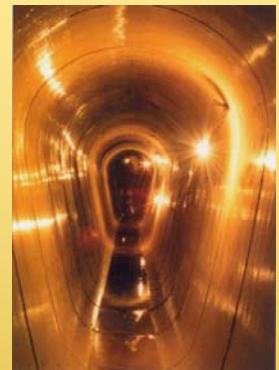
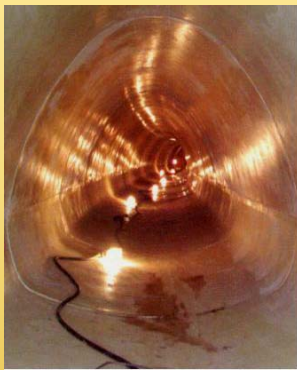


# CHANNELINE



## GRP STRUCTURAL LINING SYSTEMS

For large diameter Circular and Non-circular  
Pipeline Rehabilitation



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11/2007

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# INTRODUCTION

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Large diameter pipelines and culverts represent the backbone of any city's utility network for the collection and disposal of sewerage and effective drainage of storm-water.

In many cases the fabric of these pipelines, which may consist of brick, stone, concrete or clayware will have been constructed decades ago and although proven resilient, has eventually succumbed to the ravages of time, suffering the effects of H<sub>2</sub>S attack or erosion and may even be exhibiting signs of imminent failure due to structural

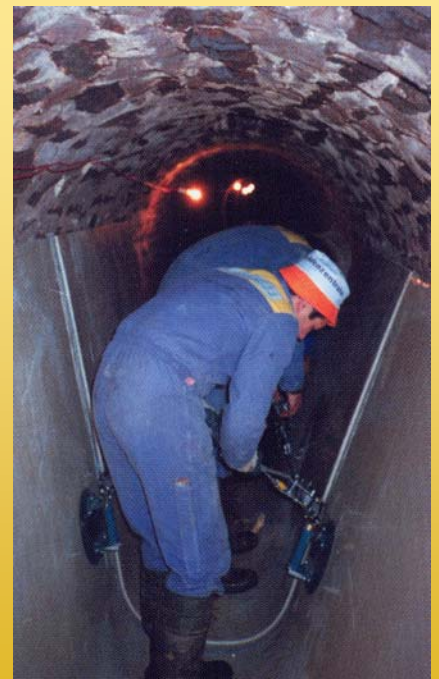
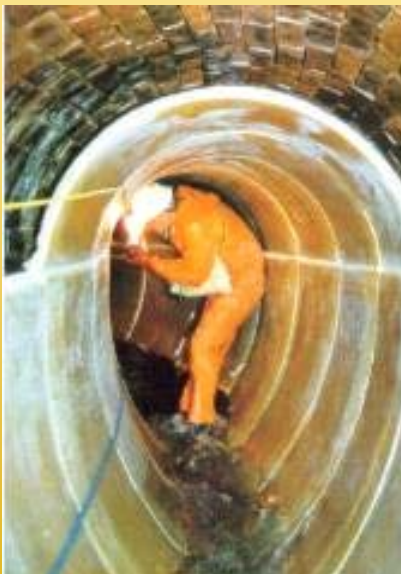
loading beyond that of its remaining capability.

At this point the need arises to consider the means by which the structural rehabilitation of these pipelines and ducts can be achieved whereby a new, 50-year plus life expectancy can be provided with a high degree of confidence.

Channeline has been involved in the provision of specialist GRP structural lining elements for just this requirement for over 25 years during which time we have accumulated an

unrivalled degree of experience relative to the rehabilitation of both circular and non-circular large diameter buried pipeline structures worldwide.

We have grown to be a global business based on the integrity and performance of the product we design and manufacture. We are proud of our heritage and committed to serve our existing and future customers in the water and wastewater industries.



# HISTORY

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Channeline International truly does have its roots firmly in the history of investigation, design and engineering of structural liner solutions for the large diameter pipeline industry.

Originally formed in the 1970's as a design consultancy company, specifically to offer services for pipeline corrosion and structural studies for the chemical, pharmaceutical and water industries, we were working on potential solutions to problems relative to structural and



corrosion failures in large diameter sewers for major water companies in Europe, as far back as 1978.

In 1979, the U.K. government commissioned the Water Research Council (WRc) to undertake a US\$ 20 million intensive research program on materials and methods of design for the structural rehabilitation of sewers and Channeline were heavily involved in this research with the WRc.

It was from this research that stemmed the original concept of structural segmental and one-piece lining systems for man entry sewers and pipelines.

This early work included painstaking analysis of matters such as:

- Finite element studies and computer modeling
- Mechanical testing
- Wet abrasion testing
- Flow monitoring

- Corrosion resistance evaluation
- Strain corrosion testing

In 1984, this investigative study resulted in the publication of the first edition of the WRc Sewerage Rehabilitation Design Manual and in the same year, Channeline produced the first commercially available "STRUCTURAL MAN-ENTRY" lining system in GRP.

During the ensuing three decades a huge amount of practical experience has been obtained enabling Channeline to further refine resin and reinforcement elements used in the product manufacture, with continuous improvements in jointing and grouting techniques.

Working closely with both end users and contractors we have now evolved what we sincerely believe to be the best GRP structural large diameter pipe rehabilitation product and methodology available on the market today.

# PRODUCT

## General description of Liner Construction

The general concept of the Channeline product is that a remarkably stiff and strong panel section is constructed, but with a relatively thin wall.

The product differs from that of standard GRP hand or filament wound pipework in several fundamental and important ways. Normal GRP pipework consists of windings of layers of resin-saturated glass, achieving its stiffness by building up ever increasing wall thickness.

Channeline however, derives its strength and stiffness through a different method, employing the mechanics of core, or sandwich panel design.

The first stage of Channeline manufacture is an inner sandwich structure incorporating a 1.5 mm corrosion barrier on the inside surface which is manufactured from high grade surface

veil precisely impregnated with Isophthalic or Vinyl-Ester resin, followed by several layers of thoroughly impregnated multi-axial engineered fabric and CSM, forming the inner sandwich skin.

Next, comes a central core, comprising of carefully metered amounts of silica and resin which is pre-batched, mixed and evenly applied to the exact thickness required.

The outer sandwich skin is then formed using several further layers of multi-axial fabric, CSM and resin, with the outer surface being treated with a bonded graded aggregate to enhance adhesion to the annular grout, which is used during the installation phase.

