BS ISO 16877:2015

BSI Standards Publication

Round steel short link chains for lifting purposes — Fine tolerance hoist chains for hand operated chain hoists — Grade TH

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National foreword

This British Standard is the UK implementation of ISO 16877:2015. It supersedes BS ISO 16877:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MHE/1, Chains and fittings.

A list of organizations represented on this committee can be obtained on request to its secretary.

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INTERNATIONAL STANDARD

ISO 16877

Second edition
2015-01-15

Round steel short link chains for lifting purposes — Fine tolerance hoist chains for hand operated chain hoists — Grade TH

Chaînes de levage en acier de section ronde à maillons courts — Chaînes de levage de tolérance fine pour palans manuels — Classe de qualité TH

Reference number
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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 111, *Round steel link chains, chain slings, components and accessories*, Subcommittee SC 1, *Chains and chain slings*.

This second edition cancels and replaces the first edition (ISO 16877:2008). Subclause 6.4.5 "Toughness" has been technically revised.

INTERNATIONAL STANDARD ISO 16877:2015(E)

Round steel short link chains for lifting purposes — Fine tolerance hoist chains for hand operated chain hoists — Grade TH

1 Scope

This International Standard specifies the requirements for fine-tolerance hoist chains of grade TH for use as load chains in hand operated chain hoists for lifting purposes. They are round steel short link chains, electrically welded, heat treated, and tested; they comply with the general conditions of acceptance of ISO 1834.

NOTE 1 The letter "T" expresses the grade in accordance with ISO 1834.

NOTE 2 The letter "H" expresses that these hoist chains are for hand operated hoists only.

NOTE 3 Resistance butt welding and flash welding are listed in ISO 4063.

The range of nominal sizes covered by this International Standard is from 3 mm to 13 mm. Fine-tolerance hoist chains, according to this International Standard, are for use in the temperature range –10 °C to 200 °C.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 497, *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers*

ISO 643, *Steels — Micrographic determination of the apparent grain size*

ISO 1834, *Short link chain for lifting purposes — General conditions of acceptance*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 14556, *Steel — Charpy V-notch pendulum impact test — Instrumented test method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1834 and the following apply.

3.1
standard gauge length
multiple pitch length based on 11 chain links

4 General conditions of acceptance

The hoist chains shall comply with the requirements of ISO 1834, as well as those of this International Standard.

5 Dimensions

5.1 Nominal size, d_n

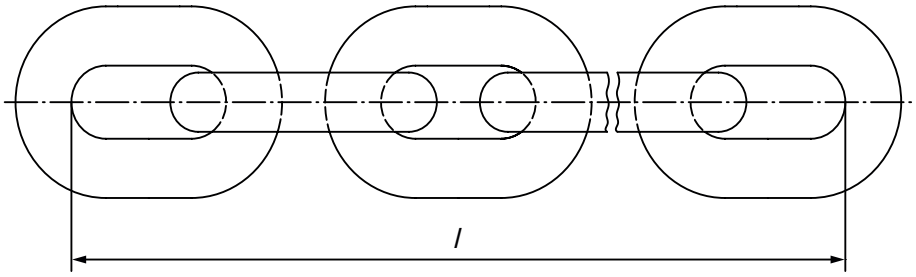
A selection of nominal sizes, d_n, of hoist chains is presented in Table 1, column 1. Other nominal sizes may be used, provided that the dimensions and tolerances are calculated in accordance with Annex A.

Table 1 — Typical dimensions (see **Figure 1**)

