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DUCTILE IRON PIPES AND FITTINGS

FOREWORD

Ductile iron pipes and fittings are used in the construction of pipelines for the conveyance, above and below ground, of potable water, raw water and sewage, and are suitable for both pressure and non-pressure applications.

This note provides general information and guidance on ductile iron pipes and fittings for use in the above applications. It has been prepared to coincide with the publication of two new European standards covering ductile iron pipes, fittings, accessories and their joints for water pipelines (BS EN 545: 1994) and sewerage pipelines (BS EN 598: 1994), which supersede the former British Standard for such products BS 4772: 1988. These new European standards have been developed in consultation with, and approved by, the responsible British Standards Committee PSE/10, the membership of which includes representatives from both the UK Water Industry and the ductile iron pipe manufacturers organisation, DIPA.

More detailed guidance on the use of ductile iron pipes is given in the Pipe Materials Selection Manuals for Water Mains[(1)], and Sewers[(2)], and in the Design Guide to Sea Outfalls[(3)].

The note has been prepared by the Ductile Iron Liaison Group (DILG) of the Engineering and Operations Committee's Materials and Standards Group. The membership of DILG is drawn from the Water Industry, relevant UK manufacturers and WRc.

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1. HISTORICAL DEVELOPMENT

The manufacture of iron pipes in the UK has undergone 3 major changes in the last century. These are summarised in Table 1.

Table 1 - Development of iron pipes

Grey cast iron (vertically cast)	-> 1920s
Grey cast iron (spun)	1920s – 1960s
Ductile cast iron (spun)	1960s ->

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Details of the manufacturing techniques, their advantages and the resulting microstructures are given in Appendix A.

2. EUROPEAN STANDARDS

2.1 New standards

The governing European Standards (ENs) for ductile iron pipes and fittings for water supply and sewerage applications are BS EN 545: 1394 and BS EN 598: 1994 respectively. BS EN 545: 1994 supersedes the existing British Standard for ductile iron pipes and fittings, BS 4772: 1988, which has now been withdrawn. BS EN 598: 1994 has no strictly equivalent British Standard antecedent, as ductile iron pipes for sewerage applications were formerly included in the scope of BS 4772: 1988.

2.2 Applications

BS EN 545: 1994 Ductile iron pipes, fittings, accessories and their joints for water pipelines

Covers:

- spun ductile iron pipes
- gravity cast fittings and pipes with cast-on flanges
- nominal sizes from DN 40 to DN 2000 inclusive
- pipes with either spigot and socket ends or flanged ends
- fittings with either socket or flanged ends
- standard lengths shown in Tables 2 and 3 for flexibly-jointed and flanged pipes respectively
- use in the temperature range 0° to 50°C, excluding frost conditions.

BS EN 598: 1994 Ductile cast iron pipes, fittings, accessories and their joints for sewerage application

Covers:

- spun ductile iron pipes
- gravity cast fittings and pipes with cast-on flanges
- nominal sizes from DN 100 to DN 2000 inclusive
- pipes with spigot and socket ends, flanges or plain ends
- fittings with either socket or flanged ends
- standard lengths of spigot and socket pipes (DN 100 to DN 2000) are as EN 545 (see Table 2)
- use with fluid temperatures of up to 50°C.

Current UK availability

- Nominal sizes from DN 80 to DN 1600
- standard lengths shown in Table 2 and 3 for flexibly-jointed and flanged pipes respectively.

Table 2 - Standarised lengths of spigot and socket pipes

DN	BS EN 545	BS 477**
	Standardised length, Lu* (m)	Pipe length (m)
40 and 50	3	}
60 to 600	5 or 5.5 or 6	} 5.5
700 and 800	5.5 or 6 or 7	}
900 to 1400	6 or 7 or 8.15	} 8 (≤ DN 1600)
1500 to 1600	8.15	}
1800 to 2000	8.15	

* The standardised length (Lu) is the effective length and is equal to the overall length minus the spigot insertion depth as given in manufacturer's catalogue.
** Withdrawn - for comparison only.

Table 3 - Standardised lengths of flanged pipes

Type of pipe	DN	BS EN 545	BS 4772+
		Standardised length, L* (m)	
with cast-on flanges	40 to 2000	0.5 or 1 or 2 or 3	to be specified
with screwed-on or	40 to 600	2 or 3 or 4 or 5	5.0
welded-on flanges	700 to 1000	2 or 3 or 4 or 5 or 6	5.0 **(≤ DN 800) 6.0 ** (≥DN 900)
	1100 to 2000	4 or 5 or 6 or 7	6.0**

* Equal to the overall length. Other lengths available by agreement between manufacturer and purchaser.
** Screwed-on flanges only available ≤ DN 600.
\+ Withdrawn - for comparison only.

2.3 Class designations

BS EN 545

The specification (or class designation) system adopted follows that previously established in ISO 2531. In this system, the class designation consists of the prefix letter "K" plus a whole number. This whole number is the co-efficient which is inserted into a formula given in BS EN 545 for the determination of the standard wall thickness.

For a given nominal pipe size, the standard wall thickness increases as the integer specified in the class designation increases.

Other K-classes of pipes may be supplied within the scope of BS EN 545, provided that they are of a wall thickness appropriate to the class designation, are

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marked accordingly, and meet all the other requirements of the standard.
Thicknesses rather than class designations are now specified in BS EN 545 for fittings. Pressure capabilities of socketed fittings should be equal to those for K9 pipes, except for branched socketed fittings (which may be less) and for fittings with one or more flanges (rating limited to that of the flange).

BS EN 598

Pipes may be manufactured to a range of minimum wall thicknesses, which increase with increasing diameter, but which are not related to the K-classification system for the pressure pipe equivalents. For fittings, the wall thickness shall be equal to or greater than that for pipes of the same DN.

It should be noted that the method of manufacture fixes the outside diameter of ductile iron pipe. Variations in pipe class (i.e. wall thickness) hence result in changes in pipe bore.

2.4 Pressure ratings

BS EN 545

The pressure performance capability of ductile iron pipes and fittings for water supply to BS EN 545 is illustrated in Tables 4 and 5: further details are given in BS EN 545.

Table 4 - Maximum values of PFA, PMA and PEA for Class K9 spigot and socket ductile iron pipe to BS EN 545 (examples)

DN	Class K9 (bar)		
	PFA(1)	PMA(1)	PEA(2)
40	64	77	96
150	64	77	96
600	36	43	48
1200	28	34	39
2000	26	31	36

PFA; allowable operating pressure (i.e. maximum internal pressure, exclusive of surges that a component can stand in permanent service).

PMA: allowable maximum operating pressure (i.e. maximum internal pressure, inclusive of surge, that a component can safely withstand in service).

PEA: allowable test pressure (i.e. maximum hydrostatic pressure which can be applied on-site to a component in a newly-installed pipeline).

(1) Operation at these pressures may be limited by the lower pressure capability of other pipeline components (e.g. flanged pipework or fittings, socketted tees, some designs of flexible joints). Refer to manufacturers' catalogues.

(2) Site hydrostatic testing at the high PEA values given (especially for DN 40 to 150) may be limited by the type and design of pipeline anchorage system and/or design of flexible joints used.

The method for determining PFA, PMA and PEA for other K-classes of ductile iron pipes is shown in Annex A of BS EN 545.

Table 5 - Maximum values of PFA, PMA and PEA for pipes and fittings incorporating one or more flanges to BS EN 545 (PN 16 and PN 25)

DN	Flange pressure limits (bar)					
	PN16			PN25		
	PFA	PMA	PEA	PFA	PMA	PEA
40 to 50	40	48	53	40	48	53
60 to 80	16	20	25	40	48	53
100 to 150	16	20	25	25	30	35
200 to 600	16	20	25	25	30	35
700 to 1200	16	20	25	25	30	35
1400 to 2000	16	20	25		-	•

Note (i) The standard flange rating used in the UK is PN 16. PN 10, 25 and 40 are generally available to order. Pressure ratings of PN 10 and PN 40 flanges are given in BS EN 545.
Note (ii) PN 10 is a non-preferred flange pressure rating for routine Water Industry applications.

