
**Irrigation applications of ductile
iron pipelines — Product design and
installation**

*Canalisations en fonte ductile pour l'irrigation — Conception des
produits et installation*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 5, *Ferrous metal pipes and metallic fittings*, Subcommittee SC 2, *Cast iron pipes, fittings and their joints*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Irrigation applications of ductile iron pipelines — Product design and installation

1 Scope

This document specifies the design factor, technical requirements, test methods, installation technologies and operation advices applicable to ductile iron pipes, fittings and accessories used in piped irrigation applications.

NOTE In this document, all pressures are relative pressures expressed in bars¹⁾.

This document also specifies materials, dimensions and tolerances, mechanical properties and standard coatings of pipes, fittings and accessories. It also gives performance requirements for all components including joints.

Joint design and gasket shapes are outside the scope of this document.

This document applies to pipes, fittings and accessories cast by any type of foundry process or manufactured by fabrication of cast components.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2531:2009, *Ductile iron pipes, fittings, accessories and their joints for water applications*

ISO 4633, *Rubber seals — Joint rings for water supply, drainage and sewerage pipelines — Specification for materials*

ISO 10802, *Ductile iron pipelines — Hydrostatic testing after installation*

ISO 10803, *Design method for ductile iron pipes*

ISO 10804, *Restrained joint systems for ductile iron pipelines — Design rules and type testing*

ISO 21051, *Construction and installation of ductile iron pipeline system*

ISO 21052, *Restrained joint systems for ductile iron pipelines — Calculation rules for lengths to be restrained*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

1) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

**3.1.1
piped irrigation network**
PIN

network of installation consisting of pipes, fittings, valves, pumps (if necessary) and other devices properly designed and installed to supply water from the source of the water to the irrigable area

**3.1.2
nominal size**
DN

alphanumeric designation of size for components of a pipework system, which is used for reference purposes

Note 1 to entry: It comprises the letters DN followed by a dimensionless whole number, which is indirectly related to the physical size, in millimetres, of the bore or outside diameter of the end connections.

[SOURCE: ISO 2531:2009, 3.20, modified — Note 2 to entry has been removed.]

**3.1.3
allowable operating pressure**
PFA

maximum internal pressure, excluding surge, which a component can safely withstand in permanent service

[SOURCE: ISO 2531:2009, 3.2]

**3.1.4
allowable site test pressure**
PEA

maximum hydrostatic pressure that a newly installed component can withstand for a relatively short duration, when either fixed above ground level or laid and backfilled underground, in order to measure the integrity and tightness of the pipeline

Note 1 to entry: This test pressure is different from the system test pressure, which is related to the design pressure of the pipeline.

[SOURCE: ISO 2531:2009, 3.3]

**3.1.5
maximum allowable operating pressure**
PMA

maximum internal pressure, including surge, which a component can safely withstand in service

[SOURCE: ISO 2531:2009, 3.17]

**3.1.6
nominal pressure**
PN

numerical designation, which is a convenient rounded number, used for reference purposes

Note 1 to entry: All components of the same *nominal size*, DN (3.1.2), designated by the same PN number have compatible mating dimensions.

[SOURCE: ISO 2531:2009, 3.19, modified — Note 2 to entry has been removed.]

3.2 Abbreviated terms

CDN canal distribution network

PVC poly (vinyl chloride)

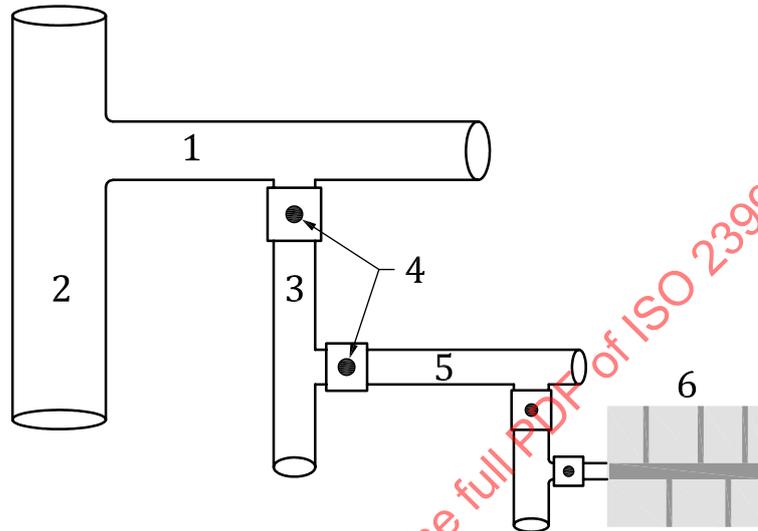
PE polyethylene

4 Piped network for irrigation applications

A pipe irrigation network (PIN) consists of water mains, water branch, field irrigation lines, hydrant or outlets and other devices (see [Figure 1](#)).

An analogy between the CDN and PIN is depicted in [Figure 1](#). Main advantages and limitations of PIN are listed in [Annex A](#).

For DI pipes, the DN range for PIN is DN 40 to DN 2 600 as per ISO 2531.



Key

- 1 branch line
- 2 main line
- 3 distribution line
- 4 control valves
- 5 minor line
- 6 field irrigation lines

Figure 1 — Pipe irrigation network (PIN)

Details of piped irrigation network planning are given in [Annex B](#).

5 Technical requirements of DI pipeline components for irrigation applications

5.1 General

The ductile iron pipeline components system consists of standardized components equipped with fully compatible socket or flange joints which facilitate the design networks of any size and complexity.

The technical requirements of DI pipeline components shall be in accordance with ISO 2531.

Note DI pipes with joints compatible with plastic piping systems (PVC or PE) and referring to ISO 16631 are outside the scope of this document.

5.2 Material characteristics

Material characteristics of pipes, fittings and accessories shall comply with ISO 2531:2009, 4.3.

5.3 Pressure class and dimensions

5.3.1 Preferred pressure classes

Components with flexible joints are classified by the allowable operating pressure (PFA) in bar, prefixed by the letter C. Components with flanged joints are classified by the PN number of the flange. The allowable pressures within a pipeline system shall be limited to the lowest pressure classification of all components within the system.

Preferred pressure classes of irrigation pipes with flexible joints are C25, C30, and C40. Other classes are allowed by agreement between the manufacturer and the customer.

Pressure classes for components with flanged joints are PN10, PN16, PN25 and PN40.

5.3.2 Allowable pressures

Allowable pressures of components are as given in [Tables 1](#) and [2](#).

