INTERNATIONAL STANDARD

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Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications —

Part 4: System design and installation guidelines

Tubes et raccords en matières plastiques — Systèmes de tubes en polyéthylène réticulé (PE-X) pour le transport de combustibles gazeux — Série métrique — Spécifications —

Partie 4: Lignes directrices pour la conception et l'installation du système

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 14531-4 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 4, *Plastic pipes and fittings for the supply of gaseous fuels*.

ISO 14531 consists of the following parts, under the general title *Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications*:

— *Part 1: Pipes*

— *Part 2: Fittings for heat-fusion jointing*

— *Part 3: Fittings for mechanical jointing (including PE-X/metal transitions)*

— *Part 4: System design and installation guidelines*

Introduction

Further to the publication of International Standards for crosslinked polyethylene (PE-X) hot-water pipes, it has become evident that the properties of PE-X, in particular its high fracture resistance and a recently established socket and saddle fusion-jointing capability, render it suitable for use in high-performance gas-distribution systems. The philosophy of ISO 14531 is to provide the basis for the introduction of PE-X gas pipe systems by the specification of a performance envelope beyond that covered by existing PE standards in order to take its application into regimes of higher operating pressures and extremes of operating temperature.

This part of ISO 14531 is therefore one part of a four-part system standard covering pipes, fittings for heat-fusion jointing, fittings for mechanical jointing and design and installation guidelines. The content is suitable for use by procurement authorities and distribution engineers responsible for the design, installation and operation of pipeline systems.

Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications —

Part 4: System design and installation guidelines

1 Scope

This part of ISO 14531 provides guidance for the design, construction, installation and on-site testing of PE-X pipeline systems. The standard deals with trenchless and open-trench installation methods.

This part of ISO 14531, when used in conjunction with the other parts of ISO 14531, provides the basis for the design, manufacture and installation of PE-X piping systems (PE-X pipes, and PE-X and PE heat-fusion fittings and mechanical fittings) for the supply of category D and category E hydrocarbon-based fuels (see ISO 13623) at

a) maximum operating pressures (MOPs) up to and including 16 bar [1)] and

b) a maximum operating temperature of +60 °C and

c) a minimum operating temperature of

   1) −50 °C

   2) −35 °C

   3) −20 °C.

This part of ISO 14531 provides for the jointing and installation of PE-X and PE heat-fusion fittings and mechanical fittings to PE-X pipes within the temperature range −5 °C to +40 °C. The jointing of pipes and fittings outside the stated temperature range should be the subject of consultation between the pipeline operator and the pipe, fitting and equipment manufacturers.

Users of this part of ISO 14531 should be aware that useful supplementary information is given in the standards listed in the bibliography.

1) 1 bar = 10^5 N/m^2 = 100 kPa.

2 Normative references

The following referenced documents are indispensable for the application 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 4065, *Thermoplastic pipes — Universal wall thickness table*

ISO 8085-3, *Polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels — Metric series — Specifications — Part 3: Electrofusion fittings*

ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

ISO 10838 (all parts), *Mechanical fittings for polyethylene piping systems for the supply of gaseous fuels*

ISO/TS 10839:2000, *Polyethylene pipes and fittings for the supply of gaseous fuels — Code of practice for design, handling and installation*

ISO 12162, *Thermoplastics materials for pipes and fittings for pressure applications — Classification and designation — Overall service (design) coefficient*

ISO 12176-2, *Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems — Part 2: Electrofusion*

ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*

ISO 13760, *Plastics pipes for the conveyance of fluids under pressure — Miner's rule — Calculation method for cumulative damage*

ISO 14531-1:2002, *Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications — Part 1: Pipes*

ISO 14531-2, *Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications — Part 2: Fittings for heat-fusion jointing*

ISO 14531-3, *Plastics pipes and fittings — Crosslinked polyethylene (PE-X) pipe systems for the conveyance of gaseous fuels — Metric series — Specifications — Part 3: Fittings for mechanical jointing (including PE-X/metal transitions)*

EN 12007-1, *Gas supply systems — Pipelines for maximum operating pressure up to and including 16 bar — Part 1: General functional recommendations*

EN 12007-2, *Gas supply systems — Pipelines for maximum operating pressure up to and including 16 bar — Part 2: Specific functional recommendations for polyethylene (MOP up to and including 10 bar)*

3 Terms and definitions

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

3.1
nominal outside diameter
d_n
numerical designation of size which is common to all components in a thermoplastics piping system other than flanges and components designated by thread size

NOTE 1 It is a convenient round number for reference purposes.

