CC: G. L. English
H. G. Lauterbach -Ch. Rn.

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE 19898

TEXTILE FIBERS DEPARTMENT

PLAINTIFF'S
EXHIBIT
DUP-1756

Centre Road Building
March 13, 1981

TO: DENA MEYER
Engineering
Louviers Building

FROM: D. M. PARRIES
Textile Fibers Marketing
Centre Road Building

WELDING BLANKET MATERIAL

Per our recent discussion, I am sending you our just printed literature on welding blankets of aramid fiber. Please let me know if you have any suggestions or recommendations as to other markets for welding blankets where this product might fit.

DMP/vcg

DU 053322

DM 483

DUP 1012028

D. Meyer

"KEVLAR" AND "NOMEX"

ARAMID FIBERS

FOR

ASBESTOS REPLACEMENT

E. I. DU PONT DE NEMOURS & CO., INC.
TEXTILE FIBERS DEPARTMENT
CENTRE ROAD BUILDING
WILMINGTON, DE 19898

Dm 484

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DE 19898

KEVLAR® AND NOMEX® ARAMID FIBERS

FIBER/FORM:	KEVLAR®			NOMEX®	
PHYSICAL PROPERTIES	FILAMENT	STAPLE YARN	CHOPPED, PULP	FILAMENT	STAPLE YARN
Density, gm/cc	1.45	1.45	1.45	1.38	1.38
Denier/Filament	1.5	1.5	1.5	1.5	1.5
Filament Dia., mils	.47	.47	≤.47	.50	.50
Filament Length, Ins.	Cont.	1.5-4.0	.08-.25	Cont.	1.5-3.0
Tenacity, gm/denier	22	9-13	≤22	5.3	3.5-4.5
Tensile Strength, psi x 10^{-3}	400	160-230	≤400	100	65-80
Modulus, psi x 10^{-6}	10	10	10	2.5	1.3-2.2
Elongation, %	4	5	4	22	35-22

THERMAL PROPERTIES

Shrinkage % at				
177°C. (350°F)		0		<1.0
285°C. (545°F)		0.5		2.5
In flames (815°C. or 1500°F)		0.5		>40
Max. Continuous use Temp.	°C	150-205		205-260
	°F	300-400		400-500
Decomposition Temp.	°C.	~480		~425
	°F.	~900		~800
Limiting Oxygen Index (LOI)		29		29

DUP 1012030

DU 053324

AM 485

KEVLAR® ARAMID FIBER

	Thermal Fabrics (Gloves & Curtains)	Clutch Facings	Brake Pads	Friction Papers	Gaskets (Beater-Add & Compressed)	Plastics Reinfmt.
PERFORMANCE						
Fiber Content, %	100	20-30	2-5	5-15	3-6	2-50
Specific Gravity	1.45	1.6-2.2	1.6-2.2	1.6-2.2	1.5-2.0	1.3
Coef. of Friction	N/A	.2 - .6	.2 - .6	--	N/A	N/A
Friction Fade	N/A	Stable	Stable	Stable	N/A	N/A
Wear Resistance	Excellent	Excellent	Excellent	Excellent	--	Excellent
Wear on Mating Surface	N/A	low	low	low	low	low
Thermal Conductivity	low	low	low	low	N/A	N/A
Creep	N/A	low	low	low	low	low
Coef. of Thermal Expansion	N/A	low	low	low	low	low
ECONOMICS (1980 prices)						
Fiber Price, $/lb.	5.75	5.50	3.75-5.00	3.75	3.75	3.75-5.75
Lifetime Cost, Asbestos = 1.00	1.00	.60-1.00	.60-1.00	1.00	1.05-1.50	1.00-1.10

DUP 1012031

DU 053325

DU PONT CONTACT

John C. Norman
Textile Fibers Department
Centre Road Building
Wilmington, DE 19898
Phone: (302)999-3546

NOMEX® ARAMID

APPLICATION:	Thermal Insulation	Protective Clothing	Electrical Insulation
Product Form:	Fiber	Fiber	Fiber
PERFORMANCE			
Specific Gravity	1.38	1.38	.3-1.38
Coef. of Thermal Expansion	Low	Low	Low
Thermal Conductivity, BTU. in/hr. ft.^{2} °F	.24	.24	.3 - .8
Dielectric Strength, Volts/mil	N/A	N/A	850
Resistance to Acid	Good	Good	Good
Resistance to Caustic	Good	Good	Good
Resistance to Solvent	Excellent	Excellent	Excellent
Limiting Oxygen Index	29	29	24-32
ECONOMICS (1980 prices)			
Price, $/lb.	6.10-19.00	6.10-19.00	6.43-14.26
Lifetime Cost, Asbestos = 1.00	.90 - 1.20	1.30 - 1.50	1.50 - 3.00

