TriShield

STEEL RIBBED POLYETHYLENE PIPE

For. . .

Storm Drains
Water Transmission
Rehabilitation • Down Drains
Culverts • Slurry Pipe • Reline

PACIFIC
CORRUGATED PIPE CO.®

STRONG • DURABLE • HYDRAULICALLY EFFICIENT • ECONOMICAL

HISTORY

SPIRAL RIB PIPE (SRP) is an extremely cost effective and hydraulically efficient pipe developed in 1984 by Pacific Corrugated Pipe Co. for storm drain and other water conveyance applications. **SRP** is nationally recognized in AASHTO and ASTM specifications and is routinely specified by numerous federal, state, county, and local agencies. Thousands of miles of **SRP** have already been installed **worldwide**.

Pacific Corrugated Pipe company has taken this product a step further and is proud to introduce the next generation -

TriShield™

STEEL RIBBED POLYETHYLENE PIPE

A STATE OF THE ART IMPROVEMENT IN PIPE TECHNOLOGY !

INTRODUCTION

TriShield steel ribbed polyethylene pipe is a state of the art composite pipe product. It combines smooth wall hydraulics and the structural strength of steel with the corrosion and abrasion resistance of high performance engineered polyethylenes.

At the core of the composite is a galvanized steel sheet with 2 ounces of zinc coating per square foot. Galvanized steel coils are delivered to an approved coil coating facility where **Trenchcoat**® tough 10 mil thick protective polymer film is laminated to the exterior side and a unique 10 mil thick engineered adhesive tie layer film is laminated to the interior side of the steel coil.

The polymer laminated steel coils are then delivered to the pipe fabricator where they are made into pipe and the polythelyene liner is applied. The liner material is extruded into the ribs and onto the inner pipe wall in a 65 mil thick sheet. The extruded polyethylene chemically bonds to the adhesive tie layer film, forming the 75 mil thick engineered liner.

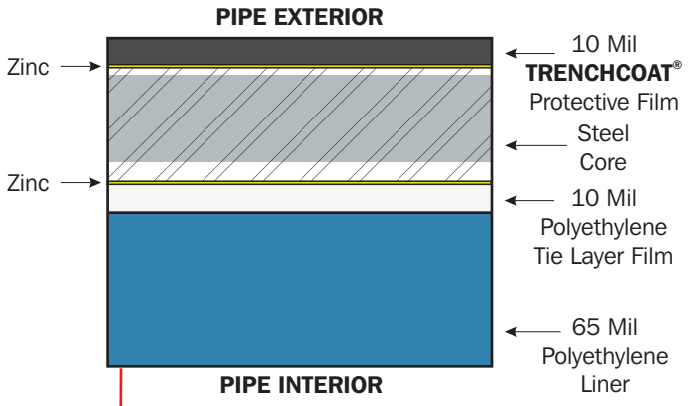
The filled ribs are slightly deltoided to provide a mechanical interlock with the pipe wall. This dual attachment system provides added assurance of composite integrity.

TriShield composite pipe provides the **Trenchcoat** polymer film for protection from potential soil side corrosion, and a 75 mil thick interior liner for protection from effluent corrosion and/or abrasion. The smooth liner also provides greatly improved hydraulic efficiency (Manning's "n"=0.0105). The galvanized coating on both sides of the steel provides secondary corrosion protection and the steel ribbed profile provides **TriShield** pipe with its superior strength and stiffness characteristics.

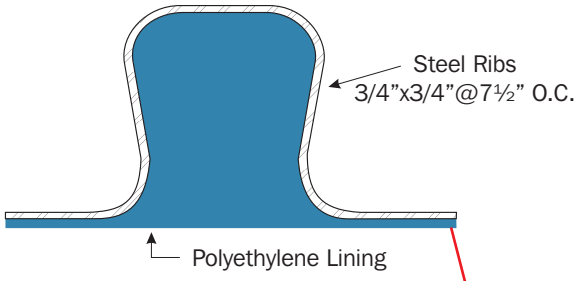
TriShield is manufactured in accordance with national specification ASTM A 978-97.

