AMERON

Installation Guide for GRE Pipe systems

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1. Introduction

1.1. Scope

This manual gives general information about various aspects that are relevant for the installation of Glassfiber Reinforced Epoxy (GRE) pipe systems. Respect for the requirements, methods and recommendations given in this guide will contribute to a successful operating pipeline system.

Authorized, trained and certified personnel can only contribute to a reliable pipeline system. Note that the remarks about the various joints in this document are for guidance only.

More specific and detailed information about underground and aboveground installations, as well as various joining methods, is given in manufacturers' referenced documents.

Fig. 1.1. Offshore unit

1.2. References

Following documentation gives additional and detailed information about various subjects, which are described in this manual

Chapter	Subject	Reference number
2.4	Product Identification	---
3.1	Packing and handling instructions	FP 167
4.1	Assembly instructions for Quick-Lock adhesive bonded joints	FP 170
4.2	Assembly instructions for Taper-Taper adhesive bonded joints	FP 564
4.3	Jointing Instructions Laminate	---
4.4	Assembly instructions for Flanges	FP 196
4.5 - 4.6	Assembly instructions for Key-Lock mechanical joints	FP 161
5.1.1	Operating instructions M74 Pipe Shaver	FP 696
5.1.1	Operating instructions M86 Pipe Shaver	FP 453
5.1.1	Operating instructions M86 XL Pipe Shaver	FP 919
5.1.1	Operating instructions M87 Pipe Shaver	FP 454
5.1.1	Operating instructions M87 XL Pipe Shaver	FP 455
5.1.1	Operating instructions M88 Pipe Shaver	FP 1022
5.1.1	Operating instructions M95 Pipe Shaver	FP 925
5.1.1	Operating instructions B1-Tool	FP 810
5.1.1.3	Operating instructions for Ameron Heating Blankets	FP 730

It is the user's responsibility to ensure that he has the latest revision of the listed documents.
Documents can be obtained via sales.service@ameron-fpg.nl

1.3. Notification

This manual provides the following information:

- A general overview on tooling and materials for pipe system installation
- A description of joining methods and systems
- Handling, storage and transporting materials
- Installation systems and procedures
- System control and safety measures

Please note that the instructions in this manual are for guidance only. Specifications written for a particular project will be normative.

We cannot describe all possible circumstances met in the field. For this reason, our experienced supervisors may deviate from given descriptions in order to achieve the optimum solution for the particular situation, using the latest techniques and methods.

Fig. 1.2. Water injection

Fig. 1.3. Mine application

2. Product introduction

2.1. Systems

GRE pipeline systems are made from glass fibers, which are impregnated with an aromatic- or cyclo-aliphatic amine cured epoxy resin.
This thermoset resin system offers superior corrosion resistance together with excellent mechanical, physical and thermal properties.

The glass fiber reinforced epoxy pipeline is resistant to the corrosive effects of mixtures with a low concentration of acids, neutral or nearly neutral salts, solvents and caustic substances, both under internal and external pressure.
A reinforced resin liner can protect the helical wound continuous glass fibers of the reinforced wall of the pipes and the structural reinforcement of the fittings internally.

2.2. Pipe fabrication process

GRE pipes are manufactured using the filament winding method. In this mechanical process, continuous glass fiber rovings are impregnated with epoxy resin.
The production of GRE starts with the preparation of a steel mandrel, which may be completed with a socket mould.
The dimensions of these tools determine the inner dimensions of the pipe, fitting and joint system.
Glass fibers are guided through a resin bath, which is filled with epoxy resin and are wound under constant tension in a specific pattern around the polished mandrel.
This process continues until the required wall thickness is reached. Generally, the higher the pressure class, the greater the wall thickness of the product will be.
The winding process ends with curing the epoxy resin in an oven, extraction of the mandrel/ mould from the product, finishing the product by cutting to length and machining the ends. The products are subjected to visual and dimensional controls as well as a hydro test.

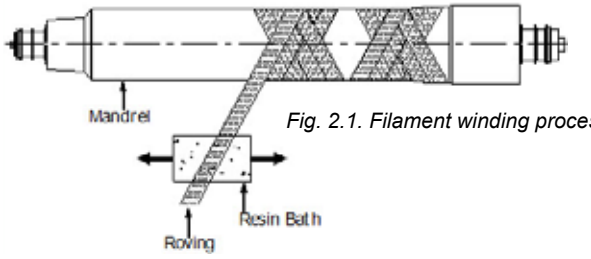

Fig. 2.1. Filament winding process

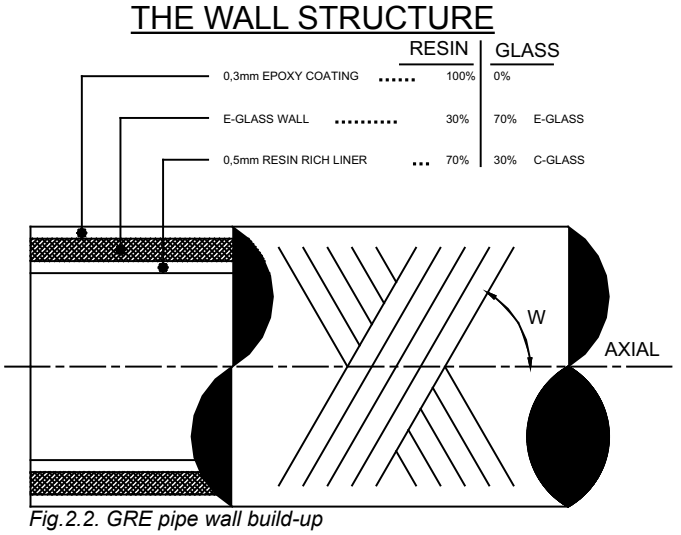

Fig.2.2. GRE pipe wall build-up


Fig.2.3. Spool manufacturing

2.3. Advantages and disadvantages of GRE compared with steel

2.3.1. Advantages

Glass Reinforced Epoxy pipe systems have a number of advantages over conventional pipe systems, of which the most important are:

- **Durable/corrosion resistant**
  GRE piping is resistant, both internally and externally, to the corrosive effects of water, oil and many chemicals.
  Cathodic protection or coating is not required.
- **Low weight/easy to install**
  The specific weight of GRE is only 25 % of steel; due to the low weight, GRE pipeline components are easier to handle without the need of heavy (lifting) equipment.
- **No initial painting or conservation**
  The epoxy topcoat on the outer surface of GRE pipe components is resistant to the influences of the installation environment and an additional external conservation is initially not required.

2.3.2. Disadvantages

Attention should be paid to the following disadvantages of GRE when comparing with conventional pipe systems, such as:

- **Impact resistance**
  The pipe system is more susceptible to impact damage due to the brittle nature of the thermoset resin system.
- **Handling**
  GRE installations require more and careful preparation due to other joining methods, handling- and transportation requirements and installation techniques.
- **Flexibility**
  The flexible GRE piping system requires specific support design.

2.4. Product identification

Products are marked with labels, which contain relevant product information.
For specific and detailed information, reference is made to manufacturers' documentation.

3. Material handling, storage and transportation

3.1. Handling

GRE products must be handled carefully to avoid any damage. Handling and transportation of GRE is not restricted by temperature. This section lists the most important requirements for handling materials before and after shipment and for storage.