NOTE 2 The nominal outside diameter expressed in millimetres is the minimum mean outside diameter $d_{e,min}$ of pipe produced in accordance with ISO 14531-1.

3.2
nominal wall thickness
e_n
nominal designation of wall thickness of a pipe in millimetres in accordance with ISO 4065

3.3
standard dimension ratio
SDR
ratio of the nominal outside diameter of a pipe to its nominal wall thickness

$$SDR = \frac{d_n}{e_n}$$

NOTE The value of the SDR is selected from Table 5 in ISO 14531-1:2002.

3.4
gaseous fuel
fuel which is in a gaseous state at a temperature of +15 °C and a pressure of 1 bar

3.5
category D gaseous fuel
natural gas

NOTE Categories of gaseous and liquid fuels are defined in detail in ISO 13623.

3.6
category E gaseous fuel
LPG vapour or natural gas conveyed in association with liquid condensate

NOTE Categories of gaseous and liquid fuels are defined in detail in ISO 13623.

3.7
design pressure
DP
pressure on which design calculations are based

NOTE The design pressure for pipes is designated DP_P and for fittings DP_F.

3.8
design stress
σ_S
pipe wall circumferential stress calculated from the design pressure DP_P and pipe SDR with a maximum limiting value determined by the quotient of $MRS_{\theta, t}$ and the overall service (design) coefficient C

3.9
maximum operating pressure
MOP
highest effective pressure, in bars, of the gas in the piping system which is allowed in continuous use

NOTE The MOP takes into account the physical and the mechanical characteristics of the components of a piping system.

3.10
temporary operating pressure
TOP
maximum pressure that can be generated on a temporary basis under the control of the regulating devices

3.11
maximum incidental pressure
MIP
maximum pressure generated for example by surges or failure of pressure control equipment and limited by the activation of overpressure protection devices

3.12
pipeline operator
private or public organization authorized to design, construct and/or operate and maintain the gas supply system

3.13
minimum required strength
MRS$_{\theta, t}$
value of σ_{lpl} for the pipe material, in megapascals, calculated using ISO 9080 for a specific design temperature θ and lifetime t and then categorized in accordance with Table 3

NOTE At 20 °C and 50 years, MRS$_{\theta, t}$ = MRS.

3.14
overall service (design) coefficient
C
overall coefficient, with a value greater than 1,0, which takes into consideration service conditions as well as properties of the components of a piping system other than those represented in the lower prediction limit (3.15)

3.15
lower prediction limit
σ_{lpl}
quantity, expressed in megapascals, which can be considered as a property of the material and which represents the 97,5 % lower prediction limit of the long-term hydrostatic strength at a temperature of 20 °C and a time of 50 years in water

3.16
heat-fusion fitting
fitting designed to connect PE-X pipes to form an assembly for subsequent jointing by heat fusion and the creation of an integral pipe-to-fitting connection

3.17
operating-temperature range
assumed range of temperatures experienced by a PE-X pipeline at the intended service location, for use in the process of designing the pipeline for operation at MOP

3.18
minimum operating temperature
T_{min}
minimum operating temperature (above and/or below ground) expected during the service life of the pipeline

3.19
maximum operating temperature
T_{max}
maximum operating temperature (above and/or below ground) expected during the service life of the pipeline

3.20
design temperature
θ
temperature used to determine MRS$_{\theta, t}$

NOTE See 4.1.5.3.

4 Requirements

4.1 Design

4.1.1 General

The design pressure (DP) of any PE-X pipeline component shall not be less than the intended maximum operating pressure (MOP) of the pipeline. The DP shall be at least 2,0 bar. The MOP shall be selected from a range of pressures up to a maximum of 16 bar in accordance with the requirements of the pipeline operator.

NOTE Requirements for MOP in the gas industry are not standardized on the basis of PN pressure ratings. An alternative classification system has been adopted in CEN (EN 12007) and is incorporated in Table 1.

