COST EFFECTIVE NON-FLAMMABLE PIPE LINERS

A Research Report By

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Prepared For

The North Dakota Department of Transportation
2003

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT

EXPERIMENTAL PROJECT NO.

1	STATE	Y EAR		NUMBER		SURF
	NDSU	01	-	01		

CONSTRUCTION PROJ NO: 8

LOCATION: 28

EVALUATION FUNDING: 48

1 X HP&R
2 CONSTRUCTION
3 DEMONSTRATION
4 IMPLEMENTATION

NEEP NO.: 49

PROPRIETARY FEATURE? 51 Yes No X

SHORT TITLE

TITLE 52: Cost Effective Non-Flammable Pipe Liners

THIS FORM

DATE 140: MO. 10 -- YR. 2003

REPORTING: 1 INITIAL 2 ANNUAL 3 FINAL X

KEY WORDS

KEY WORD 1 (145): DRAINAGE

KEY WORD 2 (167): PIPES

KEY WORD 3 (189): PLASTIC

KEY WORD 4 (211):

UNIQUE WORD (233): LINERS

PROPRIETARY FEATURE NAME (255):

CHRONOLOGY

Date Work Plan Approved (277)	Date Feature Constructed: (281)	Evaluation Scheduled Until: (285)	Evaluation Extended Until: (289)	Date Evaluation Terminated: (293)
03-2001				10-2003

QUANTITY AND COST

QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS): 297

UNITS: 305

1 LIN. FT
2 SY
3 SY-IN
4 CY
5 TON
6 LBS
7 EACH
8 LUMP SUM

UNIT COST (*Dollars, Cents*): 306

AVAILABLE EVALUATION REPORTS

CONSTRUCTION (315)	PERFORMANCE	FINAL
		X

EVALUATION

CONSTRUCTION PROBLEMS: 318

1 NONE
2 SLIGHT
3 MODERATE
4 SIGNIFICANT
5 SEVERE

PERFORMANCE: 319

1 EXCELLENT
2 GOOD
3 SATISFACTORY
4 MARGINAL
5 UNSATISFACTORY

APPLICATION

320

1 ADOPTED AS PRIMARY STD.
2 PERMITTED ALTERNATIVE
3 ADOPTED CONDITIONALLY
4 PENDING
5 REJECTED
6 NOT CONSTRUCTED

(Explain in remarks if 3, 4, 5, or 6 is checked)

REMARKS

321

Corrugated metal pipe corrode over time and are rehabilitated using liners. Ditch fires damage these liners and new replacements need to be found. Most liners consist of polyethylene which is flammable. Research included coatings, ceramic adhesives, polyurethane coatings, elastomeric coatings, resin pipes, and fiberglass pipes. Best solution was to use existing HDPE liners with concrete end caps.

Disclaimer

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Problem Statement:-

The North Dakota Department of Transportation uses corrugated metal pipe for carrying storm water beneath roads and highways. The corrugated metal pipes corrode over time (see figure 1) requiring rehabilitation using liners.

Figure 1. Pipe Culvert in Distress

Liners are primarily made up of polyethylene. Polyethylene (PE) is a highly cost effective material and several commercially available brands offer adequate structural and hydraulic properties necessary for the application. In addition these materials have adequate ultraviolet radiation resistance needed for field applications. In spite of its various advantages, polyethylene is highly flammable. Recently the DOT incurred severe damage to some pipe liners due to ditch fires. Communication with DOT personnel has indicated that more than a quarter of the length of the pipe in some instances was totally destroyed as a result of these fires. With a large number of corrugated metal pipes used in culverts in ND needing retrofit, it is necessary to find an adequate replacement or surface treatment to the currently used PE pipes to minimize risk of liners catching fire. Currently ND DOT uses PE liners of brand name ISSCO-Snap-Tite™ culvert liners.

New Liners and Methods

In order to investigate potential mitigation methods to minimize fire risk to liners, the study focused on:

1. Non flammable coatings on existing PE liners or on other pipes.
2. Concrete end caps.
3. New liner materials with or without non flammable coatings.

Cost analysis was performed based on the price quoted by manufacturers. It is assumed that installation and construction costs will be similar for all choices.

Coatings

Many coatings and paints were investigated in this project for their potential use as non flammable coatings on the liners. ND DOT uses polyethylene (PE) liners of brand name ISSCO-Snaptite. The highly flammable nature of the PE material used in these liners makes them unsuitable. In addition PE is fairly chemically inert and its adhesion to other non flammable coatings is limited. Surface roughning, which is common technique to improve adhesion of coatings also does not adequately improve the adhesion of PE with coatings. We investigated numerous paints and coatings that may be applied. Favorable among them were polyurethane, elastomeric and ceramic adhesives and ceramic based coatings such as Aremco ceramic adhesives.

1. **Ceramic Adhesives** One way of protecting the liners is to coat with non-flammable materials like the Aremcos's high temperature ceramic adhesives that can bond to ceramics, metals, glass, graphites, textiles and composite materials and can withstand temperature up to 3200 degree Fahrenheit. However, this material requires a curing temperature of 200 to 700 degree Fahrenheit. The liners cannot withstand such high temperature and hence these coatings should not be used. Its manufacturer's information is provided below.

Aremco Products, Inc.
P.O. Box 517,
707-B Executive Blvd.
Valley Cottage,
NY 10989.
Telephone Number: (914) 268-0039,
Fax: (914) 268-0041.

2. **Polyurethane coatings**
   Breakthroughs in 100% solids polyurethane coating technology have produced higher performing, non-flammable polyurethane coatings. These coatings are available from several manufacturers and are primarily used for coatings metals. Often these coatings provide 2000+ PSI adhesion to steel without primers and zero volatile organic content (VOC's). The development of 100% solids two-component coatings have been widely used. These coatings have numerous advantages over other options such as coal tar epoxy and Fiberglass Reinforced Polyester (FRP). 100% solids polyurethanes contain no amines, styrenes or VOC's. They contain no carcinogens and are non-hazardous waste when cured. They are non-flammable and considered a safe coating. They are resilient, not easily damaged and easy to inspect for damage. These coatings are sold under many brandnames such as ARMORTHANE®. Numerous manufacturers products were investigated for these coatings but the adhesion of these coatings to HDPE is extremely poor.

3. **Elastomeric coatings**
   Fluoroelastomers are available in a non-flammable liquid latex form. Fluoroelastomers are high heat and chemical resistant rubber materials utilized in molded and extruded parts. Fluoroelastomer lattices are available in various formulations. These coatings are available as two component systems, which allow the films to cure both at room temperature or at elevated temperatures. These coatings offer safe systems over solvent-based Fluoroelastomer coatings. They are non-flammable and low odor with no VOC. FluoroLatex products made by Advanced Polymer Coatings Inc may be in some instances suitable for DOT applications. These coatings may be applied on site using spray process since the coatings cure at room temperature. Due to the chemical composition of these coatings it is expected that adhesion of these coatings to HDPE is better than the polyurethane coatings. Again, adhesion of these coatings on PE is quite limited. The thickness of the coatings is of the order of 15 mil. This product is available through:

   Advanced Polymer Coatings, Inc.
   6023 Ward Lane · Levittown, PA 19057
   Tel: 215-943-1466 · Fax: 215-943-9766
   E-mail: **bpelham@apcfluoro.com** or **apcfluoro@aol.com**

   Although the coatings themselves are fire resistant, in a sustained fire, the heat will be transferred to the PE liner below, which could cause structural damage, melting or even burning of the liner. However, these coatings may protect the liner against intermittent sparks resulting from fires in the ditch.

NEW LINERS
Resin Pipes:-

Several companies manufacture resin and fiberglass based pipes as well as other composite pipes. These pipes are either cured on site or offsite. These pipes are primarily used for sewer and culvert applications and thus the composition of these pipes is engineered to provide the necessary corrosion protection. Flammability is not clearly addressed in the company literature of most pipes. The following pipes were investigated:

- INLINER by Inliner technologies Inc.

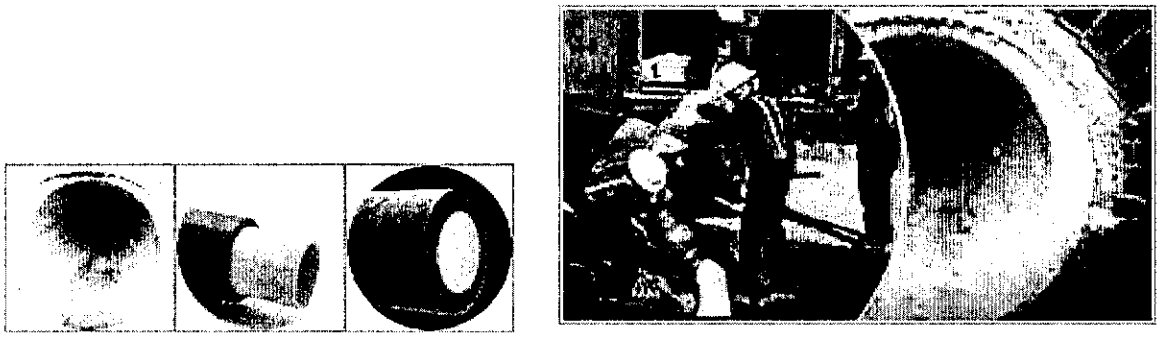


Figure 2. Cured on site pipes, also called cured-in-place-pipes (CIPP)

These pipes represent a good example of cured on site pipes. InLiner tubes are made of a felt material saturated with resin and coated with a waterproof polyethylene layer. Polyester needled felt and polyester resin systems are standard, but vinylester resins and a variety of other materials may be used when applicable. InLiner has patented two technologies for a CIPP product: ResinGuard™ and StretchGuard™.

- **ResinGuard™** protects the resin-saturated inner felt from washout, dragoff, squeezeout, and contamination during installation. For the end user this provides superior consistency of thickness and enhanced strength.
- **StretchGuard™** prevents distortion of the tube as it is pulled or inverted into a pipe. InLiner determines the required thickness of the liner using ASTM 1216, the industry standard for cured-in-place piping. StretchGuard ensures that these standards are protected during installation. This product design eliminates leaks, promotes safety, reduces risks, and protects the environment - with a 50-year service life.

Installation

Cured-in-place pipe (CIPP) consists of a soft, flexible felt tube that is impregnated with a thermoset resin, installed as a liner in an existing pipe, and cured by application of heat.

Inliner technologies, Inc.
1468 West Hospital Road
Paoli, IN 47454-9215
(licensees contacted: Lametti & Sons Inc. John Grove 16028 Forest Blvd. PO Box 477 Hugo MN 55038 ph: 651-426-1380)

- *Thermopipe™ System of Insituform Technologies*

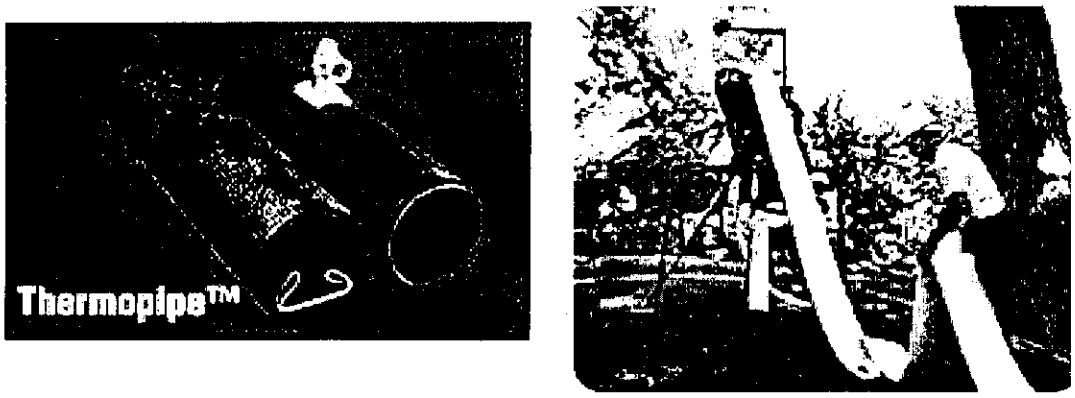
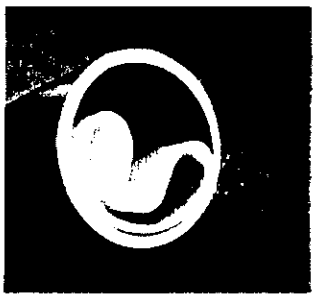


Figure 3. Thermopipe™

Another example of a cured-in-place pipe is shown in figure 3. This company specializes in high resin content pipes of diameters less than 2.5 m. This is an example of a cured in place pipe that is cured using hot water. From the high resin content of this pipe, without any surface treatment, it is expected that this pipe presents large flammability risks.

Personnel contacted: Bob Ratz, Insituform technologies USA Inc., 12450 Wayzata Blvd. Ste 224, Minnetonka, MN 55305, Ph:952-472-1692.