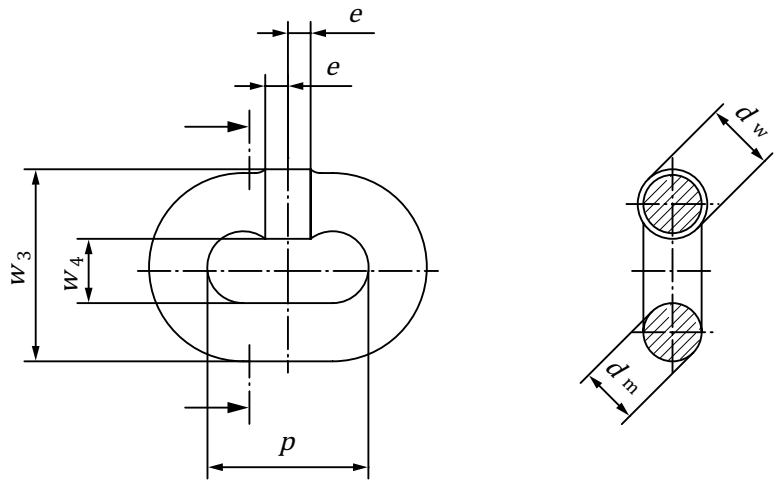
Dimensions in millimetres

1	2	3	4	5	6	7	8	9	10	11
Nominal size	**Diameter tolerance**	**Pitch**		**Width**			**Standard gauge length**		**Weld diameter**	
				Internal	**External**	**Internal**				
		Nominal	**Tolerance**	**Type 2**	**Types 1 and 2**	**Type 1**	**Nominal**	**Tolerance**	**Types 1 and 2**	**Type 2**
d_n		p_n		w_1 min.	w_3 max.	w_4 min.	l_n		d_w max.	G max.
3	±0,2	9,0	0,2	3,8	10,7	3,6	99	0,5	3,3	3,8
4	±0,2	12,0	0,3	5,0	14,3	4,8	132	0,6	4,3	5,0
5	±0,2	15,0	0,3	6,3	17,9	6,0	165	0,8	5,4	6,3
6,3	±0,3	18,9	0,4	7,9	22,6	7,6	208	1,0	6,8	7,9
7,1	±0,3	21,3	0,4	8,9	25,4	8,5	234	1,1	7,7	8,9
8	±0,3	24,0	0,5	10,0	28,6	9,6	264	1,3	8,6	10,0
9	±0,4	27,0	0,5	11,3	32,2	10,8	297	1,4	9,8	11,3
10	±0,4	30,0	0,6	12,5	35,8	12,0	330	1,6	10,8	12,5
11,2	±0,4	33,6	0,7	14,0	40,1	13,4	370	1,8	12,1	14,0
12,5	±0,5	37,5	0,7	15,6	44,8	15,0	413	2,0	13,5	15,6
13	±0,5	39,0	0,8	16,3	46,6	15,6	429	2,1	14,1	16,3

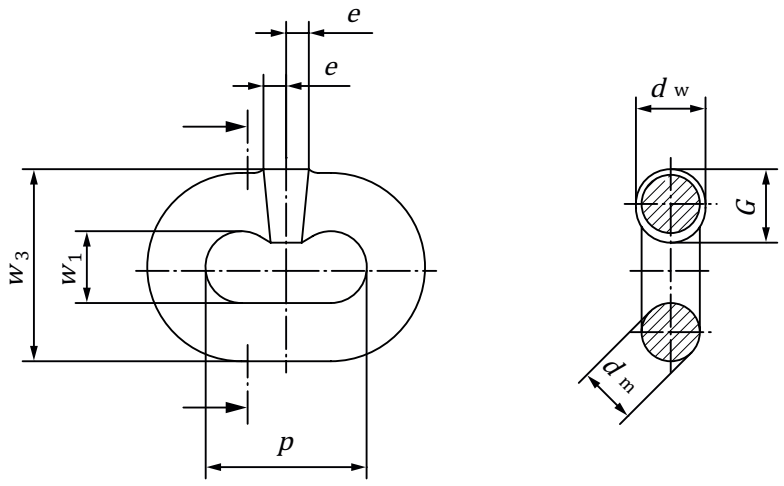
NOTE Typical dimensions for the selected nominal sizes are given, calculated, and rounded in this table, in accordance with the formulae specified in Annex A, based upon a nominal pitch of $3d_n$.



a) Multiple pitch length



b) Dimensions of chain link — Type 1



c) Dimensions of chain link — Type 2

Key

l multiple pitch length

p pitch (internal link length)

d_m measured diameter of material, except at the weld

d_w measured diameter of material at the weld (type 1) or weld dimension perpendicular to the plane of the chain link (type 2)

G dimension in other planes (type 2)

e length affected by welding, on either side of the centre of the chain link

w_1 internal width away from the weld (type 2)

w_3 external width over the weld (type 1 and type 2)

w_4 internal width at the weld (type 1)

Figure 1 — Chain link and chain dimensions

5.2 Diameter tolerance

The definition of the material diameter and method of measurement shall be in accordance with ISO 1834. The diameter tolerance of the selected nominal sizes shall be as listed in Table 1, column 2 and shall be calculated in accordance with Annex A.

5.3 Pitch

The dimensions and tolerances of the pitch for the selected nominal sizes shall be as listed in Table 1, column 3 and column 4, as shown in Figure 1, and calculated in accordance with Annex A.

The nominal pitch, p_n, is based upon $3d_n$ (where d_n is the nominal size of the hoist chain). This formula can be varied up to a maximum of $3{,}3d_n$, subject also to the tolerances specified in Annex A.

