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CHRYSOTILE ASBESTOS

GROUP 7 (SHORTS)

MARKET ANALYSIS

APRIL 1974

UNION CARBIDE
MARKETING SERVICES DEPARTMENT
Commercial Intelligence Center
270 Park Avenue, New York, N.Y. 10017

George Weihs 551-4801

Morgan Guaranty Trust Company of New York 23 Wall Street, New York, NY 10015

The Morgan Bank

February 10, 1984

Mr. William C. Thurber
Vice President &
General Manager of Tungsten & Asbestos
Union Carbide Corporation
Old Ridgebury Road
Danbury, Connecticut 06817

Dear Bill:

Enclosed is the market analysis of Chrysotile Asbestos. Please let me take this opportunity to thank you for the use of this material and all your other assistance during the project. You and your colleagues were very helpful in working with us to complete the project.

Yours truly,

Ronald M. Grobeck
Assistant Treasurer

/db

CHRYSOTILE ASBESTOS

MARKETS AND FORECASTS

For Group 7

March 1974

G. J. Weihs

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SUMMARY

U. S. consumption of asbestos fiber, Group 7 (short) is estimated at 143,800 tons for 1973. We anticipate a growth rate of about 4 1/2 - 5% per year to 1980, when domestic demand should exceed 202,500 tons. Some of this growth will depend on new uses, such as reinforced plastics and mechanical rubber goods.

It appears that Chrysotile asbestos is expected to remain in short supply.* Our sources indicate that many suppliers are planning to increase their prices by about 10% in 1974. up 18% so far

We have not considered the negative effects of possible federal regulations and consumer attitudes toward asbestos since there is independent monitoring of that aspect by UCC and the industry. An exception is in the areas of paints, where restraints by that industry are already in force.

CONCLUSIONS

1. Floor tile, currently the leading consuming product, will remain dominant to 1980.
2. Drilling muds application will grow at a healthy rate - mostly after 1975. This appears to be the best opportunity for UCC.
3. Wall board tape joint muds should continue to grow, pacing the increase in housing starts and, to some extent, commercial and industrial building. It will probably be necessary to introduce precautionary work practices, especially in the sanding operation.

* The "White House" phoned the Bureau of Mines (in my presence) to inquire if the U. S. could become self-sufficient in asbestos. The answer was "probably not." We understand from U. S. Government sources that Russia, a major supplier of asbestos, has not been honoring its customer commitments. Therefore, the coming shortage may be world-wide.

4. Paper Use of Asbestos appears to require a concentrated effort in the areas of both market research and development. sales effort

5. Best opportunity for new markets are: reinforced plastics, and elastomers (for the shoe industry.)

6. Best (and obvious) opportunity for growth is to inherit the market segment now held by Johns Manville.

7. Best opportunity for growth in established markets is oil drilling muds. and floor tile

RECOMMENDATION

1. From a market research viewpoint, plant expansion is justified, the extent of which to be determined by technology, engineering, toxicological and marketing considerations.

2. A market study of the possible use of Calidria asbestos in vinyl roll goods, and extended use in paper, should be undertaken.

THE PRODUCT

Asbestos is actually a group name that refers to fiberous minerals having different chemical compositions, but similar characteristics. The most widely used type is chrysotile. These fibers are graded according to length with longer fibers priced at 10 - 20 times higher than the shortest grades. UCC's interest focuses on group 7 - one of the shorter fibers.

Asbestos - group 7, included in the U.S. Bureau of Mines Designation BMIII, is usually combined with other materials and loses identity in the final product. For the purpose of this study we are omitting statistics on asbestos/cement, packing and gaskets, textiles and other uses for long fiber where UCC does not compete.*

THE MARKETS - General

Domestic production of asbestos during 1973 was approximately 151,000 short tons with an average value of $109 per ton. This total value ($16, 390,000) was 22% over 1972. California was the principal producing state (72%); Vermont ranked second. (For producers, plants and mine locations, see Tables 1, 2, & 3).

Apparent U.S. consumption, according to the U. S. Bureau of Mines, of all chrysotile asbestos was 871,000 tons, up 8% from 1972. Canada continues to be the major supplier.

As we continue to make inroads into the market segments served by Canadian asbestos, the total market shrinks, since that portion of product shipped which is rock, is eliminated or greatly reduced. UCC's product is approximately 96% (average) purity.

*Some group 7 applications have also been excluded on the basis of inability to compete. UCC's experience in selling the various markets is summarized in Exhibit I.

Continued after Tables-on Page 11

TABLE 1

CAPTIVE FIBER SOURCES FOR THE

MAJOR ASBESTOS PRODUCTS MANUFACTURING FIRMS

U. S. & CANADA

Company	Captive Mine(s)	Fiber-Producing Capacity (short tons/year)
The Flintkote Co.	Flintkote Mines, Ltd. Quebec (wholly owned subsidiary)	33,000
GAF Corp.	Lovell Mine Orleans, Vermont	40,000
ASARCO (through CAPO, 40% owned by ASARCO)	Lake Asbestos of Quebec Ltd.	130-150,000
Johns-Mansville (1) Products Corp.	Canadian Johns-Manville Co., Ltd.	835,000
	Coalinga Asbestos Corp., Calif. (80% interest)	15,000
National Gypsum Co.	National Asbestos Mines, Ltd.	60,000
Jim Walter Corp.	Carey-Canadian Mines, Ltd.	250,000
H. K. Porter Co., Inc.	Pacific Asbestos Corp.	40-50,000
Raybestos-Manhattan, Inc.	Cassiar Asbestos Corp. (Partial Interest)	110,000
General Dynamics Corp.	Asbestos Corp., Ltd. (54% interest)	350-500,000
Union Carbide Corp.	Union Carbide Mines San Benito, Calif.	35,000
Atlas Asbestos Corp.	Santa Cruz, California	10-20,000
Bell Asbestos Mines, Ltd.	Quebec, Canada	60,000
Advocate Mines, Ltd.	Baie Verte, Newfoundland	70,000
Jaquays Mining Co.	Gila, Arizona	3,000

(1) J. M. may cease operations in California in 1974.

TABLE 2

THE MAJOR ASBESTOS MANUFACTURING FIRMS AND PLANTS IN THE UNITED STATES

Company	Total Number of Employees	Estimated Annual Sales ($000,000)	Principal Asbestos-Based Products Manufactured	Plants-Establishments Manufacturing Asbestos Products	% of Line Related to Asbestos
American Biltrite Rubber Corp.	About 4,500; 20% involved in asbestos products	161.0	Floor tiles	14 plants involved to some degree in asbestos manufacturing	5
Armstrong Cork Co.	21,000; about 80% involved in asbestos products	550-600	Gaskets & insulating materials; vinyl asbestos tiles	Fulton, N. Y. Jackson, Miss. Kankakee, Ill. Lancaster, Pa. South Gate, Cal.	50
Certain-Teed Products Corp.	7,600	332.0	Roofing products	Santa Clara, Cal. Riverside, Cal. Ambler, Pa. Hillsboro, Texas St. Louis, Mo.	75
The Flintkote Co.	11,300	441.0	Asbestos-cement pipe; vinyl asbestos tiles; roofing products	Los Angeles, Cal. Chicago Heights, Ill. New Orleans, La. Ravenna, Ohio Chillicothe, Ohio	20
GAF Corporation	20,000 It's subsidiary, Ruberoid, is probably the sole producer of asbestos products	768.0	Asbestos-cement products; vinyl asbestos tiles; roofing products; asbestos paper	Mobile, Ala. Long Beach, Cal. Joliet, Ill. Millis, Mass. St. Louis, Mo. So. Bound Brook, N.J. Vailis Gate, N. Y. Erie, Pa. (two plants) Whitehall, Pa. Houston, Texas	5

TABLE 2 (cont'd)

Company	Total Number of Employees	Estimated Annual Sales ($000,000)	Principal Asbestos-Based Products Manufactured	Plants-Establishments Manufacturing Asbestos Products	% of Line Related to Asbestos
Jim Walter Corp.	1,000 in asbestos products manufacture - (also own Celotex)	882.0	Roofing materials	Perth Amboy, N. J. Linden, N. J. Memphis, Tenn. Lockland, Ohio Miamisburg, Ohio Wilmington, Del. Houston, Texas Tampa, Fla. Cincinnati, Ohio	12
Johns-Manville Products Corp.	25,000	796.0	Asbestos-cement products; asbestos roofing; asbestos insulating materials; millboard	Nashua, N. H. Manville, N. J. Pittsburg, Cal. Stockton, Cal. Waukegan, Ill. Marrero, La. Long Beach, Cal. Los Angeles, Cal. Green Cove Springs, Fla. Savannah, Ga. Billerica, Mass. Tilton, N. H. Denison, Texas Forth Worth, Texas	30
Nicolet Industries, Inc.	350	15.0	Asbestos paper; asbestos millboard	Ambler, Pa. Norristown, Pa. Hamilton, Ohio	100
National Gypsum Co.	14,500	519.0	Asbestos-cement products; asbestos roofing; insulating board	New Orleans, La. Millington, N. J. Mobile, Ala.	-
Raybestos Manhattan	6,500	165	Brake linings & blocks & asbestos products	Bridgeport, Ct. (Home Office)	-

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TABLE 3

TRENDS IN THE NUMBER OF

U. S. ASBESTOS PRODUCTS MANUFACTURING COMPANIES

PRODUCT	YEAR	NUMBER OF COMPANIES
Asbestos Products	1947	85
	1954	74
	1958	69
	1963	73
	1967	81
	1973	80

Sources: 1947-1967 1967 U. S. Census of Manufacturers

1967-1973 Industry Estimates

TABLE 4

DOMESTIC MARKET FOR CHRYSOTILE ASBESTOS

(Primarilly Group 7)

USE	1973	Annual % Growth	1980
(1) Floor Tile	105,000	3%	129,000
(2) Oil Drilling Muds	10,000	7%	16,000
(3) Elastomers (Shoe)	Neg.	.....	(5,000)
Mechanical Rubbers	Neg.	.....	6,000
Adhesives & Sealants	5,000	? 5-6%	7,300
(4) Reinforced Plastics (Phenolics)	Neg. (Poten. 4000)	-	15,000
Paints (Incl. Misc. coatings)	600	-	600
Filled Plastics (Phenolics)	11,000	3%	14,000
W/B Tape Joint Muds	9,000	3%	11,000
(5) Ceiling Tile	1,200	Neg.	1,400
Paper	2,000	Neg.	2,200
(6) Total	143,800 short tons	5%	202,500 short tons

(1) Excluding "long 7's" used in roll vinyls. This area should be explored.