- **U-Liner, Rinker materials Pipeline Systems**



This pipe (figure 4) is made from high-density polyethylene (HDPE), the U-Liner™ is extruded to the specific diameter to deform it into its patented "U" shape, and then coil it onto reels for delivery to the project site.

Contact: Wayne Long, Marketing Engineer, 3114 N. Greystone Drive, Morgontown, west Virginia 26508, ph: 304-5949185

Figure 4. U-Liner pipeline system

This pipe without any surface treatment is highly flammable similar to the currently used ISCO- Snap-Tite culvert liners by the DOT.

Fiberglass composite pipes:-

- **Hobas – USA** manufactures pipes made of fiberglass material. Since one ingredient of Hobas pipes is glass fiber reinforcement, Hobas pipes are commonly referred to as fiberglass pipes. However, unlike most traditional fiberglass pipes, the main constituent material in Hobas pipes is not fiberglass, but a polymer mortar. Hobas pipes are actually more similar to reinforced concrete pipes (RCP) than fiberglass pipes, but they exhibit many of the best features and performance benefits of both.

The Hobas pipe wall is constructed with thermoset polyester (or vinyl ester) resin, glass fiber reinforcements, and additives, primarily sand. Compared with RCP, the resin replaces the cement-water matrix binder, the glass fibers replace the reinforcing steel, and both products contain additives (sand, aggregate, etc.). Much like RCP, the Hobas wall materials are placed in precise locations to maximize performance. The glass fiber reinforcements are predominantly positioned near the inside and outside surfaces, similar to RCP double cage configurations. For pressure pipes, the heavily reinforced areas are increased in thickness as the pressure rating advances. The glass content reduces toward the center of the wall where ring-bending stresses are zero. The inside layer of Hobas pipes consists of a resilient, high elongation pure resin. Figure 5 shows a schematic of crossection of the Hobas pipe.

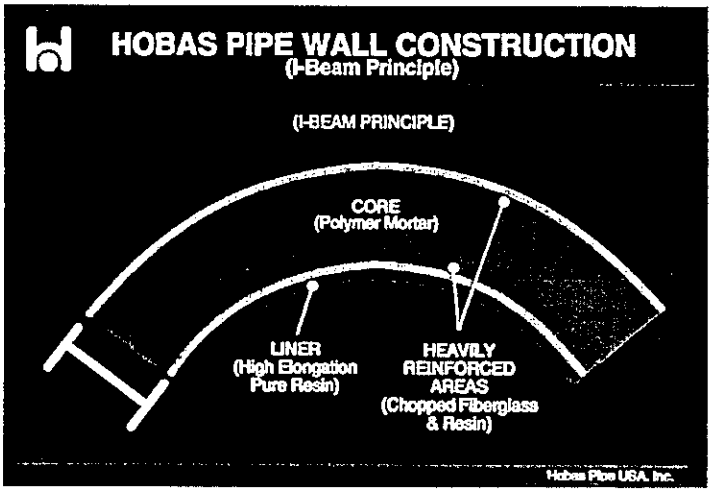
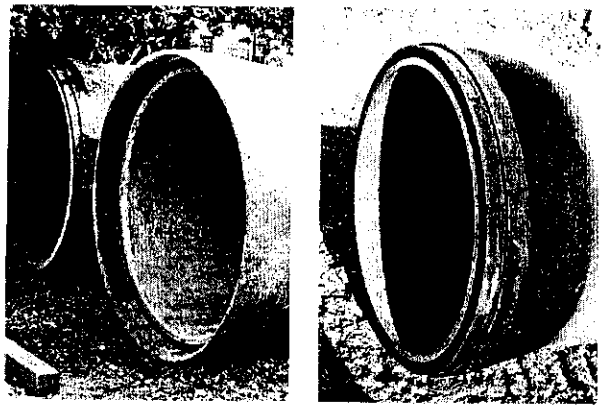


Figure 5. Schematic of crossection of the Hobas pipe.

Hobas pipes are manufactured by a unique, computer-controlled, centrifugal casting process instead of the filament wound method most common to traditional fiberglass pipes. The Hobas casting process produces very consistent, high density pipes with smooth interior and exterior surfaces.

Hobas pipes are a high performance product suitable for a wide range of installation methods and applications including many corrosive environments, high loads, and elevated temperature service. Although used primarily for sewer applications, due to excellent corrosion resistant applications, these pipes have recently also being used for culverts in Colorado and Illinois.

Hobas pipes have the best features and performance benefits of both filament wound fiberglass (FW) and reinforced concrete pipes (RCP) in addition to other unique benefits including good compatibility with pipes of other materials such as concrete with use of custom fittings (figure 6).



Fiberglass bell fabricated to mate to RCP spigot. *Special spigot and to join with RCP bell.*

Figure 6. Compatibility with other pipes through use of couplings and gaskets.

These pipes are known to perform well under diverse environmental conditions all around the world. Common applications include sewers and water portals and by Illinois and Colorado DOTs for culvert applications

Flammability: Of all of the specifications evaluated for the above pipes the Hobas pipe is most suitable for the present DOT applications. High fiberglass content in these composite pipes improves the resistance to fire as compared to the pure resin cured on site pipes described earlier (e.g. INLINER). Furthermore, several DOTs around the country are opting for these pipes for culverts due to their superior properties and long term durability. Referring to the chemical composition of the Hobas pipe as shown in the crossection

schematic in figure 5, the pipe has a high density of silica and does provide fire resistance except for the inner layer which is mostly resin. Personal communication with Hobas Co. technical and sales experts (Tom Furie) has indicated that the purpose of the inner layer is to provide **1.** a smooth surface and **2.** corrosion protection. Since these pipes have originally been fabricated for sewers these two requirements are necessary. The Hobas company has indicated to us that this pipe can be fabricated without the inner layer. This would certainly increase the mannings coefficient of the pipe but to no more than that of concrete (~0.13) while maintaining high level of nonflammability. No tests are done to prove the nonflammability but the chemical composition and high silica content in the pipe indicates that this pipe would be likely have low flammability potential and ability to withstand heat caused due to ditch fires. The manufacturer should conduct specific tests to show non flammability of their pipeliner.

HOBAS CC-GRP pipes have proven performance of high resistance to chemical attack, long design life, easy handling and customized GRP fittings.

More information on Hobas Pipes can be obtained from:

Hobas Pipe USA Inc:-

1413 Richey Road
Houston, TX
77073-3058
Phone 281-821-2200, 800-856-7473
Fax: 281-821-7715
Email: info@hobaspipeusa.com
Contact person: Kris Borst, Ph: 816-916-6441

Fiber glass pipes with end caps:-

The as-sold Hobas pipe is not resistant to fire due to the presence of high resin content in the inner layers near I.D. Therefore, to avoid fire hazards, Hobas pipes can be fitted with concrete end caps to protect from the onslaught of fire.

The end caps can be made from high performance refractory materials or also from concrete. Cost considerations and availability of varying diameters and sections makes concrete caps more suitable. Our contact with ND Concrete products Co. indicates that short length concrete end caps are available.

North Dakota Concrete Products Co.
1910 1st Av N
Fargo, ND
Ph: 701-237-9800

ZIRCAR REFRACTORY COMPOSITES, INC.
P.O. BOX 489
FLORIDA, NEW YORK 10921
TEL: 845-651-2200, FAX: 845-651-1515
email: sales@zrci.com

Marine Fabric Insulation:-

Several companies make fabrics that are designed to be highly flame retardant for marine and naval applications. Although not very cost effective these fabrics can easily be bonded to the Hobas pipe at relatively low temperatures and make the Hobas pipe non flammable. Certainly the application of the marine coating on the Hobas pipe needs to be done offsite by separate subcontractors. This does present additional cost. Of the several coatings investigated the following two seem most suitable.

1. M and A Supply company : this company makes several; products that may be used to adhere to the fiberglass pipes to enable them to be non flammable and fire retardant.
    - MAS Intumesent Coating: A two part coating system consisting of a coating of NoFire A18 and a protective topcoat material called Uracoat 3. NoFire is a one part non-flammable water based intumescent coating similar in appearance to ordinary latex base paint. Upon exposure to flame or heat, it immediately foams and swells (intumesces) providing an effective insulation and heat shield to protect the subsurface. The coating will need to be sprayed on again in the event of a fire. (Note application methodology is described in Appendix)
    - MAS *INSULFIRE* products are structural fire wall insulation blankets or sheets that are made from AMORPHOUS WOOL (AW) or CERAMIC FIBER (CER). These NON-COMBUSTIBLE fire wall products are offered with a variety of facings including standard fiberglass navy cloth (CF), reinforced mylar (WM), 2mil aluminum foil (AF) and perforated fiberglass cloth (WP).
    - MAS-KOVER-GARD #22: A woven fiberglass cloth coated on one side with a 3 mil fire retardant vinyl.
    - MAS smoke curtain fabric is 100% fiberglass cloth that is treated on both sides with a flame retardant acrylic coating. This fabric is used by US navy as a smoke barrier.

- MAS-WM white mylar facing: This is a fire resistant polyester film that is laminated to a fiberglass reinforcing scrim using a fire retardant adhesive. This offers excellent puncture resistance, high tear strength and can be heat sealed.

M and A Supply
150 North plans Industrial Road Suite S
Wallingford CT 06492
Phone: 203-294-9431, fax: 203-294-1697
EMAIL: Sales@MA-Supply.com
URL: www.ma-supply.com
Contact person: David Wright, Ph: 203-294-9431

2. Claretex Marine Fabrics manufactures non-flammable fabrics, which can be utilized for insulating the pipes as well as the existing liners from fire hazards. Claretex manufactures Tuffskin 1613 Facing, a fire-resistant polyester film laminated with a flame-retardant adhesive to a fiberglass reinforcing scrim. The adhesion of this fabric to the existing PE liners needs to be experimentally analyzed.

   - **Tuffskin 1613 Features:-**
     Toughness: excellent puncture resistance. Adaptable for heat-seal applications, Compatible with most latex surface paints, High tear strength, Available in 24", 48" or slit to non standard widths for tape, Standard roll length is 500 linear yards.
   - **CF Hullboard Facing:-**
     It is a 100% woven fiberglass cloth resin treated to ensure non-flammability and durability. Useful features are:Low toxicity, Non-flammable, Extremely durable, Available in 24" or 48" standard widths, Standard roll length is 250 linear yards.
   - **Smoke Curtain Fabrics :-**
     100% woven fiberglass cloth treated with a flame-retardant acrylic coating applied to both sides of the fabric. Fabric is used extensively for shipboard applications where a fire-retardant, lightweight fabric is needed for a fire or smoke barrier.
   - **AM Jacketing :-**
     AM is a triple-ply laminate made with fiberglass scrim, aluminized polyester, and an aluminum foil, laminated together using a fire retardant thermo-setting adhesive. Can be split into selected widths for tape applications, either with or without pressure sensitive adhesive.

Claremont sales Corp. (Manufacturers of Claretex Marine Fabrics)
290 Pratt Street

P.O. Box 952
Meriden, CT 06450
Telephone 800-222-4448, 203-238-2384, Fax 203-238-4329
Email; General info@claretex.com
url: http://www.claretex.com

RECOMMENDATIONS FOR CULVERT LINERS:

Based on our research, polyethylene has a highly surface that limits the possibility of using coatings on existing PE liners. We provide the following recommendations as potential solutions to address the flammability issue of the current PE pipeliners.

1. **Existing HDPE liners with concrete end caps.** This method provides maximum protection against fires to the existing PE liners since the concrete end caps will not allow the fire to start at the ends. It is believed that the fires originate at the pipe ends. Figure 7 shows schematic of end caps. End caps of sections $1/10^{th}$ the size of total pipe but not less than 5 ft are recommended for each end. The currently used PE pipe of the brand name ISSCO with Snaptite connections are suitable. Further, the gross thermal expansion mismatch between PE and concrete requires the use of a suitable grout between them. An epoxy based grout is recommended.

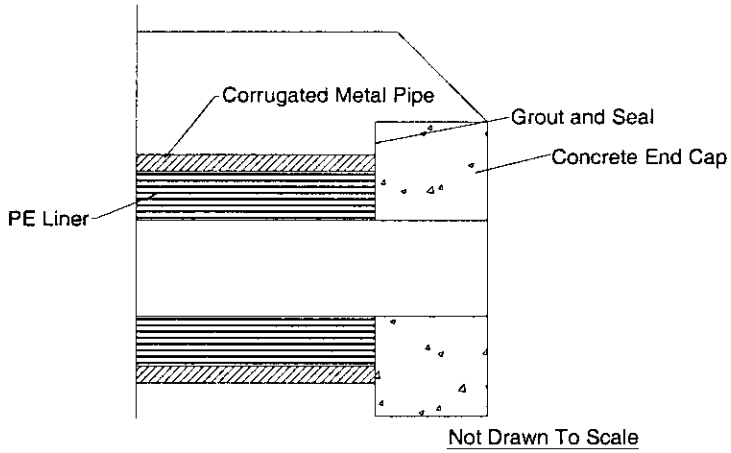


Figure 7. Schematic showing concrete end caps on pipeliners.