*The **TriShield** liner material, adhesive tie layer, and **Trenchcoat** protective film are all proprietary engineered products manufactured by **The Dow Chemical Company.***

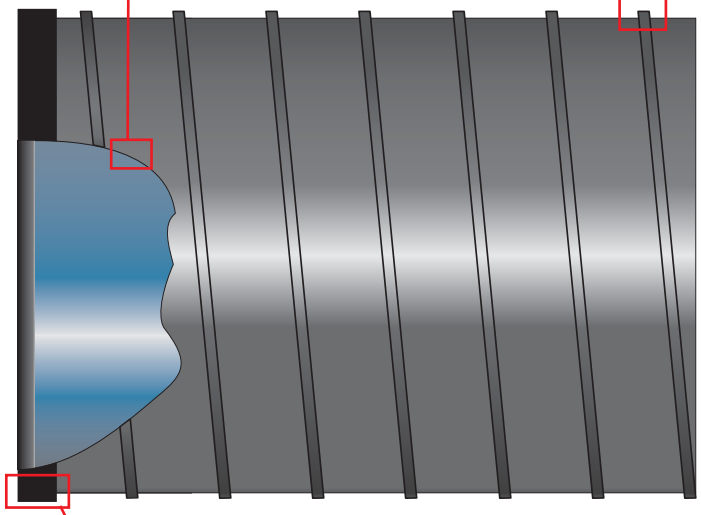
COMPOSITE WALL SECTION



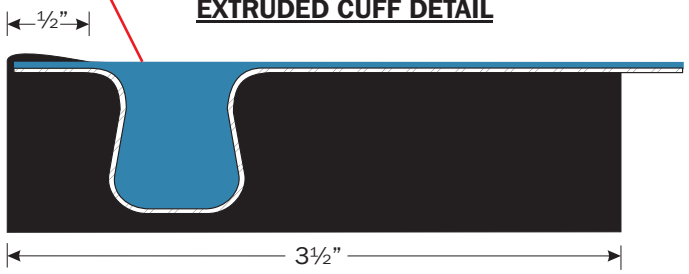
RIB SECTION



TriShield PIPE CUTAWAY



EXTRUDED CUFF DETAIL



STRUCTURAL STRENGTH

With its stiff ribbed profile, **TriShield** composite pipe has the ability to support deep fills and survive the rigors of handling and installation. Other pipe products manufactured solely of polyethylene are time sensitive to continuous loading. Steel, once loaded, maintains its structural integrity. **TriShield** pipe fill heights are comparable to or greater than those of concrete pipe and significantly greater than those of HDPE or PVC pipes of the same diameter.

TriShield Height of Cover Table

MAXIMUM COVER (FEET) FOR SPECIFIED THICKNESS *

DIAMETER OR SPAN	MINIMUM COVER	SPECIFIED WALL THICKNESS / GAUGE		
(inches)	(inches)	0.064”/16	0.079”/14	0.109”/12
24	12	72	100	167
30	12	57	80	133
36	12	48	67	111
42	12	41	57	95
48	12	36	50	83
54	18	(32)	44	74
60	18	[29]	40	67
66	18	[26]	(36)	61
72	18	**	[33]	56
78	24		[31]	51
84	24		**	(48)
90	24			(44)
96	24			[42]
102	30			[37]
108				**

TriShield Handling Weights

POUNDS PER LINEAR FOOT

SPECIFIED WALL THICKNESS / GAUGE		
0.064”/16	0.079”/14	0.109”/12
21	25	33
27	32	41
32	38	49
37	44	57
43	50	66
48	56	74
53	62	82
58	69	90
63	75	98
	81	106
	87	114
		122
		130
		138
		146

Notes:

1. Fill heights are for H20 and H25 live loads.
2. TYPE I installations are allowed unless otherwise shown.
3. ( ) Requires a TYPE II or TYPE III installation.
4. [ ] Requires a TYPE III installation.
5. For temporary construction vehicle loads (100 kips/axle load), place at least 4 feet of compacted cover over the top of the pipe.
6. * Maximum cover is based on ASTM A 796 Design Procedure.
7. ** Larger diameters may be considered if special construction techniques are used during installation. Consult pipe manufacturer for further information.
8. Minimum covers are measured to the bottom of flexible pavement or the top of rigid pavement. Cover in unpaved areas must be maintained.