Table 1 — Allowable pressures of components with flexible joints for preferred classes

Pressure class C	Allowable operating pressure	Maximum allowable operating pressure	Allowable site test pressure
	PFA bar	PMA bar	PEA bar
25	25	30	35
30	30	36	41
40	40	48	53

Table 2 — Allowable pressures of components with flanged joints

Pressure class PN	Allowable operating pressure	Maximum allowable operating pressure	Allowable site test pressure
	PFA bar	PMA bar	PEA bar
10	10	12	17
16	16	20	25
25	25	30	35
40	40	48	53

Allowable pressures of pipes with flexible joints are given in [Table 3](#).

Table 3 — Allowable pressures of pipes with flexible joints for preferred classes

DN	Pressure class C	Allowable operating pressure	Maximum allowable operating pressure	Allowable site test pressure
		PFA bar	PMA bar	PEA bar
40 to 300	40	40	48	53
350 to 600	30	30	36	41
700 to 2 600	25	25	30	35

Allowable pressures for fittings as specified in ISO 2531:2009, Tables 15 to 33 are as follows.

— Socketed fittings, except tees, are given in [Table 4](#).

- Socketed tees may be less than those given in [Table 4](#) and shall be given in the manufacturer's handbook.
- All flanged fittings and fittings with one flange, such as double-socketed tees with flanged branch, flanged spigots and flanged sockets, are limited by the flange PN and are given in [Table 2](#).

Table 4 — Allowable pressures for socketed fittings

DN	Allowable operating pressure	Maximum allowable operating pressure	Allowable site test pressure
	PFA bar	PMA bar	PEA bar
40 to 200	64	77	82
250 to 350	50	60	65
400 to 600	40	48	53
700 to 1 400	30	36	41
1 500 to 2 600	25	30	35

Appropriate limitations shall be taken into account, which can prevent the full range of these pressures being used in an installed pipeline. For example, operation at the PFA values can be limited by the lower pressure capability of other pipeline components, e.g. flanged pipework, certain types of tees and specific designs of flexible joints. When other limitations exist due to the joint type or to any specific design arrangement, they shall be given in the manufacturer's handbook.

5.3.3 Diameter of socket and spigot pipes

The dimensions of preferred pressure classes of socket and spigot pipes are as given in [Figure 2](#) and [Table 5](#).

When, by agreement between the manufacturer and the purchaser, pipes and fittings with different lengths, thicknesses and/or coatings, and other types of fittings than those given below are supplied in accordance with this document, they shall comply with all the other requirements of this document.

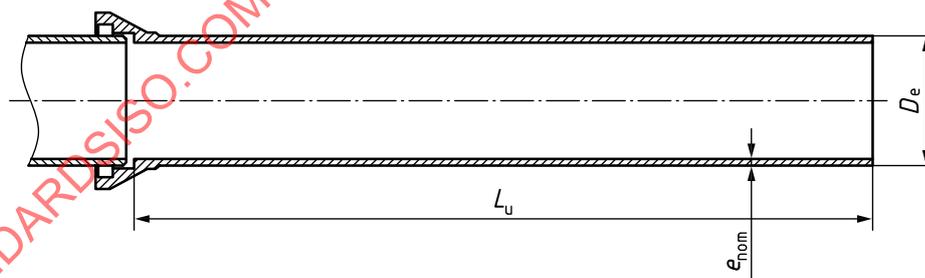
**Figure 2 — Socket and spigot pipe**

Table 5 — Preferred pressure classes of Irrigation pipes with flexible joints

DN	Spigot external diameter D_e^a mm	Pressure class	Nominal iron wall thickness e_{nom} mm
40	56	C40	4,4
50	66	C40	4,4
60	77	C40	4,4
65	82	C40	4,4
80	98	C40	4,4
100	118	C40	4,4
125	144	C40	4,5
150	170	C40	4,5
200	222	C40	4,7
250	274	C40	5,5
300	326	C40	6,2
350	378	C30	6,3 ^b
400	429	C30	6,5 ^b
450	480	C30	6,9
500	532	C30	7,5
600	635	C30	8,7
700	738	C25	8,8 ^b
800	842	C25	9,6
900	945	C25	10,6
1 000	1 048	C25	11,6
1 100	1 152	C25	12,6
1 200	1 255	C25	13,6
1 400	1 462	C25	15,7
1 500	1 565	C25	16,7
1 600	1 668	C25	17,7
1 800	1 875	C25	19,7
2 000	2 082	C25	21,8
2 200	2 288	C25	23,8
2 400	2 495	C25	25,8
2 600	2 702	C25	27,9

^a A tolerance of +1 mm applies (see ISO 2531).

^b Thickness is greater than calculated for “smoothing” between C40 and C30 and also between C30 and C25.

5.3.4 Length of Socket and spigot pipes

Socket and spigot pipes shall be supplied to the lengths given in [Figure 2](#) and [Table 6](#).

Table 6 — Standardized lengths of socket and spigot pipes

DN	Standardized lengths
	L_u m
40 and 50	3
60 to 600	4 or 5 or 5,5 or 6 or 9
700 and 800	4 or 5,5 or 6 or 7 or 9
900 to 2 600	4 or 5 or 5,5 or 6 or 7 or 8,15 or 9

NOTE: Not all the standardized lengths are available in all countries.

5.3.5 Dimensions of flanged pipes and fittings

Dimensions of flanged pipes and fittings are defined in ISO 2531.

5.4 Coating and lining for pipes

5.4.1 General

Pipes shall normally be delivered internally and externally coated.

5.4.2 External coatings

Ductile iron pipeline systems can be installed in a wide range of external soil environments. These environments can be characterized by their corrosiveness. Relevant factors to be considered for soil corrosiveness are given in ISO 2531:2009, A.1.

Coatings specified by relevant International Standards are available:

- a) metallic zinc with finishing layer in accordance with ISO 8179-1;
- b) zinc rich paint with finishing layer in accordance with ISO 8179-2;
- c) polyethylene sleeving in accordance with ISO 8180.

For other types of pipe external coatings, including their repair method, refer to the appropriate ISO standards or national standards or agreed specifications.

5.4.3 Internal linings

Ductile iron pipeline systems can be used to convey a wide range of water for irrigation, raw waters and potable waters. These internal environments can be characterized by their aggressiveness. Relevant factors to be considered for water aggressiveness are given in ISO 2531:2009, B.1.

Linings specified by relevant International Standards are available:

- a) Portland cement mortar in accordance with ISO 4179;
- b) blast furnace slag cement mortar in accordance with ISO 4179;
- c) cement mortar with seal coat in accordance with ISO 16132.

For other types of pipe internal coatings, including their repair method, refer to the appropriate ISO standards or national standards or agreed specification.

5.5 Coatings and linings for fittings and accessories

Fittings and accessories shall normally be delivered internally and externally coated. Coatings and linings for fittings and accessories are defined in ISO 2531.

5.6 Abrasion resistance of lining

Abrasive resistance of the lining shall be taken into consideration when there is sediment in water transported.