2. **Use of Hobas pipe without inner layer.** Without the inner resin layer the hobas pipe I.D. is heavily reinforced silica. This layer presents a non flammable surface. Communication with Hobas pipe sales and technical representatives has indicated that Hobas is willing to make such pipes for the ND DOT. They also indicated that the absence of inner layer does not provide the corrosion resistance as provided by the Hobas pipe with the inner layer. Wastewater as in stormwater is not a corrosive environment even with small changes in the pH. Thus, this is not regarded as a big issue. Further, absence of the inner resin layer makes the pipe more rough but as the company indicates, no more than the mannings coefficient of a concrete pipe (0.13). With these two points in perspective this is also a good choice for culvert liners.

3. **Hobas pipe without the inner layer** is compatible with existing PE liners with use of custom fittings. In order to reduce costs, sections of hobas pipes without inner layer can be used for only $1/4^{th}$ the length of the total pipe on each end. The central section of the pipeliner can be maintained as PE. This method can also be used for the currently installed PE liners for preventing future damage to the pipes. Due to the significant cost differences between PE and Hobas pipe in some projects this route might represent cost savings.

4. **Hobas pipe with inner layer and coated with marine fabric**. Several marine fabrics were investigated in this project as described earlier. The inner layer of the Hobas pipe is a high resin composition. This surface can easily bond with the MAS intumecsent coatings. Although these coatings do need to be reapplied in the event of a fire the subsurface is protected. Application of the coating represents an addition step that needs to be undertaken offsite. Installation of the pipe can then proceed as before.

COST ANALYSIS

A comparison of the material costs is done for the various recommendations. Since the installation costs are greatly dependent on the exact sizes of the projects, it is estimated that the installation costs would be quite similar for the different routes proposed.

	Viable Options	**Component 1**	**Component 2**	**Total Cost for a 42" dia-60' long pipe**
1	Existing HDPE liners with concrete end caps	HDPE liner cost 44.33" I.D. cost: $100 to150/ft (price varies with brand)	Concrete end caps cost (North Dakota Concrete Products) 24": $18/ft 42": $70/ft 54": $110/ft sizes up to 120" dia are available	$840 +($4800 to $7200) =$5640 to $8040
2	Hobas pipe without internal liner for entire length of pipeliner	Hobas Pipe 48" O. D. pipe cost: $117/ft available in		$7020

		sizes upto 144"		
3	Hobas pipe without inner layer for a ¼ section of pipe at ends.	HDPE liner cost 44.33" I.D. cost: $100-150/ft	Hobas Pipe 48" O. D. pipe cost: $117/ft available in sizes up to 144"	($3000 to $4500) + $3510= ($6500-$8010)
4	Hobas pipe coated with marine fabric insulation	Hobas pipe 48" O. D. pipe cost: $117/ft available in sizes upto 144"	MAS coatings on Hobas PipeMAS Nofire: $85/gal MAS Uracoat 3 $85/gal MAS document indicates a 10mil coverage on 160 ft^2 of area is possible with 1 gal. Hence each gallon can cover 14.55 ft linear length of a 42 " I.D. pipe	$7020 + $701 = $7720 (Note additional costs will be incurred to obtain coating covered Hobas pipe)

APPENDIX A
(MAS product literature and application methodologies)

TECHNOLOGIES, INC.
21 INDUSTRIAL AVENUE • UPPER SADDLE RIVER, NJ 07458-2301
TEL (201) 818-1616 • FAX (201) 818-8775
• E-mail Address: NoFireNJ@AOL.com • Web Site: http://www.nofiretechnologies.com

NoFire A, A-18 & A-18 Marine General Application Procedure & Technical Data

1. General Description of the Material

NoFire® is a one part non-flammable water based intumescent coating similar in appearance to ordinary latex base paint. Upon exposure to flame or heat, it immediately foams and swells (intumesces) providing an effective insulation and heat shield to protect the subsurface.

NoFire can be applied to many types of surfaces providing an attractive flat finish. NoFire can be readily topcoated by many types of latex base paints, urethanes or acrylics for attractive weather resistant finishes.

2. Surface Preparation

The surface should be clean and dry, free of dirt, oil, loose scales or paint and other foreign matter. On porous surfaces or flaky rusty surfaces, loose flakes and/or rusty scales must first be removed by scraping and a proper surface suitable for application of the coating restored.

New or Unpainted Surfaces: Priming is not required for wood, wallboard, aluminum, copper masonry and many composite surfaces. Steel surfaces may require priming. Rusting metal should be primed with a rust inhibiting primer.

Painted Surfaces: Priming is usually not required for latex, acrylic latex or alkyd painted surfaces.

Enamel paint is NOT a suitable surface for NoFire application. The enamel must be primed or removed prior to painting.

For specific information, please call your local distributor or manufacturer.

3. Mixing Procedure

Due to possible settling of contents during shipping and storage, the Product should be thoroughly mixed from bottom to top of the container. No thinning of any kind is recommended.

A 5 gallon pail of NoFire can be adequately prepared using a 3/8 inch drill with an appropriate mixing tip, and mixing for at least 5 minutes. This procedure should be repeated each day the coating material will be used.

4. Application using Spray Equipment

NoFire Formula A and A-18 can be applied using airless or conventional spray equipment. The product can be applied to the desired thickness usually in one application of up to 25 mils wet.

Do not apply when the air temperature or temperature of the surface being coated is below 40°F (5°C), or the relative humidity is above 85% or during times of any precipitation or when precipitation is expected within twenty-four hours (for exterior applications).

The required equipment is a standard conventional system or an airless paint sprayer with specifications similar to the following recommended unit:

Pump:	Airlessco model 5300SL Airless Paint Sprayer
Pressure:	2400 to 3000 PSI
Hose:	50 foot x 1/4 inch airless paint hose
Gun:	007XL Spray Gun
Tip:	535 Zip Tip, reversible tip.
Filters:	Suction Filter Only (**Do not use any kind of Line or Spray Gun Filter**)

The surface to be coated must be clean, dry and free of all loose materials. The surface should be suitable for painting, similar to any other paint job requirement.

Hold the spray gun 12 to 14 inches from the surface. Overlap each pass by approximately 30%.

The wet film thickness should be checked constantly with a wet film thickness gauge.

A practice surface should be used to gain some familiarity with the coating material and equipment. After a few minutes of practice, the operator should be able to spray a smooth coat with the desired thickness.

The coverage should be as uniform as possible, including surfaces that are normally not in plain view, such as underneath and behind overhangs. This will probably be the region with the most intense heat in the event of a fire, and require the best protection.

Any chips, cracks or thinly coated areas can be "touched up" upon inspection.

The coating should be allowed to dry for 2 - 3 hours before a second spray coat is applied, if necessary.

The coating should be allowed to dry and cure for 48 hours if possible, but no less than 24 hours, prior to topcoating.

5. Application Procedure with Brush and Roller

After proper mixing and surface preparation, apply the product directly from the container. Coat evenly and thoroughly over surface to be coated with a natural bristle brush or roller. Any chips, cracks or thinly coated areas can be "touched up" upon inspection. Do not apply multiple coats until the surface is completely dry as specified above. Do not apply when the air temperature or temperature of surface being coated is below 40° F (5° C). Do not apply when the relative humidity is above 85% or during times of any precipitation or when precipitation is expected within two hours (for exterior applications).

For best results use any good quality bristle brush or 3/8" to 1/2" nap roller cover.

6. Application Specifications

Approximate thickness for coverage - One coat application:

Brush or Roller:	6.5 - 9.5 mils wet (4 - 6 mils dry)
Spray:	9.5 - 24 mils wet (6 - 15 mils dry) depending upon spray procedure and surface to be coated.

The number of coats depends upon the total thickness needed to reach the specifications of the application.

Class A Surface Flame Spread ratings can be achieved with a wet film thickness of 0.002 – 0.0097 inches depending on the type of material, density, surface granularity, use of primer, etc. However, Class A rating is not a reliable determination of fire protection for most applications. Call manufacturer for recommendation for your application.

Examples of Spreading Rate / Coverage:

Thickness Wet	Thickness Dry	Coverage per Gallon
6.1 mils	3.8 mils	265 sqft
10 mils	6.2 mils	160 sqft
13 mils	8.1 mils	125 sqft
16 mils	9.9 mils	100 sqft
20 mils	12.4 mils	80 sqft
24 mils	15 mils	65 sqft

Porous or textured surfaces will reduce the spreading rate.

Be sure that the entire surface is thoroughly coated with a thickness equal to or greater than the minimum required on all regions of the surface, especially regions that are usually not immediately visible, such as joints or underneath overhangs.

Drying time - depends upon the ambient temperature, relative humidity and applied thickness. Approximately two hours of drying time is required when temperature is 70° F (21°C) and relative humidity is below 40% and coat is 8-9mils wet. Lower temperatures, higher RH or thicker coatings will require longer dry time. Curing time is 24 - 48 hours. Drying may be acceleratred with gentle heated airflow under 200°F. Additional coats may be applied when dry to the touch.

7. Testing Thickness after Curing

For both the NoFire coating as well as the final topcoat, the coating thickness can be measured using non-destructive, or magnetic thickness gauges. Follow the thickness gauge manufacture's procedures for correct use.

8. Clean-up Instructions

Clean all equipment immediately after use with water. If equipment needs final flush with "alcohol" to prevent metal corrosion, consult equipment manufacturer before doing so. If product has accidentally dried on equipment, use soapy water or thinner to clear residue.

9. Warnings

Use with adequate ventilation. Do not breathe vapors or spray mist. Wear an appropriate, properly fitted respirator (NIOSH/MSHA) during and after application unless air monitoring demonstrates vapor/mist levels are below applicable limits. Follow respirator manufacturer's directions for respirator use. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.

FIRST AID: In case of eye contact, flush immediately with plenty of water for at least 15 minutes and get medical attention; for skin, wash thoroughly with soap and water. If affected by inhalation of vapor or spray mist, remove to fresh air. Do not take internally. If swallowed, get medical attention. Keep out of reach of children.

Keep container closed when not in use. In case of spillage absorb with inert material and dispose of in accordance with applicable regulations. Clean up with soap and water.

10. Technical Data

Finish: Flat	**Color:** White; also available in standard color range
Viscosity: A 80 - 100 KU. A-18 85 - 115 KU.	**Approx. Weights:** A 11.1 ± 0.3 lbs. per gal A-18 11.7 ± 0.3 lbs. per gal
Solids by Weight: A 60%, A-18 63%	**Solids by Volume:** Approx. 60% A, 63% A-18
PH: 7.9 ± 0.5	**Flash Point:** None
Freeze-Thaw: Passes 5 cycles	**Federal Spec Equivalent:** TT-P-1932
Packaging: 5 gallon containers - A: gross weight 58 lbs., net weight 55 lbs. A-18 : gross weight 62 lbs., net weight 59 lbs	**Shelf Life:** Stable up to 12 months from date of shipment

11. Environmental Information:

HMIS	
Health	1
Flammability	0
Reactivity	0
Personal Protection	B
Major Ingredients	**CAS#**
Titanium Dioxide	13463677
Melamine	108781
Vinyl Acetate Latex	25067021
DiPentaerythritol	162-58-9
Ammonium Polyphosphate	6833799
Water	7732185
Aluminum Oxide	142844-00-6
Silicon Dioxide	142844-00-6

12. V.O.C. (V.O.S.): Contains max. 40 gms/liter **V.O.C.**

The NoFire product is listed by Underwriter's Laboratories of the United States as follows:
* Listing number: E129989, Component Flame Retardant Coating, QMOTZ, August 22, 1990
** Classified - COATING FIRE RETARDANT Surface Burning Characteristics R18958

Fire Hazard Classification (as per AST. Eter Board):

Flame Spread: 0 Smoke Developed Value: 0
Toxicity: 0 Military Specification MIL M-14H
U.S. Patent Numbers: 4,879,320; 4,965,296; 5,723,515

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Distributed By:
M and A Supply
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nofire™
TECHNOLOGIES, INC.
21 INDUSTRIAL AVENUE · UPPER SADDLE RIVER, NJ 07458-2301
TEL (201) 818-1616 · FAX (201) 818-8775

URACOAT 3
GENERAL APPLICATION PROCEDURE

1. General Description of the Material

Uracoat 3 is a two component aliphatic urethane enamel with a fire retardant additive, intended for use as a topcoat material over NoFire A, A18 or C9. Uracoat 3 provides a protective barrier for applications requiring high resistance to severe weather, abrasion, corrosive chemicals or fumes. It has excellent retention of color and gloss during long term weather exposure.

Uracoat 3 is not intended to be used as a standalone fire retardant. It is intended only as a topcoating for the NoFire Formulas.

2. Surface Preparation

The surface should be clean, free of dirt, oil, loose scales, loose paint or other foreign matter.

