FILE NAME: Marley (MAR)

DATE: 0000

DOC#: MAR028

DOCUMENT DESCRIPTION: Report-Physical Properties of Asbestos Fibers-Nicolet

NICOLET

PHYSICAL PROPERTIES OF ASBESTOS FIBERS

	Chrysotile	Amosite	Anthophyllite	Crocidolite	Tremolite	Acti
Specific heat B.t.u./lb./°F	0.266	0.193	0.210	0.201	0.212	0.
Average tensile strength (lb./sq. in.)	350,000	175,000	4,000 & less	500,000	5,000	1,00
Temp. at max. ignition loss, °F	1,800	1,600 to 1,800	1,800	1,200	1,800	
Filtration properties	Slow	Fast	Medium	Fast	Medium	Me
Electric charge	Pos.	Neg.	Neg.	Neg.	Neg.	N
Fusion point, °F	2,770	2,550	2,675	2,180	2,400	2,
Spinnability	Very good	Fair	Poor	Fair	Poor	F
Resistance to acids & alkalies	Poor	Good	Very good	Good	Good	
Magnetite content	0-5.2	0	0	3.0-5.9	0	
Mineral impurities present	Iron, chrome, nickel, lime	Iron	Iron	Iron	Lime	Lim
Flexibility	High	Good	Poor	Good	Poor	F
Resistance to heat	Good. Brittle at high temp.	Good. Brittle at high temp.	Very good	Poor, fuses	Fair to good	
Ionizable salts, micro-mhos (Relative elec. conductance)	1.82	1.34	0.58	0.84	—	
Color	Green, grey to white	Yellowish-brown	Yellowish-brown, sometimes almost white	Blue	White	Gr

Per Cent Loss in Weight, Room Temperature 26°C. for 528 Hours
25% Acid or Caustic

	HCl	CH_3COOH	H_3PO_4	H_2SO_4	N
Actinolite	22.56	12.14	20.10	20.60	
Amosite	12.00	3.08	11.83	11.71	
Anthophyllite	2.13	1.04	3.29	2.90	
Chrysotile	56.00	24.04	56.45	56.00	
Crocidolite	3.14	1.02	3.91	3.48	

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PROPERTIES OF ASBESTOS FIBRES