BS EN 598

The pressure performance requirements for ductile iron sewerage systems as given in BS EN 598 are related to the duty type i.e. gravity, pressure or vacuum; the relevant criteria are shown in Table 6.

Table 6 - Pressure performance capability of sewerage systems to BS EN 598

Type of operation	Maximum internal pressure (bar)	Maximum external pressure (bar)

	Continuous	Occasional	Continuous
Gravity	0 to 0.5	2	1
Pressure	6	9	1
Vacuum	-0.5	-0.8	1

3. SPECIFICATION TEST REQUIREMENTS

3.1 Comparison of European Standards with BS 4772

BS EN 545 and BS EN 598 incorporate a range of quality control test requirements (for routine factory production control) and type test requirements (to demonstrate type performance in a one-off test). These are compared with the previous requirements of BS 4772 (withdrawn) in Table 7. The key mechanical property requirements for these products (i.e. tensile strength, elongation) remain essentially the same as the criteria previously included in BS 4772.

3.2 Major changes

The following sections highlight the key developments and changes compared with BS 4772.

3.2.1 Routine quality control checks

The two most significant changes from BS 4772 are:-

- Pipe barrel outside diameter tolerances
  Both BS EN standards require the specified external diameters and tolerance values to apply at the pipe spigot end. In addition, both standards require that for pipes DN $\leq$300, the external diameter (measured circumferentially) shall be such as to allow assembly of the (flexible) joint over a minimum of two-thirds of the pipe length from the spigot end. For larger diameter pipes (i.e. DN 350 and greater), both standards require the same percentage length (67%) of the pipe barrel from the spigot should conform with this requirement, only where such pipes are supplied for cutting in the field by special agreement between the purchaser and manufacturer. Therefore, where the purchaser requires ductile iron pipes in these larger sizes to be suitable for cutting in the field, it is essential that this should be stated clearly in the tender or order.

- Cement mortar lining strength checks
  These have been introduced as a supplementary means of confirming the quality of cement mortar linings, which can now be produced from a wider range of cement types than had previously been prescribed within BS 4772 (see Section 5.1.2).

3.2.2 Type test requirements

One of the key developments in both European Standards has been the introduction of a range of type performance tests and acceptance criteria aimed

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at setting minimum product performance levels, in particular for the jointing systems. Whilst these tests demonstrate the short-term performance of such joints, only the dynamic test might be said to address their long-term performance.

Previously BS 4772 had only included a type test requirement for assessing flange-to-pipe attachments. In BS EN 545 and BS EN 598, these are supplemented by leaktightness testing of flexible joints under various combinations of either shear loading or angular deflection, and internal positive pressure, internal negative pressure, external positive pressure and (for BS EN 545 only) dynamic internal pressure (see Table 7). In BS EN 598 these tests are also supplemented by requirements for pipe stiffness, bending resistance, and resistance to chemical effluents and abrasion, none of which were previously defined in BS 4772.

It should however be noted that there are currently no type performance requirements for the internal protection systems for pipes and fittings for water supply, nor for the external protection systems for either water supply or sewerage applications.

3.2.3 Metal quality checks (including non-standard methods)

- Hardness tests - both BS EN 545 and BS EN 598 require that the quality of ductile iron castings shall be such that they can be cut, drilled, tapped and machined. If the purchaser considers that the castings do not comply with this requirement, or in cases of dispute, both standards recommend that the Brinell hardness of the castings concerned should be determined in accordance with ISO 6506. The maximum hardnesses are specified.

- Ring crush tests - although the tensile property and hardness determinations provide the purchaser with the means of establishing the quality of ductile iron pipes after delivery, they require the use of specialised test equipment which may not be readily available to all Water Utilities. A simple ring crush test has therefore been developed for use within the Water Industry on those occasions when doubt arises regarding pipe metal quality, and a decision must be reached quickly on whether to continue with pipeline installation. This test is based on measurement of the extent to which a ring section from an undamaged length of the pipe concerned can be crushed diametrically before fracture occurs (see Table 8).

Table 7 – Comparison of European Standards with BS 4772

Test	Test requirement included		
	BS EN 545	BS EN 598	BS 4772*
Quality control			
- dimensional checks	√	√	-
- tensile property determinations	√	√	√
-hydrostatic pressure tests	√	√	√
- zinc coating mass determinations	√	√	√
- paint coating thickness checks	√	√	-
- cement mortar lining thickness checks	√	√	√
- cement mortar lining compressive strength checks	√	√	-
Type performance tests			
- leaktightness of flexible joints to positive internal pressure under			
(a) shear loading	√	√	-
{b) angular deflection	√	√	-

- leaktightness of flexible joints to negative internal pressure under			
(a) shear loading	√	√	-
(b) angular deflection	√	√	-
- leaktightness of flexible joints to positive external pressure under shear loading	√	√	-
- leaktightness of flexible joints to dynamic internal pressure (water supply only)	√	-	-
- mechanical strength and leaktightness of flange-to-pipe attachment (for screwed-on or welded-on flanges; water pipes only)	√	-	√
- longitudinal bending resistance of pipe (sewerage only)	-	√	-
- diametrical stiffness of pipe (sewerage only)	-	√	-
- chemical resistance to effluent (sewerage only)	-	√	-
- abrasion resistance (sewerage only)	-	√	-
*Withdrawn - for comparison only.			

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The proposed acceptance values of minimum diametrical deflection before fracture in the ring crush test are presented in Table 8. In the event that a pipe ring sample fails to meet the appropriate requirement in the ring crush test, it is imperative that the remainder of the pipe from which the ring sample was taken should be retained for the determination of the standard tensile properties of the pipe metal. In such cases, samples of undamaged metal from the pipe concerned should, as a matter of course, be submitted to the manufacturer for investigation and comment. Note, in particular, that the pipe socket should be retained for inspection by the manufacturer (for identification purposes). If an independent evaluation of pipe metal tensile properties is also desired under such circumstances, the Water Utility should contact a reputable test laboratory for assistance.

It must be emphasised that the standard tensile properties of the material (determined in accordance with the requirements of either BS EN 545 or BS EN 598) will remain the final arbiters in all instances in which the quality of pipe metal is in dispute.

Table 8 - Ductile iron pipe ring crush test: proposed acceptance values of minimum diametrical deflection (squeeze) before fracture

Nominal size (DN)	Wall thickness (mm)	Minimum squeeze before fracture (mm)
100	>6.0	15
	≤6.0	20
150	>6.6	25
	≤6.6	45
200		60
250		80
300		100
350		120
400		140
450		160
Pipe ring sample to be cut perpendicular to the pipe axis; sides to be approximately parallel. A saw or disc cut finish is acceptable. Remove any cement mortar lining before testing. Ring width 50 ±5mm; crushing rate 300 mm/minute maximum. Platen size to be not less than the flattened dimensions of the ring.		

4. MANUFACTURING IMPERFECTIONS AND CASTING QUALITY

4.1 Types of imperfections and defects

Certain specific types of imperfections and defects can arise in centrifugally cast ductile iron pipes as a result of irregularities during manufacture. The principal types of manufacturing imperfections and defects observed in spun pipes are as follows;

(a) Imperfections

- Pits and pinholes - are shallow cavities on the external surface of the pipe. Pinholes are roughly circular cavities with diameters of the order of 1 mm. Larger, more elongated surface cavities are referred to as pits.

- Laces - are thin ribbons of metal laid down as part of a spiral on the external surface of the pipe and may extend around more than half of the pipe circumference. The metal ribbon may be more or less separated from the surrounding pipe metal.

- Laps - are formed on the pipe surface as a result of incomplete fusion between successive layers of metal laid down during the casting process. Laps are usually shallow and can be associated with slight surface depressions which are readily visible on uncoated pipes.

