that this Defendant's distributors introduced its asbestos thermal insulation product at various times into the State of Texas between July 1, 1962 and about February 1, 1972.

(c) After 1972 some of your asbestos products were still in place where installed earlier.

RESPONSE: This Defendant does not have sufficient information on which to base a response to this request, therefore this request is denied.

3. You knew your products inquired about above contained asbestos.

RESPONSE: Admit.

4. You gave no warning to the plaintiff(s) in this case of the dangers of asbestos.

RESPONSE: Deny.

5. Asbestos is a known cause of asbestosis.

(a) A known cause of mesothelioma.

(b) A known cause of cancer of other bodily organs.

(c) A known cause of lung or bronchial damage.

RESPONSE: (a) through (c) This Defendant objects to this request on the basis that it is overly broad, vague and ambiguous. Further, this Defendant objects to this request on the basis that it seeks to require an expert medical opinion which this Defendant is unable to render.

INTERROGATORIES

1. As to the person answering these interrogatories, state:

(a) Name.

(b) Title or position with Defendant.

(c) Business address.

(d) Residence address.

(e) Length of time employed by Defendant.

RESPONSE: This Defendant states that Responses to Interrogatories in cases involving alleged injury due to exposure to asbestos-containing thermal insulation products historically were prepared by Robert E. Buckley, former Vice President and Assistant to the President of Pittsburgh Corning Corporation. Mr. Buckley was believed to be the single most knowledgeable person employed by the corporation regarding its involvement in the manufacture and sale of Unibestos. Mr. Buckley is deceased. Accordingly, these responses have been prepared at the direction of Richard C. McPherson, an officer of Pittsburgh Corning Corporation.

The address for Richard C. McPherson is as follows:

800 Presque Isle Drive
Pittsburgh, PA 15239

Employed by Pittsburgh Corning Corporation since 1973.

2. State the following concerning this Defendant:

(a) Full and correct name.

RESPONSE: Pittsburgh Corning Corporation

(b) Principal place of business.

RESPONSE: 800 Presque Isle Drive
Pittsburgh, Pennsylvania 15239

(c) State of incorporation.

RESPONSE: Pennsylvania

(d) Date of incorporation and name of corporation.

RESPONSE: 1937; see (a), above.

(e) Is this Defendant authorized to transact business in the State of Texas? If so, state the date such authority was first issued and last renewed.

RESPONSE: Objection. This interrogatory is unbounded by time restraints without waiving this objection, this Defendant states it was first authorized to transact business in Texas in 1962. This Defendant last renewed its authority in 1983.

(f) Does this Defendant have an agent, representative or place of business in Texas? If so, state the name and address of such agent, representative, or place of business.

RESPONSE: Objection. This interrogatory is unbounded by time restraints without waiving this objection, this Defendant states Pittsburgh Corning Corporation has an office in Houston, Texas which is available to the corporation's sales representatives when they are in the area. All sales orders are accepted in Pittsburgh, PA.

(g) Does this Defendant have an agent for service in the State of Texas? If so, state the name and address of the registered agent.

RESPONSE: CT Corporation Systems
350 North Saint Paul
Suite 2900
Dallas, Texas 75201

3. Has this Defendant been sued under its correct name? If not, state the correct legal name of the Defendant and provide the information requested in No. 2 above concerning the Defendant as correctly named.

RESPONSE: This Defendant's correct corporate name is Pittsburgh Corning Corporation.

4. Has this Defendant ever acquired through purchase, reorganization or merger another corporation, company, or business which manufactured, sold, processed, distributed or contracted to apply insulation products containing asbestos?

RESPONSE: This Defendant manufactured and sold UNIBESTOS for the first time on July 1, 1962 on which date it purchased selected assets and facilities from Union Asbestos and Rubber Company (UNARCO) which it then utilized in the manufacture of UNIBESTOS. This Defendant does not have specific knowledge as to when UNIBESTOS was first sold, however, this Defendant believes the product was first commercially sold by UNARCO as early as 1954. Other published studies and governmental reports suggest that UNARCO first manufactured Unibestos for sale in 1937 or 1938 pursuant to the requirements and testing of the United States Navy. Pittsburgh Corning's production ceased on or about February 1, 1972. See General Objection regarding accessory products.

5. If the answer to Interrogatory No. 4 is "Yes," then state the following concerning such predecessor:

(a) Full and correct name.

(b) The principal place of business.

(c) State of incorporation.

(d) Date of acquisition by Defendant.

(e) Was this business authorized to transact business in the State of Texas?

(f) Attach copies of all papers pertaining to the acquisition.

RESPONSE: Objection. This interrogatory is irrelevant, without waiving this objection, there never existed a predecessor corporation with respect to this Defendant. See this Defendant's response to Interrogatory No. 4.

6. As to any product containing asbestos in any form, has this Defendant, or any predecessor(s):

(a) Ever designed such a product?

RESPONSE: No.

(b) Manufactured such a product?

RESPONSE: Yes. UNIBESTOS.

(c) Processed such a product?

RESPONSE: See (b) above.

(d) Sold such a product?

RESPONSE: Yes. See this Defendant's response to Interrogatory No. 4.

(e) Distributed such a product?

RESPONSE: See (d) above.

(f) Patented such a product?

RESPONSE: UNIBESTOS was not a patented product; however, this Defendant acquired a patent that related to the process by which pipecovering could be manufactured as part of its purchase agreement with Union Asbestos and Rubber Company, dated July 1, 1962. That patent #2,620,515 was issued September 9, 1952 and was for a "Method of and Apparatus for Forming Pipe Insulation".

(g) Relabeled such a product which was manufactured, sold, or distributed by another company?

RESPONSE: On July 1, 1962, this Defendant purchased selected assets and facilities of Union Asbestos and Rubber Company, which assets included a small amount of UNIBESTOS manufactured by the original producer. In addition, Defendant purchased small amounts of a product similar to UNIBESTOS and manufactured to this Defendant's specifications from Holmes Foundry in Ontario, Canada. These purchases took place in 1963 or 1964 and in early 1972 to fill orders from customers. In addition, as stated in the General Objection, from time to time, this Defendant has sold under its own name mastics manufactured by third companies; however as any asbestos in mastic is encapsulated, that product is not at issue in this litigation and this Defendant therefore objects to further response, seeking information that is irrelevant and not intended to obtain relevant or admissible evidence.

7. If your answer to No. 6(b), 6(d) and 6(e) is "Yes," then give the trade name of the product, the year the Defendant or predecessor first sold or distributed such product, and the year the Defendant last sold or distributed such product.

RESPONSE: See this Defendant's response to Interrogatory No. 4.

8. Have any of the products listed above in Interrogatory No. 6 been altered in chemical composition since first being marketed?

RESPONSE: This Defendant has no knowledge with respect to UNARCO's actions concerning the designing, developing, testing and packaging of the product during and after the product's introduction into the market. However, this Defendant made no alerations during 1962-1972.

9. If so, please state:

(a) The trade name of each such product.

(b The date each such product was altered.

(c) The nature of the alteration.

(d) The reason for the alteration.

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 8.

10. What is the name, address, and the job title of each individual who participated in the design and preparation of manufacturing specifications for each such product?

RESPONSE: See this Defendant's response to Interrogatory No. 8.

11. Do any written memoranda, specifications, blueprints or other written materials of any kind or character relating to the design and preparation of said products now exist?

RESPONSE: See this Defendant's response to Interrogatory No. 8.

12. If so, please state:

(a) List each written material or document

(b) Who presently has possession of each such document?

(c) Where is it located?

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 8.

13. In what year did the Defendant first begin selling or distributing insulation products containing asbestos?

RESPONSE: See this Defendant's response to Interrogatory No. 4.

14. In what year did the Defendant last sell the insulation product which contained asbestos?

RESPONSE: 1972.

15. As to the named Defendant or any predecessor(s) or acquired business, state the various types of products such as blocks, pipe covering, cements, tape, spray-on insulation, mastics, and cloth, and in connection with each type of product, state how the same was packaged (i.e., bags, boxes, sacks, etc.) for sale.

RESPONSE: As to UNIBESTOS during the period this Defendant manufactured an asbestos thermal insulation product, the product was shipped in paperboard cartons measuring three (3) feet in length. The other dimensions varied according to the diameters of the contents.

16. Is your company, as of the date of answering these interrogatories, still manufacturing, selling or distributing any insulation products containing asbestos? If so, give the brand name of such products, the binding material and date first manufactured.

RESPONSE: No.

17. Were each of your insulation products generally expected to reach, or were packaged to reach, the consumer or user, without substantial change in the condition in which it was sold?

RESPONSE: This Defendant's asbestos thermal insulation product was packaged to reach destinations without damage. However, circumstances and contract requirements could exist to cause parties in the supply chain to change the physical form or condition of the product before it reached ultimate user.

18. If your answer to Interrogatory No. 17 is "No," with respect to any product, explain in what way the Defendant claims its products were altered or substantially changed after sale or distribution and before reaching the insulation helper or mechanic.

RESPONSE: See this Defendant's response to Interrogatory No. 17.

19. Do you admit that asbestos insulation applicators, helpers or mechanics, were foreseeable users of Defendant's asbestos-contained insulation products, such as:

(a) Pipe covering;

(b) Blocks;

(c) Asbestos cloth;

(d) Mastics;

(e) Spray-on insulation;

(f) Rope or tape;

(g) Asbestos sheeting or millboard;

(h) Cements.

RESPONSE: This Defendant objects to this interrogatory on the basis that it seeks a legal conclusion or opinion. Without waiving this objection, this Defendant's products were designed to be applied as insulation to pipes. Therefore, it may be assumed that pipe insulators might have handled the product.

20. Based upon the material contents of your products, the method of manufacturing, and the method of application

for the purpose of insulation, can your products be generally applied by an insulator without liberating asbestos fibers?

(a) If there is a different answer concerning different products manufactured, sold, distributed, or used by your company then specify the different products by exact manufacturers name and popular name.

(b) If there is a difference in your answer depending on the year or years in which a particular product was used, then specify in detail what year or years you are referring to and the specific products you are referring to and the year involved.

RESPONSE: This Defendant manufactured UNIBESTOS in ready-to-use 3-foot long rigid half-cylinders, to be fastened to the outside surface of a pipe with two bands of wire or metal. The end of an occasional piece might need to be trimmed to achieve a tight fit. This Defendant did not believe that the application of UNIBESTOS in the intended manner caused the liberation of any significant amounts of asbestos fibers. At a much later date, and shortly before it ceased manufacturing Unibestos, it learned that asbestos fibers in amounts that were more significant could be liberated during certain cutting practices; however, this Defendant had been printing a warning on the products shipping cartons and it had participated in a campaign to distribute literature to its customers regarding safe handling and use of asbestos-containing insulation materials.

21. Was it a foreseeable use of your asbestos-containing insulation products that they may have to be removed, stripped or replaced at any time after installation? If your company contends the plaintiff(s) misused any of your products then state how and under what circumstances your product was misused.

RESPONSE: Objection. This interrogatory seeks a legal conclusion or opinion.

22. Prior to releasing the products listed in Interrogatory No. 6 to the public for sale, were any tests conducted on same to determine potential health hazards involved in the use of materials contained herein?

RESPONSE: See this Defendant's response to Interrogatory No. 4. Union Asbestos & Rubber Co. first released the UNIBESTOS product to the public. This Defendant does not know whether any such tests or studies were performed prior to that release. Prior to its commencement of manufacture this Defendant conducted no such testing.

23. If so, please state:

(a) The name, address, and job classification of each individual who conducted such tests.

(b) The results of such said tests.

(c) Date of such studies.

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 4.

24. Do any written memoranda, specifications, blueprints or other written materials of any kind or character exist relating to the testing of said products?

RESPONSE: Objection. This interrogatory is vague, ambiguous and nonspecific. Without waiving this objection, this Defendant states this Defendant does not know whether Union Asbestos & Rubber Co. conducted such tests and studies. With regard to this Defendant, this Defendant did not conduct studies as specifically described in this interrogatory. During the period 1966 through 1970, this Defendant participated in a study conducted by the Industrial Hygiene Foundation of America, Inc., chiefly to learn about the biochemical effects of amosite asbestos fibers on laboratory animals. A preliminary report indicated that amosite asbestos fibers were introduced into rats, and that asbestosis was noted in some of the animals that were autopsied according to schedule for study purposes. The remaining animals were pastured for the purpose of observing whether lung cancer or mesothelioma tumors developed. According to Defendant's recollection, the pastured animals died unexpectedly in a laboratory epidemic about January 1972, before conclusions could be drawn concerning cancers or tumors. See attached copies of IHF studies. During 1970, this Defendant caused a study to be conducted at The University of California, Berkeley. The purpose of the study was to develop a method for measuring the airborne dust concentrations of four different asbestos-containing pipe insulation materials. The study was conducted by J. Leroy Balzer, W. Clark Cooper, M.D. and Irving R. Tabershaw, M.D. The conclusions reached were:

1. A method by which certain construction materials can be tested for their potential for airborne dust generation had been developed in the course of study.

2. The material containing the highest percentage of asbestos produced the highest concentration of airborne asbestos fibers under the conditions of the test.

3. Measurement of the total dust concentration was a poor indicator of the airborne asbestos fiber concentration.

4. Pulverizing of any of the tested products within confined spaces may result in airborne asbestos fiber concentrations greater than the threshold limit value proposed in 1970.

The report on this study was provided to the United States Department of the Navy. On information and belief, the report formed the basis for a paper subsequently published by the authors. It was not the intent of the study to produce recommendations but simply to develop a method of measuring the dust potential of the different products. A second study by that group was performed in 1971 to compare the dust producing potential of this Defendant's commercial pipe insulation with the asbestos-free product that was under development.

25. If so, please state:

(a) List each such written material or document.

(b) Who presently has possession of each such document and where is it located.

RESPONSE: See attached copies.

26. Did Defendant or any of its subsidiary companies make any design changes as a result of such tests?

RESPONSE: Within a year of the receipt of the Berkeley Study this Defendant made the decision to cease the manufacture of UNIBESTOS.

27. If so, please state:

(a) The nature of the change made.

(b) The name, address, and job classification of each person in charge of making a change.

RESPONSE: See this Defendant's response to Interrogatory No. 26.

28. After releasing said products to the public, were any tests conducted thereon to determine potential health hazards involved in the use of materials contained therein?

RESPONSE: See this Defendant's response to Interrogatory No. 24.

29. If so, please state:

(a) The name, address, and job classification of each person conducting said tests.

(b) The results of said tests.

RESPONSE: See this Defendant's response to Interrogatory No. 24.

30. Prior to 1970, did you or your predecessor(s) ever have any labor inspectors or anyone from your company whose

job it was to go to areas where your products were being used or installed to make a dust level count? If so, state when this procedure started, the purpose of such procedure, and what action, if any, was taken in response to the findings, and attach results.

RESPONSE: This Defendant states that it had no control over job sites or job site workers and the numerous job site variables known only to, and capable of being affected only by insulation contractors, their employees or the employees' union. Therefore, this Defendant did not undertake or finance tests or studies at job sites, pertaining to ventilation equipment.

31. If your company performed or had performed any dust level counts, what action based on the results did your company take?

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 30.

32. Has your company or its predecessor(s) ever conducted any studies concerning the effects of the

inhalation of asbestos dust or fibers on one using or being exposed to any of the asbestos materials manufactured, sold or distributed by you, or your predecessor(s)? In answer to this question, give the date and nature of such studies, if any; the name or names of the persons conducting such studies and their addresses; what the purpose of the studies were; and attach a copy of any reports based upon such studies, showing to shom such reports were given, and the date.

RESPONSE: See this Defendant's response to Interrogatory No. 24.

33. Has your company or its predecessor(s) ever conducted or caused to be conducted, any studies designed to minimize or eliminate the inhalation of asbestos dust and fibers by those exposed to the use of your company's insulation products? If so, give the following:

(a) Name of the person or firm conducting such studies.

(b) The date the studies began and the date completed.

(c) Any publication or dissemination of the results of the studies.

(d) The nature of any action to eliminate or minimize the inhalation of asbestos dust or fibers.

(e) Attach copies.

RESPONSE: See this Defendant's response to Interrogatory No. 24.

34. If your answer to Interrogatory No. 33 is "Yes," state the name and address of such industrial hygienist or hygienists.

RESPONSE: This interrogatory cannot be answered as stated.

35. Does your company have, has it ever had, or has your predecessor(s) ever had, a Research Department? If so, give the year such Research Department was established, and whether or not such Research Department has operated continuously since being established.

(a) How much expended each year on research, etc.;

(b) What percentage of gross sales did your company or its predecessor spend on research concerning the health effects of asbestos.

RESPONSE: No, with respect to its asbestos thermal insulation product.

36. State in detail the purpose, duties and responsibilities of such Research Department.

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 35.

37. Does your company have, has it ever had, or has your predecessor ever had, a Medical Department? If so, give the year such Medical Department was established, and whether or not such Medical Department has operated continuously since being established.

(a) Name each director, chief, or head of your Medical Department year by year with the first year you had a medical director Medical Department. Give the last known address of each.

RESPONSE: Not applicable to this Defendant.

38. State in detail the duties and responsibilities of each Medical Department.

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 37.

39. Prior to 1965, did your company, or any predecessor(s) ever at any time give insulation mechanics or insulation helpers who would be applying or removing your products instructions concerning safety precautions to use in applying such products? If so, describe such instructions, to whom they were given, the dates they were given, and the manner of giving such instructions.

RESPONSE: No.

40. Did your company, or your predecessor(s), ever place any warning signs on the containers in which asbestos insulation products were packaged?

RESPONSE: Yes. Beginning in November 1968, this Defendant caused a 5-inch by 3-inch notice to be printed in red on all cartons containing UNIBESTOS. The notice read as follows: "This product contains asbestos fibers. If dust is created when this product is handled, avoid breathing the dust. If adequate ventilation control is not possible, wear respirator approved by U.S. Bureau of Mines."

41. If you have answered Interrogatory No. 40 in the affirmative, please state:

(a) On what date did your company or your predecessor, issue an order directing a warning be placed on your insulation products or containers?

(b) On what date was such warning actually first placed on your insulation products or containers?

RESPONSE: (a) and (b) See this Defendant's response to Interrogatory No. 40.

(c) On what date did your insulation products, accompanied by such warning, first reach the insulation contractor?

RESPONSE: Unknown.

(d) State the exact wording of the first warning.

(e) State the exact size of the warning printed on your asbestos products or containers.

RESPONSE: (d) and (e) See this Defendant's response to Interrogatory No. 40.

(f) Did your company, or its predecessor(s) dictate the exact size of the printed warning?

RESPONSE: Yes.

(g) Why did your company or its predecessor(s) place such warning on your asbestos insulation products or containers?

RESPONSE: In or about 1968, this Defendant learned other asbestos thermal insulation product suppliers were adding warning labels to cartons and a decision was made to do likewise. Based on available records and information it is believed that this Defendant first learned of the use of warning labels by Owens-Corning Fiberglas Kaylo with respect to pipe insulation in 1968.

(h) Did your company or its predecessor(s) place such warning on your asbestos insulation products or containers because you received a directive, command suggestion, legal opinion, or any type of communication (written or otherwise) from any persons, firm, corporation, governmental agency, committee, association, attorney or institute? If so, from which and on what date did you receive such directive, command, command suggestion, legal opinion, or any type of communication.

RESPONSE: No. The warning referred to was initiated voluntarily.

(i) If the wording of the warning has ever been changed or altered, state when it was changed, and the exact change in the wording.

RESPONSE: Not applicable to this Defendant.

42. Did your company or its predecessor, ever place any warning directly on any of its asbestos insulation pipe covering itself, blocks itself, cloth itself or millboard itself?

RESPONSE: No.

43. Did your company ever stamp the name of the company, its initials, or any identifying logo on any of its asbestos pipe covering, blocks, cloth or millboard?

RESPONSE: See this Defendant's response to Interrogatory No. 42. See also Interrogatory No. 36.

44. Did the warning inquired about in Interrogatories No. 42 and 43, or a similar warning, ever appear in any of your sales literature? If so, attach copies of such sales literature, showing the date such literature was printed.

RESPONSE: See attached copy of typical UNIBESTOS promotional brochure.

45. On what date was the sales literature inquired about in Interrogatory No. 44 first provided to distributors or sellers of your company's products, or your predecessor(s)'s products?

RESPONSE: See this Defendant's response to Interrogatory No. 44.

46. Has your company or your predecessor(s) ever devised a high temperature heat insulation which does not contain asbestos? If so, state the date that such insulation was first placed on the market.

RESPONSE: Not applicable to this Defendant.

47. Were any material safety data sheets ever prepared by your company or its predecessor(s)? If so, attach copies.

RESPONSE: As to UNIBESTOS, no, but see copy of UNIBESTOS product data sheet attached. In 1968, this Defendant participated in a campaign by which it disseminated in bulk brochures published by the

National Insulation Manufacturers Association regarding the safe handling and use of asbestos-containing insulation materials. As to mastics, yes.

48. Did your company or its predecessor ever recall any products containing asbestos from the common market?

(a) State all details of such recall, giving the name of the product, the time of recall and any further action taken in connnection with the recall.

RESPONSE: No.

49. Has your company or its predecessor(s) ever directly advised any contractor to whom you sell your products containing asbestos of threshold limit values for exposure to asbestos dust recommended by the American Conference of Governmental Industrial Hyugienists? If so, state the date or dates that you so advised such contractors, the manner in which you advised such contractor, and the name of each contractor.

RESPONSE: This Defendant was aware of the TLV's and used them to assess the air quality of its manufacturing facilities. This Defendant is unaware of any documents authored or disseminated by this Defendant that contain express reference to the threshold limit values which were distributed to any contractor. However, this Defendant is now aware of a letter from Lee B. Grant addressed to Bath Iron Works dated August 15, 1966 which referenced dust studies performed by the IHF and state health departments.

50. Prior to 1964 did your company or its predecessor(s) ever manufacture insulation products containing asbestos without a warning? List the years.

RESPONSE: Yes. See this Defendant's response to Interrogatory Nos. 40 and 41.

51. After 1964 did you ever manufacture insulation products containing asbestos without a warning? If so, list the name of the product and the years.

RESPONSE: Not applicable to this Defendant. See General Objection.

52. Prior to 1970, did your company, or any predecessor(s), ever manufacture and sell a high temperature heat insulation which does not contain asbestos? If so, state the date that such insulation was first placed on the market.

RESPONSE: Prior to 1970 this Defendant did not manufacture and sell a nonasbestos-containing rigid thermal insulation for pipe operating at temperature up to 1500 degrees F. There never existed a predecessor corporation with respect to this Defendant.

53. Is your company, as of the date of answering these interrogatories, still manufacturing, selling or distributing any insulation products containing asbestos? If so, give the brand names of such products and the binding material and date of first manufacture of such product.

RESPONSE: No.

54. If your company or your predecessor(s), ever devised a high temperature heat insulation which does not contain asbestos, state what prompted your company to devise

such high temperature heat insulation not containing asbestos.

RESPONSE: See this Defendant's response to Interrogatory No. 46. This Defendant sought to manufacture an asbestos-free high temperature product because of a decreasing supply of raw amosite asbestos fibers, and because of an increasing suspicion in the medical profession that perhaps all types of asbestos fibers presented possible health hazards in circumstances not previously believed to be of concern.

55. Has such high temperature heat insulation not containing asbestos performed satisfactorily; that is, is such insulation suitable for the purpose for which it is to be used?

RESPONSE: This Defendant is not presently engaged in the manufacture of an asbestos thermal insulation product and is therefore not qualified to render an opinion on the question set forth in this interrogatory. See this Defendant's response to Interrogatory No. 46.

56. Give the trade names of your high temperature heat insulation products which do not contain asbestos, and state fully what such insulation contains.

RESPONSE: Not applicable to this Defendant.

57. State the decade that there first existed manufacturing technology for commercial purposes the use of chemicals and minerals for combining into a high heat insulation product a substitute for asbestos in insulation materials.

RESPONSE: This Defendant does not know that such manufacturing technology exixts.

58. To your company's knowledge, in what decade was fiberglas first commercially available for insulation over 3500 degrees F.?

RESPONSE: This Defendant does not have the information requested in this interrogatory.

59. In what decade was each of the following products commercially available for use and sale:

(a) Fiberglas;

(b) Calcium silicate;

(c) Mineral wool;

(d) Rock wool;

(e) Foamglas;

(f) Ceramics;

(g) Wood pulp;

(h) Organic pulp.

RESPONSE: Objection. This interrogatory is overbroad, vague, nonspecific and nondefined as it does not suggest the use of any such identified material and thus leaves this Defendant to speculate. In addition, as phrased this interrogatory would result in a confusing and misleading response. Without waiving this objection and in further support thereof, this Defendant unsuccessfully attempted to develop a nonasbestos-containing high temperature insulation product. Thus at the time this Defendant ceased the manufacture of UNIBESTOS there was no viable substitute materials and this Defendant left the high temperature market. Finally, this interrogatory seeks information irrelevant to this Defendant.

60. List all insulation products sold in the 1940's, 1950's and 1960's which did not contain asbestos and give the physical and tensil strength and temperature decomposition date for each product.

RESPONSE: See this Defendant's response to Interrogatory No. 59.

61. Did your company or any predecessor(s) ever have a division or subsidiary company engaged in the contracting business of applying insulation products? If so, give the name of such division or subsidiary company, the full address of the home office of such division or subsidiary company, and the dates such division or subsidiary company was engaged in the contracting business.

RESPONSE: No. This Defendant did not operate contract units.

62. Did any division of your company or subsidiary company engaged in the contract business of applying insulation products ever have any claims for lung diseases or death from lung diseases, whether directly or indirectly attributed to asbestosis, mesothelioma, lung cancer or any

exposure to asbestos products. If the answer is "yes", give the name of such employees and attach copies of such claims and copies of all documents relating to the disposition and handling of such claims.

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 61.

63. Give the location of the state industrial accident board handling each such claim, the disposition of such claims, and the amounts paid in workmen's compensation benefits to each such employee, and the name of the compensation carrier.