BACKFILL & INSTALLATION

Correct backfill material, proper placement and compaction are key factors in obtaining satisfactory performance.

Minimum pipe metal thickness (gauge) is dependent upon minimum and maximum cover and installation conditions per TYPE I, TYPE II or TYPE III as noted herein. Backfill in the pipe envelope shall be granular materials with little or no plasticity; free from rocks, frozen lumps and foreign matter that could cause hard spots or that could decompose and create voids; compacted to a minimum 90% standard density per ASTM D 698 (AASHTO T99).

INSTALLATION TYPES:

TYPE I: Installation can be in an embankment or fill condition. Installations shall meet ASTM A 798 (steel) requirements. ML and CL materials are typically not recommended. Compaction equipment or methods that cause excessive deflection, distortion or damage shall not be used.

TYPE II: Installations require trench-like conditions where compaction is obtained by hand, walk-behind equipment or by saturation and vibration. Backfill materials are the same as in TYPE I installations. Special attention should be paid to proper lift thickness. Controlled moisture content and uniform gradation of backfill may be required to limit the compaction effort while maintaining pipe shape.

TYPE III: Installations have the same requirements as TYPE II installations, except that backfill materials are limited to clean, non-plastic materials that require little or no compaction effort (GP, SP), or limited to well graded granular materials classified as GW, SW, GM, SM, GC, or SC with a maximum plastic index (PI) of 10. Maximum loose lift thickness shall be eight inches. Special attention to moisture content to limit compaction effort may be required. Soil cement or cement slurries may be used in lieu of the selected granular materials.

INSTALLATION MONITORING:

Simple shape monitoring (measuring the rise and span at several points along the installation) is recommended as good practice with all types of installations. It provides a good check on proper backfill placement and compaction methods. Use soil placement and compaction methods that will ensure that the vertical pipe dimension (rise) does not decrease more than 5% of nominal diameter. Use methods that will ensure that the horizontal pipe dimension (span) does not increase more than 3% of nominal diameter. These guidelines will help ensure that the final deflections are within normal limits.

TriShield LINER

TriShield's interior wall liner material is a polyolefin plastomer (POP). The liner is both chemically and mechanically bonded to the pipe wall and exhibits excellent adhesion and durability in handling and field service.

The POP liner is produced via **INSITE™** Technology by The Dow Chemical Company. Dow has revolutionized the polyethylene industry by utilizing **INSITE** Technology to produce a new family of polyolefins that offer enhanced physical performance properties and improved polymer processability when compared to other conventional polyethylene resins such as HDPE.

Utilizing **INSITE** Technology, the interior POP liner has been custom tailored for the storm drain market. Through the combined use of molecular design capabilities and a patented single site catalyst, Dow has developed a polyolefin plastomer that is tough and elastic, while being abrasion, impact, and puncture resistant.

The resiliency and elasticity of the **TriShield** liner have been significantly improved over traditional HDPE pipe products. The added elasticity gives the liner remarkable rebound qualities which allow the liner to better resist the abrasive impact of sediment flowing through the pipe.

The liner's toughness, impact and puncture resistance work in conjunction with its elastic qualities to further improve liner durability.

In addition, an additive package for ultraviolet protection has been added to the **TriShield** pipe liner to protect it from damaging affects of the sun before burial.

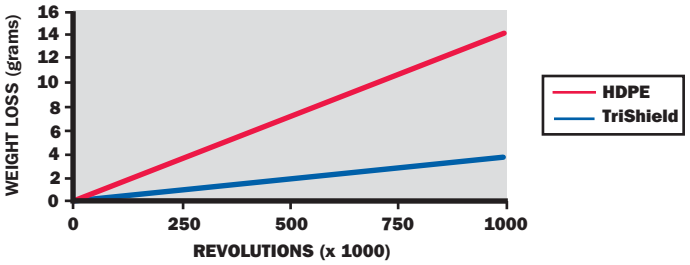
The POP resin used in **TriShield** pipe has the ability to stretch up to eight times its cross sectional area. Therefore, the POP liner will stretch beyond the limits of the steel pipe shell.

