HMS

HEAVY MOVABLE STRUCTURES, INC.

FIFTH BIENNIAL SYMPOSIUM

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Holiday Inn Surfside
Clearwater Beach, Florida

SESSION WORKSHOP PRESENTATIONS

"NARROW ENTRY WATERWAY PROTECTION"

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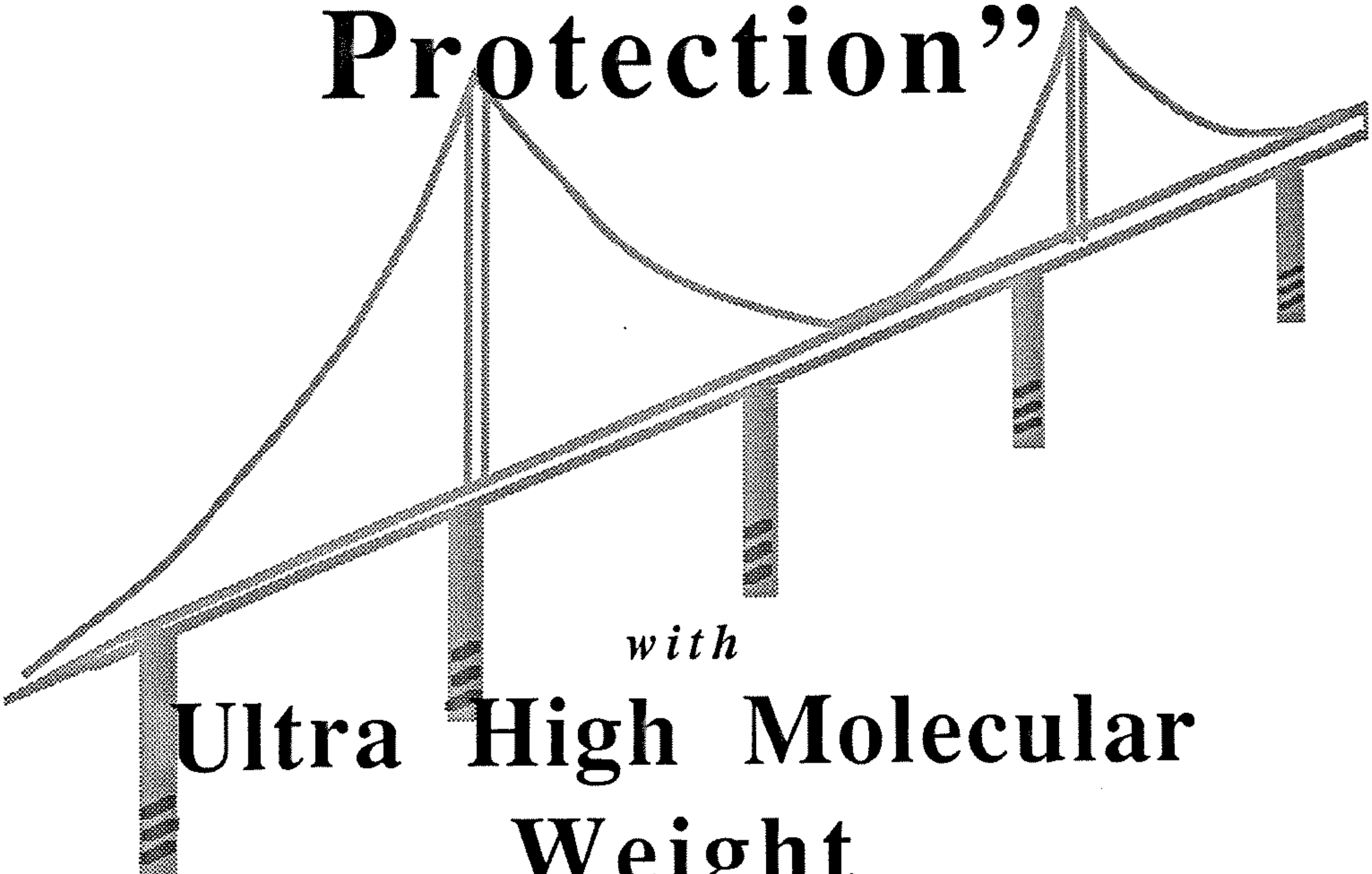
Ultra Poly, Inc.

"Narrow Entry Waterway Protection"



with

Ultra High Molecular Weight (UHMW)

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Fender Protection

The Choices:

1) Narrow entry or constricted waterways present unusual and demanding fender systems. The waterways may be old or geologically restricted or subject to tidal or wind conditions that severely tax fenders. Examples of bridge and waterway systems that will be reviewed in the discussion are 1) Panama Canal; 2) Chelsea River Bridge in Boston; 3) Alameda County drawbridges, High, Park, and Fruitvale; 4) First Avenue South bridge in Seattle, WA.

Any discussion of fendering required a review of conventional materials like wood, steel, concrete and rubber. Traditional material for fender faces are woods. The woods of choice over the last few years have changed. African and South American hardwoods have become difficult to find, are expensive, and are reportedly inconsistent in grain and knot structure. To gain additional life creosote and other chemical additives have been forced into the grain structure to impede rotting. Additional problems with boring worms and barnacle attachment limit the life expectancy of natural or chemically treated wood. It need be noted that environmental concerns about active chemical stabilizers leaching from wood are growing and in California untreated wood is the only acceptable fender face on U.S. Navy submarine piers and separators.