(2) Based on world-wide sale of U. S. production. Expect less than average growth until 1976 and over average to 1980.

(3) Based totally on acceptance in shoe industry - not incl. in 1980 total.

(4) Based solely on acceptance in thermoplastics, thermosets are future possibility which could greatly increase markets.

(5) Totally dependent on 1 customer where prospects are uncertain.

(6) Not allowing for possible restrictive actions by OSHA or EPA.

THE MARKETS (Cont'd)

The market break-down and estimated future consumption shown in Table 4 does not consider the probability that OSHA and/or EPA will force regulations on the asbestos mining and consuming industries which may hinder growth or actually eliminate some existing markets - e.g. paint.

FLOOR TILE

1973 production of vinyl-asbestos floor tile required about 105,000 tons of asbestos. The remaining portion of a typical vinyl-asbestos floor tile consists of vinyl resin, plasticizer, lubricants, stabilizer, limestone and TiO_2. Limestone contributes over 55% to the average formulation. Naturally, variations exist depending on manufacturer.

The industry suggested growth rate for vinyl asbestos floor tile is 5% per year to 1980,but resin suppliers place increasing resin demand at about 2% with less growth anticipated during 1974. This 1974 slackening of demand is attributed mostly to the shortage of raw materials. Some of the differences between estimates may be attributed to the desire of tile manufacturers to decrease scarce, expensive resin and increase filler whenever possible.

We believe an average annual growth of 3% can be envisioned based on the following assumptions:

1. Resurgence of residential soft (carpet) floor covering may hinder vinyl/asbestos tile growth. 2

2. Decline in housing starts.

3. Acceptance of soft floor coverings in business and commercial establishments.

4. Trend to smaller homes and apartments.

5. Gradual replacement of asphalt tile by vinyl asbestos.

TABLE 5

ESTIMATED 1973 ASBESTOS CONSUMPTION IN FLOOR TILE

COMPANY	CONSUMPTION (short tons)	
GAF Corp.	20,000	20
Uvalde Rock Asphalt Co.	5,000	5
Kentile, Inc.	12,000	6
Armstrong Cork Co.	20,000	0
American Biltrite Rubber Corp.	10,000	5
Flintkote Co.	20,000	5000
Others	18,000	3000
U. S. Total	105,000	44000

Source: UCC - Mining & Metals Division

TABLE 6

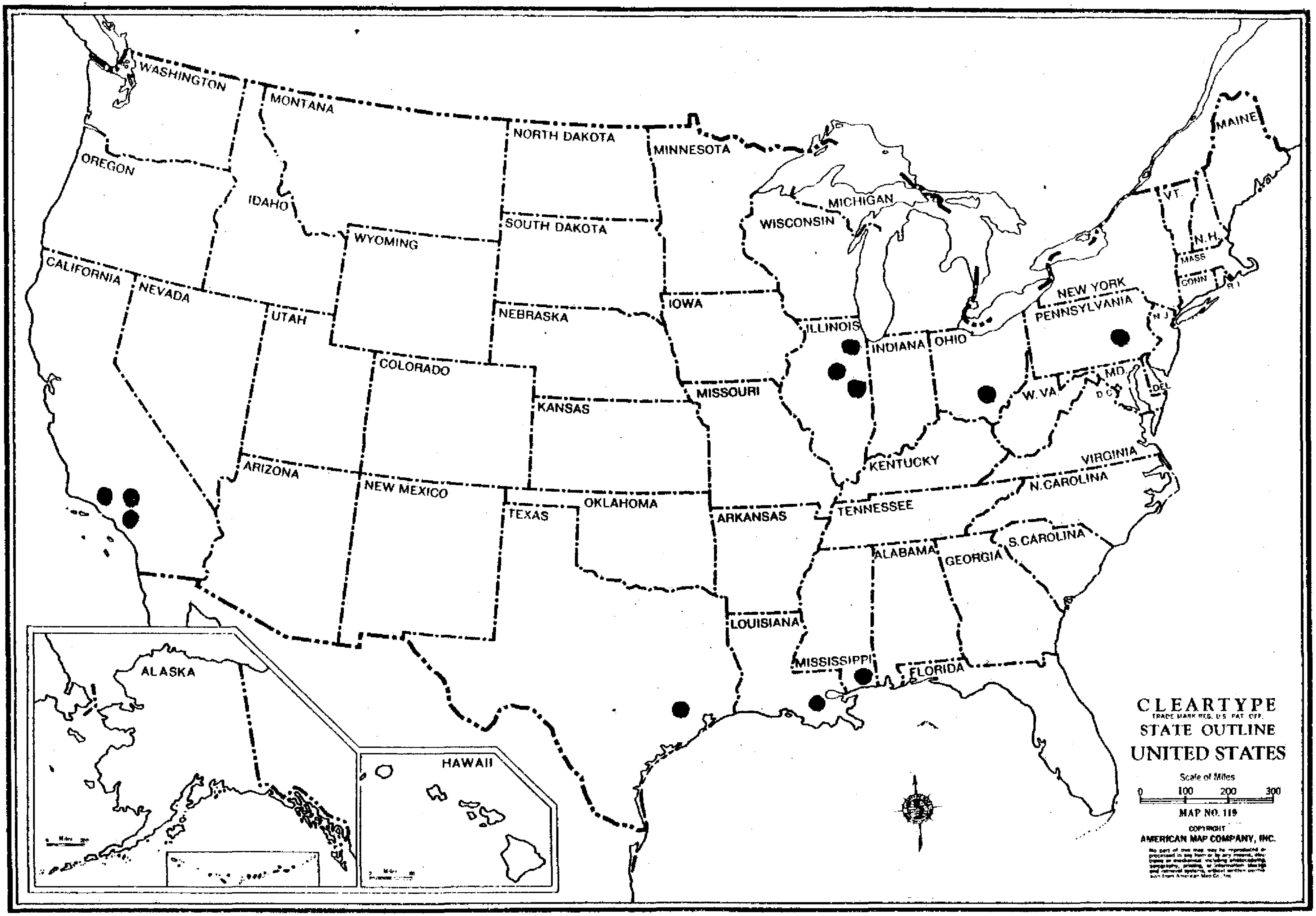
"CALIDRIA" ASBESTOS SALES FOR FLOOR TILE

YEAR	AMER. BILT Tons	AMER. BILT $M	GAF Tons	GAF $M	KENTILE Tons	KENTILE $M	Uvalde Tons	Uvalde $M	Total Tons	Total $M
1964									141	8
1965									972	54
1966									(1)7524	376
1967									7082	355
1968									5630	280
1969	1878	97	0	0	3190	160	1380	69	6448	326
1970	1721	88	260	12	3228	168	1140	57	6349	325
1971	2139	109	3490	157	2600	122	1680	84	9909	472
1972	1760	88	2618	126	3845	180	2732	136	10955	530
1973	1107	62	4695	225	2641	127	5227	230	(2)13678	644
1974 est.	720	44	3000	159	1590	82	4800	238	(2)10680	533

(1) UCC announced decision to "go out" of floor tile market and sell all plant production to HP markets. This did not materialize.

(2) Sales limited by production capacity.

FIGURE I



GEOGRAPHICAL LOCATION OF THE MAJOR VINYL - ASBESTOS FLOOR TILE PLANTS IN THE UNITED STATES

COMPETITION:

A number of companies are engaged in the mining and marketing of asbestos to the floor tile manufacturer. These companies, located in both the United States and Canada, are listed in Table 1 - 2. Competition from chemically different substances is emerging, and the tempo increasing as directives from OSHA and EPA precipitate uncertainty.

Among these are:

- An inorganic fiber, available in development quantities in the form of alumina or zerconia fiber - from ICI.

- UCC Group I, Chemicals, is working under a secrecy agreement with GAF and Flintcote to develop an asbestos substitute specifically for floor tile. This development material is reported to be a "unique resin with a polycaprolactone (family) compound." It is claimed to handle in the forming equipment equally as well as asbestos.

Additional information can be obtained on a secrecy basis, if necessary.

New Developments in Floor Tile Marketing

Developments in the industry include an announcement by Congoleum's resilient flooring group of a stepped-up program for the company's vinyl asbestos floor tile. They have instituted a number of field and management changes to support this policy. It would appear that at Congoleum, there is little fear of product use legislation at the "ultimate consumer" level.

Another new activity involves GAF, which has announced introduction of a vinyl/asbestos "do it yourself" wall tile. Heavy Fall T.V. coverage is planned. (See Figure I - Floor tile plant location.)

TABLE 7

WORLD-WIDE ASBESTOS IN FLOOR TILE*

	Tons	Source	
Argentina	5,000	Canada	
~~Europe~~ (W. Germany)	20,000	Canada	.20
S. Africa	2,500	S. Africa	
Viet Nam	11,000	Unknown	
Brazil	3,000	Canada - JM	
Taiwan	4,000	Taiwan	
Colombia	1,300	Atlas (AZ-20)	
Chile	1,700	JM Coalinga	
	48,500 Tons		

* Known Markets

cc: ~~Montello~~
4/17/7-

4/74

OIL WELL DRILLING MUDS

Asbestos is used as a viscosity control agent in drilling muds - mostly for aqueous systems but also for non-aqueous (oil) systems.*

U. S. asbestos demand was about 7000 short tons in 1973 and U. S. export amounted to an additional 3,000 short tons. Although we forecast growth at 7% per year to 1980, we believe the greater portion of growth will be realized after 1975. 1980 = 16,000 tons

Short term growth is hindered by lack of equipment such as rig availability in the U. S. which, during the early 1960's, stood at 2,000 units and today, at approximately 1,370.** It may take 2-4 years to build rig capacity to meet demands and by 1980, there could be 2,200 rigs available. There is also a shortage of pipe and other parts, and a shortage of skilled personnel which could require 2-3 year to completely overcome. However, as prices for oil products increase, the attraction of investors (money suppliers) may solve the equipment problem in a shorter period of time. Government intervention and priorities may also help.