3.1.1. Loading

Mind following requirements:

- Pipes, fittings and prefabricated parts (spools) must be transported by suitable trucks having flat bed floors
- Forklifts may be used for handling provided that the forks are padded with a protective material such as rubber or plastic
- Check for and remove any projections, nails or other sharp edges from the supporting floor before each load
- Any contact of the truck or steel container with the GRE products shall be separated by wood or rubber
- Avoid direct contact between individual GRE products during transportation
- Pipes and spools shall be lifted at least at two points by using nylon or canvas sling belts with a minimum width of 100 mm. Use the largest spool diameter to balance the load during the lift
- Secure materials by wooden wedges and supports having a minimum width of 100 mm
- Pipe supports shall be spaced at ≈3 m intervals, minimal 1 m from the ends; the support distance of nested pipes shall not exceed ≈2 m
- Tie the products in place by using either nylon or canvas sling belts
- Chains and steel cables may never be used for lifting or fixation
- Avoid support on sharp edges
- Fittings can be properly transported in crates or on pallets
- Flanges must be secured against sliding when stored on the sealing face
- Pipe ends and machined surfaces must be protected (e.g. with PE-foil)

Fig. 3.1. Vacuum lifting device

Fig. 3.2. Spool handling

Fig. 3.3. Pipe handling (unloading)

Fig. 3.4. Pipe handling (loading)

3.1.2. Unloading

The client is responsible for unloading ordered material, unless agreed otherwise.
Mind following:

- Use nylon or canvas sling belts with a minimum width of 100 mm
- Standard pipe lengths shall be lifted at minimal two supporting points
- Fix at least one sling belt around the section with the greatest diameter
- Unload one (packed) item at a time

Fig. 3.5. Crate handling

Fig. 3.6. Crate handling

Fig. 3.7. Spool handling

Fig. 3.8. Stacked pipe in stock

3.2. Storage

In order to avoid damage to GRE products, the following recommendations shall be respected:

- Provide a flat and horizontal supporting surface
- Do not store the pipes directly on the ground, onto rails or concrete floors
- Ensure suitable supports such as clean, nail free wooden beams
- Machined ends must be protected (e.g. with PE-foil)
- Bell and/or spigot ends may not touch each other
- Pipes can be stacked economically by alternating the orientation of spigot- and socket end
- Avoid pipe bending by locating supports between the layers of stacked pipe vertically above each other
- Supports must be spaced at a maximum interval of 3 m and ≈1 m from each pipe end
- The allowable stacking height is 1.5 m or 2 layers, whichever is higher
- Product diameters may flatten when stacked too high and/or too long, specially at elevated temperature
- Long term storage is recommended under tarpaulins or PE-sheets
- Pipe stacks must have side supports (e.g. wooden wedges) to prevent rolling or slipping
- Unprotected flange sealing faces shall not be placed directly on the ground or on supporting floors
- Spools shall not be stacked
- No other materials shall be loaded on top of GRE products
- Do not drop, walk, or stand on GRE products
- Avoid point loading due to careless stacking

Raw materials such as O-rings, gaskets, locking keys, adhesive kits, resin, hardener, woven roving and lubricants shall be stored in the original packaging, in a dry environment, at recommended temperatures.

The shelf life of adhesives and resins must be respected.

If any damage is observed due to transportation or during installation (e.g. excessive scratches, cracks) contact the supplier.

Never use damaged materials.

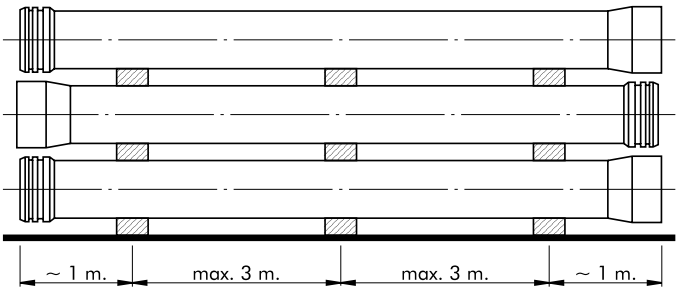

Fig. 3.9. Pipe stacking

Fig. 3.10. Wooden wedge

Fig. 3.11. Storage of fittings

4. Joining systems and preparation methods

For the joining of GRE pipe components, various types of joints can be used. This section details the characteristics of each of these joints.

4.1. Conical-Cylindrical bonded joint

This type of adhesive bonded joint consists of a slightly conical socket and a cylindrical spigot. This joint allows for an accurate assembly length with narrow tolerance and may be used for above- and underground pipe systems.

For this adhesive joint the following tools and materials are required:

- Gloves, dust mask, safety glasses
- Measuring tape, marker, bench, pipe fitters wrap-a round
- Angle cutter, hand saw or jig saw
- Shaver, grinding tools
- Rubber scraper, pulling equipment, adhesive kit
- Heating blanket or air gun, insulation blanket, digital temperature gauge
- Cleaning brush, non-fluffy cleaning rags, cleaning fluids

Summarized, the bonding procedure consists of cutting, cleaning, machining, and application of adhesive, joining and curing. The installation time depends on proper preparation, diameter and personnel.
For specific and detailed information, reference is made to manufacturers' documentation.

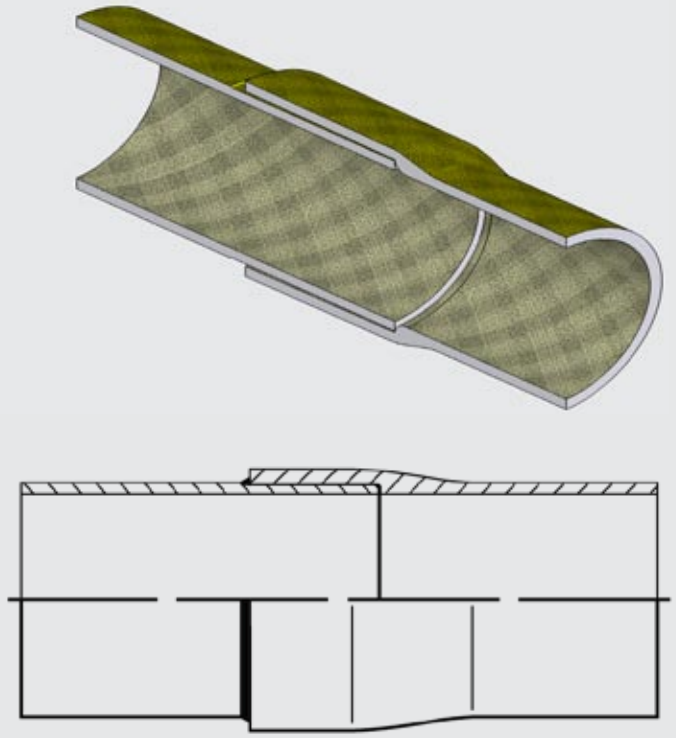

Fig. 4.1. Conical-Cylindrical bonded joint

4.2. Taper/Taper bonded joint

This adhesive bonded joint consists of a conical socket and conical spigot.

When comparing with the conical-cylindrical adhesive bonded joint this type of joint is also available in higher-pressure classes.

For specific dimensions, specific instructions are required. The tools, materials, joining procedure and installation time for the taper-taper bonded joint are similar to those of the conical-cylindrical adhesive bonded joint.

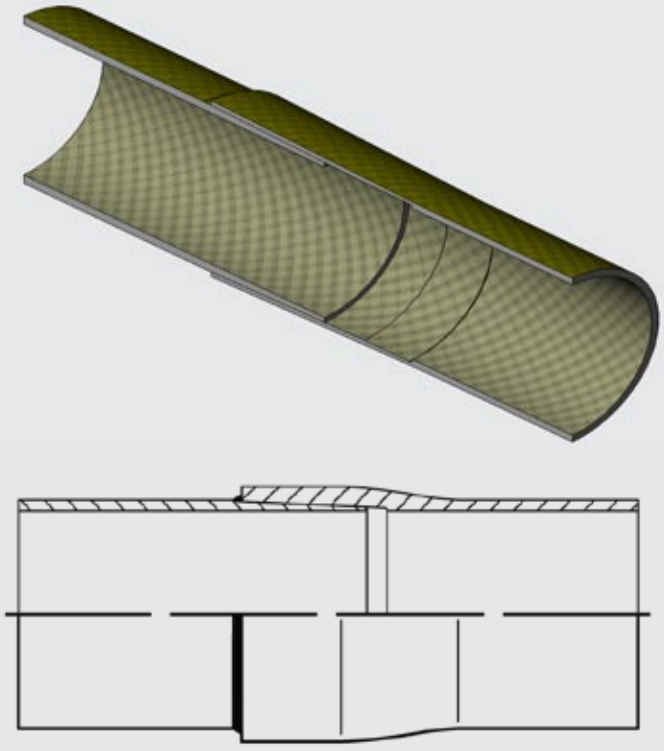

Fig. 4.2. Taper/Taper bonded joint

4.3. Laminate Joint

The laminate joint is used to join plain-ended pipe sections. After preparation of the pipe surfaces, a specific thickness of resin impregnated glass reinforcement is wrapped over a certain length around the pipes to be joined; the thickness and the length of the laminate are related to diameter and pressure.

This joint requires following tools/materials:

- Gloves, dust mask and safety glasses
- Measuring tape, marker and pipe fitters wrap around
- Angle cutter, jig saw or hand saw
- Grinding tools and flexible support disc
- Rubber scraper, scissors, brushes, resin, hardener and glass reinforcement
- Air gun, gas burner or field oven with insulation blanket and digital temperature gauge
- Cleaning brush, non-fluffy cleaning rags and cleaning fluids

The successive activities for a laminate joint are cutting, sanding, cleaning, mixing, fitting, laminating and curing. For specific and detailed information, reference is made to manufacturers' documentation.