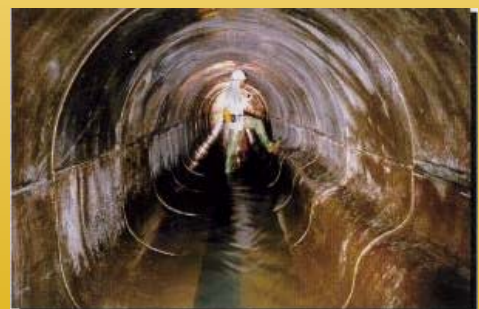
The sandwich construction process is continuous, and carefully monitored and controlled ensuring exceptional bonding of all layers throughout the process.



*Cross section of sandwich panel construction*

## Shapes & Sizes

There really is no theoretical limit to the shape and size of Channeline panel that can be effectively manufactured. Because Channeline technology includes the evolution of multi-piece segmental construction, where necessary for transportation, even very large, peculiar shaped rehabilitation projects can be accommodated using Channeline product.



# PRODUCT

The fact is, that the sheer ingenuity of the designers and constructors of large buried structures of by-gone days never ceases to amaze us.

Those most commonly encountered are:

- Circular
- Ovoid
- Egg shaped
- Elliptical
- Flattened Elliptical
- Arch barrel
- Box shaped
- Flattened Box shaped

The Channeline segments for each rehabilitation project are custom made to provide a precise fit to the size and shape required. The information needed to achieve this is obtained from a detailed site survey undertaken by the Authority, Contractor and/or Channeline representative, together with the preparation of a proving template.

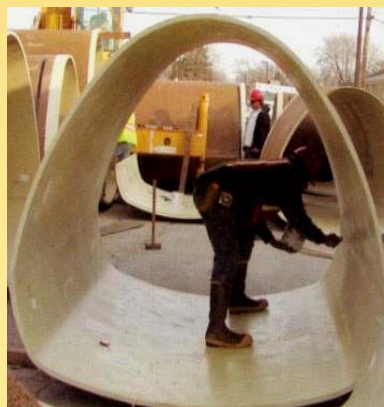
Only when all parties are satisfied that the liner dimensions are precisely right, do the dimensional details get passed to the factory floor for commencement of the mould making and panel construction activities.



*Liner fit being checked with template*



*Egg shaped Liner*



*Elliptical Liner*



*Circular Liner Segments awaiting shipment from the factory*



*Flattened Elliptical Liner*



*Box shaped Liner*



*Flattened Box Section*

# CHARACTERISTICS

Channeline Structural GRP Lining Panels are manufactured to fully comply with the WRc materials standards for GRP (Guidance note WIS 4-32-02) and are also manufactured in accordance with BS5480 and ASTM D3262.

## Mechanical Properties

At the outset of each project a detailed design analysis is undertaken, taking into account all necessary criteria such as depth of pipe, condition of existing pipe, ground loading, the likely effect of external water etc. to determine the exact requirements for the liner design. Design work is generally undertaken in compliance with the requirements of the latest edition of the WRc manual (other standards may be used) which then establishes the liner thickness needed to produce a Type I, Type II or Type III liner (see Technical Section).

This analysis takes into account the short and long-term mechanical properties such as:

- Flexural Modulus
- Bending Stress
- Tensile Stress

Panels of any required liner type strength and stiffness can be produced using the Channeline sandwich construction method.

## Corrosion Resistance

The deterioration of a sewer or culvert is often accelerated by corrosive gasses and the oxidization of Hydrogen Sulfide into sulfuric acid.

Soft mortar is not always easily identified by CCTV surveys. For Man Entry sewers manual inspection is recommended.

Most structural failures in sewers are caused by insufficient tensile capacity. Corrosion will contribute to this reduction in strength.

The resins used by Channeline are highly resistant to sewer gases and most trade effluent.

A detailed corrosion resistance guide is available from your Channeline Representative or can be downloaded from our website.

## Barcol Hardness and Abrasion Resistance

The high quality gel coat resins and surface veils used in the manufacture of Channeline panels provide an exceptional degree of resistance to impact and abrasion. Wet abrasion testing comparisons with other liner methods show impressive and superior results. The Barcol hardness of cured Channeline material is Shore D 30.

### Typical Channeline Mechanical Properties

Flexural Modulus		Bending Stress		Tensile Strength	
Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
10,000	4,000	110	60	98	45

# CHARACTERISTICS

## Hydraulic Capacity

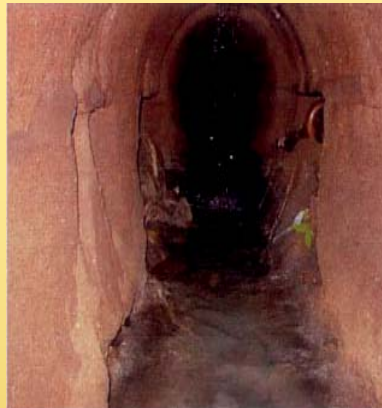
The hydraulic capacity of a sewer or culvert is dependent on the cross sectional area of the unit and the surface roughness of the sewer or culvert wall. Collapsed and protruding sections of the host pipe wall can greatly reduce the cross sectional area and increase the friction coefficient of the unit, thus dramatically reducing its hydraulic capacity.

A feature common to nearly all sewer and culvert renovation processes is that the internal surface roughness of the existing sewer or culvert is reduced, i.e. improved from a hydraulic point of view. Thus, although there is frequently a loss of cross sectional area associated with the renovation work, this is generally counteracted by the improved flow-carrying characteristics of the upgraded sewer.

The surface roughness is determined by a roughness coefficient 'k' or by the Mannings friction factor 'n'.

The surface roughness coefficient 'k' can vary from 3mm for a brick lined sewer

in poor structural condition with mortar missing to as high as 6 inches for irregular coarse stone masonry culverts. Intermediate values of surface roughness are applicable to older and defective concrete and clayware pipes.



Channeline will always provide an improvement to the flow capacity of a lined large diameter pipeline or culvert. Generally, this is in the range of 12% to 25% even though the cross sectional area of the structure has been reduced slightly.

Using the Manning method, the 'K' value of Channeline is 0.23% and the coefficient value of 'n' is 0.009. By the equivalent Colbrooke White method the Ks value of a Channeline liner is 0.03 in clean flow or 0.6 if allowance for slime is required.

## Self Cleaning

The ability of a sewer to enable silt deposition is a function of the surface roughness of the structure, which causes the flow to slow down at the liquid/pipe wall interface. Experience has shown the extremely smooth nature of the Channeline GRP material mitigates the flow/pipe wall friction so that under normal flow conditions pipelines and culverts once lined, are effectively self cleaning.

# CHARACTERISTICS

## Durability

Channeline pipeline rehabilitation liners are designed to last. The standard product design ensures a minimum 50- year life.

Sufficient empirical durability and performance data has now been accumulated by Channeline to justify design life predictions in the order of 50 to 100 years under most pipeline operating conditions.