DU PONT CONTACT

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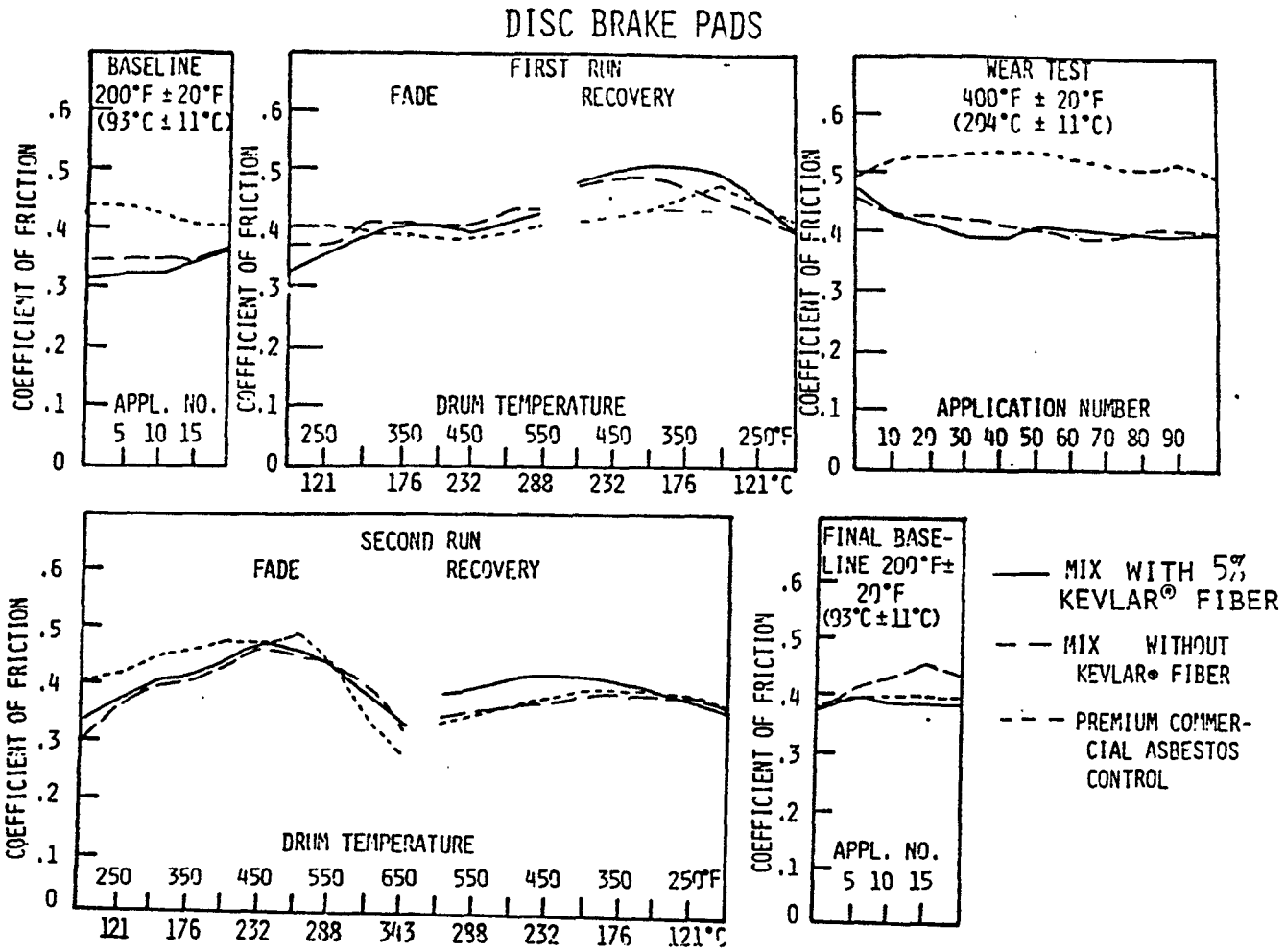
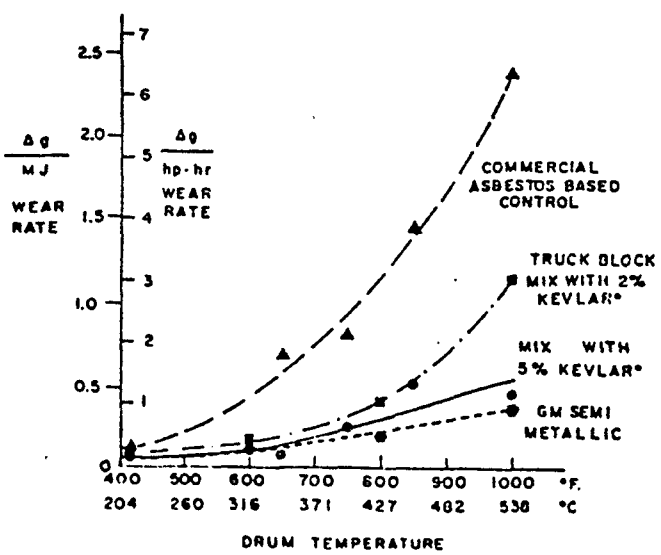
Phone: (302) 999-3951

DU 053326

DUP 1012032



J661A test plots (Chase test)



DU 053327

DUP 1012033

MATERIAL SAFETY INFORMATION

KEVLAR® ARAMID FIBER

Kevlar® aramid is an aromatic, organic composition of carbon, hydrogen, oxygen and nitrogen. When burned, its combustion products are similar to those of other organic materials comprised of the same four elements; their exact composition depends on the conditions of combustion (temperature, availability of oxygen, etc.). Kevlar® yarn is not readily biodegradable and contains no significant percentage of material extractable in water so its effect on ground water in case of landfill disposal should be negligible.

Kevlar® yarns as supplied by Du Pont have been tested for toxicity by skin contact tests on animals and humans. No toxic reactions have been observed. We have received no reports of skin irritation or other health hazard associated with this fiber during six years of extensive market development activity involving millions of pounds of fiber used in a variety of applications.

Kevlar® is not radioactive, is stable in all recommended use environments and requires no special spill procedures. In handling yarns of Kevlar®, operators should be cautioned of the unusually high strength of this product and the resultant possibility of cuts to hands or fingers caught in loops and tangles.

MATERIAL SAFETY INFORMATION

NOMEX® ARAMID FIBER

Nomex® aramid is an aromatic organic composition or carbon, hydrogen, oxygen, and nitrogen. Nomex® is difficult to ignite and will usually self extinguish in the absence of an external heat source. However, when burned, its combustion products are similar to those of other organic materials comprised of the same four elements; their exact composition depends on the conditions of combustion (temperature, availability of oxygen, etc.). Nomex® is not readily biodegradable and contains no significant percentage of materials extractable in water so its effect on ground water in case of landfill disposal should be negligible.

Nomex® fiber supplied by Du Pont has been tested for toxicity by skin contact tests on animals and humans and by inhalation and feeding tests on animals. No toxic reactions have been observed.

Nomex® fiber is not radioactive, is stable in all recommended use environments, and requires no special spill handling procedures.