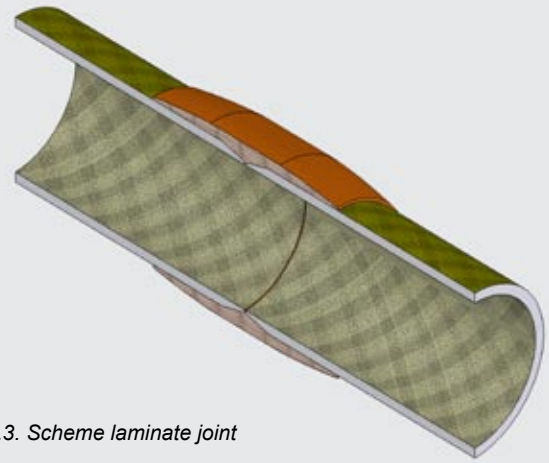

Fig. 4.3. Scheme laminate joint

Fig. 4.4. Laminate joint

4.4. Flange Joint

The flange joint connects appendages and equipment as well as other lines of different materials. Based on the application and pressure, several types are available.

For a flange joint following tools and materials are required:

- Ring spanner, torque wrench
- Bolts, nuts and washers
- Gasket

It is of major importance that GRE flanges are aligned with the counter flange. Excessive misalignment may cause high stresses, which lead to premature material failure. Generally, flange joints facilitate connections with steel piping and allow easy assembly and disassembly of piping systems.
For specific and detailed information, reference is made to manufacturers' documentation.

Fig. 4.5. Flanged joint

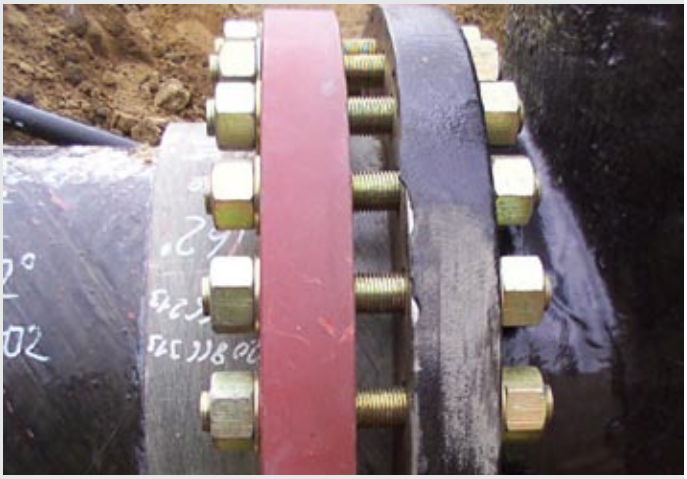

Fig. 4.6. Flange detail

4.5. Mechanical O-Ring Lock Joint

The mechanical O-ring lock joint is a tensile resistant type of joint. This restrained type of joint can be used in unrestrained environments, e.g. aboveground.
The following tools and materials are required to make such a joint:

- Pipe clamps and pulling equipment
- Lubricant, O-ring, locking key(s) and plastic or wooden mallet to drive the locking key in position
- Non-fluffy cleaning rags and cleaning fluids

The assembly procedure starts with cleaning and lubricating surfaces, then mounting clamps, aligning, pulling the spigot in the socket and mounting the locking key(s). The joint can be disassembled, but is not designed as such.
For specific and detailed information, reference is made to manufacturers' documentation.

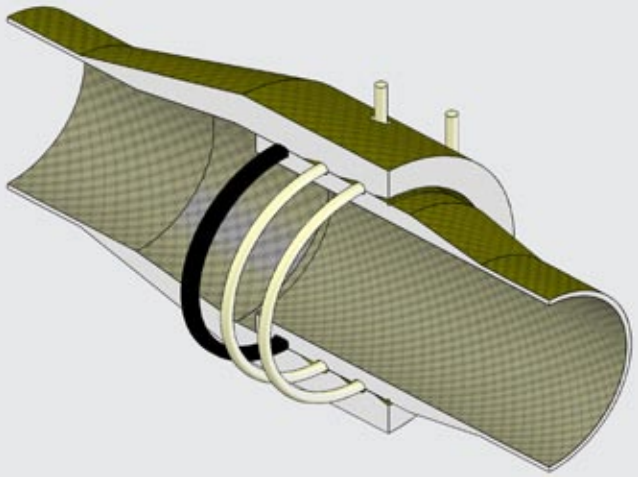

Fig. 4.7. Mechanical O-Ring lock joint (2-key)

4.6. Mechanical O-Ring Joint

The mechanical O-ring joint is a non-tensile resistant type of joint. This unrestrained type of joint can be used in a restrained environment, e.g. underground.
This type of joint is made with the following tools and materials:

- Pipe clamps and pulling equipment
- Lubricant, O-ring
- Non-fluffy cleaning rags and cleaning fluids

Joining starts with cleaning and lubricating surfaces; then mounting clamps, aligning and pulling of the spigot in the socket. For specific and detailed information, reference is made to manufacturers' documentation.

Fig. 4.8. Mechanical O-Ring joint (1-key)

4.7. Mechanical Coupler

Generally, mechanical couplers are used for joining plain-ended GRE pipes to pipes made from other materials. A step coupler can join pipes with different outer diameters. This type of joint is unrestrained. These couplers can also be used for preliminary repairs.
Specific information can be obtained from the supplier of the coupler.

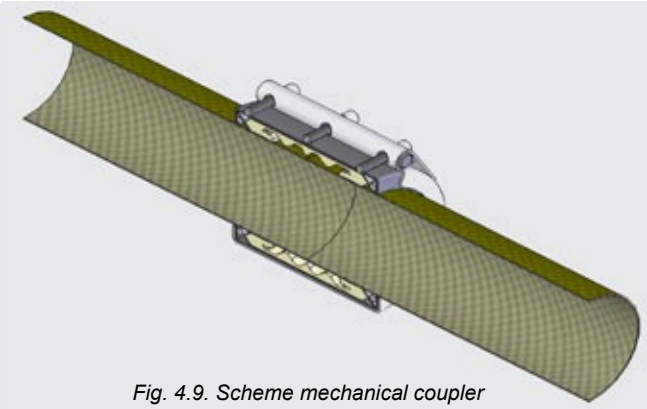

Fig. 4.9. Scheme mechanical coupler

Fig. 4.10. Various mechanical couplers

5. Tools and material

For details on tooling and materials, reference is made to manufacturers' detailed documentation.

5.1. Tools

Tools are divided in two main categories:
non-consumables and consumables.

5.1.1. Non-consumables

Non-consumable tools can be used multiple times.

5.1.1.1. Shaver

A GRE pipe shaver is a custom designed tool, which is used to prepare a spigot end for an adhesive bonded joint on a pipe. Pipes are standard supplied with the appropriate end figuration, but an adjustment to length at site requires shaving of a spigot in the field.

The shaver is mounted on an arbor.
The arbor is mounted and centred in the pipe and fixed against the inner surface of the pipe by expanding the diameter.
The shaver arm rotates around the central shaft of the arbor; the machining tool shapes the spigot end.

Fig. 5.1. M95 shaver type

Fig. 5.2. Mounted shaver (M87 type)

Fig. 5.3. Arbor

5.1.1.2. Heating blanket

Heating blankets are designed to cure adhesive bonded and laminate joints.
Blankets are made from a coiled resistance wire, which is sandwiched between two layers of silicon rubber.

To control the temperature, each blanket is furnished with a thermostat.
It is important to store the heating blanket properly in order to keep this tool in an optimal condition.

Heating blankets shall never be folded; these blankets may only be stored flat or rolled.

Fig. 5.4. Heating blanket

5.1.1.3. Pullers and band clamps

Pullers and band clamps are used to make Taper-Taper adhesive bonded joints, large diameter Conical-Cylindrical bonded joints and mechanical O-ring (lock) joints.

Band-clamps with pulling lugs must be applied at both pipe ends to be joined. The positions of the pulling lugs shall face each other.

The Taper-Taper joint must be kept under tension until curing of the adhesive is completed to avoid joint detachment.

Rubber protection pads are placed underneath the ratchets before tightening the band clamps. Put a wooden wedge between the pipe and the pulling lug to create a gap for mounting of the heating blanket.
For bonding of large diameters 3 to 4 pullers are required.
Check the pullers on defects on a regular base.