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 62.

64. Was your medical department of industrial health department or industrial hygienist responsible for contracting unit employees?

RESPONSE: Not applicable to this Defendant. See this Defendant's response to Interrogatory No. 62.

65. Did your company or its predecessor(s) ever make any industrial hygiene surveys? If so, give the date of such surveys, and attach copies of such surveys.

RESPONSE: This Defendant, from time to time, during 1962-1972 retained the Industrial Health Foundation, Pittsburgh, Pennsylvania and also Doctor Morton Corn, University of Pittsburgh, Pittsburgh, Pennsylvania, to make air-quality surveys at Defendant's asbestos thermal insulation product factories. In addition, an industrial hygiene study at the Tyler plant was conducted by J.T. Destefano in November, 1966.

66. State the year that this defendant or any predecessor(s) were first advised of either threshold limit values or maximum allowable concentrations of both asbestos dust and total dust by the American Conference of Governmental Industrial Hygienists, and state the name of the employee-official of the company receiving such advice and attach copies of the instrument communicating such advice.

RESPONSE: To the best of this Defendant's knowledge, Defendant became aware of threshold limit values pertaining to the concentration of airborne asbestos fibers in manufacturing environments in 1962 about the time Defendant purchased the UNIBESTOS product and selected related assets an facilities from Union Asbestos and Rubber Company (UNARCO). See attached copy of Ruddick to Baumler letter dated May 16, 1962 with attached articles.

67. Was such threshold limit values or maximum allowable concentrations inquired about in Interrogatory No. 66 TOTAL dust and not just asbestos dust?

RESPONSE: This Defendant objects to this interrogatory on the ground that information concerning Threshold Limit Values is public information and is as available to the Plaintiff as it is to this Defendant.

68. State in detail what test, if any, your company ever made with regard to the quantity, quality or threshold limit values of asbestos dust or particles to which insulators were exposed while using your products containing asbestos.

(a) If there were any such tests or studies, give the name or names of the person(s) conducting the tests, the date of the tests and attach true copies of any reports, findings, or memorandums concerning such tests or studies.

RESPONSE: See this Defendant's response to Interrogatory No. 33.

69. When did any official of your company first have knowledge, information or understanding that asbestos would or could or might produce the diseases of:

(a) Asbestosis;

(b) Mesothelioma;

(c) Lung cancer;

(d) Any other disease;

(e) With reference to your company give the name of such official who first had such knowledge, information or understanding;

(f) If there are any documents, records or memorandums of any kind concerning such knowledge, list them and attach copies.

RESPONSE: The term asbestos is generically applied to several different minerals, may be found in various fiber types and may be found in a wide variety of product forms. This interrogatory is overly general and nonspecific as to the type of asbestos used by this Defendant in its thermal insulation product. This Defendant is unable to state when the corporation first became aware of any reported association between asbestos exposure and any particular health hazard. Many of the individuals who were involved with Pittsburgh Corning Corporation in the early 1960's when the company first became involved with a thermal insulation product containing asbestos are now deceased. However, generally, at or about the time it entered the business, Pittsburgh Corning did acquire some information concerning asbestos as reflected in enclosures to two letters its Vice President, Karl Baumler, received in May, 1962. At that time, Pittsburgh Corning's awareness generally related mainly to manufacturing environments where it was understood that exposure to dust levels at or below the TLV level would not result in disease. Those articles did not impart any information that suggested that end users of such products were placed at risk of disease.

The information received in 1962 stated that asbestosis was a lung disease which may be suffered by some persons exposed to extreme and excessive amounts of asbestos fibers over long periods of time. Such information related primarily to heavily exposed asbestos textile manufacturing plant workers, whom it was believed had been exposed grossly in excess of the established TLVs. That information reflected the accepted scientific belief that workers could be exposed to concentrations of asbestos at or below the ACGIH-approved threshold limit value of 5 MPPCF on a time-weighted average throughout their working life, without adverse effect and that asbestosis was not a disease expected to occur with any frequency in the United States due to better work practices. Pittsburgh Corning had no belief or understanding at that time that end users of its thermal insulation product were at any risk.

Pittsburgh Corning is now aware that as reports started to appear regarding a connection between a certain type of asbestos and mesothelioma, crocidolite asbestos was the implicated fiber type. Workers exposed only to amosite asbestos (the fiber type used in Unibestos) were not found to have suffered the disease. None of the materials received by Pittsburgh Corning in 1962 mentioned mesothelioma. Beginning perhaps as early as 1965, Pittsburgh Corning may have learned of a suspected connection between asbestos generally and mesothelioma. (Pittsburgh Corning is now aware of a late 1964 memorandum which suggests that a Pittsburgh Corning employee saw a newspaper article mentioning mesothelioma. That document was not contained in Pittsburgh Corning's files and Pittsburgh Corning is unable to authenticate the document.) The literature at that time revealed that amosite asbestos was not implicated in connection with mesothelioma or lung cancer. Thereafter, in 1966, Pittsburgh Corning's supplier of amosite asbestos, and the same company that a Pittsburgh Corning employee had visited while in England in 1965, confirmed that based on its review of the research that there was "not one case of mesothelioma associated with exposure to amosite asbestos." In fact, in an article published in September, 1972, (after Pittsburgh Corning had ceased manufacturing Unibestos) Drs. Selikoff, Hammond and Churg reported that "there has been no evidence to indicate whether or not the amosite variety (of fiber) is also carcinogenic."

One article Pittsburgh Corning received in May, 1962, entitled: Some Clinical Observations of Asbestosis in Mine and Mill Workers, mentions lung cancer and asbestosis and says: "Moreover, a general statistical survey of all employees in the industry does not seem to indicate any statistical evidence of a causal relationship." Another article received by Pittsburgh Corning in 1962, Pulmonary Disability in Asbestos Workers, states: "There are several reasons for different opinions expressed concerning the relationship of asbestosis and bronchogenic carcinoma. Differences in asbestos fibers are noted." Pittsburgh Corning believes these articles contain the first references to asbestosis and lung cancer that it received and that they show no causal relationship.

At no time prior to 1972 did the scientific literature contain any epidemiologic studies that implicated amosite (the type used in its thermal insulation product) as being causally related to an increased risk of lung cancer among humans. In a publication, Carcinogenicity of Amosite Asbestos, Archives of Environmental Health, Sept. 1972, the authors state: "Few data exist concerning the comparative neoplastic potential of the several kinds of asbestos in man. Some information is available for chrysotile, crocidolite and anthophyllite. However, there has been no evidence to indicate whether or not the amosite variety is also carcinogenic."

Pittsburgh Corning has no understanding of "any other diseases" being produced by asbestos exposure. Pittsburgh Corning is aware that there is considerable debate today as to whether or not any type malignancy other than lung cancer, in conjunction with asbestosis and cigarette smoking, and mesothelioma are causally related to asbestos exposure and does not believe that medical science has generally concluded that there is any causal connection.

70. As to every asbestos product of yours which you have identified in previous interrogatories state the specific type or types of asbestos, (i.e. crocidilite, chrysotile, amosite or any others) which your products contained. If you have percentage figures available, then give the percentage as to each product.

RESPONSE: Because authentic, reliable production records of the precise percentages of components in UNIBESTOS cannot be found in this Defendant's files, and because the quantity of each component varied from one wall thickness and inner diameter to another, the information requested in this interrogatory concerning quantities of components can only be based on the following approximations:

<u>Average Percentages per Unit Volume</u>

Amosite fiber	6%
Sodium Silicate and Diatomaceous Earth	17%

<u>Average Percentages by Weight</u>

Amosite fiber	65%
Sodium Silicate and Diatomaceous Earth	35%

71. Does Defendant contend that plaintiff improperly used its product?

<u>RESPONSE</u>: Discovery is currently ongoing. Defendant will supplement its answer as soon as the information requested becomes available.

72. Set forth a list of photographs, plats, sketches or other documents in the possession of any party that will potentially be used as an exhibit at the trial of this case by you.

RESPONSE: Discovery is currently ongoing. Defendant will supplement its answer as soon as the information requested becomes available.

73. Were you or any of your agents, servants, employees aware of any of the articles described on Exhibit A prior to the year 1950?

RESPONSE: No. This Defendant was not engaged in the asbestos thermal insulation product business prior to July 1, 1962.

74. If you answered the foregoing question "Yes", then answer the following:

(a) Set forth such articles you had knowledge of and the date you acquired such knowledge.

RESPONSE: See this Defendant's response to Interrogatory No. 73.

75. As of January 1, 1965, what quantity of the following asbestos-containing insulation products were stored in your warehousing facility or facilities awaiting sale to contractors or other concerns:

(a) Pipe covering (state figure and number of boxes);

(b) Block (state figure and number of boxes);

(c) Cement (state figure and number of bags).

RESPONSE: With respect only to (a) the information requested is not in this Defendant's records. This interrogatory otherwise does not apply to this Defendant.

76. Do you have any photographs of the products inquired about above or their packages or containers? If so, please attach exact copies.

RESPONSE: See attached Unibestos promotional brochure.

77. Do you contend that none of your asbestos-containing insulation products were sold to or ever reached the premises of any or all of the concerns listed in Exhibit "B" attached hereto? If so, indicated which and explain the factual basis for this contention.

RESPONSE: Objection. This interrogatory is irrelevant, unbounded by time restraints and overbroad. Without waiving this objection, this Defendant states this Defendant did not sell its asbestos thermal insulation product to the parties listed in Exhibit B referred to in this interrogatory. However, this Defendant did not routinely acquire nor maintain a record of disposition or destination of its asbestos thermal insulation product after a sale to a purchaser was completed, except to the extent such information was a critical part of the purchase order information.

BY ______________________________

Attorney for Defendant
Pittsburgh Corning Corporation

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA)
) SS:
COUNTY OF ALLEGHENY)

BEFORE ME, the undersigned authority in and for said Commonwealth and County, personally appeared Richard C. McPherson, who being duly sworn deposes and says that he is Vice President of Human Resources with Pittsburgh Corning Corporation, that he is authorized to make this affidavit on its behalf and that the facts contained in the foregoing Amended Interrogatories are based on previous responses to similar Amended Interrogatories compiled by Robert E. Buckley who was a former Vice President and Assistant to the President of Pittsburgh Corning Corporation and who has sworn that said responses were true and correct to the best of his knowledge or information and belief.

RC McPherson

R. C. McPherson

SWORN TO AND SUBSCRIBED BEFORE ME

this 20th day of December 1990

Patricia E. McLeish

Notary Public

NOTARIAL SEAL
PATRICIA E. McLEISH, NOTARY PUBLIC
MONROEVILLE BORO, ALLEGHENY COUNTY
MY COMMISSION EXPIRES JULY 20, 1992
Member, Pennsylvania Association of Notaries

Respectfully submitted,

WELLER, WHEELUS & GREEN
P. O. BOX 350
BEAUMONT, TEXAS 77704-0350
(409) 838-0101

BY R. Lyn Stevens
R. LYN STEVENS
STATE BAR NO. 1918902

ATTORNEYS FOR DEFENDANT,
PITTSBURGH CORNING CORPORATION

CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the above and foregoing instrument has been forwarded to all known counsel of reocrd on this the 15th day of January, 1991.

R. Lyn Stevens
R. LYN STEVENS

UNIBESTOS

HIGH
TEMPERATURE
INSULATION
BY
PITTSBURGH CORNING
FOR SERVICE
UP TO 1500°

PITTSBURGH
pc
CORNING

UNIBESTOS Insulation . .

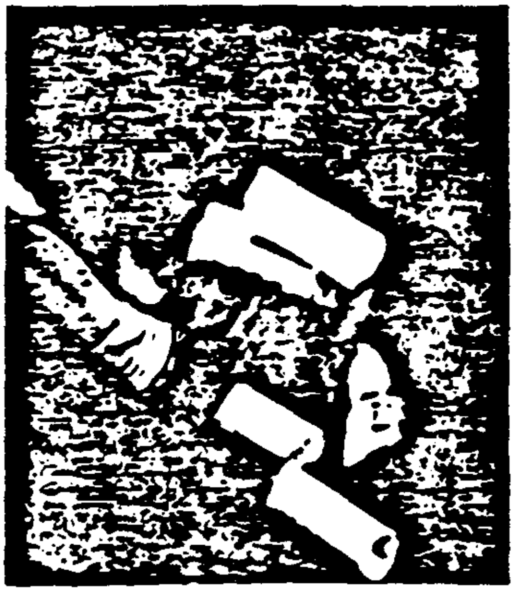
...provides superi(

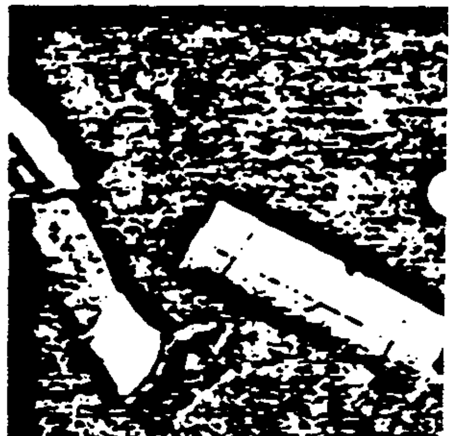
Pittsburgh Corning's UNIBESTOS is the best high temperature piping and equipment insulation available to you today. The very nature of its composition: Amosite asbestos which comprises much of UNIBESTOS; sodium silicate which is its binder; and the diatomaceous silica filler, gives UNIBESTOS a combination of thermal, chemical and physical properties unsurpassed in high temperature insulation.

UNIBESTOS is efficient in insulating, and it's rugged, too ... so rugged it's reusable, long after other types of insulation would have been replaced.

UNIBESTOS has been through extensive, controlled tests ... comparing it with the other types of high temperature insulations ... and no matter what the test has been ... highest temperatures over long periods of time; heat loss

Pound a piece of UNIBESTOS with a hammer ... hard—it won't break up like other pipe insulations will. UNIBESTOS will take the most punishing in plant use and still provide efficient high temperature insulation.





The ruggedness of UNIBESTOS is shown ... a professional football place kicker ea... shatters ordinary calcium silicate pipe in... lation (left) with one kick. The section... UNIBESTOS [illegible] same punishm... and comes through in still usable cond...

at joints; thermal conductivity ... UNIBESTOS is excellent. When actual performance of UNIBESTOS both in the laboratory and in actual installations is compared to other types of high temperature insulation, it is easy to see why it will do a better job in refineries, chemical plants, petrochemical plants, utilities plants and marine applications—anywhere the best insulation is needed for piping and equipment.

The outstanding performance of UNIBESTOS ... both in tests and on-the-job installations results from its special combination of superior materials, advanced engineering and modern, efficient manufacturing methods. The long interlacing fibers between abutting sections of UNIBESTOS form positive heat seals, making single-layer application possible. These long fibers also give UNIBESTOS its ability to resist rough handling in transit and on the job. It won't break up and dust as other commonly used materials do, even after continued removal and reapplication.

RUGGED AND TOUGH

"handleability"

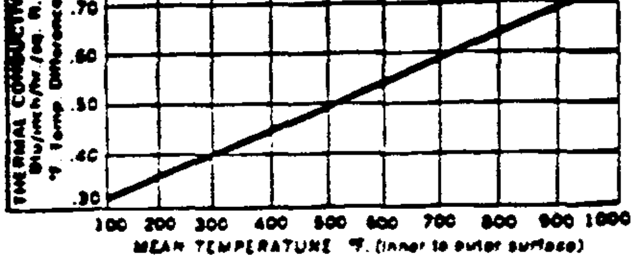
UNIBESTOS withstands moisture, acids, fumes, and corrosive atmospheres. UNIBESTOS, when dried, returns to its original rugged physical characteristics and to the same high insulating efficiency. UNIBESTOS is available up to 5" thickness for all pipe sizes from 1/2" to 36" IPS in full or half round sections up to 44" insulation O.D. It has gained widespread acceptance as the time-saving way to insulate conduit system, underground lines. Requiring less handling, no special banding, UNIBESTOS full cylinders are excellent for this type application. And naturally it won't support combustion . . . it's completely incombustible . . . affording protection for piping in case of fire or sudden and extreme rises in temperature.

UNIBESTOS' inherent strength and resilience make it the most practical high temperature insulation for use in refineries and chemical plants where frequent maintenance and/or changes must be accomplished. Other insulations would crumble, break, fall apart, but UNIBESTOS can be removed and put back on as often as necessary and still provide efficient insulation. UNIBESTOS' ruggedness provides other benefits, too . . . for contractor and user. It has great shock resistance, will take rough handling before, during and after installation thus there is less cleanup after installation, too. UNIBESTOS will also withstand compression without crumbling; heavy tools can be dropped on the line . . . workers can even walk on piping covered with UNIBESTOS without fear of it cracking or crumbling.

PHYSICAL PROPERTIES OF UNIBESTOS

Density (average)	16 lb./ft.^{3}
Compressive Strength (dry at 5% deformation)	12.0 lb./in.^{2}
Lineal Shrinkage	0.0% (one surface) exposed to 1200°F. for 24 hours. ASTM C-356 (soaking heat 1500°F) 0.8% after 24 hours.
Combustibility	Will not burn.
pH	10.5
Thermal Conductivity (K)	at 300°F mean 0.41 at 500°F mean 0.50 at 800°F mean 0.65
Temperature Range	Up to 1500°F.
Thermal Shock Resistance	Will not thermal shock.
Acid Resistance	Negligible effect from common industrial acids and caustics.
Leachable Chlorides (average)	Less than 125 ppm.
Sodium Silicate Content	Over 60,000 ppm.
Noncorrosive	Will not contribute to corrosion of stainless steel.
UNIBESTOS complies with:	Military Spec. MIL-I-24244 Military Spec. MIL-I-2781 Grade II, Class c Grade III, Class f ASTM C-391 Federal Specification HH-I-561, Type III

THERMAL CONDUCTIVITY CURVE OF UNIBESTOS



WIDEST RANGE OF SIZES

THICKNESS OF UNIBESTOS INSULATION

IRON PIPE SIZE—(IN.)		NOMINAL 1"		NOMINAL 1½"		NOMINAL 2"		NOMINAL 2½"		NOMINAL 3"		NOMINAL 3½"		NOMINAL 4"		NOMINAL 4½"		NOMINAL 5"	
NOMINAL	ACTUAL O.D.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.	O.D. OF INSULATION	WT./L.F.
½	0.84	2.9	0.7	4.0	1.3	5.0	2.1	6.6	3.8	7.6	5.0	8.6	6.4	9.6	8.0				
¾	1.05	2.9	0.8	4.0	1.3	5.0	2.1	6.6	3.7	7.6	5.0	8.6	6.4	9.6	8.0				
1	1.32	3.5	0.9	4.5	1.8	5.6	2.5	6.6	3.7	7.6	4.9	8.6	6.3	9.6	7.9				
1¼	1.66	3.5	0.8	5.0	1.9	5.6	2.5	6.6	3.6	7.6	4.8	8.6	6.2	9.6	7.8				
1½	1.90	4.0	1.1	5.0	1.9	6.6	3.5	7.6	4.0	8.6	6.2	9.6	7.8	10.6	9.8				
2	2.38	4.5	1.3	5.6	2.2	6.6	3.3	7.6	4.6	8.6	6.0	9.6	7.6	10.0	9.6				
2½	2.88	5.0	1.4	6.6	3.1	7.6	4.3	8.6	5.8	9.6	7.3	10.0	9.3	11.6	11.3				
3	3.50	5.6	1.6	6.6	2.7	7.6	4.0	8.6	5.4	9.6	7.0	10.0	9.0	11.0	11.0				
3½	4.00	6.6	2.4	7.6	3.7	8.6	5.1	9.6	6.7	10.0	8.7	11.0	10.6	12.0	12.0				
4	4.50	6.6	2.0	7.6	3.3	8.6	4.7	9.6	6.3	10.0	8.3	11.0	10.3	12.0	12.4	14.0	13.6	15.0	16.7
4½	5.00	7.6	2.0	8.6	4.3	9.6	5.9	10.0	7.9	11.0	9.8	12.0	12.0	14.0	14.9	15.0	17.5	16.0	20.2
5	5.56	7.6	2.3	8.6	3.8	9.6	5.4	10.8	7.4	11.0	9.3	12.0	11.5	14.0	14.4	15.0	15.7	16.0	18.8
6	6.63	8.6	2.6	9.6	4.2	10.0	6.1	11.0	8.1	12.0	10.2	14.0	13.3	15.0	15.9	16.0	17.5	17.0	20.6
7	7.63	9.6	3.1	10.6	4.9	11.0	6.8	12.0	9.0	14.0	12.0	15.0	14.6	16.0	17.3	17.0	19.3	18.0	22.3
8	8.63	10.0	3.4	11.6	5.4	12.0	7.5	14.0	10.6	15.0	13.1	16.0	15.9	17.0	18.9	18.0	20.9	19.0	24.0
9	9.63	11.0	3.8	12.6	5.7	14.0	8.8	15.0	11.4	16.0	14.1	17.0	17.2	18.0	20.4	19.0	22.3	20.0	27.3
10	10.75	12.0	3.9	14.0	6.8	15.0	9.3	16.0	12.0	17.0	15.1	18.0	18.4	19.0	21.0	20.0	25.7	21.0	28.8
11	11.75	14.0	4.9	15.0	7.3	16.0	10.0	17.0	13.1	18.0	16.4	19.0	19.8	20.0	23.2	21.0	26.8	22.0	30.6
12	12.75	15.0	5.2	16.0	7.8	17.0	10.9	18.0	14.2	19.0	17.8	20.0	21.0	21.0	24.6	22.0	28.4	23.0	32.4
14	14.00			17.0	7.9	18.0	11.2	19.0	14.6	20.0	18.8	21.0	21.6	22.0	26.4	23.0	29.4	24.0	33.5
15	15.00			18.0	8.7	19.0	12.0	20.0	15.5	21.0	19.1	22.0	22.9	23.0	26.9	24.0	31.0	25.0	35.3
16	16.00			19.0	9.3	20.0	12.7	21.0	16.4	22.0	20.1	23.0	24.1	24.0	28.3	25.0	32.6	26.0	37.6
18	18.00			21.0	9.9	22.0	13.7	23.0	17.7	24.0	21.0	25.0	26.2	26.0	31.2	27.0	35.9	28.0	40.8
20	20.00			23.0	11.0	24.0	14.9	25.0	19.2	26.0	24.2	27.0	28.9	28.0	33.8	29.0	38.6	30.0	44.0
22	22.00			25.0	12.0	26.0	16.8	27.0	21.5	28.0	26.3	29.0	31.4	30.0	36.6	31.0	41.9	32.0	47.5
24	24.00			27.0	13.6	28.0	18.1	29.0	23.2	30.0	28.4	31.0	33.0	32.0	38.3	33.0	45.1	34.0	51.0
26	26.00					30.0	18.9	31.0	24.3	32.0	29.9	33.0	35.6	34.0	41.5	35.0	47.6	36.0	53.9
28	28.00					32.0	20.3	33.0	26.0	34.0	31.9	35.0	38.8	36.0	44.2	37.0	52.5	38.0	59.2
30	30.00							35.0	27.2	36.0	33.4	37.0	41.7	38.0	48.4	39.0	55.2	40.0	62.2
32	32.00									38.0	37.3	39.0	44.1	40.0	51.2	41.0	58.3	42.0	65.7
34	34.00									40.0	39.4	41.0	46.6	42.0	53.9	43.0	61.5	44.0	69.2
36	36.00									42.0	41.5	43.0	49.0	44.0	56.7				

All dimensions are nominal and are subject to standard manufacturing tolerances.
Weights per lineal foot are average for thickness shown.

UNIBESTOS is made in three-foot full and half-round sections in a complete range of sizes and thicknesses. It is available for all pipe sizes from ½" to 36" IPS in thickness from 1"-5" (See chart above). It can be used for all applications up to 1500°F and it's easily cut and worked for special shapes. All these add up to the ONE pipe insulation for all your requirements, thereby simplifying ordering, stocking, installation and maintenance.

UNIBESTOS...THE SUPERIOR SINGLE LAYER HIGH TEMPERATURE INSULATION

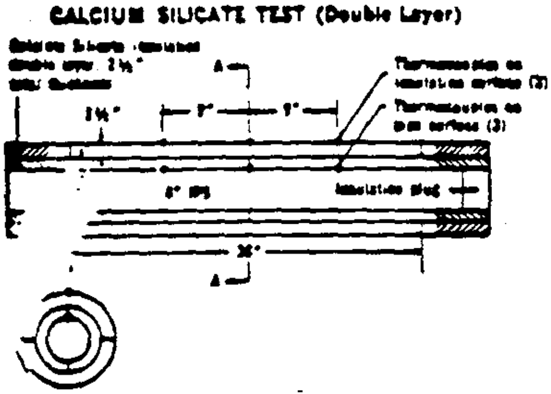
Two inherent advantages found only in UNIBESTOS—the interlocking fibrous joints and negligible shrinkage—make it the most efficient single-layer insulation on the market. In single layer application, the long, interlocking fibers of Amosite in UNIBESTOS form tight heat seals at all butt joints.

Tests witnessed by Pittsburgh Testing Laboratory (see reproduction of test report, right) show performance values measured by actual temperature difference on heated test pipes between UNIBESTOS and a calcium silicate type insulation. These tests illustrate that UNIBESTOS showed less heat loss at joints than the calcium silicate . . . that for equal thicknesses, a single layer of UNIBESTOS loses less heat at the joint than a double layer, staggered joint installation of calcium silicate. This means lower installation costs, faster installation and considerably less material handling on the job.

