FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 21052

ISO/TC **5**/SC **2**

Secretariat: AFNOR

Voting begins on:
2021-08-06

Voting terminates on:
2021-10-01

Restrained joint systems for ductile iron pipelines — Calculation rules for lengths to be restrained

Systèmes d'assemblages verrouillés pour canalisations en fonte ductile — Règles de calcul pour les longueurs à verrouiller

Reference number
ISO/FDIS 21052:2021(E)

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Foreword

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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).

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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.

Restrained joint systems for ductile iron pipelines — Calculation rules for lengths to be restrained

1 Scope

This document specifies a computation method used to determine the length of the ductile iron pipes to be restrained, when used for conveying raw water, drinking water, sewerage under pressure.

This computation method takes into account all common pipeline route changes, including changes in the diameter of the pipeline itself and dead ends at the extremity of the pipeline, the outside diameter of the pipe, the system test pressure (to estimate the thrust), depth of cover, the characteristics of the soil surrounding the pipe and trench backfilling methods for a worldwide usage. The characteristics of the restrained joint are not covered by this document but can also be considered to determine the restraining length using any appropriate method.

The computation method defined in this document is applicable to all types of restrained joint systems, with their operating pressure ratings of ductile iron pipelines complying with ISO 2531, ISO 7186 and ISO 16631.

NOTE 1 ISO 10804 deals with actual design of the joint for various operating pressures of the pipeline.

NOTE 2 National standards or established calculation methods can be used instead of this ISO standard.

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, *Ductile iron pipes, fittings, accessories and their joints for water applications*

ISO 7186, *Ductile iron products for sewerage applications*

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

ISO 16631, *Ductile iron pipes, fittings, accessories and their joints compatible with plastic (PVC or PE) piping systems, for water applications and for plastic pipeline connections, repair and replacement*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2531, ISO 10804 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
mechanical flexible joint
flexible joint in which sealing is obtained by applying pressure to the gasket by mechanical means

3.1.2
push-in flexible joint
flexible joint assembled by pushing the spigot through the gasket into the socket of the mating component

3.1.3
restrained joint
joint in which a means is provided to prevent longitudinal separation of the assembled joint

3.1.4
maximum design pressure
MDP
P_{MD}
maximum operating pressure of the system or of the pressure zone fixed by the designer considering future developments and including surge

Note 1 to entry: It is the maximum pressure considering the design pressure and surge together, where:

— MDP is designated MDPa, P_{MDa}, fixed allowance for surge (secondary distribution networks);

— MDP is designated MDPc, P_{MDc}, surge is calculated (pumping & water mains).

[SOURCE: ISO 10802:2020, 3.6]

3.1.5
system test pressure
STP
P_{ST}
pressure to which a pipeline or a pipeline section is subjected for testing purposes

Note 1 to entry: to entry:

— P_{ST} = 1,5 × P_D (when P_{MD} ≤ 10 bar), or

— P_{ST} = P_D + 5 (when P_{MD} > 10 bar)

where P_D is the design pressure.

Note 2 to entry: 1 bar is equivalent to 0,1 Mpa.

[SOURCE: ISO 10802:2020, 3.7, modified — The original note 2 to entry has been replaced by a new one.]

3.1.6
thrust force
unbalanced hydrostatic force developed at the locations of a pipeline, changing diameter or direction

3.1.7
bearing resistance
passive pressure that is generated as the pipeline attempts to separate and move into the soil

3.1.8
frictional resistance
resisting force resulting from the interaction of the pipeline with the soil encountered on the project site and the pipeline laying conditions

3.1.9
passive soil pressure
maximum pressure that the soil imparts on a structure at the prescribed depth

Note 1 to entry: The passive soil pressure is dependent upon the compaction of the soil.

