INTERNATIONAL STANDARD

ISO 13477

First edition
1997-10-01

Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4 test)

Tubes en matières thermoplastiques pour le transport des fluides — Détermination de la résistance à la propagation rapide de la fissure (RCP) — Essai à petite échelle (S4)

Reference number
ISO 13477:1997(E)

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.

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.

International Standard ISO 13477 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

Annexes A and B form an integral part of this International Standard.

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Printed in Switzerland

Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4 test)

1 Scope

This International Standard specifies a small-scale method of test for determination of arrest or propagation of a crack initiated in a thermoplastics pipe at a specified temperature and internal pressure.

It is applicable to the assessment of the performance of thermoplastics pipes intended for the supply of gases or liquids, in the latter case when air may also be present in the pipe.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 161-1:1996, *Thermoplastics pipes for the conveyance of fluids — Nominal outside diameters and nominal pressures — Part 1: Metric series.*

ISO 1167:1996, *Thermoplastics pipes for the conveyance of fluids — Resistance to internal pressure — Test method.*

ISO 3126:1974, *Plastics pipes — Measurement of dimensions.*

ISO 11922-1:1997, *Thermoplastics pipes for the conveyance of fluids — Dimensions and tolerances — Part 1: Metric series.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 161-1 and ISO 11922-1 apply.

4 Symbols

a Longitudinal crack length on the outer surface of the pipe specimen, measured from the centre of the striker blade, in millimetres

d_n Nominal external diameter of pipe, in millimetres

e_n Nominal wall thickness of pipe, in millimetres

SDR Standard dimension ratio: the ratio of the nominal external diameter d_n to the nominal wall thickness e_n

$d_{i,min}$ Minimum internal diameter of pipe, in millimetres, as calculated from the following equation:

$$d_{i,min} = d_n \left(1 - \frac{2,2}{SDR}\right)$$

5 Principle

A section of thermoplastics test pipe of specified length, maintained at a specified test temperature and containing a fluid at a specified test pressure, is subjected to an impact, near one end, designed to initiate a fast-running longitudinal crack. The crack-initiation process itself is designed so that it disturbs the test pipe as little as possible.

The test temperature and test pressure are as defined in the referring standard.

The fluid is identical to that used in the intended application, or is a substitute fluid which gives equivalent results.

Rapid decompression ahead of the propagating crack is retarded by internal baffles and by an external cage which restricts flaring of the test pipe at the edges of the fracture.

Hence this technique achieves steady-state rapid crack propagation (RCP) in a short pipe specimen at a lower pressure than that necessary to achieve propagation in the same pipe using a full-scale test.

The test pipe is subsequently examined to determine whether arrest or propagation of the crack has occurred.

From a series of such tests at different pressures but at constant temperature, the critical pressure or critical stress for RCP can be determined (see annex A for further information).

Similarly, from a series of such tests at different temperatures but at constant pressure or hoop stress, the critical temperature for RCP can be determined (see annex B for further information).

6 Test parameters

It is assumed that the following parameters will be set by the referring product standard:

a) the diameter(s) and series of the pipe(s) to be tested;

b) the pressurizing fluid, e.g. air or air plus water;

c) the test pressure(s);

d) the test temperature(s).

7 Apparatus

The apparatus shall generally conform with figure 1. Its essential features are described below.