...ludes biodegradable, long chai...

* Oil systems are used where it has been pre-determined that the subterreanean rock formations would be degraded by water.

** Rigs in operation in Canada = 258 as of 3/74. See Appendix I for additional data on rigs and wells - world-wide.

TABLE 8

UNION CARBIDE ASBESTOS (Short Tons)

SALES TO MONTELLO FOR DRILLING MUD APPLICATIONS

Product Designations	1970	1971	1972	1973	1974 (Budget)	Estimate 4/74
CSV	677	1671	1175	1319	1440	2400
NGSV	0	0	0	469	360	120
IMC/Visquik	120	0	0	999	1440	2100
Visbestos	1242	750	642	249	360	300
Total	2039	2421	1817	3036	3600*	4920

* Sales limited by plant capacity

Problems:

Problems currently facing asbestos drilling muds are:

- Possible restraints by Federal government agencies
- Shortages of asbestos may entice customers and prospects to formulate around the product. Competition on the horizon includes biodegradable, long chain polymer systems. However, these are high priced and, along with other chemicals, may continue in short supply.
- Competition from Johns Manville's "Flosal" asbestos. This may soon end which will strengthen our position in the market place, ~~especially with Phillips Petroleum.~~

Not true as long is Flosal is available.

- Order of priorities - some of the monies made available through increased prices may be ear-marked for refinery capacity rather than for drilling. There is now reported to be a short fall of over 2 million barrels per day of refining capacity.

- Continuing competition from Bentonite.

(See Appendix I for the number and location of drilling operations - world-wide)

WALL BOARD "JOINT" TAPE MUDS

U. S. production of gypsum wall board during 1973 was approximately 14 billion square feet. Assuming a requirement of 5 gallons of (3% contained asbestos) mud per 900 sq. ft. of wall, we estimate a current demand of 9000 tons of asbestos for this purpose.

Growth of gypsum wall board depends largely on housing starts as well as, other business and commercial construction. We accept a 3% average annual growth rate to 1980. Projected, this would mean a market for asbestos of about 11,000 tons in 1980.

According to the Gypsum Wallboard Association and our own internal information, there is an alleged hazard in the use of asbestos in this application due to sanding of the semi-finished job. This "dusting" is considered unacceptable by the trade in view of OSHA attitudes. Warning labels may be required.

MINOR ASBESTOS APPLICATIONS

PAINTS

The industry estimates approximately 300 tons of asbestos were consumed in textured paint during 1973 and an additional 300 tons in allied applications. Although the market for textured paint is increasing, manufacturers, fearing restrictions by OSHA, are ~~substituting~~ replacing asbestos with talc and inert pigments.

According to one source, some development work is still being done. We therefore, hesitate to eliminate asbestos paint from our future market picture and elect to carry the volume over on a "no growth" basis.

ADHESIVES AND SEALANTS

According to information received from the Adhesives and Sealants Council and others knowledgeable in the field, there is a current demand for asbestos of about 5,000 tons per year. This requirement is based on the use of asbestos in mastic adhesives, vinyl and rubber based sealants, caulks & putty. Growth is expected to approximate 5-6%/year to 1980.

CEILING TILE

Conwed Corporation, Cloquet, Minn. is the only U. S. ceiling tile manufacturer known to be using asbestos. 1973 consumption was 1200 tons - all UCC's "Calidria". Demand for 1974 is 1000 tons and maximum requirement by 1980 is put at 1400 tons. Since this is a "one customer" market, everything depends on the whim of the single company - Conwed. Other ceiling tile manufacturers such as Kaiser Gypsum and Armstrong Cork do not use asbestos.

Use of asbestos improves tensile strength in board formation, and clay and starch retention. However, major ceiling tile manufacturers can and do obtain satisfactory product substituting various organic chemicals. The contribution of asbestos - to supply the positive charge necessary to keep it and other ingredients clinging to the wire on the Fourdrinier - is important for older but apparently, not newer equipment.

Continued domestic use and growth depends substantially on the outcome of a legal suit by the Federal government against Reserve Mining Co. for allegedly dumping asbestos-like waste into the Great Lakes. If the government's case stands up, it would have an adverse effect on our future domestic ceiling tile business.* (See Table 9 for UCC exports.)

PAPER:

Three known uses for asbestos in the paper industry are:

1. Add to "furnish" for pitch control.
2. Retaining agent for such paper additives as clay.
3. TiO_2 Extender

In some cases, the use of asbestos can have dual purpose.

There are reported to be technical problems precluding asbestos use at the newer mills. In these operations, the asbestos must be added to the "furnish" in slurry form, which in many instances, results in lumping, This, the mill can not tolerate. It appears the problem can be overcome, but by costly methods. In the older mills, it is satisfactory to add the asbestos as a dry powder and lumping does not occur. Talc has been suggested to be as good as asbestos and at a cheaper price.

*Future for foreign shipments still looks bright.

A relatively new use is for electric paper. Stevens, Westfield, Mass. is the only known asbestos customer. The remaining two manufacturers are Crocker Burbank, Fittsburg, Maine and P. J. Schwetzer, Lee, Main. We believe that this use will remain relatively small.

The 1973 domestic demand for asbestos in paper is about 2000 tons per year sold to four customers: Longview (pitch control); Boise Cascade (TiO_2 Extender); Kimberly Clark (control of sheet porosity); and Prairie States (contaminant dispersion and pitch control). See Table 9 for UCC exports.

TABLE 9

ESTIMATES OF UCC EXPORTS
(~~000~~ Tons)

		1973	1977	1980
Floor Tile -	Japan	0 (1)	4,000	8,000
	Europe	0	5,000	10,000
		0	9,000	18,000
Paper -	Japan	1,000	2,300	2,600
	Europe	100	800	1,400
		1,100	3,100	4,000
Ceiling Tile	Japan	3,400	7,900	9,600

Source: Internal (UCC, NF)

Assumes capture of 50% of market by 1980 which W.R. Grace estimates to be currently 20,000 tons/year.

(1) No material avialable

Asbestos Filled Phenolic Molding Compounds:

According to an internal report (1) phenolic molding materials are catagorized by seven market areas:

	% of Total Production
1) Applaince parts - toaster handles, electrical control knobs, etc.	25
2) Automotive-transmission parts, brake parts, distributor caps, etc.	16
3) Electrical - switch gear, high voltage circuit breakers, etc.	30
4) Wiring devices - electrical parts 110V switches, plugs, etc.	12
5) Closures - bottle caps, etc.	4
6) Communications - switch terminal blocks, etc.	7
7) General industrial parts - knobs, ash trays, etc.	6

Asbestos is used largely in appliances and automotive phenolic applications which account for approximately 40% of phenolic molding materials. Some asbestos is used in electrical wiring devices and general industrial applications for specialty high-temperature resistance items, but usage is relatively small compared to the forementioned areas. Asbestos is not normally used in closures or communications parts. (See Table 10)

(1) B. L. Engalls 1-17-74

Union Carbide requires approximately 1,000 tons/year of asbestos "7 RF9" purchased from Carey. (1)

There are 3 stated reasons for not using UCC's "Calidria":

1) Since both materials are shipped FOB to distination, the freight costs from California exceed those from Carey's operation in Canada.

2) Although Calidria pellets are easier to handle in bulk, they are more difficult to disperse.

3) UCC's equipment is set up to handle the compound as received from Carey and it would require production and formulation changes to convert to "Calidria."

General Electric Co. recently announced intention to formulate away from asbestos and have changed to a combination of other fillers.

This asbestos free formulation has so far, received mixed acceptance. While the substitute may be satisfactory for some items, asbestos filled phenolics are the best performers in high temperature applications. Such items as household appliances, which operate at temperatures above 250°F, still require asbestos. We understand that GE is purchasing asbestos filled phenolics for their dissatisfied customers. G.E. is also considered to be very public relations conscious and for this reason, will promote "non asbestos" to the trade as an "environmental asset."

The loss of asbestos business to this company has been estimated at over 1,000 tons/year.

Note: There is a use for asbestos in other thermosets such as urea and melamine but this is small.

(1) Carey's total annual sale of asbestos for all applications is approximately 235,000 TPY.

TABLE 10

PHENOLIC MOLDING COMPOUNDS (1)

ASBESTOS POTENTIAL DEMAND 1973-1980

(000 Tons)

YEAR	PRODUCTION	ESTIMATED PRODUCTION CONTAINING ASBESTOS (25%)	ASBESTOS DEMAND @ (23%) AVERAGE CONTENT (Rounded)
1960	100	25	5.8
1972	170	42.5	9.8
1973	190	47.5	11.0
1974	195	48.7	11.2
1975	204	51.0	11.7
1976	210	52.5	12.0
1977	220	55	12.6
1978	230	57.5	13.2
1979	240	60.0	13.8
1980	250	62.5	14.3

Competition is also coming from less expensive materials such as talc, which recently replaced asbestos in the auto fan shroud. This was about a 1,500-2,000 ton per year outlet.

(1) UCC had, in 1973, approximately 11% of the phenolic molding compounds market.

NEW DEVELOPMENTS

RUBBER (Elastomers)

Due to the shortage and increasing price of "high" styrene resins, there is a possibility of an impending market for 5,000 tons of asbestos by the shoe industry. Interested, prospective customers include Endicott-Johnson and Thom McAn (J. F. McEllwin).

Present market for asbestos in the shoe industry is about 500-1,000 tons per year. UCC's "Calidria" does not now compete. Advantages of "Calidria" asbestos are price and expected availability.

Again, there could be an environmental problem, and since we believe its use will be a "go or no go" situation (either all or nothing), we have not added the market potential to our estimated total demand in 1980.

This application must be watched closely to determine outcome. UCC should have more definitive information within the next few months.

MECHANICAL RUBBER GOODS

Including rubber rollers, shock mounts and belting, hold a potential market of 5,000 tons/year for asbestos by 1980-81. Use in rubber tiles will also add another 1,000 tons.

OIL WELL DRILLING

During 1973 a new development occurred which could markedly increase Union Carbide Corporation's participating in the oil well drilling business. Dresser Industries has developed, and we believe have a patent application on, a silane treated asbestos (UCC silane).