*Inspection of Channeline after many Years of service*

## Lateral Connections

Many sewers and pipelines are constructed with incoming lateral connections throughout the length of the structure.

The rehabilitation of these lateral connections is easy and straightforward with the Channeline liner product. Laterals can be connected with mesh and mortar or where necessary, for severely degraded lateral connections repair mortars and GRP inserts can be prefabricated, installed and subsequently bonded to the main sewer liner to provide a smooth, durable solution.



*Lateral before rehabilitation*



*Lateral after rehabilitation*

## Bends

Most older sewers and pipelines exhibit unintended deviations or deliberate direction changes, often being of a short radius nature.

The Channeline socket and spigot jointing method allows for the alignment of each sequential panel installation to accommodate small direction changes and off-sets quickly and easily.

Where more severe direction changes and short radius bends are encountered in the pipeline Channeline can provide computer modeling and the fabrication of custom built short sectional or lobster type bend sections.



*Channeline fabricated short radius bend*

# CHARACTERISTICS

## Fittings

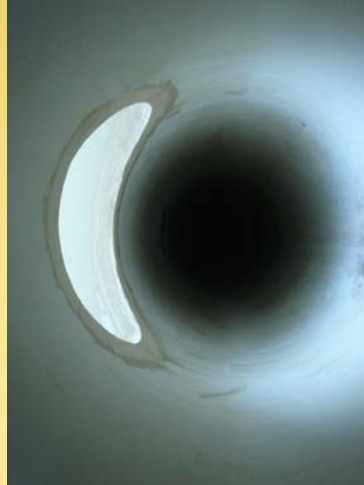
For the occasional rehabilitation project, there is a requirement for an intermediate change due to the presence of a reducer in the pipeline, the lining of a dead end, or a large diameter Tee entry.

Channeline can design and fabricate any desired fitting for such projects including:

- Concentric Reducers
- Eccentric Reducers
- Dished Ends
- Y pieces
- Equal tees
- Reducing Tees



*Funnel for Y Piece*



*Tee Piece Installed*

Optional in-line jointing can be facilitated where it is necessary to provide a liner of maximum external diameter and minimum annular gap, thus eliminating the 10mm allowance required for the socket overlap.

## Multi-piece Units

For many projects, Channeline panels are manufactured in 2.3 meter long solid sections.

Often however, due to either transportation problems or difficulties associated with access to the pipeline (e.g. entry only permitted through manholes), or in the case of a particularly large structure, it is desirable for the panels to be manufactured in two or more longitudinal sections which are site bonded above or below ground using our patented structural joint.

## Jointing Systems

Standard Channeline panels are manufactured with a socket and spigot joint, with adequate clearance and tolerance such that one panel connects easily into the next when positioned into the pipeline or sewer.



*Concentric Reducer*



*Eccentric Reducer*



*End of Channeline Egg-Shaped Panel Showing Socket Joint*



*Multipiece Channeline Sections being installed in large, complex shaped sewer*

# INSTALLATION

Channeline pipeline rehabilitation liners are installed world-wide by a network of trained and approved specialist contractors, experienced and trained in confined entry.

For a list of approved contractors in your area please ask your local Channeline sales representative, or contact our website.

## Installation Techniques

The pipeline or duct to be rehabilitated will first have been de-silted, cleaned and surveyed and the information gathered from which the design dimensions of the liners will have been determined.

Once manufactured, the liner material elements will be trucked to the job site, offloaded and stored in a convenient location close to the job site.

Access pits will have been prepared at suitable locations along the length of the pipeline and the crown of the pipeline removed so as to allow insertion of the Channeline sections.



*Liner segments in position in pipe invert*

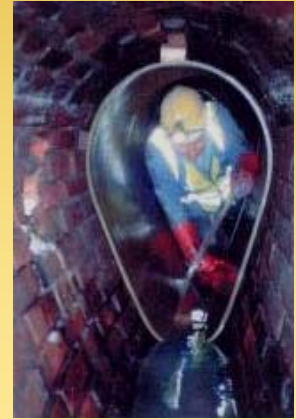
The Channeline segments are then lowered into the pipeline opening using a suitably rated crane until they rest in the invert of the pipeline at the pit location



*Segment positioned on installation trolley*

A special hydraulic trolley unit is then used to transport each liner segment along the length of the host pipe to the required location.

Once in position, the liner segment is centralized and chocked using hardwood wedges.



*Panels chocked and centralized in host pipe*

Each liner segments connects easily to the previously installed one by means of the socket and spigot joint.



Once butted together, the joints are injected with a flexible mastic epoxy adhesive/filler such as Channeline 3000 or equivalent (details of which are available upon request).



*Channeline segments delivered to site  
Awaiting installation.*

# INSTALLATION

## Grouting

During the installation of the Channeline liner segments, the sections of liner are centralized in the host pipe bore so that an even annular gap is evident between the liner and the pipe wall around the circumference of the liner.

This annular gap is subsequently filled with a low viscosity, free flowing, rapid setting, and high-strength grout.

### For WRc Type 1

Composite design this is an important factor of the installation process as it is desirable to ensure a thorough and even load transfer between the existing pipe and the liner.

In this case a high strength structural grout is recommended such as that produced with a mix of Ordinary Portland Cement, Fly Ash and water, in the appropriate quantities. Correctly mixed and installed, this will provide a grout strength in the range of 20 to 30 Mpa at 28 days (3000 to 5000 PSI).

Where deemed necessary by the contractor, consultant or customer, quantities of plasticiser and non shrink additives may be included in the mix design.

The grouting process also has the significant technical advantage of implementing the filling of any voids or defects in the existing pipe, such as missing mortar or brick, cracks in stonework or clay and the grout mix can even be adjusted in viscosity to enable the filling of ground voids and washout areas external to the host pipe.

The first stage of grouting involves the establishment of bulkheads at the ends of the section that has been lined. This is achieved using a rapid setting cementitious mortar, or brick construction with vent tubes.



*Formulation of a sealed bulkhead at the liner ends*

Once this has been done, grout ports are drilled at intervals along the crown of

the liner through which the grout can be injected.

Grout mixing is conducted above ground, using a combined mixer/pump unit, with either piston or screw pumps and continually pumped through grout hose down into the host pipe section and into the grout ports.



*Injection of grout into the annular gap*

Pumping is continued at one location until the desired level has been achieved in the annulus, which can easily be determined by “sounding” the liner with a rubber or wooded mallet. Grouting pressures are in most cases minimal, at less than 0.5 Bar. (7 PSI).



*Grout rig for mixing and pumping*

# INSTALLATION

As with all grout in place liners, grouting operations should be conducted with an understanding of the principals of buoyancy and flotation given the fact that the annulus between the liner and the host pipe is being effectively filled with a liquid and the liner forms a flexible hollow tube.