Operating pressures during transient conditions in excess of MOP are permitted provided they are of limited frequency and duration. Guidance regarding acceptable levels of transient operating pressure conditions is given in 4.1.3.

The normal permissible operating-temperature ranges for PE-X pipelines extend from −50 °C to a maximum of +60 °C and are applicable up to the maximum pressure (MOP) of 16 bar. Limiting temperatures are dependent upon the materials used in the manufacture of pipes and fittings (see 4.1.4). Operating temperatures up to 70 °C are not excluded by this part of ISO 14531 provided local regulations permit.

4.1.2 Materials

The materials and components used in PE-X pipelines shall conform to ISO 14531-1, ISO 14531-2 or ISO 14531-3, as appropriate.

Other materials, components and equipment used shall conform to a relevant ISO standard or appropriate national standard that ensures a product fit for the purpose intended.

4.1.3 Pressure ranges

Internal pressures generated in PE-X pipelines under transient operating conditions should not exceed the values given in Table 1.

Table 1 — Transient pressure limits

Pressures in bars

Maximum operating pressure (MOP)	Temporary operating pressure (TOP) [a]	Maximum incidental pressure (MIP) [b]
$5 < MOP \leqslant 16$	$1{,}20 \times MOP$	$1{,}30 \times MOP$
$2 < MOP \leqslant 5$	$1{,}30 \times MOP$	$1{,}40 \times MOP$
$0{,}1 < MOP \leqslant 2$	$1{,}50 \times MOP$	$1{,}75 \times MOP$
$MOP \leqslant 0{,}1$	$1{,}50 \times MOP$	$2{,}50 \times MOP$

[a] TOP is the maximum pressure that can be generated on a temporary basis under the control of the regulating devices.

[b] MIP is, for example, the maximum pressure generated by surges or failure of pressure control equipment and is limited by the activation of overpressure protection devices.

The use of pipes at TOP shall be the responsibility of the pipeline operator. Acceptability for use at TOP can be assessed using Miner's rule in a supplementary design calculation undertaken in accordance with the guidelines given in Annex A and in conjunction with the pipe manufacturer.

4.1.4 Minimum/maximum operating temperatures T_{min}/T_{max}

The minimum operating temperature T_{min} for PE-X pipelines shall not be lower than the critical RCP temperature for the PE-X pipe to be used. Critical rapid crack propagation (RCP) temperatures specified for PE-X pipe are given in ISO 14531-1 and listed in Table 2. The marking of the PE-X pipe should be examined for confirmation regarding the limiting critical temperature.

The maximum operating temperature T_{max} for PE-X pipelines shall not exceed the design temperature θ selected for the pipeline (see 4.1.5.3) with a limiting value of +60 °C. In exceptional circumstances a maximum operating temperature of 70 °C may be considered if permitted by local regulations and the design constraints detailed in this standard.

PE-X pipelines incorporating PE fusion fittings and mechanical fittings conforming to ISO 8085-3 and ISO 10838 respectively shall be restricted to a minimum operating temperature T_{min} of −20 °C and a maximum operating temperature T_{max} of +40 °C (see ISO 14531-2, ISO 14531-3 and the fitting manufacturer's technical file).

Table 2 — Critical RCP temperature limits for PE-X pipes

PE-X pipe	Critical RCP temperature [a] °C
Class 1	−50
Class 2	−35
Class 3	−20
[a] Corresponding stress levels are given in Part 1 of this International Standard.	

4.1.5 Pipes

4.1.5.1 General

PE-X pipes used to construct PE-X pipelines shall conform to ISO 14531-1 and shall be designed in conformity with 4.1.5.2 to 4.1.5.4.

4.1.5.2 Selection of nominal wall thickness e_n

The nominal wall thickness of the pipe e_n shall be calculated using the following equation:

$$e_n = \frac{d_n}{SDR}$$

in which the value of the SDR is pre-determined by the following relationship:

$$SDR = \frac{20 \times MRS_{\theta,t}}{DP_P \times C_M \times C_A} + 1$$

where

$MRS_{\theta,t}$ is the σ_{lpl} of the pipe material, in megapascals, calculated using ISO 9080 for a specific design temperature θ and lifetime t and then categorized in accordance with Table 3;

DP_P is the pipe design pressure, which is equal to or greater than the MOP;

C_M is a design coefficient equal to 1,25 that reflects the effect on long-term hydrostatic strength σ_{LTHS} (see 4.2.2 in ISO 14531-1:2002) of the material/process-related properties of the pipe other than those represented in σ_{lpl};

C_A is an applications-based design coefficient introduced by the pipeline operator that takes into account the pipeline MOP and the pipeline's operating environment [e.g. the type of gas being conveyed and the pipe location (remote areas or urban sites)] and any relevant national regulations.

