HISTORY OF PLASTICS PIPE SYSTEMS

Plastics Industry Pipe Association of Australia Limited ACN 086 511 686

IN AUSTRALIA

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Plastics pipe products cover a wide range including:

- electrical and communications conduit,
- pressure pipe for water, gas, wastewater and industrial process fluids,
- non pressure pipes for drainage, sewer, DWV.

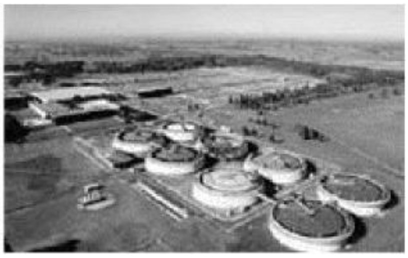
Today plastics pipe materials can be found in the majority of pipe applications and in many cases are used almost exclusively because of their excellent resistance to chemicals and environmental effects that have corroded and fractured concrete, clay, steel and cast iron. They are cost effective and have provided excellent performance.

Here is a brief history of the development of plastics pipe materials in Australia with the emphasis on the two main materials Polyvinyl Chloride (PVC) and Polyethylene (PE). There are many other common plastics pipe materials including Polypropylene (PP), Cross linked Polyethylene (PEX), Polybutylene (PB) and to a lesser extent Acrylonitrile Butadiene Styrene (ABS) and Polyamide (PA or better known as Nylon).

PVC

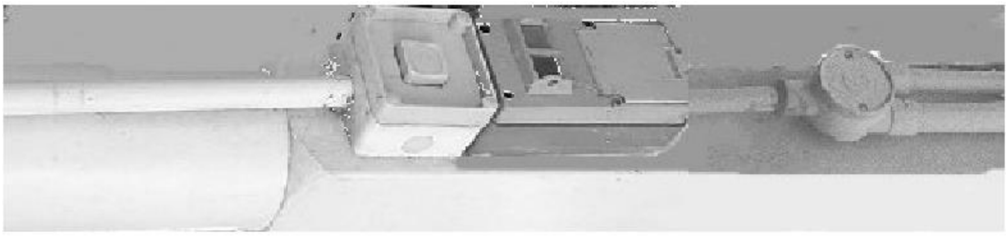
Vinyl Chloride was first prepared in a laboratory in 1838 and polymerised Vinyl Chloride (or what we now refer to as PVC) in the early 1870's by Baumann, although its commercial success did not start until the following century. The first PVC pipes were manufactured in Germany in the early 1930's – being used in construction for the Berlin Olympics facilities. Wavin has a sample of this early PVC pipe on display at their factory in Twist. These early PVC materials were derived from coal and acetylene and manufactured by extrusion. Manufacturing advances in PVC production led to the use of oil as a raw material which in turn led to mass production in the period after WW II. This coincided with major post war shortages of conventional materials such as steel and natural rubber which forced industries to look at synthetic materials.





A Belgian company converted twin-screw Italian pasta machines to extruders suitable for processing PVC and this led to PVC pipe being used to replace steel in electrical conduits and attracted interest from a Dutch provincial water authority which was the genesis of Wavin - now an international pipe and fitting company.

In the 1950's, as in Europe, production of rigid or unplasticised PVC pipe in Australia started as electrical conduit.



Australian PVC pipe manufacture commenced relatively late, possibly influenced by local PVC resin manufacture which started in 1954. By 1960 PVC had been used very extensively elsewhere in the world - Japan had 64,000kms of PVC water pipe in service with 10 years experience, while Italy, Germany, and Holland had 32,000kms, 16,000kms, and 8,000 kms of pipe installed with 12 years, 25 years, and 9 years experience respectively.

Vinidex was founded in 1960 and immediately manufactured PVC conduit from twin screw extruders developing what was for years the biggest application for PVC pipe, namely telecommunication conduits for the PMG (now Telstra) replacing asbestos cement pipes.

Humes Ltd. were also active in a joint venture with a Japanese company Sekisui which provided PVC pipe technology including raw materials and extruders.

Iplex, an established plastics fabrication company in Adelaide seeing a trend towards above-ground plumbing in the UK followed suit and developed a range of PVC fittings to replace cast iron and lead soil waste and vent systems.

Also around this time Hardie Extrusions was formed. Other notable companies of this era that pioneered PVC pipes and fittings production included ACI-Nylex, Knox Schlapp (RKS), ACI-Sloane, Vinlon,and Gay-Dor.