TEST PROCEDURE

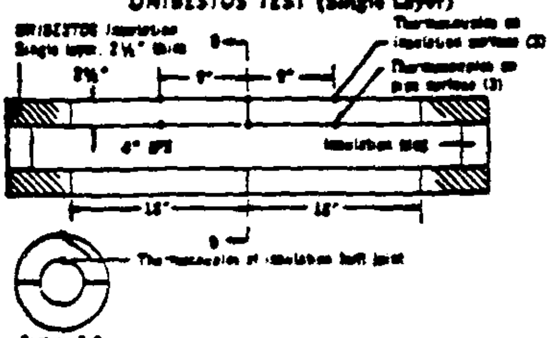
Two identical 44" long sections of 4-inch IPS heavy-duty steel pipes were used for the test. Specially wound 38" long Kanthal wires on ceramic cores were centered within the test pipes and provided the electric heat. A Chromel-Alumel thermocouple was peened into the pipe surface at the center of each test pipe, and served as a control for regulating electric heat through Wheelco temperature controllers. These couples were also used to obtain temperature readings when switched to a L & N Indicating Potentiometer. Additional thermocouples were installed on test pipe surfaces 9" on each side of center. Thermocouples were also installed on the outside surface of pipe insulation directly opposite the couples located on test pipe making a total of six thermocouples for each type insulation. Pipe ends were sealed with a calcium silicate based cement. Drawings showing the details of the two test assemblies are shown below.

CALCIUM SILICATE TEST (Double Layer)



Section A-A

UNIBESTOS TEST (Single Layer)



Section B-B

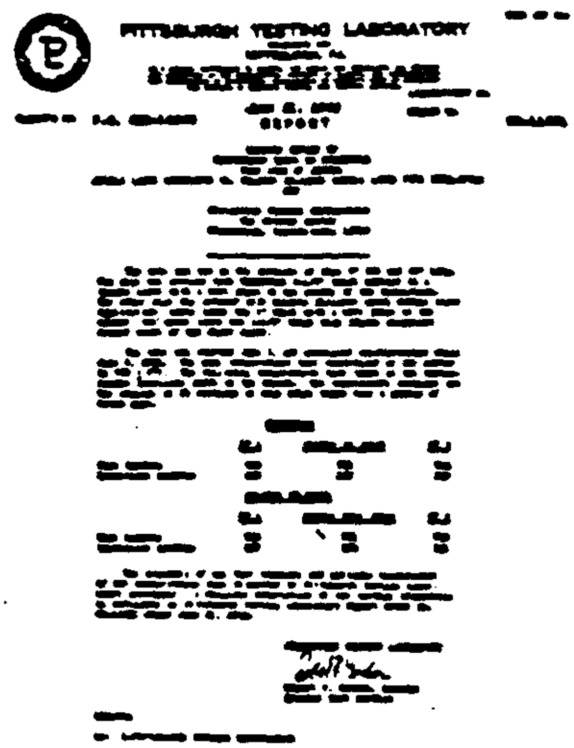


TABLE FROM PTL REPORT (Above)

UNIBESTOS

	9" L	Center at Joint	9" R
Pipe Surface	[illegible]	761	746
Insulation Surface	[illegible]	[illegible]	[illegible]

CALCIUM SILICATE

	9" L	Center over Joint	9" R
Pipe Surface	754	751	[illegible]
Insulation Surface	137	[illegible]	[illegible]

UNIBESTOS ... construction of Unit 3 ... Pacific ... UNIBESTOS ... approximately 12 miles of high tem-

CONSTANT TEMPERATURE 7-MONTHS TEST

Four separate sections of 1¼" IPS stainless steel pipe with Chromalox* electric heaters were used to test three sections of UNIBESTOS and one section of calcium silicate insulation* (all 1¼ IPS x 3" thick).

TEST UNIT	AVERAGE PIPE TEMP.	AVERAGE OUTER SURFACE TEMP.	STARTING WATTS	CONCLUDING WATTS
UNIBESTOS	[illegible]°F	[illegible]°F	[illegible]	370
Calcium Silicate*	[illegible]	[illegible]	462	461
Calcium Silicate (Replacement)	[illegible]	[illegible]	[illegible]	525
UNIBESTOS	[illegible]	164	400	[illegible]
UNIBESTOS	[illegible]	[illegible]	344	313

Results—Much more power was required to maintain approximate starting temperatures with the calcium silicate insulation, and the surface temperature was higher. The calcium silicate failed after 3 months' testing because of excessive shrinkage and deep vertical cracks about every two inches. The replacement section of calcium silicate finished the test with the same results as the original piece. The UNIBESTOS had no cracks through the wall thickness. (There was a color change next to the test pipe, characteristic of a chemical change of the iron content in the amosite asbestos which does not affect the insulating efficiency of UNIBESTOS.)

*A calcium silicate type insulation recommended to 1600°F.

JOINT HEAT-LOSS TEST

Test Results of Surface Temperatures and Heat-Loss at Joints	UNIBESTOS Pipe Insulation (Single Layer)	"B" Insulation (Single Layer)	"B" Insulation (Double Layer)
Thickness of covering, inches	2.50	2.48	2.46
Density of covering, lbs./cu. ft.	14.60	12.55	12.24
Energy supplied to heating unit, watts	[illegible]	[illegible]	610
Energy supplied to heating unit, Btu/hr.	1979	2213	2081
Temperature of pipe, °F	[illegible]	[illegible]	397
Temperature of test room, °F	75	75	75
Temperature difference (pipe minus room), °F	[illegible]	[illegible]	327
Average surface temperature (excluding joints), °F	114	122	116
Average joint temperature, °F	124	152	143
Average rise in temperature at joint, °F	[illegible]	[illegible]	27
Heat loss through end caps, Btu/hr.	[illegible]	[illegible]	344
Heat loss through covering, Btu/hr.	1735	2072	1937
Unit heat loss through covering, Btu/hr. per sq. ft. of pipe surface per degree (F) of temperature difference	0.264	0.270	[illegible]

Results—"... As a result of this investigation it seems to us it may be fairly concluded that because of its fibrous nature, which permits the extension of fibrous material across the butt joints, UNIBESTOS insulation in single layer construction is equally as efficient as double layer construction in insulating materials of a non-fibrous character where there may be more direct passage of heat through the joint." (Quotation from independent laboratory test)

*A registered trademark of Edwin L. Wiegand Co. Pittsburgh, Pa.

OF STAINLESS STEEL

For many years, industry has been bothered by the problem of stress corrosion of austenitic stainless steel caused by the leaching of chloride from ordinary insulations.

Recent laboratory investigations showed that all of the commonly used high temperature insulating materials contained these leachable chlorides — chlorides which caused stress corrosion of austenitic stainless steel under certain conditions. Corrosion-causing chlorides could also enter insulation in industrial or marine atmospheres. Many insulations actually further stress corrosion because (1) they contain none or very little of the necessary inhibitors and (2) they contain high amounts of leachable chlorides.

UNIBESTOS contains, by laboratory analysis, a significantly high amount of sodium silicate (over 50,000 parts per million), an effective inhibitor of stress corrosion . . . a greater amount than any other high temperature insulation. Corrosion-causing chlorides in UNIBESTOS average 125 parts per million.

Dana Test for stress corrosion

In this accelerated corrosion test, a test piece of Type 304 stainless steel heated to 100°C. is placed over a section of thermal insulation which is itself placed in water containing a known amount of chlorides (1500 ppm NaCl solution).

The chlorides in the test solution concentrate on the stainless steel surface as the solution reaching the surface evaporates. Cracking of the stainless steel occurs when the required quantity accumulates.

Criteria for the test is based on the performance of asbestos fiber-sodium silicate type insulation (UNIBESTOS) because it is known to contain large amounts of stress corrosion inhibitor.

Six days without cracking indicates acceptable performance of the insulation being tested.

RESULTS OF ACCELERATED "DANA" TEST PERFORMED ON UNIBESTOS AT LEHIGH TESTING LABORATORY

UNIBESTOS	PARTS PER MILLION
Leachable Chlorides	[illegible]
Total Silicates (SiO_2)	[illegible]
Calcium Silicates ($CaSiO_3$)	[illegible]
Sodium Silicates (Na_2SiO_3)	[illegible]

Five samples were subjected to the accelerated Dana Test and were satisfactory after six days exposure. The test was continued and four specimens failed after 18 days. The test was discontinued at this point.

In field installations over a period of years, no known failures from cracking have occurred in stainless piping insulated with UNIBESTOS. The asbestos fiber with the highest content sodium silicate binder combine in UNIBESTOS to prevent stress corrosion while providing superior insulating qualities.

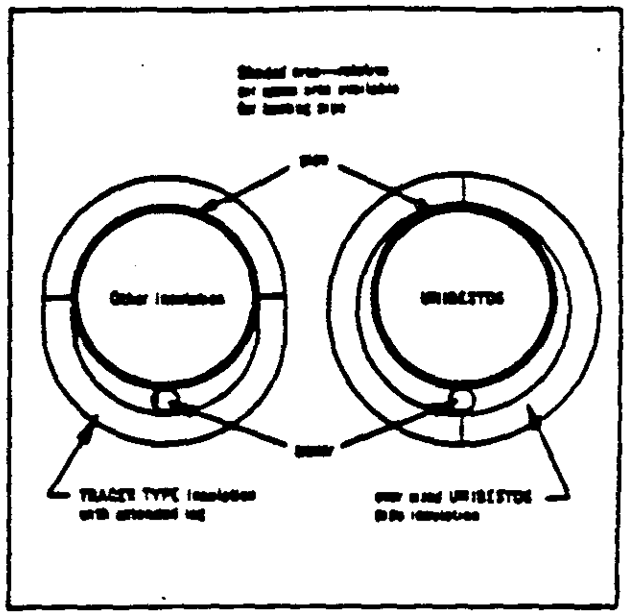
For all stainless steel piping . . . chemical plants, ships, power plants . . . wherever it's used, UNIBESTOS gives lasting, trouble free insulation in a wide temperature range — and effectively inhibits stress corrossion at the same time.

For more details and test results on stress corrosion, contact Pittsburgh Corning Industrial Sales Department.

UNIBESTOS SECTIONS REDUCE INSTALLATION COSTS AND PROVIDE MORE EFFICIENT INSULATION

UNIBESTOS is manufactured in full-round and half-round sections in all sizes and thicknesses for insulating lines from ½" to 36" IPS (most insulations stop at or below the 24" pipe size). Full- and half-round sections eliminate lags, small segments which not only take longer to apply, but of necessity contain many more joints in the finished pipe covering. Extended leg sections which other rigid insulations recommend for traced line application are also eliminated and traced line heat is used more effectively. (See diagram.)

Simply place the sections of tough, resilient UNIBESTOS around the pipe (or pipes in case of traced lines) and fasten them in place. The job is done quicker and will last . . . and last.



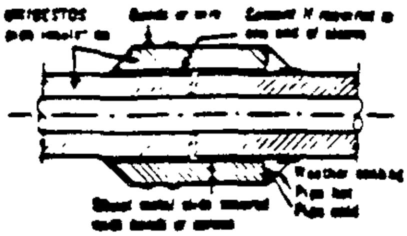
UNIBESTOS WILL NOT CRACK AT HIGH TEMPERATURE

One reason UNIBESTOS is a "one insulation" material for all applications is that over its entire temperature range (100°F to 1500°F) it will never crack, causing heat loss. High heat shrinkage cracks — common to other insulation — just don't happen with UNIBESTOS.

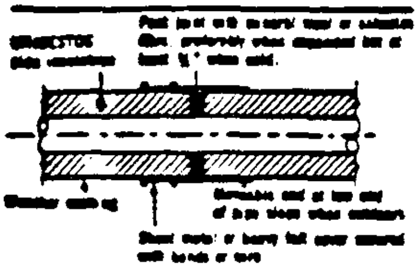
Results of heat shrinkage in a section of calcium silicate pipe insulation (left), and UNIBESTOS (right) after extended testing at high temperatures.

EXPANSION CONTROL DATA

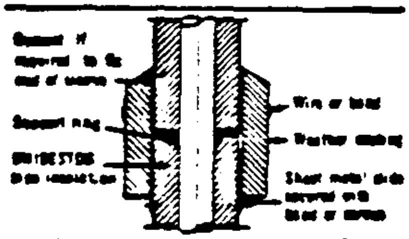
TYPICAL EXPANSION JOINTS AND FITTING COVERINGS



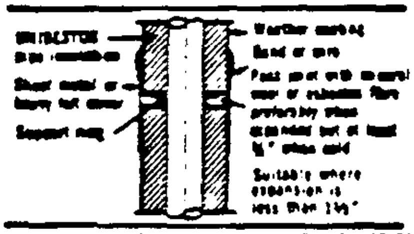
Suitable where expansion exceeds 1½"



Suitable where expansion is less than 1½"

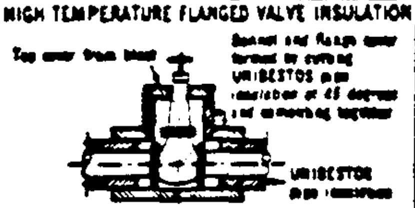


Suitable where expansion exceeds 1½"

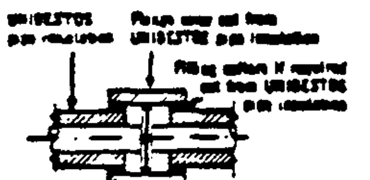


Suitable where expansion is less than 1½"

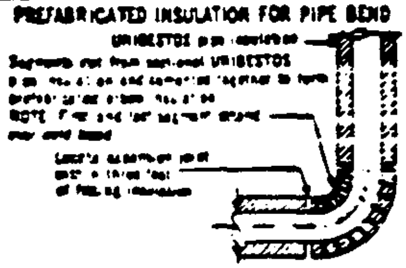
HIGH TEMPERATURE FLANGED VALVE INSULATION



FLANGE INSULATION



PREFABRICATED INSULATION FOR PIPE BEND



The above are suggested methods which may be formed in the field to meet specific requirements.

Expansion joints and fitting covers are easy to fabricate from UNIBESTOS pipe insulation on the job. Variations can be adapted using different membranes and shield for the expansion gap. All variations should meet with the approval of the design engineer on a specific project.

The number and spacing of expansion joints can be determined from the table below. For example, at 750°F pipe temperature and 24' spacing, the expansion per joint will be 1.5". Fixed points, bends, etc. should be considered in establishing locations of expansion joints.

EXPANSION CONTROL CHART

(Figures shown below are inches of expansion per joint interval indicated)

Pipe Temperature	Linear Expansion of Pipe* (Inches/100 ft.)	Interval of Expansion Joint Spacing 9'	12'	15'	18'	21'	24'	27'	30'	36'	42'	48'
1500°	14.89	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.5	5.4	6.2	7.1
1450°	14.19	1.3	1.7	2.1	2.6	3.0	3.4	3.8	4.2	5.1	6.0	6.8
1400°	13.59	1.2	1.6	2.0	2.4	2.9	3.2	3.7	4.1	4.9	5.7	6.5
1350°	12.89	1.2	1.6	1.9	2.3	2.7	3.1	3.5	3.9	4.6	5.4	6.2
1300°	12.29	1.1	1.5	1.8	2.2	2.6	3.0	3.3	3.7	4.4	5.2	5.9
1250°	11.69	1.1	1.4	1.8	2.1	2.5	2.8	3.2	3.5	4.2	4.9	5.6
1200°	11.09	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	4.0	4.7	5.3
1150°	10.49	.94	1.3	1.6	1.9	2.2	2.5	2.8	3.1	3.8	4.4	5.0
1100°	9.89	.89	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.6	4.2	4.7
1050°	9.29	.84	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.3	3.9	4.5
1000°	8.76	.79	1.0	1.3	1.6	1.8	2.1	2.4	2.6	3.2	3.7	4.2
950°	8.20	.74	.98	1.2	1.5	1.7	2.0	2.2	2.5	3.0	3.4	3.9
900°	7.65	.69	.92	1.1	1.4	1.6	1.8	2.1	2.3	2.8	3.2	3.7
850°	7.11	.64	.85	1.0	1.3	1.5	1.7	1.9	2.1	2.6	3.0	3.4
800°	6.59	.59	.79	.99	1.2	1.4	1.6	1.8	2.0	2.4	2.8	3.2
750°	6.07	.55	.73	.91	1.1	1.3	1.5	1.6	1.8	2.2	2.5	2.9
700°	5.56	.50	.67	.83	1.0	1.2	1.3	1.5	1.7	2.0	2.3	2.7
650°	5.08	.46	.61	.76	.91	1.1	1.2	1.4	1.5	1.8	2.1	2.4
600°	4.56	.41	.55	.69	.82	.96	1.1	1.2	1.4	1.6	1.9	2.2
550°	4.10	.37	.49	.62	.74	.86	.98	1.1	1.2	1.5	1.7	2.0
500°	3.63	.33	.44	.54	.65	.76	.87	.98	1.1	1.3	1.5	1.7
450°	3.16	.28	.38	.47	.57	.66	.76	.85	.95	1.1	1.3	1.5
400°	2.71	.24	.33	.41	.49	.57	.65	.73	.81	.98	1.1	1.3

*Installation temperature assumed at 70°F. Table based on carbon and low-alloy steel pipe.

NOTE: Use UNIBESTOS covered expansion joints only if expansion figure to the right of heavy line in chart is used.

JOINT STAPLING FOR INSTALLATIONS OPERATING OVER 600°F

Normally, because of the negligible shrinkage inherent in UNIBESTOS, it is not necessary to use staples at butt joints. However, at operating temperatures above 600°F, linear pipe expansion becomes a critical design factor and staples may be desired. It is recommended that 1½" x 1" steel staples be used in accordance with the following procedure*:

1. Determine pipe operating temperature.
2. From Expansion Control Chart above, determine expansion joint spacing.
3. Knowing IPS and recommended thickness, determine the weight of one lineal foot of UNIBESTOS. (See chart, P. 4.)
4. Multiply weight per lineal foot of UNIBESTOS by one-half the joint spacing.
5. Multiply (4) by 0.6 (coefficient of friction of UNIBESTOS and steel pipe) to find frictional force that staples must resist.
6. Divide (5) by 25 to determine the number of staples required per butt joint.

EXAMPLE: To determine the number of staples required for a 10-inch IPS line operating at 600°F, with a recommended thickness of 2½" UNIBESTOS, and a joint spacing of 30 ft.

IPS	TEMP	REC. THICK.	WT/FT	JOINT SPACING	½ SPACING x WT/FT	F 0	NO. OF STAPLES
10	[illegible]	2½	[illegible]	30	[illegible]	[illegible]	5

*NOTE: This technique is based on expansion of straight horizontal pipe and no allowance is made for bends, etc.

UNIBESTOS IS BETTER IN MANY WAYS

UNIBESTOS DOES NOT SHRINK

Chemically inert at high temperatures and extremely heat stable, UNIBESTOS joints stay tight, heat stays in. MORE heat stays in, because UNIBESTOS joints are more efficient in the first place. The long Amosite fibers provide a really tight heat seal.

AVAILABLE IN 1" THICKNESS UP TO 12" IPS FOR PERSONNEL PROTECTION

UNIBESTOS is made in 1" thickness up to 12" IPS and in 1½" thickness up to 24" IPS for personnel protection. (See Personnel Protection Table, below.)

UNIBESTOS IS EASY TO CUT AND WORK

Bends, elbows, tees, expansion joints, fitting covers and other irregular shapes are easily shop or field fabricated with UNIBESTOS. They'll take hard knocks and rough handling without breakage in shipment or installation, and can be removed whenever necessary and reused. The smooth coating on UNIBESTOS makes it easy to handle . . . no sharp splines or other objectionable handling characteristics.

LOW THERMAL CONDUCTIVITY

UNIBESTOS is as efficient an insulation as you can use over its broad temperature range of 100°F to 1500°F. The low thermal conductivity—"K" Value—of UNIBESTOS will provide maximum thermal efficiency throughout the life of the insulation . . . and UNIBESTOS will outlast other insulations, too. It's stronger, tougher.

SMOOTH REFRACTORY COATING PROVIDES ADVANTAGES

UNIBESTOS is manufactured with a smooth, integral refractory coating which is dust-free and makes UNIBESTOS easy to handle. This smooth, tough coating needs no jacketing indoors, and can be painted, if desired, for color coding.

UNIBESTOS sections can also be provided with canvas and aluminum jacketing at a modest additional charge.

RECOMMENDED UNIBESTOS THICKNESSES FOR PERSONNEL PROTECTION

(Surface Temperature less than 161°F., Ambient Temperature 80°F.)

NOMINAL PIPE SIZE	TEMPERATURE HOT PIPE, °F.													
	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
	TEMPERATURE DIFFERENCE PIPE TO AIR													
	120	220	320	420	520	620	720	820	920	1020	1120	1220	1320	1420
1" and Less	1	1	1	1	1	1	1½	1½	1½	2	2	2½	2½	2½
1½"	1	1	1	1	1	1½	1½	1½	2	2	2	2½	3	3
2"	1	1	1	1	1	1½	1½	1½	2	2	2½	2½	3	3
3"	1	1	1	1	1	1½	1½	2	2	2½	2½	3	3	3½
3½"	1	1	1	1	1	1	1½	1½	2	2	2½	2½	3	3½
4"	1	1	1	1	1	1½	1½	2	2	2½	2½	3	3½	3½
5"	1	1	1	1	1	1½	2	2	2½	2½	3	3	3½	4
6"	1	1	1	1	1½	1½	2	2	2½	3	3	3	3½	4
8"	1	1	1	1	1½	1½	2	2	2½	3	3	3	3½	4
10"	1	1	1	1	1½	1½	2	2½	2½	3	3½	3½	4	4
12"	1	1	1	1	1½	1½	2	2½	2½	3	3½	3½	4	4½
14" to [illegible]	1½	1½	1½	1½	1½	1½	2	2½	3	3	3½	3½	4	4½
[illegible]	1½	1½	1½	1½	1½	2	2	2½	3	3½	3½	4	4	4½

UNIBESTOS pipe insulation is manufactured in thicknesses that conform to accepted industrial and manufacturer's standards known as simplified dimensional standards. In order to conform to these standards, the outside diameters of all UNIBESTOS sections closely approximate those of iron pipes.

By conforming to these standards the installation of UNIBESTOS is further simplified and any dimensional confusion or adjustment is eliminated. These uniform manufacturing standards are particularly useful in the fabrication of valve and fitting covers, etc., where nesting layers of UNIBESTOS are required.

RECOMMENDED UNIBESTOS THICKNESSES FOR INDUSTRIAL USE

PIPE TEMP.	200°F			300°F			400°F			500°F			600°F			700°F		
TEMP. DIFF.	120°F			220°F			320°F			420°F			520°F			620°F		
PIPE SIZE	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST
½	1	16.3	93.5	1	32.4	[illegible]	1½	48.2	[illegible]	1½	57.3	[illegible]	2	67.6	[illegible]	2	[illegible]	114
¾	1	25.7	94.1	1	35.1	[illegible]	1½	[illegible]	[illegible]	1½	64.4	114	2½	64.4	[illegible]	2½	[illegible]	[illegible]
1	1	30.2	93.6	1	38.2	[illegible]	1½	[illegible]	[illegible]	1½	71.2	113	2½	71.1	[illegible]	2½	[illegible]	[illegible]
1¼	1	35.6	97.3	1	[illegible]	111	1½	57.6	[illegible]	1½	[illegible]	113	2½	[illegible]	[illegible]	2½	[illegible]	113
1½	1	33.3	[illegible]	1	[illegible]	[illegible]	2	51.4	[illegible]	2	70.6	[illegible]	3	70.5	[illegible]	3	[illegible]	[illegible]
2	1	38.7	[illegible]	1	[illegible]	[illegible]	2	[illegible]	101	2	[illegible]	[illegible]	3	91.2	[illegible]	3	125	[illegible]
2½	1	34.8	[illegible]	1	67.2	110	2	[illegible]	[illegible]	2	[illegible]	[illegible]	3	[illegible]	[illegible]	3	[illegible]	107
3	1	40.7	97.4	1	[illegible]	112	2½	70.3	98.7	2½	97.2	[illegible]	3½	[illegible]	[illegible]	3½	[illegible]	[illegible]
4	1	49.5	[illegible]	1	[illegible]	112	2½	[illegible]	[illegible]	2½	115	[illegible]	3½	[illegible]	[illegible]	3½	[illegible]	[illegible]
5	1	[illegible]	[illegible]	1	126	114	2½	[illegible]	[illegible]	2½	[illegible]	[illegible]	3½	[illegible]	[illegible]	3½	[illegible]	110
6	1½	82.7	[illegible]	1½	[illegible]	[illegible]	2½	130	[illegible]	2½	[illegible]	[illegible]	4	[illegible]	[illegible]	4	[illegible]	107
7	1½	57.6	[illegible]	1½	114	[illegible]	2½	[illegible]	[illegible]	2½	171	110	4	[illegible]	[illegible]	4	[illegible]	[illegible]
8	1½	96.6	[illegible]	1½	127	[illegible]	2½	[illegible]	[illegible]	2½	170	[illegible]	4	[illegible]	[illegible]	4	[illegible]	[illegible]
9	1½	73.1	96.6	1½	[illegible]	[illegible]	2½	140	[illegible]	2½	197	110	4	[illegible]	[illegible]	4	[illegible]	[illegible]
10	1½	74.4	96.1	1½	147	[illegible]	3	130	101	3	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	110
12	1½	85.1	96.3	1½	178	[illegible]	3	[illegible]	[illegible]	3	221	107	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]
14	[illegible]	[illegible]	95.4	1½	[illegible]	107	3	177	101	3	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]
16	1½	115	95.5	1½	216	[illegible]	3	197	101	3	273	[illegible]	5	242	[illegible]	5	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	95.9	1½	240	[illegible]	3	215	102	3	301	[illegible]	5	[illegible]	102	5	[illegible]	107
[illegible]	[illegible]	141	95.3	1½	271	[illegible]	3½	210	[illegible]	3½	[illegible]	[illegible]	5	[illegible]	[illegible]	5	[illegible]	107
24	1½	153	95.5	1½	[illegible]	[illegible]	3½	[illegible]	98.5	3½	[illegible]	[illegible]	5½	[illegible]	101	5½	[illegible]	[illegible]

RT=Recommended Thickness. HL=Heat Loss (BTU/HR/LF). ST=Surface Temperature (°F.).

