Plastics Pipes – A Look into the Future

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Abstract

The use of thermoplastics pipes systems for gas distribution has been a big success. These materials and polyethylene in particular have become the first choice for low pressure gas systems up to 10 bar, solving the corrosion and reliability issues of steel and ductile iron systems. However it is unlikely that any significant increase in pressure rating can be obtained by future material development alone. Development is now concentrated on multilayer and composite pipe constructions to satisfy specific application requirements and to increase pressure ratings respectively. This paper reviews the use, advantages and essential requirements of plastics pipes systems for gas distribution. The future potential of multilayer and Reinforced Thermoplastics Pipes (RTP) systems is discussed, the latter offering the potential for much higher pressure rated plastics based products, with potential for use in medium and even high pressure gas distribution systems.

Introduction

Natural gas is a major indigenous fuel source for many industrialised and developing countries that will be available for generations to come. The importance of providing clean dry gas for powering both industry and commerce as well providing domestic energy cannot be underestimated.

The infrastructure of the natural gas transmission and distribution systems is well developed in many countries. As an example the pipeline system in the UK has four distinct categories. The first is the source feed at pressures above 100 bar from the offshore wellheads. The second is a high-pressure grid operating at up to 85 bar known as the National Transmission System (NTS). The third is a medium-pressure grid operating at up to 38 bar known as the Local Transmission System (LTS). The fourth is a low-pressure system operating at below 7 bar, known as the Local Distribution System (LDS). Over 275,000 kilometres of pipe-work exists to provide this distribution in the UK.

Polyethylene (PE) plastics systems have been used in the UK low pressure distribution system since the late 1960s, initially for service and distribution pipes below 2 bar, but since the early 1990s for distribution up to 7 bar following the introduction of the higher strength PE 100 materials. The attraction of the plastics system is primarily corrosion resistance but also ease of handling and the potential use of ‘no-dig’ technology for installing the flexible pipe, which can be delivered to site in long coils reducing jointing and traffic disruption. Another significant advantage of polyethylene is that the fusion welded joints provide a fully end load resistant system, avoiding the reliability issue of mechanical fittings with elastomeric seals. In recent years fusion welding equipment has allowed the application of an extensive reliable low cost traceability system. Bar codes and chips are easily moulded into the

PE fittings. Such a system allows an intelligent surveillance of contractors providing a record of the installation.

Polyethylene is now the material of choice in many countries for low pressure gas distribution networks.

This paper looks into the future and the possibilities for flexible thermoplastics based pipes being suitable for medium pressure grids and even high pressure transmission systems and other applications within the distribution system.

Use of thermoplastics pipe systems for gas distribution

Polyethylene (PE) and polyvinyl chloride (PVC) were discovered in the 1930s and the use of these materials for production of water pipe commenced after the war. In the 1960's Du Pont developed a PE system with fused joints for gas distribution. This system was accepted by British Gas as a material option for their low pressure system following evaluation of several other thermoplastics. Nowadays it is virtually the only material used for new lines and renovation of the low pressure system in the UK. Other countries have followed this example, in particular France, Belgium, Spain, and Germany in Europe. The material is extensively used in Japan. Indeed the use of the PE for gas distribution in this country was shown to be a wise choice. The flexible fully end load resistant plastics system was left mostly intact after the Kobe earthquake, whilst the steel system required extensive repair, Ref. 1. The polyethylene system is currently limited to 10 bar maximum operating pressure in accordance with EN 1555 and ISO 4437, see Appendix 1.

Other thermoplastics are used for gas distribution pipes but mostly for niche applications or by preference in a few countries. These include crosslinked polyethylene (PE-X), high impact (PVC-HI) and polyamide (PA), commonly known as nylon. The latter material has the potential for higher maximum operating pressures compared with PE but only providing other essential requirements such as resistance to rapid crack propagation are demonstrated. PE-X is an interesting material. Based on polyethylene the crosslinked structure enhances the toughness and temperature resistance of the material. This enables the material to be specified for use in more harsh environments both at lower and higher temperatures. However pipes in these materials are somewhat limited in diameter availability compared with the PE system. See Appendix 1 for a list of standards specifying these materials.

