

AWS D14.8M:2009
(ISO/TR 17844:2004 IDT)
An American National Standard

Standard Methods for the Avoidance of Cold Cracks



American Welding Society



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An American National Standard**

**Approved by the
American National Standards Institute
November 11, 2008**

Standard Methods for the Avoidance of Cold Cracks

1st Edition

Prepared by the
American Welding Society (AWS) D14 Committee on Machinery and Equipment

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This is the U.S. national adoption of ISO 17844:2004, *Welding — Comparison of standardized methods for the avoidance of cold cracks*.



American Welding Society

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Foreword

This foreword is not part of AWS D14.8M:2009 (ISO/TR 17844:2004 IDT), *Standard Methods for the Avoidance of Cold Cracks*, but is included for informational purposes only.

This standard is the U.S. national adoption of ISO 17844:2004, *Welding — Comparison of standardized methods for the avoidance of cold cracks*. This identical adoption (IDT) retains the technical content, structure, and wording of the ISO document, although it contains the following editorial changes:

- (1) the decimal comma has been replaced by the decimal point, and
- (2) the words “this International Standard” have been replaced by “this standard.”

This standard makes sole use of the International System of Units (SI). Safety and health issues and concerns are beyond the scope of this standard, and therefore are not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

The purpose of this document is to compare currently available methods for determining welding procedures for avoiding hydrogen induced cold cracking during fabrication.

This subject has been extensively studied in recent years and many methods of providing guidance on avoidance of cold cracking have been published. These methods vary considerably in how comprehensively the subject has to be treated. It was considered appropriate to set certain important working criteria for selecting the published methods to be included in this document. In deciding which criteria would be adopted it was agreed that these should include the capabilities for effective use by industry, the end user. Thus the methods should be able to be used on the basis of traditionally available information and relevant factors. The agreed list of criteria was set to include the following main input parameters:

- (1) steel composition,
- (2) welding heat input,
- (3) joint geometry and material thickness,
- (4) weld hydrogen level, and
- (5) preheat

and in addition:

- (6) graphical/computer format of data.

Using the above criteria, the following methods were selected:

- (1) CE (EN 1011-2/ISO/TR 17671-2, C.2-Method A);
- (2) CET (EN 1011-2/ISO/TR 17671-2, C.3-Method B);
- (3) CE_N (JIS B 8285); and
- (4) P_{cm} (AWS D1.1).

Each method is considered in a separate clause, under the following headings:

- (1) Description of type of test data used to devise the guidelines, e.g., CTS, y-groove, etc.;
- (2) Parent metal composition and range of applicability;
- (3) Material thickness and range of applicability;
- (4) Hydrogen level and welding processes;
- (5) Heat input;
- (6) Other factors/special considerations; and
- (7) Determination of preheat (step-by-step example description).

An informative annex compares and contrasts the predictions of the methods in respect of ten different steels and a range of material thickness, joint geometries, heat inputs, and hydrogen levels.

It is important that any calculations using a given method are undertaken using the current edition of the appropriate standard.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D14 Committee on Machinery and Equipment, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Welding — Comparison of standardized methods for the avoidance of cold cracks

1 Scope

In addition to EN 1011-2/ISO/TR 17671-2, this document contains further methods for avoidance of cold cracking used by other members of ISO. This document gives guidance for manual, semi-mechanized, mechanized and automatic arc welding of ferritic steels, excluding ferritic stainless steels, in all product forms.

Further information about the materials and process parameters is given in Clauses 2 to 5.

NOTE 1 All references are listed in the annex "Bibliography."

NOTE 2 All used abbreviations in this document are explained in EN 1011-2/ISO/TR 17671-2, and Annex B.

2 CE-method

2.1 Cracking test method

This method is based on an original concept of critical hardness to avoid HAZ (heat-affected zone) hydrogen cracking. It has been empirically developed incorporating the extensive results of HAZ hardenability studies and cracking tests, the latter mainly but not exclusively being the CTS test type. In its present general format the scheme was originally published in 1973 and, with modifications and updates, has been continuously incorporated in British Standards for nearly 25 years. The experience of its use, both in the UK and elsewhere, has been extremely satisfactory.

2.2 Parent metal composition range

The parent metals covered are carbon, carbon manganese, fine grained and low alloyed steels (groups 1 to 3 of CR ISO 15608:2000).

The steels that were used over many years to develop the method have covered a wide range of compositions and it is believed that they are adequately represented by Table 1.

Table 1 — Range of chemical composition of the main constituents for parent metal for CE-method

Element	Percentage by weight
Carbon	$\geq 0.05, \leq 0.25$
Silicon	≤ 0.8
Manganese	≤ 1.7
Chromium	≤ 0.9
Copper	≤ 1.0
Nickel	≤ 2.5
Molybdenum	≤ 0.75
Vanadium	≤ 0.20

Carbon equivalent values (in %) for parent metals are calculated using the following equation (1):

$$CE_{IIW} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (1)$$

and are applicable to steels with carbon equivalents in the range $CE = 0.30\%$ to 0.70% .