All recommended thickness tables are based on 80°F ambient still air and 0.9 emissivity of surface.

RECOMMENDED UNIBESTOS THICKNESSES FOR PROCESS INDUSTRIES

Pipe Temperature	200°F			300°F			400°F			500°F			600°F			700°F			800°F		
Temperature Difference	120°F			220°F			320°F			420°F			520°F			620°F			720°F		
Pipe Size	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST
½	1	16.5	83.5	1	27.8	104	1	50.5	116	1	70.8	121	1	93.5	140	1	119	149	1½	116	134
¾	1	19.7	96.3	1	30.1	106	1	69.9	122	1	85.1	135	1½	84.8	123	1½	107	133	1½	[illegible]	[illegible]
1	1	20.2	93.6	1	30.2	104	1	62.4	117	1	87.1	130	1½	94.1	132	1½	110	131	2	126	125
1¼	1	25.6	97.3	1	40.8	111	1	50.5	126	1	112	141	1½	106	123	1½	133	132	2	150	133
1½	1	25.3	96.8	1	42.3	109	1	61.3	122	1	112	138	1½	125	130	1½	[illegible]	130	2	140	125
2	1	30.7	96.2	1	50.0	109	1	90.6	123	1	120	135	1½	135	130	1½	[illegible]	130	2	174	132
2½	1	34.8	96.8	1	67.5	110	1	106	124	1	140	138	1½	135	133	1½	172	132	2	182	125
3	1	40.7	97.8	1	80.3	112	1	126	127	1	172	141	1½	175	130	1½	221	144	2	227	130
4	1	40.0	98.8	1	98.6	112	1	140	130	1	[illegible]	140	1½	250	135	1½	[illegible]	147	2	270	142
5	1	60.8	98.8	1	116	114	1	162	120	1	254	146	1½	251	130	1½	222	160	2½	270	133
6	1	71.1	100	1	120	116	1½	182	117	1½	227	130	2	237	127	2	[illegible]	127	2½	313	135
7	1½	57.6	90.3	1½	114	105	1½	178	117	1½	230	130	2	254	130	2	[illegible]	130	2½	346	135
8	1½	64.4	94.2	1½	127	105	1½	180	118	1½	276	130	2	280	130	2	305	130	2½	315	134
9	1½	70.1	96.6	1½	130	105	1½	229	108	1½	305	131	2	305	127	2	305	137	2½	400	135
10	1½	74.4	96.1	1½	147	105	1½	230	119	1½	323	130	2	363	130	2	436	140	2½	460	135
12	1½	85.1	94.3	1½	170	105	1½	257	118	1½	375	130	2	385	130	2	[illegible]	141	2½	520	140
14	1½	88.8	95.4	1½	195	107	1½	257	121	1½	430	130	2	466	133	2	[illegible]	144	3	[illegible]	132
16	1½	115	95.6	1½	218	108	1½	265	127	1½	[illegible]	135	2	[illegible]	134	2	635	145	3	566	134
18	1½	128	95.3	1½	240	108	1½	285	122	1½	540	135	2	566	135	2	700	146	3	675	135
20	1½	141	95.3	1½	271	108	1½	406	123	1½	605	135	2½	590	135	2½	640	136	3	679	135
24	1½	152	95.6	1½	302	108	1½	461	124	1½	662	135	2½	605	135	2½	761	131	3	797	135

All recommended thickness tables are based on 80°F ambient still air and 0.9 emissivity of surface.

RECOMMENDED UNIBESTOS THICKNESSES FOR POWER AND UTILITY INDUSTRIES

Pipe Temperature	200°F			300°F			400°F			500°F			600°F			700°F			800°F		
Temperature Difference	120°F			220°F			320°F			420°F			520°F			620°F			720°F		
Pipe Size	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST	IT	HL	ST
½	1	16.5	91.5	1	27.8	104	1	50.5	116	1	70.8	120	1½	75.2	111	1½	84.6	125	2	104	119
¾	1	19.7	96.3	1	30.1	106	1	60.3	122	1	85.1	130	1½	86.8	120	1½	107	130	2	117	125
1	1	20.2	93.6	1	30.2	104	1	62.4	117	1	87.1	130	1½	91.1	122	1½	110	131	2	120	125
1¼	1	25.6	97.3	1	40.8	111	1½	57.5	105	1½	80.1	113	1½	105.0	120	2	120	126	2½	132	120
1½	1	25.3	96.8	1	42.3	109	1½	64.3	108	1½	90.1	118	2	98.8	111	2	130	117	2½	132	116
2	1	30.7	96.2	1	50.0	109	1½	72.7	109	1½	101	118	2	118	116	2	142	120	2½	154	121
2½	1	34.8	96.8	1	67.5	110	1½	74.8	104	1½	105	113	2	119	114	2	130	120	2½	164	119
3	1	40.7	97.8	1	80.3	112	1½	90.6	112	1½	126	125	2	147	120	2	160	126	3	178	119
4	1	40.8	98.8	1	98.6	112	1½	119	113	1½	161	126	2	176	126	2	[illegible]	132	3	[illegible]	120
5	1	60.8	98.8	1	116	114	1½	137	118	1½	182	125	2½	175	116	2½	[illegible]	125	3	240	123
6	1	71.1	100	1	120	116	1½	162	117	1½	227	120	2½	200	108	2½	225	126	3½	241	117
7	1½	57.6	90.8	1½	114	100	1½	178	117	1½	250	120	2½	225	119	2½	254	127	3½	270	119
8	1½	64.4	94.2	1½	127	105	1½	188	112	1½	276	120	2½	257	127	2½	[illegible]	125	3½	285	120
9	1½	70.1	96.6	1½	130	105	1½	210	110	1½	285	126	2½	[illegible]	120	2½	[illegible]	125	3½	304	120
10	1½	74.4	96.1	1½	147	105	1½	230	115	1½	323	130	2½	[illegible]	[illegible]	2½	325	126	3½	323	122
12	1½	85.1	94.3	1½	170	105	1½	257	108	1½	375	135	2½	[illegible]	122	2½	487	130	4	284	110
14	1½	88.8	95.4	1½	195	107	2	240	113	2	340	120	3	[illegible]	120	3	487	124	4	[illegible]	120
16	1½	115	95.5	1½	218	108	2	272	112	2	[illegible]	122	3	[illegible]	117	3	[illegible]	120	4	443	121
18	1½	128	95.9	1½	240	108	2	284	113	2	[illegible]	120	3	[illegible]	118	3	[illegible]	125	4	440	121
20	1½	141	96.3	1½	271	109	2	285	113	2	[illegible]	124	3	[illegible]	120	3	[illegible]	[illegible]	4	525	122
24	1½	152	96.6	1½	302	108	2	[illegible]	114	2	[illegible]	125	3	517	119	3	[illegible]	127	4½	565	118

All recommended thickness tables are based on 80°F ambient still air and 0.9 emissivity of surface.

TYPICAL SPECIFICATION FOR SINGLE-LAYER* APPLICATION

Because of the exceptional heat stability and the negligible shrinkage of UNIBESTOS, practically any installation can be completed using only a single layer of the proper thickness of UNIBESTOS. The specification below details this technique.

1. Temperature Range: UNIBESTOS shall be used on piping operating from +200°F. to +1500°F.

2. Thickness Required: Thickness shall be determined from the table of suggested thicknesses or the most economic thickness may be calculated using the NIMA Guide for determining economic thickness.

3. *Material: All piping shall be insulated with* UNIBESTOS as manufactured by Pittsburgh Corning Corporation.

4. Application: UNIBESTOS shall be applied over clean, dry surfaces. Adjoining sections shall be butted firmly together using single-layer applications. Circumferential and longitudinal joints do not require pointing with finishing cement to conserve heat. Insulation under 12" IPS shall be wired in place using 16 gauge soft annealed wire, on pipe sizes over 12", use 14 gauge wire or ½" x .020 Type 302 stainless steel bands. The wiring or bands shall be spaced no greater than 9" on centers. Fittings, flanges, and valves shall be insulated with fabricated mitered segments of UNIBESTOS equal to the thickness of the insulation of the adjoining pipe.

900°F			1000°F			1100°F			1200°F			1300°F			1400°F			1500°F		
820°F			920°F			1020°F			1120°F			1220°F			1320°F			1420°F		
RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST
1½	140	143	2	146	135	2	171	142	2	196	150	2½	181	144	2½	223	139	3	218	138
1½	159	151	2	165	141	2	193	149	2½	189	134	2½	202	138	2½	225	145	3	242	141
2	149	133	2½	157	127	2½	[illegible]	133	2½	212	140	3	219	135	3	242	140	3	272	146
2	181	141	2½	[illegible]	[illegible]	2½	217	147	3	227	136	3	246	141	3	276	140	3½	291	144
2	176	132	2½	[illegible]	[illegible]	2½	214	136	3	229	131	3	[illegible]	135	3	[illegible]	142	3½	[illegible]	139
2	210	140	2½	276	[illegible]	2½	[illegible]	142	3	[illegible]	[illegible]	3	[illegible]	144	3½	[illegible]	140	3½	343	147
2	[illegible]	[illegible]	2½	273	139	2½	[illegible]	[illegible]	3	[illegible]	137	3½	[illegible]	[illegible]	3½	[illegible]	[illegible]	4	342	137
2	274	[illegible]	2½	279	142	2½	[illegible]	[illegible]	3	[illegible]	145	3½	[illegible]	[illegible]	3½	377	[illegible]	4	[illegible]	144
2	[illegible]	151	3	[illegible]	136	3	[illegible]	141	3½	354	[illegible]	3½	[illegible]	[illegible]	4	[illegible]	141	4	[illegible]	[illegible]
2½	[illegible]	141	3	[illegible]	[illegible]	3	[illegible]	[illegible]	3½	[illegible]	141	4	[illegible]	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	[illegible]
2½	[illegible]	143	3	[illegible]	141	3	[illegible]	[illegible]	3½	[illegible]	[illegible]	4	[illegible]	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	[illegible]
2½	479	[illegible]	3½	[illegible]	[illegible]	3½	443	[illegible]	3½	[illegible]	147	4	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]
2½	[illegible]	142	3½	416	[illegible]	3½	[illegible]	[illegible]	4	540	[illegible]	4	[illegible]	144	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]
2½	[illegible]	144	3½	446	[illegible]	3½	[illegible]	141	4	[illegible]	[illegible]	4½	[illegible]	137	4½	[illegible]	142	5	[illegible]	142
2½	541	147	3½	[illegible]	137	3½	[illegible]	144	4	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]	5	718	144
2½	[illegible]	140	3½	[illegible]	[illegible]	3½	[illegible]	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	141	5	[illegible]	[illegible]	5	[illegible]	[illegible]
3	[illegible]	141	3½	[illegible]	141	3½	724	[illegible]	4½	[illegible]	[illegible]	5	[illegible]	137	5	[illegible]	142	5½	[illegible]	143
3	[illegible]	142	4	[illegible]	[illegible]	4	725	141	4½	780	141	5	[illegible]	[illegible]	5	[illegible]	142	5½	[illegible]	144
3	742	143	4	[illegible]	[illegible]	4	[illegible]	142	5	771	[illegible]	5	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	1012	[illegible]
3	825	144	4	785	[illegible]	4	[illegible]	[illegible]	5	843	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	[illegible]	141
3	[illegible]	146	4	[illegible]	137	4	[illegible]	146	5	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	[illegible]	[illegible]	6½	1130	[illegible]

All recommended thickness tables are based on 80°F ambient still air and 0.9 emissivity of surface

900°F			1000°F			1100°F			1200°F			1300°F			1400°F			1500°F		
820°F			920°F			1020°F			1120°F			1220°F			1320°F			1420°F		
RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST	RT	HL	ST
2	135	[illegible]	2½	127	117	2½	[illegible]	[illegible]	3	[illegible]	121	3	172	[illegible]	3	[illegible]	[illegible]	3½	[illegible]	[illegible]
2	141	[illegible]	2½	142	[illegible]	2½	[illegible]	127	3	176	[illegible]	3½	[illegible]	[illegible]	3½	[illegible]	127	4	219	127
2	151	[illegible]	3	147	118	3	172	[illegible]	3	197	129	3½	[illegible]	127	4	217	[illegible]	4	[illegible]	[illegible]
2½	[illegible]	127	3	170	[illegible]	3	[illegible]	[illegible]	3½	211	127	4	[illegible]	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	[illegible]
2½	[illegible]	121	3	171	[illegible]	3	[illegible]	[illegible]	3½	213	[illegible]	4	[illegible]	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	127
2½	[illegible]	[illegible]	3	[illegible]	[illegible]	3	231	[illegible]	4	[illegible]	[illegible]	4	[illegible]	127	4½	271	[illegible]	4½	[illegible]	131
2½	197	[illegible]	3	211	[illegible]	3	[illegible]	[illegible]	4	243	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]
3	214	[illegible]	3½	237	[illegible]	3½	[illegible]	[illegible]	4	[illegible]	[illegible]	4½	[illegible]	127	4½	[illegible]	[illegible]	5	[illegible]	[illegible]
3	240	127	3½	[illegible]	[illegible]	3½	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	127	5	[illegible]	[illegible]	5	[illegible]	[illegible]
3	[illegible]	[illegible]	4	276	121	4	[illegible]	[illegible]	4½	[illegible]	[illegible]	5	[illegible]	[illegible]	5	[illegible]	[illegible]	5½	[illegible]	[illegible]
3½	[illegible]	[illegible]	4	316	[illegible]	4	[illegible]	[illegible]	5	[illegible]	[illegible]	5	[illegible]	127	5	[illegible]	[illegible]	5½	[illegible]	[illegible]
3½	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]	5	[illegible]	127	5	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	427	[illegible]
3½	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	415	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]
3½	[illegible]	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	[illegible]	[illegible]
3½	424	[illegible]	4½	[illegible]	[illegible]	4½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	[illegible]	[illegible]
4	437	[illegible]	5	441	[illegible]	5	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	[illegible]	131	6	724	[illegible]
4	[illegible]	[illegible]	5	473	[illegible]	5	[illegible]	127	5½	[illegible]	[illegible]	6	[illegible]	127	6	[illegible]	[illegible]	6½	[illegible]	[illegible]
4	[illegible]	127	5	[illegible]	[illegible]	5	[illegible]	[illegible]	5½	[illegible]	[illegible]	6	[illegible]	[illegible]	6	[illegible]	[illegible]	6½	815	[illegible]
4	[illegible]	127	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	714	131	6	743	[illegible]	6½	[illegible]	[illegible]	6½	[illegible]	[illegible]
4	643	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	[illegible]	5½	781	[illegible]	6	[illegible]	[illegible]	6½	[illegible]	[illegible]	7	[illegible]	[illegible]
4½	681	[illegible]	5½	[illegible]	[illegible]	5½	[illegible]	127	5½	[illegible]	[illegible]	6½	[illegible]	[illegible]	6½	[illegible]	[illegible]	7	[illegible]	[illegible]

RT=Recommended Thickness. HL=Heat Loss (BTU/HR/LF). ST=Surface Temperature (°F.).

All recommended thickness tables are based on 80°F ambient still air and 0.9 emissivity of surface.

5. Finishes:

1. Indoor: On indoor lines, UNIBESTOS does not require a finish. If a finish is desired, it can be painted with any water base paint or a 6 oz. canvas shall be secured with a lagging adhesive. Note: Any standard insulation finish can be used over UNIBESTOS.

2. Outdoor: Outdoor piping shall be finished with a 45 lb. roofing felt lapped not less than 2". Felt jacket shall be secured with 16 gauge copper wire banded on 9" centers. Other finishes such as glass fabric and breathing pipe mastic and metal jacketing may be used. If an aluminum jacket is used the aluminum shall have a vapor barrier between the aluminum and the UNIBESTOS, or an integral barrier adhered to the aluminum jacket.

Flanges, valves and fittings may be finished in the same manner as adjacent pipe covering.

On all stainless steel lines, an adhesive compatible with stainless steel should be used for fabrication of fittings, ells, etc.

The above specifications are general in nature and final specifications shall meet with the approval of the design engineer.

*NOTE: UNIBESTOS may also be applied in double layer in accordance with common practice if desired. For piping operating over 600° F, staples may be used at butt joints of single layer in accordance with the technique showed under "Expansion Control Data", Page 8.

PITTSBURGH
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[illegible]
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product data sheet

UNIBESTOS®
high temperature insulation for service up to 1500°F

Pittsburgh Corning's UNIBESTOS is the best high temperature piping and equipment insulation available to you today. The very nature of its composition: Amosite asbestos which comprises most of UNIBESTOS; sodium silicate which is its binder; and the diatomaceous silica filler, gives UNIBESTOS a combination of thermal, chemical and physical properties unsurpassed in high temperature insulation.

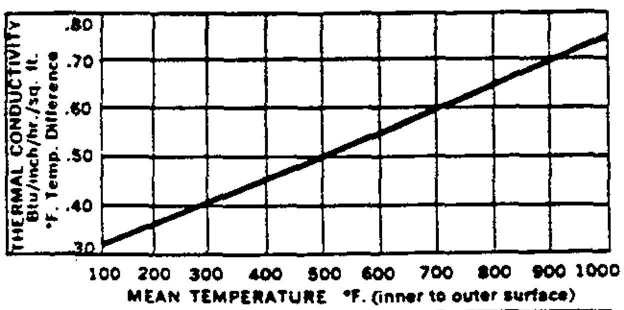
UNIBESTOS is efficient in insulating, and it's rugged, too . . . so rugged it's reusable, long after other types of insulation would have been replaced.

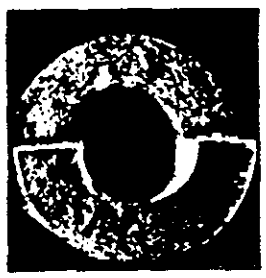
UNIBESTOS has been through extensive, controlled tests . . . comparing it with the other types of high temperature insulations . . . and no matter what the test has been . . . highest temperatures over long periods of time; heat loss at joints; thermal conductivity . . . UNIBESTOS is excellent. When actual performance of UNIBESTOS both in the laboratory and in actual installations is compared to other types of high temperature insulation, it is easy to see why it will do a better job in refineries, chemical plants, petro-chemical plants, utilities plants and marine applications—anywhere the best insulation is needed for piping and equipment.

Physical properties of UNIBESTOS

Density	16 lb./ft.³
Compressive Strength	12.5 lb./in.² / 1800 lb./ft.² (dry; at 5% deformation)
Linear Shrinkage	0.0% to 1200°F. (one surface) exposed to operating temperature for 24 hours
Hygroscopicity	3.5% 70°F. @90% R. H. 24 hours
Combustibility	Will not burn
pH	10.5
Thermal Conductivity (K)	at 300°F mean .41 at 500°F mean .50 at 800°F mean .65
Thermal Shock Resistance	Will not thermal shock
Tensile Strength	67 psi
Acid Resistance	Negligible effect on physical characteristics from common industrial acids and caustics
Leachable Chlorides (average)	Less than 125 ppm
Sodium Silicate Content	Over 60,000 ppm
Noncorrosive	Will not contribute to stress corrosion of stainless steel
UNIBESTOS complies with:	ASTM Designation C391-64 Federal Specification HH-I-561 Type III Form 1 and 2. Military Specification MIL-I-2781 *Grade II* Class c Grade III Class f

Thermal conductivity curve of UNIBESTOS





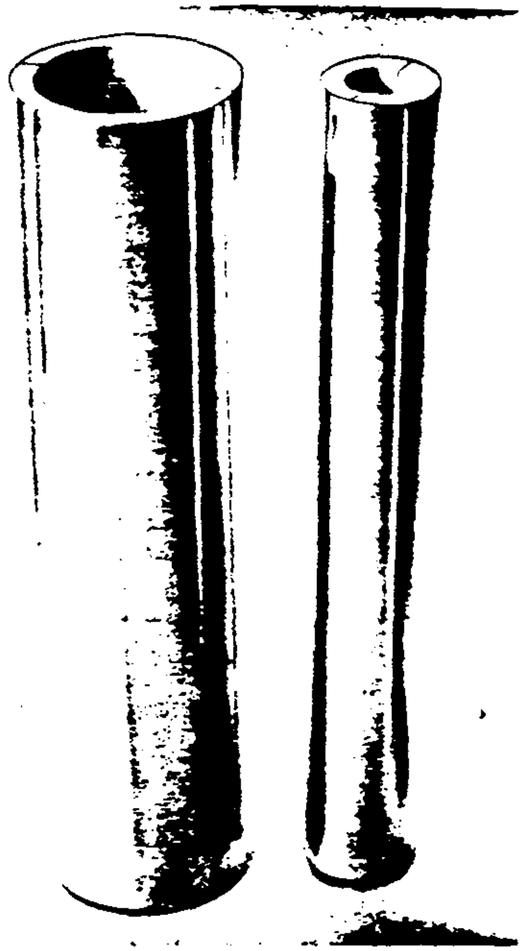
The long interlacing fibers between abutting sections of UNIBESTOS form positive heat seals, making single-layer application possible. These long fibers also give UNIBESTOS its ability to resist rough handling in transit and on the job. It won't break up and dust as other commonly used materials do, even after continued removal and reapplication.

PITTSBURGH CORNING
One Gateway Center
Pittsburgh, Pa. 15222

UNIBESTOS® high temperature insulation for service up to 1500°F

UNI-CLAD®

UNIBESTOS® with a Factory Applied .016 Aluminum Jacket



UNIBESTOS, the best high temperature insulation now available with a factory applied .016 inch aluminum jacket with an integral, polyethylene coated, kraft moisture barrier.

The jacketing employs a "Pittsburgh Lap" along the longitudinal joint to insure a good weatherproof seal. Each section is furnished with one butt joint sealer strap which contains a sealing mastic 1" wide x ¼" thick. The sealer strap, once applied, is held firmly in place by a standard locking aluminum band .020 inch thick.

USES:

UNI-CLAD is recommended for applications up to 1500°F. for power plants, refineries, chemical and petrochemical plants as well as other industries where weatherability, ruggedness, durability, and appearance are important factors.

UNI-CLAD offers savings on initial installation costs along with the ability to be removed and reused over and over again which minimizes future operation costs.

AVAILABILITY:

UNI-CLAD is available in sizes from ½" to 24" IPS and up to 5" insulation thickness in 36" lengths.

OPTIONAL JACKETING:

Stainless Steel

Type 304, .010 gauge with polyethylene coated kraft moisture barrier—application and availability same as UNI-CLAD.

Galvanized

Vinyl coated electro galvanized steel, .010 gauge with polyethylene vapor barrier—specifications and availability same as UNI-CLAD.

Felt

Standard felt in 45 pound or 55 pound in either rag or asbestos—availability same as UNI-CLAD.

Canvas

Standard canvas jacketing in 4, 6, and 8 ounce weights—availability same as UNI-CLAD.

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May 16, 1962

Mr. Karl Baumler
Vice President
Pittsburgh-Corning Corporation
4th Floor

Dear Mr. Baumler:

We are pleased to enclose the following items relative to your recent request about asbestos.

Toxic Properties - from "Sax"
Article on Asbestos - from a book by "Ladov"
A quote on "Asbestosis" - from a book by "Patty"
A discussion about "Asbestosis" - from a book by "Drinker & Hatch"
Hygienic Guide Series on Asbestos
Threshold Limit Values for 1961 - as established by the American Conference of Governmental Industrial Hygienists
A chart from "Patty" on "Asbestos Warts"

We asked the Library to trace down four articles on the subject. If and when they arrive, I'll forward them.

You will note that "Patty" quotes from a Dr. Carey P. McCord (M. D.). Dr. McCord is an authority and is retained by our company. Should you have any technical, medical or toxicological questions, we will be pleased to write him about them.

Of course, you know about our membership in the Industrial Hygiene Foundation and its services and advice are at your call.

Yours,

Clyde C. Ruddick, Manager
Safety & Plant Protection

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K. B.

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of aluminum by physicians for therapeutic or prophylactic purposes, makes only metallic aluminum available. Some investigators, notably Hannon,[73] have reported marked success in the treatment of patients with severe disability. However, when purely objective criteria have been used to measure disability the results have been somewhat less striking. Gardner, Dworski, and Delahant[74] have suggested that variations in response to aluminum therapy may be due in part to the nature of the dust that has caused the silicosis. They suggest that dust which is primarily free silica may react with aluminum more readily than dust which contains high percentages of iron. The use of aluminum generally in industry for the therapy or prophylaxis of silicosis should be contemplated only with the utmost caution.

I. ASBESTOSIS

Asbestos is a hydrated magnesium silicate. More than 90 per cent of the raw mineral used in this country and Great Britian is produced in the Canadian chrysotile mines. Asbestos is used in two general types of manufacturing processes. It may be used either by itself or mixed with other insulating materials such as diatomaceous earth for fireproofing, packing, or insulating; or it may be combined with cotton and woven as a textile for fireproof and heat-resistant clothing and other substances. Lanza[75] estimates that there are about 10,000 persons exposed to asbestos in the United States. Most observers feel that the incidence of asbestosis in American asbestos workers is quite low. Asbestosis has, however, been reported more frequently in England and Canada.

Lanza, McConnell, and Fehnel[76] concluded from their study of asbestosis that: Prolonged exposure to asbestos dust causes pulmonary fibrosis different from that produced in silicosis and demonstrable by roentgenogram. Clinically it appears to be milder than silicosis.

Definite cardiac enlargement frequently was found to be associated with asbestosis.

A predisposition to tuberculosis, due to asbestos dust, was not indicated although it was not known to what extent asbestosis may add to the mortality from pneumonia and acute nontuberculous pulmonary infections.

Symptoms. The onset of asbestosis, as of silicosis, is slow although symptoms are apt to be somewhat more marked than in silicosis. In silicosis there may be marked x-ray findings with little complaint of symptoms, whereas the opposite is likely to be the case in asbestosis. As in silicosis, dyspnea is the cardinal symptom. Anorexia occurs frequently in advanced stages, and cyanosis and clubbing of the fingers are apt to appear with greater constancy in asbestosis.