ISO/TC 138 Plastics Pipe and Fitting Systems and CEN TC 155 Plastics pipes and Fittings Systems have developed a whole suite of standards for plastics pipe systems for gas distribution, see Appendix 1. Product standards have been published for PE (up to 10 bar), PE-X (up to 16 bar), PVC-HI (up to 2 bar) and PA (potentially up to 20 bar, but RCP performance is currently subject to investigation).

In addition there are standards for multilayer pipe for indoor and outdoor applications and for RTP Reinforced Thermoplastics Pipes. It is the latter in particular which offer the potential for much higher pressure rated products and potential applications in the medium and even high pressure gas distribution systems.

Summary of the advantages of a plastics system

Plastics have solved the corrosion and leakage problems of traditional iron and steel pipes whatever the ground conditions. Above all the durability of these systems has given them a track record of trouble free service second to none. The flexibility of PE pipe allows it to be coiled and supplied in long lengths, avoiding frequent joints. A polyethylene system has an inherent resistance to the effects of ground movement from temperature fluctuation or instability because of the end load resistant fusion welded jointing systems mostly employed. Clearly an advantage for pipe buried in mining areas, recently filled or reclaimed ground, or in winter when frost results in greater ground movement. The flexibility and viscoelastic properties of plastics pipe requires a different approach to the assessment of stresses caused by burial. Compared with traditional materials high levels of strain can be safely tolerated since the associated initial stresses in the pipe wall will relax and redistribute as the ground-pipe system becomes increasingly stable while settlement and compaction takes place. An intensive field study commissioned by TEPPFA, the European Plastics Pipes and Fittings Manufacturers Association, has shown that in most cases ground and traffic loading does not need to be carefully defined even for thin walled plastics pipes. Instead a simple empirical graphical method can be used when it is considered necessary to quantify initial and final deflection values, rather than employing complex calculations, Ref.2.

The flexibility of these systems has resulted in the development of cost and time saving ‘no-dig’ installation techniques, reducing disturbance to the public. Long lengths can be pulled through holes below the ground bored by mechanical moles, avoiding the need for open cut trenches. When this is not possible narrow trenching techniques are used, possible because the jointing of pipe can be carried out on the surface and the pipe snaked into the trench afterwards. The material lends itself readily for renovation by insertion as a lining into old leaking pipelines or installation of PE pipe following ‘bursting’ of the corroded host pipe, offering further cost saving solutions to the gas engineer. ‘No-Dig’ techniques such as slip lining, Swage lining, Rolldown, Tightliner, Subline, Compact and U Liner are used to insert the pipe and to give a tight fit following reversion, Ref.3. Such techniques can result in significant reductions in installation costs compared to other pipe materials. Plastics are often colour coded to enable the application of the pipe to be identified. Typically yellow or orange for gas, or by coloured stripes on black pipe. The low friction bores of PE pipes give increased flow rates and are not subject to scale build-up. The material is biologically inert and is not subject to rodent attack. No protective layers, finishing processes or cathodic protection are required, thus avoiding additional expense and further potential risk of failure due to damage prior or during installation.

Plastics pipeline systems have been developed as integrated pipe and fitting systems. They have a track record of high reliability over a period now approaching 50 years. There is no cost penalty in obtaining these advantages, the PE system is cost effective with a long maintenance free lifetime and low whole life costs.

To summarise the principal advantages of the polyethylene system are:-

- No corrosion, biologically inert

- Leakfree fusion jointing systems, resistant to full end load and ground movement, avoiding the use of mechanical fittings with elastomeric seals
- Lightweight and resistant to site handling
- Improved hydraulic capacity from low friction bore, not subject to scale build-up
- Flexibility allows a range of cost effective installation techniques to be used
- Coiling in long lengths to reduce joint frequency
- Low cost traceability systems can be used to provide installation records
- Track record of reliability and durability in service
- Cost effective long maintenance free lifetime/low whole life costs

As a liner or coating:-

- Provides corrosion protection to allow use of a cheaper grade steel host pipe
- Liners can be inserted on site or insitu for rehabilitation purposes
- Cost effective coating application and liner installation processes

Essential requirements of plastics pipes gas distribution system

Pressure rating of a plastics pipe is not the sole performance requirement, there are other essential requirements to be taken into account before a material can be accepted for gas distribution piping, ie:-

- Fracture and impact behaviour
- Deformation
- Effect of environment
- Jointing/Weld characteristics

For gas applications it is essential that the fracture properties of the materials used are fully characterised and understood. Good resistance to slow crack growth is necessary to ensure long term durability. No risk of temperature and pressure dependent RCP rapid crack propagation in the intended operating conditions is essential, and is characterised for both steel and plastics materials before they can be accepted for gas distribution applications. Whilst PE is suitable for pressures up to 10 bar this is limited to PE 100 materials with suitable RCP resistance.