The success and growth in plastics pipe systems resulted in several mergers and acquisitions over the ensuing years. ACI-Nylex, ACI-Sloane and Vinlon were acquired by Humes Ltd. Humes Ltd. Plastics Division was subsequently sold in 1989 with part of the business being acquired by Vinidex and the remainder by Hardie Iplex. Hardie Extrusions absorbed Iplex Plastics and GayDor to become Hardie Iplex Plastics which in turn acquired Knox Schlapp (and part of Humes) to ultimately become Hardie Iplex Pipelines in the early 90's. When the Crane Group and Wavin acquired the company it became Iplex Pipelines.

The ease and speed of installation of the new PVC system in field trials created wide trade and Government interest, leading to the development of Australian Standards K138 for pressure and non-pressure pipes, A159 for pressure fittings, and A160 for non-pressure fittings. These Standards were largely based on the British standards.

The first Australian PVC sewer lining project was undertaken by the Mildura Sewerage Authority in 1964 where a 30 year old concrete sewer that had suffered extensive attack by hydrogen sulphide and was collapsing. The product used was supplied by Humes and known as "S-Lon". The project was a complete success and repeated on another Mildura sewer in 1968. Inspections in 1979 confirmed the relined sewer was in perfect condition with no degradation or root intrusion.

Manufacture of PVC pipe for water supply commenced in the mid 60's, when the State Rivers and Water Supply Commission of Victoria (SR&WSC) conducted an installation in Bendigo. This followed a trial installation for domestic and stock water supply at Rainbow West using imported Cellulose Acetate Butyrate (CAB) pipe. Full approval for urban reticulation was afforded by SR&WSC in 1967.

The Public Works Department (PWD) in NSW first used PVC in 1967 in Merriwa Shire and followed up with further Shire projects in succeeding years. Thus PVC pipe quickly gained acceptance in rural and regional projects in NSW and Victoria throughout the late 60's where PVC replaced Asbestos

Cement (AC) pipes which had a poor performance history particularly in areas of reactive soil conditions.

The 1970's saw spectacular growth in the use of PVC pipe - in the order of a compounding 25% pa. - with market substitution into SWV and the commencement of 100mm sewer house connection and 150mm mains reticulation trials. PVC was fully approved for sewer and SWV applications during the 70's.

The 70's was also a period of development for Australian PVC pipe standards. Based on AS K138, A159 and A160 standards progressed to the application based documents seen today. AS1477 covered PVC-U pressure pipe and fittings, AS1260 sewer pipe and fittings, AS1415 soil waste and vent pipe and fittings and AS1254 Stormwater pipe and fittings. AS CA67 was published covering installation and was the precursor to AS2032 and AS/NZS 2032. In the 1990s AS1260 and AS1415 were combined together with the commensurate New Zealand Standards as a single document AS/NZS1260 covering drain waste and vent applications.

Notwithstanding fierce campaigns by the clay pipe industry, PVC pipe systems made rapid inroads into the house connection market on the basis of speed and ease of installation and a competitive prime cost compared to clay pipe, assisted also by major performance issues with clay pipe systems.

The mains reticulation market for both pressure and non pressure applications progressed at a slower pace due to water agency conservatism coupled with significant political lobbying by both the clay and iron pipe industries as they saw PVC as a major threat to their historic market dominance.

The gas industry in WA (SEC of WA), Victoria (G&FC) and (NSW (AGL) began using PVC for distribution and services around 1966.

The early 70's saw industry trials commence for cold water plumbing house connections and water reticulation with the Metropolitan Water Sewerage and Drainage Board (MWS&DB) in Sydney and the Melbourne & Metropolitan Board of Works (MMBW). Small trials were conducted with pipe sizes from 20mm to 150mm diameter and observed over a period of years. Experimental trials with PVC mains utilised pipes manufactured to ASK138 1969 and AS1477 1973, the latter standard basically being a metrication of ASK138. These pipes were generally of a thinner wall (class 12) and were not compatible in outside diameter with the MMBWs' existing AC and cement lined Cast Iron (CICL) mains.

Subsequently Hardie Iplex developed an alternative thick wall pipe called "Blue Brute" based on a USA PVC Pipe Standard, AWWA C900-75 and with outside diameter compatible with grey cast and ductile iron pipes – initially only in sizes DN100 and 150. The MMBW commenced trials of 100mm Blue Brute in four construction areas in 1977.