5.4 Width

The dimensions of the width for the selected nominal sizes shall be as listed in Table 1, column 5, column 6, and column 7, as shown in Figure 1, and calculated in accordance with Annex A.

5.5 Standard gauge length

The dimensions and tolerances of the standard gauge length for the selected nominal sizes shall be as listed in Table 1, column 8 and column 9 and calculated in accordance with Annex A.

5.6 Weld diameter

The maximum diameter at the weld for the selected nominal sizes shall be as listed in Table 1, column 10 and column 11, as shown in Figure 1, and shall not exceed the following:

— type 1: the maximum diameter at the weld shall not be in excess of 8 % above the nominal size in any direction;

— type 2: the maximum diameter at the weld shall not be in excess of 8 % above the nominal size in any direction perpendicular to the plane of the chain link and 25 % in the other planes;

— the diameter of the steel at the weld shall nowhere be less than the actual diameter of the steel adjacent to the weld.

5.7 Length dimensionally affected by welding

The length dimensionally affected by welding, e, shall not extend by more than $0{,}6d_n$ to either side of the centre of the chain link (see Figure 1).

6 Material and manufacture

6.1 Quality of material

6.1.1 General

Within the limitations given in 6.1.2 to 6.1.5, it is the responsibility of the manufacturer of the hoist chain to select the type of steel to be used so that the finished hoist chain, when suitably heat treated, complies with the mechanical properties specified in this International Standard and also possesses adequate low-temperature ductility and toughness to provide resistance against impact loading.

The low-temperature ductility and toughness shall be achieved by complying with the toughness-testing requirements specified in 6.4.6.

6.1.2 Type of steel

The steel used shall be produced by the electric process or by an oxygen-blown process.

6.1.3 Deoxidation

The steel shall be fully killed and shall be made in conformity with a suitable deoxidation process in order to obtain an austenitic grain size of five or finer when tested in accordance with ISO 643.

To ensure the hoist chain is stabilized against strain-age embrittlement during services, the steel shall contain at least 0,025 % aluminium.

6.1.4 Weldability

The steel shall be of reliable weldable quality.

6.1.5 Chemical composition

The steel shall contain alloying elements in sufficient quantities so that the finished hoist chain, when heat treated in accordance with 6.2, complies with the mechanical properties specified in this International Standard.

The steel shall contain no more sulfur and phosphorus than the limits given in Table 2.

Table 2 — Sulfur and phosphorus content

Element	Max. content (% by mass) as determined by	
	Cast analysis	Check analysis
Sulfur (S)	0,025	0,030
Phosphorus (P)	0,025	0,030
Sum of S + P	0,045	0,055

6.1.6 Finished condition

In its finished condition, as supplied to the manufacturer of the hoist chain, the steel shall comply with the requirements of 6.1.2 to 6.1.5 as determined by check analysis on the rod, wire, or finished chain link.

6.2 Heat treatment

Hoist chains shall be hardened from a temperature above the Ac_3 point and tempered before being subjected to the manufacturing proof force (MPF), F_{MP}.

6.3 Working load limits (WLL)

Table 3 gives values for the working load limits (WLL), calculated on the basis given in Annex A for the selected nominal sizes.

For nominal sizes not included in Table 3, the values for the working load limits (WLL) shall be calculated in accordance with Annex A.

Table 3 — Working load limits (WLL)

Nominal size d_n	**Working load limit (WLL)** t
3	0,28
4	0,5
5	0,8
6,3	1,25
7,1	1,6
8	2,0
9	2,5
10	3,15
11,2	4,0
12,5	5,0
13	5,3

6.4 Mechanical properties

6.4.1 Manufacturing proof force (MPF)

All hoist chains shall be subjected to the manufacturing proof force (MPF), F_{MP}, at least equal to that calculated on the basis given in Annex A. For the selected nominal sizes, values are given in Table 4, column 2.

Table 4 — Manufacturing proof forces (MPF), breaking forces (BF), and bend deflection

1	**2**	**3**	**4**
Nominal size d_n	**Manufacturing proof force (MPF)** F_{MP} kN min.	**Breaking force (BF)** F_B kN min.	**Bend deflection** f mm min.
3	7,1	11,3	2
4	12,6	20,1	3
5	19,6	31,4	4
6,3	31,2	49,9	5
7,1	39,6	63,3	6
8	50,3	80,4	6
9	63,6	102,0	7
10	78,5	126,0	8

Table 4 *(continued)*

1	2	3	4
Nominal size d_n	**Manufacturing proof force (MPF)** F_{MP} kN min.	**Breaking force (BF)** F_B kN min.	**Bend deflection** f mm min.
11,2	98,5	158,0	9
12,5	123,0	196,0	10
13	133,0	212,0	10

6.4.2 Breaking force (BF)

Samples of hoist chain in the finished condition shall have a breaking force (BF), F_B, at least equal to that calculated on the basis given in Annex A. For the selected nominal sizes, values are given in Table 4, column 3.

