BRITISH STANDARD

BS EN 1252-2:2001

CONFIRMED
MARCH 2008

Cryogenic vessels — Materials —

Part 2: Toughness requirements for temperatures between –80 °C and –20 °C

The European Standard EN 1252-2:2001 has the status of a British Standard

ICS 23.020.40

National foreword

This British Standard is the official English language version of EN 1252-2:2001.

The UK participation in its preparation was entrusted to Technical Committee PVE/18, Cryogenic vessels, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard, having been prepared under the direction of the Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 23 August 2001

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 22, an inside back cover and a back cover.

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Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1252-2

April 2001

ICS 23.020.40

English version

Cryogenic vessels — Materials — Part 2: Toughness requirements for temperatures between -80 °C and -20 °C

This European Standard was approved by CEN on 19 January 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1252-2:2001 E

Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 268, Cryogenic vessels, the Secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2001, and conflicting national standards shall be withdrawn at the latest by October 2001.

For relationship with EC Directive(s), see informative Annex ZA, which is an integral part of this standard.

This document also supports the objectives of the framework Directives on Transport of Dangerous Goods. This standard has been submitted for reference into the RID and/or the technical annexes of the ADR.

Therefore, the standards listed in the normative references and covering basic requirements of the RID/ADR not addressed within the present document are normative only when the standards themselves are referred to in the RID and/or in the technical annexes of the ADR.

This European Standard is composed of the following parts:

EN 1252-1*, Cryogenic vessels — Materials — Part 1: Toughness requirements for temperatures below –80 °C.*

EN 1252-2, *Cryogenic vessels — Materials — Part 2: Toughness requirements for temperatures between - 80°C and - 20°C*.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

The use of materials at low temperatures entails special problems that have to be addressed. Consideration has to be given, in particular, to changes in mechanical characteristics, expansion and contraction phenomena and the thermal conduction of the various materials. The most important property to be considered is the material toughness at low temperature.

1 Scope

This European Standard specifies the toughness requirements of the metallic materials for use at a temperature between -80 °C and -20 °C ensuring suitability for use for the cryogenic vessels.

Fine grain and low alloyed steels with specified yield strength ≤ 460 N/mm², aluminium and aluminium alloys, copper and copper alloys and austenitic stainless steels are covered by this standard.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendements).

EN 10045-1, *Metallic materials — Charpy impact test — Part 1: Test method.*

EN 288-3:1992, A1:1997, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of steels.*

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply:

3.1
minimum metal temperature T_M
the lowest temperature defined for each of the following conditions (see also 3.2 and 3.3):

— temperature during normal operations;

— temperature during start up and shut down procedures;

— temperature that may occur during possible process upsets;

— temperature that may occur during pressure or leak testing.

3.2
temperature adjustment term T_S
term relevant to the calculation of the design reference temperature T_R and dependent on the pressure induced principal membrane stress at the appropriate minimum metal temperature

3.3
design reference temperature T_R
temperature used for determining the impact energy requirements

T_R is determined by adding the adjustment T_S to the minimum metal temperature T_M:

$$T_R = T_M + T_S$$

All applicable combinations of the temperatures T_M and T_S shall be considered and the lowest possible T_R-value shall be used for the determination of the required material impact test temperature.

3.4
impact test temperature T_{KV}
temperature at which the required impact energy has to be achieved (see clause 5)

3.5
impact energy KV
energy determined from Charpy-V-notch tests performed in accordance with EN 10045-1

3.6
reference thickness e_B
thickness of a component to be used to relate the design reference temperature T_R of the component with its required impact test temperature T_{KV} (see Figures 1 to 5). The reference thickness e_B is based on the nominal thickness (including corrosion allowance) and shall be as defined in Table 6. For butt welded components e_B is the nominal wall thickness of the component at the edge of the weld preparation.

4 Requirements for steels with specified yield strength ≤ 460 N/mm²

4.1 General

This method, based on fracture mechanics can be used to determine the requirements to avoid brittle fracture in C, CMn, fine grain and low alloy steels with a specified minimum yield strength ≤ 460 N/mm².

In this procedure the impact test temperature T_{KV} is not equal to the design reference temperature T_R.

Parent material, welds and HAZ shall meet the impact energy KV and impact test temperature T_{KV} requirements in Table 1 for design reference temperatures T_R and reference thicknesses e_B. Values of T_R shall be calculated from T_M using the values of T_S given in 4.2.

For materials with a specified minimum yield strength > 310 N/mm² the impact energy at T_{KV} given in Figure 1 and Figure 2 shall be 40 J. Where 27 J is specified in the product standard, Figure 3 for the post-weld heat treated condition applies. For the as welded case with minimum yield strength in the range > 310 N/mm² and ≤ 360 N/mm² Figure 4 applies. For minimum yield strength > 360 N/mm² Figure 5 applies.

Table 1 — Impact energy requirements

Specified minimum yield strength of base material N/mm²	Required impact energy KV (on 10 mm x 10 mm test pieces) J	Figure defining required T_{KV}	
		Non welded and post-weld heat treated	As welded
≤ 310	27	1	2
> 310, ≤ 360	40	1	2
	27	3	4
> 360	40	1	2
	27	3	5

4.2 Temperature adjustments

T_S is a temperature adjustment that can be used if the pressure induced principal membrane stress does not exceed the percentage of the maximum allowable design stress or 50 N/mm² given in Table 2.

Table 2 — Temperature adjustments

Condition	Percentage of maximum allowable design stress			Membrane stress [b]
	> 75 %; ≤ 100 %	≤ 75 %	≤ 50 %	≤ 50 N/mm²
Non welded or post-weld heat treated condition [a]	0 °C	+10 °C	+25 °C	+50 °C
As welded condition and reference thickness < 30 mm	0 °C	0 °C	0 °C	+40 °C

[a] Also applicable for equipment where all nozzles and non-temporary welded attachments are first welded to vessel components and these sub-assemblies are post-weld heat treated before being assembled into the equipment by butt-welding, but the main seams are not subsequently post-weld heat treated.