E&WS South Australia approved PVC pipe usage in 1976 and other major water agencies were close behind with Sydney Water beginning to use PVC pressure pipes in the late 1970's.

Further water reticulation trials were conducted in Melbourne and in 1982 a joint industry/MMBW working group was established chaired by a CSIRO representative to assess the long term properties of PVC pipe. Following this study, the group recommended that 100mm 'Blue Brute' be accepted as a suitable pipe material to compete with DICL but exceptions included its use in pumped supply areas until further CSIRO research was undertaken. The report identified fracture toughness as a key predictor of service life and new tests were introduced to pressure pipe standards.

In 1986 a Victorian Parliament Natural Resources and Environment Committee recommended that the MMBW's proposal for including PVC pipe as an acceptable option for its water supply reticulation system be deferred until 1990. This followed intense lobbying by the rival DI pipe manufacturer who argued potential job losses at their local plant would result from allowing the use of PVC. Water quality, and in particular lead levels, was also raised as an issue of concern but the committee was satisfied that the level of lead in the manufacture of PVC pipe did not constitute a significant health risk to domestic water users – a fact consistently proven by several subsequent and independent investigations.

Whilst the research consistently supported the fact that there was no cause for concern from lead stabilised pipe the industry opted to move to non lead stabilisers in order to both remove it completely as an issue and also to assist upstream suppliers. The first non lead stabilised pipes were introduced by ACI Nylex in the late 70s and then Hardie Iplex in 1988, and quickly followed by the other manufacturers.

At this stage PVC pipe claimed to have about 60% of the water reticulation market in Australia due mainly to its high share of rural and regional water supply programs

The early 80s also saw the introduction of Oriented PVC pipe (PVC-O), where the pipe undergoes orientation during manufacture, resulting in a doubling of hoop strength and substantial increase in impact resistance allowing a proportional reduction in wall thickness. Vinidex introduced PVC-O to the market in 1986 where it was first used in a rural water reticulation scheme in NSW.

The 1990's was an era where PVC pipe was the material of choice for the 100mm and 150mm pipe in the water, sewer, stormwater and DWV markets, and it had long replaced steel as the preferred material for electrical and telecommunications conduits.

Expanding market share into the larger sizes created a new phase in the development of PVC pipe where the focus was on material efficiency whilst maintaining compliance to pipe performance specifications. This resulted in the growth of foam core co-extruded PVC pipe and structured wall pipe for non pressure applications - with material savings between 30-40%. Ribbed PVC profile pipe both spirally wound and via travelling mould blocks were also introduced to compete with concrete in larger diameters.

Conventional PVC pipe for pressure applications was formulated to improve toughness thus enhancing resistance to crack formation and propagation - this pipe was designated Modified PVC or PVC-M. The improved properties led to the acceptance of a lower design factor in the Australian New Zealand Standard AS/NZS4765 with a consequent reduction in wall thickness and around a 30% weight saving.

The process for manufacturing PVC-O was well established but the slow, 2 stage off-line batch process meant that the significantly better properties of PVC-O could not be realised due to the high cost of the process. Innovation by Australian manufacturer Vinidex revolutionised this technique with the invention of a continuous online extrusion process which dramatically changed the manufacturing economics for this product. This technology was a world first and placed Australia as a leader in PVC pressure pipe manufacturing.

Independently analysed performance data from Australian water agencies has shown that PVC is the best performing pressure pipe option across the country. WSAA also assign a life expectancy rating for both pressure and non-pressure PVC pipe products of in excess of 100 years.