OIL WELL DRILLING (cont'd)

Technical details are meager but the new product appears to be intended for oil based systems and increases their useful operating range from about 250°F to 350°F. Dresser has asked for 1,000 tons in 1975, and discussions are in progress to determine economics and business relationships.

WATER TREATMENT

A licensing and distribution agreement has been negotiated with the Permutit Company covering the use of High Purity Asbestos in the treatment of certain types of waste water. Sales in 1974 are estimated at 300 tons. It is too early to make firm predictions, but sales in the order of 5,000-10,000 tons/year for this application are quite possible by 1980.

SYNTHETIC WOOD

A small inventor, Holman Construction of Anderson, South Carolina has been working for about 3 years on a "synthetic wood." Fiberglass strands are pulled through a die while a filled plastic is simultaneously extruded. SG-130 at a loading of 5-10% is a key ingredient for a flow control in the extruder. Owens-Corning, as a fiberglass supplier, has become increasingly involved with the project and has recently taken a two year option on the pilot plant. If the project becomes commercial, the asbestos potential could be very large.

PLASTIC REINFORCEMENTS

Union Carbide's chrysotile asbestos pellets, treated with our proprietary phenolic coupling agent, is being offered to the trade as a reinforcing fiber in thermoplastic resin systems. This fiber is designed as a substitute for glass at an approximate ratio of 1:1. Our offering is designated "RG600." (1) See Appendix II for technical information.

Market potential for RG600 is based on a reasonable share of current consumption of, and growth expectations for, glass fiber reinforcement in polypropylene, nylon, HDPE,(2) styrenics, acetates and other thermoplastics. During 1973, thermoplastics were consumed in the amounts shown in Table 11.

TABLE 11

CONSUMPTION OF THERMOPLASTICS IN 1973

RESINS	MM LBS	EST. GLASS FIBER
Polypropylene	40	10
Nylon	23	6
Engineering Plastics	34	8
Polyethylene	13	3
Styrenics	20	5
TOTAL	130 MM LBS.	32 MM LBS.
OR	(65,000 TONS)	(16,000 TONS)

(1) RG660 is 2.5 microns in length - fully liberated.

(2) It should be noted that RG600 and other grade "7" asbestos can be used to convert low density polyethylene to high density, as well as substitute for a portion of high priced, scarce, styrene monomer in some formulations.

Assuming a 25% penetration potential, we see a current available market for approximately 8,000,000 lbs. or 4,000 tons. Our present commercial penetration is nil. Market available in 1980 (assuming no growth for 1974) is about 15,000 tons.

UCC's ability to penetrate this market, in view of the entrenchment of glass, and ecological considerations, is highly problematic. Besides overcoming the negative publicity which surrounds asbestos, it will be necessary to sell at a reasonably lower price to entice those users now wed to glass and glass reinforcing technology.

We have avoided a discussion of reinforced thermoset resin reinforcement because, as of this analysis, there is no satisfactory coupling agent for asbestos in this system. However, work is proceeding with thermoset/asbestos at UCC - Bound Brook and future developments are possible. If successful, a market potential for UCC's RG600 is 8-10 times greater than that for thermoplastics alone.

SOURCES

CODE:	
	External
11	Asbestos Magazine
3	N. L. Industries (Market Research)
5	N. L. Industries (Research & Development)
1	Gypsum Wall Board Assoc.
8	Oil and Gas Journal
8	Montello
11	Bureau of Mines (U.S.)
6	Rubber Age Magazine
4	Adhesives and Sealant Council
4	Fluid Sealing Assoc.
2	Resilient Tile Institute
6	PPG Industries
3	Glidden
11	U.S.D.C.
	Internal
	UCC Chemicals & Plastics
2	A. Constantine
6	R. Lindberg
6	D. Barry
8	J. Madden
7	M. Ranney
10	G. Shipston
10	P. Potter
10	W. DeFaber
	UCC Asbestos Group
11	Marketing & Development Personnel - New York, Niagara Falls, Chicago and Atlanta
	UCC Group I R & D
7	F. Ancker - Bound Brook
8	T. Foster - South Chas.
8	S. Livengood - Tarrytown

CODES: 1) Wallboard 2) Floor Tile 3) Paints 4) Adhesives & Sealants 5) Paper 6) Elastomers 7) Plastics Reinforcement 8) Oil Drilling Muds 9) Ceiling Tile 10) Plastic-Filled Phenolics 11) General

EXHIBIT I

"CALIDRIA" ASBESTOS SALES

(Domestic & Export)

Product	Applications	Tonnage 1970	1973	1974 (Budget)
SG-10X	Floor Tile	6400	13493	10680
SG-130	Mastics	190	278	360
SG-200	Resin filler	0	100	1000
AS-200	Ceiling Tile	0	750	1400
SG-210	Tape Joint Compounds, Mastics, Sealants	917	3946	4800
HPP	Ceiling Tile, Paper, Rubber	5612	5151	5900
HPO	Resin filler, Waste Water Treatment	602	351	360
HPO-J	Drilling Fluid	0	55	240
T-135-P	Paper	438	587	480
T-135-O	Coatings		419	280
CG-135-P	Coatings	13	13	75
RG-100	Resin filler	0	106	100
RG-110	Undercoat, Mastics, etc.	650	754	1080
RG-144	Adhesives, Sealants, etc.	407	616	700
SX-14	Same as RG-144	33	50	115
RG-244	Thixotrope	185	808	882
SX-24	Same as RG-244	34	118	230
Visbestos	Drilling Fluid	1032	254	360
Imcobest	Drilling Fluid	0	999	1440
CSV	Drilling Fluid	668	1344	1440
NGSV	Drilling Fluid	0	468	360
Other		127	65	0
	TOTAL	17,308	30,725	32,282

JLM
3/26/74

APPENDIX I

Rotary-rig activity by states

	Peak No.	Low No.	Average rig activity 1973	1972	1971	1970	1969	1968	1967	1966	1965	1964
Alabama	18	7	13	15	8	7	6	3	2	2	1	2
Alaska	10	0	5	5	5	14	28	20	21	13	6	5
Inland	8	0	4	4	5	12	18	3	5	5	3	3
Offshore	3	0	1	1	0	2	10	17	16	8	3	2
Arkansas	23	8	15	15	15	13	16	7	8	10	11	9
Arizona	5	0	2	1	1	0	2	1	3	1	1	2
California	68	34	51	46	46	52	78	87	83	79	89	93
Inland	65	33	49	45	40	42	61	65	67	70	83	87
Offshore	4	0	2	1	6	10	17	22	16	9	6	6
Colorado	58	23	42	35	30	25	23	17	16	16	19	21
Florida	15	5	9	19	11	4	1	1	2	2	4	1
Georgia	2	0	1	0	0	0	0	0	0	0	0	0
Idaho	2	0	1	0	0	0	0	0	0	0	0	0
Illinois	11	1	6	14	13	14	17	22	30	30	24	20
Indiana	2	0	0	1	1	1	1	2	3	5	5	6
Iowa	1	0	1	0	1	0	0	0	0	1	0	0
Kansas	45	8	28	24	29	30	38	35	41	55	70	87
Kentucky	3	0	1	2	2	1	2	5	9	13	12	8
Louisiana	253	161	205	214	194	204	230	233	235	256	270	282
North	31	15	23	19	16	12	19	19	20	23	30	27
Inland waters	66	43	55	54	50	57	57	64	66	72	72	83
South	76	37	56	59	54	56	69	59	58	63	73	81
Offshore	97	56	71	82	74	79	85	91	91	98	95	91
Maryland	1	0	0	1	0	0	1	1	0	4	2	2
Michigan	26	10	20	17	12	11	10	10	10	9	11	13
Mississippi	44	23	29	37	39	43	40	36	33	34	35	39
Missouri	1	0	1	0	0	0	0	0	0	1	0	0
Montana	28	9	19	20	17	17	31	34	22	24	26	21
Nebraska	10	1	5	6	5	6	10	5	5	8	10	11
Nevada	2	0	0	0	1	0	0	2	1	1	2	1
New Mexico	86	40	62	55	47	40	64	68	56	60	65	79
New York	6	0	1	0	1	0	0	1	1	1	1	1
North Carolina	0	0	0	0	0	0	0	0	0	0	0	0
North Dakota	17	5	10	7	9	9	12	13	11	12	12	14
Ohio	48	21	36	22	17	24	22	22	18	14	22	56
Oklahoma	150	80	115	90	90	98	120	106	101	141	163	158
Oregon	1	0	0	0	0	0	0	0	0	1	1	0
Pennsylvania	19	6	11	8	9	9	7	5	7	10	9	11
South Dakota	3	0	1	1	1	2	1	1	0	0	2	1
Tennessee	2	0	0	0	1	2	1	0	1	1	0	0
Texas	454	328	376	322	291	302	322	329	340	387	425	477
Gulf Coast	143	82	109	91	79	73	77	88	90	103	112	135
Offshore	18	6	9	6	5	6	10	6	7	8	5	2
North	29	14	22	16	15	17	25	25	28	31	34	42
Panhandle	29	15	23	22	16	19	19	20	21	23	25	31
East	37	15	30	26	23	25	37	34	36	38	40	43
West Central	104	73	82	71	76	77	74	67	67	82	102	121
West	115	82	101	90	77	85	80	89	91	102	107	103
Utah	49	29	38	34	17	12	12	12	15	14	14	17
Virginia	3	0	1	0	1	1	0	0	0	0	1	1
Washington	0	0	0	0	0	0	0	0	1	1	0	0
West Virginia	32	6	20	16	17	16	18	16	15	19	24	16
Wyoming	105	33	70	60	45	71	81	56	44	48	50	48
Total U.S.	1,440	970	1,194	1,087	976	1,028	1,194	1,150	1,134	1,273	1,387	1,502
Canada West	272	70	175	148	120	131	149	150	144	156	163	149
Canada East	9	0	4	4	4	3	2	1	1	1	2	1
Grand Total	1,627	1,043	1,373	1,239	1,100	1,162	1,345	1,301	1,279	1,430	1,552	1,652

Source: Hughes Tool Co. Note. Peak and low figures may not add to totals.