ABRASION RESISTANCE TESTING:

Utilizing the Bed Load Abrasion Machine (ASTM A 926), samples of **TriShield** pipe were compared with samples of a typical HDPE smooth wall pipe product. The results indicate that **TriShield**'s 75 mil polyethylene pipe liner outperformed the HDPE product (on the basis of weight loss) by more than three and a half times. (See adjacent graph)

** This information is presented in good faith and represents comparative test results under specified conditions; actual performance in field applications may vary.*

BED LOAD ABRASION RESULTS



CHEMICAL RESISTANCE TESTING:

Polyethylene has been long recognized for its superior corrosion resistance. It is used both as a primary pipe material and as a barrier sheet or a wrap to protect other kinds of pipe from corrosive substances. The POP liner material used in **TriShield** pipe has been tested and found to be chemically resistant to many such substances. Some of the chemicals tested are shown in the table at right. The **TriShield** liner demonstrated "Good" chemical resistance in all cases.

*For comprehensive chemical resistance information please contact your **TriShield** sales representative.*

CHEMICALS TESTED

CHEMICAL	CONC.	CHEMICAL	CONC.
Sodium Hydroxide	5.0%	Iron Chloride	1.0%
Nitric Acid	6.3%	Sulfuric Acid	20%
Isopropyl Alcohol	10%	Ammonium Hydroxide	5.0%
Bath Soap	0.01%	Household Bleach	100%
Vegetable Oil	100%	Laundry Detergent	100%

This information is presented in good faith and does not imply that the chemical resistance of the **TriShield** liner is identical to HDPE. The overall chemical resistance of polyolefin plastomers may vary from HDPE. Acceptability in specific applications should be evaluated by a certified testing laboratory.

LINER INTEGRITY:

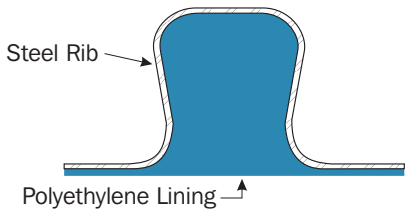
To assure long term performance, proprietary technology has been developed to molecularly bond the POP polymers with the steel core to produce a consistent and reliable bond that can withstand the physical rigors of pipe installation and service life.

In addition to the molecular bond, liner attachment is ensured by its encapsulation within the narrowed opening of the deltoid ribs. (See diagram)

This combined chemical and mechanical attachment system provides added assurance of composite integrity.

TriShield pipe's composite integrity and structural flexibility make it particularly suitable for use in areas where seismic activity is a concern.

DELTOID RIB CONFIGURATION



LINER INTEGRITY TESTING:

To demonstrate composite integrity, PSI Testing Laboratory in Pittsburgh PA, the largest testing facility in the country, has conducted extensive testing of the composite bond on typical **TriShield** pipe samples. These samples were subjected to numerous structural conditions far more rigorous than those encountered during routine installations or normal field service.

During this testing, continuous monitoring of the adhesive bond between the steel and the POP layers was documented. To further test the adhesion, several tests were conducted on samples that had been subjected to temperatures of 32° F and 150° F, cycled 20 times between 32° F and 150° F. All tests were first conducted at room temperature.

Each test case documented the liner's ability to remain intact even after the pipe shell had been totally destroyed. Additional structural tests demonstrated not only that layers remained bonded, but that the lined composite specimen significantly outperformed an identical unlined sample. The PE liner was able to assume part of the load applied during the testing procedure and still remained bonded. Therefore, the bond between the two layers displayed the ability to transfer load from one layer to the next. The sign of a superior bond!