6.4.3 Total ultimate elongation, *A*

On completion of the tensile test, the minimum total ultimate elongation, *A*, shall be in accordance with the value given in Table 5.

6.4.4 Bend deflection, *f*

Samples of single chain links shall withstand the minimum value of the deflection, *f*, calculated on the basis given in Table 5. For the selected nominal sizes, values are given in Table 4, column 4.

The samples shall be free from visible defects.

6.4.5 Surface hardness

The surface hardness at each of the two measuring points, as shown in Figure 6, shall be at least equal to the specified value in Table 5.

6.4.6 Toughness

The toughness of the finished hoist chain shall be verified by impact test method on full-size, subsize, or super subsize specimens.

The lowest service temperature (T) of the hoist chain shall be $T \geq T_{NDT}$ −20K, as a result of ISO/TR 23602. Based on a correlation between *KV* shift and the T_{NDT} shift, a *KV-T* master curve with the requirement of *KV* (0 °C) ≥ 30 J results in a value T_{NDT} −20K of ≤−10 °C. Therefore, a lowest temperature during the operation of −10 °C is possible.

Full-size specimens shall be tested in accordance with ISO 148-1. On the other hand, subsize specimens shall be tested in accordance with ISO 14556. If the chain leg is too short to extract a full-length subsize specimen, the subsize specimens shall be produced according to Figure 3 by joining additional leg parts using laser welding. Super subsize specimens shall then be tested in accordance with ISO 14556, except that the specimen dimensions shall be in accordance with Figure 4. Super subsize specimens shall be produced by joining additional leg parts using pulsed micro-laser welding. The settings for laser welding and pulsed micro-laser welding shall be such that the hardness and micro-structure of the specimen are not affected in the area of the notch. After welding, the specimens shall be machined to the specified dimensions.

Either pendulum impact type or drop weight type test equipment may be used, taking account of the accuracy of measurement of the toughness value.

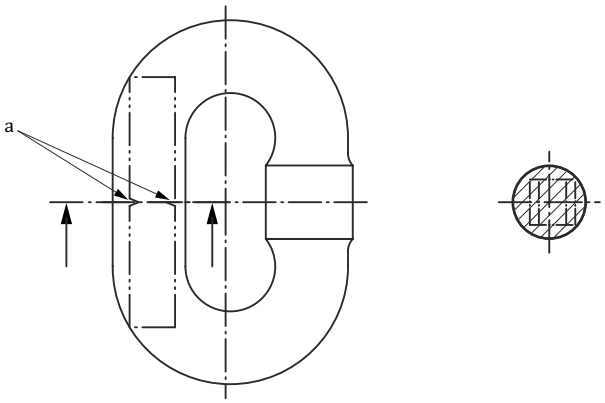
If the chain link is large enough to extract a full-size specimen, the tests shall be carried out on full-size specimens. Three specimens shall be tested, each of which shall achieve a *KV* toughness of at least 30 J at a test temperature of 0 °C.

If the chain link is too small to extract a full-size specimen but large enough to extract a subsize specimen or a welded on subsize specimen, the tests shall be carried out on subsize specimens, which shall achieve a *KV* toughness of at least 3,5 J at a test temperature of 0 °C. To ensure that the distance of the test temperature to the brittle-tough-transition temperature is sufficient, *KV* toughness 3,5 J shall be $1/2\ E_{US}$ +1 J [half upper shelf energy (USE) +1 J] or more. The test shall be carried out on 10 specimens, and the mean value used as the *KV* toughness value. The range of scattering shall be within 1,5 J.

If the chain link is too small to extract a subsize specimen, the tests shall be carried out on super subsize specimens extracted from the chain and full-size specimens made of the same material as the chain, which is heat treated so as to achieve the same ultimate tensile strength of hardness and material as the finished hoist chain. Three full-size specimens shall be tested, each of which shall achieve a *KV* toughness of at least 30 J at a test temperature of 0 °C. Three super subsize specimens shall be tested and shall show 80 % or more non-crystalline area when tested at −50 °C.

NOTE It is assumed that the transition temperature is −50 °C or lower in that case.