Worldwide oil at a glance

COUNTRY	RESERVES 1-1-74		WELLS		OIL PRODUCTION		REFINING Capacity (1,000 b/cd) 1-1-74			
	Oil (1,000 bbl)	Gas (billion cu ft)	Producing oil 7-1-73	Drilling 12-1-73	Estimated 1973 (1,000 b/d)	% change from 1972	Refineries	Crude	Cracking	Reforming
ASIA-PACIFIC										
Afghanistan	†89,840	4,900	13	4	0.2					
Australia	2,300,000	37,700	394	7	420.0	23.3	10	680.9	144.7	156.7
Bangladesh		8,000		1			1	30.6		1.6
Brunei-Malaysia	1,600,000	20,000	126	5	325.0	17.7	3	123.2		5.7
Burma	67,800	200	700	7	23.0	15.0	2	25.3		
China Rep. (Taiwan)	14,000	400	50	2	0.2		2	210.0	9.0	20.0
Guam							1	29.5		
India	779,000	2,000	1,500	9	150.0	− 0.5	10	499.1	36.1	21.8
Indonesia	10,500,000	15,000	2,567	25	1,300.0	22.6	8	427.7	19.5	7.0
Japan	19,000	700	1,084	11	15.0		45	4,939.8	277.4	486.0
Khmer Republic							1	12.5		1.8
Korea, South							3	420.0		27.6
New Zealand	†224,000	15,000	4	1	3.6	33.0	1	54.0		18.0
Okinawa (R.I.)							3	212.0		12.0
Pakistan	31,200	10,120	16	5	8.0	−11.1	3	80.5		2.5
Philippines		180		3			4	283.8	21.7	42.6
Singapore							4	699.6		20.0
Sri Lanka							1	38.0		3.5
Thailand	10,200		25	2	0.2		4	166.2	7.0	23.5
Total Asia-Pacific	15,635,040	114,200	6,479	82	2,245.2	20.0	106	8,932.7	515.4	850.3

†Condensate

COUNTRY	Oil (1,000 bbl)	Gas (billion cu ft)	Producing oil 7-1-73	Drilling 12-1-73	Estimated 1973 (1,000 b/d)	% change from 1972	Refineries	Crude	Cracking	Reforming
EUROPE										
Austria	157,000	589	1,250	5	50.0		1	220.0	16.5	24.0
Belgium							8	816.7	55.3	90.8
Cyprus							1	15.0		2.7
Denmark	248,500	1,800	4	1	3.1	−11.4	3	226.5	18.0	19.3
Finland							2	196.0	32.0	25.8
France	80,000	6,500	284	5	26.3	−12.6	23	3,140.0	182.4	389.6
Germany, West	544,000	12,308	2,782	6	133.0	− 3.4	33	2,825.7	126.1	332.9
Greece†							4	313.6		21.5
Ireland†							1	58.0		13.3
Italy-Sicily	212,000	5,300	125	7	22.3	3.7	34	3,882.0	304.7	374.6
Netherlands	251,000	92,000	319	9	28.6	− 8.6	7	1,825.5	75.0	163.9
Norway	4,000,000	23,000	4	6	37.5	13.6	3	168.0		18.5
Poland*							6	145.8	13.5	10.8
Portugal							2	110.0	12.0	15.6
Romania*							10	320.0		
Spain	60,000	500	26	4	22.2	788.0	9	1,163.0		138.5
Sweden							5	248.0		47.8
Switzerland							2	140.0		23.0
United Kingdom	10,000,000	50,000	63	18	1.5	−11.7	20	2,762.1	188.0	386.2
Yugoslavia	**438,000	1,800	1,012	8	71.0	9.7				
Total Europe	15,990,500	193,797	5,869	69	395.5	5.9	158	18,110.1	1,010.0	2,088.0

†Oil or gas discovered but not developed. *Not included in non-communist total. **Government estimate adjusted.

COUNTRY	Oil (1,000 bbl)	Gas (billion cu ft)	Producing oil 7-1-73	Drilling 12-1-73	Estimated 1973 (1,000 b/d)	% change from 1972	Refineries	Crude	Cracking	Reforming
MIDDLE EAST										
Abu Dhabi	21,500,000	12,500	142	4	1,285.5	22.5				
Bahrain	360,000	4,000	215		63.7	− 8.7	1	250.0	34.2	14.3
Dubai	2,500,000	1,000	39	2	223.0	45.8				
Iran	60,000,000	270,000	350	9	6,000.0	19.5	5	660.0	36.0	41.3
Iraq	31,500,000	22,000	133	9	1,888.2	30.5	6	98.5		5.0
Israel	2,500	25	29	1	†100.0	− 7.0	2	212.0		27.0
Jordan							1	14.1	2.3	1.0
Kuwait	64,000,000	32,500	692	1	2,890.2	− 3.6	5	646.0		20.4
Lebanon							2	53.5	7.2	7.3
Neutral Zone	17,500,000	8,000	362	1	507.5	−11.2		††		
Oman	5,250,000	2,000	97	2	271.9	− 3.5				
Qatar	6,500,000	8,000	92	3	555.5	15.2	1	1.0		
Saudi Arabia	132,000,000	50,900	627	3	7,417.9	29.4	2	428.3		15.1
Sharjah	1,500,000	1,500	*	2						
South Yemen (Aden)							1	162.0		8.6
Syria	7,100,000	700	123	1	105.7	−12.1	1	51.3		
Turkey	450,000	200	286	6	65.0		4	305.5	28.6	28.3
Total Middle East	350,162,500	413,325	3,187	44	21,374.1	18.1	31	2,882.2	108.3	168.3

†Includes captured Sinai fields. *Not yet producing. ††Included in Kuwaiti figures.

APPENDIX I (Con't)

COUNTRY	RESERVES 1-1-74: Oil (1,000 bbl)	RESERVES 1-1-74: Gas (billion cu ft)	WELLS: Producing oil 7-1-73	WELLS: Drilling 12-1-73	OIL PRODUCTION: Estimated 1973 (1,000 b/d)	OIL PRODUCTION: % change from 1972	REFINING Capacity (1,000 b/cd) 1-1-74: Refineries	Crude	Cracking	Reforming
AFRICA										
Algeria	*7,640,000	105,945	574	10	1,035.4	− 2.6	4	115.3		30.5
Angola-Cabinda	1,500,000	1,500	169	5	160.0	14.7	2	24.5		1.9
Congo Brazzaville	4,888,000	1,000	19	3	39.0	490.9				
Dahomey†										
Egypt	5,125,000	4,200	261	4	180.0	−15.0	4	180.0		
Ethiopia†							1	14.4		1.9
Gabon	1,500,000	6,500	122	4	145.0	15.4	1	17.0		2.0
Ghana†							1	25.3		9.4
Ivory Coast							1	44.2		5.0
Kenya							1	48.0		4.0
Liberia							1	10.0		2.0
Libya	25,500,000	27,000	895	9	2,116.6	− 4.5	5	16.4		1.5
Malagasay							1	1.5		0.3
Morocco	750	25	22	2	0.9	4.2	2	58.5	3.6	7.6
Mozambique†							1	17.0		2.5
Nigeria	20,000,000	40,000	898	28	2,000.0	10.0	1	60.0		6.0
Rhodesia							1	(not operating—not included in total)		
Senegal							1	18.0		2.0
Sierre Leone							1	10.0		
Sudan							1	22.0		2.0
Tanzania							1	17.0		2.6
Tunisia	950,000	1,500	56	4	87.0	4.6	1	21.4		3.0
Union of South Africa†							5	331.0	55.9	46.1
Zaire††	200,000	50					1	16.1		2.7
Zambia							1	24.6		5.6
Total Africa	**87,303,750**	**187,720**	**3,016**	**69**	**5,763.9**	**1.8**	**39**	**1,092.2**	**59.5**	**138.6**
*Revised. †Oil or gas discovered but not developed. ††To go on production at 25,000 b/d in 1975.										
WESTERN HEMISPHERE										
Antiqua							1	17.3		1.9
Argentina	2,500,000	8,000	4,096	30	442.0	2.0	14	623.6	101.2	51.4
Bahamas							1	500.0		
Barbados†	250						1	3.0		
Bolivia	260,000	10,000	253	4	47.0	7.8	5	25.5		
Brazil	799,000	921	1,265	25	170.0	3.0	10	791.8	168.6	20.8
Chile	124,000	3,400	466	6	30.0	−12.8	3	123.5	26.3	10.0
Colombia	1,432,000	2,500	2,023	8	186.0	− 5.8	6	166.1	49.5	2.0
Costa Rica†							1	7.6		1.1
Cuba							3	122.0	14.6	11.7
Dominican Republic†							2	46.0		7.0
Ecuador	5,675,000	5,000	829	6	197.0	148.1	3	35.2		
El Salvador							1	13.7		2.1
Guatemala†							2	26.0		6.0
Honduras							1	14.0		1.8
Jamaica							1	33.0		2.3
Martinique							1	14.0		2.5
Mexico	3,600,000	11,000	4,345	45	478.0	8.4	6	625.0	109.0	56.3
Netherlands Antilles							2	945.0	35.0	15.0
Nicaragua							1	13.2		2.6
Panama							1	75.0		7.5
Paraguay							1	5.0		
Peru	1,050,000	3,500	2,499	13	68.0	1.8	5	106.8	6.7	1.8
Puerto Rico							3	307.8	47.8	75.5
Trinidad & Tobago	2,200,000	5,000	2,932	15	159.0	12.4	3	461.0	26.5	27.0
Uruguay							1	43.0	4.0	3.0
Venezuela	14,000,000	42,000	12,461	20	3,370.0	4.7	12	1,531.6	46.6	19.8
Virgin Islands							1	590.0		
United States	*34,700,249	247,310	503,505	1,411	9,225.0	− 2.4	247	13,383.0	4,512.5	3,278.1
Canada	9,424,170	**50,299	22,996	171	1,750.0	14.0	41	1,788.1	427.6	290.0
Total W. Hemisphere	**75,764,669**	**388,930**	**557,670**	**1,754**	**16,122.0**	**2.0**	**380**	**22,436.8**	**5,575.9**	**3,897.2**
†Oil or gas discovered but not developed. **Does not include Arctic gas. *Includes Alaska 10 billion.										
Total Non-Communist	**524,856,459**	**1,297,972**	**576,221**	**2,018**	**45,900.7**	**9.8**	**714**	**33,454.0**	**7,269.1**	**7,142.4**
Communist World	***103,000,000**	**†735,400**			**9,312.0**	**4.5**				
Total World	**627,856,459**	**2,033,372**			**55,212.7**	**8.8**				

*Including Russia with 80 billion, Red China 20 billion, and others 3 billion.
†Including Russia 706 trillion, Red China 20 trillion, Hungary 3 trillion, and others 6.4 trillion.