RESULTS OF LINER INTEGRITY TESTING **

SIMULATED FIELD CONDITIONS	TEST NAME	TEST PROCEDURE	RESULTS	CONCLUSIONS
PIPE HANDLING	I RING BENDING	Circular cross sections of pipe were loaded to collapse using the Parallel Plate Method outlined in ASTM 2412 for pipe sections with and without the PE liner.	Readings at equivalent deflections demonstrate the ability of the lined pipe to receive a greater load when compared to unlined samples.	Tests indicate pipe can be subjected to severe generalized bending while mainmtaining the integrity of a composite. The liner added about 10% stiffness signifing a superior bond between the steel layer and the PE layer.
	II TORSION TESTING*	Strips of the composite product were twisted 360° to monitor the liner behavior.	The liner demonstrated its ability to remain bonded to the steel layer in all temperature cases.	Tests indicate that the pipe can be destroyed and yet still maintain the bond between the steel and PE layers.
PIPE LOADING OR THRUST RING	III LOCAL BENDING*	Test specimens of pipe wall were folded 90° for two tests with the ribs facing up and two tests with the rib facing down.	Temp. / Average. Loading (lb.): Tension / Compression Room Temp. 2,554 2,569 32°F 2,769 2,909 150°F 2,322 2,694 Cycles 2,651 2,409	Tests indicate the composite pipe can be subjected to severe localized tension or compression after backfilling and yet maintain the liner integrity.
	IV COMPRESSION/ SHORT COLUMN TEST	Two pipe wall sections were placed back-to-back with the curved surfaces abutting.	Localized buckling occurred at a maximum capacity of 59,000 lb., which is a 15% increase in the expected steel yield load on the effective area.	Tests indicate that the pipe maintains its composite integrity under dominant structural loading of uniform compression (ring thrust).
EFFLUENT FORCES	V SHEAR/BOND TESTING*	A plunger was used to bore inside the filled rib to shear the PE from the steel rib to the point of disbondment.	Temp. / Avg. Maximum Force (lb.) Room Temp. 1,177 32°F 1,633 150°F 707 Test Cycles 1,588	Tests indicate that the PE liner inside the rib can withstand extreme local shearing forces before any disbondment occurs.
	VI CIRCULAR TENSION	Flat strips of **TriShield** pipe were loaded to the point beyond the rupture of the steel cross section.	Calculated yield stress (based on steel x-section) = 33,450 psi Actual tested composite tensile stress achieved = 39,700 psi	Tests indicate that the PE liner can withstand incredible effluent shear forces to the point of steel rupture and still remain bonded to the steel layer.
	VII LONGITUDINAL TENSION* (CROSS RIB)	Specimens of **TriShield** pipe composed of two flat sections and a rib in the middle were stretched in tension and compared with specimens without the PE liner.	At equal loading intervals, the specimens without the liner elongated 6 times as much as the specimens with the liner.	Tests indicate that the bond strength developed by the adhesion between the PE and steel layers increased the longitudinal tensile strength by a factor of at least 1.56 for all four temperature cases. The strength increase clearly demonstrates the composite bond integrity developed between the two layers.
HYDROSTATIC FORCES	VIII RIB PRESSURE TESTING	Specimens of the **TriShield** pipe were subjected to hydrostatic pressures through a hole drilled through the soil-side of the pipe wall.	200 psi (462' of head) was applied to the rib without reaching the point of dislodging the PE from inside the steel ribs.	Tests indicate the ability of the liner to withstand extreme hydrostatic and effluent shear forces before any disbonding would occur.
	IX COMPOSITE PRESSURE TESTING	Flat strips of **TriShield** pipe were hydrostatically pressure tested by drilling a hole between the steel-PE interface.	80 psi (185' of head) was applied to the liner before detecting the slightest disbondment between layers.	Tests indicate the superior bond which adheres the two layers together. The PE layer has the ability to withstand hydrostatic loadings well in excess of the **TriShield** pipe product fill height capabilities.

* **Tests conducted At several temperature points**

** **For complete testing information, request report "Liner Integrity Tests of SRP2 Pipe Specimens" (TriShield Composite Pipe) by R.L. Brockenbrough & Associates, Inc., December 9, 1996.**