Pathology. The fibrosis in asbestosis is diffuse and tends to predominate in the basal portions of the lungs in contrast to the generalized nodular fibrosis of silicosis

[73] J. W. G. Hannon, *Trans. Can. Inst. Mining Met.*, 48, 180 (1944).
[74] L. U. Gardner, M. Dworski, and A. B. Delahant, *J. Ind. Hyg. Toxicol.*, 26, 211 (1944).
[75] A. J. Lanza, *J. Am. Med. Assoc.*, 106, 368 (1936).
[76] A. J. Lanza, W. J. McConnell, and J. W. Fehnel, *U.S. Pub. Health Repts.*, 50, 1 (1935)

From - "Industrial Hygiene and Toxicology" Vol. I
By - Patty
Pub. By - Interscience Publishers, Inc., N.Y. 1948

with a predominance in the upper portions of the lung. Bronchiectasis and bronchiolectasis are frequent, especially in the more fibrous portions. Whereas the proliferation of fibrous tissue is caused by chemical action in silica exposure, it is induced by mechanical action in asbestos exposures. Gardner[77] found that the fibrosis-producing character of asbestos could be almost eliminated by grinding the fibers so that no particles more than 2 μ in length were present. As previously mentioned, asbestos is classified among the inert dusts.

Microscopic Anatomy. Johnstone[78] described the microscopic appearance of the lungs somewhat as follows: in the early phases of the disease there is thickening of the alveolar septa which results from fibroblastic proliferation. The alveolar spaces contain numerous phagocytes. With progression of the disease fibrosis becomes more marked; the alveolar structure gradually disappears, and in its place there is now dense fibrous tissue. The few alveoli that remain in the area of fibrosis are lined with low cuboidal epithelium giving them an almost glandular appearance.

Scattered throughout the lung in both the diseased and healthy parts are spindle-shaped structures described first by McDonald.[79] These bodies are 20 to 100 μ in length and are bulbous on one or both ends so that they appear club- or dumbbell-shaped. They are brownish in color, do not stain, and give a Prussian-blue reaction for iron. Simson[80] has produced these bodies in guinea pigs by experimental exposure to atmosphere containing asbestos. Lynch[81] concludes that these "curious bodies" signify exposure to asbestos dust but do not necessarily indicate asbestosis.

X-Ray Examination. For an excellent review of roentgenographic findings in both silicosis and asbestosis the reader might well refer to Pendergrass.[82] Characteristic differences in the roentgenographic findings in silicosis and asbestosis are tabulated below:

Asbestosis	Silicosis
Fibrosis diffuse (film may have ground glass appearance from pleural involvement).	Fibrosis nodular.
Findings may be either bilateral or unilateral.	Findings characteristically bilateral.
Lesions largely in the lower one half or two thirds of the lung fields.	Lesions predominately in the upper two-thirds of the lung fields.
Emphysema in upper portion of lung fields.	Emphysema in lower portion of lung fields.

Control. Prevention of asbestosis depends entirely upon preventing exposure to concentrations of dust sufficiently high to produce the characteristic reaction.

77 L. U. Gardner, *Ind. Med.*, *9*, 45 (1940).
78 R. T. Johnstone, *Occupational Diseases.* Saunders, Philadelphia, 1942.
79 S. McDonald, *Brit. Med. J.*, *2*, 1025 (1927).
80 F. W. Simson, *Brit. Med. J.*, *1*, 885 (1928).
81 K. M. Lynch, *J. Am. Med. Assoc.*, *109*, 1947 (1936).
82 E. P. Pendergrass, "Roentgen-Ray Diagnosis in Silicosis and Asbestosis," in A. J. Lanza, *Silicosis and Asbestosis.* Oxford Univ. Press, New York, 1938.

Dreessen, DallaValle, Edwards, Miller, and Sayers[83] have found evidence to indicate that 5,000,000 particles per cubic foot of air is a satisfactory figure for the maximum permissible atmospheric concentration of asbestos to which workers may be exposed. Definite permissible standards, however, have not been established.

VI. Dust Causing Minimal Fibrosis or No Fibrosis

Gardner[77] has pointed out that any known inorganic dust other than free silica and the asbestos silicates may produce nonspecific dust reactions, as described on page 486. X-ray markings may be found in other conditions such as chronic infection and heart disease. No interference with pulmonary function or disability is produced by dust of this type and there is no influence on susceptibility to tuberculosis.

A. SILICATES

McCord,[84] from a number of sources, has compiled a list of the commonly used silicates, which is presented here:

Olivine—a magnesium silicate widely present in all basic rocks. Many varieties of this stone are known.

Calcium silicate—nonexistent in nature, but a common product of industry; may be found at blast furnaces and in production of cement and hydrated limes. Other silicates of calcium are known.

Willemite—a zinc silicate (rare).

Sodium silicate (*meta*)—the well-known water-soluble silicate, commonly called water glass. This is widely used in industry, notably as a filler in soaps. This is the only crystalline silicate of sodium, the others being amorphous glass.

Tremolite—a magnesium-calcium silicate.

Asbestos—tremolite, actinolite, chrysotile, or amianthus, all of which are essentially magnesium silicates.

Jade—another form of magnesium-calcium silicate.

Crocidolite—"blue asbestos." It is a sodium iron silicate.

Talc—a hydrated magnesium silicate with extensive industrial application.

Soapstone—a form of talc.

Agalite—a variety of talc resembling asbestos. It is used in the coating of paper, and as a paper filler.

Meerschaum—also called sepiolite. It is closely akin to talc.

Serpentine—hydrated silicate of magnesium. It is a common building stone.

Sillimanite—aluminum-containing silicate. The source of many stone tools of the stone age

Topaz—a semiprecious stone of silicate origin. Chemically it is an aluminum fluosilicate.

Fuller's earth—a hydrated silica-aluminum compound, associated with ferric oxide.

Kaolin (*kaolinite*)—many related silicates of mixed constituency.

Clays—hydrated aluminum silicates containing iron. Titanium, quartz and mica, are likely to be present in clays.

[83] W. C. Dreessen, J. M. DallaValle, T. I. Edwards, J. W. Miller, and R. R. Sayers, *U.S. Pub. Health Bull.* No. 241 (1938).

[84] C. P. McCord, *Ind. Med.*, 2, 4 (1933).

Fire clay—refractory clays, low in alkalies, but high in iron and titanium.

Ultramarine—a silicate of aluminum. It is widely used as a pigment, and there are many varieties, including blues, reds, greens, yellows, violet, and white.

Mica—a large group of silicates of different chemical constituency. All are characterized by their well-known tendency for cleavage into thin sheets. It is extensively used in industry, such as in electrical work for insulation.

Garnet—complex silicates of aluminum, iron, calcium, and magnesium. Besides being a semi-precious gem stone, garnets are used as watch bearings, in gem cutting, polishing, etc.

Feldspar—a large group of aluminum silicates entering into many minerals, for example, granite.

Permutite—a sodium-aluminum silicate of complex structure, much used in water softening.

Lava—mixed silicates of volcanic origin.

Pumice—volcanic, glassy, spongy lava. It is primarily used as a polishing agent.

Shale—a loose term applied to clays and other silicates that have been subjected to high pressures in the earth.

Slate—a substance of clay or shale origin, that has been subjected to high pressure and has metamorphosed. It contains or may contain much free silica.

Slags—Products of metal blast furnaces that contain native impurities as well as minerals such as dolomite introduced as fluxes, etc. Almost all forms of silicates may be included. Free silica may be present.

Silicon carbide—carborundum, a synthetic mineral.

Silundum—another form of synthetic silicate, akin to carborundum in chemical structure.

Fibrox—silicon oxycarbide. It closely resembles carborundum and is somewhat similarly made.

It may be stated with some certainty that none of these dusts, unless in combination with free silica, will produce nodular fibrosis; and proof of disability from breathing such dusts is lacking.

B. NONSILICEOUS DUST

Nonsiliceous dusts such as calcite, calcium carbonate, gypsum, limestone, Portland cement, and pyrolusite dusts have been listed in the classification of Miller and Sayers[55] as among those causing an absorptive tissue response and, accordingly, are not considered as producers of pneumoconiosis.

Apparent X-ray Nodulation without Fibrosis. Only brief mention will be made of baritosis and siderosis. Pendergrass[52] reports having seen several patients exposed to barium dust with widespread dense nodulation typical of that seen in simple silicosis. The individuals examined were symptom-free and not incapacitated. Sander[56] has described a similar condition caused by the inhalation of iron oxide fumes at welding operations. Exposure to iron dust or fume may produce an x-ray picture characterized by generalized nodulation. Autopsy specimens have revealed that the nodules are collections of iron with no tissue reaction or fibrosis.

[55] J. W. Miller and R. R. Sayers, *U.S. Pub. Health Repts.*, **56**, 264 (1941).
[56] O. A. Sander, *J. Ind. Hyg. Toxicol.*, **26**, 79 (1944).

resulting anemia is responsible for the production of many of the symptoms accompanying arsine poisoning; other symptoms result from the hemolysis itself, and occur during the excretion of the hemoglobin. Hemoglobin and its degradation products are commonly found in the urine. Less commonly whole blood may be passed. Occasionally, the renal tubules may be plugged by debris, with resultant suppression of urine. Jaundice, which may be severe, is a common result of the hemolysis. Frequently there is edema of the lungs, which may be accompanied by cyanosis. Kidney damage is common in patients surviving acute affects of the gas.

Signs of poisoning usually develop within several hours of exposure. Headache, dizziness, nausea and vomiting, epigastric pain and weakness occur early, followed by tea-colored urine, or bloody urine in the more severe cases. Some time later, albumen and casts may appear in the urine, or, in serious cases, there may be suppression of urine. Jaundice and tenderness over the liver may appear about the same time. Blood examination shows an anemia which may be marked. In fatal cases, the patient may develop delirium, followed by coma and death. During the acute stage of poisoning and for some weeks after, arsenic may be demonstrated in the urine. See also Arsenic and Arsenic Compounds.

Fire Hazard: Moderate, when exposed to flame (Section 6).
Explosion Hazard: Moderate when exposed to flame (Section 7).
Disaster Control: Dangerous; when heated to decompositon, it emits highly toxic fumes of arsenic; can react vigorously with oxidizing materials.
Ventilation Control (use moderate rate): Section 2
Storage and Handling: Section 7

ARSPHENAMINE

Synonym: 3-Diamino-4-dihydroxy-1-arsenobenzene hydrochloride.
Description: Light yellow, hygroscopic powder.
Formula: $C_{12}H_{12}As_2N_2O_2 \cdot 2HCl \cdot 2H_2O$
Constant:
Mol. Wt. 475.0
Toxicity: See Arsenic Compounds.
Disaster Control: See Arsenic Compounds.
Ventilation Control (use moderate rate): Section 2
Personnel Protection: Section 3
Personal Hygiene: Section 3
First Aid: Section 1
Storage and Handling: Section 7

ASBESTOS PARTICLES

Synonym: Asbestos dust.
Toxic Hazard Rating:
Acute Local: Irritant 1; Inhalation 2
Acute Systemic: 0
Chronic Local: Inhalation 3
Chronic Systemic: U
MAC: ACGIH (accepted); 5 million particles per cubic foot of air.
Toxicology: The essential lesion produced by asbestos dust is a diffuse fibrosis which probably begins as a "collar" about the terminal bronchioles. Usually, at least 4 to 7 years of exposure are required before a serious degree of fibrosis results. There is apparently less predisposition to tuberculosis than is the case with silicosis.

Clinically, the most striking sign is shortness of breath of gradually increasing intensity, often associated with a dry cough. In the early stages physical signs are absent or slight; in the later stages rales may be heard, and in long-standing cases there is frequently clubbing of the fingers. In early stages of the disease the chest x-ray reveals a ground-glass or granular change, chiefly in the lower lung fields; as the condition progresses the heart outline becomes "shaggy" and irregular patches of mottled shadowing may be seen. Asbestos bodies may be found in the sputum.

At autopsy, the pleurae are thickened and adherent and thick subpleural fibrous plaques are often present. Where the disease is far advanced there are usually

FROM "DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS"
BY N. IRVING SAX
PUB. BY - REINHOLD PUBLISHING CORP. - N.Y. - 1957

large areas of fibrosis, with emphysematous changes in the apices and bases. The alveolar walls are thickened, and the characteristic "asbestos bodies" are found.
Ventilation Control (use normal rate): Section 2
Personal Hygiene: Section 3

ASCARIDOLE
Description: Liquid.
Formula: $C_{10}H_{16}O_2$
Constants:
Mol. Wt. 168.2
B. P. 115°C @ 15 mm
Density 1.011 @ 13°/15°C
Toxicity: Details unknown. See also Peroxides, Organic.
Fire Hazard: Moderate, by spontaneous chemical reaction (Section 6).
Caution: An oxidizer.
Explosion Hazard: Explodes at 250°C.
Disaster Control: Dangerous; when heated, it emits toxic fumes and may explode; it reacts with reducing materials.
Storage and Handling: Section 7

ASPHALT
Synonyms: Bitumen; petroleum pitch.
Description: Black or dark brown mass.
Constants:
B. P.: < 470°C
Flash P. 400+°F (C.C.)
Density 0.95 - 1.1
Autoign. Temp. 905°F
Toxic Hazard Rating:
Acute Local: Irritant 2
Acute Systemic: U
Chronic Local: Irritant 2
Chronic Systemic: U
Fire Hazard: Slight, when exposed to heat or flame.
Spontaneous Heating: No
To Fight Fire: Foam, carbon dioxide, dry chemical or carbon tetrachloride (Section 6).
Personnel Protection: Section 3
Personal Hygiene: Section 3
Storage and Handling: Section 7
Shipping Regulations: Section 11.
Coast Guard Classification: Hazardous Article.

ASPIDIUM
Synonym: Male fern.
Toxic Hazard Rating:
Acute Local: Irritant 1; Allergen 1
Acute Systemic: Ingestion 2
Chronic Local: Allergen 1
Chronic Systemic: U
Fire Hazard: Slight; when heated, it emits acrid fumes (Section 6).
Personal Hygiene: Section 3
Storage and Handling: Section 7

ASPIRIN. See Acetol.

ATABRINE DIHYDROCHLORIDE. See "Atabrine" Hydrochloride.

"ATABRINE" HYDROCHLORIDE
Synonym: Quinacrine hydrochloride.
Description: Bright yellow crystals.
Formula: $C_{23}H_{30}ClN_3O \cdot 2HCl \cdot 2H_2O$
Constants:
Mol. Wt. 508.9
M. P. Decomposes 248 - 250°C
Toxic Hazard Rating:
Acute Local: Allergen 1
Acute Systemic: Ingestion 2
Chronic Local: Allergen 1
Chronic Systemic: Ingestion 2
Disaster Control: Dangerous; when heated to decomposition, it emits highly toxic fumes of chlorine.
Personal Hygiene: Section 3
Storage and Handling: Section 7

ATROPINE
Synonym: Daturine.
Description: Colorless, crystalline alkaloid.
Formula: $C_{17}H_{23}NO_3$
Constants:
Mol. Wt. 289.4
M. P. 115.5°C; sublimes at 118°C
Toxic Hazard Rating:
Acute Local: Allergen 1
Acute Systemic: Ingestion 3; Inhalation 3
Chronic Local: Allergen 1
Chronic Systemic: Ingestion 2
Fire Hazard: Slight; on decomposition it emits toxic fumes.
Ventilation Control (use moderate rate): Section 2
Personal Hygiene: Section 3
First Aid: Section 1
Storage and Handling: Section 7

ATROPINE METHYL BROMIDE. See Atropine.

ant treatment is as good as anything that can be offered for these tragic results of past ignorance.

Asbestosis. The pathologic changes produced by asbestos are not like those of silicosis. The asbestos fibers group about the neck of an alveolus and stimulate the formation of a diffuse fibrosis. There is no definite migration or transportation of the dust particles to the lymph nodes and no formation of the fibrous nodules shown in Fig. 16*a*. As the fibrosis increases, the reduction in lung area causes serious dyspnea. Lanza (273) suggested that the enlarged hearts noted frequently in his cases of second-stage asbestosis may be the result of the increased work of the heart resulting from this condition; it takes more work to pump blood through the asbestotic than through the normal lung.

Gardner stated (175, 170): "On grinding these fibrous minerals to a very fine state of subdivision they do not become more irritating but practically lose all power to provoke tissue reaction . . . ." Vorwald *et al.* (433) continued the animal work initiated by Gardner and concluded: "The duration of exposure required to develop the pulmonary reaction to inhaled asbestos dust is inversely proportional to the concentration of long fibers in the atmosphere; as the concentration is increased, the reaction develops in shorter time."

In silicosis it seems to be a general rule that, after a certain point, the victim's condition grows worse even if his exposure to dust has ceased. But Wood and Gloyne (455) stated that they have seen patients with asbestosis "whose condition appears to have remained stationary since stopping work in the factory," but they advised definitely that the individual with asbestosis be removed from his dusty job. Merewether (311) and Lanza were less certain on this point.

Asbestosis Bodies. In the lungs of patients who have died after prolonged exposure to asbestos dust and in the sputum of men with considerable asbestos-dust exposure are found what first were called *curious bodies* and later *asbestosis bodies* (Fig. 18) (140). While somewhat similar bodies can occur in the lungs of coal workers and even of normal persons, it is admitted that asbestosis bodies in sputum are characteristic of asbestosis. Stewart (402) gives considerable diagnostic weight to their presence as do Sparks (397) and Gloyne and Merewether (184).

From "INDUSTRIAL DUST"
BY- DRINKER + HATCH
PUB. BY- McGRAW-HILL 1954

Asbestosis and Lung Cancer. The British require autopsies of persons who have allegedly died as a result of industrial exposures such as cause asbestosis or silicosis. The 1947 report of the Chief Inspector of Factories (25) states that, of 235 cases of asbestosis autopsied between 1924 to 1946, 31 or 13.2 per cent were complicated by carcinoma of the lungs or pleura. This figure should

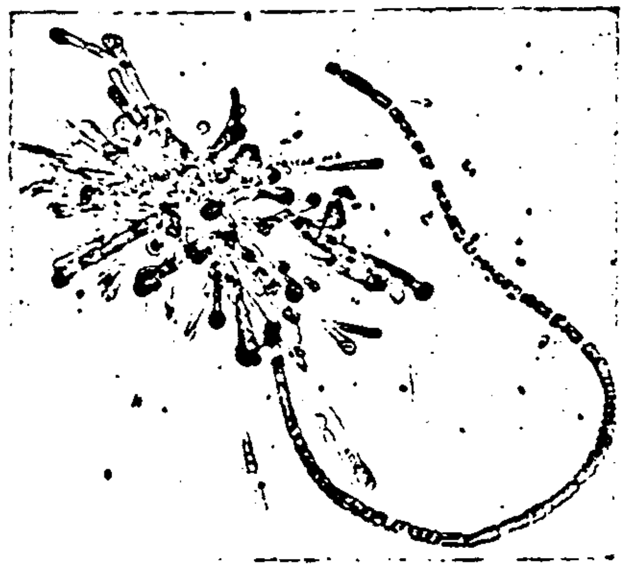

FIG. 18. Asbestosis bodies in sputum. (*After Ellman, Ref.* 140; *courtesy J. Indust. Hyg.*)

be compared with that of their cases of silicosis of whom 6884 were autopsied over the same period and in which 1.32 per cent showed cancer of the lungs. This latter is about the rate reported in the 1946 census in the United States (13 per cent of all deaths were from cancer and 1 per cent from cancer of the respiratory tract).

We do not imply that our American pathologists and our hospitals are less careful than the British in collecting data from autopsies. For example, Vorwald and Karr (434) at the Saranac Laboratories reviewed such data from their own experience and concluded that "inhaled dusts," except those containing recognized carcinogenic substances, "cannot in general be considered as etiological factors in the development of pulmonary carcinoma." But we still are a bit envious of the tidy way in which the British assemble their industrial data on morbidity and mortality.

THRESHOLD LIMIT VALUES FOR 1961[1]

Adopted at the Twenty-Third Annual Meeting of the American Conference of Governmental Industrial Hygienists, Detroit, April 9-12, 1961

Threshold limits should be used as guides in the control of health hazards and should not be regarded as fine lines between safe and dangerous concentrations. They represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect. The values listed refer to time-weighted average concentrations for a normal workday. The amount by which these figures may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations even for short periods produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All must be taken into consideration in arriving at a decision as to whether a hazardous situation exists. Special consideration should be given to the application of these values in assessing the health hazards which may be associated with exposure to combinations of two or more substances.

Threshold limits are based on the best available information from industrial experience, from experimental studies, and, when possible, from a combination of the two. These values are based on various criteria of toxic effects or on marked discomfort; thus, they should not be used as a common denominator of toxicity, nor should they be considered as the sole criterion in proving or disproving diagnosis of suspected occupational disease.

These limits are intended for use in the field of industrial hygiene and should be employed by persons trained in this field. They are not intended for use, or for modification for use, in the evaluation or control of community air pollution or air pollution nuisances.

These values are reviewed annually by the Committee on Threshold Limits for changes, revisions, or additions as further information becomes available. The Committee welcomes the suggestion of substances to be added to the list and also comments, references, or reports of experience with these materials.

Recommended Values

Gases and Vapors

Substance	PPM	Approx. Mg. per Cu.M.
Acetaldehyde	200	360
Acetic acid	10	25
Acetic anhydride	5	20
Acetone	1000	2400
Acetylene tetrabromide	1	14
Acrolein	0.5	1.2
Acrylonitrile - skin	20	45
Allyl alcohol - skin	2	5
Allyl chloride	5	15
Allyl propyl disulfide	2	12
Ammonia	100	70
Amyl acetate	200	1050
Amyl alcohol (isoamyl alcohol)	100	360
Aniline - skin	5	19
Arsine	0.05	0.2
Benzene (benzol)	25	80
Benzyl chloride	1	5
Boron trifluoride	1	3
Bromine	0.1	0.7
Butadiene (1,3-butadiene)	1000	2200
2-Butanone (methyl ethyl ketone)	200	590
Butyl acetate (n-butyl acetate)	200	950
Butyl alcohol (n-butanol)	100	300
tert. Butyl alcohol	100	300
Butylamine	5	15
Butyl cellosolve (2-butoxyethanol)	50	240
p-tert. Butyltoluene	10	60
Carbon dioxide	5000	9000
Carbon disulfide - skin	20	60
Carbon monoxide	100	110
Carbon tetrachloride - skin	25	160
Cellosolve (2-ethoxyethanol)	200	740
Cellosolve acetate (2-ethoxyethyl acetate)	100	540
Chlorine	1	3
Chlorine dioxide	0.1	0.3
Chlorine trifluoride	0.1	0.4
Chlorobenzene (monochlorobenzene)	75	350
Chloroform (trichloromethane)	50	240
1-Chloro-1-nitropropane	20	100

1. Reprinted with permission from the American Conference of Governmental Industrial Hygienists.

Note: The word "skin" following a compound's name indicates that the liquid compound can penetrate the skin to cause systemic effects.

Substance	PPM	Approx. Mg. per Cu.M.
Chloropicrin	0.1	0.7
Chloroprene (2-chloro-1,3-butadiene)	25	90
Cresol (all isomers) - skin	5	22
Cyclohexane	400	1400
Cyclohexanol	50	200
Cyclohexanone	50	200
Cyclohexene	400	1350
Decaborane - skin	0.05	0.3
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240
Diborane	0.1	0.1
o-Dichlorobenzene	50	300
p-Dichlorobenzene	75	450
Dichlorodifluoromethane	1000	4950
1,1-Dichloroethane	100	400
1,2-Dichloroethane (ethylene dichloride)	100	400
1,2-Dichloroethylene	200	790
Dichloroethyl ether	15	90
Dichloromonofluoromethane	1000	4200
1,1-Dichloro-1-nitroethane	10	60
Dichlorotetrafluoroethane	1000	7000
Diethylamine	25	75
Difluorodibromomethane	100	860
Diisobutyl ketone	50	290
Dimethylaniline (N-dimethylaniline) - skin	5	25
Dimethylformamide	20	60
1,1-Dimethylhydrazine - skin	0.5	1
Dimethylsulfate - skin	1	5
Dipropylene glycol methyl ether	100	600
Dioxane (diethylene dioxide)	100	360
Ethyl acetate	400	1400
Ethyl acrylate - skin	25	100
Ethyl alcohol (ethanol)	1000	1900
Ethylamine	25	45
Ethylbenzene	200	870
Ethyl bromide	200	890
Ethyl chloride	1000	2600
Ethyl ether	400	1200
Ethyl formate	100	300
Ethyl silicate	100	850
Ethylene chlorohydrin - skin	5	16
Ethylenediamine	10	30
Ethylene dibromide (1,2-dibromoethane)	25	190
Ethylene imine - skin	5	9
Ethylene oxide	50	90
Fluorine	0.1	0.2
Fluorotrichloromethane	1000	5600
Formaldehyde	5	6
Furfural	5	20
Furfuryl alcohol	50	200
Gasoline	500	2000
Heptane (n-heptane)	500	2000
Hexane (n-hexane)	500	1800
Hexanone (methyl butyl ketone)	100	410
Hexone (methyl isobutyl ketone)	100	410
Hydrazine - skin	1	1.3
Hydrogen bromide	3	10
Hydrogen chloride	5	7
Hydrogen cyanide - skin	10	11
Hydrogen fluoride	3	2
Hydrogen peroxide, 90%	1	1.4
Hydrogen selenide	0.05	0.2
Hydrogen sulfide	20	30
Iodine	0.1	1
Isophorone	25	140
Isopropylamine	5	12
Mesityl oxide	25	100
Methyl acetate	200	610
Methyl acetylene	1000	1650
Methyl acrylate - skin	10	35
Methylal (dimethoxymethane)	1000	3100
Methyl alcohol (methanol)	200	260
Methyl bromide - skin	20	80
Methyl cellosolve (2-methoxyethanol)	25	80
Methyl cellosolve acetate (ethylene glycol monomethyl ether acetate)	25	120
Methyl chloride	100	210
Methyl chloroform (1,1,1-trichloroethane)	500	2700
Methylcyclohexane	500	2000
Methylcyclohexanol	100	470
Methylcyclohexanone	100	460
Methyl formate	100	250
Methyl isobutyl carbinol (methyl amyl alcohol)	25	100
α-Methyl styrene	100	480
Methylene chloride (dichloromethane)	500	1750
Monomethyl aniline - skin	2	9
Naphtha (coal tar)	200	800
Naphtha (petroleum)	500	2000
Nickel carbonyl	0.001	0.007
Nitric acid	10	25
p-Nitroaniline - skin	1	6
Nitrobenzene - skin	1	5
Nitroethane	100	310
Nitrogen dioxide	5	9
Nitroglycerin	0.5	5
Nitromethane	100	250
2-Nitropropane	25	90
Nitrotoluene - skin	5	30
Octane	500	2350
Ozone	0.1	0.2
Pentane	1000	2950
Pentanone (methyl propyl ketone)	200	700
Perchloroethylene (tetrachloroethylene)	100	670
Phenol - skin	5	19
Phenylhydrazine - skin	5	22
Phosgene (carbonyl chloride)	1	4
Phosphine	0.05	0.07
Phosphorus trichloride	0.5	3
Propyl acetate	200	840
Propyl alcohol (isopropyl alcohol)	400	980
Propyl ether (isopropyl ether)	500	2100
Propylene dichloride (1,2-dichloropropane)	75	350

Substance	PPM	Approx. Mg. per Cu.M.	Substance	PPM	Approx. Mg. per Cu.M.
Propylene imine - skin	25	60	Tetrahydrofuran	200	590
Propylene oxide	100	240	Tetranitromethane	1	8
Pyridine	5	15	Toluene (toluol)	200	750
Quinone	0.1	0.4	o-Toluidine - skin	5	22
Stibine	0.1	0.5	Tolylene-2,4-diisocyanate	0.02*	0.14*
Stoddard solvent	500	2900	Trichloroethylene	100	520
Styrene monomer (phenylethylene)	100	420	Triethylamine	25	100
Sulfur dioxide	5	13	Trifluoromonobromomethane	1000	6100
Sulfur hexafluoride	1000	6000	Turpentine	100	560
Sulfur monochloride	1	6	Vinyl chloride (chloroethylene)	500	1300
Sulfur pentafluoride	0.025	0.25	Vinyl toluene	100	480
1,1,2,2-Tetrachloroethane - skin	5	35	Xylene (xylol)	200	870
			Xylidine - skin	5	25

* Probably sufficiently low to protect against primary sensitization, but may not protect persons specifically sensitized.