Fig. 5.5. Pulled adhesive joint

Fig. 5.6. Pull mechanism

Fig. 5.7. Wedge between pipe and pulling lug

5.1.1.4 Others

Other non-consumables may be required such as:

- Air gun, gas burner or field oven
- Angle cutter, hand saw or jig saw
- Pipe fitters wrap-a-round
- Pi Tape
- Grinding tool
- Insulation blankets
- Digital temperature gauge
- Generator

5.1.2. Consumables

Consumable tools can only be used once.
Following tools are supposed to be consumable:

- Measuring tape
- Pair of scissors
- Marker
- Sand paper/grinding discs P40 – P60
- Brushes
- Rubber scrappers, bucket
- Cleaning fluids, joint lubricant
- Dust masks, gloves and safety glasses

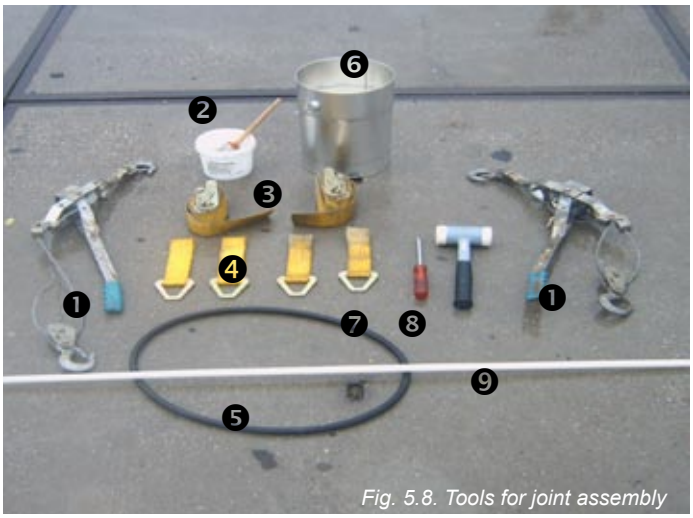

Fig. 5.8. Tools for joint assembly

❶ Powerpull (2x)
❷ Joint lubricant
❸ Band clamps (2x)
❹ Pulling rings (4x)
❺ O-ring
❻ Bucket with water
❼ Screw driver
❽ Hammer
❾ Key

5.2. Materials

5.2.1. Adhesive

Different types of adhesive are available depending on the application. Adhesive can be conductive or non-conductive.

An adhesive kit contains resin, hardener, mixing spatula and bonding instructions.
Adhesive kits contain chemicals that are sensitive to temperature and moisture.

It is important to check the expiry date of the adhesive, which is printed on the package.
Do not use adhesive or resin after indicated expiry date.

Fig. 5.9. Adhesive kit

5.2.2. O-ring

A rubber O-Ring provides sealing of the mechanical O-ring (lock) joint. Standard O-rings are made of Nitryl Butadiene Rubber (NBR).

Depending on the medium and/or temperature, other types of rubber can be supplied.

O-rings must be stored properly and flat, in a dry, cool and dark environment, free from dust and chemicals, which may attack the material.

Direct sunlight must be avoided.

Fig. 5.10. O-rings

5.2.3. Locking key

Locking keys block the longitudinal displacement of the spigot in the socket of a mechanical O-ring lock joint. Locking keys must be stored in a dry and cool location without direct exposure of sunlight. Improper storage may affect the mechanical properties negatively. For further details, reference is made to manufacturers' detailed documentation.

Fig. 5.11. Locking keys

5.3. Check of incoming material

5.3.1. Quality check

The condition of containers, crates, boxes and pallets must be checked on possible damage upon arrival. If damage has occurred to any material package, the contents might be damaged too.
Check pipes and fittings on impact damage. Materials and tooling must be dry at arrival.

The damaged state of materials and/or products when delivered must be reported and documented (e.g. clarified with pictures). Damaged materials shall be separated and quarantined from undamaged materials to avoid unintentional use.

5.3.2. Quantity check

Check the delivered quantities and the reported quantities on the packaging list. The recipient is advised to check the contents of the deliveries.

Quantity, size and configuration of materials and products should be physically checked against the data on the packing list.

Any deviation from the packing list must be reported immediately.

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6. Installation of underground pipe systems

GRE pipes are used for various applications in various soils conditions. Underground pipeline systems require accurate trench structuring, product assembly and installation.
For detailed information about underground installation, reference is made to manufacturers' documentation.

6.1. Trench construction

The trench construction highly depends on the soil parameters, such as type, density and moisture content.
The construction of the trench should comply with following requirements and recommendations:

- The trench shape is determined by the classification of the soil, which can be unstable or stable
- Top sides of the trench must be cleared from rocks or any other sharp/heavy materials
- The trench foundation shall consist of a compacted sand layer without stones or sharp objects
- Loosen a hard and uneven trench foundation in order to prevent point loading
- Keep the trench dry during installation; if necessary use of a pumping system and drainage
- The minimum width (W) at the bottom of the trench for a single pipe shall be: W = 1.25 * OD + 300 mm
- The space between the pipe and the trench wall must be 150 mm wider than the used compaction equipment
- Respecting pipe stiffness, operating conditions, soil characteristics and wheel load the minimum burial depth is 0.8 m
- The crown of the pipe must be installed below frost level

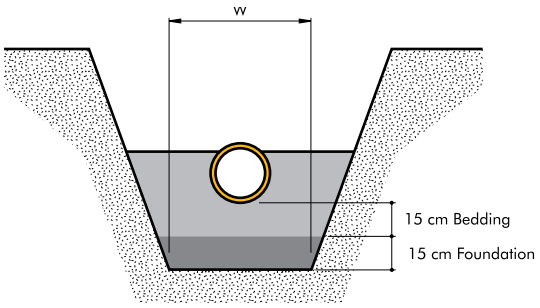


Fig. 6.3. General scheme of trench construction

6.2. System assembly

The assembly procedure of a piping system may vary per project. Generally, this procedure deals with positioning and joining of components in the plant.

6.2.1. Positioning components in the plant

After positioning of the pipe system elements next to the trench, these components have to be handled into final position in the trench.

- Small diameter pipe sections can be lowered manually using ropes, slings or light lifting devices
- Large diameter piping requires heavier equipment during final positioning
- To avoid damage the minimum bending radius of a pipe shall be respected
- Avoid unwanted objects falling into the trench during lowering pipe sections
- Use nylon sling belts or special designed equipment during product handling

Fig. 6.1. Trench in unstable soil

Fig. 6.2. Trench in stable soil

Fig. 6.4. Assembly in process

Fig. 6.5. Main assembly inside the trench

6.2.2. Joining of components

Respect next requirements and recommendations for joining of underground pipe systems:

- Inspect all products before installation
- Components with mechanical O-ring joints shall be assembled in the trench
- Adhesive bonded and laminated joints can be assembled either inside or outside the trench
- Never move or disturb a joint during the curing process
- Standard pipe lengths may be doubled in order to reduce the installation time
- Ensure sufficient space around joints for proper align ment and joining
- Keep the system centred in the trench
- Respect the allowable joint angular deflection and pipe bending radius
- Bending of a joint shall be avoided unless allowable by system design
- Changes in directions in non-restrained pipeline systems must be anchored
- Ensure stretching of the O-ring lock joints; this prevents axial displacement of the pipeline and overloading of fittings when pressurising the system
- The pipeline can be stretched by pressurizing at 0.8 * operating pressure. Mechanical stretching is recommended. Precautions shall be taken to avoid overloading of fittings
- Branches shall be left free or are installed after stretching of the header completely

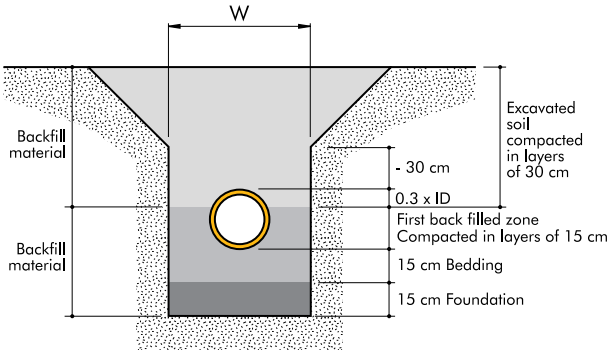


Fig. 6.6. Scheme trench construction stable soil

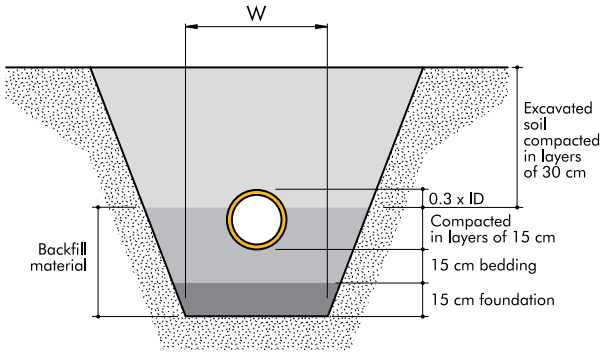


Fig. 6.7. Scheme trench construction unstable soil

6.3. Backfilling

Backfilling shall be performed according standard procedures. Trench filling, proper compaction and stabilizing of the system shall be performed in accordance with the requirements.