From
DU PONT

D. Meyer

A Preliminary Information Memo

Number 375

Date September 28, 1976

CHARACTERISTICS AND USES OF KEVLAR® 29 ARAMID

TEXTILE FIBERS DEPARTMENT
E. I. du Pont de Nemours & Co. (Inc.)
Wilmington, Delaware 19898

The information contained in this memo was prepared for rapid dissemination to meet special needs. Data and recommendations may be tentative and, as such, subject to change. For that reason, the information presented should be used only after consultation with appropriate Du Pont technical representatives to determine its currentness and validity.

THIS MEMO IS NOT INTENDED AS A PRODUCT SPECIFICATION

DUPONT Better things for better living...through chemistry

DM 496

We believe that this information is the best currently available on the subject. It is offered as a possibly helpful suggestion in experimentation you may care to undertake along these lines. Du Pont makes no guarantee of results and assumes no obligation or liability whatsoever in connection with this information. Anyone intending to use recommendations contained in this publication concerning equipment, processing techniques, or chemical products should first satisfy himself that the recommendations are suitable for his use and meet all appropriate safety and health standards. This publication is not a license to operate under, or intended to suggest infringement of, any existing patents.

Rapidly advancing knowledge of new, long term toxic effects of many chemicals has emphasized the need to reduce human exposure to many chemicals to the lowest practicable limits. Special hazards with respect to chemicals mentioned in this Memo which were known to us at the time of publication have been noted in the text or in footnotes, but we do not suggest or guarantee that other hazards do not exist. We strongly recommend that processors seek and adhere to manufacturer's or supplier's current instructions for handling each chemical they use.

CHARACTERISTICS AND USES OF KEVLAR® 29 ARAMID

I. INTRODUCTION

KEVLAR is the registered trademark for one member of DuPont's family of aromatic polyamide fibers*, which have been granted the generic name "aramid" by the Federal Trade Commission. KEVLAR 29, with a tensile strength of 400,000 lb/in² (2758 MPa†) and modulus of 9 million lb/in² (62 000 MPa), is especially suited for a number of industrial applications including ropes, cables, protective clothing, and coated fabrics. KEVLAR 49, which has a modulus of 19 million lb/in² (131 000 MPa) and the same tensile strength as KEVLAR 29, is designed for the reinforcement of plastics and offers industry a new level of composite performance**.

KEVLAR 29 is supplied by DuPont in filament yarns and staple fibers; product descriptions are shown in Table I. Fabrics and nonwoven felts are also being produced commercially from these fibers and yarns.

This bulletin describes the properties of KEVLAR 29 and typical applications, including fabrics and other products. More detailed technical information and current prices are available upon request.

TABLE I
YARNS OF KEVLAR® 29 ARAMID

Type 960
Yarn for Ropes and Cables with Special Finish for Improved Abrasion Resistance

Denier	Decitex*	Yield yd/lb	Yield (m/kg)**	Filament	Twist†	Nominal Yarn Diameter*** 10^{-3} in	Nominal Yarn Diameter*** mm
1500	1670	2976	6000	1000	0	21.2	0.54
9000	10000	497	1000	4000	0	52.0	1.32
15000	17000	298	600	10000	0	67.1	1.70

Type 961
Yarn for Ropes and Cables with Standard Finish

Denier	Decitex*	Yield yd/lb	Yield (m/kg)**	Filament	Twist†	Nominal Yarn Diameter*** 10^{-3} in	Nominal Yarn Diameter*** mm
1000	1110	4464	9000	666	0	17.3	0.44
1500	1670	2976	6000	1000	0	21.2	0.54
9000	10000	497	1000	4000	0	52.0	1.32
15000	17000	298	600	10000	0	67.1	1.70

Type 964
Yarn for Weaving Application

Denier	Decitex*	Yield yd/lb	Yield (m/kg)**	Filament	Twist†	Nominal Yarn Diameter*** 10^{-3} in	Nominal Yarn Diameter*** mm
200	220	22320	45000	134	0	7.8	0.20
400	440	11160	22500	267	0	11.0	0.28
1000	1110	4464	9000	666	0	17.3	0.44
1500	1670	2976	6000	1000	0	21.2	0.54

† Yarns are designated Rotoset
* Numbers have been rounded to conform to product descriptions adopted for uniformity in packaging and labeling
** m/kg = yd/lb x 2.016
*** Assuming 70% packing factor

* NOMEX is also included in this generic fiber category (see DuPont bulletin entitled "Properties of NOMEX Aramid Fiber").
** For further information see DuPont brochure entitled "Characteristics and Uses of KEVLAR 49 Aramid High Modulus Organic Fiber".
† MPa = MN/m² = psi x 6895 x 10^{-6}

II. FIBER PROPERTIES

The physical properties of KEVLAR 29 aramid fiber compared with those of conventional industrial nylon, DACRON* polyester, fiberglass and stainless steel are shown in Table II. It can be seen that the tensile trength of KEVLAR* 29 is more than twice that of nylon or DACRON, 15% greater than that of "E"-glass, and 60% greater than that of steel. Modulus, or stiffness, is more than 10 times that of nylon, almost 5 times that of DACRON, and is almost equivalent to that of "E"-glass. The fiber elongation-to-break is quite low compared with that of other organic fibers, and the density, while higher than that of nylon or DACRON, is about 1/2 that of glass, and 1/5 that of steel.

TABLE II
COMPARATIVE YARN PROPERTIES

	KEVLAR® 29 Aramid	DU PONT Nylon Type 728	DACRON® Polyester Type 68	"E-HTS" Glass	Stainless Steel
Tensile Strength, lb/in² (MPa)*	400,000** (2758)	143,000** (985)	162,500** (1120)	350,000*** (2412)	250,000 (1724)
Modulus, lb/in² (MPa)	9,000,000 (62000)	800,000 (5512)	2,000,000 (13780)	10,000,000 (68900)	29,000,000 (199800)
Elongation to Break, %	4.0	18.3	14.5	3.5	2.0
Density, lb/in³ (g/cm³)†	0.052 (1.44)	0.041 (1.14)	0.050 (1.38)	0.092 (2.55)	0.284 (7.83)