Be sure to allow sufficient time for the NoFire coating to properly cure before applying the Uracoat 3. Curing should be allowed for 48 hours, but no less than 24 hours.

3. Mixing Procedure

Uracoat 3 is mixed using 3 parts (Part A) to 1 part (Part B). Typically, Uracoat 3 Part A is supplied in a short filled container, allowing sufficient space for addition of Part B.

Machine stir contents of part A thoroughly from the bottom. Empty entire contents of Part B into Part A while stirring (Be sure there are no remaining solids on the bottom).

Continue machine stirring for a minimum of ten minutes, or until the material appears smooth and homogenous.

4. Application Procedure with Brush or Roller

Apply the product directly from the container after thoroughly mixed as above. Coat evenly and thoroughly over surface using a natural bristle brush or roller. Do Not apply multiple coats until the surface is completely dry as specified below. Do Not apply when the air temperature or surface temperature is below 40°F (5°C). Do Not apply when the humidity is above 85% RH or during times of any precipitation or when precipitation is expected in under two hours.

Be sure that the entire surface is thoroughly coated, especially regions that are normally not immediately visible (such as joints or underneath overhangs.)

Be sure coating thickness is equal to or greater than the minimum required for the application.

5. **Application procedure with Spray Equipment**

Uracoat 3 can be applied using airless spray equipment. Typical requirements are:

1) Airless spray, 3000 PSI pressure
2) 007 x L spray gun
3) 527 Zip Tip (.027 inch orifice)
4) 1/4 inch paint hose
5) Use suction filter (remove spray gun filter)

Applying with a spray at a distance of 12 to 14 inches from the surface, using even passes and overlapping by 30%.

Be sure that the entire surface is thoroughly coated, especially regions that are normally not immediately visible (such as joint or underneath overhangs).

Be sure coating thickness is equal to or greater than the minimum required for the application.

6. **Testing Thickness**

The coating thickness can be measured using conventional paint thickness measuring gauges for both wet and dry film coating.

Follow the manufacturers procedures for correct use of instruments.

Be sure to allow for shrinkage of the coating after drying.

7. **Warnings**

Use with adequate ventilation. Do Not breathe vapors or spray mist. Wear an appropriate, properly fitted respirator (NIOSH/MSHA) during and after application unless air monitoring demonstrates vapor/mist levels are below applicable limits. Follow respirator manufacturer's directions for respirator use. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling. Use with adequate ventilation.

FIRST AID: In case of eye contact, flush immediately with plenty of water for at least 15 minutes and get medical attention; for skin, wash thoroughly with soap and water. If affected by inhalation of vapor or spray mist, remove to fresh air. If swallowed, get medical attention.

Keep container closed when not in use. In case of spillage absorb with inert material and dispose of in accordance with applicable regulations.

nofire™
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TECHNICAL DATA SHEET
URACOAT 3
2 COMPONENT ALIPHATIC URETHANE ENAMEL

COMPONENT A	PIGMENTED ACRYLIC RESIN
COMPONENT B	CLEAR ALIPHATIC ISOCYANATE
% SOLIDS BY VOLUME:	53%
SPREADING RATE: @ 1.5 MILS DRY	560 SQ. FT. PER GALLON
DRY FILM THICKNESS:	1.5 TO 2.5 MILS PER COAT
MIXING RATIO:	3 (PART A) TO 1 (PART B) BY VOLUME
CURING TIME: TO TOUCH TO RECOAT	2 HOURS 18 HOURS
POT LIFE:	7 HOURS @ 60 F. 4 HOURS @ 77 F. 2 HOURS @ 100 F.
SURFACE TEMPERATURE:	60 F. TO 120 F.
V.O.C.:	3.34 LBS/GALLON

Distributed By:
M and A Supply
150 North Plains Industrial Rd.
Wallingford, CT 06492
Phone: 203-294-9431 Fax: 203-294-1697

TEST RESULTS - PASSES OR EXCEEDS

ABRASION: METHOD:	FED TEST METHOD: STD #141, METHOD 6192, CS-17 WHEEL, 500 GRAMS LOAD. REQUIREMENT: NO MORE THAN 100MG LOSS AFTER 1000 CYCLES
HARDNESS:	METHOD: ASTM D 3363-74 (PENCIL) REQUIREMENT: MUST PASS B. (30 DAYS AT 75 F.)
ADHESION:	METHOD: ELCOMETER ADHESION TESTER. COATING SYSTEMS APPLIED TO SANDBLASTED STEEL PANELS AND CURED FOR 30 DAYS @ 77F. REQUIREMENT: NOT LESS THAN 400 PSI PULL, AVERAGE OF 3 TESTS
FLEXIBILITY:	METHOD: ASTM D 522-60 CONICAL MANDREL. COATINGS APPLIED TO SANDBLASTED STEEL PANELS AND CURED FOR 30 DAYS @ 77F. REQUIREMENT: PASSES 1/8 INCH MANDREL WITH NOT LESS THAN 35% ELONGATION.
HUMIDITY:	METHOD: ASTM D 2247-68 REQUIREMENTS: NO BLISTERING, CRACKING, SOFTENING OR DELAMINATION OF FILM. NO MORE THAN 1/16 IN. RUST CREEPAGE AT SCRIBE AND NO MORE THAN 2% RUSTING AT EDGES AFTER 250 HOURS EXPOSURE.
EXTERIOR EXPOSURE:	METHOD: COATING SYSTEM APPLIED TO SANDBLASTED STEEL PANELS, CURED FOR 7 DAYS @ 77 F. AND EXPOSED AT 45 DEGREES FACING SOUTH. REQUIREMENTS: NO BLISTERING, CRACKING, SOFTENING OR DELAMINATION OF FILM. NO MORE THAN 1.32 IN. RUST CREEPAGE AT SCRIBE AND NO MORE THAN 2% RUSTING AT EDGES AFTER 12 MONTHS EXPOSURE.
MIXING:	STIR CONTENTS OF EACH CONTAINER, MAKING SURE NO PIGMENT REMAINS ON THE BOTTOM. POUR 3 PARTS OF PART A IN A CLEAN CONTAINER AND 1 PART OF PART B TO PART A WHILE UNDER AGITATION. MAKE SURE THEY ARE THOROUGHLY MIXED.
APPLICATION:	CAN BE APPLIED WITH BRUSH, ROLLER OR SPRAY GUN. STIR PAINT THOROUGHLY JUST BEFORE USING. PAINT ONLY WHEN TEMPERATURE OF AIR AND SURFACE IS 45 DEGREES OR HIGHER. DO NOT PAINT ON DAMP OR RAINY DAYS. TO ASSURE PENETRATION INTO CORNERS AND CREVICES, BRUSH OR SPRAY APPLICATION IS PREFERRED. HOWEVER, ROLLER APPLICATION IS SATISFACTORY ON MANY SURFACES.

SGS U.S. Testing Company Inc.

291 Fairfield Avenue
Fairfield, NJ 07004
Tel: 201-575-5252
Fax: 201-575-8271

CLIENT: NoFire Technologies
21 Industrial Ave.
Upper Saddle River, NJ 07458
Attn: Sam Godfried

SUBJECT: Surface Burning Characteristics of Building Materials

AUTHORIZATION: Client's PO no. 98-NF783 dated July 17, 1998

SAMPLE ID: One (1) sample was submitted on July 28, 1998 and identified by the Client as: "0.030 inches wet film thickness NoFire A-18 on Hexcel Panel #6339".

TEST PROCEDURE: The submitted sample was tested for Flammability in accordance with the procedures outlined in ASTM E-84-97a.

TEST DATE: August 04, 1998

PREPARED BY:

Arthur D. Fiorino, Technician
Fire Technology

SIGNED FOR THE COMPANY BY:

Hiten Pandya, Manager
Fire Technology

CLIENT: NoFire Technologies

REPORT OF TEST

TEST PROCEDURE AND RESULTS

INTRODUCTION:

This report presents test results of Flame Spread and Smoke Developed Values per ASTM E-84-97a. The report also includes Material Identification, Method of Preparation, Mounting and Conditioning of the specimens.

The tests were performed in accordance with the specifications set forth in ASTM E-84-97a, "Standard Test Method for Surface Burning Characteristics of Building Materials", both as to equipment and test procedure. This test procedure is similar to UL-723, ANSI No. 2.5, NFPA No. 255 and UBC 42-1.

The test results cover two parameters: Flame Spread and Smoke Developed Values during a 10-minute fire exposure. Inorganic cement board and red oak flooring are used as comparative standards and their responses are assigned arbitrary values of 0 and 100, respectively.

PREPARATION AND CONDITIONING:

Three (3) coated samples, each measuring 2' x 8' were placed end to end to form a 2' x 24' specimen. As the specimen was self-supporting no further preparation was necessary. The sample was conditioned at 73° ± 5° Fahrenheit and 50 ± 5% relative humidity.

TEST PROCEDURE:

The tunnel was thoroughly pre-heated by burning natural gas. When the brick temperature, sensed by a floor thermocouple, had reached the prescribed 105° Fahrenheit ± 5° Fahrenheit level, the sample was inserted in the tunnel and test conducted in accordance with the standard ASTM E-84-97a procedures.

The operation of the tunnel was checked by performing a 10-minute test with inorganic board on the day of the test.

CLIENT: NoFire Technologies

REPORT OF TEST

TEST RESULTS:

The test results, calculated in accordance with ASTM E-84-97a for Flame Spread and Smoke Developed Values are as follows:

Test Specimen	"NoFire A-18"
Flame Spread Index*	9
Smoke Developed Value*	3

*Graphs of the Flame Spread, Smoke Developed and Time-Temperature are shown on the attached charts at the end of this report.

OBSERVATIONS:

Ignition was noted after 25 seconds, along with charring, melting and blistering of the specimen directly exposed to the flame. Also observed was flaming dripping as the flame front advanced a maximum distance of 2 feet after 1.5 minutes. No afterglow or afterburn was evident after test completion.

RATING:

The National Fire Protection Association Life Safety Code 101, Section 6-5.3, "Interior Wall and Ceiling Finish Classification", has a means of classifying materials with respect to Flame Spread and Smoke Developed when tested in accordance with NFPA 255, "Method of Test of Surface Burning Characteristics of Building Materials", (ASTM E-84).

The classifications are as follows:

Class A Interior Wall & Ceiling Finish	Flame Spread - 0-25 Smoke Developed - 0-450
Class B Interior Wall & Ceiling Finish	Flame Spread - 26-75 Smoke Developed - 0-450
Class C Interior Wall & Ceiling Finish	Flame Spread - 76-200 Smoke Developed - 0-450

Since the sample received a Flame Spread of 9 and a Smoke Developed Value of 3 it would fall into the Class A Interior Wall & Ceiling Finish Category.