Dusts, Fumes and Mists

Substance	Mg. per Cu. M.
Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene) - skin	0.25
Ammate (ammonium sulfamate)	15
Antimony	0.5
ANTU (alpha-naphthyl-thiourea)	0.3
Arsenic	0.5
Barium *(soluble compounds)*	0.5
Beryllium	0.002
Cadmium oxide fume	0.1
Calcium arsenate	0.1
Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetra-hydro-4,7-methanoindane)	2
Chlorinated camphene, 60%	0.5
Chlorinated diphenyl oxide	0.5
Chlorodiphenyl (42% chlorine) - skin	1
Chlorodiphenyl (54% chlorine) - skin	0.5
Chromic acid and chromates (as CrO_3)	0.1
Crag herbicide (sodium 2-(2,4-dichlorophenoxy) ethanol hydrogen sulfate)	15
Cyanide (as CN) - skin	5
2,4-D (2,4-dichlorophenoxyacetic acid)	10
DDT (2,2-bis (p-chlorophenyl)-1,1,1-trichloroethane)	1
Dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene) - skin	0.25
Dinitrobenzene - skin	1
Dinitrotoluene - skin	1.5
Dinitro-o-cresol - skin	0.2
EPN (O-ethyl O-p-nitrophenyl thionobenzenephosphonate) - skin	0.5
Ferbam *(ferric dimethyl dithiocarbamate)*	15
Ferrovanadium dust	1
Fluoride	2.5
Hydroquinone	2
Iron oxide fume	15
Lead	0.2
Lead arsenate	0.15
Lindane (hexachlorocyclohexane, gamma isomer)	0.5
Lithium hydride	0.025
Magnesium oxide fume	15
Malathion (O,O-dimethyl dithiophosphate of diethyl mercaptosuccinate) - skin	15
Manganese	5
Mercury	0.1
Mercury (organic compounds) - skin	0.01
Methoxychlor (2,2-di-p-methoxyphenyl-1,1,1-trichloroethane)	15
Molybdenum (soluble compounds)	5
Molybdenum (insoluble compounds)	15
Nicotine - skin	0.5
Parathion (O,O-diethyl-O-p-nitrophenyl thiophosphate) - skin	0.1
Pentachloronaphthalene - skin	0.5
Pentachlorophenol - skin	0.5
Phosphoric acid	1
Phosphorus (yellow)	0.1
Phosphorus pentachloride	1
Phosphorus pentasulfide	1
Picric acid - skin	0.1
Pyrethrum	2
Rotenone	5
Selenium compounds (as Se)	0.1
Sodium fluoroacetate (1080) - skin	0.1
Sodium hydroxide	2
Strychnine	0.15
Sulfuric acid	1
TEDP (tetraethyl dithionopyrophosphate) - skin	0.2
TEPP (tetraethyl pyrophosphate) - skin	0.05
Tellurium	0.1
Tetryl (2,4,6-trinitrophenylmethylnitramine) - skin	1.5
Thallium (soluble compounds)	0.1
Thiram (tetramethyl thiuram disulfide)	5
Titanium dioxide	15

Dusts, Fumes and Mists (cont.)

Substance	Mg. per Cu. M.
Trichloronapthalene - skin	5
Trinitrotoluene - skin	1.5
Uranium	
(soluble compounds)	0.05
(insoluble compounds)	0.25
Vanadium	
(V_2O_5 dust)	0.5
(V_2O_5 fume)	0.1
Warfarin (3-(α-acetonylbenzyl)-4-hydroxycoumarin)	0.5
Yttrium	5
Zinc oxide fume	15
Zirconium compounds (as Zr)	5

Radioactivity: For permissible concentrations of radisotopes in air, see U. S. Department of Commerce, National Bureau of Standards, Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure", June 5, 1959. Also, see U. S. *Department of Commerce, National Bureau of Standards*, Handbook 59, "Permissible Dose from External Sources of Ionizing Radiation", September 24, 1954, and addendum of April 15, 1958.

Mineral and Non-Metallic Inorganic Dusts

Substance	MPPCF
Silica	
Quartz	
high (above 50% free silica)	5
medium (5 to 50% free silica)	20
low (below 5% free silica)	50
Cristobalite (above 5%)	5
Amorphous	20
Silicates	
Asbestos	5
Mica	20
Portland Cement	50
Soapstone	20
Talc	20
Miscellaneous:	
Aluminum Oxide	50
Calcite	50
Dolomite	50
Limestone	50
Marble	50
Silicon Carbide	50
Other Inert Dusts	50

Tentative Values

Substance	PPM	Approx. Mg. per Cu. M.
Acetonitrile	40	70
Allyl glycidyl ether (AGE)	10	45
Boron oxide		15
tert. Butyl chromate (as CrO_3)		0.1
n-Butyl glycidyl ether (BGE)	50	270
Butyl mercaptan	10	35
Chloroacetaldehyde	1	3
Chlorobromomethane	200	1050
DDVP (O, O-Dimethyl-2, 2-Dichlorodivinyl phosphate)		1
Diglycidyl ether (DGE)	10	55
Dimethyl acetamide	10	35
Endrin (1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octa hydro-1, 4-endo, endo-5, 8-dimethanonaphthalene)		0.25
Ethanol amine	0.5	1
Ethyl mercaptan	250	640
Glycidol	50	150
Heptachlor (1, 4, 5, 6, 7, 8, 8-heptachloro-3a, 4, 7, 7a-tetrahydro-4, 7-methanoindene)		0.25
sec-Hexyl acetate	100	590
Isopropyl glycidyl ether (IGE)	50	240
Ketene	0.5	0.9
Methyl mercaptan	50	100
1-Nitropropane	25	90
Pentaborane	0.005	0.01
Perchloromethyl mercaptan	0.1	0.8
Phenyl glycidyl ether (PGE)	50	310
Phosdrin (2-carbomethoxy-1-methyl vinyl dimethyl phosphate)		0.1
n-Propyl nitrate	25	110
Systox		0.2
2, 4, 5T (2, 4, 5-trichlorophenoxy acetic acid)		10
Teflon decomposition products (as F)		0.05
1, 2, 3-Trichloropropane	50	300
1, 1, 2-Trichloro-1, 2, 2-trifluoroethane	1000	7600
Triorthocresyl phosphate		0.1
Triphenyl phosphate		3

(Signed): William L. Ball, W. Clark Cooper, Herbert E. Stokinger, Keith H. Jacobson, Hervey B. Elkins, Russel G. Scovill, William F. Reindollar, Allan L. Coleman, Chairman

From - "INDUSTRIAL HYGIENE AND TOXICOLOGY" VOL. I
BY - PATTY
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Common External Marks of Occupation or Occupational Diseases or Other Diseases (continued)

Mark or sign	Probable cause	Significance	Comment
		Skin, continued	
Pathological sweating.	Many nonindustrial causes, but sometimes seen in lead poisoning.	Unusual sweating may be localized, odoriferous, colored, excessive. Sometimes found in heart disease, rickets, syphilis, palsy, tuberculosis, goiter, etc.	In arsenic or lead poisoning, abnormal sweating usually local to parts involved in neuritis.
Brick red (warm weather). Plum colored (cold weather).	Polycythemia (pathologic increase in numbers of red blood cells).	May be a manifestation of repeated exposure to carbon monoxide in relatively low concentrations. R. M. I.	Engorgement and congestion of superficial blood vessels. Most prominent on face. May involve conjunctivae.
Paroxysmal face and head flushing.	Chiefly associated with the menopause, this type chiefly limited to women 40 to 50.	May be associated with mental depression, excessive perspiration, weakness, insomnia, emotional instability.	Not occupational.
Lymphangitis.	Infection.	Red streak up arm or leg. Alarming indication of extension of localized pyogenic infection. R. M. I.	Frequently associated with "kernels" such as in axilla or groin.
Keratosis (farmer's warts).	Excessive sunlight, ultraviolet light, etc.	Represent warty, flat, or horny, persistent overgrowth of outer layers of skin. Characteristic of past middle age life; usually limited to exposed parts of skin; characteristic of many trades including farmers, sailors, fishermen, gardeners, trappers.	Rarely become cancerous; readily removed by electrocauterization, by x-ray and by electric needle; less well by keratin solvents. Quite common both in and out of industry.
Asbestos warts.	Mechanical penetration by asbestos fibers; possibly chemical action akin to production of silicotic nodules.	Condition usually limited to fingers and hands.	Similar condition with glass fiber workers, but in that case always mechanical.
Tumors (on skin).	Several types, both benign and malignant. Commonest variety, epithelioma.	Apart from nongrowing warts and obvious abscesses of skin, any enlarging mass on or in skin should be investigated. R. M. I.	Pigmented moles are prone to become malignant.
Tumors (beneath skin).	Frequently harmless, fatty tumors (lipomas). Attain to large size.	Because of uncertainty, every mass beneath the skin should be investigated by a physician	Skin over lipomas, if squeezed, becomes dimpled, "orange peel" sign. See next item.

ASBESTOS

Definition.—The term "asbestos," as now used, is not the name of a distinct mineral, but is a commercial term applied to any mineral which can be readily separated into more or less flexible fibers. The original asbestos was a variety of amphibole, of little present importance, but now there are several important varieties of asbestos, of which chrysotile is in most common use.

Varieties of Asbestos and Their Properties.—*Chrysotile* is a fibrous form of serpentine, with which it is always associated. It is a hydrous magnesium silicate, represented by the empirical formula $H_4Mg_3Si_2O_9$, and contains 12.9 per cent of water of composition. It occurs in aggregates of fine, crystalline silky fibers, which are flexible and have considerable tensile strength. These fibers usually range in length from less than ⅛ to 1 or 1½ inches, but fibers as long as 5 to 6 inches are sometimes found and an extreme length of 24 inches has been noted.[1] Chrysotile fibers are nearly always brilliant white, but aggregates of fibers may vary from white and pink, through yellowish and yellowish-green to olive-green. Its *Hardness* is 3 to 3.5; *Specific Gravity* 2.2 to 2.3; *Luster* sub-resinous to greasy, pearly and silky.

Crocidolite is a soda-iron, monoclinic amphibole, having the formula $NaFe\ (SiO_3)_2.FeSiO_3$. It is highly fibrous, like chrysotile, but its fibers have a higher tensile strength, and a much lower resistance to heat. Its color is a characteristic lavender-blue, and it is thus often called "blue asbestos" or "Cape Blue" (from Cape Province, South Africa). Fibers commonly range in length from less than ⅛ to 1½ inches and rarely exceed 3 inches. It has a specific gravity of 3.20 to 3.30 and a silky luster.

Anthophyllite is an anhydrous iron-magnesium silicate, having the formula $(Fe,Mg)SiO_3$. It belongs to the orthorhombic group of the amphiboles. It occurs in rather coarse, fairly long and usually rather brittle fibers of low tensile strength. It is more resistant to heat and to acids than chrysotile, so that anthophyllite low in iron is especially suitable for making chemical filters.

Amosite is an iron-rich anthophyllite found chiefly in South Africa. It was thought originally to be a new species and was described by Hall[2]

[1] HALL, A. L., "Asbestos in the Union of South Africa," *Memoir* No. 12, p. 15, Union of South Africa, Dept. of Mines and Industries, Geol. Survey, 1918.

[2] HALL, A. L., work cited, p. 21.

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as a monoclinic amphibole. Wherry[1] later examined amosite both chemically and microscopically and found it practically identical with ferroanthophyllite, an orthorhombic amphibole having the formula (Fe, Ca, H_2, Mn)O.SiO_2. When amosite contains considerable soda it approaches crocidolite in composition. Amosite is characterized by a well-developed fibrous structure, having fibers of unusual length. Lengths of 4 to 7 inches are common and an extreme length of a little over 11 inches has been observed. The fibers are flexible, but usually have less tensile strength than chrysotile. Amosite is harder and harsher than chrysotile and is said to cause excessive wear on the teeth of carding machines. It varies in color from a pale dirty-brown through various shades of gray and pale yellowish-green to nearly white. Acids have little effect on amosite and it withstands heat better than crocidolite.

Asbestos, *"amphibole" asbestos*, *"hornblende" asbestos* and *"Italian" asbestos* are various terms given to the monoclinic amphiboles, tremolite (formula $CaMg_3(SiO_3)_4$) and actinolite (formula $Ca(Mg,Fe)_3(SiO_3)_4$) when they occur in fine silky fibers. This is the original type of material to which the mineralogical name "asbestos" was given. The fibers may be fine, silky and of great length, but they usually have little tensile strength. A small amount of Italian amphibole asbestos has been used for spinning, but most of it is too weak. When pure tremolite asbestos is chemically stable and may be used for making chemical filters.

Mountain leather and *mountain cork* are, respectively, thin and thick flexible sheets made up of interlocked fibers. The "cork" variety has the elasticity and lightness of cork. It is usually from light-brown to white in color and has a specific gravity of 0.68 to 0.99. One analysis[2] of mountain cork showed silica, 57.20 per cent; peroxide of iron, 4.37 per cent; magnesia, 22.85 per cent; lime, 13.39 per cent; and water, 2.43 per cent; total, 100.24 per cent. These substances have no value as sources of asbestos fibers.

Mountain wood is a compact, fibrous substance made up of interlaced mineral fibers and closely resembling dry wood. It is usually gray to brown in color. It is sometimes found in Canadian asbestos deposits, but has no present economic value.

Analyses of Asbestos.—The following table shows the average composition of the principal types of asbestos:

[1] WHERRY, E. T., "Amosite," *Am. Mineralogist*, vol. 6, No. 12, p. 174, December, 1921.

[2] CIRKEL, FRITZ, "Chrysotile-Asbestos, Its Occurrence, Exploitation, Milling and Uses," *Mines Branch Bull.* 69, p. 21, Can. Dept. of Mines, 1910.

	1 Chrysotile	2 Crocidolite	3 Amosite	4 Anthophyllite	5 Amphibole
SiO_2	40.49	51.22	49.58	57.12	57.72
Al_2O_3	1.27	.....	2.25	0.75	0.53
Fe_2O_3 and FeO	2.53	34.08	39.64	6.36	2.80
MgO	41.41	2.48	4.79	29.44	22.61
CaO	.....	0.03	0.53	.....	13.84
Na_2O	.....	7.07	.....	.....	0.50
H_2O (const.)	14.06	4.50	3.16	5.47	0.81
MnO_2	.....	0.10			
K_2O	.....	.....	.....	.....	0.30
Total	99.76	99.48	99.95	99.14	99.11

1. Canadian chrysotile—Average of eleven analyses by CIRKEL, work cited, p. 31.
2. South African crocidolite—Analysis quoted by CIRKEL, work cited, p. 22.
3. Amosite, Transvaal, South Africa—Average of seven rather widely varying analyses quoted by WHERRY, work cited, p. 174.
4. Anthophyllite, Georgia—Analysis quoted in "Asbestos (1913–1919)," p. 6, Imperial Mineral Resources Bureau (Great Britain), 1921.
5. Italian amphibole asbesos—Analysis quoted by MARCUSE, B., "The Marketing of Asbestos," *Eng. Mining Jour.-Press*, vol. 114, No. 7, p. 278, Apr. 12, 1922.

TYPES OF STRUCTURE[1]

Most asbestos minerals are found in veins, but some may make up the whole mass of a rock. The veins contain both cross-fiber and slip-fiber asbestos. Cross-fiber asbestos lies perpendicular or nearly perpendicular to the walls of the vein. Chrysotile, crocidolite and amosite occur in this way. Slip-fiber asbestos lies parallel to the walls of the vein. Chrysotile, tremolite, actinolite and anthophyllite occur in this way. Much slip-fiber chrysotile is rather harsh. An excessively harsh slip-fiber chrysotile is known as *Picrolite*. Anthophyllite, tremolite and actinolite may occur as mass fiber, the minerals forming interlocking bundles or radial groups of fibers.

GEOLOGIC OCCURRENCE

Chrysotile.—Chrysotile asbestos is found in two entirely distinct geologic associations—in altered peridotite, an igneous rock very low in silica and high in magnesia and iron, and in limestone near its contact with sills or intrusive sheets of basic igneous rock.

Chrysotile occurs in peridotite in veins which either form a network in several directions through the rock or less commonly lie parallel. The peridotite near the veins is altered to serpentine. Few of the veins are more than an inch wide. The

[1] This section and the following section on "Geologic Occurrence" are taken from SAMPSON, EDWARD, "Asbestos in 1920," *Mineral Resources of the United States*, part 2, pp. 312–313, U. S. Geol. Survey, 1920.

great deposits of this kind are those of Quebec and of the Ural Mountains, regions that before the World War furnished nearly all the world's supply of asbestos. Deposits are worked in California, Wyoming and Vermont.

Deposits of chrysotile in limestone are rather widely distributed, but compared to those in peridotite they are small. The fiber may be rather harsh, but it is very long, unbroken fiber over 6 inches in length and of the finest quality having been found, whereas fiber over 2 inches in length is very rare in the deposits formed in peridotite. Chrysotile occurs with serpentine at or near its contact with sills of olivine diabase, usually the upper contact. The deposits in Arizona and in the Carolina district of the Transvaal are of this type. Deposits in limestone are found in Arizona, in southwestern Montana, and probably also in New Mexico.

Anthophyllite.—Deposits of mass-fiber anthophyllite occur in Georgia, North Carolina and Idaho. The occurrence of anthophyllite has been most fully described by Hopkins.[1] The anthophyllite in Georgia is a product of the alteration of peridotite. The altered rock consists almost entirely of anthophyllite. Hopkins points out that the fiber in the commercially valuable deposits has been greatly softened by weathering, which in this region has been very active. In fact, the anthophyllite appears to have been made fibrous by weathering, for the fresh anthophyllite, although it has a good prismatic cleavage, is splintery and of little or no value.

Two interesting deposits of slip-fiber anthophyllite in Maryland and California have recently been operated.

Crocidolite.—The only worked deposits of crocidolite and amosite are in the Union of South Africa.[2] Both occur as cross-fiber veins parallel to the bedding of an iron-rich siliceous argillite locally known as "ironstone." According to the published descriptions, the material of which the vein minerals are composed has been derived from the inclosing rocks as a result of regional metamorphism. The deposits cover a wide area over which they occur at the same stratigraphic horizon.

Actinolite and Tremolite.—Actinolite and tremolite usually occur in veins as slip fiber, generally in highly magnesian rocks. They appear to have been formed by metamorphic agencies, which have also extensively affected the country rock.

Geographical Distribution.—The only types of asbestos of any considerable commercial value are those which occur in strong, fine, flexible fibers ¼ inch or more in length, that is, fibers capable of being spun and woven into fabrics or matted into paper and similar products. The longer fibers, that is, those over ¾ inch, are by far the most valuable. Flexible fibers shorter than ¼ inch are used extensively, but are of such low value that they usually are mined only in conjunction with the longer fibers.

[1] Hopkins, O. B., A Report on the Asbestos, Talc and Soapstone Deposits of Georgia," *Bull.* 29, Ga. Geol. Survey, 1914.

[2] Hall, A. L., "Asbestos in the Union of South Africa," *Memoir* No. 12, Geol. Survey, 1918; "On the Mode of Occurrence and Distribution of Asbestos in the Transvaal," *Trans., Geol. Soc. S. Africa*, vol. 21, pp. 1–36, 1918.

While deposits of asbestiform minerals are widely distributed over the world, there are but few localities in which high-grade spinning fibers are found in important commercial quantities. Before the World War, Canada (Quebec) and Russia furnished most of the world's supply of high-grade asbestos. At present Russian production is small and South Africa (including Rhodesia) is the only other large source besides Canada. The United States has produced some spinning-fiber asbestos (Arizona chrysotile), chiefly during the past 10 years, but most of the domestic production has been of non-spinning anthophyllite. Other countries which are small producers are Australia, Cyprus, Italy, China and India.

Canada.[1]—Canada is the largest producer of asbestos in the world, and Canadian spinning fiber is generally regarded as of the highest grade marketed in important quantities. All the asbestos now produced is of the chrysotile variety.

While asbestos occurs in a number of districts in Canada, the only deposits which have been of great commercial importance are located in an area of Cambrian serpentine rocks which extends from northern Vermont to the Gaspé Peninsula. Within this area in Quebec asbestos occurs in three prominent belts.

1. The Danville-Orford-Bolton area, which extends into Vermont.
2. The Thetford–Black Lake area.
3. The Gaspé Peninsula area.

The *Danville-Orford-Bolton area* consists of numerous, apparently disconnected outcrops of serpentine in a narrow belt about 62 miles long. The area is heavily wooded and the rocks are so deeply covered with soil and humus that prospecting and development are difficult. There has been little production from this belt.

The *Thetford-Black Lake area* is the most important area in Quebec and is, at present, the most productive asbestos district in the world. In this area some of the most productive mines are in Coleraine, Thetford and Broughton townships. In the main area the total length of the chief serpentine belt is 23 miles and the width varies from 100 to 6,000 feet in the Black Lake area and to 3½ miles in Coleraine Township. The serpentine forms knolls and ridges from a few hundred to a thousand feet in height above the surrounding country. The Broughton and the central and eastern Thetford areas contain mainly slip-fiber deposits. The vein-fiber belt, which includes western Thetford, South Ireland and North Coleraine townships, has a developed length of about 12 miles and a maximum width of about 3½ miles. The vein-fiber belt produces the highest-grade crude and spinning fiber.

[1] The most extensive work on Canadian asbestos is that by CIRKEL, F., work cited, 316 pp.

The chrysotile veins intersect portions of the serpentine in every direction, but they usually follow straight lines. The cross-fiber veins vary in thickness from mere threads up to 2 or 3 inches, but the bulk of the asbestos mined is from ¼ to ½ inch in length. The longer fiber is often divided in the middle by a seam of serpentine carrying magnetite or chromite. Usually, the asbestos can be easily separated from the rock. Slip fiber occurs along slickensided fault planes and the fiber is arranged parallel to the walls in thin films, or in layers up to ⅜ inch or more in thickness. The slip-fiber veins yield only mill fiber; it is often of as good grade as mill fiber prepared from cross-fiber veins, but it is sometimes rather harsh.

The Canadian deposits are very extensive and the known ore reserves are large. Apparently the quality or the percentage of fiber varies little with depth. While the long fiber is the most valuable, it occurs in relatively small amounts and the chief production (by tonnage), is of the mill-fiber grades.

In the *Gaspé Peninsula area* some asbestos has been found, but difficulty of access has prevented the region from being adequately explored.

A small amount of chrysotile asbestos has been produced at Deloro, near Porcupine, Ontario. The asbestos is reported to occur in veins, up to 2½ inches wide, in serpentine and to constitute as much as 12 per cent of the rock in places.

Union of South Africa.[1]—Important deposits of asbestos occur in several localities in the Union of South Africa. The principal types of asbestos which have been produced are crocidolite and amosite, but chrysotile is also worked and will probably become of increasing importance.

Transvaal possesses important deposits of chrysotile, crocidolite, amosite and tremolite.

Amosite is found only in a belt in northeastern Transvaal between Lydenburg and Pietersburg. This belt, which is about 60 miles long by an average of 6 miles wide, contains three groups of interbedded, cross-fiber veins, varying in width to a maximum of about 12 inches. The veins are worked by underground mining. The principal mines are the Egnep and Amosa, situated near the farms Penge and Streatham, which furnish about four-fifths of the total output.

In the Carolina district chrysotile of good quality is mined principally in the Diepgezet and Goedverwacht areas.