The above-mentioned tests shall be repeated if the steel manufacturer or type of steel is changed or the chain manufacturer changes the manufacturing process.

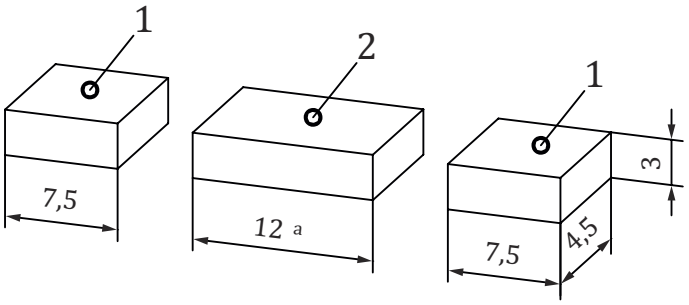


Key

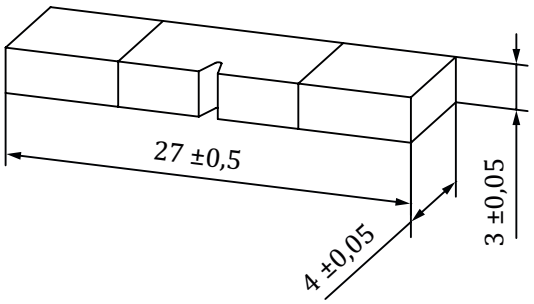
a Alternatives for orientation of the notch.

Figure 2 — Source of specimen and orientation of the notch

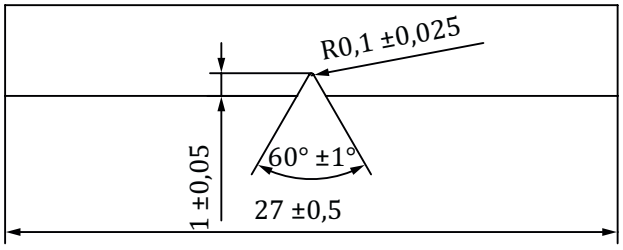
Dimensions in millimetres



a) Typical geometry of the specimen before welding



b) Welded on specimen after machining



c) Notch dimensions

Key

1 part for welding on

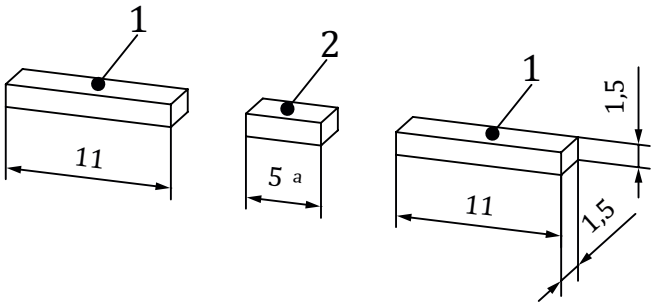
2 part of the chain leg

a Minimum length of the chain material to be tested.

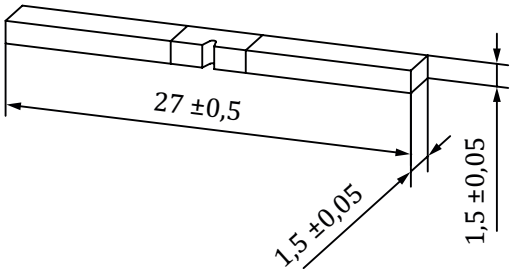
NOTE The geometry of the pendulum is in accordance with ISO 14556:2000/Amd.1:2006, Figure D.1.

Figure 3 — Subsize specimen

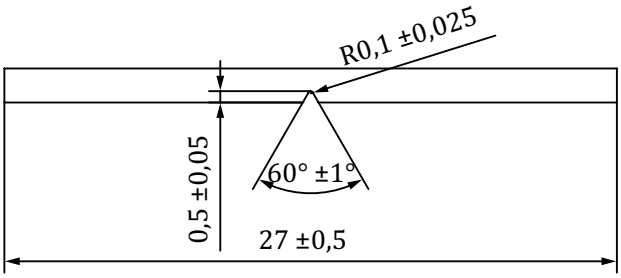
Dimensions in millimetres



a) Typical geometry of the specimen before welding



b) Notched specimen after welding



c) Notch dimensions

Key

1 part for welding on

2 part of the chain leg

a Minimum length of the chain material to be tested.

NOTE The geometry of the pendulum is in accordance with ISO 14556:2000/Amd.1:2006, Figure D.1.