If of the elements in this formula only carbon and manganese are stated on the mill sheet for carbon and carbon manganese steels, then 0.03% should be added to the calculated value to allow for residual elements and impurities. Where steels of different carbon equivalents or grades are to be joined, the higher carbon equivalent value should be used.

This carbon equivalent formula may not be suitable for boron containing steels.

2.3 Plate thickness and joint geometry

The influence of plate thickness and joint geometry is determined by calculating the combined thickness. This should be determined as the sum of the parent metal thickness averaged over a distance of 75 mm from the weld center line (see Figure 1).

Combined thickness is used to assess the heat sink of a joint for the purpose of determining the cooling rate.

If the thickness increases greatly beyond 75 mm from the weld center line, it may be necessary to use a higher combined thickness value.

Steels with thicknesses, t , in the range $6\text{ mm} \leq t \leq 100\text{ mm}$ were used in the tests to develop the scheme.

2.4 Hydrogen level and welding process

2.4.1 Hydrogen scales

The hydrogen scales to be used for any arc welding process depend principally on the weld diffusible hydrogen content (according to ISO 3690) and should be as given in Table 2.

Table 2 — Hydrogen scales

Diffusible hydrogen content (ml/100 g deposited material)	Hydrogen scale
> 15	A
$10 \leq 15$	B
$5 \leq 10$	C
$3 \leq 5$	D
≤ 3	E

Data from a wide range of arc welding processes has been used in developing the scheme and these include shielded metal arc welding (111), gas metal arc with solid wire (131, 135) and flux cored arc welding (136, 137), the latter of both gas shielded and self shielded types, and submerged arc welding (121).

NOTE The numbers in brackets are process numbers according to ISO 4063.

2.4.2 Selection of hydrogen scales

The following is general guidance on the selection of the appropriate hydrogen scale for various welding processes.

Shielded metal arc welding with basic covered electrodes can be used with the scale B to D depending on the electrode manufacturer's/supplier's classification of the consumable. Shielded metal arc welding with rutile or cellulosic electrodes should be used with scale A.

Flux cored or metal cored consumables can be used with scales B to D depending on the manufacturer's/supplier's classification of the wire electrodes. Submerged arc welding with one wire electrode (121) and flux consumable combinations can have hydrogen levels appropriate to scales B to D, although most typically these will be scale C but therefore need assessing for each named product combination and condition. Submerged arc fluxes can be classified by the manufacture/supplier but this does not necessarily confirm that a practical flux wire combination also meets the same classification.

Solid wire electrodes for gas metal arc welding (131, 135) and for gas tungsten arc welding (141) may be used with scale D unless specifically assessed and shown to meet scale E. Scale E may also be found to be appropriate for some flux cored wires (136, 137) and some shielded metal arc welding electrodes, but only after specific assessment. In achieving these low levels of hydrogen consideration should be given to the contribution of hydrogen from the shielding gas composition and atmospheric humidity.

For plasma arc welding (15), specific assessment should be made.

NOTE The numbers in brackets are process numbers according to ISO 4063.

2.5 Heat input

Heat input values (in kJ/mm) for use with Figure 2 a) to m) should be calculated in accordance with EN 1011-1/ ISO/TR 17671-1 and EN 1011-2/ISO/TR 17671-2.

For shielded metal arc welding, heat input values are expressed in Tables 3 to 6 in terms of electrode size and weld run lengths.

The details given in Tables 3 to 6 relate to electrodes having an original length of 450 mm. For other electrode lengths the following equation (2) may be used:

$$\text{Run length (mm)} = \frac{(\text{Electrode diameter})^2 \times L \times F}{\text{Heat input}} \quad (2)$$

where

L is the consumed length of the electrode (in mm) (normally the original length of 450 mm less 40 mm for stub end);

F is a factor (in kJ/mm³) having a value depending on the electrode efficiency, as follows:

efficiency approximately 95 %	$F = 0.0368$
95 % < efficiency ≤ 110 %	$F = 0.0408$
110 % < efficiency ≤ 130 %	$F = 0.0472$
efficiency > 130 %	$F = 0.0608$

Table 3 — Run length for shielded metal arc welding — 95 % electrode efficiency, approximately