(b) Defects

- Draws (or hot tears) - are oxidised cracks in the spun pipe wall. These may be produced during contraction of the pipe in the mould, or if excessive force is inadvertently applied to extract a pipe from the mould while it is still hot and in a low-strength condition.

- Cracks - can be produced as a result of impact damage to the pipe when it is in its low toughness condition after casting but prior to heat treatment.

4.2 Acceptance of casting imperfections

Neither BS EN 545 nor BS EN 598 gives any guidance on the acceptability of surface imperfections (and defects), other than to say that ductile iron pipes, fittings and accessories should be free from defects and surface imperfections which could result in non-compliance with the technical requirements and performance requirements given in clauses 4 and 5 respectively of each of these specifications. The only clear example of an unacceptable defect within the definition of these specifications is one which penetrates the full wall thickness; repair of such defects is specifically precluded by these standards, which presumably would therefore result in rejection of the casting. Other surface imperfections and defects which do not penetrate the full wall thickness may be repaired (see Section 4.3.

This is in marked contrast to BS 4772 which defined the maximum permissible depths of surface imperfections on ductile iron pipes and fittings and permitted the rectification of minor surface imperfections by simple dressing.

4.3 Rectification of defects and surface imperfections

Both BS EN 545 and BS EN 598 permit the manufacturer to repair ductile iron pipes and fittings in production, e.g. by welding, to remove surface imperfections and defects which do not affect the full wall thickness, provided that:

(a) the repairs are carried out according to a written procedure included in the manufacturer's quality system (this differs from the situation formerly in BS 4772, which required the procedure to be agreed between the purchaser and the manufacturer). Details of the weld rectification procedure, previously agreed between the UK Water Industry and manufacturers, are available upon request from the Ductile Iron Liaison Group Technical Secretary (WRc plc, Swindon, Telephone: (0793)511711).

(b) the repaired pipes and fittings comply with all of the requirements of clauses 4 and 5 in these two BS EN specifications.

5. CORROSION PREVENTION

5.1 Internal - water supply

The bore surface of unprotected ductile iron pipes can be corroded by certain raw and potable waters. This may result in the internal tuberculation of the pipe, with a consequent loss of hydraulic capacity and dirty water problems.
In order to minimise bore surface corrosion, it is essential that all ductile iron pipes and fittings should be internally protected with a suitable lining.

In this respect, it is important to consider the effects of any future changes in the water conveyed by the system when specifying the internal protection to be applied to new ductile iron water mains pipe (particularly where a change from a non-aggressive supply to a more corrosive water is likely).

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For potable water applications, the lining material must comply with the Water Supply (Water Quality) Regulations 1989 as amended by the Water Supply (Water Quality) (Amendment) Regulations 1991. (The corresponding legislative reference for Scotland is The Water Supply (Water Quality) (Scotland) Regulations 1990). In particular all new materials must have approval from the Secretary of State who is advised by the Department of the Environment Committee on Chemicals and Materials of Construction for use in Public Water Supply and Swimming Pools (DoE-CCM). Materials which were in use in public supply in the 12 months period prior to 6 July 1989 are deemed to be acceptable according to Regulation 25 in each of the above Regulations. These therefore include the BS cements identified in Table 9, and bituminous paint coatings complying with BS 3416.

The internal corrosion protection systems commonly used in the UK and permitted by BS EN 545 are listed below. Section 5.4 of this note identifies the permissible alternatives.

5.1.1 Bituminous coatings

(a) BS 4772 permitted two types of bituminous coatings, i.e. a cold-applied grade to BS 3416 and a hot-applied grade to Type 1 requirements of BS 4147.

(b) BS EN 545 refers to bituminous products or synthetic resin, but gives no specification details other than that the mean thickness shall not be less than 70µm and the local minimum thickness shall not be less than 50µm.

Equivalent specification(s) for BS 3416 and/or BS 4147 are not yet available. In the meantime, purchasers are permitted to specify to the relevant British Standards.

However, in common with other paint coatings of these thicknesses, such bituminous paint coatings do not provide a complete barrier layer, owing to the large number of through-thickness defects (holidays) which are inevitable with such thin coatings.

5.1.2 Cement mortar linings

Cement mortar linings afford a better degree of protection against the internal corrosion of ductile iron pipelines than is achieved with conventional bituminous coatings. Cement mortar linings containing free lime provide an alkaline environment adjacent to the pipe bore surface which inhibits corrosion attack, thereby preventing internal tuberculation and hence minimising any losses in hydraulic capacity. An advantage of such linings is that they are self-healing - small cracks and defects in the cement mortar lining may become bridged by the precipitation of calcium salts (autogenous healing), Cement mortar lined iron pipes have now been in service for periods of up to 50 years in the UK, with no significant evidence of lining deterioration leading to attack on the iron pipe substrate.

Material

Pipes to BS EN 545 are required normally to be supplied with an internal lining of cement mortar. The Standard permits the use of any of the cements listed in ENV 197-1, or high alumina cement, provided that the cured lining meets the requirements of clause 4.1.4 of the standard in relation to the effect of materials in contact with potable water. No guidance is given on the selection of cements for any particular applications.

It should be noted that some of the cement types listed in ENV 197-1, particularly those containing significant levels of certain industrial by-products (e.g. non-ferrous slags), may be unsuitable for water supply applications due to the potential for leaching substances from the mortar which may impair the quality of the conveyed water. In this respect, the British Standard cements previously listed in BS 4772 (see Table 9) have already been qualified as acceptable for UK supply use in accordance with the governing Regulations. In addition, whilst the durability of these British Standard cements has been established through practical experience in the UK and technical evaluations, it is not clear whether the alternatives permissible in ENV 197-1 will in all cases have equivalent performance.

At present ENV 197-1 has the effective status of a European Standard Draft for Development. As such, CEN Internal Regulations permit the co-existence of conflicting National Standards, which can therefore continue to be cited in tender documents (subject to the normal qualification "or equivalent").

Pending the formal agreement of ENV 197-1 as a full European Standard (expected in 1996), UK purchasers should continue to specify the cements previously identified as suitable In BS 4772 (see Table 9).

Table 9 - Recommended cement types for lining ductile iron pipes and fittings for water supply (pending ratification of ENV 197-1)

Cement type (BS 4772)	Applicable British Standard	Closest corresponding ENV 197-1 designation
A. Portland pulverised fuel ash cement (minimum PFA content of 25%)	BS 6588	II/B – V
B. Sulphate-resisting cement	BS 4027	I
C. Ordinary Portland Cement	BS 12	I
D. Portland blastfurnace cement	BS 146 Part 2	II/B - D

Note:

(i) Type A is most commonly supplied by UK manufacturers

(ii) Where the conveyed water has a high level of sulphate, the manufacturer should be consulted on the type of cement to be used. Guidance on the choice of cements for sulphate resistance is given in reference 5.

(iii) The ENV 197-1 cement types identified are NOT direct equivalents of the BS cements listed. Consult the relevant specifications for further details.

No guidance is given in BS EN 545 regarding the grading of the sand, other than it should be of "an appropriate grading" and this could potentially contain particles of any size up to and including the lining thickness. The maximum sand:cement ratio permitted by BS EN 545 is 3.5 (cf 2.5 in BS 4772). The water used in the mix shall be either potable water or water that has no adverse effect on lining characteristics or conveyed water quality. The cement mortar mix may be applied to the internal surface of the pipe either centrifugally or through a centrifugal applicator head, the latter being standard practice in UK manufacturing plants. Fittings should be lined internally with cement mortar by any method which produces a lining comparable to that obtained on pipes.

Thicknesses

The minimum cement mortar lining thicknesses permitted in BS EN 545 are shown in Table 10. The combination of the lower nominal lining thicknesses for pipes up to DN 300, and the maximum permissible negative tolerances, indicates the possibility of receiving. pipes with linings significantly thinner than those traditionally considered necessary in the UK to guarantee effective protection to the pipe substrate for 50 years.