6.3.1. Procedure and requirements

The procedure and the requirements comprise:

- Temporary installation devices must be removed prior to backfilling
- The maximum particle size for pipe zone embedment is related to the pipe diameter and is described in the backfill material specification
- Dumping large quantities of backfill material at one spot on top of the pipe may cause damage; spread the applied backfill material
- Backfill material shall be compacted in layers of 150 mm. The pipe may not be displaced due to backfilling
- When reaching a compaction height of 0.3 * ID below the crown of the pipe, compaction may be continued in layers of 300 mm
- Each layer of backfill shall have a compaction grade of at least 85 % Standard Proctor Density (SPD)
- Compaction is performed on both sides of the pipe, never across the pipe. A vibrating plate with an impact force of 3000 N is used
- Do not use heavy pneumatic hammers or vibrating equipment until having reached a backfill level of 500 mm over the crown of the pipe.
- Avoid any contact between compaction tools and GRE-product

Fig. 6.8. Pipe assembly in process in prepared trench

6.3.2. Backfill material specification
For classification of various backfill materials and types of embedment, reference is made to AWWA Manual M45 or ASTM D 3839.

Note that highly plastic and organic soil materials are not suitable for backfilling and must be excluded from the pipe zone embedment.

6.3.3. Other backfilling methods
Use of the saturation method does not give any better result than the above-described method.

The grade of compaction is lost if compaction by saturation is performed after mechanical compaction. When saturating the trench, avoid floating of the pipeline as well as erosion of the side support. Do not backfill if the ground is already saturated.

The saturation method may only be used for free draining soils, when the drainage pumps are kept in operation and the pipe system is completely filled with liquid.

Fig. 6.9. Compaction of backfill material

6.4. Special underground installations
Road crossings and channel crossings demand particular attention and requirements.

6.4.1. Road crossing
Precautions shall be taken to protect pipes, which cross underneath roads against the possible consequences of traffic loads.

Possible alternatives are:
- Jacket pipe
- Relief plate
- Burial depth
- Pipe stiffness

6.4.1.1. Jacket pipe
The GRE pipe is nested in a jacket pipe. In order to avoid direct contact between both pipes, spacers centre the GRE pipe. These spacers also support the GRE pipe at a maximum distance of 3 m. The jacket pipe should be longer than the width of the road.

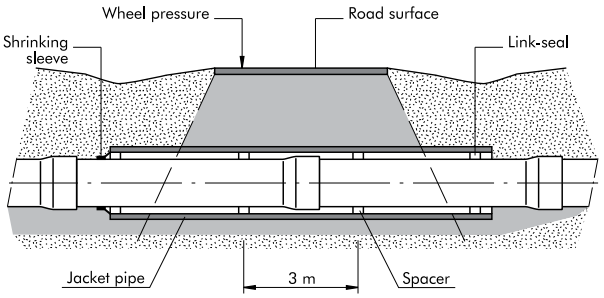


Fig. 6.10. Jacket pipe at road crossing

6.4.1.2. Relief plates
Relief plates are used if pipes are installed at shallow depth in well compacted sandy soils or in case the soil- and traffic load cause an excessive loading or deformation of the GRE. The plate is specially designed and dimensioned to minimise the transfer of wheel load on the pipe.

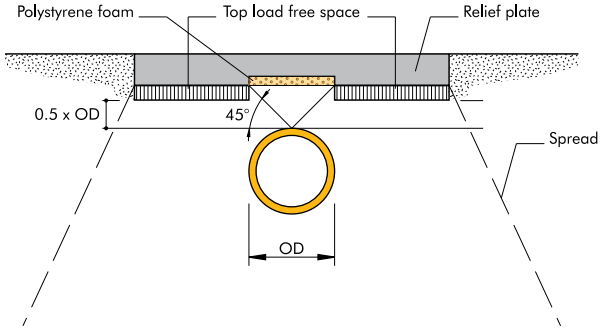


Fig. 6.11. Relief plate

6.4.1.3. Burial depth
Generally, the influence of the wheel load of traffic passing a buried pipe reduces with increasing burial depth.
However, with increasing burial depth the soil load on the buried pipe increases.
Our engineers may assist to determine an optimal solution.

6.4.1.4. Pipe stiffness
Pipes with higher stiffness are better resistant to external loads due to traffic loads. Stiffness of pipe can be increased by increasing the wall thickness.

6.4.2. Channel crossing

The common method to install underwater mains is to assemble the pipe on the bank of the canal or river. The pipe can be lowered using a floating crane or other lifting equipment; care should be taken to ensure sufficient pipe supports.

The process starts by sealing the ends of the pipe and pulling the system into the water; the pipe keeps floating. Then, the pipe is filled and carefully sunk into its final position.

Flexible joints can be used for underwater piping if the installation is performed using a cofferdam construction; this makes the installation similar to an onshore assembly.

Note that underwater pipes should be covered sufficiently to prevent floating and damage (e.g. by anchors).

Fig. 6.12. Lowering underwater main

6.5. Alignment

Undulating land levels with minor difference in height can be followed by the flexibility of the system.
Joints or pipe bending, if assessed by system design, ensures no lateral displacement while allowing angular deflection.

Fig. 6.13. Pipe alignment

6.6. Settlement

Flexible joints have to be installed in pairs; one joint is placed at the beginning of the deviation while the other is located at the end of this area, in order to create a rocker pipe. The rocker pipe will act as a hinge.

The longer the rocker pipe, the higher the loads on the joints. This can be avoided by adding more joints that are flexible. Based on the soil parameters, the number of joints is determined.

Note that the length of the sections shall be limited in order to avoid excessive bending which may result in failure of pipe or joint.
The section length = ID + minimal 0.5 m. Mechanical O-ring joints shall be installed at both ends to accommodate further settlements.

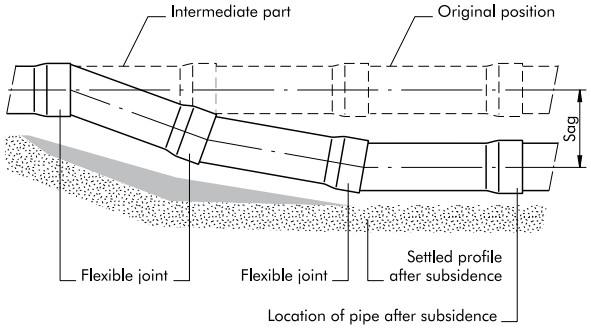


Fig. 6.14. Settlement

6.7. Pipe cast in concrete

In some cases, pipe systems may be cast in concrete. Such applications require following:

- Do not pour concrete directly onto pipe
- The vibrating poker must be kept at least 300 mm away from the pipe
- The pipe system must be pressure tested prior to casting
- Cradles are provided with steel clamps and rubber lining in order to prevent floating
- Buckling of the pipe during casting can be prevented by pressurizing the system.

Note that concrete shrinks when setting; this may result in extra loading of the GRE pipe system. Ensure that the allowable pressure is not exceeded by using pressure relief valves.

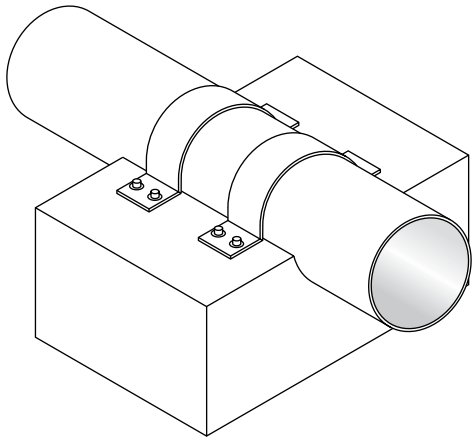


Fig. 6.15. Pipe cast in concrete

7. Installation of aboveground pipe systems

Aboveground pipe systems may be subjected to various loadings resulting from operation of the system.
Next to the information in this section, reference is made to specific manufacturer's documentation.