[b] In this case the membrane stress should take account of internal and external pressure and dead weight.

4.3 Procedure for base material lower than 10 mm thick

Minimum T_R values are given in Table 3 for use when the base material is less than 10 mm thick and the testing temperature T_{KV} is 20 °C. The impact energy requirements are as specified in the relevant materials standards.

If these materials are to be used below the T_R values given in Table 3 the testing shall be performed in accordance with the relevant curve for 10 mm in Figure 1 to Figure 5. The required energies for the sub-sized specimens are given in Table 4.

Table 3 — Minimum T_R-values for base material less than 10 mm thick and t_{KV} = 20 °C

Thickness mm	**AW** °C	**PWHT** °C
8	-20	-35
6	-25	-40
4	-40	-55
2	-55	-70

5 General test requirements

Where impact tests are required they shall be Charpy V-notched tests in accordance with EN 10045-1. The impact energy requirements shall be met in the base material, heat affected zone and weld metal. The specimen position shall be in accordance with EN 288-3:1992/A1:1997, 7.4.4. From each sample three specimens shall be tested for each of the required positions and test temperatures. The mean value of the three specimens shall be at least equal to the impact energy requirement. Only one specimen may show a lower value, but this value shall not be less than 70 % of this requirement.

The required values for base material refer to the transverse direction. If transverse properties are not obtainable, the minimum impact energy requirements specified for transverse test pieces shall be multiplied by the factor 1,5 for C, CMn, fine grained and low alloyed steels with a minimum specified yield strength ≤ 460 N/mm². (For other materials refer to product standard).

5.1 Sub-sized specimens

If the base material is less than 10 mm thick the energy requirements are given in Table 4.

Table 4 — Impact requirements for sub-sized Charpy V-notched specimen if the base material is less than 10 mm thick

Dimensions in millimetres

Specimen geometry mm x mm		
10 x 10	10 x 7,5	10 x 5
27 J	22 J	19 J
40 J	32 J	28 J

Alternatively, where proportional reduced energy requirements are preferred, Table 5 shall be applied.

5.2 Sub-sized specimens for components from which it is not possible to extract specimens of section size equal to the reference thickness

shaped components and/or weld procedure and production plates where the xtracted is either < 10 mm or not representative of the section thickness.

In these cases sub-sized specimens shall be tested at lower impact test temperature to model the behaviour for a full thickness specimen. The temperature shifts are given in Table 5.

Impact tests should be performed on the maximum thickness that can be extracted from the component under consideration.

Table 5 — Equivalent impact energy requirements when sub-sized specimens are extracted from thicker sections

Dimensions in millimetres

Required impact energy KV J	**Specimen geometry** mm x mm	**Sub-sized specimen requirement**		
		KV J	**Specimen geometry** mm x mm	**Shift of impact test temperature**
27	10 x 10	20 14	7,5 x 10 5,0 x 10	T_{KV} - 5 °C T_{KV} - 20 °C
40	10 x 10	30 20	7,5 x 10 5,0 x 10	T_{KV} - 5 °C T_{KV} - 20 °C
20	7,5 x 10	14	5,0 x 10	T_{KV} - 15 °C
30	7,5 x 10	20	5,0 x 10	T_{KV} - 15 °C

6 Welds

When materials are to be joined by welding, the choice of consumables and procedures (see EN 288 standards) shall ensure that the required impact energy properties are achieved in weld and heat affected zone regions, when tested in accordance with clause 5.

The required impact energy shall be at least equal to the specified impact energy for the base metal.

7 Requirements for aluminium and aluminium alloys, copper and copper alloys and austenitic stainless steels

Toughness of aluminium and aluminium alloys, copper and copper alloys and austenitic stainless steels is inherently high enough at low temperature to render impact test unnecessary.

Welds of austenitic stainless steels shall be impact tested if the material certificate for the weld consumable shows that it has a ferrite content exceeding 10 %.