When the calculated value of SDR is not a recognized value defined in ISO 4065, the next lower value shall be selected.

NOTE The product of C_m and C_A is nominally equal to C, the overall service (design) coefficient as defined in ISO 12162. Rounding of the SDR value may lead to a value of $C > C_m \times C_A$.

4.1.5.3 Design temperature θ

The design temperature θ is the anticipated maximum operating temperature of the pipe at the intended pipe position. The selected design temperature shall not be less than 0 °C nor greater than 60 °C.

NOTE A design based upon the maximum operating temperature is regarded as conservative, and an advantage may be gained from a precise analysis that incorporates Miner's rule (see ISO 13760), utilizing safety factors agreed to by the pipeline operator.

4.1.5.4 Overall service (design) coefficient C

Using the selected SDR value determined in accordance with 4.1.5.2, calculate the design stress σ_S from

$$\sigma_S = \frac{DP_P}{20}(SDR - 1)$$

and then the overall service (design) coefficient C from

$$C = \frac{MRS_{\theta,t}}{\sigma_S}$$

The selection and/or acceptance of the coefficient C shall be the responsibility of the pipeline operator who is defined in 3.12.

NOTE Currently for gas applications a minimum value of C equal to 2,0 is incorporated in ISO 4437 for PE pipes. If not otherwise defined by the pipeline operator, this value should also be used for PE-X.

Table 3 — Categorized values for $CRS_{\theta, t}$

Range of σ_{lpl} at θ and t MPa	$CRS_{\theta, t}$ [a] MPa
$5{,}00 \leqslant \sigma_{lpl} \leqslant 5{,}59$	5,00
$5{,}60 \leqslant \sigma_{lpl} \leqslant 6{,}29$	5,60
$6{,}30 \leqslant \sigma_{lpl} \leqslant 7{,}19$	6,30
$7{,}20 \leqslant \sigma_{lpl} \leqslant 7{,}99$	7,20
$8{,}00 \leqslant \sigma_{lpl} \leqslant 8{,}99$	8,00
$9{,}00 \leqslant \sigma_{lpl} \leqslant 9{,}99$	9,00
$10{,}00 \leqslant \sigma_{lpl} \leqslant 11{,}19$	10,00
$11{,}20 \leqslant \sigma_{lpl} \leqslant 12{,}49$	11,20
$12{,}50 \leqslant \sigma_{lpl} \leqslant 13{,}99$	12,50
[a] This list of categorized values is subject to review dependent upon the outcome of the revision of ISO 12162.	

4.1.6 Pipeline components

4.1.6.1 Heat-fusion fittings

4.1.6.1.1 Selection criteria

Heat-fusion fittings selected for use shall have at the pipeline design temperature θ a design pressure DP_F, as declared by the fitting manufacturer in his technical file (see ISO 14531-2), equal to or greater than the design pressure of the pipe DP_P.

Heat-fusion fittings selected for use with PE-X pipes to form a PE-X pipeline system shall conform to ISO 14531-2 (alternatively, fittings conforming to ISO 8085-3 may be used provided that the additional tests specified in ISO 14531-2 for ISO 8085-3 fittings have been completed satisfactorily).

Fittings manufactured to ISO 14531-2 can be expected to have an operating-temperature range up to the minimum/maximum defined by the temperature limits of −50 °C and +60 °C. The fitting manufacturer's technical file shall be inspected to establish the permissible operating-temperature range of the fitting. The minimum permissible operating temperature of the fitting shall be equal to or higher than the applicable temperature listed in Table 2. The maximum permissible operating temperature of the fitting shall be equal to or lower than the design temperature θ. The acceptable operating-temperature range for fittings conforming to ISO 8085-3 is −20 °C to +40 °C.

Heat-fusion fittings selected for connection to PE-X pipes shall have an SDR application range that includes the SDR of the pipe to which connection is intended.