Heat input kJ/mm	Run length from 410 mm of a 450 mm electrode of diameter					
	2.5	3.2	4.0	5.0	6.0	6.3
	mm	mm	mm	mm	mm	mm
0.8	120	195	300	470		
1.0	95	155	240	375	545	600
1.2		130	200	315	450	500
1.4		110	170	270	390	430
1.6		95	150	235	340	375
1.8		85	135	210	300	335
2.0			120	190	270	300
2.2			110	170	245	270
2.5			95	150	215	240
3.0			80	125	180	200
3.5				110	155	170
4.0				95	135	150
4.5				85	120	135
5.0					110	120
5.5					100	110

Table 4 — Run length for shielded metal arc welding — $95\% < \text{electrode efficiency} \leq 110\%$

Heat input kJ/mm	Run length from 410 mm of a 450 mm electrode of diameter					
	2.5	3.2	4.0	5.0	6.0	6.3
	mm	mm	mm	mm	mm	mm
0.8	130	215	325	525		
1.0	105	170	270	420	600	
1.2	85	145	225	350	500	555
1.4		120	190	300	430	475
1.6		105	165	260	375	415
1.8		95	150	230	335	370
2.0		85	135	210	300	330
2.2			120	190	275	300
2.5			105	165	240	265
3.0			90	140	200	220
3.5				120	170	190
4.0				105	150	165
4.5				95	135	150
5.0				85	120	135
5.5					110	120

Table 5 — Run length for shielded metal arc welding — $110 \% < \text{electrode efficiency} \leq 130 \%$

Heat input kJ/mm	Run length from 410 mm of a 450 mm electrode of diameter					
	2.5	3.2	4.0	5.0	6.0	6.3
	mm	mm	mm	mm	mm	mm
0.8	150	250	385	605		
1.0	120	200	310	485		
1.2	100	165	260	405	580	
1.4	85	140	220	345	500	550
1.6		125	195	300	435	480
1.8		110	170	270	385	425
2.0		100	155	240	350	385
2.2		90	140	220	315	350
2.5			125	195	280	305
3.0			105	160	230	255
3.5			90	140	200	220
4.0				120	175	190
4.5				110	155	170
5.0				95	140	155
5.5				90	125	140

Table 6 — Run length for shielded metal arc welding — electrode efficiency > 130 %

Heat input kJ/mm	Run length from 410 mm of a 450 mm electrode of diameter				
	3.2	4.0	5.0	6.0	6.3
	mm	mm	mm	mm	mm
0.8	320	500			
1.0	255	400	625		
1.2	215	330	520		
1.4	180	285	445		
1.6	160	250	390	560	620
1.8	140	220	345	500	550
2.0	130	200	310	450	495
2.2	115	180	285	410	450
2.5	100	160	250	360	395
3.0	85	135	210	300	330
3.5		115	180	255	285
4.0		100	155	225	245
4.5		90	140	200	220
5.0			125	180	200
5.5			115	165	180

2.6 Special considerations

2.6.1 Conditions which might require more stringent procedures

The preheating conditions presented in Figure 2 a) to m) have been found from experience to provide a satisfactory basis for deriving safe welding procedures for many welded fabrications. However, the risk of hydrogen cracking is influenced by several parameters and these can sometimes exert an adverse influence greater than accounted for in Figure 2 a) to m). The following covers some of the factors that may increase the risk of cracking to above that envisaged in drawing up the data in Figure 2. Precise quantification of the effects of these factors on the need for a more stringent procedure and on the changes to the welding procedure required to avoid cracking cannot be made at present. The following should therefore be considered as guidelines only.

Joint restraint is a complex function of section thickness, weld preparation, joint geometry and the stiffness of the structure. Welds made in section thicknesses above approximately 50 mm and root runs in double bevel butt joints may require more stringent procedures.

Certain welding processes may not be adequate for avoiding weld metal hydrogen cracking when welding steels of low carbon equivalent. This is more likely to be the case when welding thick sections (e.g. greater than approximately 50 mm) and with higher heat inputs.

The use of higher strength alloyed weld metal or carbon manganese weld metal with a manganese content above approximately 1.5 % may lead to higher operative stresses. Whether or not this causes an increased risk of HAZ cracking, the weld deposit would generally be harder and more susceptible to cracking itself, and in this condition increased precautions against hydrogen cracking are advised.

Experience and research have indicated that lowering the inclusion content of the steel, principally by lowering the sulfur content (but also the oxygen content), may increase the hardness of the heat-affected zone, and possibly cause a small increase in the risk of HAZ hydrogen cracking. Accurate quantification of the effect is not presently practicable.

Although modifications to the procedures to deal with welds involving the above factors can, in principle, be obtained through a change in heat input or preheat or weld hydrogen level, the most effective modification is to lower the weld hydrogen level. This can be done either directly, by lowering the weld hydrogen input to the weld (use of lower hydrogen welding processes or consumables), or by increasing hydrogen loss from the weld by diffusion through the use of post-heat for a period of time after welding. The required post-heat time will depend on many factors, but a period of 2 h to 3 h has been found to be beneficial in many instances. It is recommended that the required modifications to the procedures be derived by the use of adequate joint simulation weld testing.