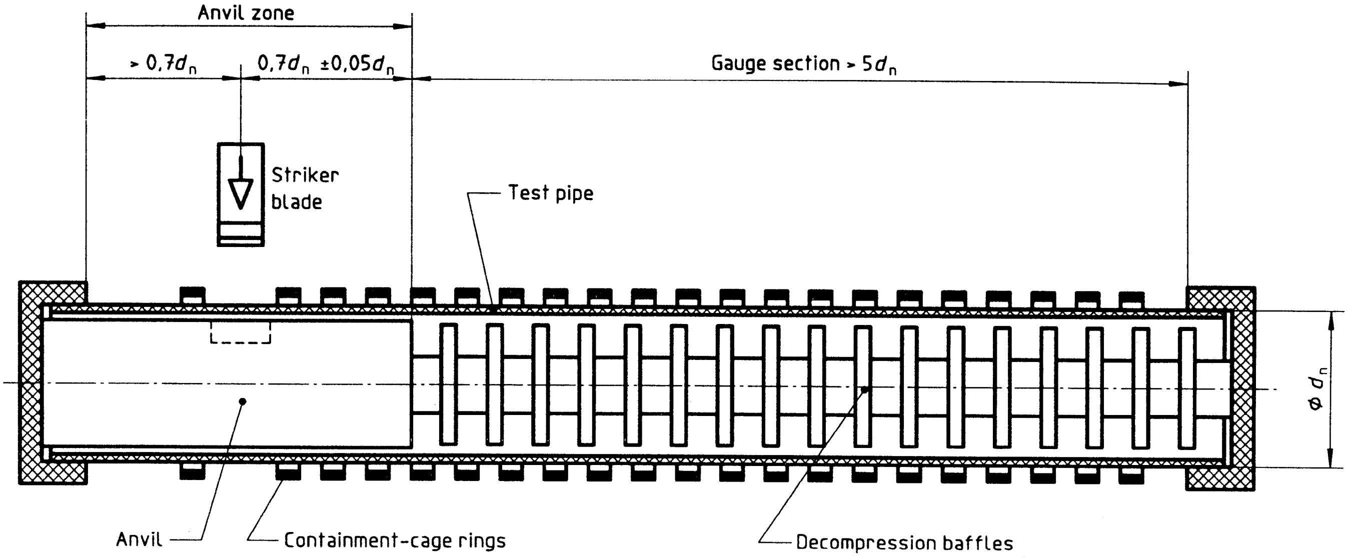

Figure 1 — Apparatus for S4 test

7.1 Containment cage

The containment cage shall allow free expansion of the test pipe during pressurization, but shall restrict radial expansion during fracture to within a maximum diameter of 1,1 $d_n \pm 0{,}04\, d_n$ at all points round the circumference. The cage rings shall not touch or be supported by the test pipe and shall be concentric with it.

Within the region between the crack-initiation point and the end of the gauge length, the pitch of the containment rings shall be 0,35 $d_n \pm 0{,}05\, d_n$ and the longitudinal width of each ring shall be 0,15 $d_n \pm 0{,}05\, d_n$.

7.2 Gauge length

The gauge length shall be greater than 5 d_n. At least 70 % of its internal volume shall be occupied by pressurized air which can expand without restriction to drive the test pipe wall radially outwards

Instrumentation shall be provided to measure the static pressure inside the test pipe to an accuracy of ± 1 %.

7.3 Decompression baffles

The decompression baffles shall be 0,95 $d_{i,min} \pm 0{,}01\, d_{i,min}$ in diameter. The pitch of the baffles shall be 0,4 $d_{n\,-0{,}1 d_n}^{\;\;0}$.

7.4 Crack-initiation equipment

The length of the striker-blade edge shall be 0,4 $d_n \pm 0{,}05\, d_n$. The height of the blade shall be greater than the nominal wall thickness (e_n) of the test pipe (see figure 2).

The blade shall not penetrate deeper than 1 e_n to 1,5 e_n from the outer surface of the test pipe and the striker shall not directly impact the outside surface of the test pipe with any point other than the blade itself. An internal anvil of circular cross-section shall ensure that the inner surface of the test pipe cannot deform, under impact of the blade, to a diameter of less than 0,98 $d_{i,min} \pm 0{,}01\, d_{i,min}$ throughout the anvil zone. A slot shall be provided in the anvil to ensure that the blade is not damaged during crack initiation. The volume of this slot shall not exceed 1 % of $\frac{\pi d_n^3}{4}$.