	ACTINOLITE	ANOSITE (FERRO ANTHOPHYLLITE)	ANTHOPHYLLITE	CHRYSOTILE	CROCIDOLITE	TREMOLITE
STRUCTURE	RETICULATED LONG PRISMATIC CRYSTALS AND FIBRES	LAMELLAR, COARSE TO FINE FIBROUS AND ASBESTIFORM	LAMELLAR, FIBROUS ASBESTIFORM	IN VEINS OF SERPENTINE, ETC.	FIBROUS IN IRON-STONES	LONG, PRISMATIC AND FIBROUS AGGREGATES
MINERAL ASSOCIATION	IN LIMESTONE AND IN CRYSTALLINE SCHISTS	IN CRYSTALLINE SCHISTS ETC.	IN CRYSTALLINE SCHISTS AND GNEISSES	IN ALTERED PERIDOTITE ADJACENT TO SERPENTINE & LIMESTONE NEAR CONTACT WITH BASIC IGNEOUS ROCKS	IRON RICH SILICIOUS ARGILLITE IN QUARTZOSE SCHISTS	IN Mg LIMESTONES AS ALTERATION PROD. OF HIGHLY MAGNESIAN ROCKS, METAMORPHIC AND IGNEOUS ROCKS.
ORIGIN	RESULTS OF CONTACT METAMORPHISM	METAMORPHIC	METAMORPHIC, USUALLY FROM OLIVINE	ALTERATION & METAMORPHISM OF BASIC IGNEOUS ROCKS RICH IN MAGNESIAN SILICATES	REGIONAL METAMORPHISM	METAMORPHIC
VEINING	SLIP OR MASS FIBRE	CROSS FIBRE	SLIP, MASS FIBRE UNORIENTED AND INTERLACING	CROSS AND SLIP FIBRES	CROSS FIBRE	SLIP OR MASS FIBRE
ESSENTIAL COMPOSITION	Ca, Mg, Fe, SILICATE WATER UP TO 5%	SILICATE OF Fe AND Mg HIGHER IRON THAN ANTHOPHYLLITE	Mg SILICATE WITH IRON	HYDROUS SILICATES OF MAGNESIA	SILICATE OF Na AND Fe WITH SOME WATER	Ca & Mg SILICATE WITH SOME WATER
THEORETICAL FORMULA	$Ca(Mg,Fe)_3(SiO_3)_4 \times H_2O$	$(Fe.Mg)SiO_3$ 1-5% H_2O	$(Mg.Fe)_7Si_8O_{22}(OH)_2$	$3MgO.\ 2SiO_2 2H_2O$	$Na\ Fe\ (SiO_3)_2 FeSiO_3 \times H_2O$	$Ca_2Mg_5Si_8O_{22}(OH)_2$
CRYSTAL STRUCTURE	LONG & THIN COLUMNAR TO FIBROUS	PRISMATIC, LAMELLAR TO FIBROUS	PRISMATIC, LAMELLAR TO FIBROUS	FIBROUS AND ASBESTIFORM	FIBROUS	LONG & THIN COLUMNAR TO FIBROUS
CRYSTAL SYSTEM	MONOCLINIC	± ORTHORHOMBIC	ORTHORHOMBIC	MONOCLINIC (PSEUDO-ORTHORHOMBIC!)	MONOCLINIC	MONOCLINIC
COLOR	GREENISH	ASH GRAY, GREENISH, OR BROWN	GRAYISH WHITE, BROWN, GRAY OR GREEN	WHITE, GRAY, GREEN, YELLOWISH	LAVENDER, BLUE, GREENISH	GRAY-WHITE, GREENISH, YELLOWISH, BLUISH
LUSTRE	SILKY	VITREOUS, SOMEWHAT PEARLY	VITREOUS TO PEARLY	SILKY	SILKY TO DULL	SILKY
HARDNESS	6±	5.5–6.0	5.5–6.0	2.5–4.0	4	5.5
SPECIFIC GRAVITY	3.0–3.2	3.1–3.25	2.85–3.1	2.4–2.6	3.2–3.3	2.9–3.2
CLEAVAGE	110 PERFECT	110 PERFECT	110 PERFECT	010 PERFECT	110 PERFECT	110 PERFECT
OPTICAL PROPERTIES	BIAXIAL NEGATIVE EXTINCTION INCLINED	BIAXIAL & POSITIVE EXTINCTION PARALLEL	BIAXIAL POSITIVE EXTINCTION PARALLEL	BIAXIAL POSITIVE EXTINCTION PARALLEL	BIAXIAL ± EXTINCTION INCLINED	BIAXIAL NEGATIVE EXTINCTION INCLINED
REFRACTIVE INDEX	1.63± WEAKLY PLEOCHROIC	1.64±	1.61±	1.50 – 1.55	1.7 PLEOCHROIC	1.61±
FUSIBILITY	FUSIBLE AT 4	FUSIBLE AT 6, LOSES WATER AT MODERATE TEMPERATURES	INFUSIBLE OR DIFFICULTLY FUSIBLE	FUSIBLE AT 6	FUSIBLE AT 3	FUSIBLE AT 4
FLEXIBILITY	BRITTLE AND NONFLEXIBLE	GOOD, LESS THAN CHRYSOTILE	VERY BRITTLE, NONFLEXIBLE	VERY FLEXIBLE	FAIR TO GOOD	GENERALLY BRITTLE, SOMETIMES FLEXIBLE
LENGTH	SHORT TO LONG	2" TO 11" VARIES	SHORT	SHORT TO LONG	SHORT TO LONG	SHORT TO LONG
TEXTURE	HARSH	COARSE BUT SOMEWHAT PLIABLE	HARSH	SOFT TO HARSH, ALSO SILKY	SOFT TO HARSH	GENERALLY HARSH, SOMETIMES SOFT
TENSILE STRENGTH	VERY WEAK	FAIR, LESS THAN CHRYSOTILE	VERY WEAK	VERY GOOD	VERY GOOD, HIGHEST OF ALL VARIETIES	WEAK
ACID RESISTANCE	RELATIVELY INSOLUBLE IN HCl	FAIRLY RESISTANT TO ACIDS	FAIRLY RESISTANT TO ACIDS	SOLUBLE UP TO APPROXIMATELY 57%	FAIRLY RESISTANT TO ACIDS	FAIRLY RESISTANT TO ACIDS
SPINNABILITY	POOR	FAIR	POOR	BEST	FAIR	GENERALLY POOR. SOME ARE SPINNABLE

*Recent studies claim that the crystal structure is monoclinic.