Where there are no national rules available or no local experience, the following approaches can be considered:

- abrasive resistance test according to ISO 7186:2011, 7.7: a practical method to evaluate the direct effect of raw water on the lining (fluid test and criteria of performance to be calibrated to waters in irrigation);
- Miller's approach (for critical case): a theoretical approach that takes into account the relative abrasiveness of the fluid (Miller index) and the material coefficient of the lining (if these are known).

5.7 Marking

All pipes and fittings shall be durably and legibly marked and shall bear at least the following indications:

- a) a reference to this document, i.e. ISO 23991:2022;
- b) the manufacturer's name or mark;
- c) identification of the year of manufacture;
- d) identification as ductile iron;
- e) the DN;
- f) the PN rating of flanges, if applicable;
- g) the C pressure class of socket and spigot pipe.

Items b) to f) shall be cast-on or cold stamped.

Items a) and g) can be applied by any method, e.g. painted on the castings.

5.8 Joints and leak tightness requirements

5.8.1 Flexible joints

All flexible joints for ductile iron pipes and components shall be designed in accordance with ISO 2531.

Their spigots external diameters, D_e , and their tolerances shall conform to ISO 2531:2009, 4.2.2.1. Rubber gasket materials shall conform to ISO 4633 for water applications.

5.8.2 Restrained joints

Restrained joints for ductile iron pipelines shall be designed in accordance with ISO 10804.

Their spigot external diameters, D_e , and their tolerances shall conform to ISO 2531:2009, 4.2.2.1.

The allowable pressure of restrained joints of pipes and fittings may be less than the classes of pipes given in [5.3 \(Tables 1 and 2\)](#) and shall be as per the manufacturer's handbook.

6 Valves, irrigation hydrant, water meter

Irrigation hydrant is valve apparatus intended to ensure the delivery of water to a user network, from a distribution network usually buried underground. The irrigation hydrant consists of the body of the hydrant and one or more distribution outlet.

It features at least a shut-off function and a metering function. It may also integrate the flow rate limitation and pressure regulation functions.

When selecting an irrigation hydrant, the downstream flow rate and pressure are the main considerations besides the DN and PN (flange) of connections to irrigation network and user network.

In addition, factors may be considered include, but are not limited to, solid content in water, filtering device and its maintenance before metering and nozzle, antifreeze drain for cold condition, air release device for air accumulation under the gate of hydrant.

7 Designing factors of DI pipeline components for irrigation applications

7.1 General

This Clause deals with the main designing parameters for PIN. It is presupposed that designing for irrigation network complies with the requirements of the local authorities when they exist.

7.2 Pipe layout

Once the source, water availability, proposed command area, location of outlets and discharge cut-off schedule have been finalized, the next step is the fixation of layout of conveyance network (i.e. pipes layout) and optimization of diameters within the available head loss.

7.3 PIN classification

There are different classifications of PIN, based on different aspects.

— Based on driving force

- a) Gravity piped irrigation network: The piped irrigation network in which the driving force is completely provided by falling topographical levels, is called gravity piped irrigation network.
- b) Pumped piped irrigation network: The piped irrigation network in which the gravitational force is supplemented by external energy such as pumps is called pumped piped irrigation network.

— Based on distribution network

- a) Tree piped irrigation network: In the tree piped irrigation network, each outlet gets its supply from one and only one route.
- b) Loop piped irrigation network: In the loop piped irrigation network, each outlet gets its supply from more than one route.

— Based on operating pressure

- a) Low pressure piped irrigation network: In this type of piped irrigation network, the operating pressures are between 1 bar to 4 bar.
- b) Medium pressure piped irrigation network: In this type of piped irrigation network, the operating pressures are between 4 bar to 10 bar.
- c) High pressure piped irrigation network: In this type of piped irrigation network, the operating pressures are a minim 10 bar.

- Based on pressure control
 - a) Open piped irrigation network: In this type of piped irrigation network, the pressure is controlled by pressure regulating tanks/stand pipes open to atmosphere.
 - b) Closed piped irrigation network: In this type of piped irrigation network, the pressure is controlled by pressure regulating valves.
 - c) Semi-closed piped irrigation network: In a closed piped irrigation network, if the pressure is controlled by regulating tanks in a part of the system and by pressure regulating valves in another part, then it is called a semi-closed piped irrigation network.

Where large heads are not required, the underground pipe line system is used, which is essentially a low-pressure system, also known as an open or semi-closed system. This system is open to atmosphere with the operating pressure seldom exceeding 5 bar to 6 bar. The available level differences of falling topography provide the operating head for the system under gravity for the low-pressure flows.

Where large heads are required, underground pipe line system is used, which is essentially a high-pressure system, also known as a closed system. This system is not open to atmosphere with the operating pressure exceeding 10 bar for drip and 20 bar for sprinklers. Usually gravity head is not sufficient to create such a high pressure; therefore, pumps are used for this kind of system.

7.4 Hydraulic design

7.4.1 Water demand

The water demand for irrigation depends upon the type of crop cultivated, soil types, topographical condition, drainage and local weather conditions. The actual water demand and irrigation regulation shall be determined in consultation with regional agricultural authorization. The water demand calculation is outside the scope of this document. As the result of such a calculation, the designed flow rate of a pipeline outlet is the maximum flow rate required at each irrigation outlet and is obtained as follows:

$$Q_a = \sum_i^m Q_i$$

where

Q_a is the accumulated flow rates required at pipeline outlets (irrigation devices), in m³/h;

Q_i is the design flow rate of an irrigation device connected to the pipeline, in m³/h;

m is the maximum number of irrigation devices used at the same time.

The irrigation efficiencies are the ratios between each stages of water conveyances and application.

- For open canal water conveyance, water efficiency is about 0,5 to 0,7 (losses are from evaporation and seepage, efficiency due to local conditions).
- For closed PIN water conveyance, water efficiency of ductile iron pipelines is about 0,95.
- For field application, water efficiency is about 90 % for drip and 75 % for sprinkler.

[Annex C](#) gives information on irrigation efficiencies.