2.6.2 Relaxations

Relaxations of the welding procedures may be possible under the following conditions:

- *General preheating.* If the whole component or a width more than twice that stated in Clause 12 of EN 1011-2 : 2001 (ISO/TR 17671-2:2002) is preheated, it is generally possible to reduce the preheating temperature by a limited amount;
- *Limited heat sink.* If the heat sink is limited in one or more directions (e.g. when the shortest heat path is less than ten times the fillet leg length) especially in the thicker plate (e.g. in the case of a lap joint where the outstand is only marginally greater than the fillet weld leg length), it is possible to reduce preheating levels;
- *Austenitic consumables.* In some circumstances where sufficient preheating to ensure crack-free welds is impracticable an advantage may be gained by using certain austenitic or high nickel alloyed consumables. In such cases preheat may not be necessary, especially if the condition of the consumable is such as to deposit weld metal containing very low levels of hydrogen;
- *Joint fit up.* Close fillet welds (where the root opening is 0.5 mm or less) may justify relaxation in the welding procedure.

2.6.3 Simplified conditions for shield metal arc welding

Where single run minimum leg length fillet welds are specified in the design, Table 7 may be used to obtain the approximate heat input values for use in determining the welding procedure from Figure 2.

Table 7 — Values for heat input for shielded metal arc welding of single run fillet welds

Minimum leg length mm	Heat input for electrodes with covering types ^a and electrodes efficiencies		
	R and RR < 110 % kJ/mm	B < 130 % kJ/mm	R and RR > 130 % kJ/mm
4	0.8	1.0	—
5	1.1	1.4	0.6
6	1.6	1.8	0.9
8	2.2	2.7	1.3
^a Covering types (R, RR, B) see ISO 2560.			

These values are appropriate for the practical situation where a contractor is required to make single run fillet welds of a specified dimension related to the minimum leg length of the fillet welds, and where in practice one leg would be longer than that minimum, as for example in a horizontal-vertical fillet weld (position PB according to ISO 6947) and the data is therefore not appropriate for direct conversion to welds of specified throat dimension.

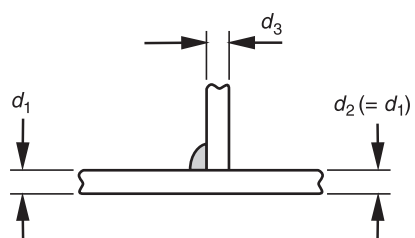
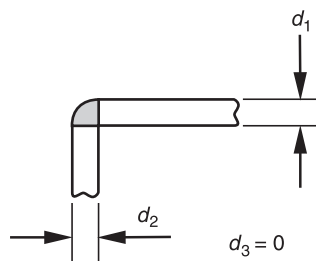
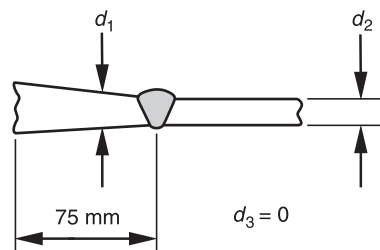
In other cases heat input should be controlled by control of electrode runout (see Table 6) or directly through welding parameters.

2.7 Determination of preheat

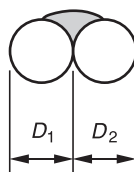
Table 8 — Steps for the determination of preheat

Step	Terms	Clause/figure/ equation	Example
1	Determine the carbon equivalent of the steel. This may be assessed by reference to mill certificates or the maximum carbon equivalent in the steel standard.	Equation (1)	0.45 %
2	Determine the hydrogen scale of the welding process and consumable as hydrogen scale A, B, C, D or E.	2.4 and Table 2	Shielded metal arc welding and that the weld hydrogen level is appropriate to scale B in Table 2
3	Determine whether the joint is a fillet or butt weld.	—	Butt weld
4	From Figure 2 select the appropriate graph for scale B and carbon equivalent of 0.45. Use Figure 2 e). When a graph for the selected hydrogen scale and carbon equivalent is not available use the graph appropriate to the next highest carbon equivalent value.	—	Figure 2 e)
5	Determine the heat input to be used. This can be done either by reference to 2.5 or by using the minimum run dimensions for the butt weld.	Table 5	Assume this will be deposited with a 4 mm electrode to be run out in about 260 mm of run length 1.2 kJ/mm
6	Determine the combined thickness of the butt joint, referring to 2.3.	—	Assume calculated combined thickness of 50 mm
7	Using Figure 2 e), plot the coordinates of 1.2 kJ/mm heat input and 50 mm combined thickness. The preheating temperature to be used should be obtained by reading the preheat line immediately above or to the left of the coordinated point for the heat input and combined thickness. Read off minimum preheating and interpass temperature required. Variation at step 7. In the event that the preheat is undesirable, proceed as follows.	—	75 °C
8	Re-examine Figure 2 e) to determine the minimum heat input for no preheat (20 °C line, normally).	—	For butt weld example: 1.4 kJ/mm
9	If by reference to Table 5 and consideration of welding position this heat input is feasible, proceed using electrode diameter and run length chosen from Table 5. If not feasible, proceed to step 10.	—	—
10	Using Figure 2 a) and d) examine the feasibility for using lower hydrogen levels (by the use of higher electrode drying temperatures or change of consumables or change of the welding process) to avoid the need for preheat at acceptable heat input levels.	—	—