By characterising and understanding these aspects of performance in detail, material suppliers and manufacturers are able to introduce new products to the end user with confidence of their fitness for purpose. Such attention to detail covered by standards and specifications for plastics systems has undoubtedly contributed to their success and needs to be addressed prior to the commercialisation of new products.

Future Development of Plastics Systems

Monolayer thermoplastics piping systems have perhaps reached their potential limit, fulfilling all the requirements of low pressure gas distribution systems to give the gas engineer a reliable low whole life cost asset. Future development may result in improved jointing productivity, perfection of low cost installation techniques, and availability of larger diameter pipes and fittings. However it is unlikely that any significant increase in pressure rating can be obtained by material development alone. Orientation has been used to increase the rating of PVC for water pipe but this technology has yet to be transferred commercially to polyethylene pipes. Future development is likely to be with multilayer and composite pipe constructions to satisfy specific application requirements and to increase pressure rating respectively.

Multilayer Pipe

There has been a lot of interest in multilayer pipe in the plastics pipes industry in recent years. This has resulted in the development and publication of standards for both indoor and outdoor gas applications utilising such products, ISO 17484 and ISO 18225 respectively, see Appendix 1. Co-extrusion of pipes with metal or different polymer layers is a highly developed process and a method of obtaining pipe with specific material properties on the bore or external layer.

Small diameter PE or PE-X pipes with a thin aluminium centre layer have become popular for installation within buildings in preference to copper, see Fig.1. Such pipes can be handled and bent in a similar fashion to copper but can be easier to install. PE or PE-X pipes with polymer barrier layers are also used, for example EVOH (ethylene vinyl alcohol). Evaluation of these systems for gas within buildings has concluded that it is desirable to have a barrier layer to resist odorant permeation, Ref. 4. The use of such pipes for gas distribution within buildings is subject to national legislation but has been strongly adopted in the Netherlands and Germany. The issue of risk of failure in a fire has been answered, but flow activated shut off valves are specified also, Ref. 5.

1 – PE or PE-X liner

2 – Adhesive layer

3 – Welded aluminium layer

4 – Adhesive layer

5 – PE or PE-X outer layer

Fig. 1 Example of a typical multilayer pipe construction

Gaz de France and Gas Natural Spain were involved in the DIGBUIL project to evaluate PE-X pipe systems for indoor gas. Although reaching a successful outcome, these organisations are continuing to evaluate these systems.

Another purpose of multilayer plastics pipe construction is for products for use in contaminated ground. Reclamation of land in urban environments, so called 'brown field sites', means there may remain some risk of hydrocarbons or other contaminants remaining in the earth. Pipes with barrier layers are used.

In recent years polyethylene suppliers have developed materials with exceptionally high resistance to crack growth comparable to PE-X. This has resulted in manufacturers developing co-extruded pipe with external and internal layers of such materials. Products highly resistant to external damage created during installation and to allow burial in any ground condition without the need for expensive imported sand backfill have been developed. Such types of pipes are incorporate in ISO 4437, and are proposed to be included in the revision of EN 1555.

RTP Reinforced Thermoplastics Pipes

Whilst providing useful solutions for the gas engineer for specific applications multilayer pipes are not going to revolutionise the use of plastic systems in the gas industry. However RTP pipes have great potential to do this by meeting requirements for medium and even high pressure transmission lines. These pipes and jointing systems have been developed by several companies including Pipelife, Coflexip, Flexpipe, and Wellstream using aramid tapes, glass fibre and even steel chord reinforcement. Another 'all PE' product has been introduced recently by Egeplast which utilises an oriented PE tape to reinforce the PE base pipe in their HexelOne product, Ref.6. This has the advantage for recycling of being a single material. These products offer a solution to the corrosion issues of steel. Supplied in coils to reduce jointing with the other advantages of plastics can result in a substantial cost saving on a whole life cost basis. Oil companies have been using such products successfully for hydrocarbons and gas gathering for more than 10 years now.