4.1.6.1.2 Fusion compatibility

Fusion compatibility of heat-fusion fittings with PE-X pipes shall be a primary consideration at the pipeline design stage.

PE-X fittings manufactured to conform to ISO 14531-2 may not be compatible with all PE-X pipes produced to ISO 14531-1. Information regarding specific fusion compatibility relationships (fitting/pipe) shall be sought from the technical file of the fitting manufacturer.

NOTE Consultation with the fitting manufacturer should be undertaken in conjunction with reference to the guidance given in ISO 14531-2.

Fittings in conformity with ISO 14531-2 may be manufactured from PE 80 and PE 100 materials. PE fittings of this type shall only be used if they are individually marked with ISO 8085 as the standard reference number supported by evidence given in the manufacturer's technical file regarding use and suitability for fusion jointing to PE-X pipe.

4.1.6.2 Mechanical fittings — selection criteria

Mechanical fittings selected for use shall have at the pipeline design temperature θ, a design pressure $DP_{F(\theta)}$ as declared by the fitting manufacturer in his technical file (see ISO 14531-3), equal to or greater than the design pressure for the pipe, DP_P.

Mechanical fittings (metal and plastic bodied) selected for use with PE-X pipes to form a PE-X pipeline system shall conform to ISO 14531-3. Alternatively, fittings conforming to ISO 10838-1, ISO 10838-2 or ISO 10838-3 may be used provided that the additional tests specified in ISO 14531-3 for ISO 10838 fittings have been completed satisfactorily.

Fittings manufactured to ISO 14531-3 can be expected to have an operating temperature range up to a maximum defined by temperature limits of −50 °C and +60 °C. The technical file of the fitting manufacturer shall be inspected to establish the permissible operating-temperature range of the fitting. The minimum permissible operating temperature of the fitting shall be equal to or higher than the applicable temperature listed in Table 2. The maximum permissible operating temperature of the fitting shall be equal to or lower than the design temperature θ. The acceptable operating-temperature range for fittings conforming to ISO 10838-1, ISO 10838-2 or ISO 10838-3 is −20 °C to +40 °C.

Mechanical fittings conforming to ISO 14531-3 or ISO 10838, selected for use with PE-X pipes to form a PE-X pipeline system, should be regarded as full-end-load-resistant with a resistance to longitudinal tensile force at least as good as pipe.

The use of anti-shear sleeves should be considered in cases where substantial relative movement is anticipated between the fitting and PE-X pipe of $d_e \leqslant 40$ mm.

NOTE Manufacturer’s advice should be sought regarding allowable limits in such circumstances.

Consideration shall be given to the need for the on-site corrosion protection of metallic parts not claimed to be corrosion-resistant by the fitting manufacturer.

4.1.6.3 Protection systems

4.1.6.3.1 External interference

For above- and below-ground pipe systems, the possibility of direct external interference and the effect of consequential pipeline failure shall be established during the design process, and the need for and extent of pipeline protection determined. National safety regulations shall be taken into account.

NOTE Where appropriate, and dependent upon the pipeline location and MOP, the following measures should be considered individually or in combination to minimize the risk of damage from interference:

a) the use of protective sleeves;

b) the provision of other protective structures above and/or around the pipeline such as concrete slabs or paving;

c) the installation of marker/detection tape;

d) the erection of easily visible pipeline location markers, particularly at road, rail, river and canal crossings;

e) the installation of buried PE-X pipelines with increased cover to ensure that the pipes are below the normal level of external activities.

The design of protective systems shall take into account the effect of soil settlement on their stability and the need to provide access for maintenance and system extension. Protective structures shall be designed to avoid subjecting PE-X pipelines to additional stresses.

4.1.6.3.2 Above-ground installations — Long-term weathering exposure (to UV radiation levels greater than 3,5 GJ/m^2)

For long-term storage and above-ground use, extensive exposure to daylight throughout the intended service life is a possibility and PE-X pipes conforming to ISO 14531-1 may not have adequate long-term weathering resistance for this purpose. Additional protection is necessary that may take the form of a physical covering on the pipes or the use of pipe materials suitably compounded to provide resistance to weathering greater than that specified in ISO 14531-1.

Where materials are compounded to provide enhanced UV protection, pipe manufacturers should be consulted to ensure that the ability of such products to conform to ISO 14531 is not impaired.