Table 10 - Cement mortar lining thickness minima as specified in BS EN 545 (N.B. NOT RECOMMENDED)

DN	Nominal lining thickness (mm)	Tolerance (mm)	Minimum lining thickness (mm)
40 to 300	3.5	-1.5	2.0
350 to 600	5.0	-2.0	3.0
700 to 1200	6.0	-2.5	3.5
1400 to 2000	9.0	-3.0	6.0

For UK water supply applications, it is strongly recommended that purchasers should exercise their prerogative within BS EN 545 to specify thicker cement mortar linings for ductile iron pipes and fittings in accordance with Table 11.

Table 11 - Recommended cement mortar lining thicknesses, maximum crack widths and radial displacements for ductile iron pipes and fittings

DN	Thickness* (mm)			Maximum crack width and max. radial displacement** (mm)
	Nominal	Min. arithmetic-cal mean value	Individual minimum	
80	5	3.5	2.5	0.8
100 – 300	5	4.5	3.5	0.8
350 – 600	5	4.5	3.5	1.0
700 – 1200	6	5.5	4.5	1.2
1400 - 2000	9	8.0	7.0	1.5

* As per BS 4772

** As per BS EN 545 (NB. These values are reduced from those previously permitted in BS 4772)

In order to avoid excessive cement lining thicknesses when purchasing according to Table 11, the user should additionally specify that the minimum clear bores in Table 12 should apply.

Table 12 - Minimum bore clearance of cement mortar lined pipe

DN	Minimum bore of cement mortar lined pipe (mm)
80	67.0
100	87.0
150	137.0
200	187,0
250	237.0
300	287.0

In cases of dispute, it is recommended that the bore clearance should be checked by passing a flat disc gauge, 10 mm thick (maximum) of the appropriate diameter in Table 12, down the bore of the lined pipe, with the plane of the disc gauge positioned at 90° to the pipe axis.

Surface Condition

BS EN 545 permits cement mortar linings to be smoothed by trowel provided that the trowel marks do not reduce the lining thickness to below the minimum specified value. No limits are however set on the maximum peak-to-trough height of such ridges. Since

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this can increase the hydraulic roughness of the finished pipe bore, BS 4772 had set the maximum peak-to-trough height of any trowel ridges to (0.008 P + 0.3)mm, where P (mm) is the pitch (spacing) between consecutive peaks in the pipe axial direction. This was aimed at ensuring that the Hazen-Williams coefficient, C, did not fall below 143 for the pipe sizes affected i.e. $\geq$DN 900).

BS EN 545 permits the presence of shrinkage cracks in dry finished linings, provided they do not affect the stability of the lining, and provided that their widths and my radial displacements at such cracks do not exceed the limits given in Table 11. In this respect, experience has shown that cracks in linings due to pipe expansion or mortar shrinkage tend to close on continuous exposure to water, and substantially heal by an autogenous process. In a similar fashion, areas of disbonded linings tend to swell and retighten on continuous exposure to water. Apart from this, the lining surface should be substantially free from laitance, but fine crazing and hairline cracks associated with cement-rich surfaces are permitted.

Seal Coats

Unsealed cement mortar linings can give rise to problems of lime leaching and consequent high pH levels in supply when conveying soft (i.e. low carbonate alkalinity) water, particularly where flow rates are low and residence times are lengthy, e.g. in dead end sections of small diameter mains. It is recommended that unsealed, factory-applied PFA-modified cement mortars should not be used if the alkalinity of the supply water is less than 25 mg calcium carbonate per litre(6).

Elevated pH levels in supply associated with lime leaching from unsealed cement mortar linings are transient, but can last for many months (in some cases, years) after commissioning, dependent on the carbonate alkalinity of the conveyed water. The risk of very high pH levels in supply can be reduced substantially, certainly in the short term, by the application of a coating (typically bituminous paint) to the bore of cement mortar lined pipe. Although bituminous seal coats have been used in the UK since the 1920's, research is currently in progress to define more closely the durability and performance of current bituminous seal coats on centrifugally-applied cement mortar linings.

Seal coats comply with the requirements of BS xxxx, (in the course of development), which identifies the type performance and quality control test requirements necessary for such materials to ensure that seal-coated ductile iron pipes and fittings should not impair the quality of the conveyed water (particularly with respect to taste and odour).

5.2 Internal - sewerage

All lining materials for sewerage applications must be capable of meeting the requirements of the chemical resistance and (for pipes only) abrasion tests in BS EN 598.

5.2.1 Cement mortar linings

Pipes to BS EN 598 are required normally to be supplied with a lining of high alumina cement mortar, with the end surfaces which can come into contact with the conveyed effluents (socket internal surface and spigot external surface) coated with either an epoxy-based paint or fusion-bonded epoxy. Lining thicknesses are required to be in accordance with those shown in Table 10. BS EN 598 makes no provision to permit the specification of lining thicker than the standard.

5.2.2 Epoxy coating

Ductile iron fittings and accessories to BS EN 598 are normally required to be supplied with an internal (and external) epoxy coating; this may be either an epoxy paint, or an epoxy powder (see also Section 5.3.2(c).

All lining materials shall comply with the relevant European standards, where these exist; if these are not available, they shall comply with ISO or National standards, or with an agreed technical specification (e.g. WIS 4-52-01).

5.3 External (water supply and sewerage)

5.3.1 Corrosion mechanisms

External corrosion of buried iron mains occurs by an aqueous electrochemical mechanism. In terms of corrosivity, the precise environmental conditions experienced by a buried main can range from atmospheric to fully immersed, depending on the degree of soil compaction and its moisture content. In general, wet clay is more corrosive than a well-drained sandy soil. Furthermore, the heterogeneous nature of soils can give rise to different areas of the pipe surface being exposed to different soil environments. This can result in the generation of microscopic and/or macroscopic differential concentration cells along the pipe, which can exacerbate localised corrosive attack (pitting).

This is thought to be a particular problem where clay is used for backfilling the pipe trench. Large clay clods can take up to 15 years to fully reconsolidate after pipe laying. During this period, differentia] aeration cells may be generated along the pipe surface between areas in contact with the clay and areas where no contact occurs due to soil bridging - this can produce pitting attack of the pipe in those areas in contact with the clay. Rapid corrosion of unprotected iron pipes also occurs in made-up soils containing ashes, clinker, domestic refuse, industrial waste and chemical effluents. Microbiological attack of buried iron mains can take place under anaerobic conditions, e.g. in permanently waterlogged soils, due to the action of sulphate-reducing bacteria. The problem of external corrosion attack on unprotected ductile iron pipe has been reviewed comprehensively by WRc[7].

Soil resistivity is generally acknowledged to be the most convenient and reliable single indicator of the corrosivity of soils towards buried iron mains. Experience in the UK has shown that, in general, soils exhibiting resistivities less than 40 ohm.m (4000 ohm.cm) are potentially corrosive towards mains having only a coating of bituminous paint.

Of the other parameters which have been used to supplement the assessment of corrosivity based on soil resistivity measurements, moisture content appears to be the most useful. Since soil resistivity and moisture content are inevitably interrelated, it is clear that the resistivity (and hence corrosivity) of a soil may exhibit seasonal variations due to changes in water table level, etc. Thus, soil resistivity determinations carried out on a single occasion may not necessarily identify all of the potentially corrosive areas along the line of a main.

It must also be recognised that these measures alone will not necessarily identify the presence of other potentially corrosive pipe backfill materials, such as made-up ground, soils containing ash or clinker, naturally occurring coal particles, waste materials or otherwise contaminated soil. The presence of such materials may only be identified from soil maps, historic records of site usage, local knowledge, existing site investigations reports and/or trial hole sampling and analysis.

It is clearly advisable that all ductile iron pipes and fittings should be adequately protected against external corrosion. When specifying the external protection system for a buried iron main, consideration should be given to the effects of any foreseeable changes in the soil environment which may arise in the future, e.g. due to changes in the soil drainage, effects of highway construction, etc.

5.3.2 Protection systems

The following sections review the external corrosion protection systems commonly used on ductile iron pipes and fittings in the UK with reference to BS EN 545 and BS EN 598, and the alternatives permissible within their respective scopes.