Fig. 7.1. Aboveground pipe system

7.1. Supports

Supports not only provide system fixation, loading relief and clinching but also protection. Prior to installation, supports are checked for location, type and span as detailed in drawings and specifications of the project. Supports can be differentiated as fixed, guided sliding and free sliding supports.

Fig. 7.2. Pipe supports

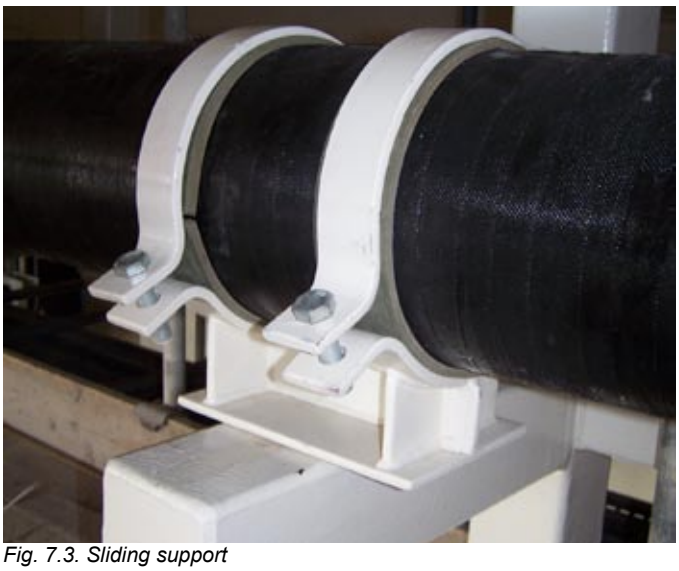


Fig. 7.3. Sliding support

7.1.1. General

Functional pipe supporting can be obtained with the aid of system design analysis.
Following aspects need to be respected:

- Pipes resting on sleepers are supplied with 180° saddles, which are bonded to the pipe at the support location to protect the pipe against wear damage from possible pipe movements
- The length of the wear saddle must be 50 mm longer than the calculated pipe displacement plus the support width
- Allow pipe expansion within a clamp
- In vertical pipe assemblies, the sockets of O-ring joints shall point downwards, so water cannot be trapped in the socket. Entrapped water in the socket may cause joint damage when freezing
- For clamp dimensions, reference is made to manufacturers' detailed documentation
- Mechanical O-ring joints require minimal one support per pipe length
  The distance of the support to the joint is maximal 20 % of the pipe length

7.1.2. Fixed support points

Fixed points may never be realized by tightening the bolts of the pipe clamps. This may lead to pipe deformations and excessive wall stresses.

Mind the following requirements for fixed points:

- Fixation saddles shall be positioned on both sides, at the shoe side of the clamp
- Laminated fixation saddles shall be applied on both sides of the clamp
- When using non-restrained jointing systems each pipe shall be fixed
- Each change of direction in a non-restrained pipeline shall be anchored to prevent pipe joints coming apart
- Check whether the positions of pipe supports are still in accordance with the installation requirements after testing. The supporting elements might be dislocated due to test pressure

Note that the mechanical O-ring lock joints must be fully stretched to avoid movement of pipe sections and consequently possible overloading. For further details on this type of joint, reference is made to manufacturers' documentation.

Fig. 7.4. Support with fixed point

Fig. 7.5. Fixed point with bonded saddles

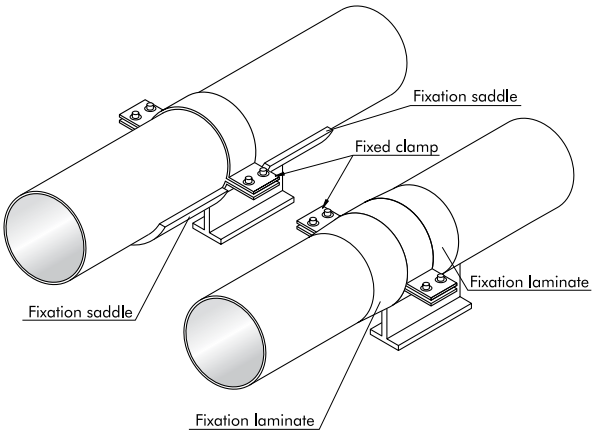


Fig. 7.6. Collars on both sides of the pipe clamp

7.2. Pipe clamps

Various types of pipe supports are available.
Following considerations must be respected:

- Avoid point loads by using clamps made of flat strips instead of U-bolts. The width of the strip is related to the pipe diameter. For large diameter pipe double clamps may be applied
- The inside of the clamp is furnished with a rubber or cork liner to compensate the uneven pipe outer surface and to minimise abrasion due to pipe movement and vibration
- Longitudinal movement in the clamps is not advised. Generally, movement between the clamp shoe and the support structure shall realize sliding of supports

For detailed information on clamps, reference is made to manufacturers' documentation.

Fig. 7.7. Pipe clamp

7.3. Valves

To avoid overstressing of pipes by the weight of valves or other heavy equipment it is advised to support pipe accessories on the flange bolts.

The load on the pipeline by operating the valve shall be carried by the support of the pipe structure. In case of a GRE flange mounted against a steel flange, the support is preferably fixed to the steel flange.

Fig. 7.8. Valve

7.4. Bellows

GRE products can absorb low amplitude vibrations due to the flexible properties of the composite material.
To eliminate high amplitude vibrations caused by e.g. pumps and to compensate soil settlement or expansion of e.g. tanks joined with pipes, bellows can be applied.

Bellows facilitate dismantling of pipe sections, valves, orifice flanges and gaskets. This equipment also absorbs pipe movements due to cyclic pressure and/or temperature in pipe systems that are joined with relatively stiff adhesive bonded joints.

In many cases, bellows are directly joined to the vibrating item by means of flanges. Note that the pipe section next to the bellow shall be supported separately to absorb the pipe loads.

Fig. 7.9. Bellow

7.5. Pipe connections through walls

Several alternatives are available for passing pipes through walls. In case of anticipated settlement of the wall or pipeline, flexible couplings must be installed on both sides of the wall.
The joints shall be positioned as close as possible outside the wall.

7.5.1. GRE pipe with sealing puddle flange

The factory made puddle flange consists of a GRE ring, which is laminated on the pipe.

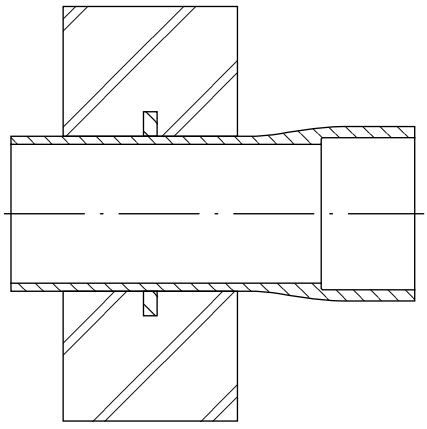


Fig. 7.10. Puddle flange

7.5.2. Sand coated GRE pipe

A sand coating on a GRE pipe offers an excellent adhesion between concrete and GRE.

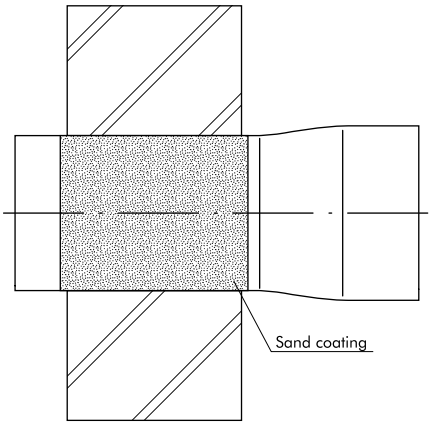


Fig. 7.11. Sand coated GRE pipe casted in concrete

7.5.3. Link seal

This type of wall penetration consists of several linked rubber parts, which fit in the circular space between the outer surface of a GRE pipe and the diameter of a hole in a wall. A sufficiently smooth inner surface of the wall can be obtained by:

- Mounting a steel pipe section with water seal before pouring mortar
- Drilling a hole with a crown drill having diamond inlays
- Fixing a removable plastic casing pipe section before pouring mortar

The rubber parts are linked together with bolts and form a rubber chain. The rubber sections are compressed by tightening the bolts.
All components of the link seal can be made of various material qualities.