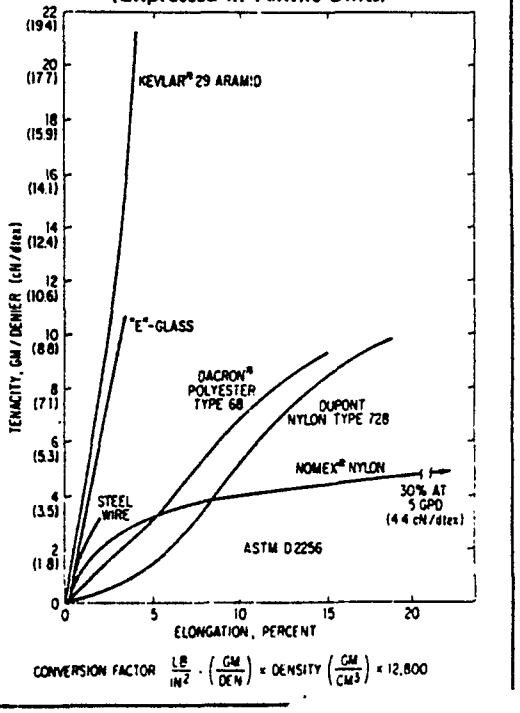
*MPa = MN/m² = lb/in² x 6.895 x 10⁻³
**Unimpregnated twisted yarn test – ASTM D2256
***Impregnated strand test – ASTM D2343
†g/cm³ = lb/in³ x 27.68

The nearly linear stress/strain curve to failure of KEVLAR 29 is similar to that of glass, but unlike those of other organic fibers (Figure 1). Because it is relatively insensitive to fiber surface defects, the tensile strength of KEVLAR 29 is uniform along the length of the fiber; for example, a twisted 1500 denier (1670 dtex) yarn tested at 100 in. (2540 mm) gage length retains 95% of its 1 in. (25.4 mm) gage strength. KEVLAR 29, available in yarns of up to 15,000 denier** (16 700 decitex)***, is comprised of many continuous, round cross-section filaments each having a denier of about 1.5 (1.7 decitex) and a diameter slightly under 0.5 mil (0.013 mm).

Tensile strength is measured by ASTM D2256 using yarn samples twisted to 1.1 twist multiplier (T.M.) on 10 in. (254 mm) gage length at 50% per minute elongation rate. The formula for twist multiplier and the significant effect that twist level has on tensile strength are shown in Figure 2.

The 0.052 lb/in³ (1.44 g/cm³) density of KEVLAR 29 results in a higher specific† tensile strength than is currently available from any other material commercially available and a specific† molulus higher than that of glass fiber. These properties (Figure 3) form the key to market opportunities in ropes and cables and other uses where the ratio of strength to weight is important.

FIGURE 1
STRESS-STRAIN BEHAVIOR OF YARNS
(Expressed in Textile Units)



* Du Pont registered trademark
** Denier is weight in grams of 9000 meters
*** Decitex is weight in grams of 10,000 meters
† Tensile strength or modulus divided by density.

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FIGURE 2
THE EFFECT OF TWIST ON THE TENSILE STRENGTH OF KEVLAR® 29 ARAMID
(Textile Units)

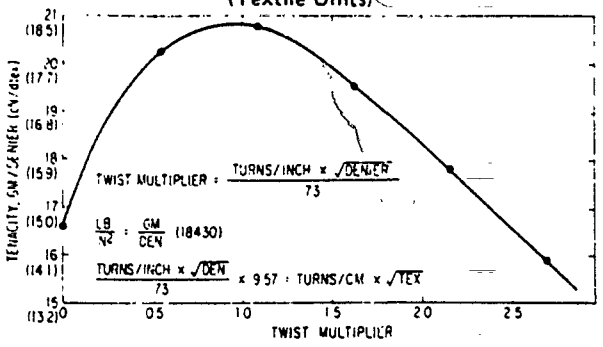
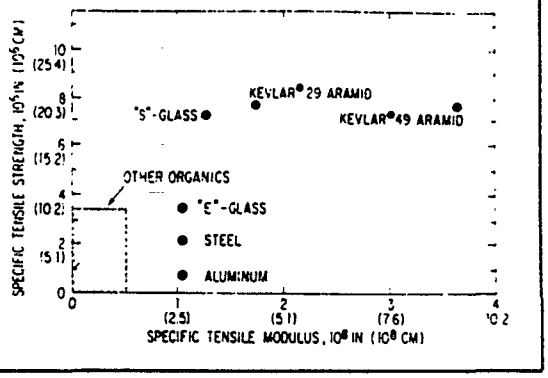


FIGURE 3
SPECIFIC TENSILE STRENGTH AND SPECIFIC TENSILE MODULUS OF FIBERS AND OTHER MATERIALS



KEVLAR** 29 also has high toughness which yields good textile processibility and high impact strength; for example, loop strength is 55% of straight breaking strength.

KEVLAR 29 has good thermal stability, retaining a high percentage of room temperature properties when tested up to 355°F (180°C) (Figure 4). The fiber exhibits virtually no shrinkage between room temperature and 320°F (160°C). KEVLAR 29 does not melt or support combustion under normal environmental conditions but will carbonize at about 800°F (427°C). At arctic temperatures of -50°F (-46°C), it exhibits essentially no embrittlement or degradation of fiber properties.

The chemical resistance of KEVLAR* 29 is excellent except in a few strong acids (Table III). The effect of ultraviolet light will vary with the thickness of the item exposed. Very thin fabric (4.5 mil, 0.114 mm), if exposed directly to Florida sunshine for a period of 5 weeks, will lose about half of its tensile strength