d_1 = AVERAGE THICKNESS OVER A LENGTH OF 75 mm



COMBINED THICKNESS = $d_1 + d_2 + d_3$



COMBINED THICKNESS = $\frac{1}{2} (D_1 + D_2)$ TO TAKE ACCOUNT OF HEAT SINK.

MAXIMUM DIAMETER 40 mm FOR BAR

Figure 1 — Examples for determination of combined thickness

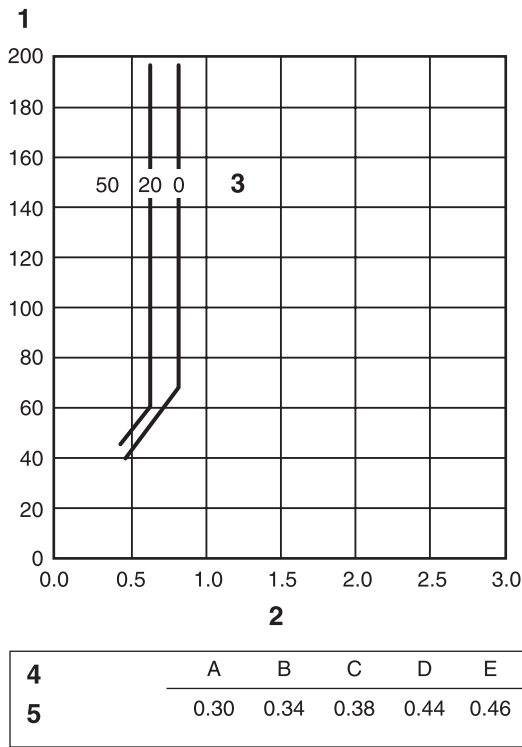


Figure 2a)

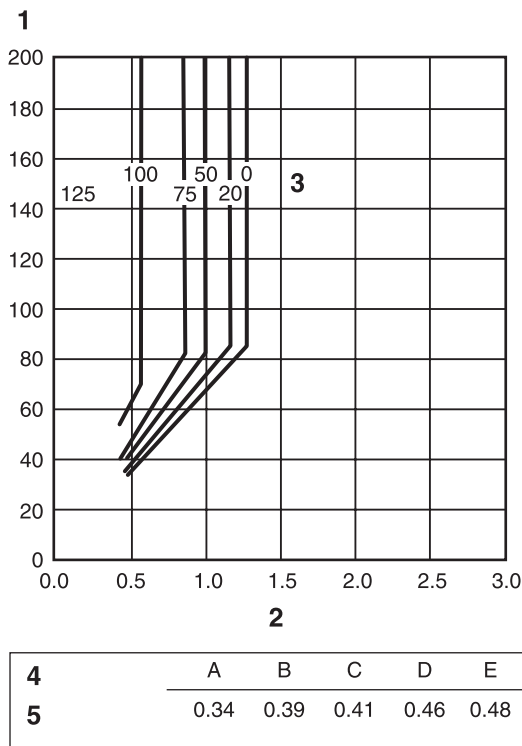


Figure 2b)

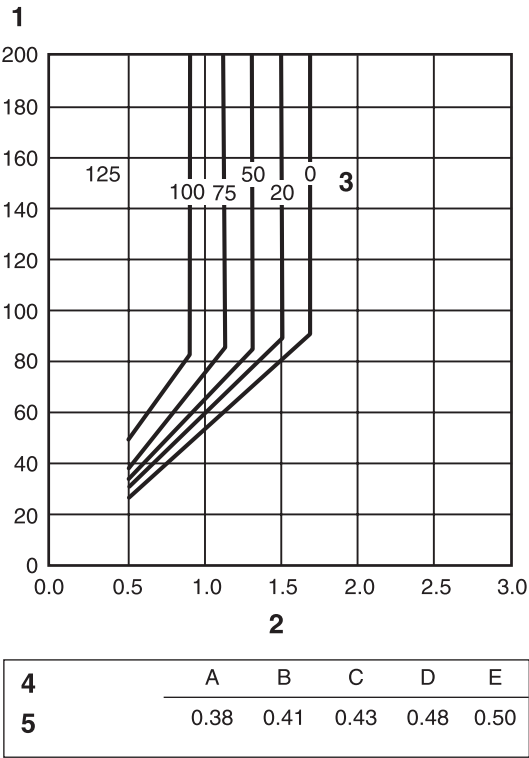


Figure 2c)