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APPENDIX II

COUPLED CHRYSOTILE ASBESTOS REINFORCED THERMOPLASTICS

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Introduction

Chrysotile asbestos (1) is a serpentine mineral occurring in nature as macroscopic bundles of colloidal-size fibers. Union Carbide's 'Calidria' asbestos is a domestic chrysotile asbestos which by specially developed wet process beneficiation techniques has been highly purified and liberated into individual fibers having diameters of 250-300Å and average lengths of 2-5 μ, i.e. aspects ratios in the range of 65-200. 'Calidria' asbestos is commercially available as 1/8" diameter pellets which can be readily handled and processed with a minimum of dust generation. A new grade of 'Calidria' asbestos has recently been introduced (RG 600) where the asbestos surface has been pretreated with a novel, proprietary coupling agent. The coupling agent treatment has markedly increased the reinforcing efficiency of chrysotile asbestos in thermoplastic resins, especially in the polyolefins, and has also enabled dramatic improvements in process heat stability and heat aging of polypropylene (PP) and poly(vinyl chloride) (PVC) composites. The new 'Calidria' grade RG 600 provides the formulator and molder of thermoplastic composites with a highly cost-effective reinforcing agent which can be used to obtain unique combinations of material properties.

Mechanisms of Reinforcement

Colloidal chrysotile asbestos has many inherent properties which make it interesting as a reinforcement for plastics: a) the stiffness is more than twice that of E-glass; b) the tensile strength is at least equivalent to E-glass; c) the surface of extruded or molded 'Calidria' composites is smooth in contrast to fiberglass composites which have a rough and abrasive surface texture; d) the 'Calidria' compounds can be processed and reprocessed without fiber attrition, i.e. without deterioration of mechanical properties whereas glass fibers undergo severe breakage during normal extrusion and molding processes. On the negative side, e) the practical reinforcement efficiency attainable with chrysotile fibrils has been very much below theoretical expectations, especially in polyolefins; and f) the thermal and oxidative stability of labile polymers such as polypropylene and PVC are adversely affected by incorporation of natural chrysotile fibers.

The micromechanics theories of short fiber composites (2) have been utilized to help identify the principal causes of the low practical reinforcement efficiency of chrysotile fibrils in thermoplastic resins. These studies have shown that two principal causes are low fiber/matrix adhesion and difficulties in achieving satisfactory fiber dispersion at the colloidal level during normal compounding processes. In retrospect, it is perhaps not too surprising that these two phenomena have such large effects on the reinforcing efficiency of colloidal asbestos fibers.

Chrysotile asbestos has a Brucite (magnesium hydroxide) surface with poor wetting characteristics for non-polar polymers. Due to the colloidal dimensions of liberated chrysotile fibrils, it has not been possible to determine experimentally the adhesion (interfacial shear strength) between various matrix resins and chrysotile fibrils. However, even for the case of perfect fiber/matrix adhesion, the critical fiber length is of the order of the average actual fiber length of 'Calidria' fibrils. For lower levels of adhesion, the critical fiber length will be much longer which means that the reinforcement efficiency is in the range of extreme sensitivity to interfacial adhesion.[2] Similarly, low levels of fiber dispersion on the colloidal level have the effect of reducing the apparent aspect ratio of the fibrils which again will have a pronounced negative effect on the reinforcement efficiency in this fiber length range.

A novel class of proprietary coupling and dispersing agents has now been developed which conveniently can be applied directly to the chrysotile asbestos prior to pelletizing. The coupling agent used in RG600 was designed specifically to promote adhesion between the Brucite surface of chrysotile and polyolefins, especially polypropylene, but it has beneficial effects in thermoplastic resins in general. The establishment of true interfacial activity of the coupling agent is presented in Table I. It is seen that the coupling agent in and of itself does not significantly alter the tensile strength, modulus or heat distortion temperature (HDT) of a thermoplastic resin such as HDPE. However, when the coupling agent is present in chrysotile reinforced composites, improvements over uncoupled chrysotile of 63% in tensile strength, 79% in tensile modulus and 52% in HDT are found. Figure 1 illustrates the approximate concentration dependence of mechanical properties with weight percent fiber surface coverage. An abrupt change in slope of plots comparing tensile strength, tensile modulus and HDT with % coupling agents based on the total composite weight is found at approximately 1.8% additive. Assuming $\sim 60\, m^2/g$ surface area for well liberated chrysotile fibers, this value corresponds quite closely to monolayer coverage of the fibrils. Little improvement in mechanical properties or further reductions in mold shrinkage are observed at levels of additive above 2%. These results are classic illustrations of interfacial activity.

The improvement in dispersibility of chrysotile fibers effected by the coupling agent is shown in Figure 2. Chrysotile/polystyrene composites were prepared from natural (RG144) and modified chrysotile (RG600) with identical compounding conditions and shear history. The electron micrographs show clearly the increase in apparent fiber aspect ratios caused by the coupling agent treatment.

The relative efficiency of the coupling agent in various thermoplastic polymers is shown in Table II. The tensile strength of a composite (σ_c) can be expressed by the rule of mixtures [2]

$$\sigma_c = e \cdot \sigma_f V_f + \sigma_m (1 - V_f)$$

where σ_f and σ_m are tensile strengths of fiber and matrix, respectively, V_f is the fiber volume fraction and e is an over-all efficiency factor. The coupling agent efficiency (α) is defined as

$$\alpha = \frac{e_c}{e_o}$$

i.e. the efficiency factor ratio between samples with (e_c) and without (e_o) coupling agent. Table II shows that the coupling agent is highly effective in the polyolefins, exceptionally so in polypropylene, but marked effects are attained in a broad range of thermoplastics.

RG 600 Composite Properties

The following ASTM test methods were used to evaluate the composite materials: tensile properties (D-638-64T), flexure properties (D-790-66), HDT (D-648-56), specific gravity (D-792-64T), coefficient of linear thermal expansion (D-696-44), notched Izod impact strength (D-256-56).

The thermal stability of chrysotile/PP blends is a particularly important property; therefore special attention was given to its determination. Since subjective tests such as the time to 10% or 25% crazing of the surface of a composite are a dubious measure of thermal stability, we report the induction time for a calorimetric response to the onset of oxidative degradation as measured by a differential scanning calorimeter (DSC). Tests of thermal oxidative stability were performed on 10 mil films pressed from injection molded bars. A Perkin Elmer Model 1-B DSC was used throughout. The stability at 230°C in air was measured.

Tables III and IV show that at all levels of filler between 18 and 36% marked improvements in tensile and flexure strengths are obtained in HDPE and PP resins reinforced with RG600 over natural well liberated chrysotile fibers. At the optimum loading of approximately 30% by weight, use of RG600 to reinforce a standard grade polypropylene yields, as shown in Table V, substantial improvements in all mechanical and thermal properties when compared to commercially available asbestos reinforced polypropylene composites. Table VI compares improvements in mechanical properties between coupled and uncoupled asbestos and glass polypropylene composites, respectively. Coupled asbestos/PP is close to standard glass reinforced PP in overall properties and in general will compare favorably with all glass/PP composites on a cost/performance basis.

Figures 3 and 4 respectively illustrate the improvements obtained with RG600 in HDT and flexure modulus compared with unfilled PP and a RG144/PP blend. It is clear that RG600 at the 18% level has superior properties compared with unmodified chrysotile at twice the fiber loading. At the optimum level of 30% RG600, improvements of 112% in HDT and 275% in flexure modulus are obtained over the base resin.

Tables VII and VIII show the properties of Nylon 6 reinforced with RG600 vs RG144 and other commonly used inorganic reinforcements. The superior combination of high moduli, strength and heat distortion at low loadings is evident.

Unlike fiberglass reinforcement, chrysotile fibers have been long known to accelerate the thermally induced oxidative degradation of thermally labile polymers such as PP and PVC. The coupling agent present in RG600 inhibits this tendency as shown in Figure 5 where at chrysotile loadings of 40% improvement of 685% in the thermal stability under accelerated conditions are attained. With the surface modification present in RG600, as is shown in Figure 6, adequate thermal stability of chrysotile/PP blends can be achieved with reasonable levels of standard antioxidants. Formulations of RG600 at the 30% level in PP with 0.7% hindered phenol (based on the composite wt.) and showing stabilities of 56 min @ 230°C by DSC retain their mechanical strengths in excess of 700 hrs at 150°C in an air circulating oven. At times approaching 2000 hrs similar composites show no sign of surface crazing in a 150°C oven aging test.

The improvements attained in RG600 reinforced thermally labile polymers are particularly striking the the case of PVC composites where oxidative degradation of the matrix during hot compounding in the presence of natural chrysotile is a severe problem. A 200% increase in the time to significant thermal oxidative degradation has been found in comparisons between untreated and surface modified chrysotile filled rigid PVC blends by a high speed mill test. At a milling speed of 110 ft/min and roll temperatures of 190°C significant discoloration and evolution of volatile chlorides occurred only after 9 minutes for 20% RG600 blends as compared to 3 minutes for 20% RG144 blends. The stability of the asbestos blends under standard milling conditions is therefore significantly improved.

RG600/polyolefin composites have exceptional wet strength retention, far exceeding those attainable with fiberglas reinforcements. The data in Table IX show that even after 2 and 7 days immersion in boiling water, there is no decrease but an actual increase in the mechanical and heat distortion properties of the composites. This is a singularly important advantage in a number of practical applications.

Another important property in formulating reinforced thermoplastics is impact strength. Often practical requirements will dictate a certain minimum impact strength combined with high modulus and strength. As is well known, short reinforcing fibers generally contribute little and often even detract from the impact properties of a polymer. However, unique composite properties are often attainable by the proper choice of base resin. For example, impact modified PVC and high impact polyolefins combined with RG600 enable formulation of PVC and polyolefin base composites having overall property combinations similar to those of impact polystyrene and ABS. In general, RG600 in the hands of skilled formulators of the plastics industry should open up many unique and novel applications for reinforced thermoplastics.