The practicalities of buoyancy and flotation can be dealt with in several ways, but the most common is to undertake the grout filling of the annulus in three or more stages, dependent upon the height and diameter of the liner.

This normally involves the installation of grout in a first stage to approximately the 5 O’Clock to 7 O’Clock portion of the annulus, which is then left to cure so as to “lock in” the base of the liner at the pipe invert.

The grouting of subsequent stages or “lifts” is then conducted, with an adequate curing time in between operations, commonly toward the spring line, and then in one or more subsequent stages to the top of the pipe.

Upon completion of the grouting process, the grout port holes are sealed by plugging using the liner cores taken from those locations and an epoxy adhesive, or other acceptable equivalent.

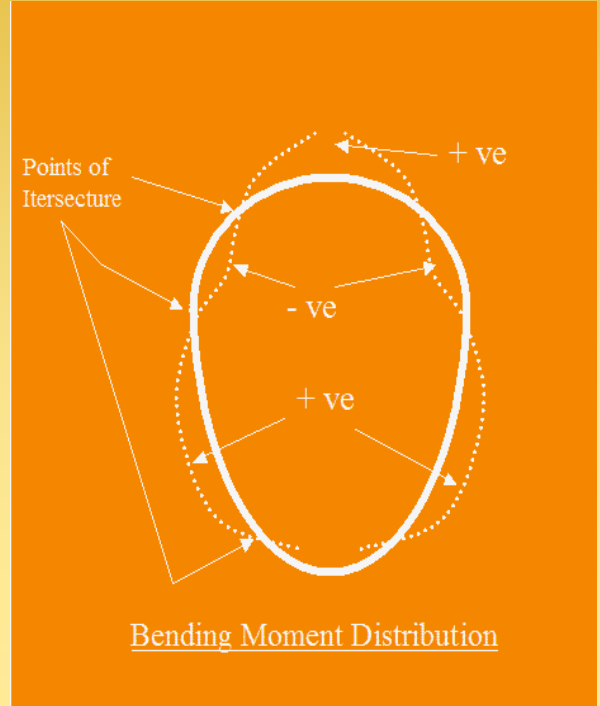
**Channeline technical staff should be consulted for guidance on all grouting issues and a full grout specification and installation procedure is available upon request from any Channeline office.**

# TECHNICAL SECTION

## Sewer Defects

The need to rehabilitate a sewer or storm water drain arises following the cognizance of the fact that the load bearing capacity of the pipeline either has, or is shortly to, become insufficient to continue to support the gravitational forces acting upon it. In short, if its not repaired then it will probably collapse.

An understanding of the failure mechanism of the variety of different shaped pipeline structures is important in determining the design principals of a rehabilitation liner and much of the work necessary to understand this process was covered by the WRc and Channeline during the studies conducted in the 1980's.

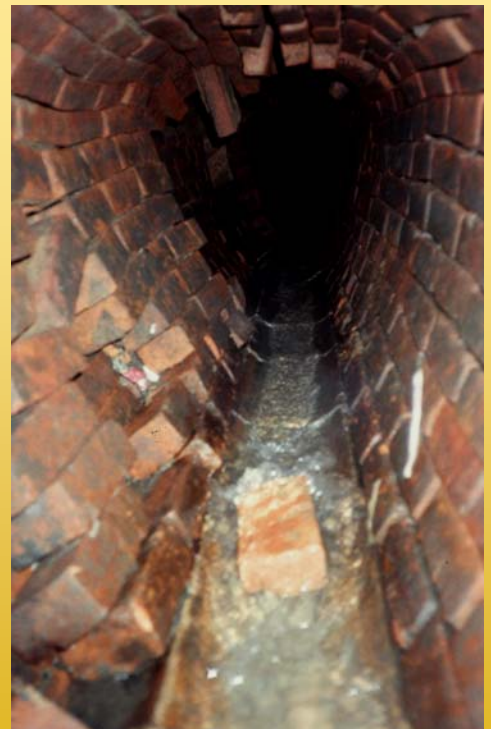


For example, it is known that as a pipeline structure become weakened by corrosion, positive bending moments act to force the sewer to deform inwards, whereas negative bending moments act to force the sewer outwards.

This is clearly demonstrated in the photograph opposite, where the effects of both positive and negative forces are clearly evident.

For a circular profile, there are 4 points of intersechure. For an egg profile there are 6 points of intersechure.

This is why, for segmental liner design, Channeline uses patented "Tongue and Groove" longitudinal joints which are positioned at the points of intersechure, i.e. at the points of zero bending.



# TECHNICAL SECTION

## The General Principals of Type I, Type II, & Type III designs

### WRc Type I (composite) design

Type I design utilizes the existing sewer and relies on a bond (or resistance to shear at the interfaces), between the lining, grout and sewer wall so that the renovated sewer acts as a composite. It relies on tensile and compressive loads being transferred from the outer face to the inner face through the grout. Just as the vertical web from an I-beam requires sufficient strength to transfer load from the top flange to the bottom flange without buckling, so the grout must be of sufficient strength to transfer load from the existing wall to the liner. Foam and low strength grouts are considered unsuitable for Type I designs.

WRc Type I design is based

on standard engineering and composite formulae and was the result of 5 years of intensive research which commenced in 1978 and included finite element and computer modelling techniques. Suitability of materials and design parameters were examined and established and the 1st Edition of the WRc Design Manual was published in 1984. The current edition is now considered the standard design reference for the renovation of sewers and culverts.

Type I design examines the effects of vertical pressure from road and over burden, it does not examine external hydraulic head or ground water effects on the structure. For calculations long term (50 Year) values should be used.

WRc state that an increase in external ground water level is often experienced after renovation and should be considered.

Percolation of ground water through the existing structure and grout will result in external water pressure acting directly on the liner during and after construction. It is therefore important for liners to resist this pressure independent of bond and mechanical fixing to the grout. WRc recommend that for Type I designs with ground water, calculations for external hydraulic head acting independently on the lining should be carried out using the Type II design method.

# TECHNICAL SECTION

## WRc Type II (stand alone) design

WRc Type II design calculations examine the safe external hydraulic working head limited by stress and deflection using Timoshenko theory for flexible pipe design. It assumes that no bond will exist between the liner and the existing structure and is based on standard critical buckling formulae for external hydraulic loadings with an enhancement factor for external support. **It does not examine the effects of vertical pressure from road loading and overburden.** In some cases it can be assumed that the existing sewer will carry the road loadings in other cases additional calculations will be required. WRC state that Type I design method can be used to check road loading and overburden for GRP but they do not

consider CIPP (Cured in place pipe) and thermoplastics as suitable for composite Type I designs. WRC advise that any cavity between the liner and the Host pipe and the surrounding soil may require filling with grout to allow an enhancement factor to be used.