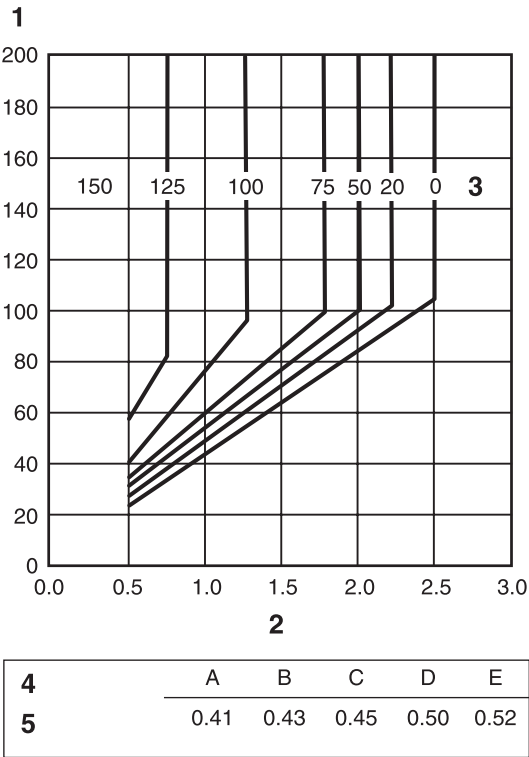


Figure 2d)

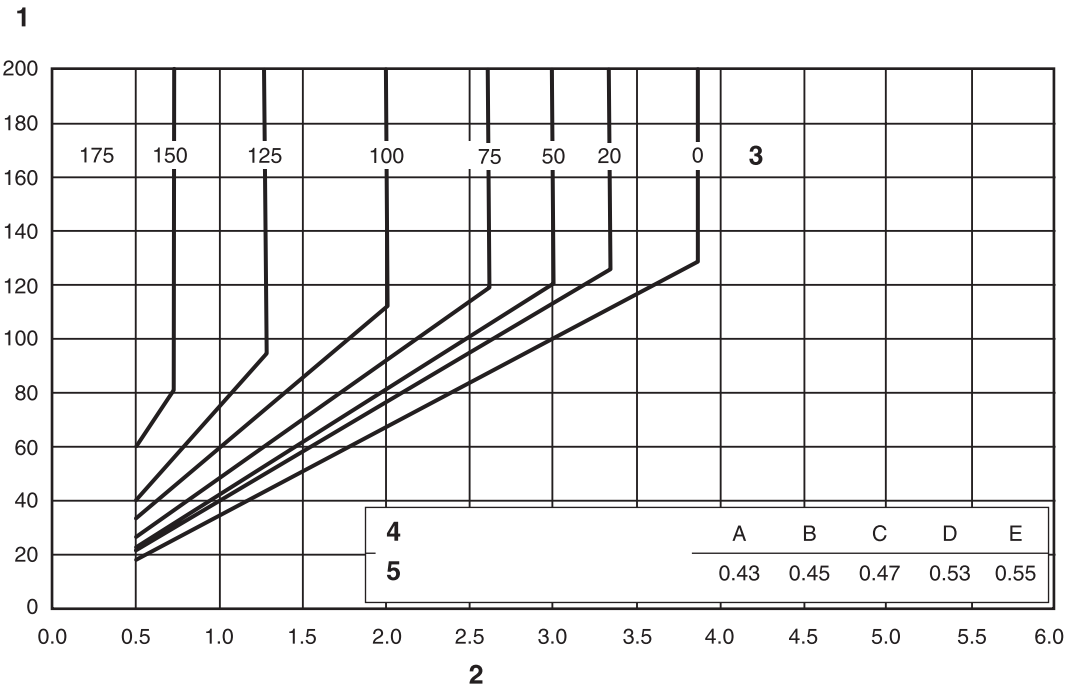


Figure 2e)