FIGURE 4
THE EFFECT OF TEMPERATURE ON THE TENSILE STRENGTH OF KEVLAR® 29 ARAMID

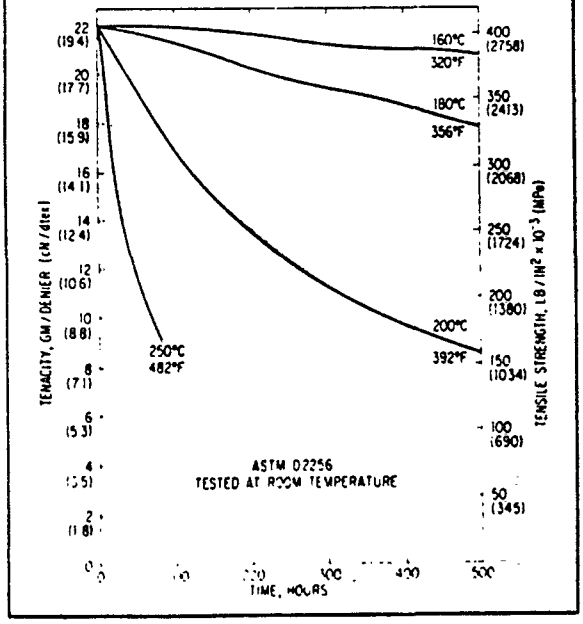


TABLE III
CHEMICAL RESISTANCE OF YARN OF KEVLAR® 29 ARAMID

Environment (100 hr* exposure at 70°F; 21°C)	Tensile Strength Loss %
ACIDS	
Formic (90%)	10
Hydrochloric (37%)	90
Hydrofluoric (10%)	12
Nitric (70%)	82
Sulfuric (70%)	100
OTHER CHEMICALS	
Brake Fluid (312 hr)	2
Greases (moS_2 and Lithium base)	0
Jet Fluid (JP-4) (300 hr)	0
Ozone (1000 hr)	0
Tap Water	0
Boiling Water	0
Superheated Water 156°C (313°F) 80 hr	16

*Except where noted.

*Du Pont registered trademark.

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(Table IV). In thicker items, such as the 1/2 in. (12.7 mm) diameter rope shown in the table, the majority of the yarns are protected by the outer layer and the strength loss is minimal. Although self-screening may be sufficient for some applications, the addition of opaque jacketing may be required for increased UV resistance under critical conditions.

KEVLAR® 29 has an equilibrium moisture level of 7% at 72° F (22°C) at 55 R.H., and a negative coefficient of thermal expansion of -2×10^{-6}/°C (-1.1×10^{-6}/°F).

KEVLAR 29 has excellent dynamic and static fatigue resistance (Table V, Figure 5), as well as stress relaxation behavior (Figure 6). Creep rate is equivalent to that of fiberglass, but unlike glass, is much less susceptible to creep-rupture, even at levels as high as 70% ultimate tensile strength. Additional information on creep, fatigue, and impact properties is available upon request.

TABLE IV
ULTRAVIOLET STABILITY OF KELVAR® 29 ARAMID

Product Form	Break Load	Strength Loss (%)
Fabric, 4.5 mil (0.114 mm) thickness		
Unexposed	300 lb/in (525 N/cm)	–
Florida Sun (5 weeks)	154 lb/in (270 N/cm)	49
Rope, ½" (12.7 mm) diameter		
Unexposed	11,400 lb (50,700 N)	–
Florida Sun (6 mo.)	10,260 lb (45,700 N)	10

TABLE V
EFFECT OF TENSION-TENSION FATIGUE ON KEVLAR® 29 ARAMID

Cycled Between (% of Ultimate Tensile Strength) High	Low	No. of Cycles	Break Load After Cycling Lb	(N)	Decrease in Tensile Strength Due to Fatigue
Control		–	124	552	–
74	45	1000	130	578	None
52	29	1000	137	610	None
31	8	1000	132	587	None
10	0	13×10^6	118	525	5%

1500 denier (1670 dtex) 2-ply yarn of KEVLAR® 29 was tested using air-actuated 4-D cord clamps on an Instron test machine, at 10" (254 mm) original gage length, 10% per minute elongation, and at 55% R.H. and 72° F (22° C).

FIGURE 5
CREEP OF YARNS OF KEVLAR® 29 AND KEVLAR® 49 ARAMID AT 50% OF ULTIMATE STRENGTH

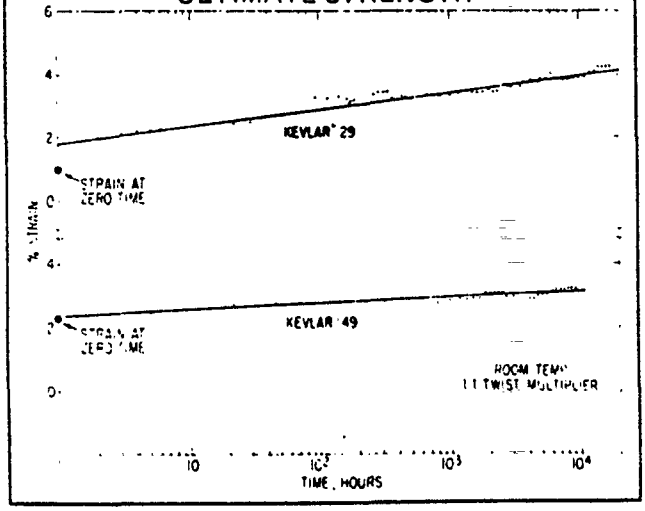
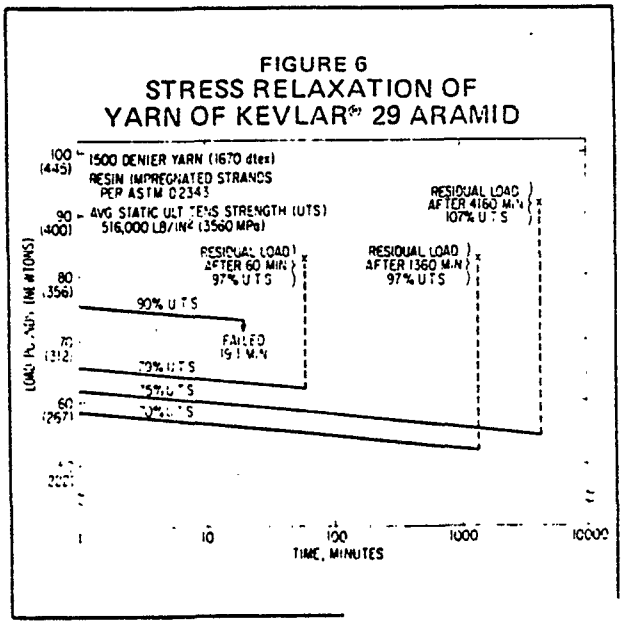


FIGURE 6
STRESS RELAXATION OF YARN OF KEVLAR® 29 ARAMID



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*Du Pont registered trademark.