For large diameter (Man Entry) sewers thermoplastics such as PVC and Polyethylene become impractical to use for Type II designs because of their relatively low long term modulus and resulting thickness.

The relative thickness of a 1.5 metre (60") diameter liner with good external support (enhancement factor of 7) and safe working external head of 3 metres (10') based on Type II design method are 17.5 mm for GRP; 30 mm for CIPP; and 72 mm for Polyethylene and PVC.

For non-circular liners, formulae are provided in the WRC manual. For circular liners tables are included, alternatively the formulae used to construct tables based on the flexural modulus of the liners can be used and is included in the description of method of design. For Type II designs long term (50 year) values should be used.

Where a combination of Type I and Type II designs are used, the design is referred to as a Type I design with a Type II check. For these categories the linings must have the required characteristics for both methods. GRP is the only material currently listed by WRC as suitable for both Type I and Type II designs.

# TECHNICAL SECTION

## WRc Type-III (corrosion barrier) design

Type III design is a non structural permanent shutter. This design can be considered only if no external ground water is present or is likely to build up. It will give corrosion protection and improvement in the flow capacity only. It is not considered as giving improved resistance to ground and traffic loadings.

Type III liners are rarely used today due to the small cost advantage gained over a structural lining and possible risk of blockage.

Materials suitable for Type I, Type II and Type III design methods are listed in WRC Rehabilitation Design Manual section 111/37 table 5.1

When renovating a sewer or culvert it is important to establish the design criteria and the cause of

deterioration. It is also important to note that after renovation, ground water levels are likely to increase.

Both Type I and Type II design methods use mechanical properties at 50 years plus a factor of safety of 2 to give a minimum design life of 50 years. Actual life expectancy is in excess of 100 years.

Where ground water is likely to be present it is prudent to combine both Type I and Type II designs using the 50 year long term mechanical properties for both design methods.

### Materials listed as suitable for WRC Type I, Type II and Type III design methods

The suitability and selection of materials for renovation is as important as the suitability and selection of the design method if the required design life is to be achieved.

## Suitable materials per WRc

Design Method	Materials Suitable For Long Term Structural Design
WRc Type I	Gunite Glass Reinforced Cement (GRC) Polyester Resin Concrete (PRC) Glass Reinforced Plastic (GRP)
WRc Type II	Polyethylene Glass Reinforced Plastic (GRP) > 5mm. thick Cured in place liners > 6mm. Polypropylene
WRc Type I & Type II	Glass Reinforced Plastic (GRP) > 5mmn thick
WRc Type III	GRP and Thermoplastics

# TECHNICAL SECTION

From the table it can be seen that cement based systems are listed suitable for Type I designs only. Cured in place and thermoplastics are listed suitable for Type-II design only and GRP is suitable for Type I , Type II and Type III.

## Resistance to corrosive attack

Very often the deterioration of a pipe or culvert is accelerated by corrosive gases and the oxidization of Hydrogen sulphide to sulphuric acid. Soft mortar and/or loss of mortar at the joints in brick built sewers are good indications of corrosive attack. These conditions are not always easily identified by CCTV surveys.

Where corrosive attack is evident the selection of a suitable lining material is

necessary whether it be for Type I or Type II design method. WRC list GRP, CIP and Thermoplastics are highly resistant to acids, sulphates and alkalis.

They list cementitious materials as resistant to alkalis but not acids.

Sulphate resistant cements are resistant to alkalis , natural sulphates, but they are not resistant to sulphuric acid.

## Resistance to Wet Abrasion

Extensive wet abrasion testing was carried out by both Northumbrian Water and WRC. Relative abrasion resistance is listed in the WRC Rehabilitation Design Manual as a relative number but actual WRC wet abrasion test results are shown opposite showing % loss of thickness.

## Comparative Wet Abrasion

### Results

MATERIAL	AVE % LOSS OF THICKNESS
Polyethylene	0 % (surface roughened and Ks value reduced after testing)
GRP (Channeline)	0.230%
Cured in Place (CIPP)	0.3 15%
PRC	0.365%
Cement based (AC, OR CONCRETE ETC)	15%

# TECHNICAL SECTION

## Flow Capacity

There will normally be a reduction in cross sectional area of the sewer after renovation. However when polymeric materials such as GRP, CIP, Polyethylene etc. are used it is normal to experience an improvement in flow capacity due to the low Ks ( Colbrooke white) value of 0.03

WRC recommend the Colbrooke -White method. as giving the best evaluation of flow capacity of sewers currently available. They list a range of Ks values for both deteriorated and new sewers in various materials. However Manning should give comparable results.

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a range of Ks values for both deteriorated and new sewers in various materials. However Manning should give comparable results.

## The importance of Shear Bond at the interface for WRC Type I designs

For liners with low tensile stress values, tensile failure will generally occur before shear failure of the interface bond. For high tensile materials such as GRP (FRP) shear failure at the interface will generally occur before the tensile stress of the liner is exceeded. WRC recommend that both shear and tensile strengths be examined

For Type I composite structures, the resistance to shear at the grout /liner

interface is of major importance. Prior to the publication of the WRC design manual, WRC undertook detailed evaluation and shear testing of a wide range of materials with different grouts. An abbreviated table of average bond shear stress test values from these tests in is shown overleaf.

The shear bond values are taken from extensive testing of flat plate samples. WRC concluded that the shear bond strength at the interface was proportional to the compressive strength of the grout used, It therefore follows that as the compressive strength of the grout increases with time, so does the bond strength.

# TECHNICAL SECTION

## Comparative shear bond values on lining materials

Grout 28 day comp. strength Material	Cement/~water N/mm <sup>2</sup> (74.5)	Accelerated set LCP N/mm <sup>2</sup> (12.5)	OPC /PFA/water N/mm <sup>2</sup> (13.5)
Glass Reinforced Cement. Roughened back face	1.54	0.47	0.81 N/mm <sup>2</sup> (117 psi)
Glass Reinforced Plastic 1.5 3n-an Grit bonded to back face	2.05	0.75	1.31 N/mm <sup>2</sup> (190 psi)
Polyester reinforced Concrete (no longer manufactured)	1.91	0.85	1.43 N/mm <sup>2</sup> (207 psi)

## Comparative Mechanical Properties of lining materials

	Flexural Modulus		Bending Stress		Tensile Strength	
	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term
GRP (Channeline)	10,000	4,000	110	60	98	45
CIP	2,200	620	25	10	18	8
GRC	8,000 to 12,000		6	6	4.5	4.5
Gunitite			8	8		
Polyethylene	130	50	25	10	8	6

For calculation purposes the 50 year values are generally used.