Pipe Construction

Fig.2 An example of a PE/Aramid tape/PE product, Soluforce-Pipelife

Typically a polyethylene PE 100 base pipe is wrapped with a filament or tape reinforcement, and a PE outer protective layer is extruded on top. For higher temperature application a cross-linked polyethylene PE-X or other plastics base pipe could be used, see Fig.2. The helically wrapped layers of the reinforcing tape allow the construction to have considerably increased pressure ratings compared with a monolayer thermoplastics pipe. Aramid tapes (eg Twaron or Kevlar) offer the best mix of properties compared with the cheaper glass option. High tensile strength, low creep, corrosion resistance, and high impact strength give assurance of a durable composite product. Steel tape or cords are used to obtain even higher pressures but with a slightly increased risk of corrosion. A polyethylene outer protective layer is extruded over the reinforcement layers to protect them, providing abrasion resistance.

The new approach by Egeplast GmbH is to use a high strength oriented PE tape as the reinforcement in their HexelOne product, termed a 'mono-composite' as it is an all PE construction. Orientation, ie stretching beyond the yield strain, is a well known way of increasing the mechanical properties of PE. Like all plastics pipes the outer layer can be colour coded and striped to indicate the application and protected by a suitable material formulation for UV resistance for above ground applications, see Fig.3.

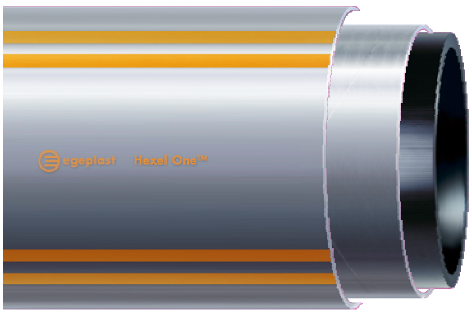

Fig.3 PE/Oriented PE tape/PE product developed by Egeplast GmbH.

All the advantages of plastics pipes as discussed are retained in these products which are supplied coiled in lengths up to 500 m dependent on diameter, only limited for transportation height restrictions. With such infrequent joints, projects of the order 20 km have been installed in as few as 12 days. Typically diameters up to 200 mm are available commercially currently. Production of larger diameters would not be a problem but the limitation of transport of coils makes this less practical. It is feasible to have a mobile extrusion unit to manufacture continuous long lengths on site but this would require considerable investment for these types of products. No requirement for cathodic protection, and low or no maintenance should make these pipelines very attractive to the gas engineer.

Properties

The base pipe provides a corrosion resistant liner with a smooth surface providing greater flow properties than steel.

Long term strength testing of aramid reinforced pipes has shown that ratings of over 150 bar can be achieved with a 50 years design basis at 65°C, Ref . 7. Higher ratings could be obtained using steel reinforcement but to completely remove any long term corrosion issues an all polymer construction should be chosen for gas distribution piping. Pressure ratings are based on 50 year design basis from predictions made from a series of hydrostatic stress rupture tests up to 10000 h using either EN ISO 9080 or ASTM-D 2992-96 methods.

However there are other considerations to take into account for gas applications. Gas will permeate through the inner base pipe and accumulate in the reinforcement layer. This is more of a problem for ‘non bonded’ pipe constructions where the reinforcing layers are laying loose in the annulus between the pipe cover and the liner and will necessitate some form of venting at fittings, otherwise blistering of the outer layer could occur at a relatively low pressure. In a bonded construction, gas can also accumulate in the reinforcement annuli (every reinforcing wire has its own micro annulus), but a much higher pressure is required to cause blistering because the cover is bonded to the liner. Tests conducted have shown that there is no risk of blow off of the outer layer at pressures below 42 bar at 65°C, Ref 8. This means that maximum operating pressure for gas at 20°C should be limited to around this pressure unless other precautions can be taken. To increase the potential pressure rating, a barrier layer could be incorporated in the base pipe, ideally on the bore to avoid collapse of the pipe in an uncontrolled decompression. Additives can be used with PE to reduce permeation, or alternatively another thermoplastic selected with increased barrier properties. Such RTP products are being developed to increase the potential pressure range of these pipes for gas. Alternatively if the design of the reinforcement could allow for tracking of gas, venting at fittings could be designed into the system but at a cost. Limiting the pressure allows a cheaper and lighter construction reducing typical aramid content by 40% to give a cost effective design for gas applications with a rating of 20-25 bar, Ref.8.