3.1.10
restrained length
minimum length to be restrained in order to balance *thrust forces* (3.1.6) and prevent disassembly or separation of the pipeline

3.2 Symbols

A	cross-sectional area of pipe, in m^2
A_p	surface area of the pipe bearing on the soil, in m^2/m
C	pipe-soil cohesion, equals $f_c C_s$, in kN/m^2;
C_s	soil cohesion, in kN/m^2 (see Table 2)
D_e	outside diameter of pipe spigot, in m (see Annex A)
f_c	ratio of pipe-soil cohesion to soil cohesion (see Table 2)
F_f	unit frictional resistance, in kN/m
F_s	unit frictional force assuming 1/2 the pipe circumference bears against the soil, in kN/m
$(F_s)_b$	unit frictional force assuming the entire pipe circumference contacts the soil, in kN/m
f_φ	ratio of pipe-soil friction angle to soil friction angle (see Table 2)
h	thrust block height, in m
H	depth of cover to top of pipe, in m
H_c	depth of cover to pipe centreline, in m
K_n	trench condition modifier (see Table 2)
L	minimum required restrained pipe length, in m
N_φ	$= \tan^2 (45° + \varphi/2)$
P	system test pressure, in kN/m^2
P_p	passive soil pressure, in kN/m^2
R_s	unit bearing resistance, in kN/m
T	resultant thrust force, in kN
γ	backfill soil density, in kN/m^3 (see Table 2)
W	unit normal force on pipe = $2\ W_e + W_p + W_w$, in kN/m
W_e	earth prism load = $\gamma\ HD_e$, in kN/m
W_p	unit weight of pipe, in kN/m (see Annex A)
W_w	unit weight of water, kN/m (see Annex A)
θ	bend angle, in degrees

δ pipe-soil friction angle, equals f_φ φ, in degrees;

φ soil internal friction angle, in degrees (see Table 2)

S_f safety factor (see 4.2)

4 Thrust restraint principles, calculation rules and general specification

4.1 Thrust forces

When underground or above-ground pipelines are in operation, unbalanced hydrostatic or hydrodynamic forces are developed at many locations under the internal pressure of the fluid in the pipeline, this is known as thrust forces. Unless the pipe joints in these areas are restrained against longitudinal movement, joint separation can result. These thrust forces are developed at locations where the pipeline changes either in diameter or in direction. Such locations include horizontal and vertical bends, tees, wyes, reducers, offsets, pipe bifurcations and valves.

At these locations the thrust forces are resisted with thrust blocks at the focus of the thrust force, or by installing a group of restrained joint pipes, in such a way that the unbalanced force is transmitted to the surrounding soil or pedestals (above-ground installation, without overstressing the pipeline wall and without subjecting the pipeline to joint separation).

The present standard studies and provides formulae which enable to balance thrust forces with the adequate quantity of restrained joint pipes.

Proper care shall be taken by the designer when chambers are installed within the restrained length of the pipeline.

The manufacturer’s recommendations for selecting the type of restrained joint shall also be taken into account.

4.2 Calculation rules and general specification

The following parameters shall be taken into account: the cross-sectional area of the pipe (Table A.1), the pipeline changes generating the thrust force (Clause 5), the outside diameter of the pipe (Table A.1), the depth of cover of the pipe (see Figure 6), the characteristics of the soil surrounding the pipe and the trench backfilling methods (Clauses 7 and 9), the pipeline external coating system (bituminous, epoxy and acrylic paints or polyethylene encased pipe, PU and other extruded coatings - Clause 8).

The system test pressure (STP) of the pipeline is calculated from the maximum design pressure (MDP) and shall be used to estimate the thrust forces (Clause 5); and a safety factor of 2 is recommended.

For each pipeline changes and their combination, a specific formula is provided to calculate the length of pipes to be restrained. The list of common situations is provided in Table 1 together with the subclause number:

Table 1 — Type of common situation

Description	Subclause number
Horizontal bends	10.1
Vertical down bends	10.2
Vertical up bends	10.3
Tees	10.4
Reducers	10.5
Dead ends	10.6

Table 1 *(continued)*

Description	Subclause number
Encroaching restrained lengths	10.7
Equal angle vertical offset (θ)	10.8
Combined horizontal equal angle bends (θ)	10.9
Combined horizontal unequal angle bends	10.10
Combined vertical equal angle offsets (θ)	10.11
Pipeline under obstruction	10.11.1
Pipeline over obstruction	10.11.2