High-grade, pure-white chrysotile occurs near Kaapsche Hoop about 28 miles northwest of Barberton. Here the percentage of fiber is very high, averaging about 40 per cent fiber and 60 per cent rock. Moreover, over

[1] The best work on the asbestos deposits of the Union of South Africa, is by HALL, A. L., work cited, 152 pp. See also HALL, A. L., "On the Asbestos Occurrence near Kaapsche Hoop in the Barberton District," *Trans. Geol. Soc. S. Africa*, vol. 24, pp. 168–181. 1921. (Abstract in *Eng. Mining Jour.-Press*, vol. 113, No. 13, p. 524 April 1, 1922.) The account here given is taken largely from Hall's work as abstracted in "Asbestos" (1913–1919), work cited, pp. 14–16.

25 per cent of the fiber is over 1 inch long, compared with less than 1.5 per cent in Canada.

In *Cape Province* crocidolite is the only variety of asbestos worked. It occurs in interbedded cross-fiber veins in a belt extending from the farm Lovedale, 20 miles southeast of Prieska, in a northerly direction as far as Mashowing River in British Bechuanaland, with a possible extension into the districts of Vryburg and Mafeking.

In *Natal* chrysotile of inferior grade occurs somewhat sparingly.

Rhodesia.[1]—Rhodesia is the most important source of asbestos in British South Africa. Both chrysotile and amphibole asbestos occur abundantly in many localities in southern Rhodesia. The largest production comes from the Shabani fields in the Belingwe district and from the Mashaba area in the Victoria district. In both areas chrysotile of excellent quality is found in veins of the cross-fiber type. The Shabani field, so far as it has been explored, is about 6 miles long by 1 mile wide. The fiber varies from ⅛ to 2 inches in length. The Mashaba area seems to be smaller and the fiber is rarely over ¾ inch in length. The yield of asbestos fiber in the Mashaba area is said to range from 1 to 1.5 per cent of the rock broken, and in the Shabani area from 1.5 to 3 per cent.

Asbestos also occurs, and has been prospected to some extent, in the Lomagundi and Bulawayo districts.

Russia.[2]—While Russia before the World War was the second largest producer of asbestos, recent detailed descriptions of Russian deposits are not available. A general description of these deposits was given by Diller[3] in 1908, from which the following is taken:

> Russian asbestos is much harsher to the touch than Canadian, and less suitable for spinning, but before the World War the production was large and growing.
>
> There are two general districts in which asbestos has been produced. The first, and by far the largest and most important, is in the Perm district of the Urals in which there were 25 mines in operation in 1905. The principal mines are 51 miles north of Ekaterinburg, where a zone about 18 miles long by 2 to 3 miles wide has been developed, but other localities are known nearly to Orenburg. The other developed district is in the Minusinsk district on the Yenisei River in Siberia, but many other undeveloped deposits are reported in the Altai mountains region and to the southward.

Before the war most of the Russian asbestos was exported to Germany. For several years after the Russian revolution no asbestos production was reported, but a small production was noted in 1922.

[1] See MENNELL, F. P., *S. Africa Jour. Ind.*, vol. 1, p. 1411, 1918. Also anonymous articles in *S. Africa Mining Eng. Jour.*, sp. ed., pp. 82–89, December, 1920. The description given here is from "Asbestos" (1913–1919), work cited, pp. 11–12.

[2] See CIRKEL, F., work cited, pp. 222–229.

[3] DILLER, J. S., "Asbestos," *Mineral Resources of the United States*, part 2, pp. 702–703, U. S. Geol. Survey, 1908.

United States.[1]—Both spinning-fiber chrysotile and non-spinning anthophyllite occur in the United States, but the former is not found in large quantities, and production, compared to that of Canada, has been very small. While deposits of asbestos have been reported in many states, production has resulted from but few deposits. Arizona has been the only important producer of chrysotile, but a small production has come at various times in the past from Vermont, Wyoming and California. Anthophyllite has been produced mainly in Georgia, but Idaho, Maryland and Californa have also been producers.

Arizona.[2]—Chrysotile asbestos occurs in several localities in Arizona, but it is mined chiefly in two regions: in the Grand Canyon, and in the field 24 to 40 miles in a direct line north and east of Globe. The production in the Grand Canyon district has been small and not continuous. The Globe field is about 50 miles in length and 20 miles in width in a deeply cut mountainous region along Salt River and covers an area of of about 700 square miles. Most of the mines in the Globe region are in four districts; (1) near Chrysotile on Ash Creek, about 41 miles from the railroad shipping point; (2) near Salt Bank on Salt River; (3) near the summit of Coon Creek Butte, at the south end of the Sierra Ancha; and (4) near the head of Sloane Creek, a branch of Canyon Creek.

The asbestos, which is of the cross-fiber type, occurs in veins in limestone chiefly near the upper contact with intruded sheets of diabase. Arizona chrysotile differs chemically from Canadian chrysotile in the very small amount of iron oxide which the former contains (Arizona usually 1 per cent or less of FeO and Canada usually 2.5 per cent or more of FeO). A part of the Arizona fiber is very soft and silky and a part is harsh and splintery. These two phases often occur in the same vein with no visible boundary between, and are hard to distinguish. This necessitates very careful sorting and milling if a high-grade fiber is to be produced. While spinning fiber of good grade and length can be produced, users state that the highest grades are so fine and silky that there is a high loss in spinning. Fiber lengths up to 4 inches sometimes occur but lengths less than 2½ inches are most common.

Vermont.[3]—Asbestos deposits occur at four localities near Lowell, in northern Vermont, connected with the serpentine belt which contains the great asbestos mines of Canada. The asbestos is chrysotile of both

[1] See Diller, J. S., "The Types, Modes of Occurrence and Important Deposits of Asbestos in the United States," *Bull.* 470, pp. 505–524, U. S. Geol. Survey, 1911. See also *Mineral Resources of the United States*, U. S. Geol. Survey, annual, for various years, particularly since 1907.

[2] See *Mineral Resources of the United States*, U. S. Geol. Survey, part 2, pp. 342–347, 1913; pp. 96–99, 1914; pp. 197–201, 1917; pp. 546–551, 1918; pp. 300–304, 1919; pp. 313–316, 1920; pp. 136–138, 1921.

[3] See Richardson, C. H., *Seventh Annual Report*, Vermont Geol. Survey, pp. 315–330, 1909–1910.

the cross-fiber and the slip-fiber types, but it is so short that only mill fiber can be produced. Several unsuccessful attempts have been made to work these deposits at various times.

Wyoming.—Deposits of cross- and slip-fiber chrysotile asbestos occur in Wyoming in several localities and fiber has been produced in small quantities at various times in the past. These deposits are located (1) on Caspar Mountain, 8 miles south of Caspar; (2) on Smith Creek, 20 miles southeast of Caspar; (3) 28 miles south of Lander; (4) near Berry Creek in Lincoln County, on the north side of Forellen Peak, 35 miles from the nearest shipping point at Ashton, Idaho.

Some of the Wyoming fiber is 1 inch long, but most of it is much shorter and but a very small porportion is of spinning grade.

California.—While asbestos, of both the chrysotile and amphibole varieties, has been found in at least twelve counties in California and a small production obtained from a few properties, no large deposits of high-grade spinning fiber have been developed. Most of the deposits are apparently small or of low grade, and production has been only a few tons a year.

Georgia.[1]—Mass-fiber anthophyllite asbestos has been produced for many years in Georgia. While occurrences have been noted in many counties forming a belt across the northwestern part of the state from Rabun to Harris counties, the most important deposits are in White and Habersham counties. The chief deposits that have been worked are 3 miles southwest of Sall Mountain in White County and near Hollywood in Habersham County. In the best portions of the deposits the whole rock is fibrous and as much as 95 per cent of the rock quarried is recovered as fiber. The rocks of the region in general are deeply weathered and the workings are confined to open cuts or quarries in the weathered rock. At greater depths the rock is harder and less fibrous. While the fiber is long, it is so brittle that it is valueless for spinning purposes. It has been used chiefly for making fireproof paints and cements.

Idaho.—Anthophyllite asbestos, similar to that at Sall Mountain, Georgia, occurs about 14 miles southeast of Kamiah, Lewis County, Idaho. The fiber is short and brittle, and therefore suitable only for low-grade uses. A small tonnage was produced annually for a few years, and the fiber shipped to Spokane, Washington, where it was used for paints, cements, pipe covering, plaster and other local purposes.

Maryland.—Slip-fiber anthophyllite asbestos occurs in the softened and weathered portions of gneissoid schists a few miles north of Pylesville, Hartford County, Maryland. The veins are generally small and the usable portions limited to the disintegrating residual material within

[1] See Hopkins, O. B., "The Asbestos Talc and Soapstone Deposits of Georgia," *Bull.* 29, pp. 75–189, Ga. Geol. Survey, 1914.

10 feet of the surface. A small annual tonnage has been produced for several years. The fiber has been cleaned and prepared for filter purposes.

Other States.—Small deposits of amphibole asbestos have been reported near Dalton, *Massachusetts;* New Hartford, *Connecticut;* Cumberland, *Rhode Island;* Pateros, *Washington;* Bedford City and Rocky Mount, *Virginia;* Cane River, *North Carolina;* and Llano, *Texas.* A small output of low-grade asbestos (variety not noted) was produced in 1918 a few miles north of Mount Vernon, Grant County, *Oregon.* Chrysotile has been reported on the head waters of East Mile Creek, *Montana;* and near Great Falls, *Virginia.*

Cyprus.—Large deposits of asbestos occur on the Island of Cyprus and production has been important. Both chrysotile and anthophyllite are found, the former at Amianods, near Troodos in the Limasol district. The best grades come from Paphos. Much of the material produced is short-fibered, but some is of a grade that may be mixed with Canadian fiber.

Italy.—Italy is a small producer of asbestos, most of which is apparently of the amphibole variety. There are three asbestos districts in Italy: (1) in the Susa Valley near Mount Cenis; (2) in the Aosta Valley. from Ivrea to Chatillon; (3) and in the Valtellina district of Lombardy near Sondrio. Italy does not produce sufficient spinning fiber for her own needs, but imports chiefly from Canada and Africa.

Other Countries.[1]—Asbestos deposits, of both the chrysotile and amphibole types, are known in many other countries, and from some of them have come small and irregular productions, but none of them are of great present importance. This may be due to small size of deposits, low grade of fiber or remoteness from transportation and markets.

Some of the countries in which deposits of asbestos have been worked or have been reported are: *Australia, China, Japan, India, Finland, Switzerland, Greece, Turkey, Portugal, Spain, France, Germany, Norway* and *Great Britain.*

Production and Consumption. *World Production.*—The production of asbestos in the principal asbestos-producing countries in the world is shown in the following table prepared from statistics collected from various official sources.

It will be noted from this table that Canada is by far the largest producer of asbestos. The figures given, however, are somewhat misleading, in that much of the Canadian production is of the lower grades of mill fiber, shingle stock, etc., while most of the asbestos produced in Rhodesia and in the Union of South Africa is of high-grade spinning fiber. The local consumption of asbestos in these latter countries is very small and hence there is little local demand for the lower grades of fiber. These lower grades command too low a price to justify the expense of transpor-

[1] See Cirkel, F., work cited, pp. 214–244. "Asbestos" (1913–1919), work cited, pp. 8–32.

WORLD'S PRODUCTION OF ASBESTOS 1913–1921
Metric tons

	1913	1914	1915	1916	1917	1918	1919	1920	1921
Australia:									
New South Wales	......	......	......	......	5	......	145	675	960
South Australia	......	......	......	......	......	......	......	5	2
Tasmania	......	......	......	......	275	2,900	52		
Western Australia	......	......	......	......	......	......	64	180	230
British South Africa:									
Rhodesia	203	442	1,823	5,586	8,675	7,778	8,689	17,076	17,716
Union	873	1,080	1,940	4,224	5,642	2,333	3,567	6,452	4,646
Canada	124,239	87,580	100,826	121,053	122,925	128,334	124,070	162,038	84,151
China	......	......	......	......	378	243	69	5	13
Chosen	......	......	......	......	......	......	132	*	*
Cyprus	......	......	......	......	1,066	232	1,252	910	*
India	......	......	......	......	150	363	394	1,347	321
Italy	175	171	162	82	85	60	98	165	420
Philippine Islands	......	......	......	......	......	70	375		
Russia	17,494	15,691	9,779	8,192	......	*	*	1,478	3,604
United States	998	1,131	1,570	1,342	1,776	905	1,053	1,495	754
Approximate total	144,042	106,095	116,100	140,479	140,997	144,215	140,262	192,236	113,800

* Figures not yet available.

tation for long distances. The distribution of Canadian (Quebec) production by grades *in 1920 is shown in the following table from Mineral Industry:*

PRODUCTION OF ASBESTOS IN THE PROVINCE OF QUEBEC FOR 1920

Shipments and sales			Average value per ton	Stock on hand, Dec. 31, 1920	
Designation of grade	Tons	Value		Tons	Value
Crude No. 1	1,026	$ 1,513,457	$1,475.10	446	$ 659,259
Crude No. 2	2,830	2,295,927	811.28	854	829,438
Spinning fiber	13,983	3,915,562	280.02	1,929	653,115
Shingle fiber	16,784	1,852,210	110.36	1,306	172,476
Paper stocks and others	142,982	5,097,416	35.65	18,826	118,060
	177,605	$14,674,572	$ 82.62	23,361	$2,432,348
Asbestic	19,716	$ 43,559	$ 2.20	125	$ 274
Totals	197,321	$14,718,131	....	23,336	$2,432,622

Quantity of rock mined during the year, 3,099,122 tons.

United States.—The United States is the largest consumer of high-grade asbestos in the world and the largest manufacturer of asbestos goods. Domestic production furnishes only a very small proportion of the requirements for crude asbestos. While imports come chiefly from

Canada, South African and Rhodesian asbestos is being used in important and increasing amounts.

The following table published by the U. S. Geological Survey shows the domestic production of asbestos in recent years:

DOMESTIC ASBESTOS MARKETED IN THE UNITED STATES, 1913–1921

Year	Chrysotile		Amphibole		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1913	......	....	1,100	$11,000	1,100	$ 11,000
1914	22	$ 5,450	1,225	13,515	1,247	18,965
1915	316	65,148	1,415	11,804	1,731	76,952
1916	808*	167,683*	830	13,311	1,638*	180,994*
1917	1,391*	279,270*	567	11,744	1,958*	291,014*
1918	392*	101,059*	606	17,628	998*	118,687*
1919	502	229,265	659	19,000	1,161	248,265
1920	1,245	661,907*	403	16,324	1,648	678,231*
1921	438	313,268	393	23,700	831	336,968

* Revised figures

In recent years most of the domestic chrysotile fiber produced has come from Arizona and most of the amphibole from Georgia.

Imports and exports of crude and manufactured asbestos are shown in the following table:

UNITED STATES IMPORTS AND EXPORTS OF ASBESTOS[1]
In long tons

Year	Imports			Exports		
	Unmanufactured		Manufactured	Unmanufactured		Manufactured
	Quantity	Value	Value	Quantity	Value	Value
1912	63,860	$1,456,012	$363,759	...	....	$ 601,701
1913	86,737	1,928,705	389,664	...	....	754,102
1914	64,166	1,407,758	368,344	...	....	513,037
1915	83,541	1,981,483	137,320	...	....	764,050
1916	103,716	3,303,470	135,064	279	$ 6,133	1,209,076
1917	119,739	4,521,172	65,096	632	116,580	1,932,551
1918	122,946	6,337,585	27,476	622	51,053	2,493,325
1919	129,777	7,369,685	257,381	999	157,416	3,529,348
1920	149,605	9,120,253	619,054	549	141,071	4,431,132
1921	64,698	2,918,802	379,858	464	101,616	2,606,426

[1] *Bureau of Foreign and Domestic Commerce.*

Great Britain.—Great Britain produces practically no asbestos, but is the second largest manufacturer of asbestos products. Raw asbestos is imported chiefly from Canada, Rhodesia and South Africa.

Mining and Milling. *Canada.*[1]—*Mining methods* used in the Quebec districts may be divided into three general classes; (1) open pits; (2) "glory holes" and shrinkage stopes; and (3) combined open and underground workings. Methods used in mining slip-fiber differ from those used at cross-fiber deposits, for in the latter type the long fiber ("crude") must be carefully separated from the mill fiber before milling, while in the slip-fiber deposits no such care is necessary and nearly the entire output of the mine is milled.

The earliest workings were all of the open-pit type and such operations are still the most common today.

The overburden, consisting of clays, sands and gravels, varies from practically nothing to as much as 60 feet. Methods of stripping vary from simple hand methods, where the overburden is light (5 to 10 feet, as at Broughton), to steam-shovel and hydraulic methods for very heavy overburden (up to 60 feet or more, as at the King mine at Thetford).

After the rock is stripped, the pits are carried downward in benches 20 to 75 feet high (average about 40 feet). Drilling is now usually done with compressed-air hammer or piston drills, ranging in size from light hammer drills to heavy submarine-type drills which will drill 3-inch holes to a depth of 75 feet. After the ore is shot down, it is further reduced in size by *block-holing* or *mud-capping*. Slip-fiber rock is then loaded directly into buckets, pans or quarry cars by hand or by small steam shovels. Cross-fiber rock is first carefully sorted and rough-cobbed to remove all the crude grade, and the mill rock is then loaded into pans for hoisting. The crude grade is recobbed, re-sorted, graded and packed in bags for shipment.

In small pits hoisting may be done by derricks, but in large operations very large cableway systems are used. At one mine narrow-gage cars are hoisted through an inclined tunnel to mill bins or waste-rock dumps.

At the surface large bin storage for mill rock is often provided, to facilitate continuous mill operation during the winter months.

Where the open pits have become too deep for efficient operation, or where the overburden is too heavy to be removed economically, underground or combination methods are used. In some mines tunnels are driven under the pits and the ore milled down through raises into cars below (glory-hole system). A typical shrinkage-stope method is used by at least one company. Another mine is developed by a three-compartment, vertical shaft 515 feet deep. In this mine the ore is recovered by

[1] One of the best recent articles on asbestos mining and milling in Canada is that by RUKEYSER, W. A., "Asbestos Mining and Milling in Quebec;" *Eng. Mining Jour.-Press*, vol. 113, Nos. 15 and 16, pp. 617–625 and 670–677, Apr. 15 and 22, 1922.

glory holes extending to the surface or to the bottoms of old pits. Some mines are worked partly by ordinary open-pit methods and partly by glory-hole methods.

Milling methods, used at the various mills, vary in detail, but they are nearly all identical in principle. The objects of milling are to recover as much of the fiber as possible free from dirt and adhering rock and to handle the ore as gently as possible in order to minimize the reduction of fiber length by attrition. The general methods used are: coarse-crushing; drying; recrushing in stages, each stage being followed by screening, during

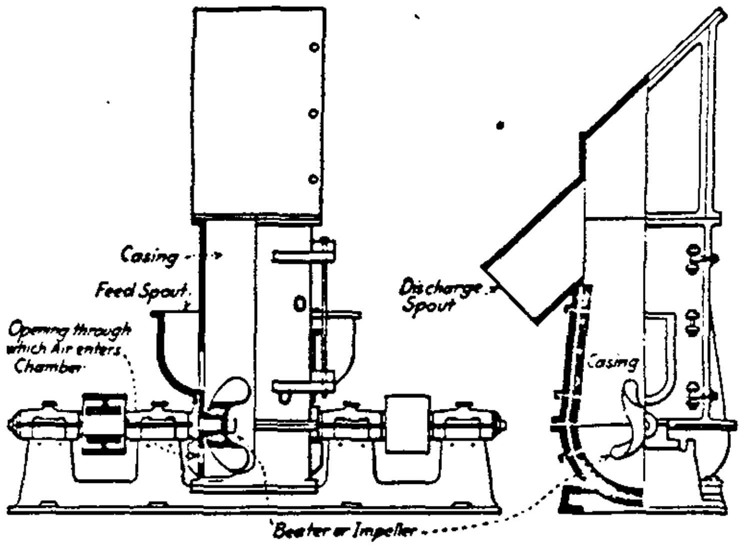

Fig. 2.—Sketch of "Laurie Cyclone."

which air suction effects the separation of the fiber from the rock gangue; collection of the fiber; cleaning of adhering dust and rock particles by rescreening; grading; and, finally, bagging for shipment.

Primary crushing is usually done in jaw crushers, and drying in direct or indirect-heat rotary driers. Secondary crushers may be of either the jaw or the gyratory type. The screening at this stage is usually done on long, flat, shaking, screen tables, which serve to remove fine rock waste and spread out the ore so that the freed fiber may be removed by suction. The final stages of crushing or grinding are done in special types of pulverizers, known as "Cyclones" and "Jumbos," developed in the asbestos industry. RuKeyser,[1] in describing these machine, states:

The desired effect in the reduction of the asbestos-bearing rock is one of straight impact and disintegration, permitting the freeing of the fiber and at the same time "fluffing" it. A minimum of grinding or shear action is desired.

[1] RuKeyser, W. A., work cited, pp. 674–675.

The "Cyclone" (see Fig. 2) consists essentially of two cast-steel impellers shaped like a ship's screw, weighing approximately 1,000 pounds each and made to revolve at a high speed (2,000 to 2,200 r.p.m.) in an inclosed chamber lined with manganese-steel plates to withstand the impact of the rock hurled against it. If a lesser action is desired, the impellers may be made to revolve in the same direction, but in the usual practice they are rotated in opposite direction to each other. It is claimed by many that the "Cyclone" produces a great amount of attrition, injuring the fiber; is of low capacity, wasteful of power and necessitates frequent and costly repairs. The impellers must often be changed every two days, owing to the high speed at which they are revolved. and must be balanced on their shafts with extreme care.

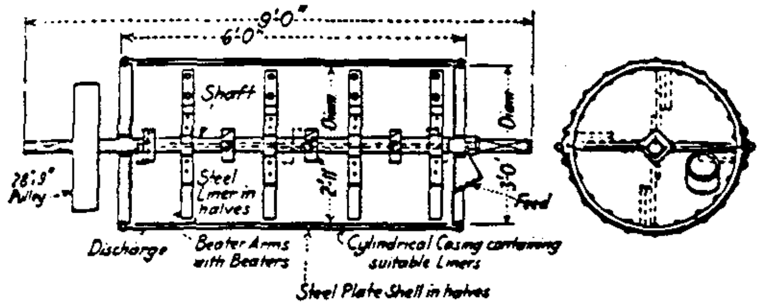

FIG. 3.—Sketch of "Jumbo."

The above considerations led to the development of the "Jumbo," a machine, better mechanically, which has for some time replaced the "Cyclone" on the Broughton rock. Within the past two years much experimentation has been done using the "Jumbo" on the harder Thetford and Black Lake rocks, and the machine is finding a great deal of favor with some operators who have discarded the "Cyclone." The "Jumbo" (see Fig. 3) is really a modification of the ordinary pulverizer, consisting primarily of a horizontal shaft fitted with a series of arms, these in turn carrying "beaters." The whole is caused to revolve at from 400 to 800 r.p.m. (as the nature of the rock dictates) in a cylindrical casing lined with suitable plates. The rock, fed from above at one end, is made to pass through the machine by a deflection of the beaters, and drops out at the other end.

From the "Jumbos" or "Cyclones" the ore again passes over a series of screen tables until the fiber is all removed from the rock by suction. The fiber is collected in conical steel-tank collectors, passed through a series of rotary or shaking-table screens, to remove dust and rock particles, and then to graders. Graders are slowly revolving hexagonal or octagonal screens, which separate the asbestos into the commercial lengths of fiber. The products from the grades go to their respective bins from which they are packed, in 100-pound bags, by hand or by semi-mechanical packers.

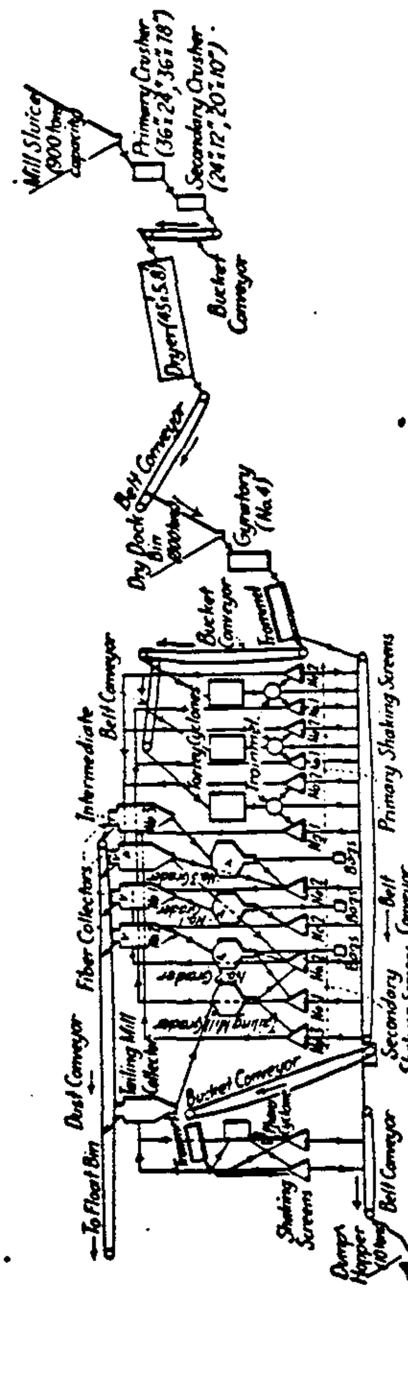

Fig. 4.—Typical flow-sheet of a cross fiber mill.

The accompanying flow sheets (Figs. 4 and 5) after RuKeyser are said to be typical, one of cross-fiber milling at Thetford and the other of slip-fiber practice at Broughton.