Figure 4 — Super subsize specimen

Table 5 — Mechanical properties

Line	Mechanical property		Requirement
1	Specified minimum nominal stress at breaking force (BF), F_B:	$\sigma_{BF\,min} = \frac{2(F_B)}{\pi d_n{}^2}$	800 N/mm^2
2	Specified minimum nominal stress at manufacturing proof force (MPF), F_{MP}:	$\sigma_{MPF\,min} = \frac{2(F_{MP})}{\pi d_n{}^2}$	500 N/mm^2
3	Percentage ratio of specified minimum nominal stress at manufacturing proof force (MPF), F_{MP}, to the specified minimum nominal stress at breaking force (BF), F_B:	$\frac{\sigma_{MPF\,min}}{\sigma_{BF\,min}}$	62,5 %
4	Specified minimum total ultimate elongation, A		15 %
5	Specified minimum bend deflection, f		$0{,}8d_n$
6	Specified maximum nominal stress at working load limit (WLL)	$\sigma_{WLL\,max}$	200 N/mm^2
7	Specified minimum surface hardness		360 HV10
8	Specified minimum *KV* toughness of full-size test specimens at 0 °C		30 J
9	Specified minimum *KV* toughness of subsize test specimens at 0 °C		3,5 J

NOTE 1 The nominal stresses given in this table are obtained by dividing the force by the total cross-section of both sides of the chain link, i.e. they are mean stresses. The stresses are in fact not uniform and at the extrados, particularly at the crown, the maximum fibre stress is considerably greater.

NOTE 2 The values for the working load can be selected to comply with the national regulations, but in no case shall they exceed the values for the working load limit in Table 3.

7 Verification of safety requirements

7.1 Size of lot and selection of samples

The size of the lot from which the samples shall be selected shall be 200 m. An excess fraction of the length of lot shall be considered as a separate lot. Samples shall then be selected in accordance with ISO 1834.

7.2 Manufacturing proof force (MPF) — Acceptance criteria

The hoist chain shall withstand the manufacturing proof force (MPF) as specified in 6.4.1.

7.3 Breaking force (BF) and total ultimate elongation — Acceptance criteria

The testing machine and test procedure for the static tensile test shall be as specified in ISO 1834.

The testing machines and equipment used in the static tensile test and the bend test (see 7.4.1) shall comply with class 1 of machine range specified in ISO 7500-1.

Upon completion of the static tensile test, the requirements of 6.4.2 and 6.4.3 shall be met.

7.4 Bend deflection

7.4.1 Bend test

The test equipment and procedure shall be as specified in ISO 1834.

Each single-link sample shall be bent by a deflection, *f*, as given in Table 4, column 4 and shown in Figure 5. Following the removal of the force, the link sample shall be examined by a competent person.

NOTE Where necessary, a surface coating can be removed after the bend test to enable this examination to be carried out.

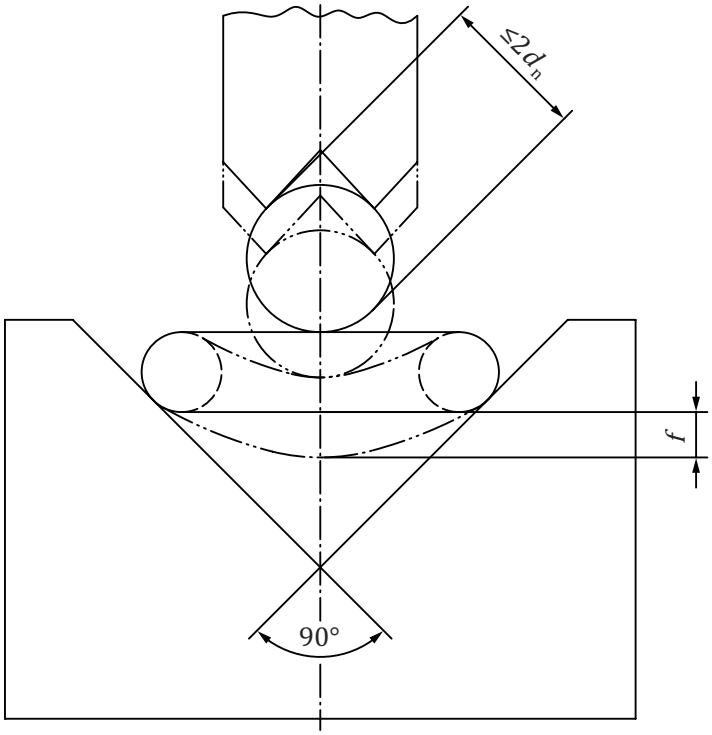


Figure 5 — Bend deflection, *f*

7.4.2 Bend deflection — Acceptance criteria

Upon completion of the bend test, the requirements of 6.4.4 shall be met.