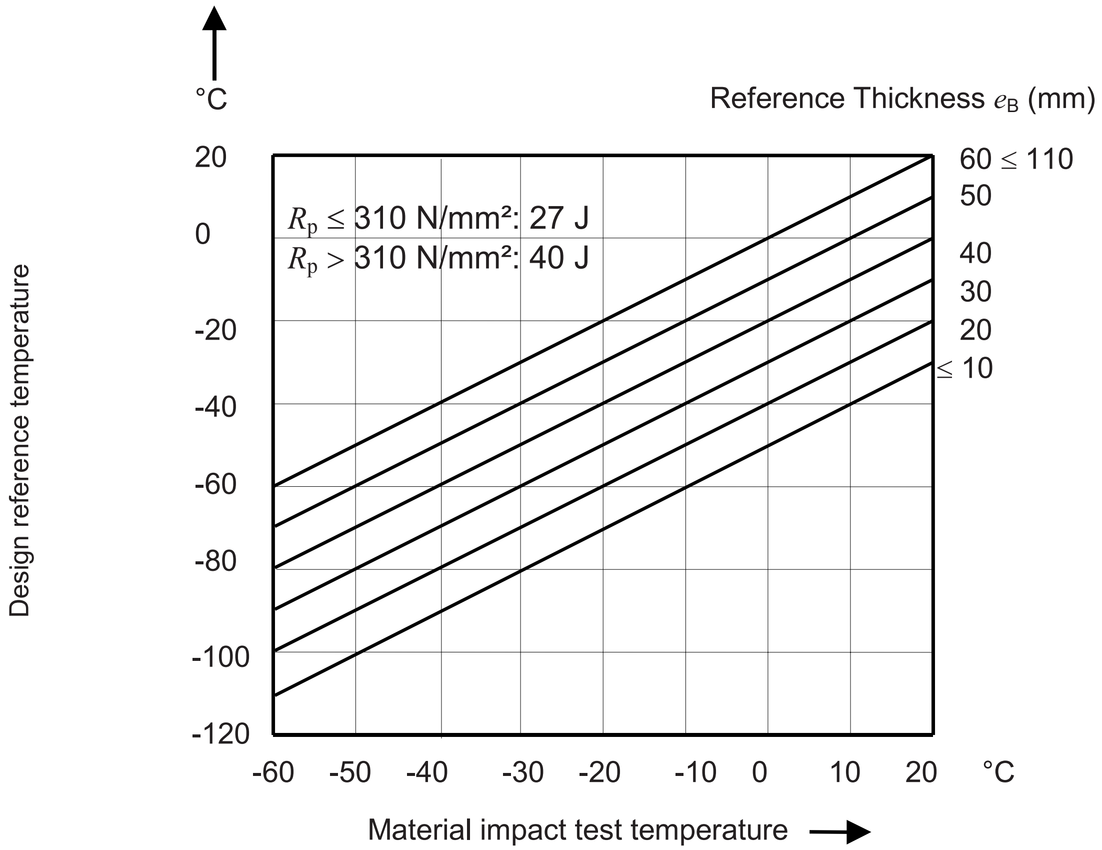


Figure 1 — Design reference temperature and impact test temperature post-weld heat treated condition

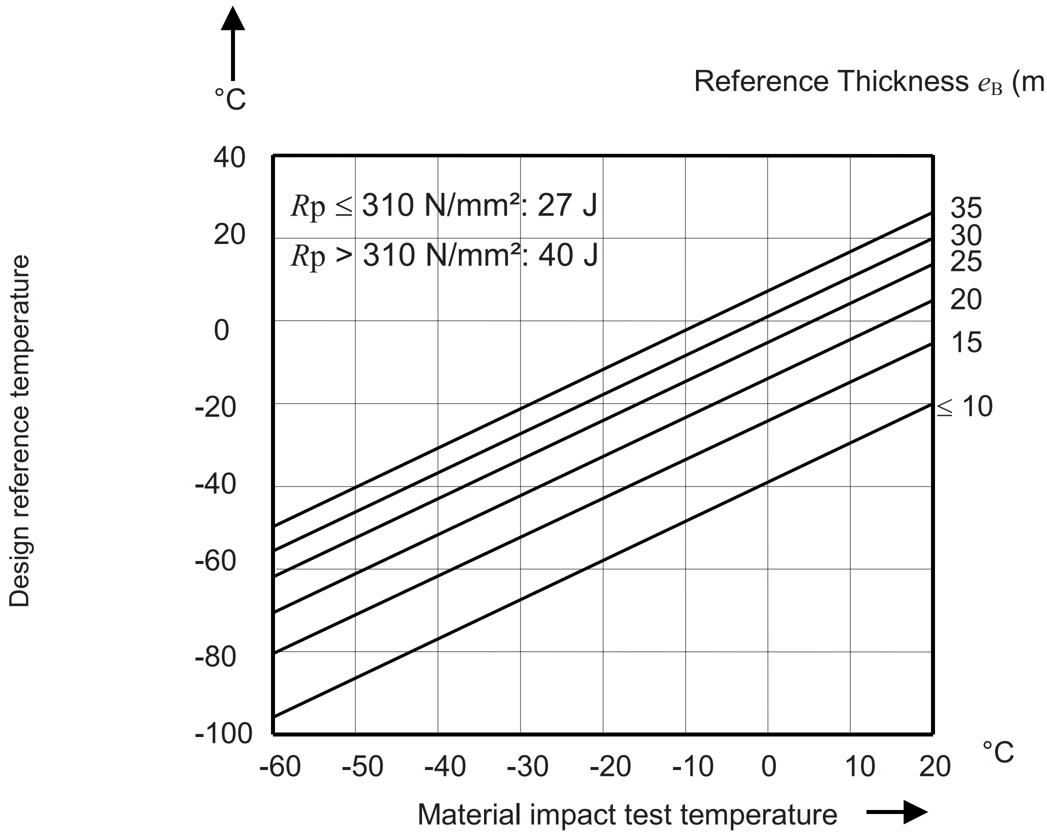
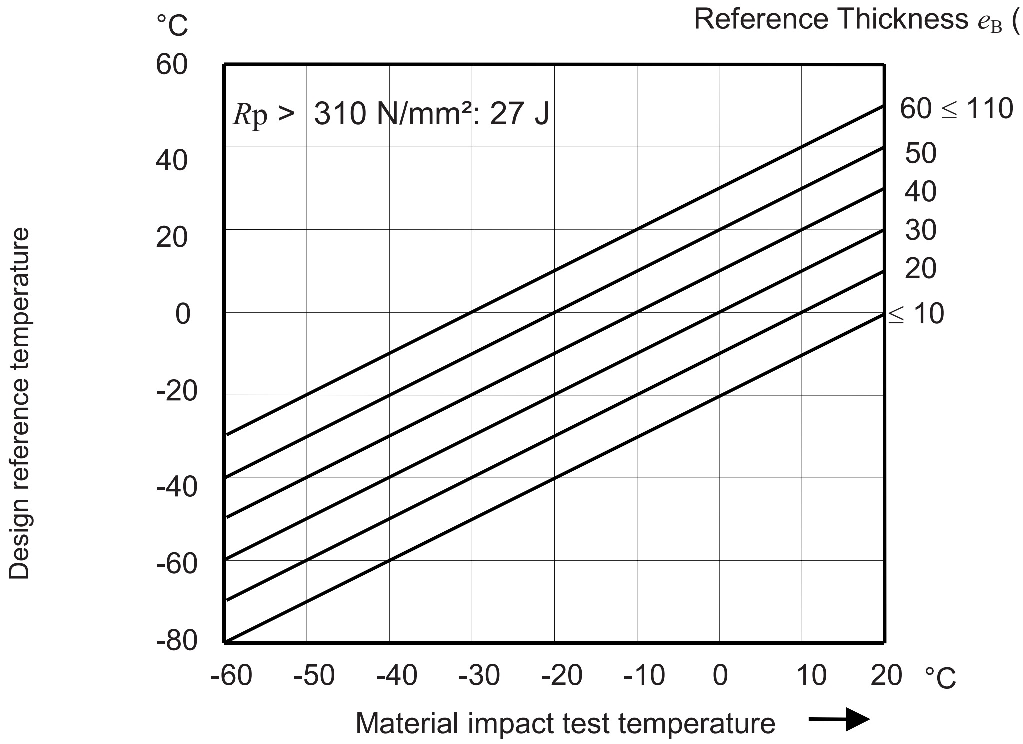