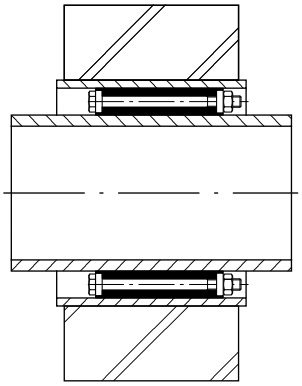


Fig. 7.12. Sketch link seal

Link seals allow for some angular deflection and lateral movement. After having mounted the GRE pipe in the link seal the rubber elements are compressed by tightening the bolts evenly. The expanded rubber sections seal the room between GRE and concrete.

Fig. 7.13. Link seal

7.5.4. Special sealing shape

This wall penetration consists of a steel pipe, which is provided with flanges. One of the flanges is profiled to fit a sealing element. By tightening the nuts, the seal is compressed in the annular space between the flange and the pipe and provides an excellent seal.

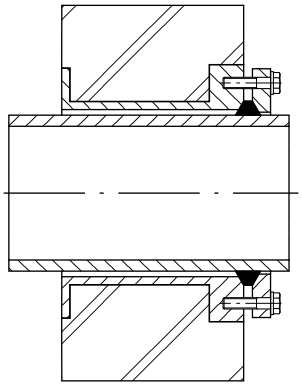


Fig. 7.14. Special sealing shape

7.5.5. Plain wall passing

When passing a pipe through a wall, the outer surface of the pipe must be protected with a flexible material, e.g. a 5 mm thick rubber layer, protruding 100 mm at both sides of the wall.

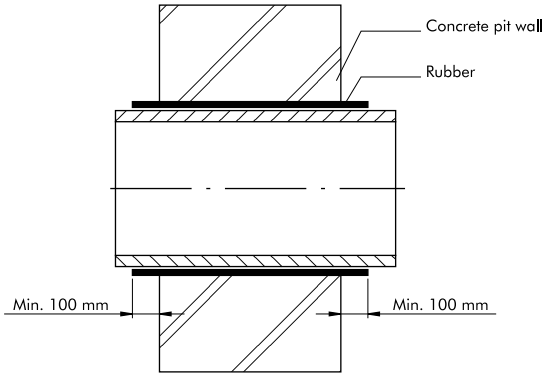


Fig. 7.15. Plain wall passing

7.6. Joining with other materials

The most appropriate method to join objects of different materials is by using a flange. A mechanical coupler might be an alternative. For details about these joints, reference is made to manufacturers' documentation.

Flanges can be drilled according most of the relevant standards. When a flanged GRE pipe section is joined with a metal pipe section, the metal section must be anchored to avoid transmission of loads and displacements to the GRE pipe sections.

Instrument connections can be made using a saddle and a bushing.

Fig. 7.16. Joining to other materials

7.7. UV-resistance

The topcoat of GRE pipes and fittings consist of a resin rich layer. This layer offers sufficient protection against UV-radiation.
When exposed to weather conditions the epoxy topcoat may be attacked on the long term; this may result in a chalked outer surface.

After several years of operation, the chalked layer may be removed and replaced by a resistant, protective polyurethane paint coating. Contact the manufacturer for advice.

8. Quality Control/Quality Assurance

8.1. General
To assure good workmanship, only qualified and certified personnel shall be allowed to work on the installation of GRE pipeline systems.

Always strictly follow the installation manuals next to the necessary instruction guidelines. When making joints, it is necessary to execute the required steps in the correct sequence.

Never compromise on work quality and follow the instructions assigned from handling and storing through joining and installing GRE materials.

8.2. Joint traceability
As part of the quality control and on behalf of the traceability of adhesive bonded joint data, the following information should be registered during installation for each joint:

1. Name or registration info of the pipe-fitter
2. Joint identification (number)
3. Start/end of the curing process
4. Heat blanket identification (number)
5. Identification (number) of adhesive batch
6. Temperature of heating blanket (optional)

8.3. Possible installation defects
Following table lists a number of defect types along with acceptance criteria and recommended corrective actions:

Table 8.1. Defect, acceptance criterion, corrective action

Defect	Inspection method	Cause	Acceptance criterion	Corrective action
Incorrect spool dimensions	Visual	Incorrect prefabrication	Can difference be compensated elsewhere in the system? Can system not be compensated?	Accept Reject
Misaligned spools	Visual	Misaligned components e.g. flanges	Can difference be compensated elsewhere in the system? Can system not be compensated?	Accept Reject
Misaligned joint	Visual	Movement during cure. Incorrect shave dimensions	Not permitted	Reject
Diameter restriction	Visual	Application of too much adhesive	Maximum height (h) of adhesive seam is 0.05 * ID or 10 mm, whichever is smaller	If accessible, remove by grinding
Impact, wear, or abrasive damage	Visual	Incorrect transport or handling	According to ISO 14692, Annex A, Table A1	Major defect: replace Minor defect: repair
Leaking joint	Hydro test	Joining not properly performed	Not permitted	Reject

9. Field Test Procedure

9.1. General

Before the installed pipeline system is operational, the system has to be hydro tested to ensure the integrity and leak tightness. Hydro testing of the pipeline system will be performed in two steps:

1. Integrity test
   The test pressure shall be increased over an agreed duration at an agreed pressure level in order to prove the maximum pressure resistance of the system.
2. Leak tightness test
   The test pressure shall be increased to an agreed pressure level at which the joints can be inspected visually

Pressure level and test duration can be stated in an Inspection and Test section of the Site Quality Plan.

All safety precautions must be applied. It is important to test the integrity of the system first, to avoid the risk of injury during visual inspection. All pressure gauges and pumps must be suitable and calibrated. Ensure that the pipeline can be vented and drained.
The pressure gauge must be mounted between a valve and the pipeline system in order to indicate the test pressure in the GRE system after having closed the valve, which is mounted after the pump. Due to the head of water, the pressure gauge should be located at the lowest point in the system. The pressure gauge should have a maximum scale reading of approximately twice the test pressure.

If the system is not designed to withstand any negative pressure, which might occur during testing, then the system needs to be protected by an air release valve. Trapped air should be released by using vent(s).

The application of GRE pipeline systems may vary from long, (buried) line pipe applications to small skid piping systems.

Joint types might vary from laminate joints to mechanical joints with O-ring seal, with or without locking strip.

Each system requires its specific testing method. For each system, the test procedure has to be described in the Inspection and Testing Section of the Site Quality Plan. This Inspection and Test Plan (ITP) must be established before the project starts.

The advices for testing mentioned in the following paragraphs are for guidance only and are not mandatory.

9.2. Preparation

Prior to hydro testing, the following issues shall be checked:

- All material that should not be on the inside of the pipeline system shall be removed
- All joining procedures shall be completed
- Trenches should be partially backfilled and compacted; the joints should be left exposed
- All supports, guides, and (temporary) anchors shall be in place and functional before pressurizing the system
- All temporary supports and installation aids shall be removed
- Unless stated otherwise, all valves should be through-body tested
- All check valves shall be removed to enable monitoring of the full line
- Flange bolts shall be made up to the correct torque
- Buried pipe systems must be backfilled sufficiently to restrain the system

9.3. Filling, stabilizing, testing and depressurizing

9.3.1. Filling and stabilizing

Fill the pipeline at the lowest point with water using a small diameter branch connection and vent the trapped air at the highest point(s) of the system. Long straight sections may be vented using an inflatable ball or foam pig to expel any air and impurities.

Fig. 9.1. Various pipe pigs

After filling, the line is pressurized gradually up to 0.8 * Design Pressure; the pressure shall be maintained for 24 hours in order to allow the system to set and the pressure to stabilise. For small above ground systems, it is allowed to reduce the stabilising time.

9.3.2. Testing

Once the pressure is stabilised, the integrity of the pipe system is tested first in accordance with agreements.

Depending on the system a pressure drop might occur. In all cases, leakage of joints, pipes or fittings is not allowed. For safety reasons, an inspection of the system because of a possible leakage is not permitted when the pipeline is loaded at integrity test pressure level. This has to be mentioned in the ITP.

When the integrity test has been completed successfully, depressurise the system to leak tightness test pressure level. Duration of the leak tightness test normally depends on the time needed to inspect all joints, pipes and fittings visually.

It is preferable to test the line in sections, for example the length of one-day installation. The line is temporarily closed using, e.g. a test plug and a flange at the end. The blind flange should be provided with an air release valve.