2) Elastomers in general and most notably rubber have been an alternative used as fenders and fender facing. Rubber has been and continues to be a common fender face product. The rebound characteristics of rubber encourage energy deflection and redirection. Rubber can exhibit mark off as its high friction surface rubs along a hull. Tearing of the rubber in a fender is accomplished when its tensile strength is exceeded, the rubber cannot elongate further and rips or tears. Note on the sample table examples of rubber backed poly products that combine rubber rebound backing with low coefficient of friction, non marking faces.

3) Fender systems are designed to decrease high friction and impact forces. It is the task of fendering elements to absorb developing forces in different conditions and have them be borne by the fender system. New high performance fender systems and fender facing material are available. Designs by major Japanese and U.S. European companies reveal considerable basic research into energy absorption and vessel handling. We have borrowed from both Goodyear and Trellex Morse literature, Goodyear's brochure is entitled Marine Fendering Engineering Data brochure #821-973-981. Also used extensively is Minimizing Dock Cost with Proper Fender Selection, by Ed Kiedaish, January 1991. Both companies publish detailed design

The Choices: *cont..*

information on the myriad of shapes and buckling rubber products that can absorb energy. We urge you to utilize the data available from the major rubber fender manufacturers. Top their data we wish to make available the product flexibility and design criteria on the fender face product. It is often your experience that restricted waterways especially bridges mean custom design and non-standard configurations. How then does one determine the correct fender face. Let me offer some design choices and briefly describe their implications. All UHMW polymers break down through ultra violet degradation. Thus of primary importance is the call out for UV stability. Black is the most effective and least costly additive. It is added to 1 1/2 percent and is non marking. Colored UHMW UV stabilized is also available is non marking and in Hi Visibility colors for aesthetic reasons has been used extensively. What better way to show a danger area than to highlight the fender face is danger orange, red or yellow. We have documentation on fenders designed with high visibility faces. Please contact me after the discussion.

4) The introduction of inexpensive lower molecular weight polyethylene (HDPE) fendering has been driven in part to satisfy the needs of port facilities and the short-coming of timbers and elastomers. Where timber and elastomers failed, HDPE fendering was seen as a reasonable alternative. With low coefficient of friction (slick surface) and good chemical resistance, HDPE has grown in popularity. However, lower molecular weight polyethylene used in harboring and marine construction have impact and abrasion limitations.

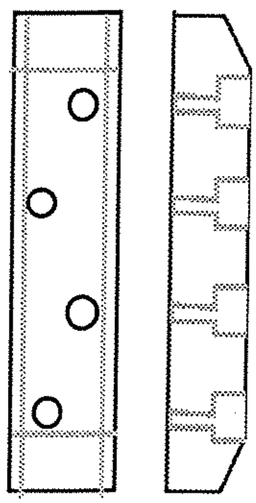
5) With optimum sliding characteristics, combining ultra high molecular weight polymers impact abrasion and low friction UHMW is gaining wider acceptance. Limitations of HDPE have sparked the development of Ultra High Molecular

Weight(UHMW) polyethylene fendering. UHMW PE exhibits the following properties:

- exceptional impact resistance under extreme conditions
- outstanding sliding properties due to extremely low coefficient of friction, .15 or less.
- very high resistance to (environmental) stress cracking even under high deformation and the lowest temperatures
- UV stabilized
- energy-absorbing capacity at high stress rates
- resistance to abrasive wear
- dimensional stability under heat
- further enhancement of specific physical properties through various additives

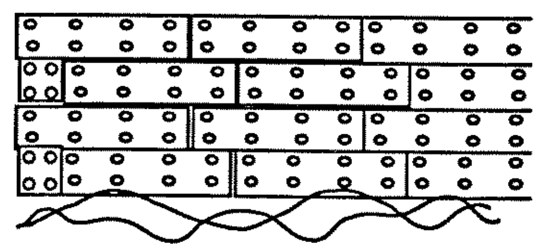
The Choices: *cont..*

UHMW is virtually unbreakable,is impervious to marine borers(a major cause of traditional timber failure), absorbs no water, can be stabilized against UV degradation and is self lubricating. UHMW polyethylene is highly resistant to a broad spectrum of corrosive chemicals and reagents. UHMW is extremely impact resistant and much more abrasion resistant than wood, elastomers, HDPE and other plastic fendering.