Figure 2 — Design reference temperature and impact test temperature as welded condition



...nce temperature and impact test temperature post-weld heat treated condition

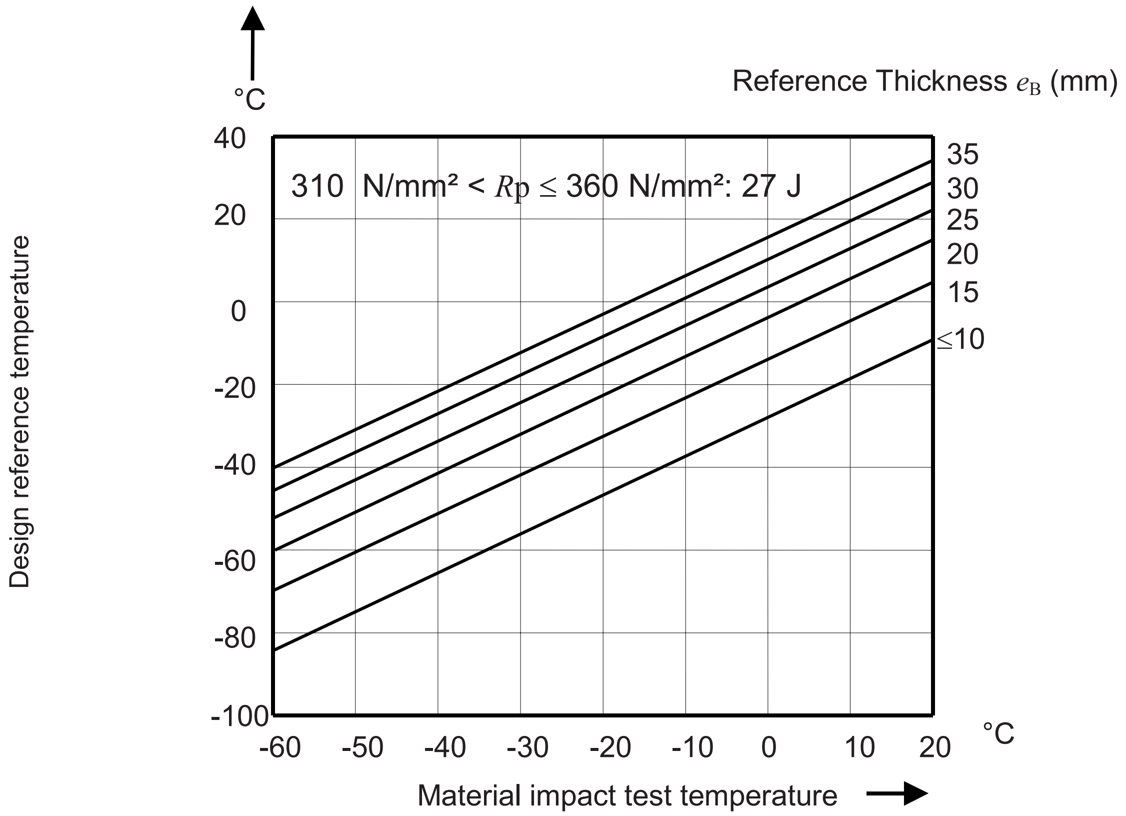
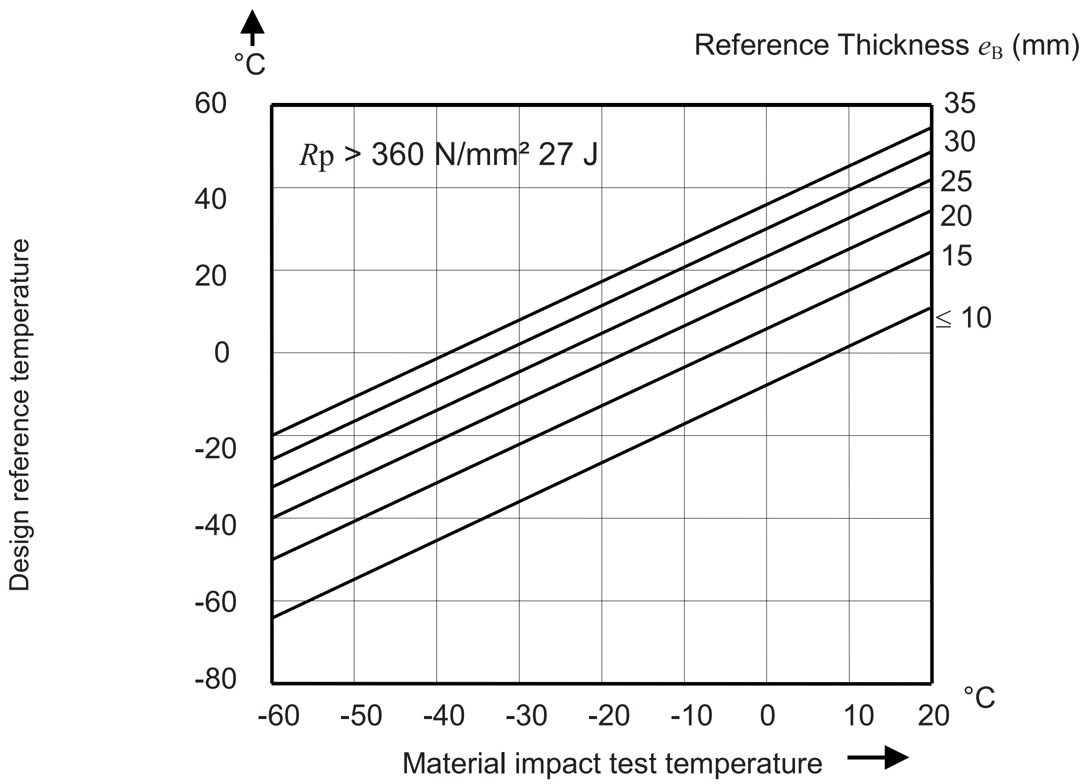
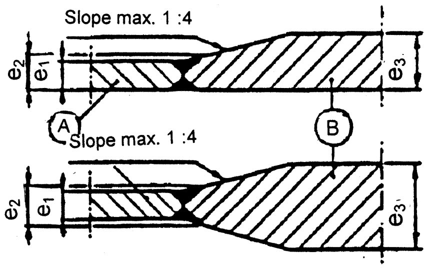
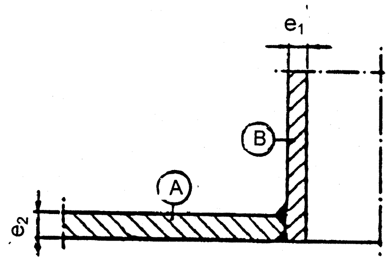
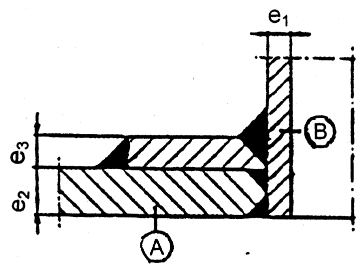
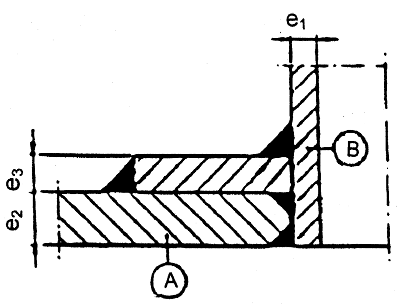