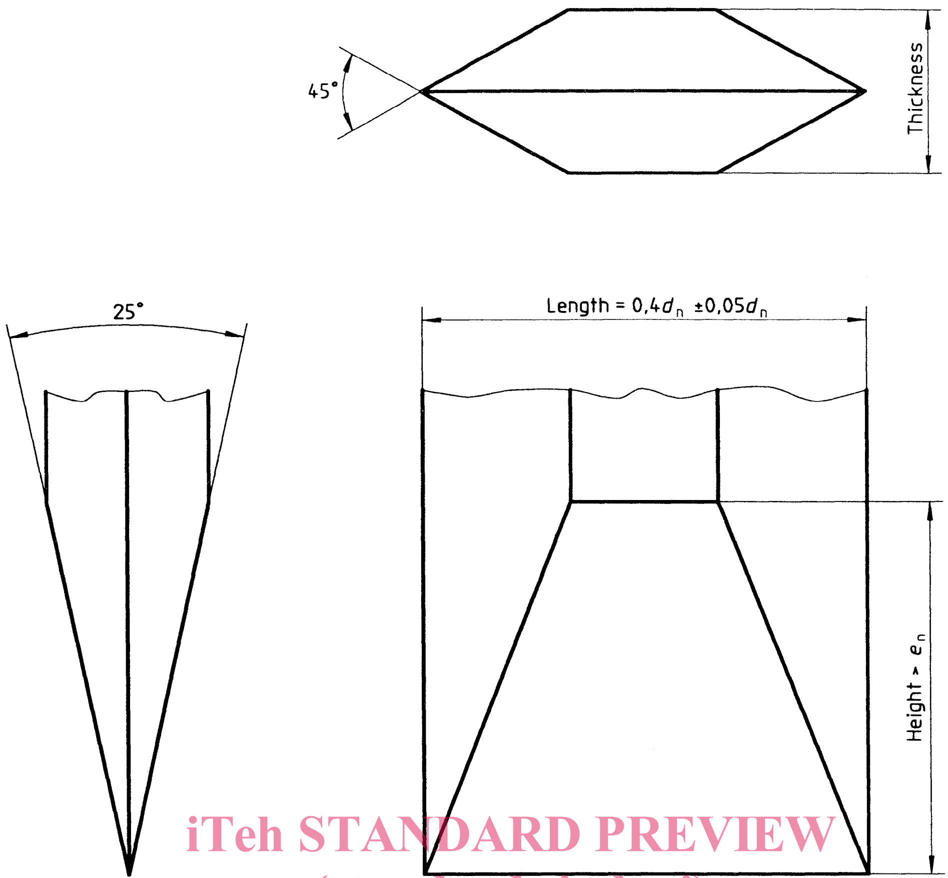

Figure 2 — Striker-blade geometry

7.5 Endcaps

Endcaps ensuring a leaktight seal shall be fitted over each end of the test pipe.

8 Test pieces

The test pieces shall be straight sections of pipe, cut with square ends to a length of $7\,d_n{}^{+1d_n}_{\;0}$

The test-pipe surfaces along the gauge length shall not be prepared or treated in any way. Chamfering of the crack-initiation end to facilitate fitting of the test pipe may be carried out.

When difficulty is encountered in the initiation of a satisfactory crack (see 10.1), internal notching of the test pipe surface along the anvil zone may be carried out. The notch shall not extend into the gauge section. A razor notch of at least 1 mm depth has been found to be satisfactory in the case of PE pipe.

9 Conditioning

The test temperature as specified by the referring standard shall usually be attained, to within ${}^{\;0}_{-2}$ °C, by immersion in a conditioning fluid. The conditioning time shall be at least as defined in ISO 1167 for the wall thickness of the test pipe. The conditioning fluid shall not affect the properties of the pipe.

All necessary precautions shall be taken to ensure that no significant increase in the temperature of the test pipe occurs prior to testing. Crack initiation shall follow within 3 min of removal of the test pipe from the conditioning fluid.

10 Test procedure

10.1 Using unpressurized pipe sections having a minimum gauge length of 5 d_n, establish initiation conditions to generate a crack length a of at least 1 d_n. The striker velocity shall be 15 m/s ± 5 m/s. If necessary, introduce a notch (see clause 8).

10.2 Maintaining these initiation conditions, pressurize the test pipe with the specified pressurizing fluid to the test pressure within ± 1 %. Perform the test and measure the crack length a.

11 Interpretation of results

Crack arrest is defined as having taken place when $a \leqslant 4{,}7\ d_n$.

Crack propagation is defined as having taken place when $a > 4{,}7\ d_n$.

12 Test report

The test report shall include the following information:

a) a reference to this International Standard and to the referring standard;

b) all details necessary for complete identification of the test pipe(s), including the manufacturer, the polymer used for manufacture, the production date(s) and the identification marking on the test pipe(s);

c) the nominal pipe diameter(s) and pipe series;

d) the gauge length(s);

e) the test temperature(s) and conditioning method;

f) the test pressure(s);

g) the crack length(s) a;

h) a statement as to whether rapid crack propagation or arrest occurred;

i) the date(s) of the test(s);

j) details of any factors which may have affected the results, such as any incidents or any operations not specified in this International Standard.

Annex A
(normative)

Determination of critical pressure (or hoop stress)

A.1 General

A single test which results in crack arrest indicates that the critical pressure for propagation is greater than the test pressure.

The following method is recommended for determining, at a given temperature, the critical pressure (or hoop stress) above which a crack initiated through the wall of a thermoplastics pipe will propagate steadily along the pipe.