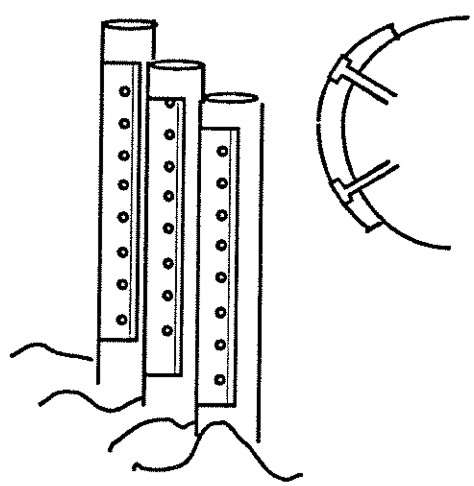


Tapered Fenders

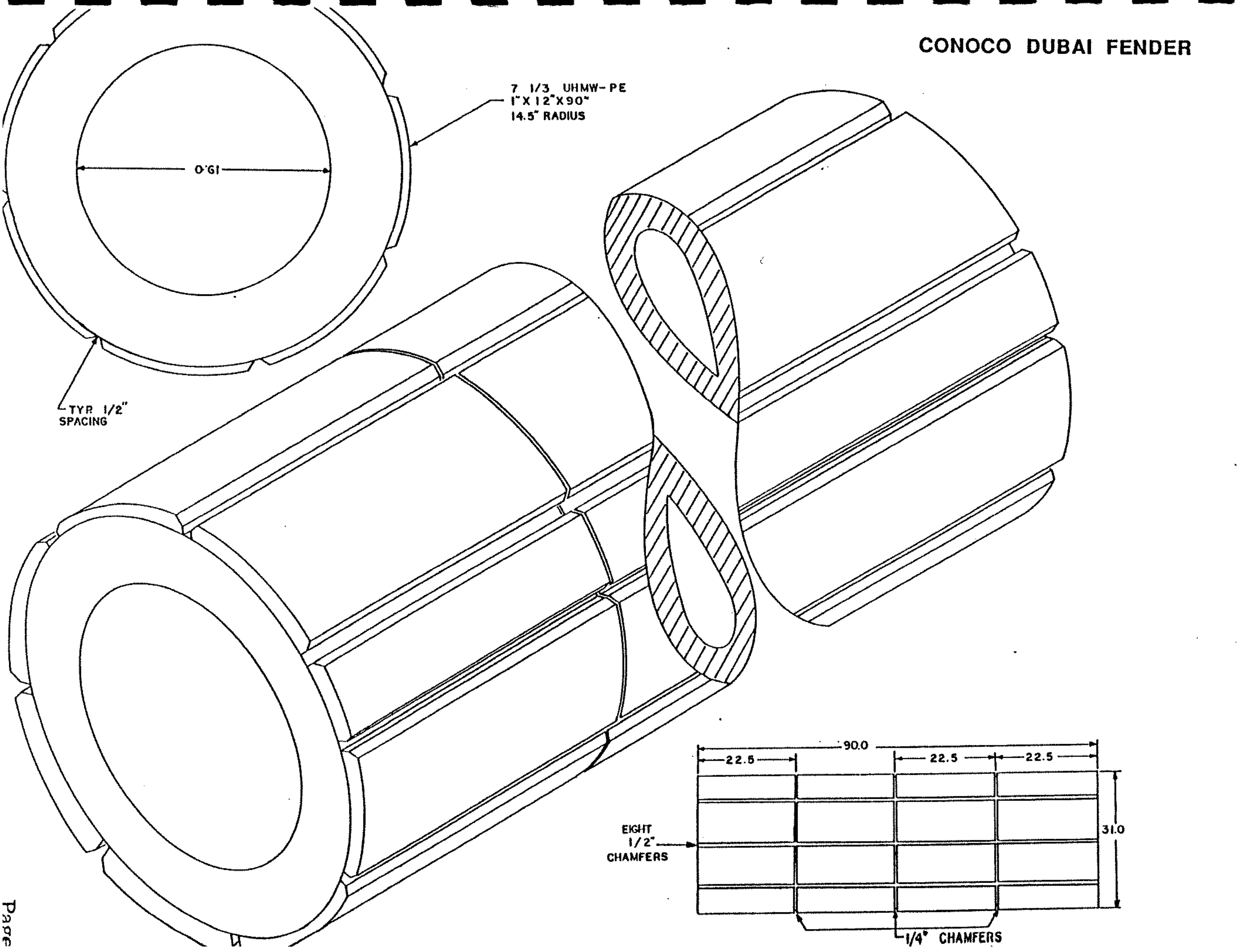
Sheet Panels



Pile Wraps

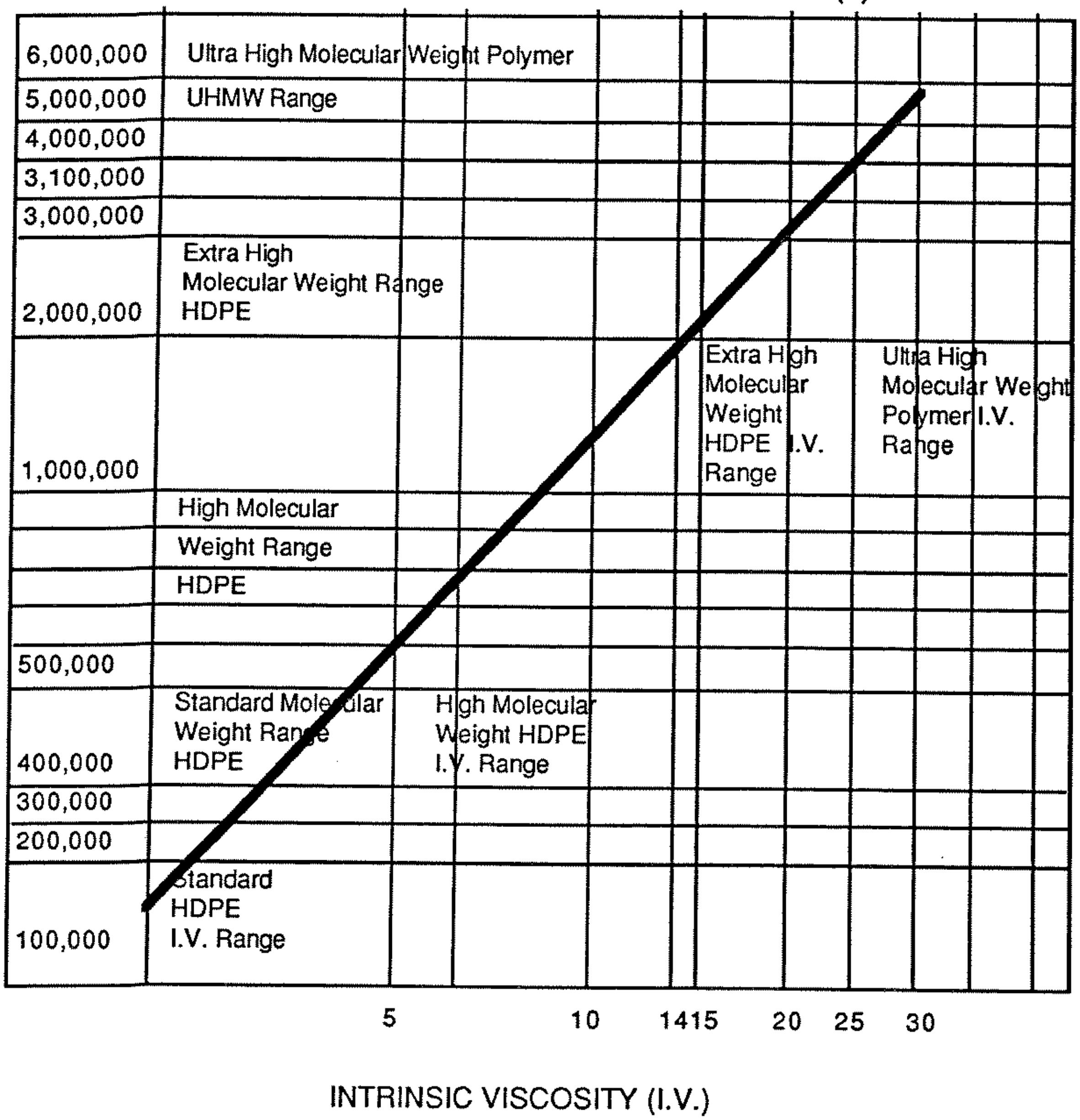


CONOCO DUBAI FENDER



Specifications:

UHMW POLYMER RELATIONSHIP I.V. TO M.W. (1)



(1) Variations due to molecular branching and configuration permit only approximations of M.W. per $M.W. = 5.37 \times 10^4 (I.V.)^{1.37}$
We cannot anticipate all conditions under which this information and different manufactures products may be used. Users are advised to make their own test to determine the safety and suitability of each such product or product combination for their own purposes.

UHMW

The Ultimate Polymer

Ultra High Molecular Weight polyethylene (UHMW) exhibits the best overall physical properties for fendering applications.

UHMW demonstrates other outstanding characteristics:

Low Friction
Noncorroding
Nonabsorbent
Nonconductive
Easy to machine
Abrasion Resistance
Exceptional Impact Resistance - No Notch Sensitivity
Non Breaking or Splintering
Excelent Gouge Resistance

These characteristics are maintained to very low temperatures, -100 degrees Celsius or at very high temperatures, 160 degrees Fahrenheit.