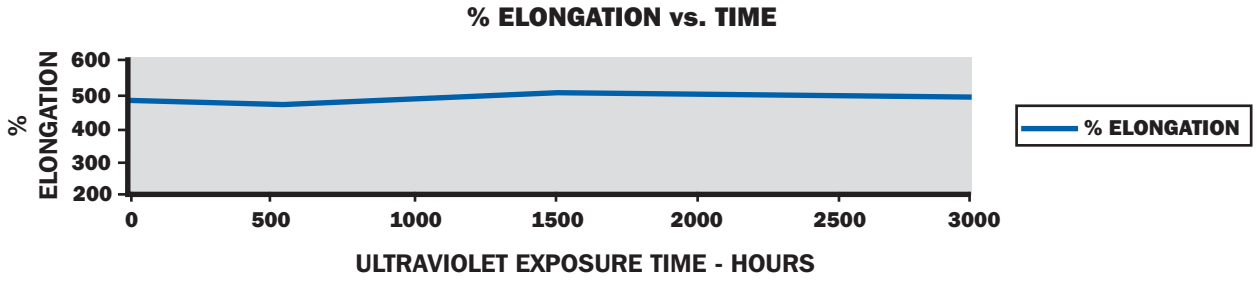
TRENCHCOAT PROTECTIVE FILM

Trenchcoat protective film, manufactured by The Dow Chemical Company, is an essential component of **TriShield** composite pipe. This tough, heavy gauge polymer film provides primary protection for the steel core against potentially corrosive elements in the backfill environment. **Trenchcoat** protective film is bonded to the soil side of the pipe wall and functions as both a physical and a dielectric barrier against most acids, salts, and alkalines that might be present in the backfill material. The zinc coating provides secondary protection.

A recent national corrosion survey concluded that the soil side service life of ***plain galvanized steel pipe alone*** exceeds 75 years in over 90% of all installations. Don Waters of Corrpro Companies, Inc. concluded in his report Field Performance of Polymer Coated Corrugated Steel Pipe "We can not find any data to suggest that this pipe coating would not provide at least one hundred years of service". With its dual protective coating systems (sacrifical zinc+**Trenchcoat** polymer barrier), **TriShield** pipe can provide a soil side service life that meets or exceeds most agency requirements.

ULTRAVIOLET (UV) STABILITY:

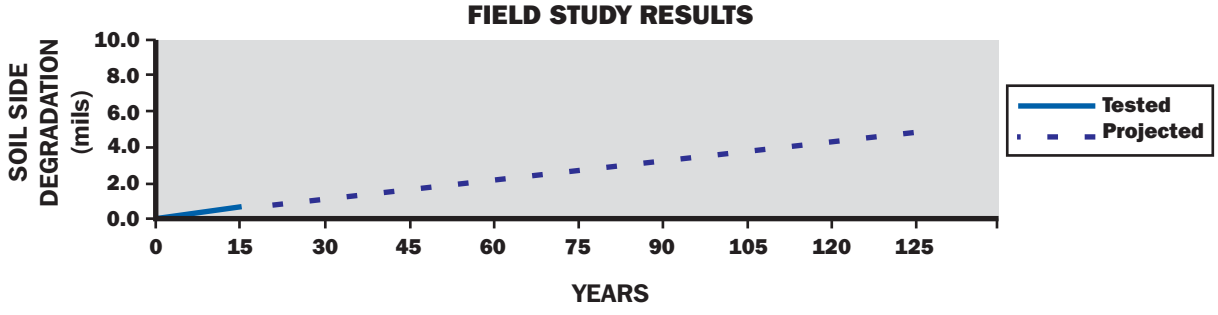
Trenchcoat protective film demonstrates excellent resistance to UV exposure. It retains its ability to elongate and resist embrittlement after extended UV exposure. Tests cycled at intervals of 8 hours of UV light and 4 hours of condensation at 37 degrees C, utilizing QUV testing equipment with a "B" bulb, have been performed. ASTM test D 882 was performed at various intervals to monitor the physical properties of the film during the test. The following graph illustrates the results of that test.



FIELD TESTING:

Field testing on samples to determine the extent of degradation on the polymeric film, were also conducted. Coupons gathered from various polymer pre-coated corrugated steel pipe installations having a service life in excess of 15 years revealed that, under microscopic and infrared microspectroscopic analysis, minimal degradation of the protective film had occurred.

Projecting the degradation rate of **Trenchcoat** protective film on a linear time continuum indicates a film service life of more than 125 years (see graph below). Combining this projected exterior film life with an expected life span of up to 75 years (depending on the environment) for galvanized steel core can make **Trishield** a stronger and longer-lasting alternative to other underground pipe products.