Figure 4 — Design reference temperature and impact test temperature as welded condition



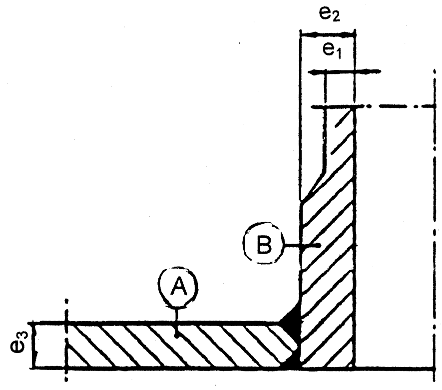
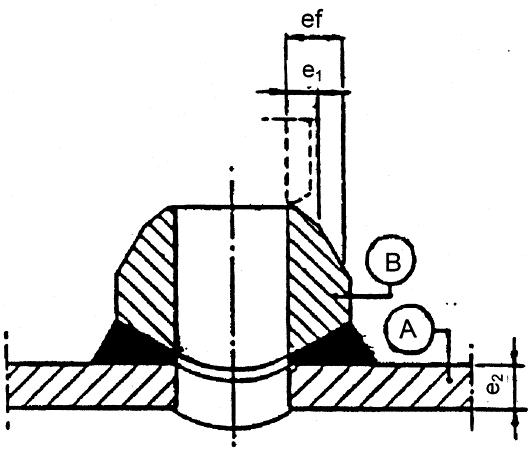
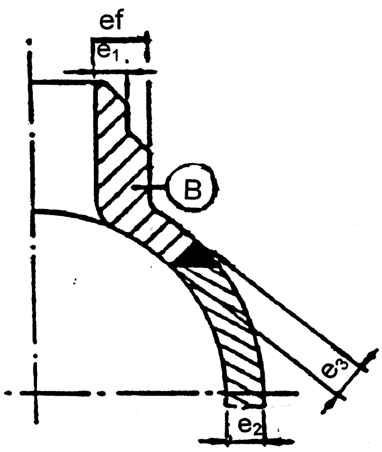
ence temperature and impact test temperature as welded condition

Table 6 — Reference thickness e_B

Construction detail	As welded or PWHT	Reference thickness		
		Part A	Weld	Part B
Butt welded components of unequal thickness 	A-W	e_1	e_2	e_2 check e_3 in Figures 1 or 3 [a]
	PWHT	e_1	e_2	e_3
Branches and nozzles 	A-W	e_2	e_2	e_1
	PWHT	e_2	e_2	e_1
	A-W	e_2	e_2 or e_3 if thicker	e_1
	PWHT	e_2	e_2 or e_3 if thicker	e_1
	A-W	e_2	e_2 or e_3 if thicker	e_1
	PWHT	e_2	e_2 or e_3 if thicker	e_1

[a] The minimum test temperature of the conditions: e_2 (AW), e_3 (PWHT) shall be taken.

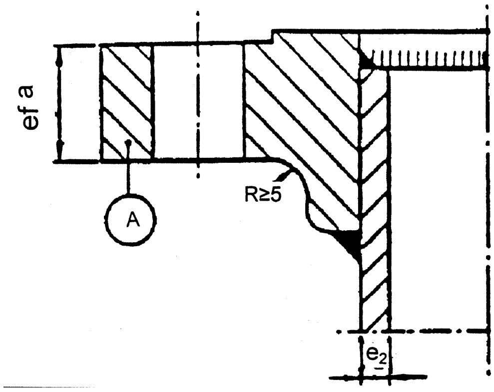
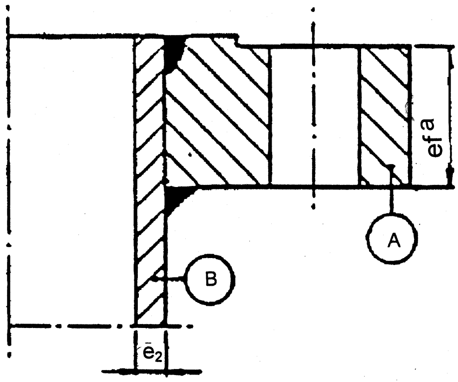
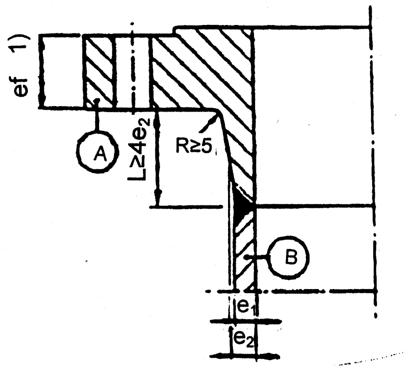
Table 6 (continued)