PVC Standards Development		PVC Pipe Key Features
	50's	• '54 Australian PVC resin manufacture begins
• AS K138 first Australian PVC pipe standard published • AS A159 first Australian PVC standard for pressure fittings • AS A160 First Australian PVC standard for non pressure fittings • '67 AS K138 revised and updated • '69 AS K138 revised and updated	60's	• '60 Vinidex established, produces PVC conduit • Humes established • Hardie Extrusion (forerunner of Iplex) established • ACI-Nylex, Knox Schlapp (RKS), Gay Dor, ACI-Sloane, Vinlon established • PVC becomes material of choice for conduit • PVC SWV and sewer pipes into service • '65 NSW Dept Local Govt approves PVC • Victorian State Rivers & Water Supply trials & in'67 approves PVC pressure pipe • '67 PWD NSW Merriwa trials of PVC pressure pipe
• '73 AS1477 first published –metric version of K138 & includes joints and fittings • AS1260 first published based on K138 • AS1254 first published based on K138 • '71 AS CA67, Installation of PVC pipe systems published • AS1415 first published	70's	• Regional water agencies widely use PVC • PVC approved nationally for DWV and stormwater • PVC used extensively in irrigation • Sydney Water and SA Water (E&WS) begin using PVC. '76 E&WS approves PVC • PVC becomes material of choice for stormwater • Melbourne Water (MMBW) water supply trials • PVC used for gas distribution and services - WA, Vic and NSW
• AS2977 published for series 2 cast iron compatible OD PVC pressure pipes – DN100 and 150 sizes • AS2032 first published based on ASCA67	80's	• PVC-O batch process used in Australia • PVC predominant material for DWV and stormwater • PVC rapidly gaining acceptance in sewer applications • PVC predominant conduit material • PVC pressure pipe gaining acceptance • Structured wall for non pressure introduced
• AS/NZS4765 published (PVC-M) • AS4441 published (PVC-O) • AS2977 superseded by revised AS/NZS1477, series 2 size range expanded • AS1260 & AS1415 combined to form AS/NZS 1260	90's	• Foam for non pressure introduced • PVC-M introduced • PVC becomes material of choice for pressure and non pressure water and sewer reticulation • PVC-O online process introduced
• AS/NZS4765 revised • AS/NZS4441 revised • AS/NZS2032 revised • AS/NZS1477 revised	2000's	• PVC-M and PVC-O become predominant pressure pipe options • PVC pipes achieve greater acceptance in larger sizes

Polyethylene

Polyethylene (PE) is another common polymer used to manufacturer pipe. The history of PE manufacture dates back to the early 1930s with the production of what was known as Low Density Polyethylene (LDPE). The reference to density relates to the density of the PE compound and was a term used to describe a range of PE pipe materials in the past. The first so called high density PE compounds were produced in the early 1950's with medium density materials coming somewhat later in the 1980's.

The designation of PE pipe materials has changed over the years. Initially LDPE was Type 30 and HDPE type 50, subsequently nomenclature moved to LDPE, MDPE and HDPE. Today PE pipe material nomenclature is based on minimum required strength (MRS) – hence modern PE pipe materials include classifications such as PE80 and PE100 where the number relates to the material's long term strength.

DPE was used for irrigation pipe applications until the advent of HDPE which saw wider use in the late 50's with manufacturers like Nylex, Vinidex, Parfrey Plastics, Flowmaster, Humes, Iplex, PPI, IPS (now George Fischer) progressively developing manufacturing plants around Australia since the 1960's.

Australian Standards for PE began to appear in the early 60's with ASK 119, forerunner of AS 1159. AS CA 69, covering installation, was published in the late 1970's, followed by AS2033 and AS/NZS 2033.

Fuelled by demand from rural applications and the mining boom in Western Australia, Type 50 HDPE pipe capacity increased rapidly throughout the 1960's, 70's and into the 80's with size capabilities up to 800mm diameter, and a move away from Type 50 PE resin to HDPE PE80 offering improved pipe properties - in particular tensile strength and resistance to slow crack growth. From the early 70's the water industry embraced PE for many specialist applications such as the sewer pipeline river crossing in Devenport Tasmania, the Gold Coast Sewer Ocean Outfall (DN1000), water supply to Magnetic Island or the Darwin Sewer Outfall installed in 1975.

Medium density PE (MDPE PE80) continued to make inroads into the mining and gas markets, and Linear Low Density Polyethylene (LLDPE), dominated the rapidly expanding micro irrigation market.

The major infrastructure utility to embrace PE at an early stage was the gas industry. This was largely based on the successful introduction of PE into the UK gas industry in the late 60's to replace the troublesome cast iron pipe networks. At this point it is appropriate to spend some time mapping the development of PE through the Australian gas industry.

Polyethylene (PE) pipes were introduced to the gas industry in the late 1960's, offering corrosion resistance, resistance to the effects of gas constituents, ease of installation and cost-effectiveness. British Gas (BG) commenced using PE in 1969 and the Gas & Fuel Corporation of Victoria (G&FC) in 1973. Jointing techniques are butt fusion, electrofusion, socket fusion, and mechanical joints. They have enabled system properties of joints to be the same as for pipes.