LABORATORY TESTING:

During its 25 years of service, **Trenchcoat** protective film has undergone rigorous laboratory testing and intensive field studies. Tests have been conducted for adhesion, imperviousness, dielectric strength, reagent exposure, and resistance to acids, bases, and salts, all with excellent results.

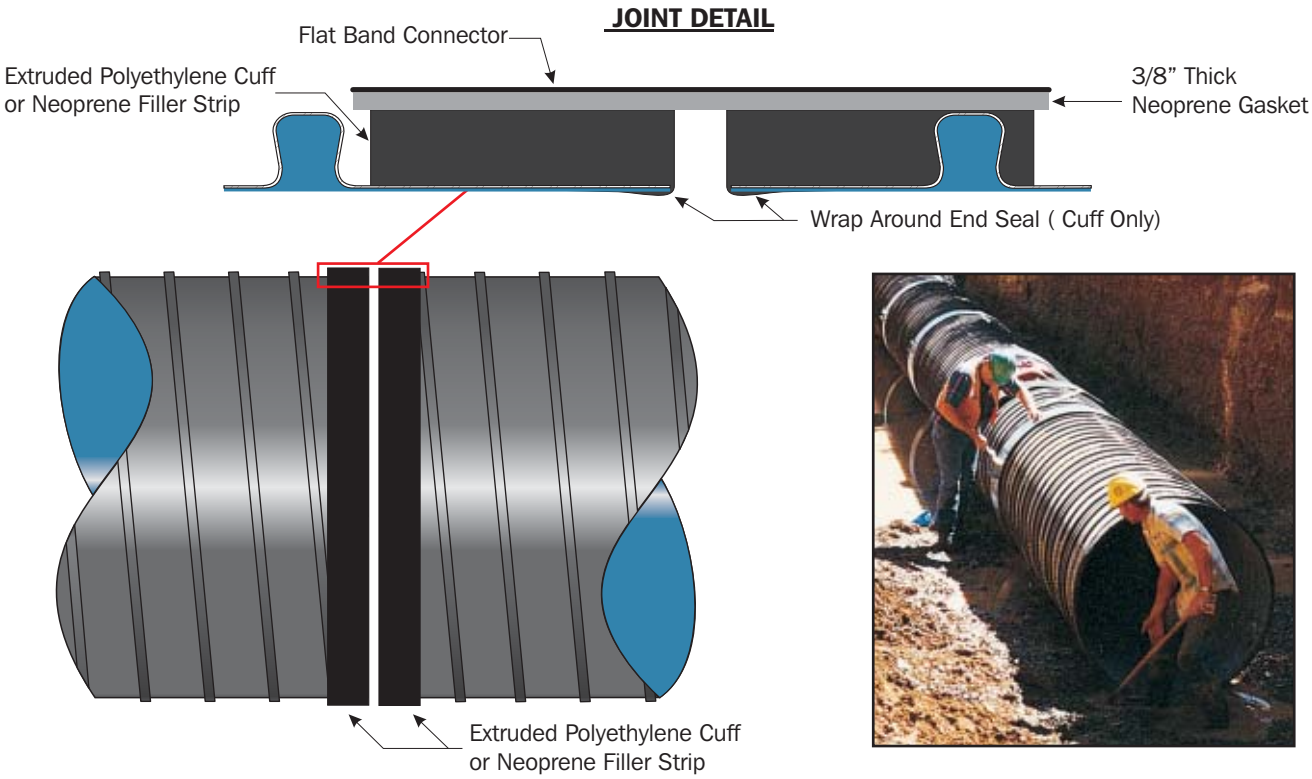
** Please contact Pacific Corrugated Pipe Company for actual test results, case histories, reports, or other information on **Trenchcoat** protective film.*

ACCEPTANCE:

Trenchcoat protective film is accepted by the US Department of Agriculture, the Federal Highway Administration, and most state departments of transportation. It has also been recognized by the National Corrugated Steel Pipe Association (NCSPA) and the National Coil Coaters Association (NCCA).

Trenchcoat protective film meets or exceeds all requirements of national specifications ASTM A 742 and AASHTO M 246.