<u>References</u>:

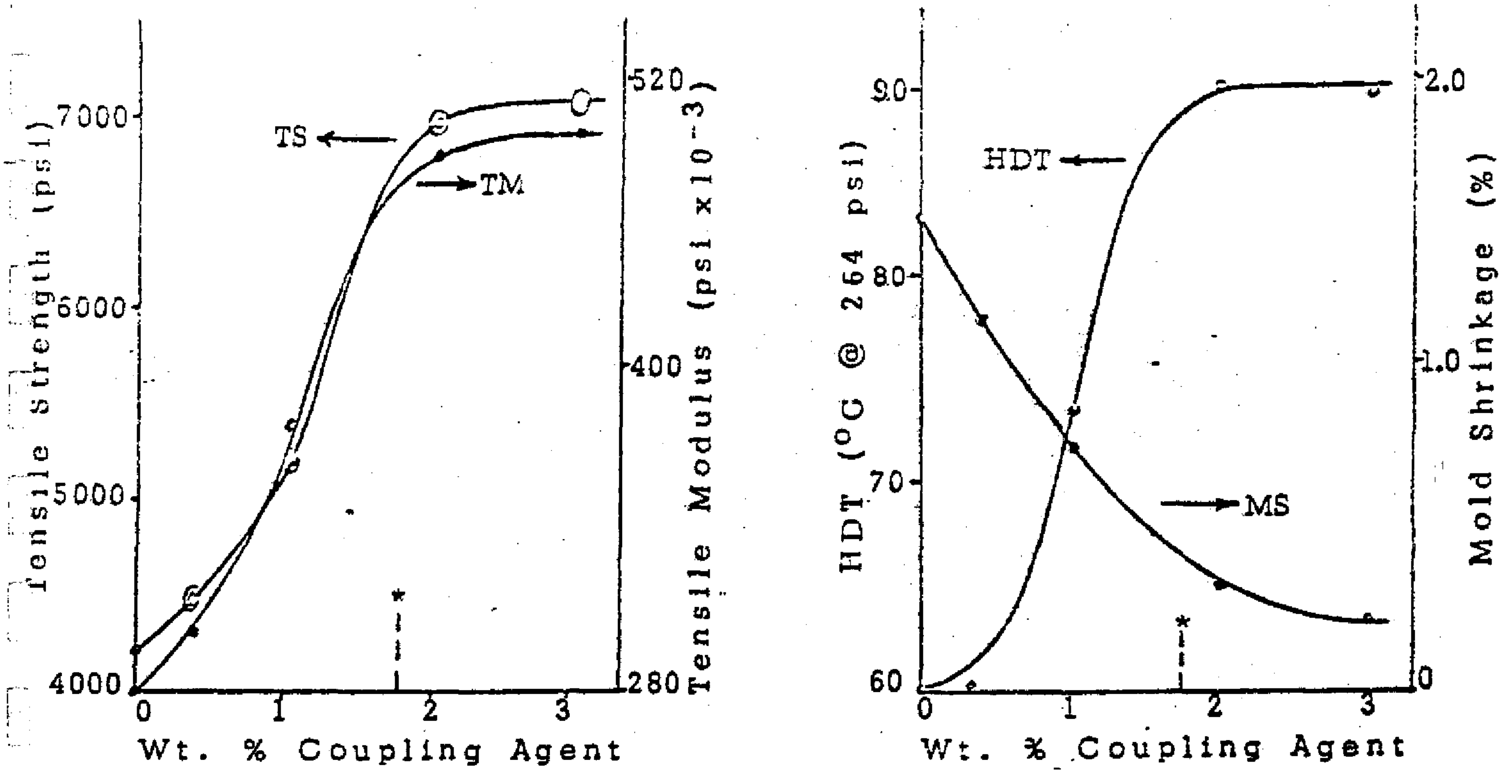
(1) R. E. Byrne: 'Asbestos Fibers', Modern Plastics Encyclopedia, 386-390, 1969-1970.

(2) L. Ongchin, W. K. Olender, F. H. Ancker: 'Fiber/Matrix Adhesion and the Fracture Behavior of Glass Reinforced High Density Polyethylene' 27th Annual Techn. Conf., Reinforced Plastics/Composite Institute, Soc. Plastics Ind., 1972.

FIGURE 1

INTERFACIAL ACTIVITY OF COUPLING AGENT

(20% wt. Chrysotile - HDPE Composites)[1]



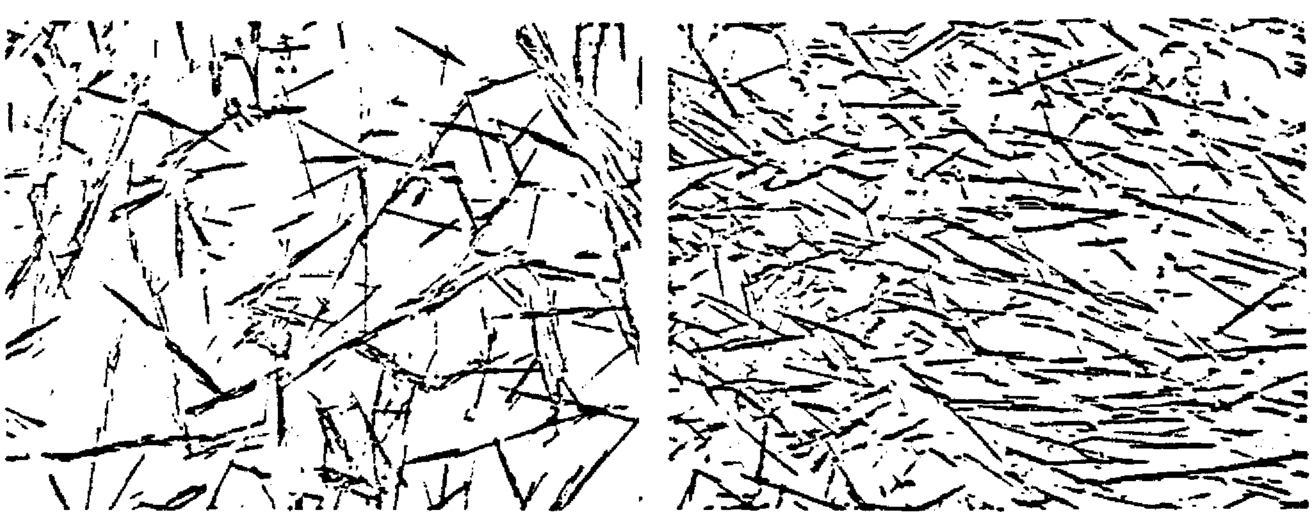
1) Resin supplied by Union Carbide (Grade DMDJ-7008) - ram injection molded test specimens.

* Calculated wt. % coupling agent for monolayer coverage of asbestos.

FIGURE 2

ELECTRON MICROGRAPHS OF CHRYSOTILE/POLYSTYRENE COMPOSITE

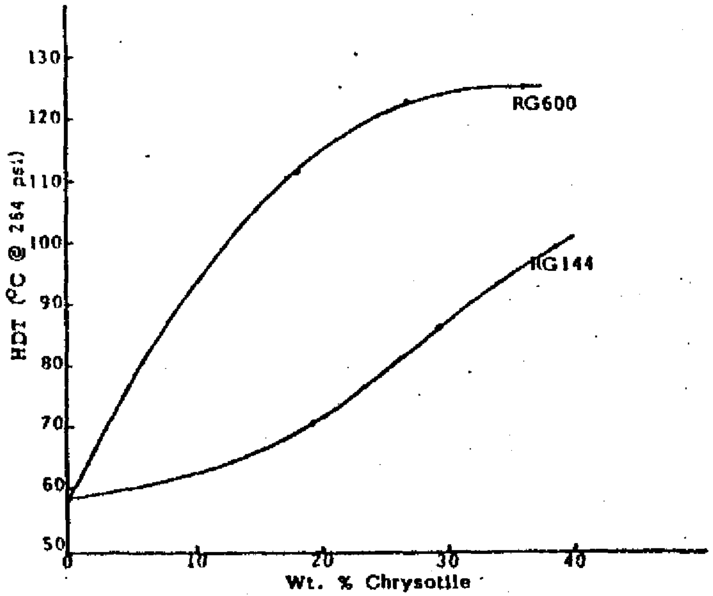
(Magnification 14,000 times)



a) 30% wt. RG144 b) 30% wt. RG600

FIGU

HEAT DISTORTION TEMPERATURE OF CHRYSOTILE REINFORCED POLYPROPYLENE



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CHRYSOTILE REINFORCED POLYPROPYLENE