Produced from the highest molecular weight resins made, UHMW has an average molecular weight, (the number representing the combined atomic weights in a molecule) of from 3.1 to 6 million, in compliance with ASTM 4020-81 (see Attch. 1.a.-c).

UHMW PE performs where other materials fail.

Typical Physical Properties Virgin UHMW PE

PROPERTY	ASTM TEST	UNITS	VALUE
Density	D 1501	gm/cm^3	.923
Izod Impact	D 256A	ft. lb./in.	33.1
Abrasion Resistance	Sand Slurry	Percent	0.65
Hardness	Shore	D	67
Hardness	Rockwell	R	26
Tensile Yield	D 638	psi	3,000
Ultimate Elongation	D 638	psi	5,100
Crosslink	-	percent	79
Coefficient of friction Static and Kinetic			.10

Data Courtesy of American Hoechst Corporation

Standard Specification for Ultra-High-Molecular-Weight Polyethylene Molding and Extrusion Materials[1]

This standard is issued under the fixed designation D 4020; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

ε1 NOTE—The equation for intrinsic viscosity was added editorially to Note 1 and several sections were revised editorially in February 1987.

1. Scope

1.1 This specification provides for the identification of virgin, unmodified ultra-high-molecular-weight polyethylene (UHMW-PE) plastics molding and extrusion materials. This identification is made in such a manner that the seller and purchaser can agree on the acceptability of different commercial lots or shipments.