Construction detail	As welded or PWHT	Reference thickness		
		Part A	Weld	Part B
	A-W	e_3	e_2 or e_3 if thicker	e_2
	PWHT	e_3	e_2 or e_3 if thicker	e_2
	A-W	e_2	e_2	e_1 or $e_f/4$ if thicker
	PWHT	e_2	e_2	e_1 [a] or $e_f/4$ if thicker if necessary check e_1 in Figures 2 or 4
	A-W	e_2	e_3	e_3 or $e_f/4$ if thicker
	PWHT	e_2	e_3	e_3 [b] or $e_f/4$ if thicker if necessary check e_1 in Figures 2 or 4

[a] The minimum test temperature of the conditions: e_1 (AW), $e_f/4$ (PWHT) shall be taken.

[b] [illegible] of the conditions: e_2 (AW), $e_f/4$ (PWHT) shall be taken.

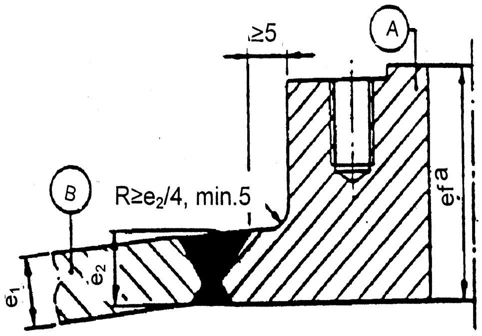
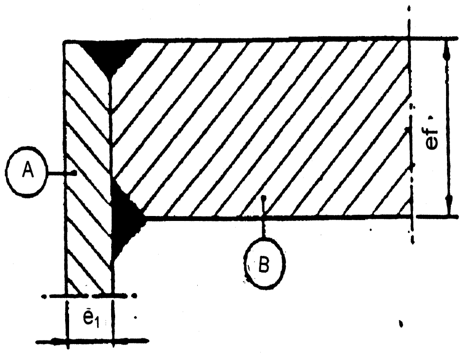
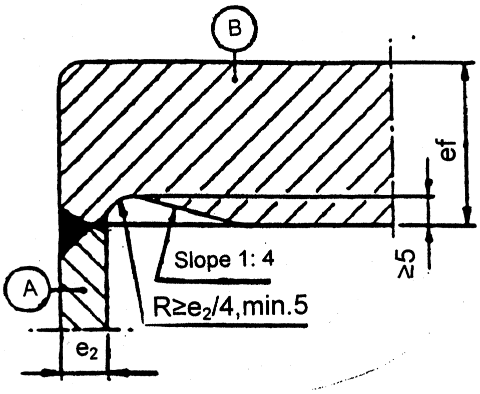
Table 6 (continued)

Construction detail	As welded or PWHT	Reference thickness		
		Part A	Weld	Part B
Slip-on and plate flanges 	A-W	$e_f/4$	e_2	e_2
	PWHT	$e_f/4$	e_2	e_2
	A-W	$e_f/4$	e_2	e_2
	PWHT	$e_f/4$	e_2	e_2
Forged or cast welding neck flanges 	A-W	e_2 [b] check $e_f/4$ in Figures 1 or 3	e_2	e_1
	PWHT	e_2 or $e_f/4$ if thicker	e_2	e_1

[a] e_f may be measured radially if that gives an advantage

[b] The minimum test temperature of the conditions: e_2 (AW), e_f /4 (PWHT) shall be taken.

Table 6 (continued)

Construction detail	As welded or PWHT	Reference thickness		
		Part A	Weld	Part B
Pad-type flanges 	A-W	e_2 [b] check $e_f/4$ in Figures 1 or 3	e_2	e_1
	PWHT	e_2 or $e_f/4$ if thicker	e_2	e_1
Flat ends 	A-W	e_1	e_1	$e_f/4$ or e_1 if thicker
	PWHT	$e1$	$e1$	$e_f/4$ or $e1$ if thicker
	A-W	e_2	e_2	e_2 [b] check $e_f/4$ in Figures 1 or 3
	PWHT	e_2	e_2	$e_f/4$ or e_2 if thicker

[a] e_f may be measured radially if that gives an advantage.

[b] The minimum test temperature of the conditions: e_2 (AW), $e_f/4$ (PWHT) shall be taken.

Table 6 (continued)