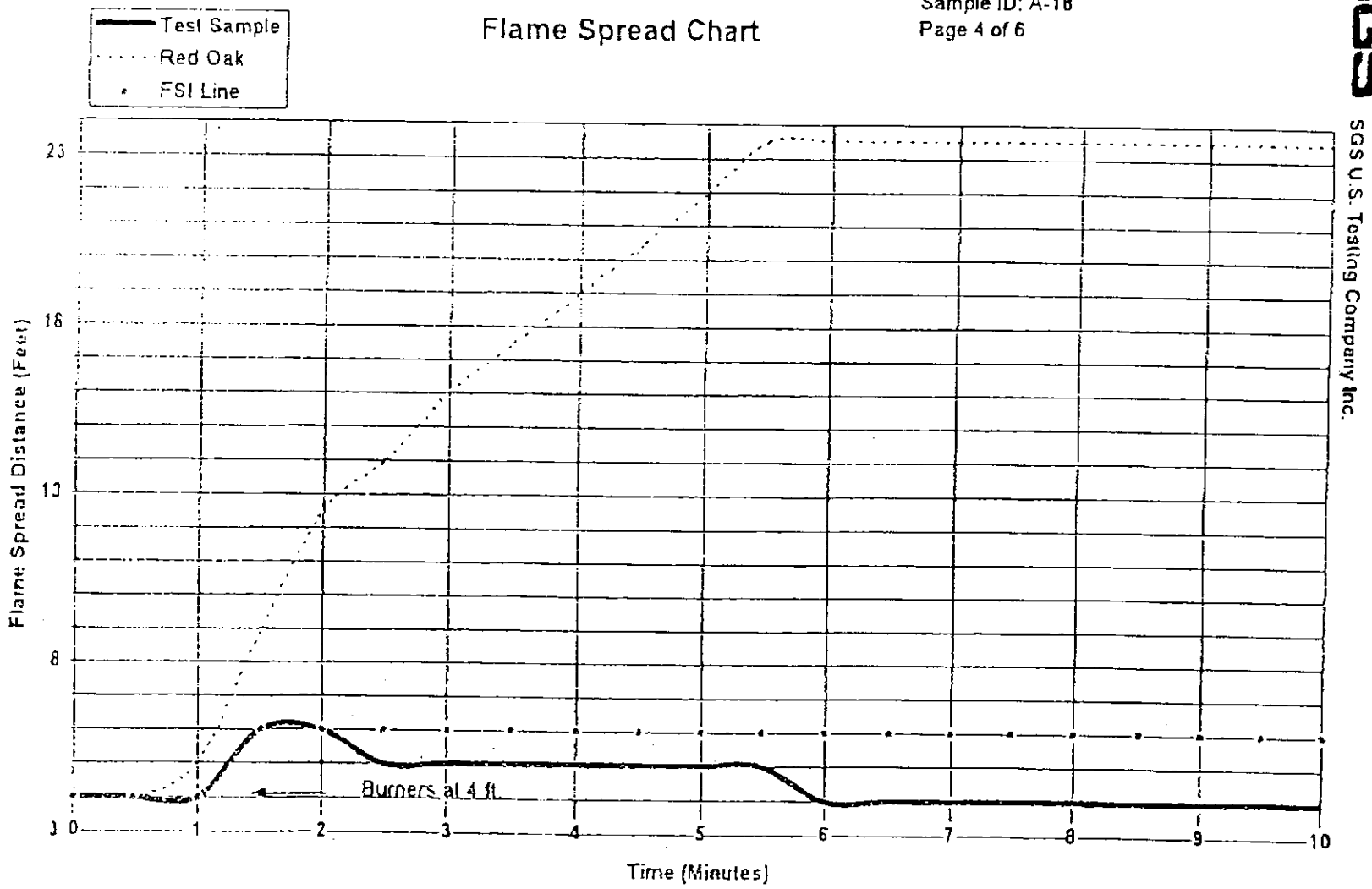
End of Report

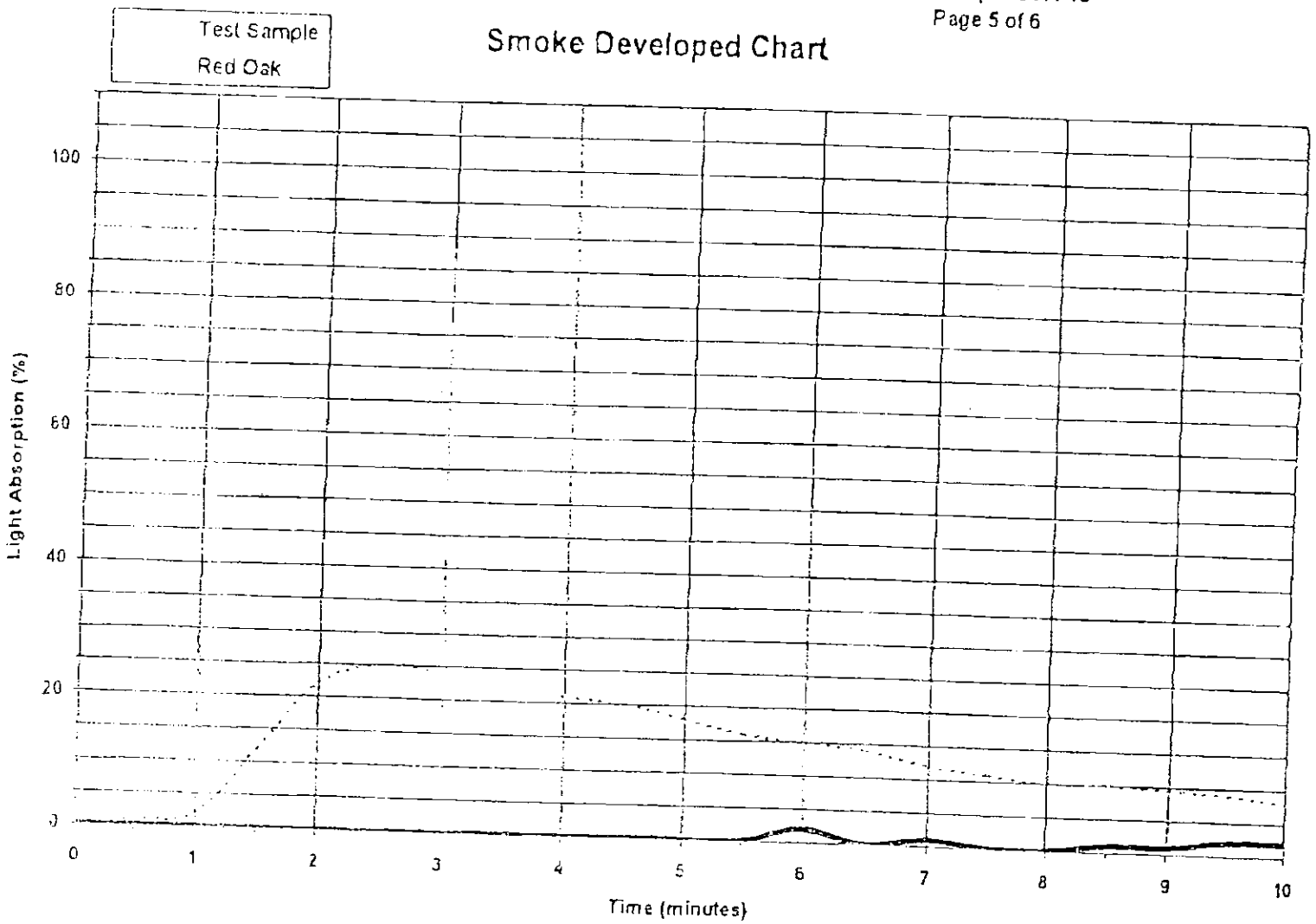
REPORT OF TEST

Client: NoFire Technologies
Report No: 112621-1
Sample ID: A-18

SGS U.S. Testing Company Inc.

Flame Spread Chart

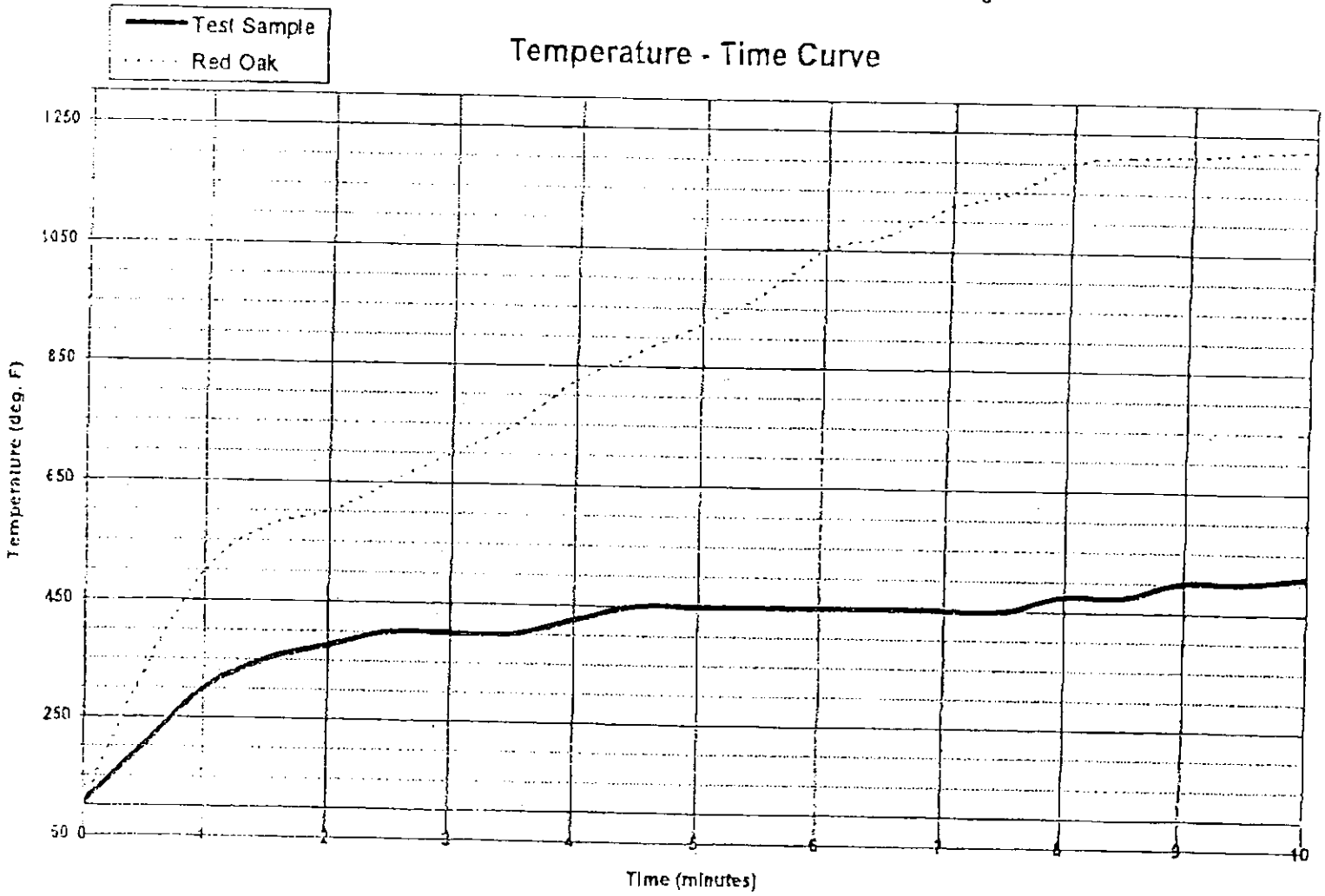




REPORT OF TEST

REPORT OF TEST

Client: NoFire Technologies
Report No: 112621-1
Sample ID: A-18



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Telex No. 6852015

Underwriters Laboratories Inc.®

MELVILLE - January 29, 1990

No Fire Engineering Inc.
Mr. Otis Hastings
21 Industrial Ave.
Upper Saddle River, NJ 07458

Distributed By:
M and A Supply
150 North Plains Industrial Rd.
Wallingford, CT 06492
Phone: 203-294-9431 Fax: 203-294-1697

Our Reference: E129989, 90NE50029, OCDT2

Subject: Insulating Devices and Materials
UL 94 and 746C Flammability Results on Grades PVC-3, PVC-4, AL-2 and SS-1

Gentlemen:

We have conducted UL 94 and 746C Flammability Tests on the subject materials. The following is a summary of the results obtained:

Matl. Dsg.	Color	Min. Thickness (mm)	UL 94 Flammability Classification
PVC-3	NC	4.78	94V-0
		4.78	746-5VS
PVC-4	NC	4.16	94V-0
AL-2	NC	1.70	746-5VS
SS-1	NC	1.65	746-5VS

A final report is being prepared and will be sent to your attention as soon as it is available.

If you have any questions or comments, please feel free to contact us.

Very truly yours,

Robert N. Desa

ROBERT N. DESA
Senior Engineering Assistant
Casualty & Chemical Hazards Dept.

REVIEWED BY:

Thomas H Cybula

THOMAS H. CYBULA
Engineering Group Leader
Casualty & Chemical Hazards Dept.

A. G. BERTRAM
Associate Managing Engineer
Casualty & Chemical Hazards Dept.

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01903556.1

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Underwriters Laboratories Inc.®

MELVILLE - March 15, 1990

No Fire Engineering Inc.
Mr. Otis Hastings
21 Industrial Ave.
Upper Saddle River, NJ 07458

Our Reference: E129989, 90ME50029, QMOT2

Subject: Flame Retardant Coatings
UL 94 and 746C Flammability Results of No Fire-1, Applied to Substrates PVC-3, PVC-4, AL 2 and SS-1

Gentlemen:

We have conducted UL 94 and 746C Flammability Tests on the subject materials. The following is a summary of the results obtained:

Flame Retardant Coating DSG	Flame Retardant Coating mm Min. Thk.	Substrate Matl. Dsg.	Substrate Color	Substrate Min. Thickness (mm)+ Coating	UL94 Flammability Classification
No Fire-1	0.14	PVC-3	NC	4.78	94V-0
				4.78	746-5VS
No Fire-1	0.20	PVC-4	NC	4.16	94V-0
No Fire-1	0.09	AL-2	NC	1.70	746-5VS
No Fire-1	0.17	SS-1	NC	1.65	746-5VS

A final report is being prepared and will be sent to your attention as soon as it is available.

If you have any questions or comments, please feel free to contact us.

Very truly yours,

ROBERT N. DESA
Senior Engineering Assistant
Casualty & Chemical Hazards Dept.

REVIEWED BY:

THOMAS N. CYBULA
Engineering Group Leader
Casualty & Chemical Hazards Dept.

A. G. BERTRAM
Associate Managing Engineer
Casualty & Chemical Hazards Dept.

RND/jf
03902042

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MELVILLE - May 14, 1990

No Fire Engineering Inc.
Mr. Otis Hastings
21 Industrial Avenue
Upper Saddle River, NJ 07458

Our Reference: E129989, 90ME50029

Subject: Surface Resistivity of Flame Retardant Coating NO FIRE-1

Dear Mr. Hastings:

We have completed Surface Resistivity Testing, as described in Section 58 of UL 746C, on your Flame Retardant Coating NO FIRE-1. Testing was conducted on stainless steel substrate SS-1 and PVC substrate PVC-3 and both were found to be in compliance with the standard.