An approximate estimate of the proportions of the various grades of fiber produced at a modern Canadian mine and mill as noted by Dustan[1]

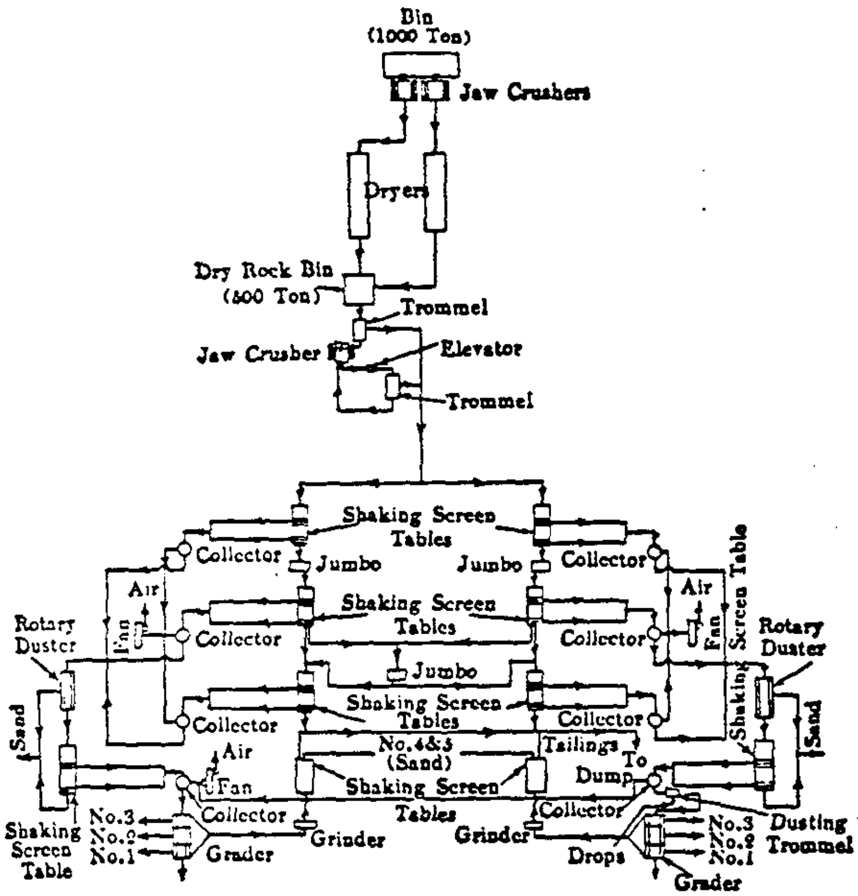

Fig. 5.—Typical flow-sheet of a slip-fiber mill.

is given below. The figures given are not averages and individual mills probably show considerable variations from these estimates; for example, the percentages of mill fiber shown are higher than recent averages for all operations in Quebec.

[1] Dunstan, B., "*Queensland Govt. Mining Jour.*," p. 372, Sept. 15, 1920.

ASBESTOS MINE AND MILL PRODUCTS

Unmanufactured grades and their approximate percentages in mine and mill rock

Products and Waste	General Range of Percentages, Per Cent
From the rock mined:	
Crude asbestos	
Grade I (over 1 inch)[a]	0 to 0.3
Grade II (average ¾ inch)[a]	0.3 to 0.9
Milling rock	30 to 60
Mine waste	40 to 70
From the rock milled:	
Mill stock	6 to 12
Mill fiber, No. 1 (average ⅝ inch)[b]	0.5 to 2
Mill fiber, No. 2 (average ⅜ inch)[b]	1.5 to 4.5
Paper stock (average ¼ inch)[b]	4.0 to 8.0
Mill waste (or)	88 to 94
Asbestic powder and sand[c]	44 to 60
(and) Mill waste	34 to 44
Contents of total asbestos:	
Crude asbestos (grades Nos. 1 and 2)	3.0 to 8.0
Mill stock:	
Mill fibers, Nos. 1 and 2	20 to 40
Paper stock	60 to 80
Total mine and mill product from rock:	
Total asbestos (all grades except asbestic)	3.6 to 7.4
Crude asbestos (grades Nos. 1 and 2)	0.3 to 0.9
Mill stock (fibers Nos. 1 and 2)[a]	1.5 to 2.9
Paper stock (mill fiber No. 3)[b]	1.8 to 3.6
Asbestic (powder and sand)[c]	20 to 30
Total waste rock (mine and mill)	67 to 97

[a] Spinning quality varies from ¾ to over 1 inch.
[b] Quality suitable for manufacture of paper, sheet, board, etc.
[c] Suitable for paint, plaster, etc.

United States.—The chrysotile asbestos in Arizona is obtained chiefly by underground mining methods, usually by tunneling along the asbestos veins. In 1918, the Ash Creek mine was reported to have about 10,000 feet of underground workings arranged in four levels, of which the longest tunnel reached a point about 600 feet into the mountain. Nearly all the Arizona asbestos has been marketed as hand-cobbed crude, as no mills have been erected.

In California both underground and open-pit methods of mining have been used, but production has been very small. In 1921 two mills were built, adopting the principles and machines used in Quebec.

In Vermont, mining has been done by open-cut methods, but there has been no commercial production in recent years. Several mills have been built at various times, the latest completed in 1922, following the methods used in Canadian slip-fiber mills.

South Africa and Rhodesia.—In the various sections of the Union and of Rhodesia both open-pit and underground mining methods are used. Often the open-pit workings are small and irregular, but in the larger and deeper underground mines more systematic methods are used. For example, in the southern sections of the crocidolite area of Cape Province a system of overhand stoping is used without timber. The ore is roughly hand-cobbed underground and the waste is allowed to accumulate in the workings, so as to keep the floor within working distance of the roof.

Milling methods have usually been very simple in the past. In most cases the ore has been hand-cobbed, screened in hand sieves or simple mechanical screens, graded and bagged. At some of the operations in Rhodesia more elaborate methods of preparation are reported to be in use, but no descriptions are available.

Specifications, Grades and Tests.—Since, for most important commercial uses, strong, flexible fiber is needed, the brittle anthophyllite type of asbestos needs little mention here. The chief exception is that of filter-fiber asbestos. For this purpose a fairly strong fiber is needed and the asbestos must be of such chemical composition that it is practically unaffected by common acids and alkalies. Tremolite is often used for this purpose.

Some of the physical properties which good asbestos fibers must possess for various uses are as follows: good fiber length, good flexibility, fine fibers, silkiness, high tensile strength, resistance to acids and alkalies, resistance to sea water and moist air, high melting point, resistance to heat, high heat-insulating value, high electrical-insulating value, good "spinnability" (that is, capable of being easily spun into products of good quality without undue loss and breakage of fiber). There are now so many and such diversified uses for asbestos that not all of these properties are necessary for any single use. Thus, short fibers may be used for asbestos-paper and asbestos-cement shingles, while long fibers are needed for asbestos textiles. For some purposes two or more types of asbestos with different physical properties (for example, crocidolite and chrysotile) may be mixed advantageously.

A comparison of some of the physical properties of crocidolite, chrysotile and amosite is given in the following table:

COMPARISON OF PROPERTIES OF CHRYSOTILE, CROCIDOLITE AND AMOSITE[1]

Property	Chrysotile	Crocidolite	Amosite
Fiber length (usual maximum)	1½ to 2 inches	1½ to 3 inches	7 inches
Tensile strength	High	Higher than chrysotile	Good
Flexibility	High	High	Good
Fineness of fiber	Very fine	Fine	Fine
Resistance to heat	Good, but becomes brittle	Poor; fuses to a glass	Good, but becomes brittle
Resistance to acids, alkalies and sea water	Poor	Good	Good
Electrical-insulating value	Fair to good	Good	
Heat-insulating value	Good	Good for moderate heat	Good
Spinnability	Excellent	Fair	Fair

[1] The properties noted above apply to best grades of each type.
Authorities, CIRKEL and HALL, works cited.

For spinning purposes, Canadian chrysotile is considered the best in the world. Arizona chrysotile is good, but is apt to be lacking in uniformity and to contain harsh, brittle fibers. Some users state that the fiber is so fine and silky that there are large losses in spinning. Crocidolite is not in high favor in the United States, because it is rather difficult to fiberize properly; it is rather dirty and dusty compared with Canadian chrysotile; and its fusion point is low. Crocidolite and amosite, usually mixed with some chrysotile, however, are used much more extensively in England and Europe. Amosite fiber is harsher than chrysotile, and is rather dirty and dusty to handle; it has been used but little in the United States.

Asbestos is often erroneously called a refractory material, but it cannot properly be so classed. Crocidolite fuses at a relatively low temperature to a black glass. Both chrysotile and amosite lose their water of composition at a moderate temperature and become inflexible and very brittle. Nor has asbestos alone a high heat-insulating value, compared with such materials as basic magnesium carbonate. Asbestos is noncombustible and capable of being woven into fabrics, and these are the properties upon which much of the value of high-grade asbestos depends.

The quality of asbestos and its suitability for most uses may be easily determined by a few simple tests. Length, color, silkiness, flexibility and, to some extent, fineness of fiber and tensile strength may be determined by inspection. A sample of asbestos should be fiberized by rubbing or crushing between the fingers. Single fibers may then be tested for flexibility and tensile strength by bending and breaking. Several fibers may be twisted into a strand or yarn and again tested for flexibility and strength. Asbestos of good quality should be easily fiberized, soft, silky, strong, flexible and easily twisted into a strong yarn. Fibers ¼ inch or more in length and otherwise of good grade are of commercial interest.

The grading of asbestos for market varies in different districts and at different plants. In Canada there are two main grades, crude and fiber, each of which are divided into subgrades, in each case based on length of fiber. Crude, produced entirely by hand picking and cobbing, consists of all cross-fiber asbestos over ⅜ inch long. No. 1 crude consists of fiber over ¾ inch long (average 1 inch). No. 2 crude consists of fiber from ⅜ to ¾ inch long (average ⅝ inch).

Mill-fiber grades have not been well standardized. They are based on screen tests, but different producers use different classifications. Screen tests are made in a standard testing machine, which consists of four trays, 24 by 14 by 4 inches, fitting one on top of another. The top or No. 1 tray is fitted with a screen bottom of 2 mesh (No. 11 wire); No. 2 screen is 4 mesh (No. 17 wire); No. 3 screen is 10 mesh (No. 18 wire); the bottom tray is a solid pan. The nest of screens is fastened to a frame, so arranged that it may be vibrated horizontally with a 1½-inch throw, by an eccentric revolving at 300 revolutions per minute. In making a test, 1 pound (16 ounces) of fiber is placed in the top tray and shaken for exactly 2 minutes. The residue on each screen and in the bottom pan is weighed separately and the weight recorded in ounces. Thus, a fiber testing 0-8-6-2 (total 16 ounces) is one of which 8 ounces is retained on the second screen, 6 ounces on the third and 2 ounces of shorts in the pan.

While grades made by different Canadian producers vary somewhat, *Marcuse*[1] states that the following fiber tests may be taken as averages:

Long-spinning fiber	2-8-4-2
Medium-spinning and compressed-sheet fiber	0-8-6-2
Pipe-covering fibers	0-5-8-3
Shingle stocks	0-1½-9½-5
Paper and millboard stocks	0-0-10-6
Cement stocks	0-0-5-11

Shorts are not sold on length but according to color and cleanliness. Color is of prime importance. *Asbestic* is finely ground asbestos sand mill tailings.

[1] MARCUSE, B., "The Marketing of Asbestos," *Eng. Mining Jour.-Press*, vol. 114, No. 7, p. 278, Aug. 12, 1922.

Grades of South African and Rhodesian asbestos vary somewhat, but seem to range about as follows:

Grade	Length of Fiber
D	Over 1¾ to 2 inches
C	1¼ to 1¾ or 2 inches
B	¾ to 1¼ inches
A	⅜ to ¾ inches
S	Up to ⅜ inch
X	*Siftings*
DA	Discolored fiber up to ¾ inch
DB	Discolored fiber longer than ¾ inch

Markets[1] and Prices.—The United States is the largest consumer of asbestos and manufacturer of asbestos products, with the United Kingdom standing second. Before the war the chief international marketing point was Hamburg, but during and since the war New York has taken the lead. Much of the South African and Rhodesian asbestos is marketed in London. Some of the largest manufacturers of asbestos products own mines in Canada or elsewhere which partly or wholly supply their needs for raw asbestos. Smaller consumers buy either directly from the producers or from dealers and agents.

Asbestos crudes and fibers are packed in 100-pound bags and sold at a price (including cost of bags) per 2,000-pound ton, usually f.o.b. cars mines. Crudes bulk about 40 cubic feet per 2,000-pound ton and fibers 60 to 90 cubic feet per ton. Sand and shorts are sold by the net ton and shipped either in bags or in bulk. Most producers have certain brand or grade marks (thus X, XX and C grades), but, while the same marks may be used by different producers, the grades do not necessarily correspond. Most asbestos is sold on sample and test.

Prices on all grades of asbestos increased greatly during and after the war, reaching a peak early in 1921. In 1913, No. 1, crude sold for $320 to $350 per ton, and early in 1921 it was quoted at over $3,000 per ton. The average value of all grades of Canadian asbestos sold increased from $26 in 1909 to $80 in 1919. After the peak, reached in 1921, prices began to fall rapidly until pre-war levels were nearly reached. In May, 1923, the following prices were quoted in the *Engineering and Mining Journal-Press:*

Asbestos.—Crude No. 1, $500; No. 2, $250 to $325; long-spinning fibers, $135 to $200; magnesia and compressed sheet fiber, $100 to $150; shingle stock, $65 to $85; paper stock, $35 to $42; cement stock, $20 to $25; shorts, $9 to $14—all per short ton, f.o.b. mines, Quebec, Canada.

Utilization.[2]—The uses for asbestos are so many and so varied that a simple enumeration of all of them cannot be given here. The main

[1] See Marcuse, B., "The Marketing of Asbestos," work cited.

[2] See Cirkel, F., work cited, pp. 245–289; also anonymous, "Asbestos," Tariff Information Survey N-20, 56 pp., U. S. Tariff Commission, 1921.

uses for asbestos fall into a few fairly well-defined groups, namely: (1) asbestos yarns, cordage cloth and similar textile products; (2) asbestos paper, compressed sheets, blocks, etc; (3) asbestos-cement products, such as asbestos shingles, lumber, corrugated siding, etc.; (4) heat-insulating cements; (5) boiler and pipe coverings (asbestos plus basic magnesium carbonate) and corrugated asbestos paper; (6) as an ingredient in paints and roofing cements (shorts, asbestic, ground anthophyllite, etc.); (7) asbestos fibers used as such for filtering, packing, etc.

From primary manufactured products, such as asbestos yarns, cordage and paper, a multitude of secondary finished products are produced, such as automobile brake-band linings, steam packing and pipe coverings. It should be noted that, while very long spinning fiber is essential for some purposes, the bulk of the asbestos marketed is for use in products in which much shorter mill fibers may be used.

Brown[1] has given a very good summary of the principal uses of asbestos.

BIBLIOGRAPHY

The literature dealing with asbestos and asbestos products is extensive and a complete bibliography cannot be given here. The brief bibliography given below contains some of the more important works, particularly those which have appeared in recent years. References marked thus (*) are the most detailed and comprehensive, and those marked thus (†) contain bibliographies.

Asbestos, monthly magazine published by Secretarial Service, 246 North 17th St., Philadelphia, Pa., first issue July, 1919.

Asbestos, periodical published intermittently by Turner Brothers Asbestos Company, Ltd., Rochdale, England.

ALLEN, M. A., and BUTLER, G. M.: "Asbestos," *Bull.* 113, 31 pp., Arizona Bureau of Mines, University of Arizona, 1921.

BOWLES, OLIVER: Chapter on "Asbestos," pp. 388–401, "Political and Commercial Geology," SPURR, J. E., Editor, McGraw-Hill Book Company, Inc., New York, 1920.

BROWN, J. COGGIN: Notes on "Asbestos," *Bull.* No. 20, 31 pp., *Indian Ind. & Labour*, Calcutta, 1922.

*CIRKEL, FRITZ: "Chrysotile Asbestos, Its Occurrence, Exploitation, Milling and Uses," 2nd ed., 316 pp., *Mines Branch*, Canada Dept. of Mines, 1910.

†DILLER, J. S.: "The Types, Modes of Occurrence, and Important Deposits of Asbestos in the United States," *Bull.* 470, pp. 505–524, U. S. Geol. Survey, 1911.

DUNSTAN, B.: "Queensland Mineral Deposits, No. 3, Asbestos," *Queensland Govt. Mining Jour.*, vol. 17, p. 372, 1916.

*HALL, A. L.: "Asbestos in the Union of South Africa," *Memoir* No. 12, 152 pp., Dept. of Mines and Industries, Union of South Africa Geol. Survey, 1918.

HALL, A. L.: "On the Asbestos Occurrences near Kaapsche Hoop in the Barberton District," *Trans. Geol. Soc. S. Africa*, vol. 24, pp. 168–181, 1921.

HOPKINS, O. B.: "The Asbestos, Talc and Soapstone Deposits of Georgia," *Bull.* 29, pp. 75–189, Ga. Geol. Survey, 1914.

HOPKINS, O. B.: "Asbestos Deposits of Georgia," *Trans. Amer. Inst. Mining Eng.*, vol. 50, pp. 964–973, 1915.

[1] BROWN, J. COGGIN, work cited, pp. 9–12.

HUBBARD, W. D.: "The Black Lake Asbestos Area," *Eng. Mining Jour.*, vol. 112, No. 10, pp. 365–368, Sept. 3, 1921.

HUBBARD, W. D.: "Milling Asbestos Ore in Quebec," *Mining Sci. Press*, pp. 932–936, Dec. 31, 1921.

MARCURE, B.: "The Marketing of Asbestos," *Eng. Mining Jour.-Press*, vol. 114, No. 7, pp. 277–279, Aug. 12, 1922.

MERRILL, G. P.: "The Non-metallic Minerals," 2nd ed., pp. 183–197, John Wiley & Sons, Inc., New York, 1910.

RICHARDSON, C. H.: "Asbestos in Vermont," *Seventh Annual Report*, pp. 315–330, State Geologist of Vermont, 1909–1910.

*RUKEYSER, W. A.: "Asbestos Mining and Milling in Quebec," *Eng. Mining Jour.-Press*, vol. 113, Nos. 15 and 16, pp. 617–625 and 670–677, Apr. 15 and 22, 1922.

SUMMERS, A. L.: "Asbestos and the Asbestos Industry," 107 pp., Pitman and Sons, London, no date, probably 1921.

TABER, STEPHEN: "The Genesis of Asbestos and Asbestiform Minerals," *Trans. Amer. Inst. Mining. Eng.*, vol. 57, pp. 62–98, 1918.

WAGNER, P. A.: "Asbestos," *S. African Jour. Ind.*, vol. ?, No. 3, pp. 251–270, 1917.

YOUNG, J. H.: "How Asbestos-protected Metal was Developed Commercially," *Chem. Met. Eng.*, vol. 28, No. 6, pp. 244–247, Feb. 7, 1923.

Anonymous: "Asbestos Manufactured Products and Uses," *Raw Material*, pp. 108–113, March, 1920.

†Anonymous: "Asbestos" (1913–1919), 34 pp., Imperial Mineral Resources Bureau (Great Britain), 1921.

*Anonymous: "Asbestos," *Tariff Information Survey* N-20, 56 pp., U. S. Tariff Commission, 1921.

Anonymous: Chapter on "Asbestos," *Report on Mining Operations in the Province of Quebec*, annual, Quebec Dept. of Colonization, Mines and Fisheries, Bureau of Mines, Quebec, Canada.

Various authors: Chapter on "Asbestos," *Mineral Resources of the United States*, annual since 1899, U. S. Geol. Survey.

Various authors: Chapter on "Asbestos," *Mineral Industry*, annual, McGraw-Hill Book Company, Inc., New York.

C. RECOMMENDED CONTROL PROCEDURES: To prevent exposure to high concentrations of amorphous silica dust, process ventilation and/or enclosure are the best means of control. For some operations a dust respirator approved by the U. S. Bureau of Mines may be satisfactory.

IV. Specific Procedures

A. FIRST AID: None.

B. SPECIAL MEDICAL PROCEDURES:

(1) Preplacement: Clinical and chest radiographic examinations should be made on all persons prior to job assignment.

(2) Periodic: Since there is only limited information about the harmful effects of amorphous silica in industry, exposed personnel should have careful periodic medical examinations, including chest x-ray. Pulmonary function testing may be useful.

(3) Treatment: No satisfactory treatment other than removal from exposure, and therapy for any complicating infection.

V. Literature References

1. Cooper, W. C., et al: Industrial Hygiene Foundation Transaction Bulletin No. 30, 182–194.
2. Drinker, P. and Hatch, T.: Industrial Dust. McGraw-Hill Co., Inc. New York, 1954.
3. Fraser, D. A.: *AMA Arch. of Ind. Hyg. and Occ. Med., 8:* 412, 1953.
4. Lambie, J. S.: *Ind. Med., 7:* 470, 1938.
5. Palicard, A. and Collet, A.: *AMA Arch. of Ind. Hyg. and Occ. Med., 9:* 389, 1954.
6. Schepers, G. W. H., et al: *AMA Arch. of Ind. Health, 16:* 125, 1957; *ibid, 16:* 203, 1957; *ibid, 16:* 280, 1957; *ibid. 16:* 363, 1957; *ibid, 16:* 499, 1957.
7. Smart, R. H. and Anderson, W. M.: *Ind. Med. and Surg., 21:* 509, 1952.
8. Tebbens, B. D. and Beard, R. R.: *AMA Arch. Ind. Health, 16:* 55, 1957.
9. U. S. Public Health Service; California Department of Public Health; Nevada State Health Department; Oregon State Board of Health: Progress Report of Study of Pneumoconiosis Hazards in the Diatomite Processing Industry. 1955.

Asbestos

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 5 million particles per cubic foot of air (MPPCF).[1]

(1) Basis for Recommendation: Experience in industry,[3, 4, 8, 12, 13] and animal experiments.[4, 7]

B. SEVERITY OF HAZARDS:

(1) Health: Long continued inhalation of asbestos dust results in a form of pneumoconiosis known as asbestosis. The primary effect of inhalation is an interstitial pulmonary fibrosis. The disease is characterized by asbestos bodies in the lungs and sputum. Based on roentgenological examinations, asbestosis can be classified as minimal, moderate, and advanced. It is a serious disease in some instances, but more frequently it remains nondisabling for many years, even without appreciable symptoms, as long as some other serious disease does not supervene to cause death.[2] Chief symptoms of advanced asbestosis are variable cough, dyspnea, substernal chest pains, decreased chest expansion, weakness, emaciation, clubbed finger tips, and curved fingernails. Any appreciable decrease in the amount of asbestos dust in the breathing atmosphere will cause a decrease in the incidence and severity of asbestosis. Individual suceptibility varies.[2] There have been reports of an increased incidence of lung cancer in persons with asbestosis.[2]

(2) Fire: None.

C. SHORT EXPOSURE TOLERANCE: Not applicable:

II. Significant Properties

A fibrous magnesium calcium silicate which occurs in various combinations as white, greyish or greenish masses, either compact or of long silky fibers, flax-like and readily separated. About 95% of commerical asbestos is chrysotile, which is derived from serpentine, and is a hydrous magnesium silicate containing from 12 to 14 per cent water of crystallization.

III. Industrial Hygiene Practice

A. RECOGNITION: The spinning and weaving of asbestos, in combination with other textiles for fire proof and heat resistant cloth, results in dust exposure. It may be used by itself or combined with other materials for valve packings, gaskets, boiler lagging and pipe covering, protective clothing, shielding materials, and as automotive brake linings. In the building industry it is used in the manufacture of asbestos cement products, heat insulating, and fireproofing materials.

B. EVALUATION OF EXPOSURES: Asbestos dust may be sampled with the electrostatic precipitator or by the impinger method using alcohol or alcohol and water, as the collecting medium,[4,8] and dust counts made by the standard light field technique.[5] The recommended maximum atmospheric concentration of 5 MPPCF is based upon the impinger sampling procedure.

C. RECOMMENDED CONTROL PROCEDURES: Prevention of asbestosis depends entirely upon preventing exposure to concentrations of dust sufficiently high to produce the characteristic reaction. Enclosure or local exhaust ventilation are the principal means of dust control. U. S. Bureau of Mines approved dust respirators may be worn as protection for some operations.

IV. Specific Procedures

A. FIRST AID: None.

B. SPECIAL MEDICAL PROCEDURES:

(1) Preplacement: Clinical and radiographic chest examinations prior to job assignment.

(2) Periodic: Exposed personnel should have periodic clinical examinations for signs and symptoms of asbestosis. These should include examination of the sputum for asbestosis bodies, and chest x-rays of good quality.

(3) Treatment: No satisfactory treatment other than removal from exposure and therapy for any complicating infection.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health, 16:* 261, 1957.
2. Cartier, Paul: *AMA Arch. of Ind. Health, 11:* 204, 1955.
3. Doll, R.: *Brit. J. Ind. Med., 12:* 8, 1955.
4. Dreesen, W. C., et al: Public Health Bulletin No. 241, Supt. of Doc., Washington, D. C., 1938.
5. Drinker, P. and Hatch, T.: Industrial Dust. McGraw-Hill Book Co., Inc., New York, 1954.
6. Fairhall, Lawrence T.: Industrial Toxicology. The Williams & Wilkins Co., Baltimore, Md., 1957
7. King, E. J., et al: Thorax I, p. 188, 1946.
8. Lynch, K. M.: *AMA Arch. of Ind. Health, 11:* 185, 1955.
9. McPheeters, S. B.: *J. Ind. Hyg. & Tox., 18:* 229, 1936.
10. Page, R. T. and Bloomfield, J. J.: *Pub. Health Repts. 52:* 1713, 1937.
11. Patty, Frank A.: Industrial Hygiene and Toxicology, Vol. 1. Interscience Publishers, Inc., New York, 1948.
12. Smith, K. W., *AMA Arch. of Ind. Health, 12:* 198, 1955.
13. Vorwald, A. J., et al: *AMA Arch. Ind. Hyg. and Occup. Med. 3:* 1, 1951.