MARDEP00455

NICOLET INDUSTRIES, INC.
NICOLET AVENUE
FLORHAM PARK, NEW JERSEY

Physical Properties of Asbestos

	Chrysotile	Amosite	Anthophyllite	Crocidolite	Tremolite	Actinolite
Specific heat B.t.u./lb./°F.	0.266	0.193	0.210	0.201	0.212	0.217
Tensile strength, lb./sq. in.	80,000 100,000	16,000 90,000	4,000 & less	100,000 300,000	1,000 8,000	1,000 & less
Temp. at max. ignition loss, °F.	1,800	1,600 to 1,800	1,800	1,250	1,800	—
Filtration properties	Slow	Fast	Medium	Fast	Medium	Medium
Electric charge	Pos.	Neg.	Neg.	Neg.	Neg.	Neg.
Fusion point, °F.	2,770	2,550	2,675	2,180	2,400	2,540
Spinnability	Very good	Fair	Poor	Fair	Poor	Poor
Resistance to acids & alkalies	Poor	Good	Very good	Good	Good	Fair
Magnetite content	0-5.2	0	0	3.0-5.9	0	——
Mineral impurities present	Iron, chrome, nickel, lime	Iron	Iron	Iron	Lime	Lime, iron
Flexibility	High	Good	Poor	Good	Poor	Poor
Resistance to heat	Good. Brittle at high temp.	Good. Brittle at high temp.	Very good	Poor, fuses	Fair to good	——
Ionizable salts, micro-mhos (Relative elec. conductance)	1.82	1.34	0.58	0.84	——	——
Colour	Green, grey to white	Yellowish-brown	Yellowish-brown, Sometimes almost white	Blue	White	Greenish

Comparison of Approximate Fibre Diameters

Type of Fibre	Fibre Diameter in Inches	Fibrils in One Linear Inch
Human hair	0.00158	630
Ramie	0.000985	1,015
Wool	0.0008 to 0.0011	900 to 1,250
Cotton	0.0004	2,500
Rayons	0.0003	3,300
Nylon	0.0003	3,300
Glass	0.00026	3,840
Rock wool	0.000142 to 0.000284	3,520 to 7,040
Asbestos (Chrysotile)	0.000000706 to 0.00000118	850,000 to 1,400,000

Comparison of Tensile Strengths of Various Materials

Type of Material	Tensile Strength (Lb./Sq. In.)
Ingot iron	45,000
Wrought iron	48,000
Carbon steel	155,000
Ni-Cr steel	243,000
Piano steel wire	300,000
Cotton fibre	73,000 to 89,000
Rock wool	60,000
Glass fibre	100,000 to 200,000
Chrysotile asbestos	80,000 to 100,000
Crocidolite asbestos	100,000 to 300,000

Comparison of Surface Area of Various Fibres

Type of Fibre	Surface Area by N_2 Adsorption (Sq. Cm./Gram)
Nylon	3,100
Acetate rayon	3,800
Cotton	7,200
Silk	7,600
Wool	9,600
Viscose rayon	9,800
Asbestos (Chrysotile)	130,000 to 220,000

Effect of Temperature on Loss in Weight of Asbestos Fibres

Temp. °F.	Time	Loss in Weight			
		Amosite %	Anthophyllite %	Chrysotile %	Croc
400	2 hr.	0.23	0.05	0.30	0.
600	"	0.57	0.24	0.85	0.
700	"	0.80	0.30	1.78	0.
800	"	0.98	0.28	2.17	0.
900	"	1.07	0.41	2.83	0.
1,000	"	1.16	0.44	3.99	0.
1,100	"	1.36	0.52	10.28	1.
1,200	"	1.39	0.54	12.75	1.
1,250	"	1.43	0.54	13.43	1.
1,300	"		0.64		
1,400	"	1.52	1.12	13.62	0.
1,700	"		1.73		
1,800	"	1.53	2.39	13.77	0.

*Iron changing in weight due to oxidation.

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For the caustic solubility tests, solid pellets of sodium hydroxide were dissolved in distilled water to obtain a 25 per cent solution, by weight.

Each fibre sample, consisting of 10 grams, was accurately weighed and placed in a flask containing 300 c.c. of the 25 per cent acid or caustic solution.