The designed flow rate of a pipeline Q :

$$Q = \frac{Q_a}{E_t}$$

where

Q is the designed flow rate of an irrigation pipeline system;

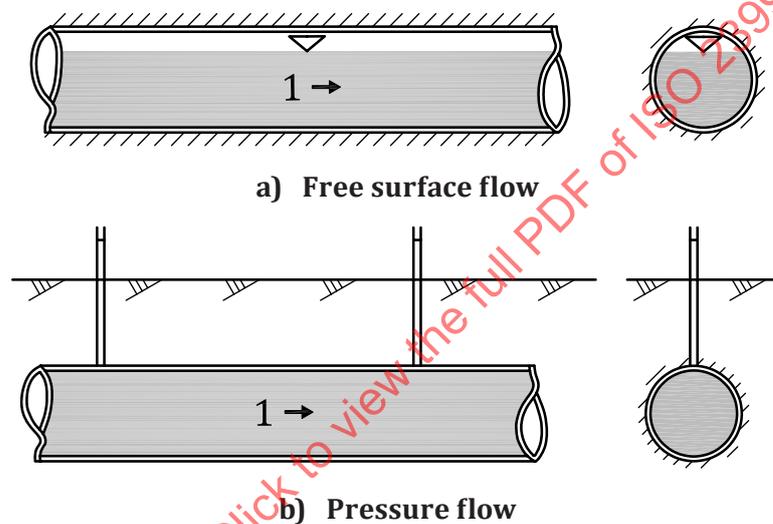
Q_a is the accumulated flow rates required at pipeline outlets (irrigation devices), in m^3/h ;

E_t is the total irrigation system efficiency.

7.4.2 Diameter selection and head loss calculation

The flow in an open channel or in a closed conduit having a free surface is referred to as free surface flow or open channel flow [see [Figure 3 a\)](#)]. Free surface is usually subjected to atmospheric pressure.

A conduit flowing full has no free surface; then the flow is called pipe flow or pressurized flow [see [Figure 3 b\)](#)].



Key

1 flow

Figure 3 — Flow in pipe

Various formulae are available for calculating the head loss in pipes. The following formulae have been popularly used. However, national standards of design method of irrigation networks shall be respected when they exist.

NOTE 1 Values of roughness coefficients can be different in different countries. The values recommended hereunder are for references. Local experimental results or other considerations warrant the adoption of any other value for the coefficient.

NOTE 2 The nominal values of the internal diameters of centrifugally cast ductile iron pipes, expressed in millimetres, are approximately equal to the numbers indicating their nominal sizes, DN.

— Colebrook-White formula for pressure conduits:

$$\frac{1}{\sqrt{f}} = -2 \log_{10} \left[\frac{k}{3,7d} + \frac{2,51}{Re\sqrt{f}} \right]$$

where

f is Darcy's friction coefficient, dimensionless;

k is the roughness projection, in mm;

d is the diameter of the pipe, in mm;

Re is the Reynolds number, which is equal to the velocity multiplied by the diameter divided by the viscosity.

For general design purposes, with cement lined ductile iron pipe and clear water, the value for all sizes is recommended as $k = 0,1$ mm in order to take into account all the different head losses caused by singular points (tee fittings, elbows, valves, etc.) and slightly less (0,06 mm to 0,08 mm) for large mains with a small number of fittings per kilometre.

Higher k value can be considered in case of raw water with specific phenomena due to quality of the water (sand deposit, organic growth, etc.).

— Hazen William formula for pressure conduits:

$$V = 0,849 C R_h^{0,63} J^{0,54}$$

where

V is the velocity, in m/s;

C is Hazen William coefficient;

R_h is the hydraulic radius in m ($R_h = D/4$ for a pressure conduit);

D is the diameter of the pipe, in m;

J is the head loss per metre of conduit.

For general design purposes, with cement lined ductile iron pipe, C , Hazen William coefficient is recommended as $C = 140$.

— Manning's formula for free flow conduits:

$$V = \frac{1}{n} R_h^{\frac{2}{3}} S^{\frac{1}{2}}$$

where

V is the velocity, in m/s;

n is Manning's coefficient of roughness;

R_h is the hydraulic radius, in m;

S is the slope of the hydraulic grade-line.

For general design purposes, with cement lined ductile iron pipe, the value for all sizes is recommended as $n = 0,013$.

— Darcy-Weisbach's formula:

$$S = \frac{H}{L} = \frac{fV^2}{2gD}$$

where

- S is the slope of the hydraulic grade-line;
- H is the head loss due to friction over length L , in m;
- L is the length, in m;
- f is Darcy's friction coefficient, dimensionless;
- V is the velocity, in m/s;
- g is the acceleration due to gravity, in m/s²;
- D is the diameter of the pipe, in m.

For general design purposes, with cement lined ductile iron pipe, the value for all sizes is recommended as $f = 0,01$ to $0,02$.

7.4.3 Flow velocity

7.4.3.1 Maximum velocity

The higher the velocity, the greater the risk of damage through surges and water hammer. This risk particularly applies to pipes subject to uncontrolled starting and stopping. Using larger pipe results in a smaller water velocity for a given flow rate, but smaller pipe is often preferred for cost reasons. It is suggested to carry out water hammer analysis under such situations where higher velocities are provided. For general design purposes, the maximum velocity may be limited to 3,0 m/s.

7.4.3.2 Minimum velocity

Low velocities may cause sedimentation in pipes. Designers shall specify pipe diameters and flow rates that allow for a minimum operational water velocity, and also irrigation systems that utilize emitters with small apertures such as drip and micro sprinklers. This ensures that any sediment or solids are flushed through the lines. For general design purposes, the minimum velocity should be 0,7 m/s to avoid sedimentation risk. However, in some cases it is not possible to attain. In that cases proper scouring arrangement should be provided in pipeline to take care the flushing.

7.4.3.3 Economical velocity

Selection of pipe is done taking into account the techno-economic optimum between cost of pipe and cost of pumping. Specific calculations shall be performed to reach the economical velocity for each case.

7.5 Mechanical design

7.5.1 Pressure resistance

DI pipelines are designed to withstand pressures generally much greater than the values usually encountered on the networks.

Tensile properties of pipes, fittings and accessories are given in ISO 2531:2009, Table 8. The minimum wall thickness of pipes is calculated with a safety factor of 3 with respect to the allowable operating pressure, as detailed in ISO 2531:2009, Annex E.

7.5.2 Deflection resistance

The diametral stiffness and allowable diametral deflection of irrigation DI pipe in preferred class are given in ISO 2531:2009, Annex D.

7.6 Protection against soil corrosiveness

7.6.1 General

Ductile iron pipeline systems may pass through in a wide range of external environments. Evaluation of the corrosivity of the soil into which the proposed pipeline is to be installed is necessary to determine the appropriate protection that would be recommended.

7.6.2 Metallic zinc-based coatings

Metallic zinc-based coatings are suitable for the majority of the soil. Field of use in relation to the characteristics of soils are given in ISO 8179-1:2017, Annex B.

Metallic zinc-based coatings consist of a layer of metallic zinc or zinc alloy, covered by a finishing layer of synthetic resin compatible with zinc. Both layers are works applied, adhering perfectly to the surface of the cast iron. The metallic zinc-based coating is malleable and deformable, and absorbs impacts in transit or on site without breaking. A zinc-based coating restores the continuity of the protective layer at points that have suffered limited damage, by galvanic effect between the exposed cast iron and the zinc near the damaged area (impacts in transit, scraping during backfilling).