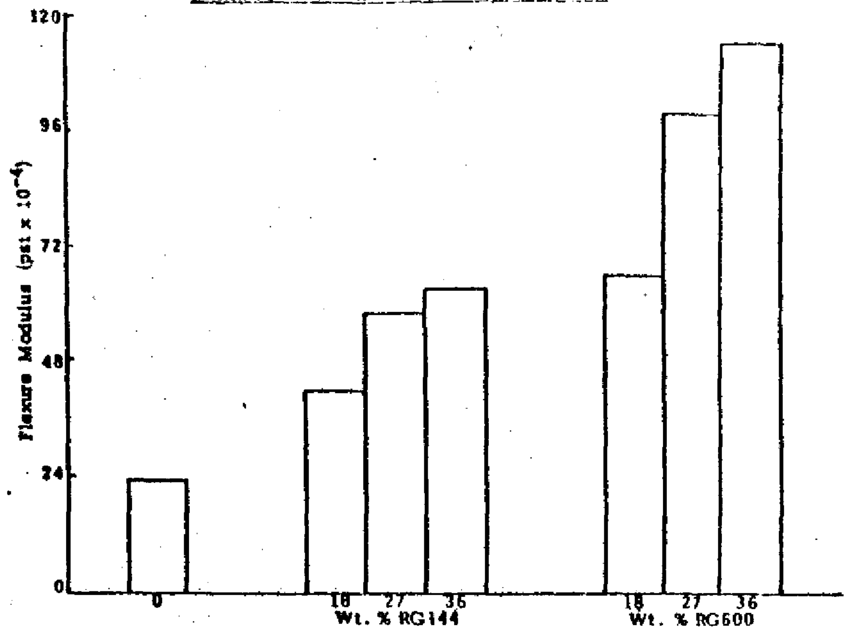

FIGURE 5

COUPLING AGENT EFFECTS ON THERMAL STABILITY OF CHRYSOTILE/POLYPROPYLENE BLENDS

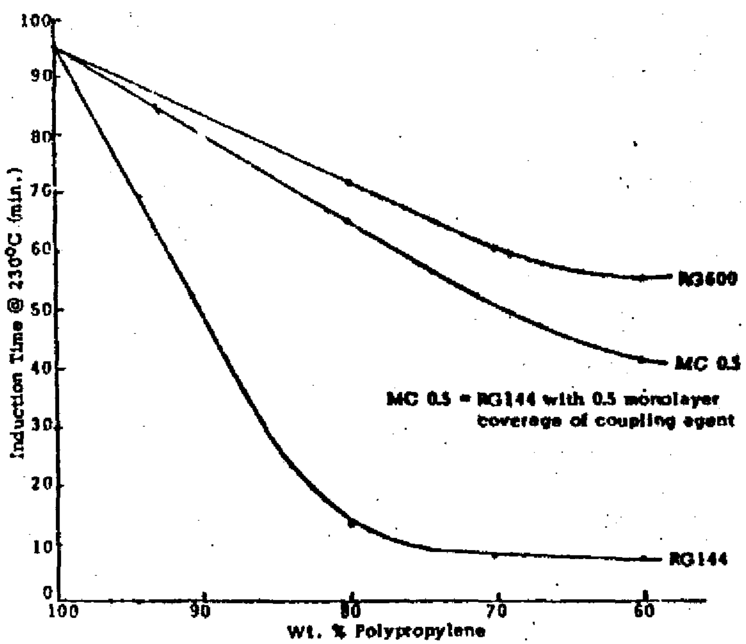

FIGURE 6

THERMAL STABILITY OF CHRYSOTILE/POLYPROPYLENE BLENDS

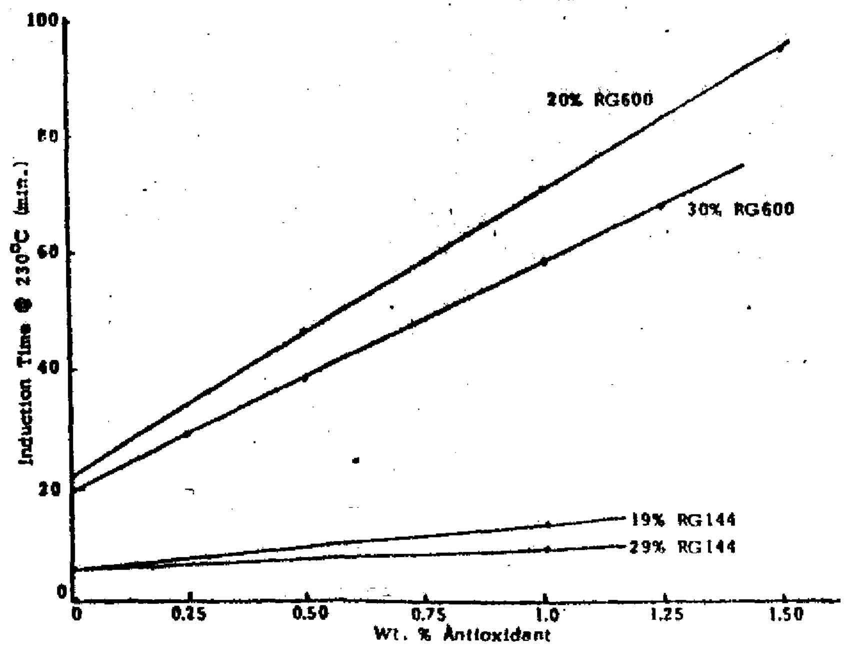

TABLE II

EFFICIENCY FACTORS FOR COUPLED CHRYSOTILE (RG600) FILLED THERMOPLASTICS

Efficiency Factor	Polyamide[1]	Polyester[2]	PS[3]	HDPE[4]	PP[5]
α	1.27	1.16	1.34	1.56	2.80

(1) Nylon 6 (200-001) supplied by Firestone
(2) "Tenite 7DRO" supplied by Eastman
(3) Polystyrene (PS) SMD-3500 supplied by Union Carbide Corp.
(4) High Density Polyethylene (HDPE) DMDJ-7008 supplied by Union Carbide Corp.
(5) Polypropylene (PP) 5524S supplied by Shell.

TABLE III

TENSILE STRENGTH OF CHRYSOTILE REINFORCED POLYOLEFINS[1]

Wt. % RG144	HDPE[2] (psi)	PP[3] (psi)
19	4195	4910
27	4020	5900
36	—	5060
0	2770	4590
Wt. % RG600		
18	5450	6220
27	6550	7300
36	6300	7400

(1) Ram injection molded bars
(2) High Density Polyethylene (UCC - DMDJ-7008)
(3) Polypropylene (Shell 5524S)

TABLE IV

FLEXURE STRENGTH OF CHRYSOTILE REINFORCED POLYOLEFINS[1]

Wt. % RG144	HDPE[2] (psi)	PP[3] (psi)
19	6730	9,100
27	9230	10,400
36	—	10,200
0	3900	6,780
Wt. % RG600		
18	8,900	11,900
27	11,000	12,900
36	11,450	13,400

(1) Ram injection molded bars
(2) High Density Polyethylene (UCC - DMDJ-7008)
(3) Polypropylene (Shell 5524S)

TABLE I

INTERFACIAL ACTIVITY OF COUPLING AGENT[1]

Additive[2] wt. %		Tensile (psi) Strength	Tensile (psi) Modulus	HDT (°C) (264 psi)
	None	3050	132,000	44
2%	Coupling Agent	2900	135,000	38
18.6%	Chrysotile	4200	280,000	60
18% / 2%	Chrysotile / Coupling Agent	6850	500,000	91

(1) High density polyethylene composites
(2) Additives compounded individually into the fluxed resin on a twin roll mill

TABLE V

ASBESTOS/POLYPROPYLENE COMPOSITES

Property Measured	1 40% Anthophyllite*	2 40% Chrysotile**	3 40% Asbestos***	4 30% RG600****
Tensile Strength (psi)	4800	4500	4500	7300
Flexure Strength (psi)	7800	7500	—	12,900
Flexure Modulus (psi)	650,000	600,000	550,000	992,000
Coefficient of Linear Expansion ($\times 10^{-5}$/°C)	3.5	3.0	—	1.9
Mold Shrinkage	1.0%	1.0%	—	0.5%
	—	—	0.01 in/in	0.004 in/in
Heat Distortion Temperature (°C)				
@ 66 psi	144	130	—	150
@ 264 psi	—	—	95	123

* Oleform 2016 - Amoco
** Arpylene APPN1040 - Turner Brothers Asbestos Co.
*** Propathene 22/44 Black 9040-1
**** Coupled short fiber Chrysotile reinforced PP (Shell 5524S)

TABLE VI

REINFORCED POLYPROPYLENE

Reinforcement	Tensile (psi) Strength	Tensile (psi) Modulus	Flexure (psi) Strength	Flexure (psi) Modulus	HDT (°C) (264 psi)
27% RG144 (1)	5,900	460,000	10,400	580,000	87
27% RG600 (1)	7,300	580,000	12,900	992,000	123
30% Glass (1)	8,100	735,000	14,000	850,000	124
30% Glass (2)	14,000	800,000	24,000.	900,000	153

(1) Polypropylene supplied by Shell (5524S)
(2) Modified polypropylene supplied by Hercules (PCO72)

TABLE VII

CHRYSOTILE REINFORCED NYLON 6[1]

Reinforcement[2]	Tensile (psi) Strength	Tensile (psi) Modulus	Flexure (psi) Strength	Flexure (psi) Modulus	HDT (°C) (264 psi)	Notched Izod (ft-lbs/in)
15% RG144	12,400	725,000	22,000	754,000	151	0.94
15% RG600	14,000	820,000	24,800	834,000	164	1.01

(1) Nylon 6 supplied by Firestone (Grade 200-001) - Ram injection molded test specimens.
(2) Samples contain 0.31% polyamide stabilizers based on the resin content.

TABLE VIII

NYLON 6 REINFORCEMENT[1]
Pretreated Mineral Fillers

	Unfilled[2]	15% RG600	30% Wollastonite[3]	15% Glass[4]	30% Glass[4]
Flexure					
Strength (psi)	12,000	24,800	16,800	18,000	25,900
Modulus ($x\ 10^{-3}$ psi)	290	834	660	455	890
Tensile					
Strength (psi)	8,400	14,000	9,900	11,800	15,700
Modulus ($x\ 10^{-3}$ psi)	330	820	634	612	976
NOTCHED IZOD (ft-lb/in. notch)	1.31	1.01	1.04	1.29	1.81
HDT (°C) 264 psi	74	164	86	187	199

(1) Ram injection molded bars
(2) Nylon 6 supplied by Firestone - 200-001
(3) Wollastonite F-1 pretreated with 1% wt. aminosilane
(4) Silane treated glass reinforced nylon supplied by Firestone - 415-001 and 430-001

TABLE IX

DRY-WET MECHANICALS FOR CHRYSOTILE/THERMOPLASTIC COMPOSITES[1]

Sample Wt. % Filler	Resin	Test[2] @ 100°C (days)	Tensile (psi)[5] Strength (B)	Tensile (psi)[5] Strength (A)	Tensile (psi x 10^{-3}) Mod. (B)	Tensile (psi x 10^{-3}) Mod. (A)	HDT (°C) @ 264 psi (B)	HDT (°C) @ 264 psi (A)
30% RG144	PP[3]	7	4160	4010	299	258	62	58
30% RG600	"	7	6310	6500	507	545	95	106
19% RG144	HDPE[4]	2	3990	3730	264	215	58	45
20% RG600	"	2	5510	5560	406	426	81	99
30% RG600	"	2	6540	6860	536	589	96	110

(1) Ram injection molded test specimens
(2) Total immersion in boiling water
(3) PP = Polypropylene supplied by Shell (5524S)
(4) HDPE = High Density Polyethylene supplied by Union Carbide (DMDJ-7008)
(5) Before test = (B); After test = (A)