7.5 Hardness test — Acceptance criteria

The number of samples for surface hardness testing shall be the same as those required for the static tensile test and bend test specified in ISO 1834. Each sample, in accordance with ISO 1834, shall consist of three single links.

Each single link shall be subjected to surface hardness testing, carried out in accordance with ISO 6507-1, with measurements taken at two points as shown in Figure 6.

Special jigging shall be used to ensure that the curvature of the link surface does not affect the validity of the measurements taken. Each result shall then meet the requirements of 6.4.5.

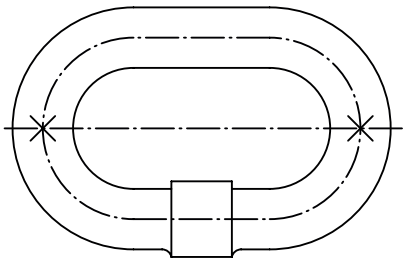


Figure 6 — Hardness test measurement points

7.6 Toughness of chain test material

7.6.1 Toughness test

Specimens shall be tested in accordance with ISO 148-1 or ISO 14556, as appropriate according to the size of the specimen.

7.6.2 Toughness test — Acceptance criteria

The requirements of 6.4.6 shall be met. The requirements shall be verified by the testing of a specimen at a temperature in the upper shelf with a 100 % non-crystalline area as the basis for Formula (1).

$$E_D \geq \frac{1}{2} E_{US} + 1\ J \quad (1)$$

where

E_D is the design energy, expressed in joules;

E_{US} is the upper shelf energy, expressed in joules.

8 Marking

8.1 Grade marking

The grade mark for the hoist chain is “TH”. The marking shall conform to ISO 1834 and shall be applied as specified in ISO 1834.

8.2 Manufacturer’s marking

The manufacturer’s mark shall be applied as specified in ISO 1834.

9 Manufacturer’s certificate

The manufacturer shall, if required, supply a certificate of testing and examination with every supply of hoist chain containing the information detailed in ISO 1834.

10 Information for assembly into the chain hoist and for use

10.1 General

The following information is to assist the manufacturer of the hoist chain to prepare information for assembly of the hoist chain into the chain hoist and for its use. The manufacturer can provide additional information, but in order to perform satisfactorily in the service, the minimum requirements of 10.2 to 10.4 shall be met.

10.2 Assembly of hoist chain into the chain hoist

To ensure a smooth running of the hoist chain over the pocket wheels without unusual impacts, the driven pocket wheels and idle pocket wheels shall be designed to suit the hoist chain.

The hoist chain shall be guided smoothly and without twist into and out of the pocket wheels.

To avoid deformation of the last chain link of the hoist chain, the chain-connecting parts of the chain hoist shall be designed in a way to permit at least 5 % free movement relative to the inside width of the chain link.

10.3 Hoist chain use

WARNING — Hoist chains shall not be used as parts of chain slings. Also, the hoist chain in a chain hoist shall not be used as sling chain in basket hitch or choke hitch as illustrated in ISO 3056.

Hoist chains will not be adversely affected by temperatures down to –10°C, and therefore, no reduction in the working load limit (WLL) is necessary. Where hoist chains are to be used at temperatures below –10°C, the manufacturer shall be consulted.

Hoist chains shall not be galvanized or subjected to any plating processes without the approval of the manufacturer.

Hoist chains shall also not be allowed to pick up dirt, etc. that would impair its free movement.

In order to attain maximum service life of hoist chains, adequate lubrication, particularly in the interlink contact areas, is necessary.

10.4 Inspection

The procedures to be followed by the operator for the inspection of hoist chains at intervals in the service shall be in accordance with the hoist manufacturer's instructions, covering inspection, discard criteria, and records.

NOTE Further general guidance on hoist chain inspection procedures is given in ISO 7592:1983, Annex B.

Annex A
(normative)

Bases for calculation

A.1 Nominal size

The nominal size for the selected hoist chains, except for the nominal sizes 3 and 13, are following the R20 series of preferred number in accordance with ISO 497.

A.2 Diameter tolerance

The diameter tolerance shall be ±4 % of the nominal size of the hoist chain.

A.3 Pitch, multiple pitch, and width

The dimensions specified in Table 1 are based on the following formulae:

— nominal pitch, p_n, based upon $3d_n$ with a maximum nominal value of $3{,}3d_n$;

— minimum internal width, $w_4 = 1{,}2d_n$, at the weld;

— minimum internal width, $w_1 = 1{,}25d_n$, away from the weld;

— maximum external width, $w_3 = 3{,}75d_n$, over the weld.