The pipe sockets, spigots and flanges are factory coated, so that after the joints are assembled there is no need to touch up the coating on site.

7.6.3 Alternative coatings

Alternative protections are suitable for highly corrosive soils or specific environments.

- a) In highly corrosive soil: extruded polyethylene coating, polyurethane coating, cement mortar coating, adhesive tapes.
- b) In rocky soil: fibre reinforced cement mortar coating.
- c) To prevent the freezing of water: thermal isolation according to ISO 9349.
- d) To prevent influence of stray current in soil: electrical isolation of thick organic coating (extruded polyethylene coating, polyurethane coating).

7.7 Protection against water aggressiveness

7.7.1 General

Water for irrigation can be raw water, recycled water or potable water.

Ductile iron pipeline systems, including pipes, fittings, accessories and joints, consist of various materials. When used for conveying water intended for irrigation, the materials in contact with the water shall meet the relevant requirements of the national standards, taking into account regulations in the country of use with respect to effect on water quality.

7.7.2 Cement lining

Cement linings according to ISO 4179 are suitable for the majorities of waters and raw waters used in irrigation.

However, abrasive resistance of the lining shall be taken into consideration when there are sediments in water transported. Erosion mainly depends on the type of sediment particles (size, profile, density, hardness, etc.) and on the water flow characteristics (velocity, laminar or turbulent, etc.) transported.

[Subclause 5.6](#) specifies different methods to evaluate the abrasion resistance.

8 Laying DI pipeline components for irrigation applications

8.1 laying calculations

The structural design of ductile iron pipe in different trench conditions and different surface loads shall be in accordance with ISO 10803.

Calculation rules for lengths to be restrained shall be in accordance with ISO 21052.

8.2 laying operations

8.2.1 General

Laying operations for ductile iron pipelines shall be in accordance with ISO 21051. A site hydrostatic acceptance test shall be carried out after laying, in order to check the stability and leak tightness of the main before it goes into service. The hydrostatic testing after installation shall be in accordance with ISO 10802.

[Subclauses 8.2.2 to 8.2.8](#) highlight certain practices.

8.2.2 Layout

Minimum overburden shall be taken into consideration to avoid land acquisition problem; and depth of cover shall take into account cultivation depth and risks of frozen.

Pipeline layout should be parallel with ditch, trench and road, and avoid fill section segments and areas with possible landslide or flood. The land acquisition should be minimum to nil when laid parallel to existing communications lines. The pipe network below the distributor off take should be entirely underground which results in little or no loss of farm land.

If horizontal pipe sections are used, release of air and draining of the dirt are not possible. So, in case of horizontal ground surface, artificial slopes are given to pipes to be laid.

8.2.3 Handling

The ductile cast iron structure has a high elastic deformability and a high resistance to crack initiation: it results in excellent impact resistance. DI pipe are efficient and robust parts, perfectly suited to transport conditions over long distances (truck, train or ship), handling conditions on sites and to different types of backfilling.

8.2.4 Laying in trench

A buried pipe is an elastic structure surrounded by an elastic medium; its equilibrium results from a number of action-reaction forces distributed around the pipe. Consequently, the mechanical behaviour of buried pipes can best be understood by considering the pipe-soil system equilibrium.

As used in ISO 10803, Spangler's formula for buried pipe shows that pipe ovalization is equal to the vertical load at pipe crown (earth load and traffic load) divided by the sum of pipe stiffness and soil stiffness.

$$O_p = \frac{L_v}{S_p + S_s}$$

where

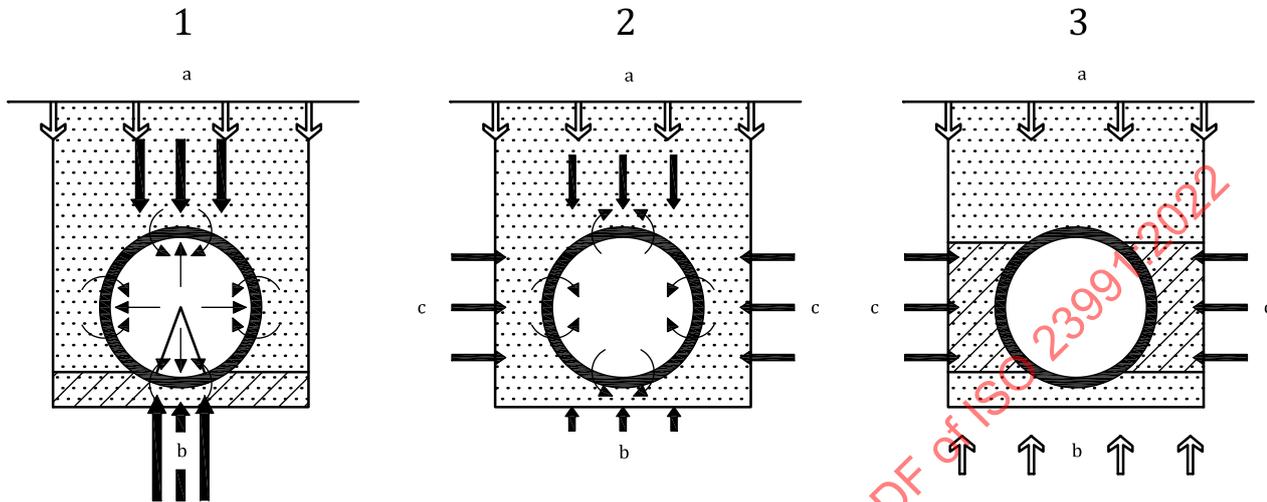
O_p is the pipe ovalization;

L_v is the vertical load at the pipe crown;

S_p is the pipe stiffness;

S_s is the soil stiffness.

Thus, pipes used for trunk mains are classified as rigid, semi-rigid or flexible according to their respective behaviour under loads (see Figure 4).



Key

- 1 rigid pipe
- 2 semi-rigid pipe
- 3 flexible pipe
- a Vertical load.
- b Bedding reaction.
- c Passive resistance.

Figure 4 — Pipe-soil system equilibrium

- a) Rigid pipe (pipe stiffness is much more than soil stiffness): the pipe carries all the load; side support is negligible. Design strength is determined by applying factors to test crushing strength. Care should be taken to the bedding quality and stability.
- b) Semi-rigid pipe (pipe stiffness is in the range of soil stiffness): loads are equally distributed around the pipe. Design strength is determined by limiting stress in pipe wall and deflection limits may be imposed by coating or lining integrity consideration.
- c) Flexible pipe (pipe stiffness is much less than soil stiffness): the system's equilibrium relies mainly on the ground support; removal of side support can be catastrophic. Design strength is determined by buckling stability, but deflection and wall stress or strain shall be limited. Care should be taken to the compaction and stability of the side backfill.