1.2 It is not intended to differentiate between various molecular weight grades of ultra-high-molecular-weight polyethylene commercially available.

1.3 It is not the function of this specification to provide specific engineering data for design purposes.

1.4 Ultra-high-molecular-weight polyethylenes, as defined in this specification, are those linear polymers of ethylene which have a relative viscosity of 2.30 or greater, in accordance with the test procedures described herein.

1.5 The values stated in SI units are to be regarded as the standard. The values in parentheses are given for information only.

1.6 The following precautionary caveat pertains to the test method portion, Section 7, of this specification: *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 883 Definitions of Terms Relating to Plastics[2]

D 1601 Test Method for Dilute Solution Viscosity of Ethylene Polymers[3]

D 1898 Practice for Sampling of Plastics[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions of terms used in this specification are in accordance with Definitions D 883.

3.2 *Description of Term Specific to this Standard:*

3.2.1 *ultra-high-molecular-weight polyethylene moldin[g] and extrusion materials*—as defined by this specification, applies to those substantially linear polyethylenes which have a relative viscosity of 2.30 or greater, at a concentration o[f] 0.05 %, at 135°C, in decahydronaphthalene.

NOTE 1—It has been common practice to refer to the "molecular weight" of UHMW-PE resins. The following calculations can be used [to] approximate the specific viscosity (η_{sp}), reduced viscosity (ηred [or] R.S.V.), intrinsic viscosity (η or I.V.), and the approximate weight average molecular weight of virgin resin. The solution viscosity test on thermally processed material is invalid due to inadequate solubility an[d] possible crosslinking.

$$\text{Relative viscosity} = \eta_r = \frac{t_s - \frac{k}{t_s}}{t_o - \frac{k}{t_o}}$$

$$\text{Specific viscosity} = \eta_{sp} = \eta_r - 1$$

$$\text{Reduced viscosity} = \eta_{red} = \frac{\eta_{sp}}{C}$$

$$\text{Intrinsic viscosity} = [\eta] = (2\eta sp - 2 \ln \eta rel)^{1/2}$$

limiting viscosity number at 0 % concentration

$$\text{Nominal molecular weight} = 5.37 \times 10^4 [\eta]^{1.37}$$

where:

k = kinetic energy correction constant for the particul[ar] viscometer used,
t_s = flow time in seconds of solution at 135°C,
t_o = flow time in seconds of pure solvent at 135°C, and
C = concentration.

4. Classification

4.1 It is recognized that dilute solution viscosity measur[e]ments can only be made on virgin resin. Therefore, the following test and limits shall be used to determine the properties of virgin polymer only.

5. Materials and Manufacture

5.1 The molding and extrusion material shall be UHM[W] polyethylene in the form of powder, granules, or pellets.

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.12 on Olefin Plastics.
Current edition approved June 26, 1981. Published October 1981.

[2] *Annual Book of ASTM Standards*, Vols 08.01 and 08.04.

[3] *Annual Book of ASTM Standards*, Vol 08.02.

5.2 The molding and extrusion materials shall be as uniform in composition and size and as free of contamination as can be achieved by good manufacturing practice. If necessary, the level of contamination may be agreed upon between the seller and the purchaser.

5.3 Unless controlled by requirements specified elsewhere in this specification, the color and translucence of molded or extruded pieces, formed under conditions recommended by the manufacturer of the material, will be comparable within commercial match tolerances to the color and translucence of standard molded or extruded samples of the same thickness supplied in advance by the manufacturer of the material.

6. Sampling

6.1 A batch or lot shall be considered as a unit of manufacture and may consist of a blend of two or more production runs of the same material.

6.2 Unless otherwise agreed upon between the seller and the purchaser, the material shall be sampled in accordance with the procedure described in the general and specific sampling procedures of Practice D 1898. Adequate statistical sampling prior to packaging shall be considered an acceptable alternative.

7. Test Method

7.1 *Dilute Solution Viscosity*—Use Test Method D 1601, as modified in Annex A1.

ANNEX

(Mandatory Information)

A1. DILUTE SOLUTION VISCOSITY

A1.1 General Description

A1.1.1 The test sequence consists of dissolving UHMW-PE in decahydronaphthalene (0.05 g/100 mL) at 150°C and then measuring the relative viscosity at 135°C in an Ubbelohde No. 1 viscometer. The relative solution viscosity may be calculated from these experimental data.

A1.2 Apparatus

A1.2.1 *Analytical Balance.*

A1.2.2 *Microscope Slide Cover Slip.*

A1.2.3 *Hot Plate,* with magnetic stirrer.

A1.2.4 *Erlenmeyer Flask,* 250-mL, with glass stopper.

A1.2.5 *Vacuum Drying Oven.*

A1.2.6 *Vacuum Aspirator.*

A1.2.7 *Viscometer,* Ubbelohde No. 1.

A1.2.8 *Constant-Temperature Bath,* 135 ± 0.1°C, with a 305-mm diameter by 460 mm (12 by 18-in.) tall glass jar as a container, and having a suitable support for the viscometer.

A1.2.9 *Buret,* 100-mL capacity, 0.1-mL subdivisions.