(a) Zinc coatings

Ductile iron pipes for both water supply (to BS EN 545) and sewerage applications (to BS EN 598) are required normally to be supplied with an external coating of sprayed zinc metal (minimum of 130 g/m^2 mean), with a finishing layer of a bituminous paint or synthetic resin compatible with zinc (minimum of 70 µm mean), as illustrated in Figure 1. It has been clearly demonstrated[8,9,10] that the metallic zinc coating system can protect areas of coating damage by itself corroding sacrificially, provided that the damaged areas are not too large.

However, the sacrificial protection to damaged areas may be regarded as of limited duration, particularly in aggressive soil environments and where coating damage is extensive. Consequently, it is recommended that all new ductile iron mains should have additional PE sleeving protection applied, unless a soil survey or local knowledge of the ground conditions indicates that the soil is non-aggressive. Care is however required in the interpretation of soil resistivity surveys or "local knowledge", which are not in all cases fool proof indicators, particularly in urban situations where the presence of disturbed ground or prior contamination (e.g. on redevelopment sites) may invalidate the assessment. Reference may be made to manufacturers literature for guidance on the range of suitability of zinc coatings.

Furthermore, current evidence[8] indicates that the alternative of zinc-rich paint is not as effective as metallic zinc with respect to the sacrificial protection of coating damage sites.

(b) Bituminous coatings

Bituminous paint coatings are normally applied as the finishing layer to the external zinc coating on all ductile iron pipes (water supply and sewerage), and as the standard external finish for all other ductile iron fittings and accessories within the scope of BS EN 545 for water supply (see Figure 1). However, bituminous coatings of these thicknesses do not provide a complete barrier layer, owing to the large numbers of through-thickness defects (holidays) which are inevitable with such thin coatings. Whilst such bitumen coatings are primarily intended to prevent atmospheric corrosion of iron pipes and fittings, in the

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stockyard, they can provide a limited degree of protection against corrosion in certain less aggressive soils, e.g. well drained sandy soils. In corrosive soils, additional external protection is essential to ensure satisfactory service lives.

(c) Epoxy coatings
Ductile iron fittings and accessories to BS EN 598 are normally required to be supplied with an external coating of either epoxy paint or epoxy powder. No details are specified for such coatings. WIS 4-52-01 details the UK Water Industry performance requirements and application methods for polymeric anti-corrosion (barrier) coatings. Where such coatings do NOT additionally meet all of the performance requirements for coated metal substrates in WIS 4-52-01, it is recommended that fittings and accessories thus coated should additionally be protected externally by wrapping with loose PE sleeving prior to burial.

(d) Polyethylene (PE) sleeving

- Background

The use of polyethylene (PE) film for wrapping iron pipes and fittings to provide protection against external corrosion attack in soils was pioneered in the USA during the 1950's, and was first introduced into the UK during the 1960's. Loose sleeving is now the most commonly used method of external corrosion protection for buried ductile iron pipelines in the UK Water Industry. PE sleeving may be applied either in the factory (on pipes) or on site.

The method differs from conventional corrosion protection practice in that PE film, in either flat sheet or tubular form, is applied loose over the pipe or fitting surface. This is secured in place either using adhesive tape, or bands of adhesive at the sheet edges, to form a tight-fitting envelope around the pipe or fitting, rather than a fully bonded system, as is the case for conventional coatings. Although not intended to be a fully air- and/or water-tight enclosure, the primary aim of the PE sleeving is to prevent direct contact between the pipeline and the surrounding trench fill material. Correctly applied and installed, loose PE sleeving is a simple and inexpensive technique which can significantly reduce the risk of external corrosion failure on buried ductile iron mains in most naturally-occurring soils in the UK. The mechanism of corrosion protection afforded by PE-sleeving has been discussed in a WRc Report[11] which includes a summary of field experience with PE sleeved iron pipes. The performance of correctly-installed loose PE sleeving has recently been demonstrated in a series of pipe exhumations in the USA[12]. There it was found that sleeved pipes laid in a range of corrosive soils for up to 28 years had suffered negligible levels of corrosion attack.

- Specifications and guidance

PE sleeving for ductile iron pipelines should conform with the requirements in BS 6076: 1994 for factory or site application, as appropriate. Blue coloured PE sleeving should be used for wrapping potable water mains, red for gravity/low pressure sewerage, and black PE for all other applications.

PE-sleeved pipes and fittings should be transported, handled and installed in accordance with the guidance in IGNs 4-50-01 and 4-50-02 for site - and factory-applied sleeving respectively.

Pipes and fittings protected with loose PE sleeving should be handled with care at all times to prevent damage to the sleeving film. Whilst research has suggested that small tears, rips and punctures could be tolerated in the sleeving provided that no contact occurs between the soil and pipe surface, it is recommended that **all** sleeving damage should be repaired before pipe laying, e.g. with plastic adhesive tape for smaller defects, or with an additional patch of film taped or glued over larger areas of damage. Repair of sleeving damage also minimises the risk of the pipe surface subsequently, becoming exposed to flowing (ground) water, which otherwise could effectively provide an unlimited supply of fresh corrodent to sustain the corrosion reaction.

- Limitations

It follows that the standard protection system of zinc coating with finishing layer plus PE sleeving may not be sufficiently robust to provide adequate corrosion protection in:

- Natural soils with resistivities less than 1000 ohm.cm;
- soils containing relatively large (e.g. >30 mm size) hard and sharp-edged

objects, e.g. clay soils containing large flints, some shaley soils, etc. which may damage the sleeving (unless the pipe is to be bedded and surrounded in suitable selected/imported backfill);

- contaminated soils[13] where for example ash, clinker, domestic and/or industrial refuse may be present (again, unless the pipe is to be bedded and surrounded in suitable selected/imported backfill); and

- locations where there is a risk of stray (interference) currents from adjacent impressed current cathodic protection (CP) systems, DC railway operations, etc. The potential risk of corrosion arising from such causes needs to be assessed through liaison with operators of impressed current CP/DC traction systems in the vicinity of the proposed pipeline. Guidance on interaction testing for impressed current CP systems is given in BS 7361. In cases of doubt, expert guidance should be sought.

It is further recommended that ductile iron pipeline joints should **not** be electrically overbonded, as there is evidence that this can stimulate galvanic corrosion at any areas of bare metal (e.g. ground spigot surfaces). In addition, polyethylene sleeving (either factory- or site-applied) is NOT recommended for use in conjunction with cathodic protection systems for buried iron pipelines. The corrosion protection afforded by PE sleeving may however fail where there is a high risk of sleeving damage due to interference after installation. In such situations where pipelines are to be laid in high-risk environments, consideration should be given to the specification (albeit at extra cost) of more sophisticated corrosion protection measures.

(e) Factory-applied PE sleeving

Factory-applied PE sleeving was first introduced in the UK in 1986 and is now supplied on a significant proportion of all new ductile iron pipes. It involves the application of a number of sheets of PE film to the pipe "cigarette wrap" fashion (see Figure 1). The film is attached to the pipe by bands of adhesive at the longitudinal and circumferential edges; the film is overlapped onto itself at the longitudinal edges, and onto the pipe or other lengths of film at the circumferential edges, by prescribed lengths. Factory application of PE sleeving ensures that the sleeving material is wrapped tightly and uniformly over the pipe barrel; this is important if the full effectiveness of loose sleeving is to be achieved. In addition, application in the factory eliminates the risk of soil entrapment between the sleeving and the pipe surface, which can be a problem with the site application method.

Care must be taken in the transportation, handling and laying of factory-sleeved pipe to minimise the risk and extent of sleeving damage, which should be properly repaired prior to burial. The importance of correct on-site joint and fittings protection should also not be overlooked. Guidance on these issues is given in IGN 4-50-02. The pipe manufacturers may also be consulted for further guidance where appropriate.