Ductile iron pipes are classed as semi-rigid. They provide a good compromise between resistance to top loading and vertical deflection, thus providing long term operational security. Values of pipe stiffness and soil stiffness are given in ISO 2531:2009, Annex D and ISO 10803.

A small DN of DI pipe does not require excessive compaction rates when it is laid in trenches. It can be laid in high and low height of cover and enable reuse of native backfills rather than using materials imported from distant quarries.

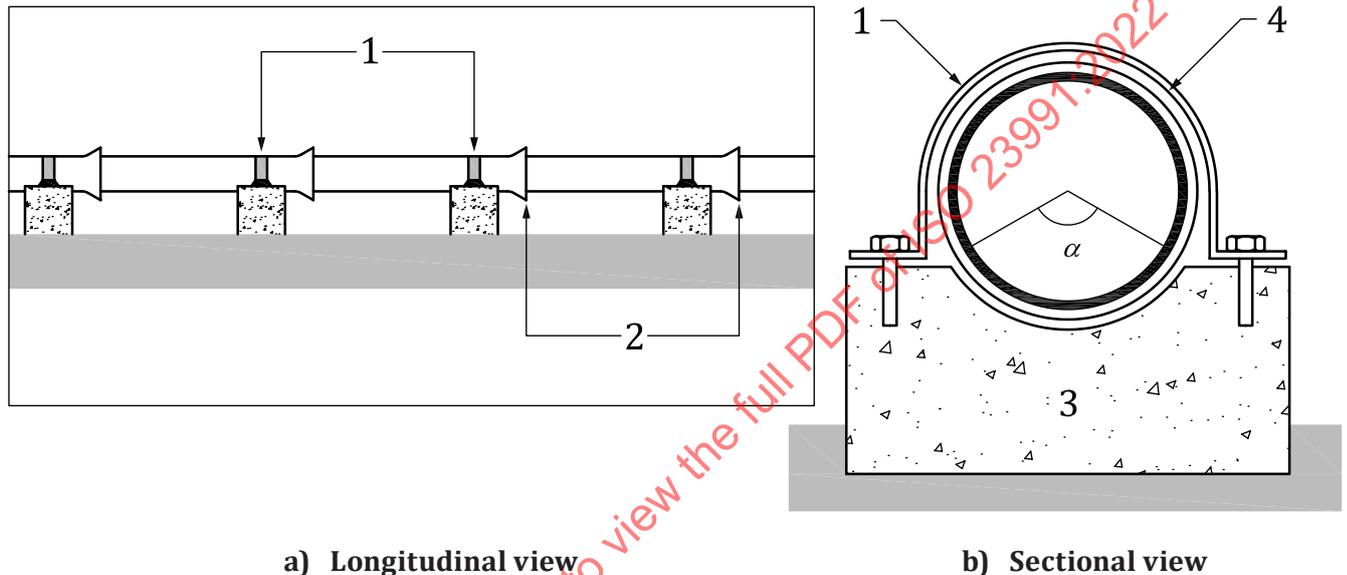
A large DN of DI pipe offers also optimum mechanical stability over time, to withstand unforeseeable overloading conditions (due to, e.g. very poor bedding, ground movement, heavy surface traffic) without

risk of buckling This good practice participates in the preservation of soil in its natural state while reducing costs and the site's environment footprint.

8.2.5 Laying above ground

Laying of a main above ground involves determining the support system, the accommodation of thermal expansion, and the anchorage of components subjected to hydraulic thrust (see [Figure 5](#)).

The advantage of ductile iron pipelines is that they do not require the installation of expansion absorbers. Supports can be made in the workshop and easily installed on site; the flexible joints adjust to any misalignment of the supports and act as thermal expansion joints.



Key

- 1 clamps (fixed points)
- 2 joints (expansion accommodations)
- 3 concrete support (behind the socket)
- 4 rubber ring (between pipe and clamp)
- α saddle angle (120° is a good precaution)

Figure 5 — Laying above ground

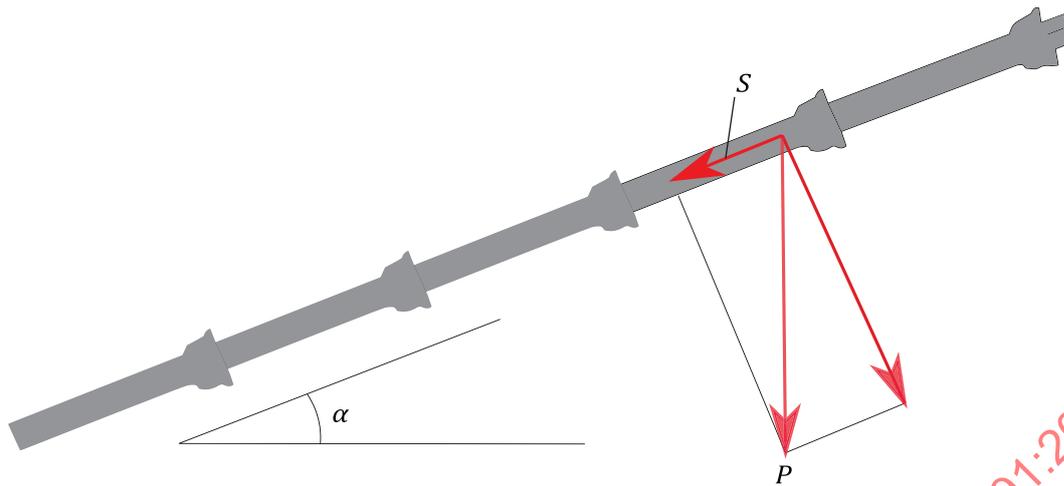
Components subjected to hydraulic thrust (e.g. bends, tees, tapers) shall be stabilized with an anchor block. Directional changes involving large radius bends can be negotiated simply by joint deflection (within the specified limits). In this case, care shall be taken to reinforce the saddle anchorage of pipes involved, having assessed the hydraulic thrusts at the deflected joint positions.

An adequate safety margin on the support dimensions (saddles and clamps) should be provided to compensate for hydraulic forces due to any misalignment of the pipes

8.2.6 Laying in slope

Beyond a certain angle, the friction force between a buried main and the ground is insufficient to hold the main. The axial component of the gravity force (see [Figure 6](#)) then shall be counteracted by the use of anchor blocks or anchored joints, or a combination of both techniques.

ISO 21051:2020, 18.4 provides specific recommendations and needed calculations, depending on the type of soil and its characteristics.



- Key**
- α slope angle
 - P gravity force
 - S axial component of P (slip)

Figure 6 — Laying in slope

8.2.7 Laying in an open canal

DI pipelines can be laid in an open canal with or without backfill. In any case, the following shall be taken into account.