For substrate SS-1, after conditioning of 40 hours at 23°C and 50% R.H., the average Surface Resistivity was 1.1×10^{9} ohms. After conditioning of 168 hours at 35°C and 90% R.H., the average Surface Resistivity was 2.2×10^{6} ohms.

For substrate PVC-3, after conditioning of 40 hours at 23°C and 50% R.H. the average Surface Resistivity was 3.8×10^{11} ohms. After conditioning of 168 hours at 35°C and 90% R.H. the average Surface Resistivity was 2.3×10^{7} ohms.

We have attached Appendix A for your reference.

Additional testing is currently being conducted to cover the other areas outlined in Section 58 of UL 746C, as discussed.

If you have any further questions concerning this matter, please do not hesitate to contact us.

Very truly yours,

ROBERT N. DESA (Ext. 413)
Senior Engineering Assistant
Casualty & Chemical Hazards
Department

REVIEWED BY:

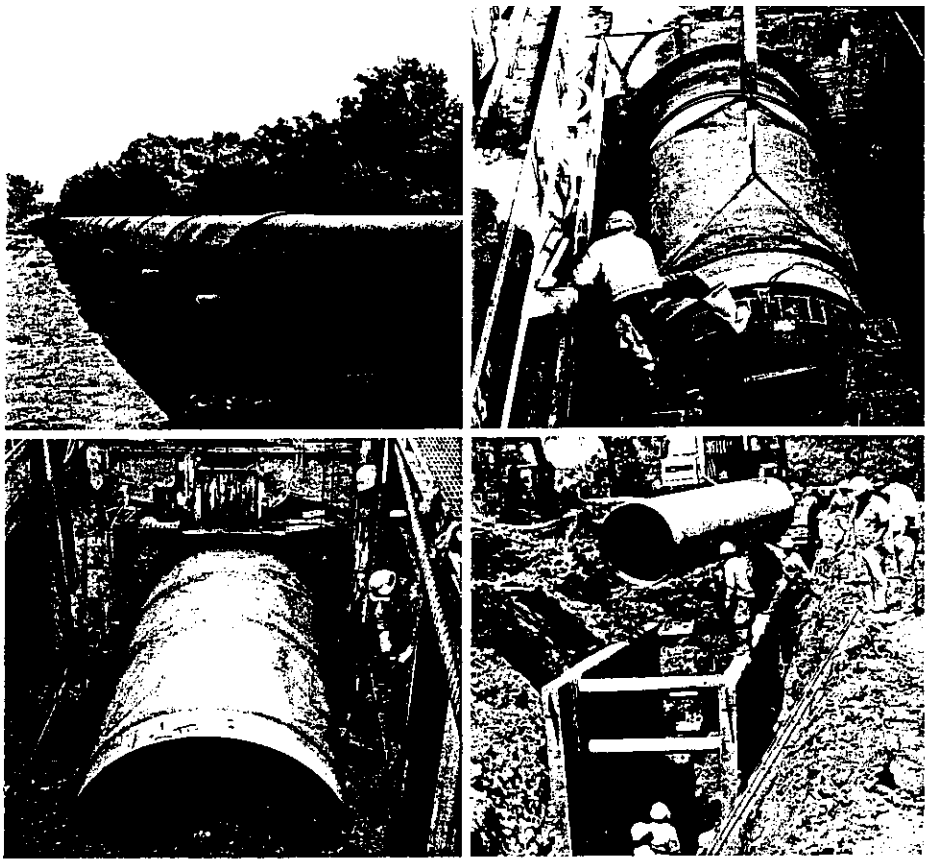
THOMAS H. CYBULA (Ext. 540)
Engineering Group Leader
Casualty & Chemical Hazards
Department

SURFACE RESISTIVITY (ASTM D-257)

MATERIAL: No Fire-1 On Stainless Steel Substrate SS-1

CONDITIONING	SPECIMEN	BRIDGE DIALS		R_s (OHMS)	SURFACE RESISTIVITY (OHMS)
		OHMS	MULTIPLIER		
After 40 Hours at 23°C - 50% R.H.	1	.45	8	$.45 \times 10^8$	1.2×10^9
	2	.43	8	$.43 \times 10^8$	1.1×10^9
	3	.42	8	$.42 \times 10^8$	1.1×10^9
				AVERAGE:	1.1×10^9
After 168 Hours at 35°C - 90% R.H.	1	6.4	4	6.4×10^4	1.7×10^6
	2	8.1	4	8.1×10^4	2.2×10^6
	3	9.6	4	9.6×10^4	2.6×10^6
				AVERAGE:	2.2×10^6
MATERIAL: No Fire-1 On PVC Substrate PVC-3					
After 40 Hours at 23°C - 50% R.H.	1	1.9	10	1.9×10^{10}	5.1×10^{11}
	2	1.4	10	1.4×10^{10}	3.7×10^{11}
	3	1.0	10	1.0×10^{10}	2.7×10^{11}
				AVERAGE:	3.8×10^{11}
After 168 Hours at 35°C - 90% R.H.	1	15.1	5	15.1×10^5	4.0×10^7
	2	8.2	5	8.2×10^5	2.2×10^7
	3	2.1	5	2.1×10^5	0.6×10^7
				AVERAGE:	2.3×10^7

APPENDIX B
(Hobas Pipe Company literature)



Large Diameter Centrifugally Cast Fiberglass Mortar Pipe Product Brochure 12" & Larger

HOBAS

Hobas Pipe USA, Inc.

Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe for Direct Bury Installation - Gravity Service

Part I General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

C. ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings that utilize elastomeric sealing gaskets made of EPDM rubber compound as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize fiberglass, gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: Hobas Pipe USA, Inc.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Coupling joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Burial: The bedding and burial of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 A of the product brochure)

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and coupling components.
2. Apply joint lubricant to pipe ends and elastomeric seals of coupling. Use only lubricants approved by the pipe manufacturer.
3. Use suitable equipment and end protection to push or pull the pipes together.
4. Do not exceed forces recommended by the manufacturer for coupling pipe.
5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.
2. Low Pressure Air Test: Each reach may be tested with air pressure (max 5 psi). The system passes the test if the pressure drop due to leakage through the pipe or pipe joints is less than or equal to the specified amount over the prescribed time period.
3. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.
4. Deflection: Maximum allowable long-term deflection is normally 5% of the initial diameter.

Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe for Sliplining Installation - Gravity Service

PART 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

C. ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

PART 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure.

B. Joints: Unless otherwise specified, the pipe shall be field connected with low-profile, fiberglass bell-spigot joints or flush fiberglass bell-spigot joints, when the fit requires. Either joint shall utilize elastomeric sealing gaskets as the sole means to maintain joint water tightness and shall meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize fiberglass, gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays.

D. Acceptable Manufacturer: Hobas Pipe USA, Inc.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipe barrel shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. When required by radius curves, pit size, sewer irregularities, etc., pipe shall be supplied in nominal lengths of 10 feet or other even divisions of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi (may range from 18 psi to 46 psi and sometimes higher).

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, and Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

PART 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specs and the manufacturer's requirements (Section 14 B of product brochure).

B. Pipe Grouting: Annular space grouting shall not damage the liner and shall conform to the manufacturer's requirements (Section 14 B of product brochure).

C. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

D. Jointing

1. Clean ends of pipe and joint components.
2. Apply joint lubricant to the bell interior surface and the elastomeric seals. Use only lubricants approved by the pipe manufacturer.
3. Use suitable equipment and end protection to push or pull the pipes together.
4. Do not exceed forces recommended by the manufacturer for joining or pushing pipe .
5. Join pipes in straight alignment then deflect to the required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

E. Field Tests

1. Acceptance of the installed liner shall be based on a video taped TV inspection after grouting to assure all joints are properly assembled, no damage exists and that any leakage or deformation is within the allowable limits.

Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe for Jacking Installation - Gravity Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

C. ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings or bell-spigot joints that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. The joint shall have approximately the same O.D. as the pipe, so when the pipes are assembled, the joints are essentially flush with the pipe outside surface. Joints at tie-ins, when needed, may utilize fiberglass, gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: Hobas Pipe USA, Inc.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 10 or 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness, measured at the bottom of the spigot gasket groove where the wall cross-section has been reduced, is determined from the maximum jacking load. Minimum factor of safety against jacking force is 2.5 based on straight alignment.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/16".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 140 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, and Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 C of product brochure).

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and joint components.
2. Apply joint lubricant to the bell interior surface and the elastomeric seals. Use only lubricants approved by the pipe manufacturer.
3. Use suitable equipment and end protection to push the pipes together.
4. Do not exceed forces recommended by the manufacturer for joining or pushing pipe.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.
2. Low Pressure Air Test: Each reach may be tested with air pressure (max 5 psi). The system passes the test if the pressure drop due to leakage through the pipe or pipe joints is less than or equal to the specified amount over the prescribed time period.
3. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.
4. Deflection: Maximum allowable long-term deflection is typically 3% of the initial diameter.

Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe for Above Ground Installation - Gravity Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

C. ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between the purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the pipe.

E. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings that utilize elastomeric sealing gaskets made of EPDM rubber compound as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize fiberglass, gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: Hobas Pipe USA, Inc.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D 3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Coupling joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 18 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Custom
Should the Owner request to see spec
pipes during any phase of the manufa
turing process, the manufacturer must p
vide the Owner with adequate advance r
tice of when and where the production
those pipes will take place.

2.06 Packaging, Handling, Shipping

A. Packaging, handling, and shipping shall b
done in accordance with the manufac
turer's instructions.

Part 3 Execution

3.01 Installation

A. The installation of pipe and fittings shal
be in accordance with the project plans
and specifications and the manufacturer's
requirements (Section 14 D of the prod
uct brochure).

B. Pipe Handling: Use textile slings, other
suitable materials or a forklift. Use of
chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and coupling components.
2. Apply joint lubricant to pipe ends and the elastomeric seals of coupling. Use only lubricants approved by the pipe manufacturer.
3. Use suitable equipment and end protection to push or pull the pipes together.
4. Do not exceed forces recommended by the manufacturer for coupling pipe.
5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.
2. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.

Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe for Tunnel Carrier Installation - Gravity Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

C. ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between the purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings or bell-spigot joints, "flush" or "non-flush", that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize fiberglass, gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: Hobas Pipe USA, Inc.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. When required by radius curves, pit size, or other limitations restrict the pipe to shorter lengths, nominal sections of 10 feet or other even divisions of 20 feet shall be used. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 E of the product brochure).

B. Pipe Grouting: Annular space grouting shall not damage the liner and shall conform to the manufacturer's requirements (Section 14 E of product brochure).

C. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

D. Jointing:

1. Clean ends of pipe and coupling components.
2. Apply joint lubricant to pipe ends or bell interior surfaces and the elastomeric seals. Use only lubricants approved by the pipe manufacturer.
3. Use suitable equipment and end protection to push or pull the pipes together.
4. Do not exceed forces recommended by the manufacturer for joining or pushing pipe.
5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

E. Field Tests

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.
2. Low Pressure Air Test: Each reach may be tested with air pressure (max 5 psi). The system passes the test if the pressure drop due to leakage through the pipe or pipe joints is less than or equal to the specified amount over the prescribed time period.
3. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.
4. Deflection: Maximum allowable long-term deflection is normally 5% of the initial diameter.

Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe for Pressure Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3754 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe.

B. AWWA C950 - AWWA Standard for Fiberglass Pressure Pipe

C. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

D. ASTM D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The pipe nominal pressure class (PN) shall be equal to or greater than the maximum sustained operating pressure of the line. The maximum transient (operating plus surge) pressure of the line shall not exceed the pipe nominal pressure class by more than 40%.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings that utilize elastomeric sealing gaskets made of EPDM rubber compound as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Tie-ins, when needed, may utilize gasket-sealed mechanical couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used. Unbalanced thrust forces shall be restrained with thrust blocks or other suitable methods. Fiberglass tees, wyes, laterals, or other similar fittings shall be fully encased in reinforced concrete designed to withstand the pressure forces.

D. Acceptable Manufacturer: Hobas Pipe USA, Inc.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with AWWA C950. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of $^1/_8$".

2.04 Testing

A. Pipes: Pipes shall be manufactured in accordance with the applicable standard.

B. Joints: Coupling joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi.

D. Tensile Strength: Pipe hoop tensile strength for pressure pipe shall be verified as specified in applicable standard (ASTM D3754 or AWWA C950) or by random burst testing at the same sampling frequency. All pipes shall be capable of withstanding a test pressure of two (2) times the maximum sustained operating pressure of the line without leaking or cracking. This performance shall be verified as agreed between the buyer and seller.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, and Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 of product brochure).