DU 053334

III. FABRICS

Woven fabrics of KEVLAR* 29 aramid have a balance of properties generally unattainable with traditional textile fibers or with fiberglass, including the high strength and stability of glass fabrics at significantly lower weight. They also have a balance of tensile and tear strengths superior to that attainable with other organic fibers, thus eliminating the necessity to over-construct fabrics to obtain high tear strength. Typical fabric properties are discussed under Applications.

Because of its unique combination of physical properties and organic composition, KEVLAR 29 is an inherently "tough" material. However, yarns, rovings, fabrics, and coated fabrics can be cut and trimmed using sharp, clean tools. Scissors must have close tolerances between cutting surfaces and serrated scissors** are preferred since they prevent the material from slipping out from between the cutting surfaces. Good quality canvas, upholstery, and carpet shears (for example, Wiss #4 I.S.) or electric scissors (for example, United Cloth Cutting Machine Co. #LIL 25159) will also satisfactorily cut fabrics of KEVLAR 29. The canvas shears are also available with serrations**.

Multiple plies of fabrics of KEVLAR 29 can be cut using a sabre saw with a special blade tipped with tungsten carbide**. Additional information on cutting is available upon request.

IV. APPLICATIONS

A. Ballistics

Fabrics of KEVLAR 29 are being extensively used in ballistic garments to protect law enforcement officers from handgun threats and in military flak jackets and helmets. KEVLAR 29 is also being evaluated in other ballistic protective end uses such as armored cars and trucks, bomb disposal blankets, military personnel carriers, bank teller cages, explosives storage and transportation cases, military aircraft, jet engine blade containment, and blankets and curtains surrounding high speed machinery. Fabrics may be used untreated in "soft" armor, or impregnated with thermoset, thermoplastic, or elastomeric resin systems and then molded into "flexible" or "hard" armor which have structural integrity as well as ballistic resistance.

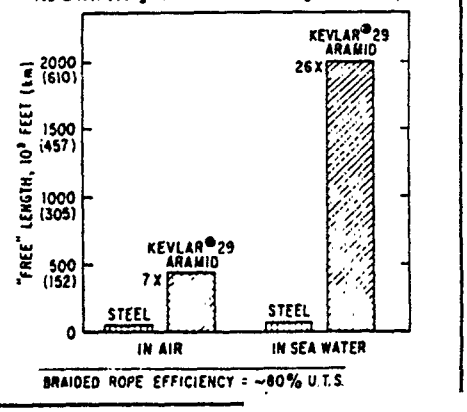
B. Protective Apparel

High strength, cut resistance, and thermal insulating characteristics of KEVLAR 29 make it attractive for protective apparel applications. Gloves made from continuous filament or spun yarn fabrics show good cut resistance and durability in metal and glass handling operations. When these same glove constructions are backed by felts of KEVLAR 29, additional thermal and puncture protection are obtained. Combinations of ballistic fabric and felt of KEVLAR 29 are being evaluated for lightweight protective aprons for meat cutters and knee pads for chainsaw operators.

C. Ropes and Cables

KEVLAR 29 is replacing steel in tension members and cables where very high specific tensile strength, low stretch, good electrical properties, cyclic and creep fatigue resistance, and toughness are important. The high strength-to-weight ratio is the primary reason for the use of KEVLAR 29 in very long cables of up to 5 miles (8 km), such as those used in oceanographic and aerospace markets. Figure 7 illustrates the "free" length of KEVLAR 29 that will support itself in both air and water, as compared with steel. KEVLAR 29 is also replacing other organic fibers such as DACRON* polyester or nylon in applications where low stretch, or reduced weight and diameter (at equivalent strength), is desirable.

FIGURE 7
"FREE" LENGTH COMPARISON
(Length at which Strength Member Breaks of Its Own Weight = Tensile Strength/Density)



*Du Pont registered trademark.

** Available for Technology Associates, Inc., P.O. Box 7163, Wilmington, Delaware 19803.

TABLE VI
TYPICAL ROPE PROPERTIES

BRAID	Diameter in. (mm)	Weight lb/100 ft (kg/100 m)	Break Strength lb (N)
KEVLAR* 29 Aramid	5/8 (15.9)	10.3 (15.3)	34,000 (151 300)
DACRON* Polyester	5/8 (15.9)	14.0 (20.8)	13,000 (57 850)
KEVLAR 29	2 (50.8)	136 (202)	277,000 (1 232 650)
DACRON	2 (50.8)	126 (187)	106,000 (471 700)
Nylon	2 (50.8)	106 (158)	117,000 (520 650)
WIRE ROPE (7 x 19)			
KEVLAR 29	1/2 (12.7)	8.0 (11.9)	25,000 (111 250)
Galvanized Steel	1/2 (12.7)	45.8 (68.2)	22,800 (101 460)

*Du Pont registered trademark

TABLE VII
AIR SUPPORTED SHELTER FABRIC

	Nylon	KEVLAR® 29 Aramid
Weight – oz/yd² (g/m²)		
Fabric	5.1 (173)	2.1 (71)
Coating	9.9 (336)	9.2 (312)
Total	15.0 (509)	11.3 (383)
Thickness – mil (mm)	16 (0.41)	11 (0.28)
Tensile Strength – lb/in (N/m)	300 (525)	380 (665)
Relative Specific Strength*	1.0	1.7
Tear Strength – lb (N)	20 (89)	25 (111)
Relative Specific Strength*	1.0	1.7
Burst – lb/in² (kPa)	840 (5792)	900 (6206)

*Strength to weight, Nylon = 1.0

A wire rope construction of KEVLAR* 29 can provide the same high strength as a steel cable at one-fifth the weight (Table VI). Specific applications under development are deep-sea mooring lines, electro-mechanical cables, mining and drilling cables, antenna guys, and running and standing rigging for boats.