(f) Site-applied PE sleeving

Loose PE sleeving is most commonly installed on site on ductile iron pipelines in the form of tubular film. Cut lengths are slipped over the pipe or fitting, pulled tight and overlapped to form a snug-fitting envelope, and secured in place with bands of plastic adhesive tape (see Figure 1). Guidance on the site application of loose PE sleeving is given in IGN 4-50-01.

Ductile iron
with oxide s

Care must be taken to avoid sleeving damage both during site application and installation, and any damage should be suitably repaired. In addition, care must be taken to avoid. entrapment of soil between the sleeving and pipe surface, as this has been identified as the cause of at least some external corrosion failures on PE sleeved, **bitumen coated** ductile iron mains in the UK[14]. Problems may also arise if the sleeving is poorly applied such that large gaps are left between the sleeving and pipe surface, or poorly sealed such that groundwater is able to flow freely through the annulus between the sleeving and pipe surface. (In this respect is should be noted that corrosion attack under loose PE sleeving can only be sustained if a supply of fresh corrodent (e.g. oxygenated or acidic groundwater) to the pipe surface is maintained.)

Clearly, where the quality of site-applied sleeving cannot be assured or may be uncertain (e.g. due to limitations of available supervision), the protection afforded by the sleeving may be compromised in:-

- highly acidic (pH $\leq$5) soils and alkaline (pH $\geq$9) soils;

- soils where the water table level is either intermittently or continuously above the pipe invert (e.g. peat marsh, salt marsh, waterlogged heavy clays and alluvial soils), particularly if the resistivity is less than 1000

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ohm.cm and/or the groundwater chloride content is greater than about 300 ppm; and

- situations where the pipe trench may act as a drain for groundwater.

In these situations, it may be prudent to consider more sophisticated alternative protection measures.

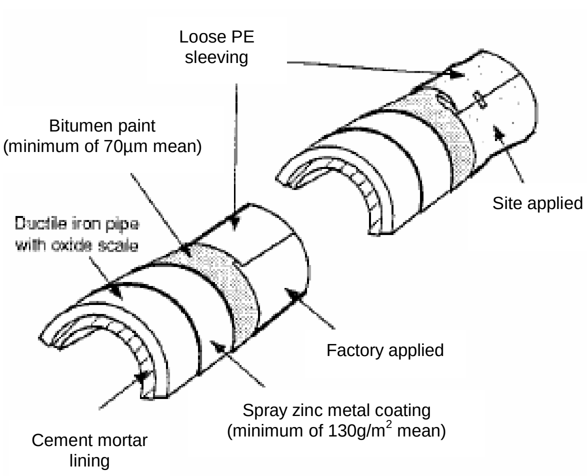

Figure 1 – Ductile iron pipe: corrosion protection systems (not to scale)

5.4 Alternative corrosion protection systems

Coatings and linings other than those supplied as standard may be used by agreement between the purchaser and manufacturer within the scopes of BS EN 545 and BS EN 598. These are as follows:

Pipes - external coatings

- zinc-rich paint coating plus finishing layer;
- thicker metallic zinc coating plus finishing layer;
- PE sleeving (as a supplement to zinc coating with finishing layer);
- extruded polyethylene;
- extruded polypropylene;
- polyurethane;
- adhesive tapes;
- fibre reinforced cement mortar.

Pipes - internal linings

- polyurethane;
- thicker cement mortar lining*;
- cement mortar lining with seal coat*;
- bituminous paint*;
- Portland blastfurnace cement mortar§;
- polyethylene§,
- epoxy resins§.

Fittings/accessories - external coatings

- zinc coating with finishing layer;
- PE sleeving (as a supplement to bituminous paint or to zinc coating with finishing layer);
- adhesive tapes;
- epoxy*;
- bituminous paint§.

Fittings/accessories - internal linings

- polyurethane;
- cement mortar lining with seal coat*;
- thicker cement mortar lining*;
- epoxy*;
- high alumina cement mortar lining§;
- blastfurnace slag cement mortar lining§.

* BS EN 545 water supply only.
§ BS EN 598 sewerage only.

Such coatings and/or linings should comply with the relevant EN standards or, where no EN standard exists, they should comply with relevant ISO or National standards, or with an agreed technical specification. Whilst all lining materials identified in BS EN 545 must comply with the requirements of clause 4.1.4 regarding their effects on conveyed water quality, purchasers should additionally confirm the approval status of such products for use in supply applications against the requirements of the prevailing relevant National Regulations. This particularly applies to the alternative lining materials identified as acceptable within BS EN 545.

Internal cement mortar linings for water supply applications should meet the thickness criteria detailed in Table 11, and all cement mortar lined pipes should meet the bore clearance criteria detailed in Table 12. Bitumen paint lining alone is not considered adequate for the internal protection of ductile iron pipes, fittings and accessories which are likely to be exposed to soft, aggressive waters during their expected service life. It is recommended that polymeric lining materials permitted by these specifications (polyethylene, epoxy, polyurethane) should at least be able to meet the appropriate requirements in WIS 4-52-01, in addition to those of any relevant EN, ISO or National specification.

In certain soils, more sophisticated external corrosion protection measures than the recommended loose PE sleeving plus external zinc coating with finishing layer (for pipes) or bituminous paint (for fittings) may be required (see Section 5.3.2 (d)). Polymeric coatings (polyethylene, polypropylene, polyurethane, epoxy) for such applications should at least comply with the appropriate requirements in WIS 4-52-01, in addition to those of any relevant EN, ISO or National standard. Tape wrappings may also be used in such situations. Pending the publication of National/European standards for anti-corrosion tapes and their application, purchasers should ensure that their specifications for such products address the following requirements, as a minimum:

- the applied wrapping should be free of holidays (i.e. through-thickness defects);
- adhesion of the tape wrapping to the pipe;
- damage resistance of the tape wrapping, such as to impact (e.g. falling stones in backfilling operations), and penetration (e.g. by stones in backfill);
- biodegradation resistance.

5.5 Cathodic protection

There will be occasions when it will be necessary to use the polymeric coatings (or tape wrappings) detailed above in conjunction with a correctly designed, installed and maintained cathodic protection system. The purchaser is then left with a choice which balances the cost of coating with that of cathodic protection governed by the prevailing conditions. Clearly, high level coating and pipelaying specifications and practices giving holiday (defect) free coatings would certainly result in lower protective current demands (impressed current systems) or longer anode lives (sacrificial anode systems), and would influence subsequent maintenance costs. Whilst the cathodic protection of ductile iron pipelines is technically feasible, conventional CP systems may be impracticable for certain applications, e.g. for small diameter distribution mains laid in congested urban areas. The long-term effectiveness of some of the joint overbonding systems which are available for providing electrical continuity on ductile iron mains with rubber gasketted joints can depend critically on the skill of the installer and the level of site supervision, which should also be taken into consideration at the design stage. Lastly, but by no means least, the adoption of CP as a corrosion protection measure necessarily involves a long-term commitment to the provision of adequate resources for monitoring and maintaining the performance of the system, and therefore may be either financially or operationally unattractive. Guidance may be obtained from the pipe manufacturer and experienced CP engineers. Techniques have recently been developed for the retrospective application of cathodic protection to existing buried ductile iron mains, for use particularly where these are known to be suffering external corrosion attack[15].

6. JOINTS

Two basic types of joints are available for ductile iron pipes and fittings, i.e.:

6.1 Spigot and socket type joints with flexible elastomeric sealing rings

(a) Push-fit joints

- commonly used for buried ductile iron pipelines
- ease of assembly and reliability
- can accommodate some angular deflections in the pipeline, and also some longitudinal movement.

(b) Bolted gland joints

- offer similar joint flexibilities to push-fit joints
- pipelines with such joints will therefore tolerate limited ground movements.

However, ail unrestrained bends and tees require anchorage to resist the longitudinal forces experienced by pipelines under pressure.

(c) Mechanically-anchored spigot and socket joints

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- sealing rings for push-fit joints with moulded-in toothed metal inserts; currently available for pipes up to and including DN 400 from UK manufacturers (excluding DN 350).