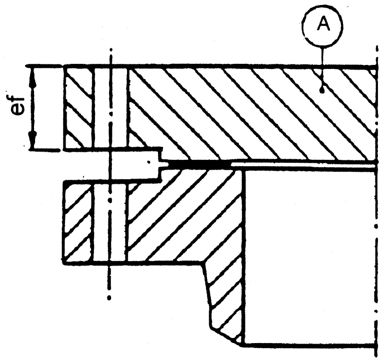
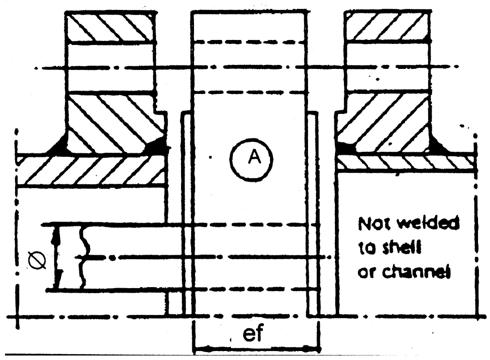
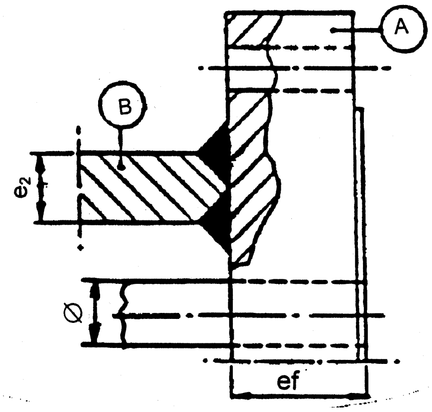
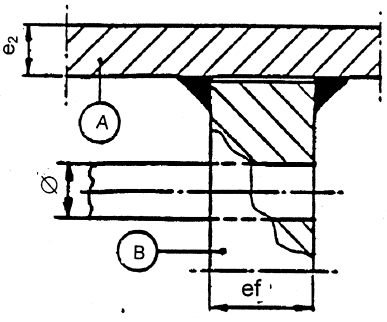
Construction detail	As welded or PWHT	Reference thickness		
		Part A	**Weld**	**Part B**
Covers and blind flanges 	A-W	$e_f/4$	—	—
	PWHT	$e_f/4$	—	—
Tube plates 	A-W	n. a.	n. a.	n. a.
	PWHT	$e_f/4$	n. a.	n. a.
	A-W	$e_f/4$ or e_2 if thicker	e_2	e_2
	PWHT	$e_f/4$ or e_2 if thicker	e_2	e_2

Table 6 (continued)

<table>
<tr><th rowspan="2">Construction detail</th><th rowspan="2">As welded or PWHT</th><th colspan="3">Reference thickness</th></tr>
<tr><th>Part A</th><th>Weld</th><th>Part B</th></tr>
<tr><td rowspan="2">Welded into shell/channel


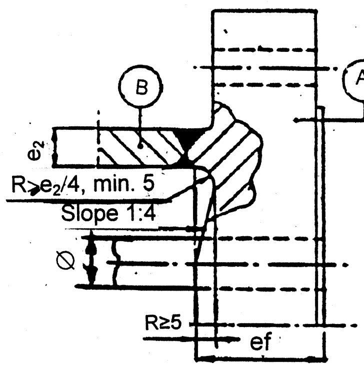
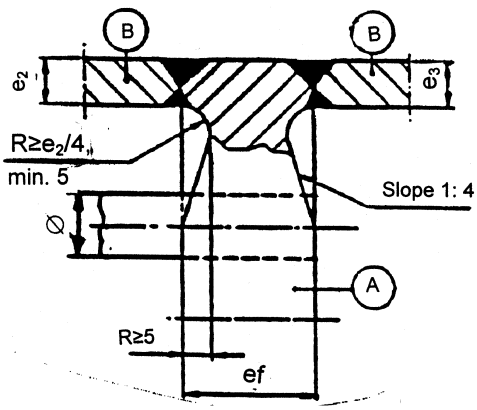
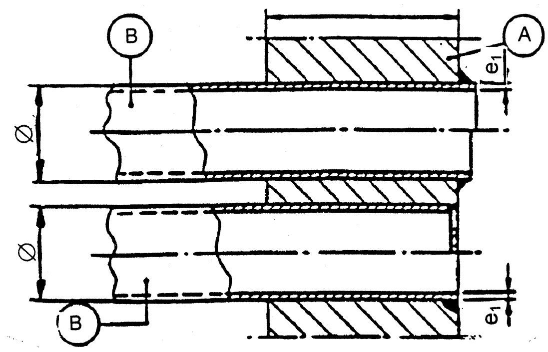
Preferably not to be used</td><td>A-W</td><td>$e_f/4$
or e_2
if thicker</td><td>e_2</td><td>e_2</td></tr>
<tr><td>PWHT</td><td>$e_f/4$
or e_2
if thicker</td><td>e_2</td><td>e_2</td></tr>
<tr><td rowspan="2">Forged tube plate with stubs

</td><td>A-W</td><td>e_2[a]
check $e_f/4$
in Figures 1
or 3</td><td>e_2</td><td>e_2</td></tr>
<tr><td>PWHT</td><td>$e_f/4$
or e_2
if thicker</td><td>e_2</td><td>e_2</td></tr>
<tr><td rowspan="2">
</td><td>A-W</td><td>e_2[a]
or e_3
if thicker
check $e_f/4$
in Figures 1
or 3</td><td>e_2
(e_3)</td><td>e_2
(e_3)</td></tr>
<tr><td>PWHT</td><td>$e_f/4$
or e_2
or e_3
if thicker</td><td>e_2
(e_3)</td><td>e_2
(e_3)</td></tr>
<tr><td colspan="5">[a] The minimum test temperature of the conditions: e_2 (AW), $e_f/4$ (PWHT) shall be taken.</td></tr>
</table>

Table 6 (concluded)

Construction detail	As welded or PWHT	Reference thickness		
		Part A	Weld	Part B
Tube-to-tube plate connection 	A-W	[[a]]	e_1	e_1
	PWHT	[[a]]	e_1	e_1
[a] Reference thickness of part A is unaffected by this connection.				

Annex ZA
(informative)
Relationship of this document with EC Directives

This European standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of EC Directives: Pressure equipment directive 97/23/EC.

The clauses of this standard given in Table ZA.1 are likely to support requirements of Directives.

Compliance with the clauses of this standard provides one means of conforming with the specific essential requirements of the Directive concerned and associated EFTA regulations.

WARNING: Other requirements and other EC Directives may be applicable to the product(s) falling within the scope of this standard.

Table ZA.1 — Comparison between PED and this European standard

Harmonized clauses of EN 1252-2	Content	PED
All clauses	Impact strength	Annex I § 2.2.3b)
All clauses	Material characteristics	Annex I § 7.5

Annex ZB
(informative)
Case proposal — Technical justification for the temperature adjustment term

ZB.1 General

The regulations and standards of France, Sweden and Great Britain are based on fracture mechanics considerations. The basis of the French standard is the Sanz concept (1). The basis of the Swedish standard is the work of Sandström (2). The British standard is based on wide plate tests, the results of which were reassessed in 1998 on the basis of fracture mechanics considerations (3).