D. Industrial and Coated Fabrics

A coated fabric of KEVLAR 29 has high tensile strength, excellent resistance to tearing and cutting, low weight and bulk, good dimensional stability and flame resistance. These properties suggest a number of uses such as inflatables (life-rafts, escape slides), architectural structures (either air- or cable-supported), and a variety of collapsible, portable storage containers. Table VII illustrates the advantages over nylon of a fabric of KEVLAR 29, coated with HYPALON* synthetic rubber, for air-supported shelters. In Table VIII are listed a few of the polymeric coating systems that have been successfully applied to fabrics of KEVLAR 29. Adhesion promoters suitable for use with nylon fabrics are generally effective with KEVLAR 29.

E. Tapes and Webbings

The high tensile strength of yarns of KEVLAR 29 is very useful in parachute component materials where reductions in weight and bulk are critically important. A variety of tapes, webbings, tubular webbings and braided cords of KEVLAR 29 have been developed that have the same strength, but weigh only about 30 to 40% as much as their nylon counterparts. Tentative draft specifications for these materials have been written by the Air Force Materials Lab.

Ribbon parachutes have been made to equal dimensions and equal strength using components of all-nylon and all-KEVLAR 29. The parachute of KEVLAR 29 weighed only one-half as much and required one-half the storage volume as the nylon parachute. KEVLAR 29 is also being used in drogue parachutes, as components in personnel parachutes, and in weapons delivery systems.

*Du Pont registered trademark.

TABLE VIII
COATING MATERIALS USED SUCCESSFULLY WITH KEVLAR® 29 ARAMID

Coating	Typical End Uses
Neoprene Synthetic Rubber	Inflatable Boats
HYPALON® Synthetic Rubber	Pond Liners, Tarpaulins
Nitrile Rubber	Pressure Diaphragms
NORDEL® Hydrocarbon Rubber	Heat-Resistant Conveyor Belts
Buna-N	Hoses
Urethane Polymers	Inflatable Structures
Silicon and Fluorosilicon	Belting
Polyvinyl Chloride	Air-Supported Structures
TEFLON® (TFE, FEP) Fluorocarbon Resin	Non-Stick Belts
Polyvinyl Alcohol	Specialty Uses
Laminations– TEDLAR® Polyvinyl Fluoride MYLAR® Polyester	Lighter-than-Aircraft

F. Asbestos Replacement

Because of exceptional resistance to high temperatures and also low thermal conductivity, KEVLAR* 29 aramid has great promise as an asbestos replacement in applications up to about 400°F (204°C) or to even higher temperatures when the contact is intermittent or short term. Table IX shows the relative thermal conductivity of both fabric and felt of KEVLAR 29 compared to asbestos and fiberglass fabrics. KEVLAR 29 provides equal protection at equal thickness or superior protection when compared on a weight basis.

KEVLAR 29 is being used to replace asbestos in roll covers for conducting hot glass tubing, protective heat shields around glass annealing ovens and protective gloves. It is also being evaluated in many applications as replacement for asbestos in the reinforcing of plastics or elastomers such as grinding wheels, brake linings, and concrete pipe. In general, either a fabric or felt of KEVLAR 29 is used as the reinforcing material. In some cases, the individual staple fibers are dispersed through the plastic matrix prior to molding or curing.

TABLE IX
THERMAL CONDUCTIVITY OF KEVLAR® 29 ARAMID COMPARED TO ASBESTOS AND FIBERGLASS

Fabric	Weight oz/yd² (g/m²)	Thickness 10^{-3} in (mm)	Lag Time (Sec.)	cal/cm² · s	Temp. Rise–°F (°C) in 25 sec.
KEVLAR 29	9.8 (333)	30 (0.76)	0	.324	108 (60)
KEVLAR 29 (3 ply)	29.4 (998)	85 (2.16)	3	.162	54 (30)
KEVLAR 29 (Felt)	27.0 (917)	105 (2.67)	1.5	0.084	28 (16)
Fiberglass	8.4 (285)	12 (0.30)	0	.600	200 (111)
Fiberglass (8 ply)	67.2 (2282)	85 (2.16)	5.1	.105	35 (19)
Asbestos	40.8 (1386)	90 (2.29)	2.5	.168	55 (31)

*Du Pont registered trademark.

For additional information on "Kevlar" 29 aramid, please contact:

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TEXTILE FIBERS DEPARTMENT
KEVLAR® SPECIAL PRODUCTS
CENTRE ROAD BUILDING
WILMINGTON, DELAWARE 19898

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NOMEX®
Aramid
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TECHNICAL INFORMATION

PROPERTIES AND PERFORMANCE OF NOMEX® ARAMID PAPER TYPE 411

(Replaces Bulletin N-254 which should be destroyed)

INTRODUCTION

NOMEX* aramid paper, composed solely of highly aromatic polyamide synthetic material, provides unusually stable properties:

- NOMEX does not melt and drip nor support combustion in air.
- NOMEX retains useful mechanical and electrical properties for long times at temperatures above the melting point of nylon and polyester.
- NOMEX is generally: insoluble; compatible with common industrial oils and varnishes; and resistant to chemical and radiative degradation.

NOMEX aramid paper is made from short-length aramid fibers (floc) plus microscopic fibrous binder particles (fibrids) of the same polymer. These are combined in a water suspension and formed into a sheet structure on a paper machine, with no extraneous binders or fillers. This uncalendered product is Type 411, with relatively low density (about 0.3 g/cm³) and available in thicknesses ranging from 5 through 23 mils (0.13-0.58 mm). (NOMEX papers are also available in higher-density calendered versions. For further information, see the Technical Information Bulletins on properties and performance of NOMEX aramid paper Types 410 and 414.)

*Du Pont registered trademark

DUP 1012045

DM 500

DU 053339

APPLICATIONS

NOMEX® paper Type 411 is recognized by Underwriters' Laboratories as a 220°C electrical insulation. It is highly conformable, with a soft absorptive surface, offering high bulk and resilience, and is suitable for use in:

Motors
- Phase insulation for end coil groups:
  - — Bonding enhanced by high surface absorbency.
  - — Highly conformable.