Fig. 9.2. Field test unit

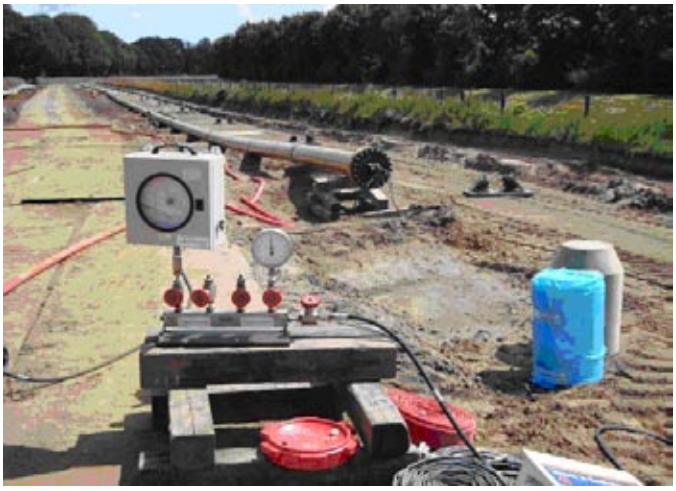


Fig. 9.3. Test pressure recording

After testing of the installed section the test plug, needs to be pushed back about 2 meters by pressuring air via the air release valve. The excess water is released by opening the valve at the begin of the line. After securing of the test plug, e.g. by inflation, the temporary flange connection can be removed and the assembly may proceed. The advantage of this method is that the test medium stays in the tested section and does not need to be re-filled for hydro testing of the next section.

Any leak caused by incorrect assembly of the joint can be detected easily. Extreme movements can be prevented by partially filling and compacting of the trench.
Note that temperature changes over a 24 hours period will affect the pressure in a closed system.

A drop in pressure during the night does not always indicate that there is a leak in the system. When testing a system the ambient temperature should be measured.

GRE material behaves different from steel due to the low weight, the flexibility of the joint and elasticity of the material. In case of a failure during hydro testing, the line will move due to the sudden release of stored energy; there might be a risk of injury to personnel.

Note that testing with air or gas is extremely dangerous and should be avoided. Systems shall never be tested with an inflammable fluid or gas.
The manufacturer of GRE pipe systems does not take any responsibility for any damage resulting from the use of these methods.
The following causes may affect pressure drop and consequently result in hydro test failures:

- Leakage of pipeline accessories
- Leakage of gaskets
- Leaking joints
- Leakage of pipes

The system shall be considered to have passed the hydro test if there is no leaking of water from the piping at any location and there is no significant pressure loss that can be accounted for by usual engineering considerations.

9.3.3. Depressurising
Depressurisation of the system must be carried out carefully to avoid a negative pressure.

In the unlikely event, GRE pipes, joints and/or fittings may have to be repaired. Repair on the pipeline system shall be performed according described instructions.

10. Repair

The repair procedure shall be prepared and qualified by the contractor in accordance with the pipe manufacturer's recommendations. It shall be demonstrated that the repair method restores the specified properties.

Leaks in pipe, fittings and joints are repaired by replacing the defective part. In some cases, especially for buried systems, insufficient space and/or difficult accessibility to pipes and fittings may occur.

Each application of a GRE pipe system and each type of product or design requires a different repair and/or replacement procedure.

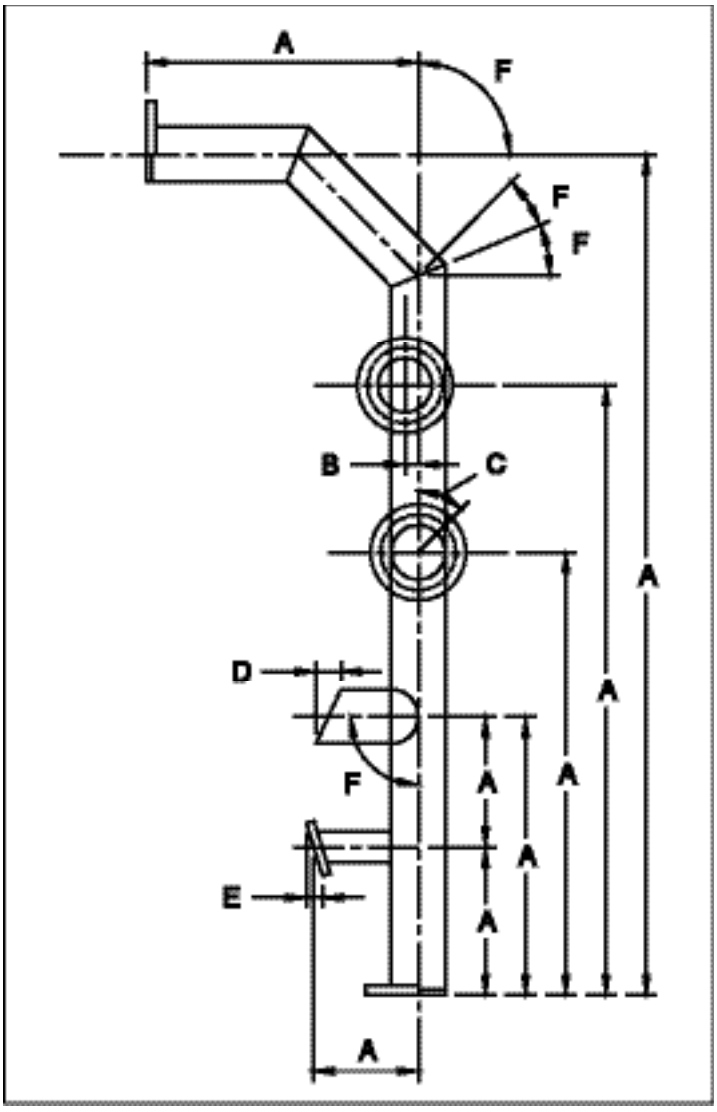
For further details, reference is made to manufacturer's documentation.

11. Tolerances

It is recommended to consider and use the dimensional tolerances illustrated and figured below.

Tolerances to dimensional reference

Internal diameter mm	A	B	C	D	E	F
25 - 200	±5 mm	±3 mm	±0,5°	±3 mm	±1 mm	±0,5°
250 - 300	±5 mm	±3 mm	±0,3°	±3 mm	±1 mm	±0,5°
350 - 400	±5 mm	±3 mm	±0,3°	±3 mm	±2 mm	±0,5°
450 - 600	±10 mm	±5 mm	±0,3°	±3 mm	±2 mm	±0,5°
700 - 900	±10 mm	±5 mm	±0,2°	±4 mm	±3 mm	±0,5°
1000 - 1200	±10 mm	±5 mm	±0,15°	±6 mm	±3 mm	±0,5°



Dimension A

a) Face to face dimensions

b) Center to face dimensions

c) Location of attachments

d) Center to center dimensions

Dimension B
Lateral translation of branches or connections

Dimension C
Rotation of flanges, from the indicated position

Dimension D
End preparations

Dimension E
Cut of alignment of flanges from the indicated position, measured across the full gasket face

Dimension F
Angular deflection

12. Safety precautions

The following safety precautions should be respected when using GRE products. The required rescue and safety measures when using resin and hardener for adhesive or lamination sets are shown under the R- and S- code numbers which are listed in manufacturer's documentation.

12.1. Resin, hardener, adhesive and lamination sets
In order to avoid irritation of the respiratory system, satisfactory ventilation should be provided. If a system is hydro tested, adequate safety precautions must be taken, as a "safe test pressure" does not exist. Any pressure in itself is dangerous.

Experienced personnel must operate the test equipment. Persons not involved in the test or inspection are not allowed in the immediate area of the tested system. Only one person should be in charge and everyone else must follow his/her instructions.

Do not change anything on the pipe system when it is under pressure. Leaking joints may only be repaired after the pressure has been fully released.

The test equipment must be installed at a safe distance from the connection to the pipe system.
If welding needs to take place, the GRE material must be protected from hot works.

12.2. Cutting, shaving and sanding
When cutting or grinding GRE materials the following personal protection is necessary to protect eyes and skin:

- A dust mask covering nose and mouth
- A pair of safety goggles
- Gloves and overall
- Close overall sleeves with adhesive tape to keep the dust out
- Wear protective clothing to protect the body
- Machining should be carried in a well-ventilated room or in open air

12.3. Environment
Always clean up the work area. GRE and cured adhesive are chemically inert and do not have to be treated as chemical waste.
Waste shall always be disposed in an environment friendly manner.

13. Important Notice

specialized training in accordance with currently acceptable industry practice. Variations in environment, changes in operating procedures, or extrapolation of data may cause unsatisfactory results.

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