RCP Rapid crack propagation is a consideration for pipes used for gas distribution no matter what materials are used, steel or plastics. An uncontrolled crack can propagate hundreds of metres allowing a large volume of gas to escape. It has been shown that RTP pipes are not vulnerable to this form of crack propagation because the wrapped tape over the inner pipe prevents crack growth in the axial direction, Ref.8. RTP pipes have good resistance to external impact and damage. Aramid is the fibre used in the construction of bullit proof vests. In fact these pipes can be squeezed off to stop flow in the same way as a PE pipe, see Fig.4. Although steel pipes may be considered more resistant to damage, coatings can be damaged easily leading to premature corrosion. In fire tests RTP pipes were resistant for 6 minutes against 1100°C jet fire, whereas steel lasted only a few seconds, Ref.9.

Fig.4 Squeeze-off of flexible RTP pipe

Manufacturers have gone to great lengths to demonstrate the robustness of the system. Although not a part of any official qualification procedure according to API RP15S, the success of using reinforced plastic pipe in harsh oil and gas operating conditions critically depends on damage tolerance to resist the harsh treatment and of the system. In practical circumstances, a flexible pipe may be subjected to high axial deformations, impact loads, and wear and tear. Under the supervision of Instituto Politecnico Nacional (IPN) from México, RTP was subjected to a test cycle emulating in-field maltreatment, and the effects of land-slides and earth quakes, Ref.10. Most tests were performed using equipment, which allows the imposition of all kinds of dynamic deformations on a pipe while simultaneously assessing the dynamic hydrostatic pressure capability. The "maltreatment" consisted of high impact loading, by a falling weight of 12.5 kg (tip radius 50 mm) from a height of 4 meters. After impacting, the pipe was bent to a radius of 1.25 meters, well below the recommended minimum bending radius in service of 3.00 meters, and pressurised to burst, see Fig.5. The remaining burst strength in the different stages of the maltreatment process was compared to bursting pressure of a virgin straight pipe sample. To simulate the effect of imposed axial loading during a land slide, a pipe sample was loaded to 9% elongation, and subsequently burst tested. Finally, the effect of pipe cover damage on the burst strength was assessed on a pipe that was first impact loaded (12.5 kg / 4 meters) on a pre-damaged area. All these severe tests resulted in a maximum reduction of burst strength of only around 8% or lower.

Fig.5 Bending strength test on Soluforce RTP pipe

These test programmes have given the oil industry reassurance of robustness of these pipe systems. This should be more than reassuring for the gas engineer as distribution pipes are normally buried and operated in a more benign environment.

Installation and Jointing

Various mechanical jointing systems have been developed for RTP pipes which allow bolted metal flanges or metal ends for welding in the field to be incorporated. The swaged or compression type fittings are hydraulically pressed into RTP pipe ends. It is important that the inner fibre layer is protected from contact with media carried by the pipe.

However for potential RTP gas distribution systems, a special jointing technique has been developed based on polyethylene electrofusion technology, Ref. 11. In this jointing method an inner sleeve joining the bores of the RTP pipe ends is welded in-situ using the electrofusion technique, see Fig.6. This ensures that the fibre layer at the pipe end will not be exposed to gas. A special scraper has been developed to scrape the inside of the PE liner pipe prior to welding, scraping prior to welding being normal practice for PE electrofusion welding. Alternatively a simple buttweld of the base pipe ends could be made. An external fibre-reinforced sleeve, pushed over one of the pipe ends prior to welding the inner base pipe, is moved over both pipe ends. This sleeve also incorporates an electric coil to allow fusion to the outer surface of each pipe. Before moving the sleeve over both pipe ends, the end of these pipes have been scraped and adapted to the required dimensions. The surface area covered by this sleeve joint is designed to ensure that the joint is fully resistant to end load developed at the rated pressure.