4.2 Construction

4.2.1 Handling, transport and storage

The following guidelines are of a general nature. More detailed information is given in ISO/TS 10839.

Pipes and fittings intended for use in the construction of PE-X systems should be transported and stored using procedures designed to avoid excessive component deformation which is likely to create jointing difficulties, and piercing or scoring damage induced by contact with sharp objects and other projections which may affect component strength. Permissible levels of deformation are influenced by the design of the jointing equipment in use, and manufacturer's guidance should be sought. Components with surface defects penetrating further than 10 % of the nominal wall thickness should not be used.

Susceptibility to deformation and damage increases with ambient temperature, and particular care should be exercised in high-temperature environments. In conditions of low sub-zero temperatures, the flexibility of PE-X pipes is substantially reduced, and more care is necessary in dispensing pipe from coils or drums to safeguard operating personnel, particularly against whiplash injury.

PE-X pipes not protected in accordance with 4.1.6.3.2 may be stored outside in direct daylight provided the storage time is monitored and minimized to avoid exposure to excessive levels of UV radiation likely to impair the properties of the component relative to its “as purchased” condition. Maximum permissible storage times will vary dependent upon geographical location (see Figure B.1 in ISO/TS 10839:2000). Guidance from the manufacturer should be sought when establishing local requirements. Care should be taken during the storage of PE-X pipes with protective coatings to avoid coating damage and increased vulnerability to UV attack.

Storage of fittings in direct daylight should be avoided.

The possibility of contamination of pipes and fittings by extraneous chemical substances likely to impair component performance should be considered in the preparation of handling and storage procedures. It is particularly important to prevent contamination of jointing surfaces.

4.2.2 Jointing

4.2.2.1 General

PE-X pipelines may be constructed using heat-fusion jointing techniques and/or mechanical methods. Personnel shall be competent in the appropriate method.

Written procedures for jointing, equipment operation, visual examination and, where applicable, non-destructive inspection techniques, authorized by the pipeline operator and/or the component manufacturer, shall be utilized.

The suitability of procedures and equipment for use outside the ambient temperature range −5 °C to +40 °C is not covered by this part of ISO 14531, but if required such applications should be the subject of consultation on a project-by-project basis between the pipeline operator and the pipe, fitting and equipment manufacturers.

4.2.2.2 Joint integrity

Joints shall be subjected to a full visual examination in accordance with written procedures by the personnel engaged in jointing.

Additional visual examination and/or non-destructive inspection shall be carried out by a competent person at a frequency dependent upon the conditions of use. The results of the inspection shall be recorded.

Destructive testing of joints selected by the pipeline operator may be carried out to assess their conformity to the requirements of this part of ISO 14531. If such testing is carried out, the results shall be recorded.

4.2.2.3 Heat-fusion joints

Heat fusion shall be limited to socket and saddle procedures in association with equipment conforming for example to ISO 12176-2 (electrofusion). Other equipment may be introduced provided a satisfactory fitness-for-purpose assessment is conducted by the pipeline operator.

The limits to the ambient temperature for effective jointing in accordance with this part of ISO 14531 are a minimum temperature of −5 °C and a maximum temperature of +40 °C. The suitability for use of all jointing equipment throughout the temperature range −5 °C to +40 °C shall be established. However, as stated in Clause 1, jointing may be possible outside this range by agreement between the pipeline operator and the pipe, fitting and equipment manufacturers.

The possible effects of wind chill and rain shall be taken into account and consideration given to the use of shielding around the jointing area. Capping of pipe ends may be necessary to prevent the flow of cold air past the joint zone. Extra care in handling components may be necessary when working in extreme conditions.

The pipe/spigot SDR shall be within the range indicated for the fitting socket/saddle (see fitting manufacturer's technical file).

The integrity and reliability of fusion joints depends upon

a) the cleanliness of the components and the jointing equipment;

b) the circularity and alignment of the components;

c) the temperature of the surfaces to be joined.

Joint surfaces shall be clean and free from degradation, contamination and damage immediately prior to component assembly and fusion.