The long term properties are based on physical testing in accordance -with the relevant BS, DIN, ISO and ASTM standards.

# TECHNICAL SECTION

## Summary

The mode of failure and collapse of man entry sewers and culverts is generally due to inadequate tensile capacity of the structure. This may be caused by corrosion resulting in softening of the mortar joints, abrasion infiltration or excessive road or hydraulic loading. It can also be due to adjacent piling or tunnelling works. In many cases the duty of the road has increased with time and the sewers have exceeded the original design loading. It is rare for sewers to collapse due to failure in compression.

The critical loading on sewers and culverts is generally external but surcharge loads on sewers and culverts are not uncommon and may expose inadequate tensile hoop strength of the structure. In many cases tensile fractures both longitudinal and circumferential and loss of shape to the soffit are quite visible. These give a good indication of the critical loading. In other cases, particularly with brick built

sewers with soft or missing mortar in the joints, there may be little if any visual evidence of the problems when viewed by CCTV. For large man entry sewers and culverts routine manual inspection is strongly recommended. If external head is being relieved by infiltration at invert level it is reasonable to assume that cavities, caused by the infiltration, exist between the brickwork and the surrounding soil at the sidewall of the sewer which may result in a K value approaching zero and therefore induce high positive bending moments in the structure. In cases like this collapses will sometimes occur when there is a sudden soil settlement and horizontal load is transferred to the sewer wall in the positive bending moment areas.

The prime objective of renovation design must therefore be to add sufficient tensile capacity to the sewer to resist a wide range of external loadings. In certain cases induced stress due to surcharge loadings must also be considered.

If it is known that a sewer or culvert is structurally inadequate to carry current and future loads it is not sufficient to adopt a wait and see policy. Emergency repairs are not cost effective and do not normally solve the real problem. Claims from flooding damage due to collapses can be high.

If a sewer is known to be structurally inadequate, it needs renovating.

The publication of the WRC Sewerage Rehabilitation Manual has enabled Water Company, City and Consulting Engineers to adopt and budget for ongoing sewer renovation programs. It was first published in 1984 following five years of extensive research work and trials. It has been updated recently and enables engineers to select and specify suitable and proven design methods and materials for renovation for various conditions.

Engineers are also able to use the principles of the WRC design manual for non-standard culverts and sewers.

# TECHNICAL SECTION

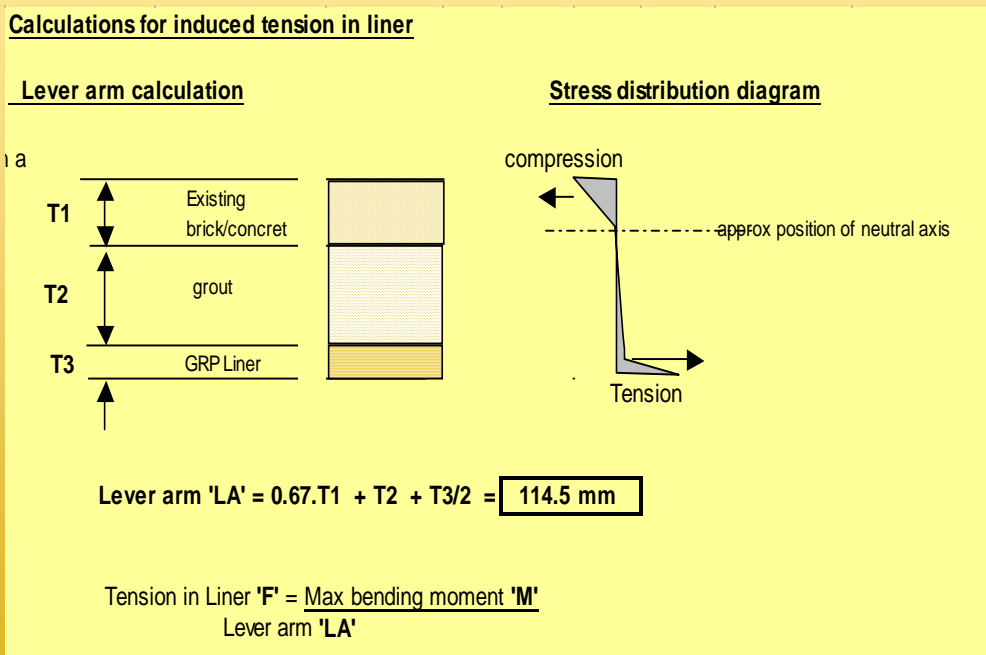
## Description of WRC Method of Calculation for Type1 Composite Design for Standard and Non Standard Culverts

As defined in WRC rehabilitation manual but extended to cover curved arch forms of larger diameters.

General engineering design method for loading :



1. From basic principles, the induced maximum bending moment acting on the culvert can be calculated using standard bending formulae.



# TECHNICAL SECTION

2. Any increase/decrease in lever arm will respectively decrease/increase the force transferred to the lining. (Typical principle of I beam).

$$\text{FORCE } F = BM/td$$

3. By comparing the force F transferred to the liner with the tensile capacity of the liner, the factor of safety of the composite structure can be considered. The centre core (annular concrete or grout) must be of sufficient strength (min 9 N/mm<sup>2</sup>) to transfer load to the liner through the composite structure.

From the WRC manual

Tensile capacity  $T_c$  = tensile strength x thickness and the factor of safety = Tensile capacity force in the Lining.

For high tensile materials such as GRP, composite design failure will generally be due to shear at the panel grout interface and not tensile failure of the liner, The limitation of the composite design is the ability of the panel / grout interface to resist shear during bending. WRC recommend that in these cases a limit be placed on the design by incorporating the shear stress formulae for a curved beam into the standard tensile capacity equation.

The shear strength formula for a curved composite beam

$$= (7r / 8 \times \text{lowest shear bond value for flat plate} (.68) \times \text{Dia} / \text{thickness})$$

$$= 0.267 \cdot \text{Dia} / t \text{ ( as per latest edition of the WRC SRIVI )}$$

The lowest shear bond value used for calculation purposes is 0.68 N/mm<sup>2</sup>- The lowest value found from testing a range of both GRP and Cementitious materials.

WRC's research program for structural renovation of sewers included extensive testing of the shear strength at the panel grout interface and formed the basis of the design manual. The shear bond values are taken from extensive testing of flat plate samples of various materials and the lowest values used in subsequent formulae. From tests carried out by WRC it was found that the shear bond strength at the interface was proportional to the compressive strength of the annular filling.