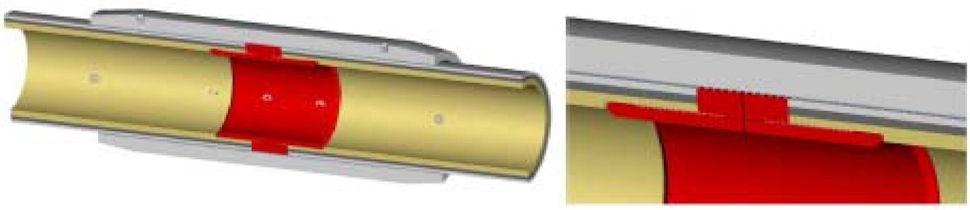

Fig.6 An example of an RTP electrofusion jointing system.

The application of the electro-fusion technique allows for a fast and safe jointing of reinforced plastic pipes. A standard PE electro-fusion control unit can be used which is part of the basic equipment used in PE pipe system installation. A high voltage current is not required. The technique is suitable not only for standard RTP pipe joints but also for repair and integration work.

Fig.7 Stainless steel end connection with EF sleeve, Soluforce-Pipelife

Various tests have been carried out on these joints. Testing is performed by subjecting such joints to elevated pressure and temperature. In all these tests failure occurred in the pipe by tensile failure of the fibres which proves that the joints are stronger than the pipe material. Axial tensile loading tests have been performed, which did not result in failure of the joints or the occurrence of leakage. Bending tests have been performed using a bending radius of 1.5 m for 100 mm pipe at 20 °C. After loading for 1 hour the joint assembly was tested under internal water pressure at a pressure of 40 bar. No leakage or failure occurred. Most flexible pipe systems have metal fittings, which are prone to corrosion and therefore not inspection and maintenance free. RTP however, distinguishes itself as a flexible pipe system with a fully non-metallic plastics coupling system. This eliminates the need for regular inspection and maintenance.

Standards and specifications for RTP Pipe

A technical specification for RTP pipe for gas applications up to 40 bar was developed by ISO/TC 138/SC4 and published in 2005, see Appendix 1. It is applicable for a wide range of service temperatures and base pipes in PE, PE-X, and other materials. It specifies a qualification testing procedure for RTP systems. It provides a procedure for reconfirmation of the design basis that may be used for product variants where changes have been made in design, materials or the manufacturing process.

At the same time the American Petroleum Institute specification API RP 15S was developed for spoolable RTP pipe, see Appendix 1. This provides guidelines for the design, manufacture, qualification and application of spoolable reinforced plastic line pipe in oilfield flowline applications, including transport of multiphase fluids, hydrocarbon gases, hydrocarbon liquids and water. Such products typically consist of a continuous plastic liner reinforced with either glass reinforced epoxy - Spoolable Composite Pipe (SCP), or aramid fibers - Reinforced Thermoplastic Pipe (RTP).

Fig.8 Long length coils avoid frequent joints allowing 'plough-in' installation

For offshore use, additional requirements may apply. This recommended practice includes guidelines for determining material properties, pressure ratings, safety factors and service factors, and minimum performance requirements. It also includes guidelines for manufacturing, quality control tests, and typical installation methods. The recommended practice uses proven ASTM testing methods for establishing long-term performance, and serves as the basis for qualification of the RTP.

Besides the ISO and API specifications in Germany the DVGW , Deutsche Vereinigung des Gas- und Wasserfaches, has issued a specification, DVGW VP 642:2004, see Appendix 1. This specification is more or less in line with the draft ISO specification but is limited to a maximum operating pressure of 42 bar, and for the "light" aramid-based system to 25 bar.

Applications

RTP has an extensive track record of at least 10 years for oil industry applications in the Middle East, SE Asia and Europe. It was originally designed for above ground on-shore applications in the Middle East desert where the corrosive conditions caused steel lines to fail in a few years. These applications include oil gathering with pressures up to 70 bar and water injection pipelines up to 90 bar. At least 500 km of RTP pipes have been installed. It has also proved successful in notoriously corrosive tropical areas. In those applications the pipe is usually buried. A very big advantage here is the fact that it only needs a very small trench, little site equipment and can be installed by unskilled labour. The use of RTP pipe is making inroads in the offshore industry. Here the ease of installation is the major drive as well as corrosion resistance. The collapse resistance due to external hydrostatic load is a key element in designing such pipelines. Since the reinforcing fibres hardly contribute to the ring stiffness of the pipe, RTP possesses about the same collapse resistance as HDPE pipe of the same diameter / wall thickness ratio. For gas and multi-phase applications the maximum allowed safe water depth for a 20 year life of the pipe is around 25-40 meters depending on the pipe diameter. However, for water applications, the pipe is always filled with water and can then theoretically be installed in any water depth. A nice example of such an application is a project for hydro testing 900 m deep gas pipelines, Ref. 10.