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and coupling components.
2. Apply joint lubricant to pipe ends and the elastomeric seals of coupling. Use only lubricants approved by the pipe manufacturer.
3. Use suitable equipment and end protection to push or pull the pipes together.
4. Do not exceed forces recommended by the manufacturer for coupling pipe.
5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

D. Field Tests:

1. Pressure Test: Pressure pipes may be field tested after completion of the installation (including required thrust restraints) at a maximum pressure of 1.5 times the system operating pressure not to exceed 1.5 x PN. Prior to testing, assure that all work has been properly completed.

   When filling the line assure that all air is expelled to avoid dangerous build-up of compressed air potential energy. Pressurize the line slowly, so pressure surges exceeding test pressures are not developed. Check for leaks when the test pressure has stabilized.

2. Deflection: Maximum Allowable long-term deflection is normally 5% of the initial diameter.

Appendix B Pipe Dimensions & Weights

Class SN 18* (minimum pipe stiffness of 18 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN**/SN					
		0 /18		50/18		100/18	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
12	13.45	0.22	10	0.22	10	0.21	9
18	19.5	0.30	19	0.29	19	0.29	18
20	21.6	0.32	23	0.32	23	0.32	22
24	25.8	0.38	32	0.37	31	0.37	30
26	28.0	0.41	38	0.40	37	0.40	35
28	30.0	0.43	42	0.43	42	0.42	39
30	32.0	0.46	48	0.45	47	0.45	45
33	34.0	0.48	53	0.48	53	0.47	50
36	38.3	0.54	67	0.53	66	0.52	61
40	42.9	0.60	83	0.59	82	0.58	77
42	44.5	0.62	89	0.61	88	0.60	82
43	45.9	0.64	95	0.63	93	0.62	87
45	47.7	0.66	101	0.65	100	0.64	94
48	50.8	0.70	114	0.69	113	0.68	106
51	53.9	0.74	128	0.73	126	0.72	118
54	57.1	0.78	143	0.77	141	0.76	132
57	60.0	0.82	157	0.81	155	0.80	146
60	62.9	0.86	173	0.84	169	0.83	159
63	66.0	0.90	189	0.88	185	0.87	174
66	69.2	0.94	207	0.92	203	0.91	191
69	72.5	0.98	226	0.97	224	0.95	209
72	75.4	1.02	245	1.00	240	0.99	226
78	81.6	1.10	285	1.08	280	1.07	264
82	87.0	1.17	323	1.15	318	1.13	297
84	88.6	1.19	334	1.17	329	1.15	308
90	94.3	1.26	377	1.24	371	1.22	347
96	99.5	1.33	419	1.31	413	1.29	387
102	108.0	1.44	492	1.42	485	1.40	455

* Normally not available for direct bury.

** Maximum nominal working pressure class in psi.

Class SN 36 (minimum pipe stiffness of 36 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN*/SN									
		0 /36		50/36		100/36		150/36		200/36	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
12	13.45	0.26	12	0.26	12	0.26	11	0.25	10	0.25	10
18	19.5	0.36	23	0.36	23	0.35	21	0.35	21	0.34	20
20	21.6	0.40	28	0.39	28	0.39	26	0.38	25	0.37	24
24	25.8	0.46	39	0.46	39	0.45	36	0.45	35	0.44	33
26	28.0	0.50	45	0.50	45	0.49	42	0.48	40	0.47	38
28	30.0	0.53	51	0.53	51	0.52	48	0.51	45	0.50	44
30	32.0	0.57	59	0.56	58	0.55	54	0.54	51	0.53	49
33	34.0	0.60	66	0.59	64	0.58	60	0.57	57	0.56	55
36	38.3	0.67	82	0.66	81	0.65	76	0.64	72	0.63	69
40	42.9	0.74	101	0.74	101	0.73	95	0.71	89	0.70	86
42	44.5	0.77	109	0.76	108	0.75	101	0.74	96	0.72	92
43	45.9	0.79	116	0.79	116	0.77	107	0.76	102	0.74	97
45	47.7	0.82	125	0.81	123	0.80	116	0.78	109	0.77	105
48	50.8	0.87	141	0.86	139	0.85	131	0.83	123	0.82	119
51	53.9	0.92	157	0.91	156	0.90	147	0.88	138	0.86	132
54	57.1	0.97	176	0.97	176	0.95	164	0.93	155	0.91	148
57	60.0	1.02	194	1.01	192	1.00	181	0.98	171		
60	62.9	1.07	213	1.06	211	1.04	197	1.02	186		
63	66.0	1.12	234	1.11	232	1.09	217	1.06	203		
66	69.2	1.17	256	1.16	254	1.14	237	1.12	225		
69	72.5	1.22	279	1.21	277	1.20	261	1.17	246		
72	75.4	1.27	302	1.26	300	1.24	281	1.21	264		
78	81.6	1.37	353	1.36	350	1.34	328	1.31	309		
82	87.0	1.46	400	1.45	398	1.43	373				
84	88.6	1.49	416	1.48	413	1.45	385				
90	94.3	1.58	469	1.57	466	1.54	435				
96	99.5	1.66	520	1.65	516	1.62	482				
102	108.0	1.80	611	1.79	608	1.76	568				

* Maximum nominal working pressure class in psi.

Class SN 46 (minimum pipe stiffness of 46 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN*/SN									
		0/46		50/46		100/46		150/46		200/46	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
12	13.45	0.28	13	0.28	13	0.28	12	0.27	11	0.27	11
18	19.5	0.39	25	0.39	25	0.38	23	0.37	22	0.37	21
20	21.6	0.43	30	0.42	29	0.42	28	0.41	27	0.40	25
24	25.8	0.50	42	0.50	42	0.49	39	0.48	37	0.47	35
26	28.0	0.54	49	0.53	48	0.53	46	0.52	43	0.51	41
28	30.0	0.57	55	0.57	55	0.56	51	0.55	49	0.54	47
30	32.0	0.61	63	0.60	62	0.60	59	0.58	55	0.57	53
33	34.0	0.64	70	0.64	70	0.63	65	0.62	62	0.60	59
36	38.3	0.72	88	0.72	88	0.70	81	0.69	77	0.68	75
40	42.9	0.80	109	0.80	109	0.78	101	0.77	96	0.75	92
42	44.5	0.83	117	0.82	116	0.81	109	0.79	103	0.78	99
43	45.9	0.85	124	0.85	124	0.84	117	0.82	110	0.80	105
45	47.7	0.89	135	0.88	133	0.87	125	0.85	118	0.83	113
48	50.8	0.94	151	0.93	150	0.92	141	0.90	133	0.88	127
51	53.9	1.00	171	0.99	169	0.97	158	0.95	149	0.93	142
54	57.1	1.05	190	1.04	188	1.03	177	1.01	167	0.98	159
57	60.0	1.10	209	1.09	207	1.08	195	1.05	183		
60	62.9	1.15	228	1.15	228	1.13	213	1.10	200		
63	66.0	1.21	252	1.20	250	1.18	234	1.15	220		
66	69.2	1.27	277	1.26	275	1.24	257	1.21	242		
69	72.5	1.32	301	1.31	299	1.29	280	1.26	264		
72	75.4	1.38	328	1.36	323	1.34	303	1.31	285		
78	81.6	1.48	380	1.47	377	1.45	354	1.42	334		
82	87.0	1.58	432	1.57	429	1.54	400				
84	88.6	1.61	448	1.60	445	1.57	416				
90	94.3	1.71	506	1.69	500	1.67	470				
96	99.5	1.80	562	1.79	559	1.76	522				
102	108.0	1.95	660	1.93	654	1.90	612				

* Maximum nominal working pressure class in psi.

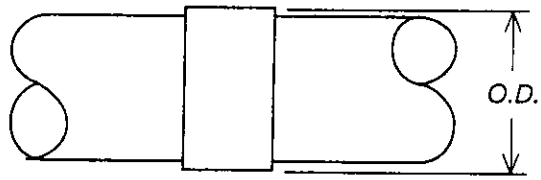
Class SN 72 (minimum pipe stiffness of 72 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN*/SN									
		0 & 50/72		100/72		150/72		200/72		250/72	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
12	13.45	0.32	14	0.31	13	0.31	13	0.31	12	0.30	12
18	19.5	0.44	28	0.44	26	0.43	25	0.42	24	0.42	24
20	21.6	0.49	34	0.48	32	0.47	30	0.47	29	0.46	28
24	25.8	0.57	47	0.56	44	0.56	42	0.55	41	0.54	40
26	28.0	0.62	55	0.61	52	0.60	49	0.59	47	0.58	46
28	30.0	0.66	63	0.65	59	0.64	56	0.63	54	0.62	52
30	32.0	0.70	71	0.69	67	0.68	64	0.67	61	0.66	59
33	34.0	0.74	80	0.73	75	0.72	71	0.71	69		
36	38.3	0.83	101	0.81	94	0.80	89	0.79	86		
40	42.9	0.92	125	0.91	117	0.89	111	0.88	107		
42	44.5	0.95	134	0.94	126	0.93	120	0.91	115		
43	45.9	0.98	142	0.97	134	0.95	126	0.94	122		
45	47.7	1.02	153	1.00	143	0.99	137	0.97	131		
48	50.8	1.08	173	1.07	163	1.05	154	1.03	148		
51	53.9	1.15	195	1.13	182	1.11	173	1.10	167		
54	57.1	1.21	217	1.19	203	1.17	193	1.16	187		
57	60.0	1.27	239	1.25	224	1.23	212				
60	62.9	1.33	263	1.31	246	1.29	233				
63	66.0	1.39	288	1.37	270	1.35	256				
66	69.2	1.46	317	1.44	297	1.41	280				
69	72.5	1.53	348	1.50	324	1.48	308				
72	75.4	1.59	375	1.56	350	1.54	333				
78	81.6	1.71	437	1.69	410	1.66	388				
82	87.0	1.82	495	1.79	463						
84	88.6	1.86	515	1.83	482						
90	94.3	1.97	581	1.94	543						
96	99.5	2.08	646	2.05	605						
102	108.0	2.25	758	2.22	711						

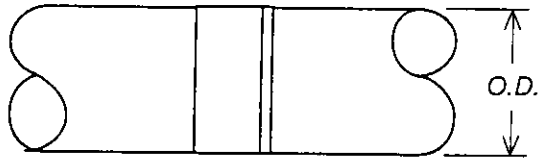
* Maximum nominal working pressure class in psi.

Appendix C Joint Dimensions & Weights

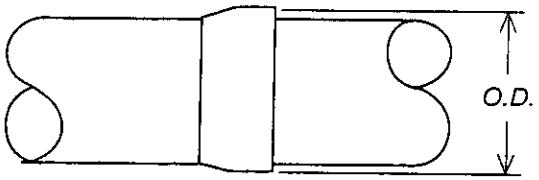
Nominal Pipe Size (in.)	Nominal Outside Diameter, OD (in.)							
	FWC Coupling					Low Profile Bell	Flush Bell-Spigot	Pressure Relining
	PN 0 PN 50	PN 100	PN 150	PN 200	PN 250			
12	15.2	15.2	15.2	15.2	15.3	14.3	13.5	
18	21.3	21.3	21.3	21.3	21.4	20.4	19.5	
20	23.4	23.4	23.4	23.4	23.6	22.5	21.6	
24	27.6	27.6	27.6	27.7	27.9	26.8	25.8	
26	29.8	29.8	29.8	30.0	30.2	29.0	28.0	
28	31.9	31.9	32.0	32.1	32.3	31.0	30.0	
30	33.9	33.9	34.0	34.2	34.4	33.0	32.0	
33	35.9	35.9	36.1	36.3		35.0	34.0	
36	40.2	40.2	40.4	40.6		39.3	38.3	FWC
40	44.9	44.9	45.2	45.5		44.0	42.9	
42	46.5	46.5	46.8	47.2		45.6	44.5	
43	47.9	47.9	48.2	48.6		47.0	45.9	
45	49.7	49.7	50.0	50.4		48.8	47.7	
48	52.8	52.9	53.2	53.6		51.9	50.8	
51	56.0	56.1	56.5	56.8		55.0	53.9	O.D.'s Plus
54	59.2	59.4	59.8	60.1		58.2	57.1	
57	62.2	62.5	62.8			61.2	60.0	
60	65.2	65.5	65.9			64.1	62.9	
63	68.3	68.7	69.1			67.2	66.0	
66	71.6	72.0	72.4			70.4	69.2	0.4
69	74.9	75.4	75.8			73.8	72.5	
72	77.9	78.3	78.8			76.7	75.4	
78	84.2	84.7	85.3			82.9	81.6	
82	89.6	90.2				88.4	87.0	
84	91.4	92.0				90.0	88.6	
90	97.1	97.8				95.7	94.3	
96	102.5	103.1				101.0	99.5	
102	111.1	111.7				109.5	108.0	



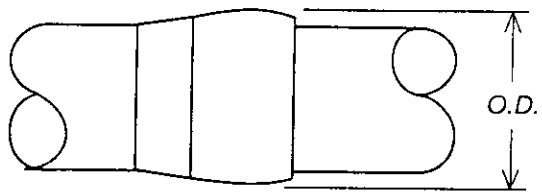
FWC COUPLING



FLUSH BELL-SPIGOT



LOW PROFILE BELL



PRESSURE RELINING

C

Nominal Pipe Size (in.)	FWC Coupling Nominal Weight (lb.)				
	PN 0 PN 50	PN 100	PN 150	PN 200	PN 250
12	14	14	14	14	19
18	20	20	20	20	26
20	22	22	22	28	32
24	34	34	34	37	53
26	37	37	37	42	60
28	40	40	40	47	68
30	42	42	45	53	76
33	45	45	48	59	
36	51	51	57	69	
40	57	57	69	83	
42	59	59	73	111	
43	61	61	77	117	
45	63	63	81	123	
48	67	70	90	135	
51	71	77	120	150	
54	75	83	133	165	
57	80	89	148		
60	112	140	170		
63	118	151	192		
66	124	163	215		
69	133	177	234		
72	142	191	252		
78	155	205	300		
82	167	236			
84	172	245			
90	187	274			
96	201	300			
102	223	343			

Appendix D: Pipe Material Properties and Characteristics

Material properties of Hobas Pipe USA pipes exceed the requirements of ASTM D3262 for non-pressure applications and of AWWA C950 for pressure service. Actual properties vary depending on pressure and stiffness class. The following range of values covers most pipe constructions. For values specific to individual pipes contact Hobas Pipe USA, Inc.