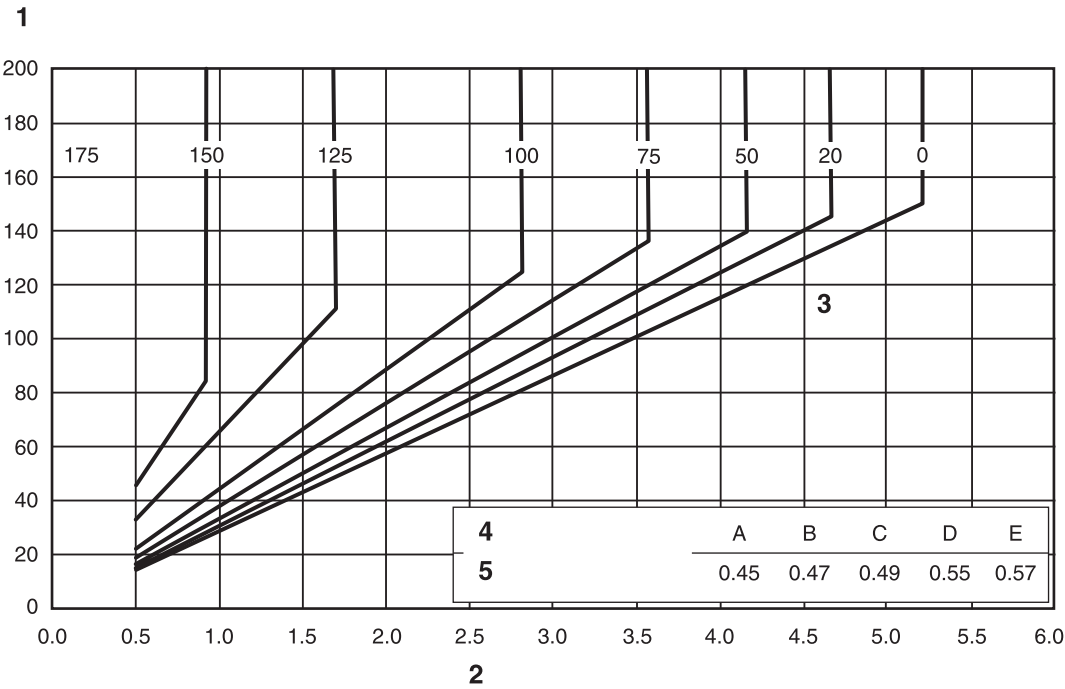


Figure 2f)

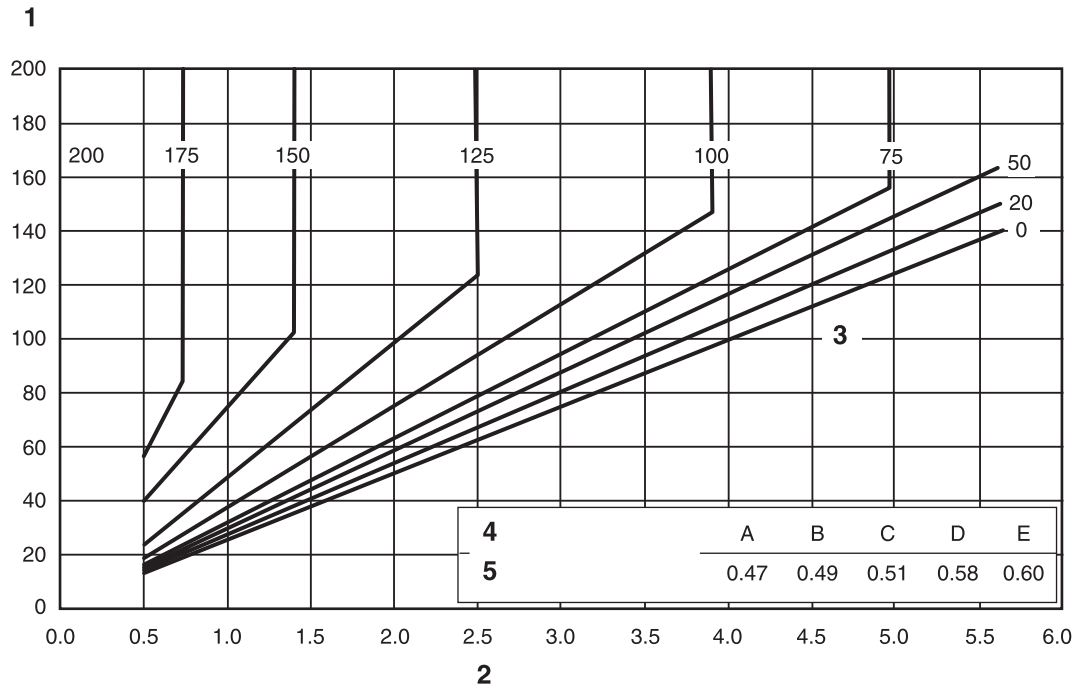


Figure 2g)