BG evaluated High Density Polyethylene (HDPE) and Medium Density Polyethylene (MDPE), opting for MDPE, but in Australia the older "first generation" HDPE was initially used because of local manufacture of this material and concerns about the reliability of supply of imported polymers. Although MDPE was known to confer superior properties in terms of resistance to crack growth and long term strength, G&FC, along with Allgas and Sagasco, continued to successfully use "first generation" HDPE. The transition to MDPE commenced during the 1980's.

During this period, Australian Standards AS 1463 for PE compounds, and AS 1667, AS 2718 for PE gas pipes, AS 1460 for fittings, plus AS 3723 for installation, were used as the basic specifications. Because AS 1463 specified the requirements relevant to HDPE, the use of MDPE to this specification provided additional security.

Subsequently, PE almost totally replaced metallic pipe materials within the material's size and pressure range, such that in 1988, G&FC reported annual usage of 280 km of Class 250 (250 kPa) and 1162 km of Class 575 (575 kPa) in sizes up to 50mm.

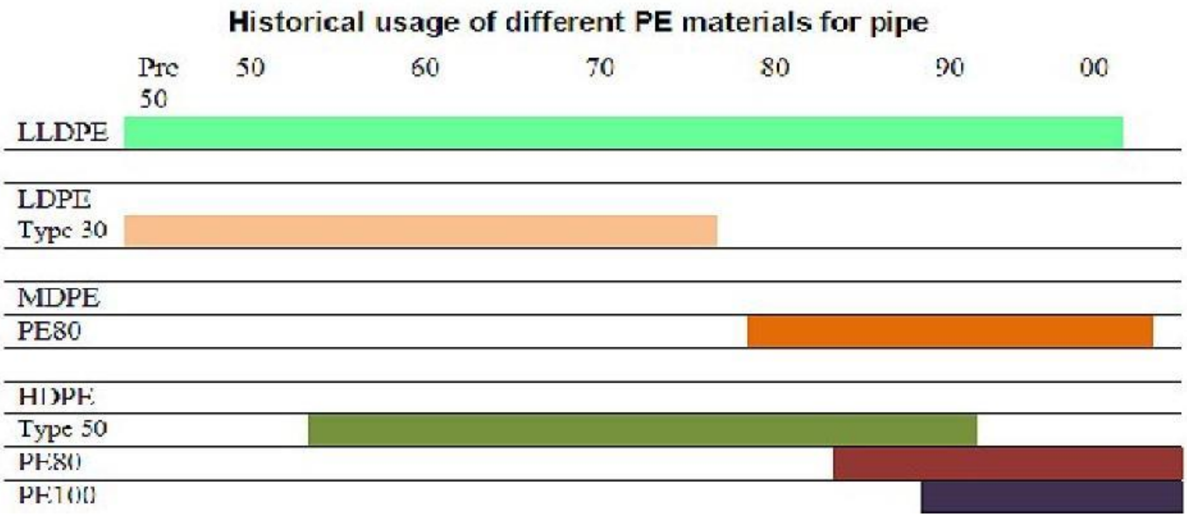
Large PE pipe

In 1989, BG commenced use of PE 100 HDPE for higher pressure applications (up to 7 bar) and larger diameters, the key attributes being improved long term strength, stress crack resistance, and resistance to rapid crack propagation (RCP).

In 1991, the Plastics Industry Association (PIA) addressed the need for national specifications to cover the new materials and developed PIA 11590 so that industry could adopt this advanced specification whilst Australian Standards were being redeveloped. In 1993, new Australian Standards, AS 4130(Int) and AS 4131(Int) were introduced for PE pipes and compounds to incorporate the new grades and appropriate performance requirements. However, these Standards did not address fuel gas applications and subsequently, in 1995, AS/NZS 4130 and AS/NZS 4131 were introduced, covering all pressure applications, including fuel gas. These standards were subsequently revised again in 2001 and 2003.

Test requirements were increased to reflect the improved material properties, especially for PE 100 grades, with minimum critical pressure for RCP raised to the equivalent of 38.6 bar at 0? C. In addition, resistance to slow crack growth requirements were increased for both PE 80 and PE 100. These increased levels provided further assurance of long term performance under adverse conditions, such as surface damage and localised loading.