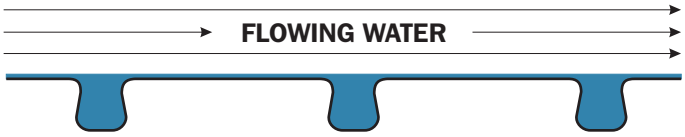
STANDARD JOINT CONNECTION



HYDRAULICS

TriShield pipe is not only tough and durable, but demonstrates exceptional hydraulic efficiency as well. It is suitable for use on storm drain, irrigation, small hydro, and most other gravity water conveyance projects where hydraulic efficiency is a design consideration.

TriShield pipe can be made to the nearest diameter inch of size required, within the available size range. With a design Manning's "n" of 0.0105 and variable sizing, **TriShield** pipe often allows designers to downsize a pipe system from a standard incremental pipe size to the actual size needed. This is particularly important when clearance and flow capacities are critical.



SMOOTH WALL LINER ALLOWS LAMINAR FLOW

Smaller sizes increase velocity for a given discharge. This can be a useful design consideration for maintaining minimum or self cleaning velocities at very low slopes. Smaller sizes also reduce material and installation costs.

TriShield pipe, with its smooth polyethylene liner, helps reduce maintenance costs by discouraging sedimentation and debris snags.

MANNINGS FORMULA

$$V = \frac{0.590}{n} D^{2/3} S^{1/2} \qquad Q = \frac{0.463}{n} D^{8/3} S^{1/2}$$

For design purposes, the appropriate Manning's "n" for **TriShield** pipe is:

"n" = 0.0105

A review of testing performed clearly demonstrates the ability of TriShield pipe to function as a true composite. Its performance under extreme conditions is far in excess of its intended design criteria. It is the engineered bond which ensures TriShield pipe's ability to withstand actual in-service structural, corrosive, and abrasive forces.

ECONOMIC BENEFITS

COST: In small diameters, **TriShield** pipe is cost competitive with other pipe products while providing notable strength, installation and durability benefits. In larger diameters, significant savings can be realized.

SIZE & WEIGHT: **TriShield** pipe can substantially reduce field installation costs because smaller equipment and labor crews are needed for handling and installation. Lighter weight means more pipe per truckload and lower transportation costs. In addition, the thinner wall thickness of **TriShield** pipe allows narrower and shallower trenches. This can significantly reduce right-of-way requirements as well as excavation and backfill quantities, especially in deep fill situations.

DIAMETERS AND LENGTHS: Unlike concrete, clay, polyethylene, or PVC pipe products, **TriShield** pipe requires no forms for its manufacture. This is advantageous for two reasons. First, **TriShield** pipe can be manufactured to any diameter within the available size range. This feature can lower pipe costs, reduce excavation and backfill quantities, and help alleviate clearance problems. Currently, available pipe sizes range from 24 to 108 inches in diameter. Larger diameters may be considered if special construction techniques are used. Consult pipe manufacturer for additional information.

Secondly, **TriShield** pipe lengths are limited only by feasibility of transportation. Longer lengths mean fewer pieces to handle and fewer joints to assemble.

REHABILITATION

For rehabilitation installations, reduced wall thickness, a low Manning's 'n' and the ability to fabricate pipe to any specific length and diameter often allows **TriShield** pipe to maintain host pipe flow capabilities. Thinner pipe walls mean maximum retained flow area.

PRODUCT APPLICATIONS

* Storm Drains
* Rehabilitation / Reline
* Culverts
* Water Transmission
* Down Drains
* Slurry Pipe

TriShield: THE STRONG, DURABLE PIPE FOR YOUR NEXT PROJECT!

*The information in this brochure should be checked in detail by the professional engineer responsible for the design to verify its accuracy. Also, the assumptions and methods used to obtain the information should be reviewed to make certain that they are applicable and suitable for the design. Any specifications and other data referring to mechanical properties, physical properties, and/or chemical properties relate to tested values based on analysis performed at that time. No express warranty or implied warranties of merchantability or fitness for any purpose are created or intended by this document. U.S. Patent No.'s 5,316,606 and 5,480,505. Other U.S. and Foreign Patents Pending.

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