# TECHNICAL SECTION

Although higher values of shear bond may be used it is prudent to use the lowest figure of shear bond of 0.68 N/mm<sup>2</sup> when using grouts of between 9.5 -12 N/mm<sup>2</sup>. 28 day compressive strength.

From the WRC design manual

Tensile capacity  $T_c$  limited by shear at the interface then becomes

$$T_c = (0.267 \times \text{Dia}) \times t = 0.267 \times \text{Dia}$$

(in place of tensile stress of the material and derived from  $n/8 \times .68 \times D / t$ )

Having established tensile capacity based on interface shear strength this can then be compared with the actual induced force  $F$  at the interface and in the lining due to loading, and a factor of safety established for the design.

i.e. Factor of Safety = Tensile Capacity  $T_c$  ( WRC recommend a minimum factor of 2)  
induced force  $F$

The maximum bending moment is at the crown where the lining is in tension and the old sewer is in compression.

Pin joints are assumed at the springing since no tensile capacity is taken to exist on the outer face of the sewer wall. It is therefore assumed that the tendency is for the crown to flatten and spread outward.

Bending moment coefficients are given in the manual for both no voids and suspect voids behind the brickwork.

In an over consolidated clay it may sometimes happen that horizontal pressure tends to force the springing inwards so the design case with the lining in tension is at the springing.

The basic principles of the WRC design are from standard engineering design references and can be applied to culverts outside the scope of the manual by using the shear calculation for specific curves and shear bond strengths.

# TECHNICAL SECTION

The design for renovation of large culverts up to 5 meters diameter and outside the scope of the WRC manual have been carried out successfully using the basic engineering principles of the WRC manual by incorporating the shear stress equation for curved arch as the design limitation.

This method of design is recognized as being one of the most effective methods of renovation design, utilizing the existing structure.

## Flat Top and Other Shapes

Structural designs calculations for flat top, box ovoid and horse shoe culverts and sewers can also be carried out using the bending moment coefficients listed in the WRC Rehabilitation manual and WRC 56E Report.

Flat top culverts were covered in the earlier WRC publication, 'Structural Design of Renovated Sewer Systems External Report 56E' Mich formed the basis for the current manual.

For calculation purposes based on the WRC method, it is assumed that the grout/concrete annulus filling around the periphery of the liner is of a constant thickness. It is therefore prudent to assume that the existing culvert follows the same curvature and that the lever arm used to calculate the force in the liner is constant. In reality, for flat top sewers using curved soffit liners, the lever arm increases substantially as it moves away from the centre of soffit and the induced forces at the grout /panel interface reduce proportionally. The increase in lever arm is not assumed in the calculations. Although this may be considered an over design, it does allow the principles of the WRC design manual for a Type 1 design for curved arch liners to be used in flat top box culverts.

## Description of Type II calculations and Tables

A Type II design examines the resistance to external hydraulic loading.

Most text books quote Timoshenko, Spangler and Von Mises for external loadings. Tables and charts have been drawn up to enable safe working head or critical buckling pressure to be obtained.

For Non-Circular Type II Liners, WRC use a derivative of the Timoshenko formulae. which examine both deflection and induced banding stress.

# TECHNICAL SECTION

These are shown in the WRC manual as

Safe working external head limited by stress .....H1 = 340 SL  
 $(T/1)^2$

SL is long term Flexural Stress

Safe working external head limited by stress.....H2 = R 236  
 $EL (t/1)^3$

EL is long term Flexural modulus.

R = 1 for curved ( egg ) form and .5 for flat sided culverts,

Factor of safety included in formulae is 2 plus 50 year value.

For Circular Type2 Liners, WRC give a table where safe working head based on pipe stiffness can be read off.

This table is based on the following formula from WRC 56E Report

Critical Buckling =  $P_c = f_s \cdot f_a \cdot \frac{2E}{(1-\nu^2)} \left(\frac{t}{D}\right)^3$  Pressure.

$P_c = (0.00981 h)$  in  $N/mm^2$

$F_s$  is the enhancement factor based on external support provided to the liner

(1 for unsupported and can be up to 10 for full support. Cured in place liners use a factor of 7).

$F_a$  is correction factor for out of roundness read from graph. (5% = 0.7  $E$  is 50 year long term Flexural modulus in the radial direction.  $\nu$  is Poisson's ratio. (0.3 for GRP)

$T$  is liner thickness Safe head =  $P_c/2$  for a factor of safety of 2

$D$  is liner diameter in mm

Therefore safe head =  $\frac{f_s \cdot f_a \cdot 2E}{2 \cdot (1-\nu^2)} \cdot \left(\frac{t}{D}\right)^3 \cdot \frac{1}{0.00981}$  METERS

Transposing

Liner Thickness (Fof S 50 years +2) =  $D^3 \nu H \cdot (1-\nu^2) \cdot X \cdot 0.00981 \cdot f_s \cdot f_a \cdot E$

Using the above formulae allows engineers to calculate safe head based on long term flexural modulus and stress, and thickness' for depths and diameters outside of the tables and charts currently available.

# CHEMICAL RESISTANCE

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The resin selection utilized for the construction of Channeline product will be determined in accordance with the service conditions and operating environment anticipated for the service life of the pipeline.

A full tabular listing of chemical reagents and environments, based on extensive laboratory tests and field service experience, is available on our website and as a separate document.

Prospective users of Channeline product are invited to consult the Channeline Technical Services Department for advice on specific exposure conditions and a full chemical resistance guide. Please contact the nearest Channeline Sales Office for further advice.

# LONG TERM PERFORMANCE TESTING

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Channeline products have been the subject of extensive long-term performance testing both in house and by many independent laboratories and test houses worldwide.

These tests include:

- Ring stiffness tests
- Flexural modulus tests
- Flexural Creep tests
- Ageing tests under exposure to Sulfuric acid
- Leak tests, internal and external
- Wet abrasion tests
- Strain corrosion tests
- Chemical resistance

Testing procedure results are available for Channeline material in conformance with the following International Standards:

## **ASTM D 3262**

Standard Specification for Fiberglass Sewer Pipes

## **BS 5480**

Standard Specification for Reinforced Plastic (GRP) Pipes and Fittings for Water Supply and Sewerage

## **ASTM D638-96**

Standard Test Method for Tensile Properties of Plastics

## **ASTM D790-96**

Standard Test Method for Flexural Properties of Plastics

## **ASTM D2412-96**

Standard Test Method for Stiffness by Parallel Plate Method

## **ASTM D2583-95**

Standard Test Method for Indentation Hardness by Means of Barcol Impresser

## **ASTM D2584-94**

Standard Test Method for Ignition Loss of Cured Reinforced Resins

## **ASTM D3567-97**

Standard Practice for Determining Dimensions of Fiberglass Pipe and Fittings.