- anchored push-in joints of the tie-bar type are available in the full size range DN 80 to DN 2000.

The angular deflection limits of flexible joints on ductile iron pipes and fittings are shown in Table 13. It should be noted that the designed capability of UK manufactured pipe products with flexible joints exceeds the minimum requirements of BS EN 545.

Table 13 - Angular deflection limits of flexible joints on ductile iron pipes and fittings

Joint type	Nominal size (DN)	Angular deflection (degrees)	
		BS EN 545 and BS EN 598 minimum requirement	UK manufacturers' products designed capability
Push-lit	40 to 300 350 to 600 ≥ 700	3½ 2½ 1½	5 4 4
Push-fit with tie-bar	40 to 300 350 to 600 ≥ 700	1¾ 1¼ ¾	5 4 4
Toothed anchor gasket push-fit	40 to 300 350 to 600 ≥ 700	1¾ 1¼ ¾	3* 3 (≤ DN 400)* -
Bolted mechanical	40 to 300 350 to 600 ≥700	3½ 2½ 1½	4 4 (≤ DN 1600)**
* ≤ DN 150, PMA = 16 bar (minimum) ; ≤ DN 400. PMA = 10 bar (minimum)(DN 350 not available): see manufacturer's catalogues for more information. ** Fittings only available			

The end-load resistance of anchored flexible joint types is not however covered by BS EN 545. Guidance on end-load performance levels is given in IGN 4-01-02.

It should be noted that, whilst the external diameters and tolerances of pipe (and fitting) spigots are specified in BS EN 545 and BS EN 598, individual manufacturers products are generally designed such that their flexible joints meet the specified performance requirements (see Section 6.3) over a tighter tolerance range, which may differ from one manufacturer to the next. Consequently, whilst pipes to each of these BS EN standards may be interconnectable with others to the same standard, they may not necessarily be completely interchangeable, in terms of flexible joint performance. Where products to the same standard from different manufacturers are to be used, the manufacturers should be consulted for guidance on how to ensure adequate joint performance at high pressures (e.g. via measurement and selection of spigot external diameter).

6.2 Flanged joints sealed with a flexible elastomeric gasket

Mainly recommended for "above ground" applications and for the installation of valves, etc. in spigot and socket jointed pipelines.

6.3 Performance requirements

Elastomeric gaskets for both spigot and socket (flexible) joints and flanged (rigid) joints should meet the requirements of BS 2494: 1990 and, for water mains applications, must be suitable for use in contact with potable water.

Gaskets for flanged joints should conform with the dimensional requirements of ISO 7483. Reference should also be made to IGNs 4-40-01 and 4-40-02 which discuss the selection, properties, storage and installation requirements for elastomeric seals and sealing rings.

Flexible joints are required to meet the type performance requirements identified in Table 14 as a minimum.

For welded-on and screwed-on flanges, the flange to pipe attachment is subject to:

- a combined pressure and bending load test;
- an internal pressure; 2x flange rating (minimum);
- an externally applied bending moment; equivalent to four times weight of pipes and contained water, with the joint positioned at the mid point of a simply - supported span of:
  8 m for sixes ≤ DN 250
  12 m for sizes DN 300 and greater.

Table 14 - Flexible joints: performance requirements (BS EN 545)

Joint Must Survive	Joint configuration	
	• Maximum annulus • Withdrawn to allowable value • Shear of 50 DN (N) across joint	• Maximum annulus • Joint deflected (see Table 13)
Positive internal pressure 1.5p + 5(bar)	√	√
Negative internal pressure -0.9 bar (-0.1 bar abs)	√	√
Positive external pressure of 2 bar	Optional	Not required
Cyclic internal pressure 0.5p to p; 24000 cycles	√	Not required
p = allowable operating pressure of the joint declared by manufacturer		

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7. FITTINGS

BS EN 545 allows for two different series of ductile iron pipeline fittings for water supply applications, i.e.:

- Series A - the dimensions of these fittings correspond to those detailed in ISO 2531; and

- Series B - the dimensions of these fittings are in accordance with a "Unified Design" approach. This "Unified Design" approach has been introduced to enable manufacturers to achieve greater efficiency and economy in production by basing standard fittings designs on a minimum number of component parts of foundry tackle. The Series B fittings are generally limited to a maximum size of DN 450 at this stage.

A wide range of socketed and flanged ductile iron fittings is available.

It should be noted that the ranges of types and dimensions of both Series A and Series B fittings detailed in BS EN 545 do not in all cases coincide with those previously given in BS 4772.

Consequently, when ordering fittings which are not detailed in the tables in BS EN 545, the purchaser should consult the manufacturers' catalogues, to:

(a) determine which of Series A or Series B fittings is being offered; and

(b) check the key dimensions of the products of interest, as these may differ significantly from one supplier to another.

For similar reasons, manufacturers' catalogues should be consulted when considering the replacement of existing ductile iron pipeline fittings, in order to ensure any dimensional differences are identified and taken into account in the design of the replacement section.

Various ductile iron adaptors are available for joining metric-size ductile iron pipe to existing imperial-size pipe, e.g.:

(i) Double spigot change piece;

(ii) Spigot and socket change piece plus metric collar;

(iii) Double socket change collar. The use of a double socket collar is only recommended where the differential force produced by internal pressure is insufficient to produce movement of the collar;

(iv) Wide tolerance coupling.

8. CONNECTIONS

Normal tapping methods and machines are suitable for making service connections to ductile iron mains, provided that certain precautions are observed, i.e.:

(a) For service connections sealed directly into the wall of a ductile iron main, the diameter of the service connection hole should not exceed one-sixth of the nominal main diameter. Where an external sea is to be used, the diameter of the service connection hole should not exceed a quarter of the nominal main diameter. Where the diameter of the connection exceeds a quarter of the nominal main diameter, a drilled and tapped collar of suitable design should be used.

(b) The drill should be sharp and accurately shaped. Hardened drill bits should be used when drilling into cement mortar lined ductile iron mains.

(c) The drill should be fed gradually without overtightening the drill feed screw.

(d) When drilling cement mortar lined pipes, the rate of feed should be reduced and the drill speed increased immediately the drill penetrates into the lining. Lubrication of the drill with water is also recommended while drilling through the cement mortar fining.

(e) The service connection should not be overtightened if it is threaded directly into the iron mains pipe.

When making service connections to a PE-sleeved ductile iron main, it is essential to repair any damage to the film caused by the tapping machine and to protect all exposed metal surfaces at the connection by the application of waterproof wrapping tape. For underpressure tapping of PE sleeved ductile iron mains, sufficient area of the sleeving film must be cut away so that the tapping machine can be located directly onto the pipe surface, in order to effect a satisfactory pressure-tight seal. Further guidance on these aspects is given in IGN 4-50-01 and 4-50-02.

Service connections to iron mains are conventionally made using copper alloy (e.g. gunmetal) ferrules. In addition, some use continues to be made of copper tube for new service connections in certain areas, although MDPE pipe now generally predominates for this application, principally due to its lower cost.

The direct attachment of a copper service connection (i.e. copper alloy ferrule with or without a copper service pipe) to an iron main introduces the risk of stimulating galvanic corrosion attack on the iron pipe by the electrochemically more noble copper service. This risk will be less where MDPE is used for the communication pipe since, in this case, the galvanic couple is limited to the small area of copper alloy ferrule attached to a relatively large area of iron pipe.

In order to minimise the risk of galvanic corrosion action on the external surface of the iron pipe, it is essential to protect all the exposed surfaces of the ferrule, after installation, using a suitable waterproof wrapping tape in accordance with the guidance in IGN 4-50-01 and 4-50-02, as appropriate. Alternatively, the ferrule may be electrically isolated from the main using a suitable insulating piece. For similar reasons, where copper tube is to be used for making service connections to uninsulated copper alloy ferrules on iron mains, plastic coated tube should be specified, or alternatively bare copper tube should be protected by wrapping with a suitable waterproof tape. After installation, it is equally important to protect any remaining areas of exposed metal on the service line (e.g. areas of coating cutback at the ends of coated copper tube), again using a suitable waterproof wrapping tape (see IGN 4-50-01 and 4-50-02).