Pipe Property	Range of Values[1]	
E-Modulus[1] (10^6 psi):	PN 0	PN 50 to 250
* Circumferential Flexural	1.0 to 1.9	1.3 to 2.4
* Circumferential Tensile	–	0.5 to 2.8
* Axial Tensile	0.4 to 0.8	0.4 to 1.7
Strength[1] (10^3 psi):		
* Circumferential Tensile	–	7.0 to 33.0
* Axial Tensile	1.4 to 2.1	1.4 to 6.4
* Compressive	10.5	12.6
Thermal Coefficient of Linear Expansion (axial)	16×10^{-6}	in./in./°F.

Note 1: Values given are for the reinforced wall (ie. Liner is not included.)

Flow Factors vary somewhat with pipe diameter and flow rate. The following values have been found to be typically representative long-term and are commonly used.

* *Hazen-Williams*	*"C" 155*
* *Manning's*	*"n" 0.009*

Appendix G Deflected Pipe Minimum Inside Diameters

Class SN 18

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN/SN					
		0 /18		50/18		100/18	
		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
12	13.45	12.48	12.22	12.48	12.22	12.50	12.24
18	19.5	18.18	17.81	18.20	17.83	18.20	17.83
20	21.6	20.18	19.76	20.18	19.76	20.18	19.76
24	25.8	24.13	23.63	24.15	23.65	24.15	23.65
26	28.0	26.20	25.66	26.22	25.68	26.22	25.68
28	30.0	28.10	27.52	28.10	27.52	28.12	27.54
30	32.0	29.98	29.36	30.00	29.38	30.00	29.38
33	34.0	31.88	31.22	31.88	31.22	31.90	31.24
36	38.3	35.92	35.18	35.94	35.20	35.97	35.22
40	42.9	40.26	39.43	40.28	39.45	40.30	39.47
42	44.5	41.77	40.91	41.79	40.93	41.81	40.95
43	45.9	43.09	42.20	43.11	42.22	43.13	42.24
45	47.7	44.80	43.87	44.82	43.89	44.84	43.91
48	50.8	47.72	46.74	47.74	46.76	47.76	46.78
51	53.9	50.64	49.60	50.67	49.62	50.69	49.64
54	57.1	53.67	52.56	53.69	52.58	53.71	52.60
57	60.0	56.40	55.23	56.42	55.25	56.44	55.27
60	62.9	59.13	57.91	59.17	57.95	59.19	57.97
63	66.0	62.05	60.77	62.09	60.81	62.11	60.83
66	69.2	65.07	63.73	65.12	63.77	65.14	63.79
69	72.5	68.19	66.79	68.21	66.81	68.26	66.85
72	75.4	70.92	69.46	70.97	69.50	70.99	69.52
78	81.6	76.77	75.19	76.81	75.23	76.84	75.25
82	87.0	81.87	80.18	81.91	80.22	81.95	80.26
84	88.6	83.38	81.66	83.42	81.70	83.46	81.74
90	94.3	88.76	86.93	88.80	86.97	88.85	87.01
96	99.5	93.66	91.73	93.70	91.77	93.75	91.81
102	108.0	101.68	99.59	101.72	99.63	101.76	99.67

Class SN 36

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN/SN									
		0 /36		50/36		100/36		150/36		200/36	
		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
12	13.45	12.40	12.14	12.40	12.14	12.40	12.14	12.42	12.16	12.42	12.16
18	19.5	18.06	17.69	18.06	17.69	18.08	17.71	18.08	17.71	18.10	17.73
20	21.6	20.01	19.60	20.03	19.62	20.03	19.62	20.05	19.64	20.07	19.66
24	25.8	23.96	23.47	23.96	23.47	23.98	23.49	23.98	23.49	24.00	23.51
26	28.0	26.02	25.48	26.02	25.48	26.04	25.50	26.06	25.52	26.08	25.54
28	30.0	27.89	27.32	27.89	27.32	27.91	27.34	27.93	27.36	27.96	27.38
30	32.0	29.75	29.14	29.77	29.16	29.79	29.18	29.81	29.20	29.83	29.22
33	34.0	31.63	30.98	31.65	31.00	31.67	31.02	31.69	31.04	31.71	31.06
36	38.3	35.66	34.92	35.68	34.94	35.70	34.96	35.72	34.98	35.74	35.00
40	42.9	39.97	39.15	39.97	39.15	40.00	39.17	40.04	39.21	40.06	39.23
42	44.5	41.47	40.61	41.49	40.63	41.51	40.65	41.53	40.67	41.57	40.71
43	45.9	42.78	41.90	42.78	41.90	42.82	41.94	42.84	41.96	42.88	42.00
45	47.7	44.47	43.55	44.49	43.57	44.51	43.59	44.55	43.63	44.57	43.65
48	50.8	47.37	46.39	47.39	46.41	47.41	46.43	47.45	46.47	47.47	46.49
51	53.9	50.27	49.24	50.30	49.26	50.32	49.28	50.36	49.32	50.40	49.36
54	57.1	53.28	52.18	53.28	52.18	53.32	52.22	53.36	52.26	53.40	52.30
57	60.0	55.99	54.83	56.01	54.85	56.03	54.87	56.07	54.91		
60	62.9	58.70	57.49	58.72	57.51	58.76	57.55	58.80	57.59		
63	66.0	61.60	60.33	61.62	60.35	61.66	60.39	61.72	60.45		
66	69.2	64.60	63.27	64.62	63.29	64.66	63.33	64.70	63.37		
69	72.5	67.70	66.30	67.72	66.32	67.74	66.34	67.80	66.40		
72	75.4	70.41	68.96	70.43	68.98	70.47	69.02	70.53	69.08		
78	81.6	76.22	74.65	76.24	74.67	76.28	74.71	76.34	74.77		
82	87.0	81.27	79.60	81.29	79.62	81.33	79.66				
84	88.6	82.76	81.06	82.78	81.08	82.84	81.14				
90	94.3	88.11	86.29	88.13	86.31	88.19	86.37				
96	99.5	92.98	91.07	93.01	91.09	93.07	91.15				
102	108.0	100.94	98.86	100.96	98.88	101.02	98.94				

Class SN 46

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN/SN									
		0/46		50/46		100/46		150/46		200/46	
		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
12	13.45	12.35	12.10	12.35	12.10	12.35	12.10	12.37	12.12	12.37	12.12
18	19.5	18.00	17.63	18.00	17.63	18.02	17.65	18.04	17.67	18.04	17.67
20	21.6	19.95	19.54	19.97	19.56	19.97	19.56	19.99	19.58	20.01	19.60
24	25.8	23.88	23.39	23.88	23.39	23.90	23.41	23.92	23.43	23.94	23.45
26	28.0	25.93	25.40	25.95	25.42	25.95	25.42	25.97	25.44	25.99	25.46
28	30.0	27.81	27.24	27.81	27.24	27.83	27.26	27.85	27.28	27.87	27.30
30	32.0	29.67	29.06	29.69	29.08	29.69	29.08	29.73	29.12	29.75	29.14
33	34.0	31.55	30.90	31.55	30.90	31.57	30.92	31.59	30.94	31.63	30.98
36	38.3	35.55	34.82	35.55	34.82	35.60	34.86	35.62	34.88	35.64	34.90
40	42.9	39.85	39.03	39.85	39.03	39.89	39.07	39.91	39.09	39.95	39.13
42	44.5	41.34	40.49	41.36	40.51	41.38	40.53	41.42	40.57	41.44	40.59
43	45.9	42.66	41.78	42.66	41.78	42.68	41.80	42.72	41.84	42.76	41.88
45	47.7	44.32	43.41	44.34	43.43	44.36	43.45	44.40	43.49	44.45	43.53
48	50.8	47.23	46.25	47.25	46.27	47.27	46.29	47.31	46.33	47.35	46.37
51	53.9	50.11	49.08	50.13	49.10	50.17	49.14	50.21	49.18	50.25	49.22
54	57.1	53.11	52.02	53.13	52.04	53.15	52.06	53.19	52.10	53.26	52.16
57	60.0	55.82	54.67	55.84	54.69	55.86	54.71	55.92	54.77		
60	62.9	58.53	57.32	58.53	57.32	58.57	57.37	58.63	57.43		
63	66.0	61.42	60.15	61.44	60.17	61.48	60.21	61.54	60.27		
66	69.2	64.40	63.07	64.42	63.09	64.46	63.13	64.52	63.19		
69	72.5	67.49	66.10	67.51	66.12	67.56	66.16	67.62	66.22		
72	75.4	70.18	68.74	70.22	68.78	70.27	68.82	70.33	68.88		
78	81.6	75.99	74.43	76.01	74.45	76.05	74.49	76.12	74.55		
82	87.0	81.02	79.35	81.05	79.37	81.11	79.43				
84	88.6	82.51	80.81	82.54	80.83	82.60	80.89				
90	94.3	87.84	86.03	87.88	86.07	87.92	86.11				
96	99.5	92.70	90.79	92.72	90.81	92.78	90.87				
102	108.0	100.63	98.56	100.67	98.60	100.74	98.66				

Class SN 72

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN/SN									
		0/72 & 50/72		100/72		150/72		200/72		250/72	
		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
12	13.45	12.27	12.02	12.29	12.04	12.29	12.04	12.29	12.04	12.31	12.06
18	19.5	17.89	17.52	17.89	17.52	17.91	17.54	17.93	17.57	17.93	17.57
20	21.6	19.83	19.42	19.85	19.44	19.87	19.46	19.88	19.47	19.89	19.48
24	25.8	23.74	23.25	23.76	23.27	23.76	23.27	23.78	23.29	23.80	23.31
26	28.0	25.77	25.24	25.79	25.26	25.81	25.28	25.83	25.30	25.85	25.32
28	30.0	27.63	27.06	27.65	27.08	27.67	27.10	27.69	27.12	27.71	27.14
30	32.0	29.48	28.88	29.50	28.90	29.53	28.92	29.55	28.94	29.57	28.96
33	34.0	31.34	30.70	31.36	30.72	31.38	30.74	31.40	30.76		
36	38.3	35.33	34.60	35.37	34.64	35.39	34.66	35.41	34.68		
40	42.9	39.60	38.79	39.63	38.81	39.67	38.85	39.69	38.87		
42	44.5	41.10	40.25	41.12	40.27	41.14	40.29	41.18	40.33		
43	45.9	42.39	41.52	42.41	41.54	42.45	41.58	42.47	41.60		
45	47.7	44.06	43.15	44.10	43.19	44.12	43.21	44.16	43.25		
48	50.8	46.94	45.97	46.96	45.99	47.00	46.03	47.04	46.07		
51	53.9	49.80	48.77	49.84	48.82	49.88	48.86	49.90	48.88		
54	57.1	52.78	51.69	52.82	51.73	52.86	51.77	52.89	51.79		
57	60.0	55.47	54.33	55.51	54.37	55.55	54.41				
60	62.9	58.16	56.96	58.20	57.00	58.24	57.04				
63	66.0	61.05	59.79	61.09	59.83	61.13	59.87				
66	69.2	64.01	62.69	64.05	62.73	64.11	62.79				
69	72.5	67.06	65.68	67.12	65.74	67.17	65.78				
72	75.4	69.75	68.31	69.81	68.37	69.85	68.41				
78	81.6	75.52	73.96	75.56	74.00	75.62	74.06				
82	87.0	80.53	78.87	80.59	78.93						
84	88.6	82.00	80.31	82.06	80.37						
90	94.3	87.30	85.50	87.37	85.56						
96	99.5	92.12	90.22	92.18	90.28						
102	108.0	100.02	97.95	100.08	98.02						