Field Experience for Gas

Over the last 6 years practical experience with onshore gas lines is rapidly increasing. Table 1 details the trial and service installations using the Pipelife Soluforce RTP products evaluated by GERG, European Gas Research Group, Ref.12.

Following approval to the DVGW specification there have been other demonstration trials with German gas companies using the electro-fusion jointing technique.

A 4.5 km line for Badenwerk Gas GmbH was installed by ploughing to a depth 1.5 m, completed in 3 weeks. The line was subject to 84 bar leakage test and a 105 bar strength test and is operating at 25 bar. In Hannover (Eon-Ruhrgas) 630 m of 100 mm were installed witin an old 400 mm line. The line was tested at 75 bar leakage and 115 bar strength. It is operated at 25 bar. In October 2005 430 m of 100 mm pipe was installed by conventional digging techniques for an EON-Ruhrgas stoirage facility at Eschenfelden. The line is operated at a pressure of 42 bar. All the latter installations utilised the Pipelife 'classic' product. However for a further project for EON-Ruhrgas in Dorsten, 60 m of the Pipelife 'light' product has been installed for 25 bar operation.

Date	**Company**	**Field/Location**	**Application**	**Press/Temp**	**Size**	**Length**
Nov 03	Fahum Gas Egypt	El Fayoum	Gas distribution	36 bar/20°C	4 in	380 m
Apr 04	VNG	Berlin Plant	Brine gas waste line		5 in	60 m
Aug 04	Badenwerk Gas GmbH	Buchig-Oberacker	Gas distribution	25 bar/15°C	5 in	4500 m
Oct 04	Ruhrgas Germany	Hannover relining	Gas distribution	25 bar/15°C	4 in	600 m
Mar 05	SGC Syna	SJC-SBC	Sour Gas	90 bar/60°C	4 in	6 m
Aug 05	Shell Brunei	Seria	ULLG	50 bar/25°C	5 in	18 km
Aug 05	Shell Syria (AFPC)	Tanak Field	Production gas	98 bar/55°C	5 in	11 m
Oct 05	E.ON Germany	Hirschbach	Gas	22-42 bar/15°C	4 in	440 m

Table 1: RTP trial and service gas pipelines

Following the above experience and extensive testing, the final report of the GERG project concludes that 'based on the long term (50 years) resistance to internal pressure of RTP 'light', the cover blow off pressure and a safety design factor of 2, RTP light pipeline systems can be applied in gas distribution systems up to pressures of at least 22 bar, Ref.12. The limiting factor is perhaps the potential cover blow off pressure, but by the use of barrier layers/additives or venting of the reinforcement operating pressure this could be increased considerably as discussed.

Costs

Whilst the cost of an aramid reinforced PE RTP pipe can be approximately 40% higher than a carbon steel pipe, no external, internal coating or cathodic protection is required. Welding, installation, trenching and backfilling costs are considerably reduced, particularly when long pipe lengths can be used and installation by ploughing vastly increased rates of installation. To gain the most economical advantage out of the flexibility of RTP, the pipe routing deserves careful consideration. Being flexible and being delivered in long length coils, it is often possible to design the system in such manner that prefabricated elbows and bends can be totally avoided, thus saving considerable expenses. The totally corrosion resistant all plastics systems increases potential lifetime with low or zero maintenance costs, all adding up to a reduced whole life cost. The GERG project concluded that potential cost reductions of 25% can be obtained compared with steel systems, Ref. 12.

Conclusion

The use of thermoplastics pipeline systems for gas distribution has been a big success, providing the gas engineer with a durable asset with potential lifetimes well in excess of steel and iron systems. These materials and polyethylene in particular have become the first choice for low pressure gas systems up to 10 bar, solving the corrosion and reliability issues of the metal systems.