A1.2.10 *Stopwatch,* 0.2-s reading.

A1.2.11 *Still* for decahydronaphthalene.

A1.2.12 *Glass Funnel,* with heating mantle.

A1.3 Reagents

A1.3.1 *Decahydronaphthalene,* freshly distilled.

A1.3.2 *Tetrakis* [methylene 3-(3′,5′-di-*tert*-butyl-4′-hydroxphenyl) propionate] methane[4].

A.1.3.3 *Xylene,* industrial-grade.

A.1.3.4 *Sulfuric Acid–Potassium Dichromate Cleaning Solution*—To 35 mL of a saturated solution of potassium dichromate ($K_2Cr_2O_7$), carefully add 1 L of concentrated sulfuric acid (H_2SO_4).

A1.3.5 *Acetone,* reagent-grade.

A.1.4 Procedure

A1.4.1 *Decahydronaphthalene Preparation*—Distill in accordance with method D 1601 and add 0.2 % tetrakis [methylene 3-(3′,5′-di-*tert*-butyl-4′-hydroxyphenyl) propionate] methane.

A1.4.2 *Cleaning the Viscometer*—Clean the viscometer thoroughly with the cleaning solution, wash several times with distilled water, rinse with acetone, and purge with dry nitrogen.

A1.4.3 *Solution Preparation*—Dry the UHMW-PE in a vacuum oven for 2 h at 60°C. Weigh 35 to 43 mg of the dry UHMW-PE onto a slide cover slip. Use the buret to transfer the decahydronaphthalene at room temperature into the Erlenmeyer flask, measuring, in millilitres, a volume equal to 1.8 times the UHMW-PE weight in milligrams, for example, 36 mg of UHMW-PE and 64.8 mL of decahydronaphthalene. Heat the decahydronaphthalene, with stirring, to 150°C, and drop in the UHMW-PE and its slide cover slip. Continue stirring at 150°C for 1 h, with the flask lightly stoppered.

A1.4.4 *Viscosity Measurement:*

A1.4.4.1 Place the clean viscometer into the constant-temperature bath, fill with decahydronaphthalene, and allow the viscometer and solvent to come to thermal equilibrium at 135 ± 0.1°C. Determine the viscosity of the solvent. Remove the decahydronaphthalene with vacuum and wash the viscometer with 200 mL of warm (110 to 120°C) xylene. Remove with vacuum and aspirate dry air or nitrogen to dry the viscometer (2 or 3 min). It is essential that the whole viscometer be dry.

[4] The anitioxidant (Irganox® 1010) is available from Ciba-Geigy, Ardsley, NY.

A1.4.4.2 Meanwhile, place the flask of polymer solution into the 135°C bath and allow it to equilibrate. Transfer sufficient solution to fill the viscometer to the mark (see Note A1.1) and determine the viscosity of the solution.

A1.4.4.3 Between uses, clean the viscometer as described in A1.4.2. Prolonged waits between uses (overnight, etc.) will require the use of the $H_2SO_4 - K_2Cr_2O_7$ cleaning solution.

NOTE A1.1—Filling of the viscometer is made easier by the use of a glass funnel warmed with a heating mantle. This helps to prevent the UHMW-PE from precipitating.

A1.5 Calculation

A1.5.1 Calculate the relative solution viscosity as follows:

$$\eta_r = \frac{t_s - \frac{k}{t_s}}{t_o - \frac{k}{t_o}}$$

where:

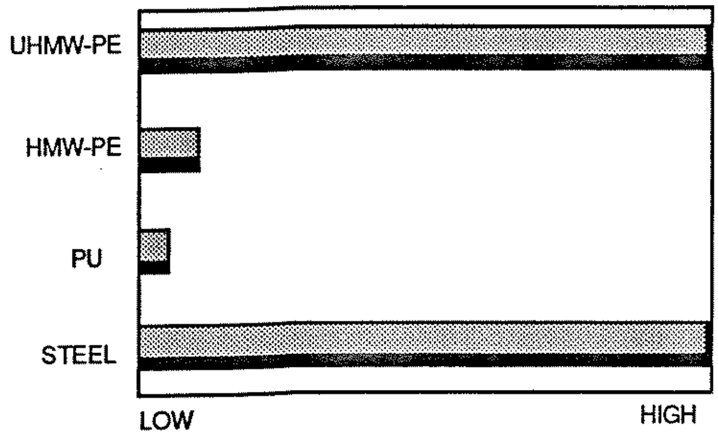
k = kinectic energy correction constant for the particular viscometer used,

t_s = flow time of solution at 135°C, and

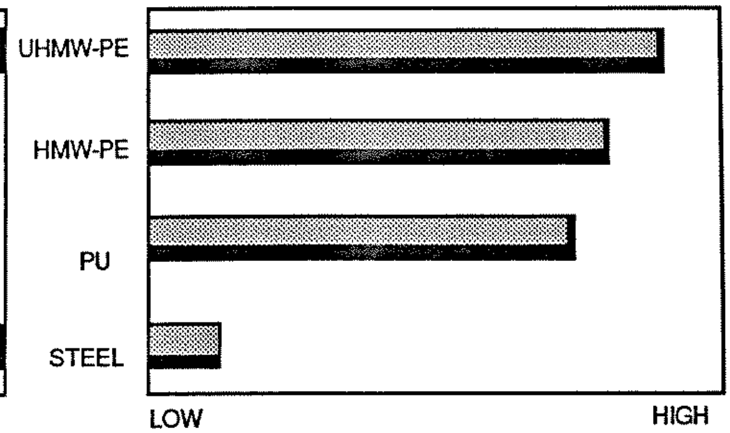
t_o = flow time of pure solvent at 135°C.