- a) Specific points: relevant restrained pipe length (if backfilled pipes) or thrust concrete block (if not backfilled pipes) shall be designed at the changing of direction or diameter in order to counter balanced the thrust forces.
- b) Buoyance in case the canal is filled with water: pipe can be float and joint can be disconnected. Civil structure or fixture shall be made to avoid this risk. Relevant safety factor shall be applied in calculation of buoyancy, depending on the risk evaluation but not less than 1,1.

Example formulae for buoyancy balance calculation are as follows:

$$K_f \leq \frac{\sum V}{P_{ek}}$$

where

- K_f is the safety coefficient for anti-buoyancy, not less than 1,1;
- $\sum V$ is the downward force caused by total loads acted on pipes, in kN/m;
- P_{ek} is the buoyancy force acted on pipes, in kN/m.

$$\sum V = G_p + G_w + F_b$$

where

- G_p is the pipe gravity, in kN/m;

G_w is the gravity of water in pipe, in kN/m, which should be taken as zero in all cases;

F_b is the force to be balanced by civil structure, in kN/m.

F_b can be balanced by civil structure as concrete block, clamps, encasement.

[Table 7](#) gives the calculation results of the force to be balanced by civil structure for some pipes of irrigation, preferred class, with safety coefficient equal to 1,1.

Table 7 — Force to be balanced with safety coefficient equal to 1,1

DN	Pressure class	Buoyancy force acted on pipe P_{ek} kN/m	Pipe gravity G_p kN/m	Force to be balanced by civil structure F_b kN/m
100	C40	0,200	0,137	0,082
150	C40	0,379	0,204	0,212
200	C40	0,612	0,281	0,393
250	C40	0,909	0,395	0,605
300	C40	1,270	0,519	0,878
350	C30	1,746	0,665	1,255
400	C30	2,204	0,777	1,647
450	C30	2,745	0,918	2,102
500	C30	3,337	1,088	2,583
600	C30	4,685	1,475	3,678
700	C25	6,429	1,811	5,261
800	C25	8,285	2,241	6,873
900	C25	10,335	2,737	8,631
1 000	C25	12,622	3,276	10,607
1 100	C25	15,395	3,970	12,965
1 200	C25	18,245	4,626	15,444
1 400	C25	23,943	6,349	19,989
1 500	C25	27,558	7,244	23,070
1 600	C25	31,195	8,072	26,242
1 800	C25	39,244	9,934	33,234
2 000	C25	48,411	12,051	41,201

8.2.8 Trenchless laying

Different trenchless technologies can be used to lay ductile iron pipeline: horizontal direction drilling (HDD), pipe bursting, pipe jacking and casing method.

These technologies can facilitate the irrigation projects when open trench laying is not feasible or not preferred. ISO 13470 gives the details of the product specification, design method and installation criterial of DI pipelines in trenchless application.

8.3 Pipeline assembling

8.3.1 General

The flexible push-on joint is simply assembled by pushing a spigot into a socket. The installation is simple and rapid. Typical designs of flexible push-on joints are given in [Annex D](#).

While assembling, the spigot shall be centred and introduced into the perfectly aligned socket. The joint can only be deflected when fully assembled and before pressurizing the system. The maximum angular deflection of flexible joint shall be the maximum allowable deflection indicated in the manufacturer's handbook.

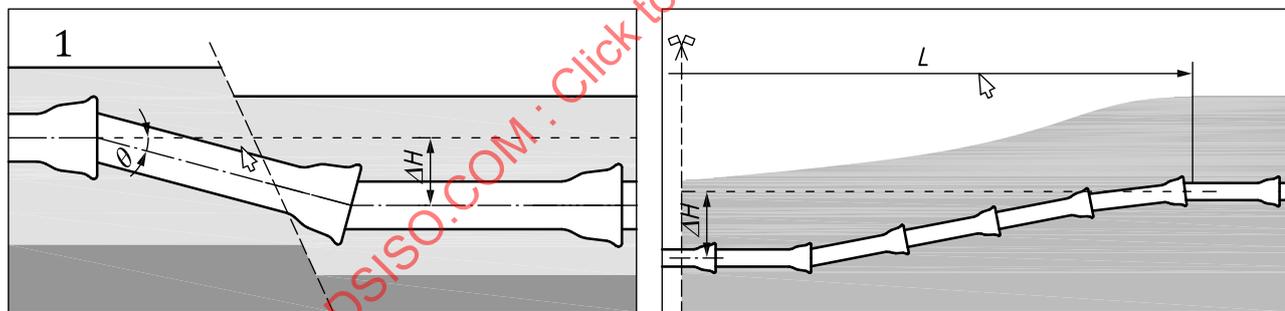
In general, ISO 2531 specifies that possible angular deflection of flexible joint shall not be less than 3°30' for DN 40 to DN 300, 2°30' for DN 350 to DN 600, and 1°30' for DN 700 to DN 2 600 (these minimum deflections do not apply to restrained joint pipe).

Flexible push-on joints are fully type tested to ensure leak tightness under the most unfavourable conditions of castings tolerances and joint movements, as required by ISO 2531:2009, 5.1. All joints are tested with:

- a) positive internal pressure (service and overpressure);
- b) negative internal pressure (accidental transient pressure);
- c) cyclical internal pressure (performance in fatigue when proximity of pumps);
- d) positive external pressure (water ingress tightness from the outside - empty pipe).

8.3.2 Advantages of flexible push-on joint in inconsistent or unstable ground

A pipeline's route may pass through inconsistent or unstable ground (marshy regions, subsidence due to pumping underground water, mining areas, consolidation of roadwork backfill, etc.). Experience has shown that when soil movements occur, pipes shall be able to match the deformation imposed by the mass of moving earth rather than resisting the often considerable mechanical stress (axial and bending stresses). For extensive and uniform subsidence, the joint allows the pipe to function like a flexible chain. Of course, deformation extremes are determined by the maximum admissible deflection and slippage for each joint (see [Figure 7](#)).



a) Local subsidence

b) Uniformed subsidence

Key

- 1 ground
- ΔH subsidence
- θ joint deflection
- L length of subsided section

Figure 7 — Subsidence

Also, ductile iron pipelines are generally considered to have a good behaviour in earthquakes since their joints are flexible and expand/contract according to the seismic motion to minimize the stress on the pipe body. Details of criteria and conditions are given in ISO 16134.

9 Operation and total cost of ownership of a PIN

9.1 Operation and maintenance

Objective of proper operation and maintenance of piped irrigation network is to provide irrigation water as per designed quality and quantity, with adequate pressure at convenient location and time, at competitive cost, on a sustainable basis.

Operation refers to timely and daily operation of the components of pipe irrigation network such as pumping system (pumps/motors/variable frequency drives), rising mains/gravity mains, distribution system, balancing reservoirs/distribution chamber.