Where scraping is necessary to create pipe surfaces that are clean, free from contamination and of a diameter that is dimensionally suitable for immediate jointing by heat fusion, care should be taken to avoid excessive removal of surface material (more than 0,2 mm depth) with a consequent significant dimensional change to the component. This is particularly relevant for small-diameter pipes. The need for scraping should be determined from the pipe and fitting manufacturer's technical file and/or installation procedure.

Where applicable, the removal of external protective layers from pipes prior to fusion jointing shall be undertaken with care using the tools provided to avoid damage to the jointing surfaces.

Good component alignment and pipe circularity are essential for the production of a high-quality joint. Pipe and fitting clamps shall be used for this purpose and shall be maintained in position until the required joint cooling time has elapsed.

4.2.2.4 Mechanical joints

Mechanical joints that require the PE-X pipe to be threaded shall not be used.

Any fluids supplied to assist in the lubrication of pipes and fittings during assembly and for protection against corrosion shall be used in accordance with the written instructions of the fitting manufacturer. In the case of pre-assembled metal/PE-X transition fittings, care shall be taken to avoid any contamination of pipe surfaces likely to be used for heat-fusion jointing.

The interchange of non-integral stiffener inserts between fittings shall be avoided unless carried out under the guidance of the pipeline operator.

4.3 Laying

4.3.1 General

Care shall be taken to avoid installing damaged pipelines. In particular, pipelines shall not be installed when there is evidence of surface defects deeper than 10 % of the nominal wall thickness of the pipe or fitting.

Changes in the direction of a PE-X pipeline should be achieved using in-line fittings such as preformed pipe bends and elbow fittings produced in accordance with ISO 14531-2 or mechanical fittings manufactured to ISO 14531-3.

Natural flexing of the PE-X pipe to achieve changes in direction is allowed provided the bend radius is limited to a minimum value dependent upon the pipe SDR and the properties of the pipe material at the installation temperature in order to avoid buckling of the pipe.

NOTE Allowable bend radii are usually expressed as multiples of the pipe diameter d_n (e.g. $15d_n$) or in relation to the pipe SDR. For PE-X pipes and installation temperatures in the range 5 °C to 23 °C, the multiple should be a minimum of $12d_n$ or 1,0 times the pipe SDR, whichever is the smaller. Bends containing joints should be limited to $20d_n$ or 1,5 times the pipe SDR, whichever is the smaller.

When installing pipes at higher or lower ambient temperatures, revision of the bend radius limits may be necessary and the pipe manufacturer should be consulted regarding applicable limits.

Bend radius limits for the sizes of ancillary PE-X pipes described in Annex A of ISO 14531-1:2002 should be $5d_n$.

4.3.2 Open-trench installation

The PE-X pipeline should be evenly bedded on the bottom of the trench which may be backfilled using the excavated material. Where this contains materials likely to damage the pipe, it may be necessary to be selective as regards the backfill material. The pipe manufacturer should be consulted regarding the damage potential of backfill materials.

NOTE When installing pipelines in rocky terrain, it is important to ensure that the pipe exhibits a high level of resistance to slow crack growth (SCG) generated by rock impingement. Satisfactory resistance to rock impingement is demonstrated by meeting the requirements for SCG given in ISO 14531-1 using the notched-pipe test. The full-notch creep test (FNCT) and notched tensile test (PENT) given in the Bibliography may also be suitable for assessment of SCG resistance.

Backfill compaction should be carried out with care, using procedures designed to provide adequate pipe support consistent with the avoidance of a detrimental level of induced installation stress. Mechanical compaction procedures should ensure that the pipeline is not exposed to direct contact with compaction equipment.

4.3.3 Trenchless installation

Laying procedures shall take into account the need to avoid the possible exposure of the pipeline to unnecessarily high installation stresses. Trenchless installations involving the use of tensile drag forces applied to long lengths of pipe for pipe re-sizing and/or placement should be monitored to avoid an overstressed pipeline installation.

When PE-X pipes produced in accordance with ISO 14531-1 have been subjected to further solid-state processing prior to installation to change their shape and/or reduce their size, they shall be tested to ensure continuing compliance with the performance requirements of ISO 14531-1. Specialized pipe shapes, e.g. U-shaped pipes, shall meet the requirements of ISO 14531-1 in the as-installed state after on-site re-forming operations.