The fracture mechanics concepts take into account the influence of wall thickness, loading rate and of the conditions “as welded”, “unwelded”, “post-weld heat treated”.

In the German regulations and standards, minimum values for impact energy are determined on the basis of extensive operational experience. Brittle fracture reducing influences by means of reduction of the wall thickness, loading rates and stress-relief are not taken into consideration additionally.

All concepts consider the influence of the load level on the toughness (T_2). Agreement was reached in the sub-group Low Temperature on the use of brittle fracture concept of Sandström (2), which is applied in the Swedish standard and is contained in Method 2 “Technical requirements”, previously entitled “Code of Practice developed from fracture mechanics”. The agreement reached in favour of the Sandström concept was essentially due to two things. On the one hand the concept contains the formula by Sanz, which is used in the French standard, and on the other hand the type of classification into strength classes is similar to the existing standards, for example of the British and also the Dutch Standard.

ZB.2 The brittle fracture concept

The fundamental requirement of the brittle fracture concept is that components with defect do not fail with a loading at the level of the yield point R_{el}. For this purpose a certain material toughness is required for the material used, with:

$$K_{IC} > K_{CComponent}$$

The correlation of the fracture toughness with the impact energy forms the basis of the Sandström concept (2). The equation of Barsom and Rolfe, which is based on a large number of steels, is used for the correlation. Later investigations have also confirmed the validity of the equations.

$$K_{IC} = \delta E^{1/2} (KV)^{3/4}$$

In the correlation two yield point ranges are assumed. The fracture toughness values in the transfer from brittle to ductile behaviour are correlated with the impact energy values. The results are as follows:

— Materials with $R_{el} \leq 310$ N/mm²: requirements of 27 J

— (corresponds to $K_{IC} = 78 \text{ MPa}\sqrt{m}$)

— Materials with $R_{el} > 310$ N/mm²: requirements of 40 J

ponds to $K_{IC} = 105 \text{ MPa}\sqrt{m}$)

ZB.3 Assumptions for the calculation of the minimum operating temperature

Defect size:

For the defect size a semi-elliptical surface defect with a depth of 0,25 times the wall thickness was taken, which corresponds to the provisions of the ASME Code Section III.

Loads:

The loads are assumed as 1,4 times the yield in the A-W condition. The loads consist of the permitted primary stress and remaining residual stresses.

In the PWHT state, loads are assumed to be equivalent to the yield point. On these assumptions the minimum operating temperatures are calculated.

The calculation of the minimum metal temperature is conducted according to Sandström (2) with the following equation:

$$T_M = \ln\left(\frac{K_c - K_0}{K_1 - K_0}\right) :\beta + T_{KV} + \Delta T_e$$

T_{KV} Impact test temperature T_{27J} or T_{40J} ($K_{IC} = 78\ \text{MPa}\sqrt{m}$ or $105\ \text{MPa}\sqrt{m}$)

K_c Stress intensity factor $K_C = \sigma\sqrt{(a\pi)}$

β Constant 1/60 °

K_0 Constant $25\ \text{MPa}\sqrt{m}$

ΔT_e Correction term for the influence of the component thickness.

The correction term ΔT_e takes into consideration the influence of the wall thickness. The starting factor of the concept is a wall thickness greater than or equal to 110 mm. If the wall thickness becomes less, this influences the stress condition and has beneficial effects on the brittle fracture safety. The transition from the multi-dimensional strain condition to the level plain strain condition is taken into account by means of the correction term.

In the Sandström concept, the influence of the yield point on the size of the plastic zone is also taken into consideration, in addition to the influence of the wall thickness. This leads to a correction terms t_{ps} .

The correction term is proportional to $(K_c/\sigma)^2$, where σ is the yield stress $(R_{el}/R_m)/2$ of the material.

Definition of the temperature displacement ΔT_e by comparison of t_{ps} with the component thickness, *t*.

$$e = t + 110\ t_{ps}, t_{ps} < 110\text{mm}$$

$$e = t_{ps}, t_{ps} \geq 110\text{mm}$$

$$\Delta T_e = 0,\ e > 110$$

$$\Delta T_e = 0{,}53e - 59,\ 110 > e > 60$$

$$\Delta T_e = 0{,}97e - 85,\ 60 > e > 30$$

$$\Delta T_e = 1{,}8e - 110,\ 30 > e > 10$$

T_M is calculated as a function of the impact test temperature T_{KV} and the component thickness. The result of the calculations are the Figures 1 to 5, which show the impact test temperatures as a function of wall thickness for the yield point ranges. Figure 1 shows the dependence for the condition unwelded and/or post-weld heat treated. From a thickness of 60 mm the impact test temperature is equal to the minimum metal temperature. If the component thickness becomes less, the strain condition is shifted in the direction of plain strain condition. This is taken into consideration with a lower minimum metal temperature.

ZB.4 Temperature adjustment term

In the brittle fracture concept, loads at the level of the yield point and/or 1,4 times the yield point are assumed. If the actual loads are under the maximum permissible loads, this is taken into account with a temperature adjustment term TS. The temperature TR is determined from the minimum metal temperature and TS. The temperature adjustment term has the effect that the material can be used at lower temperatures.

The Swedish Standard, like AD-W 10 or BS 5500, provides for a temperature adjustment term for loads below the permissible load.

ZB.5 Literature

— (1) Sanz G. Rev. Metal CIT 1980 pp 621-642.

— (2) Sandström, R. Scandinavian J of Metallurgy 16 (1987), pp 242-252.

— (3) Garwood S.J. and Dervhan JB “The fracture toughness requirements of BS 5500” ASME pressure vessel and piping conference (1988), paper 88 - PBP-7.

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