Whilst there is also a potential risk of galvanic corrosion attack on the internal surface of an iron main where copper service lines are used, there have been no incidents of internal attack leading to failure on iron mains in the UK which have been attributed to this cause. Furthermore, the risk of this occurring is considered to be negligible where MDPE is used for the communication pipe, owing to the relatively small ratio of ferrule to pipe bore surface area.

9. HANDLING AND LAYING

The excellent strength and ductility of ductile iron pipes and fittings render them considerably less liable to damage and fracture during transportation, handling and laying than grey iron castings. Ductile iron pipes and fittings must nevertheless be handled and laid with care in order to minimise damage to the internal and external corrosion protection systems, and also to prevent damage to the joint faces. Where appropriate, canvas or webbing slings should be used for lifting PE sleeved pipes; unprotected chain slings should not be used as these will damage the sleeving. For similar reasons, chocks should also be protected to prevent damage to the sleeving. The pipeline should be laid on a properly prepared, even bed, with joint holes made to accommodate the pipe socket so that the pipe is supported evenly along its length.

The backfill used for buried mains should not contain large stones, sharp rocks or other materials which could damage the external coating of the pipe. The trench Fill material should preferably not be poured directly onto the pipe, but should be tipped into the side of the trench to minimise impact damage to the external corrosion protection system, and should be compacted according to the recommended procedure.

Where ductile iron pipes are delivered with end caps, these should be left in place to prevent contaminants entering the pipe right until the pipe is ready to be installed in the line under construction. Similarly, the ends of pipelines under construction should be end-capped to minimise the ingress of soil and other contaminants.

The installation of ductile iron pipelines for water supply applications shall be carried out in accordance with the requirements of BS EN 805 which will become the lead standard for pipeline installation in Europe, when published. Further guidance on general pipe laying practice can be found in the British Standard Code of Practice BS 8010 Pipelines, Part 1: 1988 Pipelines in land: general; and on laying ductile iron pipelines in BS 8010, Part 2, Section 2.1: 1987. Further guidance can also be obtained from the pipe manufacturers.

Ductile iron pipelines for sewerage applications must be installed in accordance with BS EN 476; additional guidance may be found in BS 8005: Sewerage, Parts 0, 1 and 2.

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APPENDIX A - HISTORICAL DEVELOPMENT

Until the early 1920s, iron pipes were normally manufactured by casting grey iron into vertical sand moulds (pit casting). These pipes were invariably eccentric (i.e. non-uniform wall thickness) due to difficulties in pipe mould core location; they exhibited relatively low strengths and poor ductilities, the latter being due to the flake graphite form and the high phosphorus content of cast iron produced by foundries of that period. The microstructure of vertically cast grey iron pipe is illustrated in Figure A.1(a). The casting of grey iron pipes in horizontal, water-cooled, spinning metal moulds began commercially in the United Kingdom during 1922. This high production rate technique eliminated certain sand casting defects (e.g. blowholes) and in particular resulted in uniform pipe wall thicknesses. Furthermore, the refinement of pipe wall microstructure achieved by the centrifugal casting and subsequent heat treatment process (which was necessary to break down the chilled microstructure of metal spun cast iron) resulted in somewhat higher tensile strengths and ductilities than those obtained by pit casting: the microstructure of spun grey iron pipe is shown in Figure A.1(b). The combination of enhanced tensile properties and uniform pipe wall thickness obtained by centrifugal casting thus allowed the manufacture of thinner, and hence lighter, pipes than had previously been possible with the pit casting technique.

Spun ductile iron pipes were first manufactured in the United Kingdom on a commercial scale in 1961. Ductile iron is produced by treating a low phosphorus, low sulphur, grey iron melt with magnesium immediately prior to casting. This treatment causes the carbon present in the melt to precipitate predominantly in the form of graphite nodules on solidification, rather than as flake graphite (as is normally the case for grey cast irons). In order to improve the as-cast microstructure, developed as a result of centrifugal casting into water-cooled moulds, ductile iron pipes are subsequently heat treated. The finished pipe wall microstructure consists of a uniform distribution of spheroidal graphite particles in a substantially ferritic matrix, as shown in Figure A.1(c). This confers a combination of tensile strength and ductility on the material which is markedly superior to that which can be achieved in grey iron pipes.

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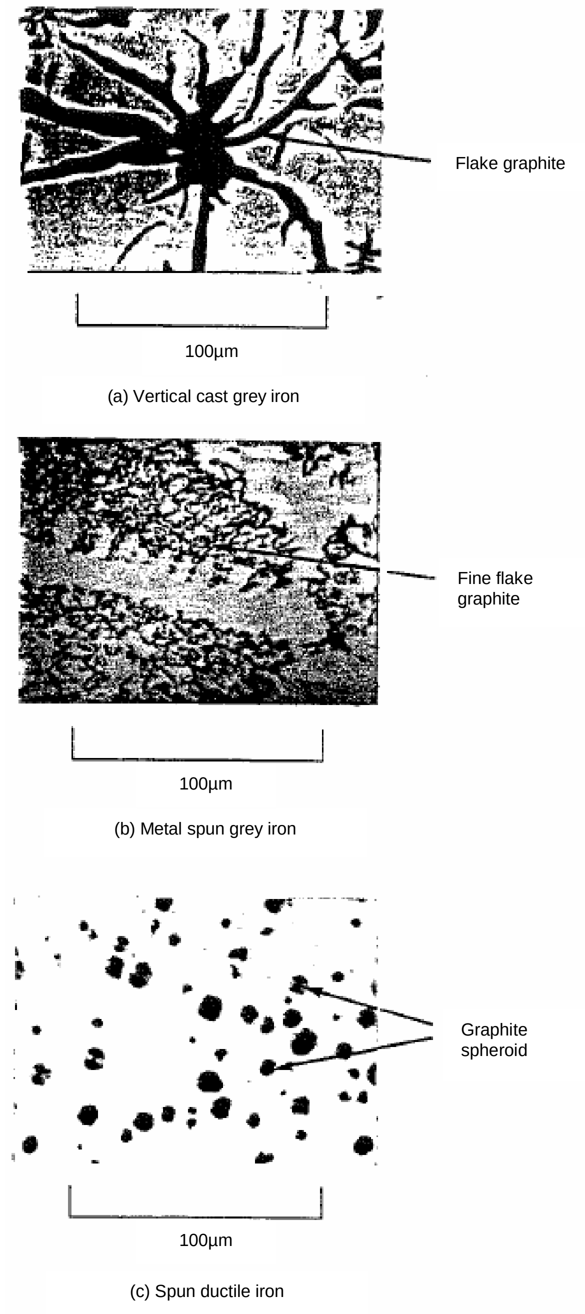
The greater strength of ductile iron permits the manufacture of pipes and fittings with thinner walls than those of similar diameter grey iron castings. Thus, spun ductile iron pipes are typically 30% lighter than equivalent spun grey iron pipes. Where there is a potential risk of pipeline failure due to external stresses, the superior mechanical properties of ductile iron pipes and fittings render them considerably more resistant to fracture under beam loading conditions than equivalent grey iron castings. Ductile iron castings are also resistant to the deep fissure corrosion which can occur on metal spun grey iron pipes under certain combinations of stress and soil environment (as distinct from simple corrosion, such as thinning, pitting, etc.). Ductile iron pipes and fittings (in common with their grey cast iron counterparts) are, however, susceptible to corrosion attack (i.e. thinning and/or pitting) by some conveyed waters (notably soft waters) and some soils (usually of low resistivity)[6] unless adequately protected (see Sections 5.3 and 5.4).



(a) Vertical cast grey iron

(b) Metal spun grey iron

(c) Spun ductile iron

Figure A.1 – typical cast iron pipe microstructures (as polished)