COMPARISON OF UHMW TO OTHER MATERIALS

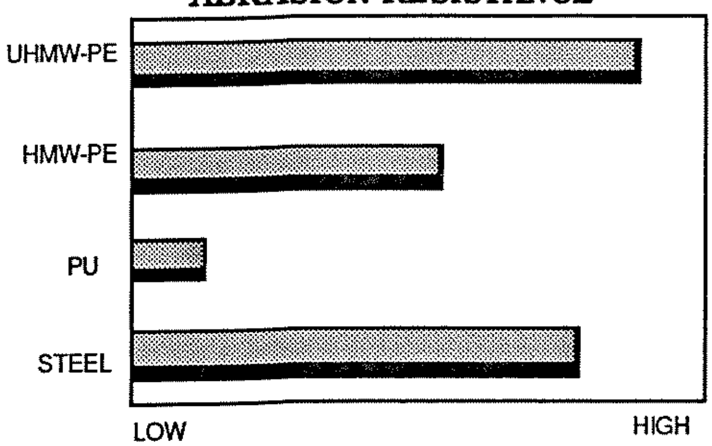
IMPACT RESISTANCE



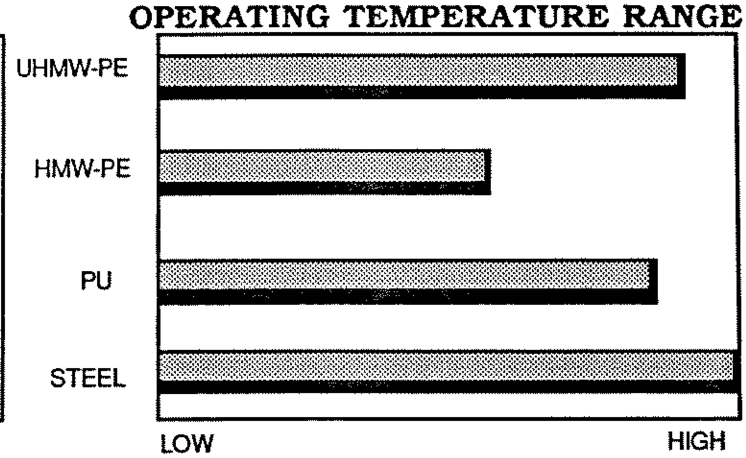
CHEMICAL REISTANCE



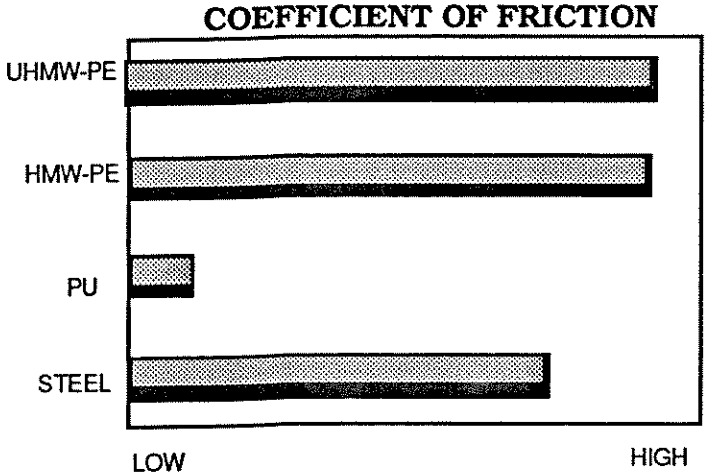
ABRASION RESISTANCE



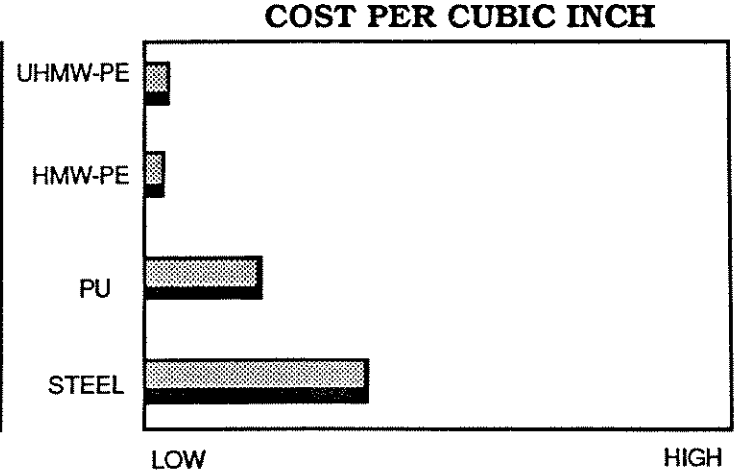
OPERATING TEMPERATURE RANGE



COEFFICIENT OF FRICTION



COST PER CUBIC INCH



**Data Courtesy of Hoechst Celanese*

* PU = Polyurethane

Enhanced UHMW :

While virgin UHMW exhibits impressive physical characteristics, specific physical property values can be enhanced. Combine the toughness of virgin UHMW with high-performance additives to create products suitable for many uses.