## **ASTM D3681-96**

Standard Method for Determining Chemical Resistance of Fiberglass pipe in Deflection Condition.

## **BS 2782/ISO 527**

Standard method for the Testing of Plastics.

## **IGN-4-32-02**

**Appendix A:** Sewer Lining Dimensions and Design Methods.

**Appendix B:** Methods of Manufacture of GRP Sewer Liners.

**Appendix C:** Short Term and Long Term Flexural Modulus Methods.

**Appendix D:** Method of Determining Shear Bond Strength.

**Appendix E:** Method for the Analysis of Construction (loss of ignition)

**Appendix F:** Sampling Frequency for QC tests

# QUALITY CONTROL AND TESTING

At Channeline, our overall policy is simple: Use the best people to engineer the best solutions and manufacture the best products to the highest standards and yet still continue to strive to improve in all that we do.

It goes without saying that with a quality policy this bold, we stand or fall by our performance. We therefore take all quality issues very seriously indeed.

Our manufacturing facility has been, for many years certified operators to the requirements of ISO 9001:2000/EN, ISO 9001:2000/BS EN, ISO 9001/2000/ANSI/ASQC and have also recently adopted ISO 14000 because we care about the environment too.

Rigid in house quality control during manufacture is ingrained in our philosophy,

which, together with strict inspection and testing regimes and the ability to coordinate with third party inspectors and external test houses, ensures we deliver on our quality pledge.

Daily and batch testing of each material production run is carried out by our QC department to verify conformity with the following project requirements:

Dimensional checks of wall thickness, I.D; O.D; Height and width.

- Bending and flexural modulus
- Tensile tests
- Socket and Spigot fit
- Barcol Hardness
- Visual appearance

Certificates of Conformity are issued to each customer together with the test result handbook for each delivery shipped.



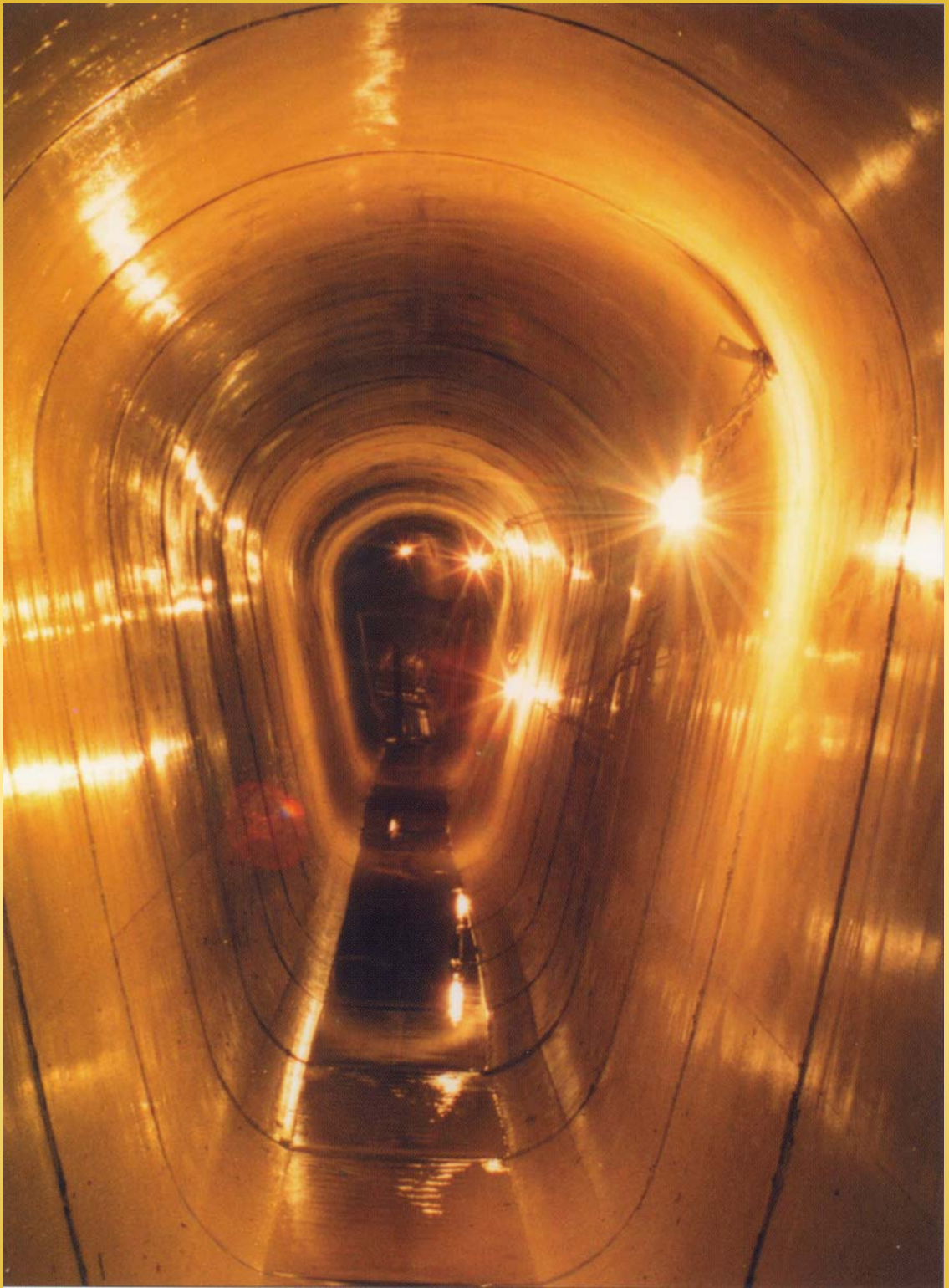
*Bending & Flexural Tests*



*Dimensional Testing*



*Barcol Hardness Test*



**CHANNELINE**

# GLOBAL COVERAGE

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**CHANNELINE** Sales offices and representatives are available in most countries throughout the world.

Channeline products have been used in projects in the following countries and case studies are available on our website or from your Channeline Sales Representative upon request :

- |               |                |                             |
|---------------|----------------|-----------------------------|
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| ■ Ireland     | ■ Kuwait       | ■ Czech Republic & Slovakia |
| ■ Belgium     | ■ Germany      | ■ United Arab Emirates      |
| ■ France      | ■ Poland       | ■ Russia                    |
| ■ Holland     | ■ Denmark      | ■ Canada                    |
| ■ Luxembourg  | ■ Finland      | ■ USA                       |
| ■ Sweden      | ■ Portugal     | ■ Argentina                 |
| ■ Switzerland | ■ Italy        | ■ Uruguay                   |

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