Solid-state processing and/or re-forming operations on PE-X pipes shall not detrimentally affect the fusion- or mechanical-jointing capability of such pipes. Jointed connections (fusion and mechanical) designed for use with processed pipes shall meet the performance requirements of ISO 14531-2 or ISO 14531-3, as appropriate.

NOTE Dimensional recovery prior to jointing of pipes subjected to solid-state processing is important. In the case of socket joints where access to the pipe ends is possible, permanent recovery is achieved by means of inserted pipe stiffeners. For saddle connections, the use of stiffener inserts is not practicable and care is necessary in selecting a suitable area of the pipe for jointing, particularly when attaching saddle fittings to folded pipes.

4.3.4 Stopping the gas flow

The gas flow may be stopped in PE-X pipes by the use of the squeeze-off technique down to a minimum temperature of -50 °C (see ISO 14531-1). The equipment employed for squeeze-off operations shall be capable of withstanding safely, at the minimum ambient working temperature, all loads generated during equipment assembly, operation and dismantling.

The squeeze-off position shall be permanently marked to assist in avoiding subsequent repeated squeeze-off operations at the same place during the lifetime of the pipe.

5 Tests on site

5.1 General

The pipeline operator shall ensure, after installation and prior to commissioning, that the strength and leaktightness of the PE-X pipeline is fit for the purpose intended. The test method(s) employed shall take account of relevant national and local safety regulations.

5.2 Pressure test

Pressure testing shall be conducted at ambient temperature. The test pressure shall be greater than the MIP (see Table 1) and within the limits given by the following formula (see EN 12007-2):

$$\text{MIP} < p_{\text{TEST}} \leqslant 0{,}9 p_{\text{RCP}}$$

where, as can be inferred from ISO 14531-1:2002, Table 1, p_{RCP} is given by

$$p_{\text{RCP}} = 0{,}8 \times \frac{20 \times \text{MRS}}{(\text{SDR} - 1)}$$

NOTE 1 The above test pressure limits assume a maximum pipeline temperature of 30 °C and a maximum test duration of 24 h. Deviations from the test conditions are permissible subject to consultation with the pipe manufacturer regarding the effect on the permissible value of the test pressure.

NOTE 2 Selection of hydrostatic test pressures should take into account the possible occurrence of localized pressure peaks due to adverse pipeline contour and elevation characteristics.

Consideration shall be given to the need for any special precautions to be taken to protect persons and property, particularly if air or inert gas is used as the test medium.

Pressurized PE-X pipelines at ambient temperature are subject to expansion by creep that could affect the results of the internal-pressure test. At higher test pressures, this effect may be significant. Appropriate allowance should be made for pressure drop due to creep when interpreting pressure test data. Temperature variations and the duration of the test can also affect the result and shall also be taken into account.

If air is used, oil from the compressor shall be prevented from entering the pipeline and the air temperature shall not exceed 40 °C in order to avoid damage to the pipe and/or fittings.

Annex A
(informative)

Assessment of lifetime using Miner's rule

A.1 Scope

This annex is intended to provide guidance when undertaking a design assessment of the effect on the operating life of a PE-X pipeline of pressure fluctuations, i.e. time spent at TOP and at MOP. It should be read in conjunction with ISO 13760 which describes the use of Miner's rule.

A.2 Procedure

Following the procedure described in ISO 13760, use Miner's rule and the four-coefficient model derived in accordance with ISO 14531-1:2002, Subclause 4.2.2, describing the long-term behaviour of PE-X pipes, to determine the lifetime of the pipeline for the time spent at TOP and the time spent at MOP, using appropriate design factors where necessary.

The result should be greater than the intended lifetime of the pipe system.

A.3 Design assessment report

The design assessment report shall include the following information:

a) a reference to this part of ISO 14531;

b) all details necessary for full identification of the pipe, e.g. material, manufacturer, pipe diameter and SDR;

c) the MOP;

d) the TOP;

e) the time spent at TOP;

f) the time spent at MOP;

g) the design temperature;

h) any design factors used in the calculation;

i) the expected lifetime for the TOP and MOP times used.

Bibliography

[1] ISO 16241, *Notch tensile test to measure the resistance to slow crack growth of polyethylene materials for pipe and fitting products (PENT)*

[2] ISO 16770, *Plastics — Determination of environmental stress cracking (ESC) of polyethylene — Full-notch creep test (FNCT)*

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