- Cross-linked UHMW PE for enhanced abrasion resistance
- UV Stable, colored UHMW
- Antistatic, colored UHMW
- Antistatic, black UHMW
- Conductive, Black UHMW
- Flame Retardant UHMW
- Glass filled UHMW for enhanced dimensional stability and compression resistance.
- FDA compliant, colored UHMW
- Silicone filled for lower coefficient of friction

A collective blend for marine grade UHMW exhibits the following enhanced properties:

DESCRIPTION: Ultra High Molecular Weight Polyethylene, crosslinked virgin grade, averaging 3.1-6 million molecular weight, in full compliance with ASTM 4020-81 standards. UV stabilized with 2.5 percent carbon black.

Property	Test Method	Unit	Value[2]
Specific Gravity	ASTM D792	gm/cc	0.923
Tensile, Ultimate	ASTM D638	psi	5600
Yield Tensile Strength	ASTM D638	psi	3100
Elongation at Break	ASTM D638	percent	570
Tens. Modulus Elast.	ASTM D638	psi	70,000-150,000
Flexural Modulus	ASTM D790	psi	110,000-130,000
Brittleness Temp.	ASTM D746	°F	-115
Heat Distortion Temp. at 66 psi	ASTM D846	°C	88
Thermal Expansion	ASTM D648	F^{-1}	5.5×10^{-5}
Hardness	ASTM D2240	Shore D	67
Rockwell Hardness	ASTM D785	--	60-65
Abrasion (Scale Virgin UHMW = 100)	Sand Slurry	--	49
Izod Impact	ASTM D256	ft lb/" notch	29-31
Coefficient Friction	ASTM D1894	static/kinetic	.06-.13

UHMW In Action:

During the past decade UHMW has been placed in a variety of marine environments, producing exceptional results. Currently UHMW is in use at Panama Canal. Chelsea River Bridge in Connecticut, Alameda County, CA at High Street, Park, and Fruitvale bridges, and 1st Avenue Street Bridge and other tough marine applications. Each application proposed its own special set of circumstances.

Panama Canal/St. Lawrence Seaway:

Problem:

This narrow passage from East to West is under constant hammering from passing ships, which drift and rock north and south (side to side). The damage would be extensive and expensive were the concrete walls not protected by fendering. For decades, the fendering was all Ekki wood - a hardwood from South American rain forest. Now, Ekki is in very short supply.

Solution:

UHMW is replacing the Ekki wood fendering. UHMW fender boards are being bolted between wooden wing wall boards. The UHMW installation creates a barrier for the wood, vessels will not be available to wear the wood any deeper that the UHMW will allow. Canal walls are protected even better with a fender material which gives high slip with better abrasion resistance.

Results:

The Panama Canal Commission is please with the performance of the UHMW and continues to install UHMW along the canal as replacement of previous fender systems presents itself. Current plans call for full 5" thick sheet installations with no wood.

Chelsea River Bridge, (Boston, MA):

Problem:

Narrow entry waterway of extremely old bridge. Major gas line between Boston and Chelsea runs under the bridge and needs solid protection. Wood fenders on the drawbridge side were sunk from ongoing vessel impact.

Solution:

Black UV Stabilized UHMW chosen for its low coefficient of friction, durability and low maintenance. UHMW mounted to existing wood wing walls. Continuous length boards mounted horizontally to prevent gaps that may catch passing vessels.

UHMW In Action:

Chelsea River Bridge, (Boston, MA) cont..:

Results:

First half of project finished and operational. Second half of project is being supplied with Orange high visibility UHMW and mounted horizontally on the drawbridge operation side.

High, Park and Fruitvale Bridges (Alameda County, CA):

Problem:

Marine life had eaten away existing creosote treated timbers leaving exposed bolts to potentially damage passing pleasure and work boats. 1/2 million ton barges pass through entryway at speeds up to 10 knots, creating severe impact when collision occurs.

Solution:

UHMW-PE was chosen for its durability, ease of installation, cost effectiveness, and because it is environmentally safe. The county replaced its wooden whales, spacer blocks, and fender panels with custom colored UHMW sheet panels, mounted with stainless steel mounting bolts and washers to the existing steel piles with cathodic protection system.

Results:

The project was completed in two separate jobs. The engineers first replaced the fendering on two bridges, then came back a year later and incorporated UHMW into new area's on the third bridge. The fact that they used the product, gained experience with its ability, then expanded its uses speaks for itself.

1st Avenue Street Bridge (Seattle, WA):

Problem:

Large vessels must pass through a narrow waterway where a history of collisions with the fender system have caused untimely and expensive repairs.

Solution:

UHMW faced elastomers fenders are being placed to absorb energy, keep the vessel moving through the narrow passage, and reduce the reaction forces on the bridge structure.

Results:

Although the job has not been completed, officials anticipate excellent results.