Maintenance is defined as the act of keeping the structures, plants, machinery, equipment, other facilities and ancillary requirements like access roads, buildings etc. in an optimum working order. Maintenance includes replacements, correction of defects, preventive/routine maintenance and also breakdown maintenance. In a pipe irrigation system, maintenance of the conduits, gates, valves, and metering devices are very important

9.2 Life cycle cost analysis

Water is supplied through pipes over centuries. With various technologies invented, various types of pipe materials are developed and are in use in different parts of the world. With so many years of practice, the authorities have experienced the direct and indirect cost implications that are necessary to be considered while designing piped irrigation systems. It is essential to account for life cycle cost of the pipe supply system while arriving at the most suitable and economical pipe diameters and proper selection of pipe material.

For authorities and engineers designing pipeline systems, the life cycle cost analysis serves as a tool to study various scenarios to determine the right solution for site specific conditions and community values, as well as to provide the necessary data to support those decisions.

For the purpose, ISO 21053 may be used as a guideline method, while adapting key parameters which are specific to local irrigation applications.

9.3 Key parameters for life cycle cost

The following key drivers for life cycle cost reduction can be considered for DI pipe.

- Service life: A service life of 100 years is commonly recognized for ductile iron pipes buried in usual conditions. However, the service life can be reduced or increased considering the nature of the pipe coating, the local soil conditions and the in-use conditions.
- Leakage incident: Strong material properties and flexibility of joints contribute to preventing the leakage incident on buried ductile iron pipes.
- Conveyance capacity: For a given nominal diameter, ductile iron pipes are duly designed with a larger internal diameter in order to reduce the head loss on energy pumping and the operation cost such as the electric power usage cost. The internal diameter is a more influent factor on the head loss than the surface roughness coefficient.
- Time in operation: The use of irrigation pipes depends on the demand of water irrigation. It can be limited to a few hours daily and a few months per year.

9.4 Circular economy

A circular economy takes a whole system's perspective, where resources are systematically restored or regenerated. It means being more effective and optimizing how resources are managed across their life cycle in order to have a positive impact on the natural environment and society.

- Durability: Mechanical characteristics of the DI material are permanent in time and no degradation in reuse. It is a durable material that can be in use for decades or even for centuries.
- Recyclability: Ductile cast iron, derived largely from scrap, is 100 % recyclable. Excavated iron pipe can be reused as a raw material to manufacture new ductile iron pipes. Benefits of lower-cost production can be expected in a case where natural resources are used, allowing the disposal cost to be reduced.
- Rate of reuse: The reuse of recycled scrap recovered from iron and steel manufacture is considered inexhaustible, made easier due to the proximity of metal recyclers and due to a worldwide collecting organisation.
- Preservation of soil: Cast iron pipelines are rigid and robust and do not require excessive compaction rates when they are laid in trenches. They enable the reuse of native backfills rather than materials imported from distant quarries. This good practice participates in the preservation of soil in its natural state while reducing costs and the site's ecological footprint.

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Annex A (informative)

Advantages of piped irrigation networks

The advantages of pressurized piped irrigation network over canal distribution network are as follows:

- a) as most of the piped distribution systems are underground, right-of-way problems are significantly reduced, allowing more direct and rational layouts to be chosen;
- b) because outlet location is not limited by topography, pipe systems can better accommodate existing patterns of land ownership with the minimum of disruption compared with CDN. PIN is also a better option for undulating topography;
- c) cross drainage and cross masonry (communication) structures can be omitted or minimized;
- d) with no damage due to heavy rainfall or flood during monsoon, PIN is more suitable for flood-prone areas;
- e) increase in cultural command area (CCA) as compared to canals, as the water losses are negligible and acquired land for canal network can also be used for cultivation as piped irrigation network is underground;
- f) shorter transit times for water from source to field, and lower conveyance losses;
- g) less execution time for PIN as compared to CDN;
- h) in case of canals, the marshes and the ponds caused by excessive seepage, in course of time become the colonies of the mosquito, which gives rise to vector borne diseases; this can be minimized by adopting piped irrigation network, further salinity and water logging can be reduced;
- i) increase in project efficiency of the piped irrigation network is about 20 % as compared to CDN;
- j) fertilizers/chemical can also be mixed with the water and contaminate the same;
- k) quantity of water supplied by piped irrigation network is easily measurable; hence water auditing can be accurately measured.

In addition, the PIN systems especially are preferred over CDN alternatives in the following situations:

- where water is valuable both, in terms of the crops which can be grown and limited availability as evidenced by low reservoir capacity or restrictive controls on water abstraction from river or groundwater sources;
- where poorly cohesive soils would result in high seepage losses from open canals;
- where irrigable land cannot be reached by an open canal system due to high ground levels.

Annex B (informative)

Piped irrigation network planning

B.1 Data required for PIN planning

The following data is required for planning and layout of a pipe system: topographical map of the area, subsurface data, water availability, subsoil water level in the area and quality of the underground water, rainfall data, soil characteristics, existing crop pattern, existing drainage and drainage facilities, and possibility of water logging and siltation. It is required to conduct a socio-economic study and agro-economic survey of the project area. An adequate investigation should be carried out to collect the data given by digging trial pits and boreholes, where necessary, to ascertain the nature of soil encountered along different alternative alignments.

B.2 Route selection of pipe network

The following points should be maintained for selecting the proper layout of the pipeline.

- a) The length of pipelines in the network is minimal, as much as possible.
- b) Pumping is avoided if possible, or the least pumping effort is needed.
- c) High water pressure is avoided.
- d) Very low or high velocities are avoided because low velocities cause sedimentation in pipes, and high velocities cause corrosion of the pipe.
- e) If horizontal pipe sections are used, the release of air and draining of the dirt are not possible. So, in the flat ground surface, artificial slopes are given to pipes to be laid.

B.3 Design of a network for irrigation by rotation

B.3.1 General

In PIN design, an essential task is to maintain the source's water level, as the total system is designed to run all the outlets in the entire command area. With piped irrigation network, it can be efficiently designed to keep the discharge of pipe outlet proportionate to its culturable area and total outlets to run at a time; hence there is no head, middle and tail reach differentiation of the command. A hydrant is provided to an individual having a farm holding more than 2 hectares in an outlet's command area. Rotation only among the hydrant is necessary; and it can be performed in the ways specified in [B.3.2](#) and [B.3.3](#).

B.3.2 Rotation at hydrant level

In PIN design, the duty of water to be supplied at each outlet corresponds to the total area served by the outlet. This discharge or stream size is then rotated through the hydrant provided at individual plots in turn and proportional to their size for a pre-planned period of time.

B.3.3 Rotation at branch level

For small estates, the stream size equivalent to the duty of the area served by one hydrant can prove to be insufficient. This situation can be overcome by grouping several hydrants on a given branch. It