Two sets of tests were conducted, one at room temperature (26°C.) for indefinite periods, the other at boiling temperature in a reflux condenser for two hours. At the end of each test, the fibres were removed from the solutions, washed free from acids or caustic, dried, and weighed.

Table III shows the solubilities of these particular asbestos fibres in the four acids used and in caustic soda.

The action of boiling acids on asbestos fibres is severe, with chrysotile the most soluble. Acetic acid was not so effective as the mineral acids in dissolving chrysotile, and caustic had even less action on this mineral.

After chrysotile fibres had lost 55 per cent of their weight, examination showed the fibre structure to be almost all silica, brittle, and very fragile.

The high solubility values for actinolite are, it is believed, due to the presence of soluble minerals as impurities in the commercial product used by industry.

Anthophyllite seemed to resist acid action better than any other variety with crocidolite second best, tremolite third, and amosite fourth.

All these solubilities would vary depending upon the source of the fibre and whether the samples represented pieces of 'crudes', or milled fibres as purchased on the market.

The action of acids and caustic at room temperature is slower than at boiling temperatures but if the fibres are kept immersed in the solvent for a sufficient length of time, the solubilities finally reach the values obtained at boiling temperatures.

The tests at room temperature were conducted for periods of 24 hours, 192 hours, 360 hours, and 528 hours. After each time period, the fibres were removed, washed, and weighed, and the solubility calculated. The fibres were then replaced in fresh solutions of acid or caustic to begin the next cycle.

For convenience, only the solubility data for 528 hours are given in Table III since at this point most of the fibres apparently reached their maximum solubility, and this was approximately equal to the solubility after a two-hour treatment in boiling acids or caustic.

Such information is invaluable to a manufacturer desiring to produce an asbestos product which will be exposed to conditions similar to those in the tests. The most resistant fibre, if available in commercial quantities, naturally will be selected for the product.

TABLE III.—SOLUBILITY OF ASBESTOS

Per Cent Loss in Weight, Re-fluxing Two Hours
25% Acid or Caustic

	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Actinolite	20.31	12.28	20.19	20.38	9.25
Amosite	12.84	2.63	11.67	11.35	6.97
Anthophyllite	2.66	0.60	3.16	2.73	1.22
Chrysotile	55.69	23.42	55.18	55.75	0.99
Crocidolite	4.38	0.91	4.37	3.69	1.35
Tremolite	4.77	1.99	4.99	4.58	1.80

Per Cent Loss in Weight, Room Temperature 26°C. for 528 Hours
25% Acid or Caustic

	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Actinolite	22.55	12.14	20.10	20.60	9.43
Amosite	12.00	3.08	11.83	11.71	6.82
Anthophylite	2.13	1.04	3.29	2.90	1.77
Chrysotile	56.00	24.04	56.45	56.00	1.03
Crocidolite	3.14	1.02	3.91	3.48	1.20
Tremolite	4.22	1.41	4.89	4.74	1.65

EFFECT OF HEAT ON ASBESTOS

Since asbestos fibres frequently are exposed to elevated temperatures, it is necessary to determine which fibre most satisfactorily meets the demands.

With this in mind, the same fibres as used in the solubility tests were subjected to two hours' exposure at temperatures varying from 400°F. to 1,800°F., and the weight loss measured. The samples, after drying to eliminate surface moisture, were weighed, placed in a muffle

TABLE IV.— EFFECT OF TEMPERATURE ON LOSS IN WEIGHT OF ASBESTOS FIBRES

TEMP. °F.	TIME	LOSS IN WEIGHT				
		AMOSITE %	ANTHOPHYLLITE %	CHRYSOTILE %	CROCIDOLITE %	TREMOLITE %
400	2 hr.	0.23	0.05	0.30	0.08	0.04
600	"	0.57	0.24	0.85	0.25	0.08
700	"	0.80	0.30	1.78	0.49	0.13
800	"	0.98	0.38	2.17	0.73	0.22
900	"	1.07	0.41	2.83	0.83	0.26
1,000	"	1.16	0.44	3.99	0.86	0.29
1,100	"	1.36	0.52	10.38	1.00	0.37
1,200	"	1.39	0.54	12.75	1.04	0.37
1,400	"	1.43	0.54	13.43	1.03	0.47
1,500	"		0.64			0.56
1,600	"	1.52	1.12	13.62	0.93*	0.67
1,700	"		1.73			1.40
1,800	"	1.53	2.39	13.77	0.77*	2.18

*Iron changing in weight due to oxidation.

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