The tolerance for both the pitch and the standard gauge length is based on the following tolerance formula:

$$\left(\frac{1{,}65}{n} + 0{,}33\right) \text{in } \% \tag{A.1}$$

where

n is the number of chain links.

This tolerance is usually divided into +2/3 and −1/3 for both the pitch and the standard gauge length.

The dimensions given in Table 1 are fully calculated values, rounded to the nearest 0,1 mm for values up to 100 mm. Values ≥100 mm are rounded to the nearest 1 mm. The dimensions and tolerance for the nominal sizes other than those given in Table 1 shall be calculated using the above formulae.

A.4 Weld diameter

The diameter at the weld shall not exceed $1{,}08d_n$ (d_w for Type 1 and Type 2) or $1{,}25d_n$ (G for Type 2).

A.5 Working load limits and test requirements

A.5.1 General

The stresses used in the calculation of the values for WLL, MPF, and BF in Formulae (A.2) to (A.4), given in A.5.2 to A.5.4, are nominal stresses as follows:

a) maximum nominal stress at working load limit (WLL): $\sigma_{\mathrm{WLL\,max}} = 200\,\mathrm{N/mm^2}$;

b) minimum nominal stress at manufacturing proof force (MPF): $\sigma_{\mathrm{MPF\,min}} = 500\,\mathrm{N/mm^2}$;

c) minimum nominal stress at breaking force (BF): $\sigma_{\mathrm{BF\,min}} = 800\,\mathrm{N/mm^2}$.

A.5.2 Working load limit (WLL)

The maximum rounded values for the working load limit (WLL), such as those listed for the selected nominal sizes in Table 3, column 1, are based on Formula (A.2):

$$M_{\mathrm{WLLmax}} = \frac{2 \times \frac{1}{4} \times \pi \times 200 \times d_n^2}{g \times 1\,000} \qquad \text{(A.2)}$$

$$M_{\mathrm{WLL\,max}} = 0{,}032\,035\,{d_{\mathrm{n}}}^2$$

where

M_{WLLmax} is the working load limit (WLL), expressed in tonnes;

g is the acceleration due to gravity, expressed in metres per square second ($\mathrm{m/s^2}$, i.e. 9,806 65).

Based upon ISO 2374, the calculated values are rounded down to the nearest lower value of the R40 series of preferred numbers in accordance with ISO 497. These rounded values are listed in Table 3.

A.5.3 Manufacturing proof force (MPF)

The minimum rounded values for the manufacturing proof force (MPF), such as those listed for the selected nominal sizes in Table 4, column 2, are based on Formula (A.3):

$$F_{\mathrm{MPmin}} = \frac{2 \times \frac{1}{4} \times \pi \times 500 \times d_n^2}{1\,000} \qquad \text{(A.3)}$$

$$F_{\mathrm{MPmin}} = 0{,}785\,398\,{d_{\mathrm{n}}}^2$$

where

F_{MPmin} is the manufacturing proof force (MPF), expressed in kilonewtons.

The calculated values <100 kN are rounded to 0,1 kN. The calculated values ≥100 kN are then rounded to 1 kN. These rounded values are listed in Table 4, column 2.

A.5.4 Breaking force (BF)

The minimum rounded values for the breaking force (BF), such as those listed for the selected nominal sizes in Table 4, column 3, are based on Formula (A.4):

$$F_{\mathrm{B\,min}} = \frac{2 \times \frac{1}{4} \times \pi \times 800 \times d_{\mathrm{n}}^{2}}{1\,000}$$

$$F_{\mathrm{B\,min}} = 1{,}256\,637\, d_{\mathrm{n}}{}^{2} \qquad \text{(A.4)}$$

where

$F_{\mathrm{B\,min}}$ is the breaking force (BF), expressed in kilonewtons.

The calculated values <100 kN are rounded to 0,1 kN. The calculated values ≥100 kN are then rounded to 1 kN. These rounded values are listed in Table 4, column 3.

A.5.5 Bend deflection

The values for the bend deflection, *f*, are based on Formula (A.5):

$$f = 0{,}8 \times d_{\mathrm{n}} \qquad \text{(A.5)}$$

where

f is the bend deflection, expressed in millimetres.

The calculated values are rounded to 1 mm. These rounded values are listed in Table 4, column 4.

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[1] ISO 2374, *Lifting appliances — Range of maximum capacities for basic models*

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