Transformers
- Layer insulation for strip- and wire-wound types.
- End pack-out: high bulk and resilience.

Appliances
- Barrier insulation.

UL Applications
- Recognized as 220°C insulation by UL (file no. E31739).
- Du Pont's UL-recognized systems (file no. E57692):
  - — Cover 130-220°C classes.
  - — Specify wire, sleeving, spacers, tapes, tie cords, and varnishes with ground insulation of NOMEX.
  - — Eliminate lengthy, costly heat-aging tests of insulation system.

Other
- Replace high-temperature inorganic insulations like asbestos and glass.
- Laminates:
  - — Flexible: can be adhesive-bonded to other sheet materials.
  - — Rigid: thick, dense and rigid laminates can be made by applying heat and pressure to stacked sheets. Complex shapes may be machined.
- Deep-drawn shapes may be made using hot-pressing techniques.
- Impregnation is also possible, although the semi-closed void structure makes complete impregnation with medium-to-high-viscosity resins more difficult than the low paper density suggests.

TYPICAL PROPERTIES

Electrical

Important electrical properties of typical Type 411 NOMEX aramid papers are shown in Table I. Although unprotected NOMEX Type 411 absorbs up to 14% water at high humidities, electrical properties are relatively unaffected, in contrast to most porous materials. After 6 days' exposure at 96% RH, for example, NOMEX Type 411 typically retains 96% of its dielectric strength under bone-dry conditions.

TABLE I

Typical* Electrical Properties of NOMEX® Aramid Paper Type 411
(Not to be used as product specifications)

Nominal Thickness	mils	5	7	10	15	23
	(mm)	(0.13)	(0.18)	(0.25)	(0.38)	(0.58)
Dielectric Strength						
AC Rapid Rise, ASTM D-149**	V/mil	310	310	320	330	330
	(kV/mm)	(12)	(12)	(13)	(13)	(13)
Dielectric Constant ASTM D-150***	(10^3 Hz)	1.3	1.3	1.3	1.4	1.4
Dissipation Factor ASTM D-150***	(10^3 Hz)	0.005	0.005	0.005	0.005	0.005

*Room temperature and 55% RH. **2 in. (51 mm) diameter electrodes. ***1 in. (25 mm) diameter electrodes under 20 lb./in.^{2} (140 kPa) pressure.

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DU 053340

Physical

Typical physical properties of NOMEX Type 411 are listed in Table II. At 220°C, Type 411 papers retain about 80% of their room-temperature breaking strength, and their elongation to break is roughly doubled or tripled. NOMEX paper also retains good physical properties at very low temperatures such as —196°C in liquid nitrogen.

Thermal, Chemical, Radiative

The long-term thermal stability of NOMEX Type 411 is attested by its 220°C UL recognition. The molecular structure responsible for this excellent heat resistance also results in outstanding chemical stability. NOMEX papers are unusually resistant to most common acids and alkalies, as well as to high-energy (nuclear) radiation. Common industrial solvents (alcohol, ketones, acetone, toluene, xylene) have only a slight swelling effect. As illustrated by the UL-recognized systems previously mentioned, NOMEX papers are fully compatible and used commercially with:

- Transformer oils and askarels.
- Refrigerant gases.
- Commonly-used electrical varnishes and adhesives (polyimides, silicones, epoxies, polyesters, acrylics, phenolics, synthetic rubbers, etc.).

More detailed data on chemical and radiative resistance is available in the bulletin on properties and performance of NOMEX aramid paper Type 410 (which is chemically identical to Type 411).

TABLE II

Typical* Physical Properties of NOMEX® Aramid Paper Type 411

(Not to be used as product specifications)

Nominal Thickness	mils		5	7	10	15	23
	(mm)		(0.13)	(0.18)	(0.25)	(0.38)	(0.58)
Basis Weight	oz./yd.²		1.2	1.9	2.3	3.9	5.9
	(g/m²)		(41)	(64)	(78)	(130)	(200)
Tensile Strength, ASTM D-828-60	lb./in.	MD	10	16	20	32	46
		XD	5	10	12	20	30
	(N/cm)	MD	(17)	(28)	(35)	(56)	(80)
		XD	(9)	(17)	(21)	(35)	(52)
Elongation, ASTM D-828-60	%	MD	3.5	3.5	3.4	3.2	3.2
		XD	4.8	5.0	5.2	5.2	4.8
Finch Edge Tear, ASTM D-827-47	lb.	MD	10	17	23	40	57
		XD	6	11	14	26	38
	(N)	MD	(45)	(76)	(100)	(180)	(250)
		XD	(27)	(49)	(62)	(120)	(170)
Elmendorf Tear, ASTM D-869	g	MD	130	170	240	500	630
		XD	180	260	350	680	980
	(N)	MD	(1.3)	(1.7)	(2.4)	(4.9)	(6.2)
		XD	(1.8)	(2.6)	(3.4)	(6.7)	(9.6)
Shrinkage @ 240°C	%	MD	1.2	0.9	0.8	0.9	0.9
		XD	1.5	1.0	0.8	0.8	0.7

*Room temperature and 55% RH.
MD = machine direction.
XD = cross direction.

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DU 053341

AVAILABILITY

Orders and requests for additional information on NOMEX aramid paper Type 411 should be directed to

E. I. du Pont de Nemours & Co., Inc.
Textile Fibers Department
NOMEX Marketing
Centre Road Building
Wilmington, Delaware 19898
Phone: (302) 999-4693

or to the following authorized distributors of NOMEX paper:

Brownell Electro, Inc.
85 Tenth Avenue
New York, New York 10011
Phone: (212) 924-6000

Complete-Reading Electric Company
100 South Jefferson Street
Chicago, Illinois 60606
Phone: (312) 236-5390

Electrical Insulation Suppliers
1255 Collier Road, N.W.
Atlanta, Georgia 30325
Phone: (404) 355-1651

Electrical Specialty Co.
213 E. Harris Avenue
So. San Francisco, California 94080
Phone: (415) 589-9611

Essex International, Inc.
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1510 Wall Street
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