However it is unlikely that any significant increase in pressure rating can be obtained by plastics material development alone. Future development will most probably be concentrated on multilayer and composite pipe constructions to satisfy specific application requirements and to increase pressure ratings respectively, allowing use in medium and even high pressure gas distribution pipelines.

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Appendix 1

List of Standards

Thermoplastics Pipes Systems for Gas

EN 1555-1 to 5:2002, Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE)
CEN/TS 1555-7:2003 Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) - Part 7: Guidance for the assessment of conformity.

ISO 4437:2007 Buried polyethylene (PE) pipes for the supply of gaseous fuels – Metric Series – Specifications

ISO 6993-1to 4:2004 Buried, high-impact poly(vinyl chloride) (PVC-HI) piping systems for the supply of gaseous fuels

ISO 8085-1-3:2001 Polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels -- Metric series -- Specifications

ISO 14531-1 to 4 Plastics pipes and fitting – Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels – Metric series – Specifications

ISO 22621-1/2 Plastics piping systems for the supply of gaseous fuels for maximum operating pressure up to and including 20 bar — Polyamide (PA):
(Parts 3 to 6 still under development)

Multilayer Pipe Systems for Gas

ISO 17484-1/2 Plastics piping systems. Multi-layered pipe systems for indoor gas installations with a maximum operating pressure up to and including 5 bar

ISO 18225:2007 Multilayer piping systems for outdoor gas installations – Specifications for systems

RTP Pipe Systems for Gas

ISO TS 18226:2006 Reinforced thermoplastics pipes (RTP) for high pressure gas applications

ISO TS 18226:2005 Reinforced thermoplastics pipes system for gaseous fuels

API RP 15S, Recommended Practice for the Qualification of Spoolable Reinforced Plastic Line Pipe, published by the American Petroleum Institute (API) 2006.

DVGW Technische Regel VP 642 (2004), „Faserverstaerkte PE-Rohre (RTP) und zugehoerige Verbinder fuer Gasleitungen mit Betriebsdruecken ueber 16 bar“

Appendix 2

List of relevant organisations

Marcogaz

The representative body of the European Natural Gas Industry on all technical issues. The aim is to monitor and take influence when needed on European technical regulation, standardisation and certification with respect to integrity and safety of pipeline systems, equipment, and the rational use of energy. **www.marcogaz.org**

PE 100+ Association

The PE 100+ Association is an industry organisation of several polyethylene (PE) manufacturers whose objective is to promote consistent quality at the highest level in the production and the use of polyethylene for PE 100 pipes. **www.pe100plus.net**

TEPPFA – European Plastics Pipes and Fittings Association

TEPPFA is the trade association representing manufacturers and national associations of plastic pipe systems in Europe, actively involved in the promotion and acceptance of plastics pipes systems for all applications. TEPPFA want to raise awareness of the value that plastics pipes systems offer for a sustainable future. **www.teppfa.com**

GERG European Gas Research Group

GERG policy is focused on the support of the European gas industry, which is achieved by research and technological innovation in all aspects of the gas chain; from production and processing, through transmission, storage and distribution, to utilisation of natural gas. **www.gerg.info**

DVGW

Deutsche Vereinigung des Gas- und Wasserfaches is the German Technical and Scientific Association for Gas and Water and is indispensable for self-regulation in the gas and water supply industry. Technical rules sets the standard in both Germany and within Europe for the utmost safety combined with the best possible efficiency.

www.dvgw.de

ISO International Standards Organisation

Organisation for the development of globally relevant standards for all sectors of industry. **www.iso.org**

CEN European Committee for Standardisation

The European Committee for Standardization (CEN) is a business facilitator in Europe, removing trade barriers for European industry and consumers. Its mission is to foster the European economy in global trading, the welfare of European citizens and the environment. Through its services it provides a platform for the development of European Standards and other technical specifications. **www.cen.eu**

ASTM American Society for the Testing of Materials

ASTM is an open forum for the development of high quality, market relevant international standards used in the USA and around the world. **www.astm.org**

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The PE 100+ Association	**www.pe100plus.net**
Soluforce Pipelife – Netherlands BV	**www.soluforce.net**
Friatec AG	**www.friatec.de**
Egeplast GmbH	**www.egeplast.de**