A.2 Symbols

p	Test pressure, in bars
p_{cS4}	Critical pressure, in bars
σ_{cS4}	Critical hoop stress, in megapascals
d_{em}	Mean outside diameter of test pipe, in millimetres
D	Average of the mean outside diameters d_{em}, in millimetres
e_t	Mean wall thickness of test pipe along (main) crack, in millimetres

A.3 Principle

A series of tests at various pressures but constant temperature is used to determine the critical pressure (or critical hoop stress) at which there is a sharp transition from abrupt arrest of an initial crack to continued steady propagation of the crack.

A.4 Procedure

A.4.1 General

Using a range of test pressures, and following the procedure in clause 10, obtain

a) at least one test result with crack arrest (i.e. $a \leqslant 4{,}7\ d_n$);

b) at least one test result with crack propagation (i.e. $a > 4{,}7\ d_n$).

A.4.2 Critical hoop stress

A.4.2.1 Preparation

Using a π-tape, measure the mean outside diameter d_{em}, in accordance with ISO 3126, at three points along the test pipe. Calculate and record the average of these results as D.

A.4.2.2 After testing

Measure the wall thickness, in accordance with ISO 3126, at intervals along the test pipe adjacent to the crack path, or main crack path if there is more than one. Record the individual wall-thickness values, and calculate and record the mean value e_t.

If fracture is accompanied by wall thinning, carry out all the thickness measurements a sufficient distance away from the crack path.

A.5 Analysis to determine critical pressure

It is useful to plot a graph of crack length against test pressure (see figure A.1).

The critical pressure p_{cS4} is defined as the highest crack-arrest pressure below the lowest crack-propagation pressure.

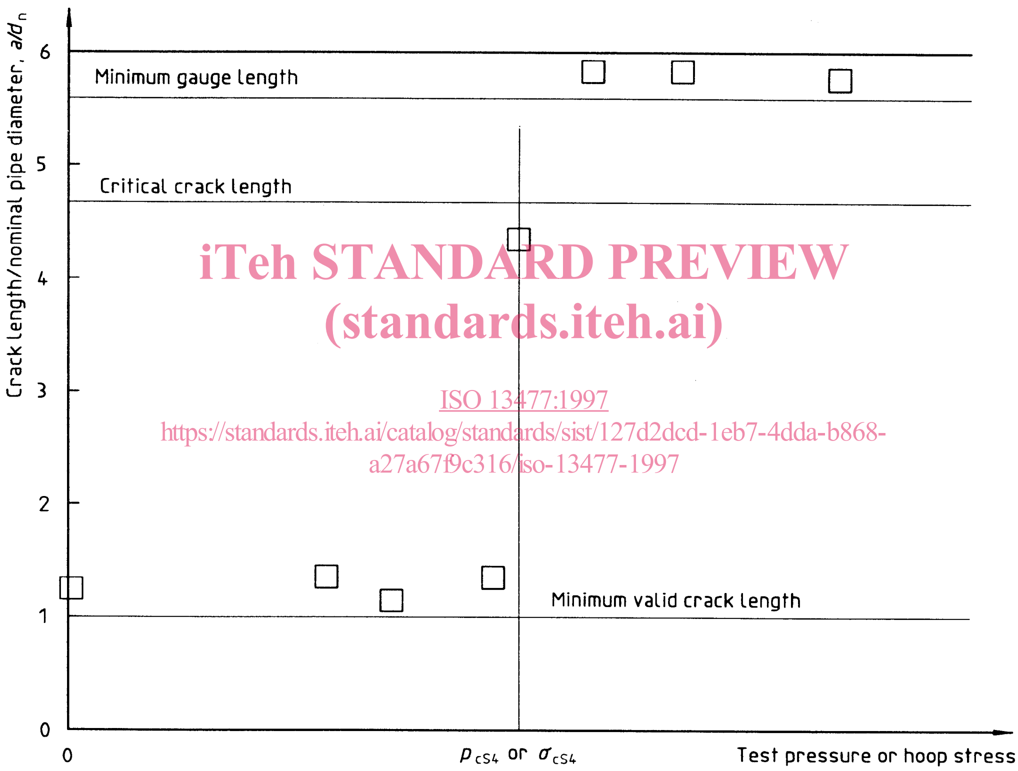

Figure A.1 — Typical test-data plot to determine critical pressure or critical hoop stress (p_{cS4} or σ_{cS4})

A.6 Analysis to determine critical hoop stress

For each test pipe, calculate the hoop stress σ, in megapascals, using the following equation:

$$\sigma = \frac{p(D - e_t)}{20 e_t}$$

where

p is the test pressure, in bars;