PE 100 materials are now being routinely used in Europe and Scandinavia for fuel gas applications at pressures up to 10 bar, with both pipes and fittings available in PE 100 material. In Australia, GCI Kenny has designed a PE 100 system to operate at pressures up to 1050 kPa for Great Southern Energy, for the Tumut Pipeline Project – others have subsequently followed.



With an unprecedented demand for minerals with the emergence of China in particular as a manufacturing superpower, mining underwent a massive boom which resulted in spectacular growth in the large bore PE pipe market and demand for pipe diameters in excess of one metre.

The mining, gas and rural water supply sectors have been the traditional heartland for PE in Australia. In recent years the water industry has also embraced PE particularly when trenchless installation techniques like directional drilling, pipe cracking, slip and swage lining have led to increased usage in water and waste water applications.

The development of PE 100 in Europe quickly found favour as the preferred pipeline material for large diameter PE pipe given its inherent higher stiffness, hydrostatic pressure performance and, resistance to slow crack growth coupled with predicted lifetime performance is in excess of 100years.

PE100 represents a significant leap forward in terms of material properties over earlier PE materials – more so than the MRS numbers suggest. The early PE materials were uni or monomodal meaning the molecular weight for a given material was distributed around a single value. PE100 on the other hand is a bimodal material in which a dual molecular weight distribution exists. This "blend" of molecular weight fractions allows significantly better optimisation of material properties than is possible with unimodal materials. The bimodal PE100 materials therefore exhibit high strength with excellent long term properties such as slow crack growth resistance. Bimodal PE80 materials are also now available.
In summary, developments in polyethylene pipe and fitting materials continue to improve already outstanding properties and afford the asset owner confidence in long term durability and system life.

PE Standards Development		PE Pipe Key Features
	50's	• HDPE compounds produced
• AS K119 first published • AS AS1159 developed from AS K119	60's	• Major companies to establish over the decade include Nylex, Vinidex, Iplex, Humes, PPI, IPS (now George Fischer), Parfry Plastics and Flowmaster • Main materials are LDPE Type 30 and HDPE Type 50 • PE is accepted by rural water supply and mining sectors
• AS1463 first published • AS1667 first published • AS2718 first published • AS1460 first published • AS3723 first published • AS CA67 first published	70's	• Gas and Fuel Victoria introduce PE for gas distribution • Main materials are LDPE Type 30 and HDPE Type 50 • Water and waste water authorities use PE for specialist projects such as submarine pipelines. •
• AS2033 first published	80's	• PE80 material introduced • PE becomes default gas distribution pipe system • Trenchless installation and rehabilitation options using PE become commonplace in water and waste water industries & telecommunications
• PIA 11590 developed • AS4129 first published • AS4130 first published • AS4131 first published	90's	• PE100 material introduced • Mining boom sees rapid growth in large diameter PE systems
• AS4130 revised 01 & 03 • AS4131 revised 01 & 03 • AS/NZS2033 revised	2000's	• PE trenchless rehabilitation and directional drilling increase

Other Polyolefins

Heating systems held out the promise of substantial markets for plastics pipe and although Cross Linked Polyethylene (PEX), had been trialled based on imported systems for hot water plumbing, it was Polybutylene (PB) which made the first impact based on local manufacture and utilising brass and copper fittings. The history of PB in Australia is very good and in marked contrast to that in the USA. Thicker walled pipe and differences in fittings represent the main differences between the USA and Australian PB systems.

In the hot water plumbing market and following overseas trends, there was a shift to PEX as the major plastic pipe system, over PB, with both systems accounting for over half the market, replacing copper. Polypropylene was also used to a lesser extent in these applications.

Polypropylene (PP) pipe

The large bore sewer and drainage market saw the introduction of co-extruded bi-wall Polypropylene (PP) by Iplex in 2002 and subsequently by Vinidex. The product offers advantages with respect to toughness and ease of installation with the usual absence of internal or external corrosion. The latter are significant causes for concern with concrete and ferrous pipe systems that suffer from internal degradation from sewer gases and external degradation from ground conditions.

As the first decade of this century draws to a close, plastics pipe systems have, with the exception of very large diameters, and pipelines of extreme pressure requirements, become the material of choice in the majority of pipeline applications. This is due to both the continual material and process innovation, and the fundamental properties of the basic product, namely design flexibility, light weight, corrosion resistance, and toughness.

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