4.3 Standard jointing systems offer no longitudinal restraint

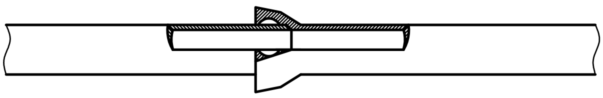
Ductile iron pipes and fittings are most often joined with push-in or mechanical flexible joints (Figure 1). Neither of these joints provide significant restraint against longitudinal separation other than the friction, between the gasket and the plain end of the pipe or fitting. Tests have shown that this frictional resistance of these joints are unpredictable. Thus, these joints should be considered as offering no longitudinal restraint for design purposes.

4.4 Restrained joint systems

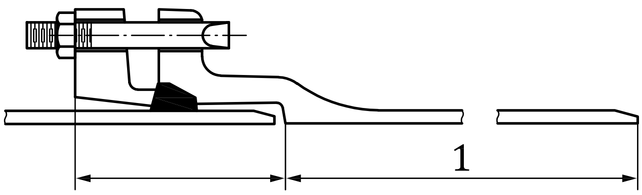
The primary objective of the restrained joint system is to design a system to transmit the unbalanced forces to the surrounding soil without overstressing the pipeline wall and without subjecting the pipeline to joint separation. In order to accomplish the transfer of the unbalanced forces, the friction and passive resistance have been relied upon.

4.5 Length to be restrained

The length of the pipe, with restrained joints on each side of the focus of a thrust force, is calculated using the sum of the components of the unbalanced forces in the direction of the corresponding leg. The objective of the thrust restraint design using a restrained joint system is to extend the side of the fitting with inseparable joints so that the fitting can transmit the unbalanced forces to the surrounding soil.



a) Push-in flexible joint



b) Mechanical flexible joint

Key

1 nominal laying length

Figure 1 — Push-in and mechanical flexible joints

4.6 Restrained design method

This document shows the method to calculate the quantum of thrust forces for the most common situations and the approaches to the design of restrained joint systems for balancing these forces. The suggested design approaches are conservatively based on accepted principles of soil mechanics.

4.7 Gravity thrust blocks

The design of gravity thrust blocks to counter the thrust forces in pipeline systems is not covered by this document. Thrust blocks/anchor blocks should not interfere with the angular deflection and axial movement of restrained joints as prescribed by the manufacturer.

5 Thrust force

5.1 Internal hydrostatic pressure in straight pipes

The internal hydrostatic pressure acts perpendicularly on any plane with a force equal to the pressure (P) times the area (A) of the plane. All components of these forces acting radially within a pipe are balanced by circumferential tension in the wall of the pipe. Axial components acting on a plane perpendicular to the pipe through a straight section of the pipe are balanced internally by the force acting on each side of the plane (Figure 2).

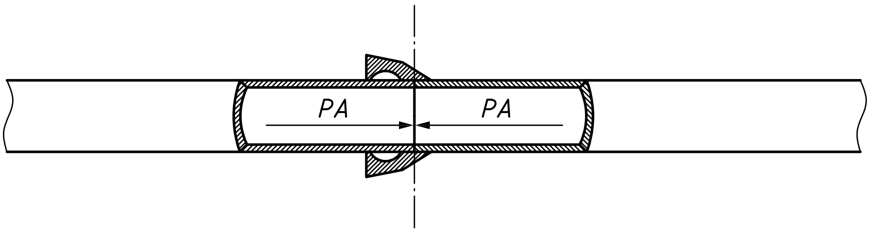


Figure 2 — Internally balanced force

5.2 Internal hydrostatic pressure in bends

In the case of a bend as shown in Figure 3, the forces PA acting axially along each side of the bend are not balanced. The vector sum of these forces is shown as T. This is the thrust force. In order to prevent separation of the joints, a reaction equal to and in the opposite direction of T, shall be established.

$$T = 2PA\sin\frac{\theta}{2} \qquad (1)$$

where

T is the resultant thrust force, in kN;

P is the system test pressure, in kN/m^2;

A is the cross-sectional area of pipe, in m^2;

θ is the bend angle, in degrees.