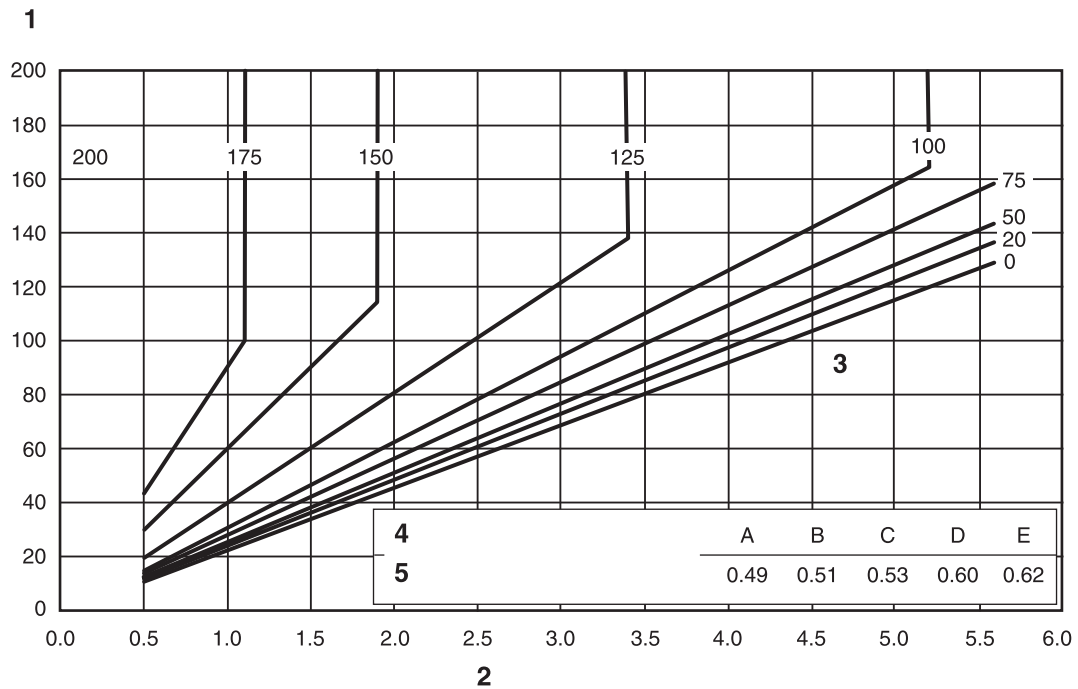


Figure 2h)

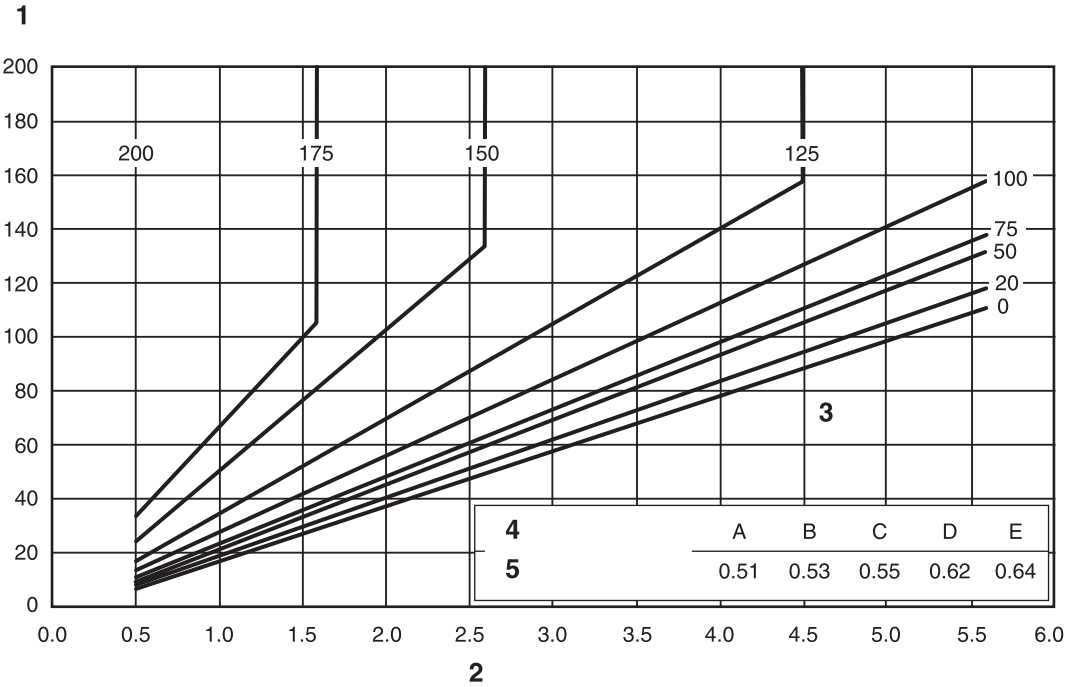


Figure 2i)

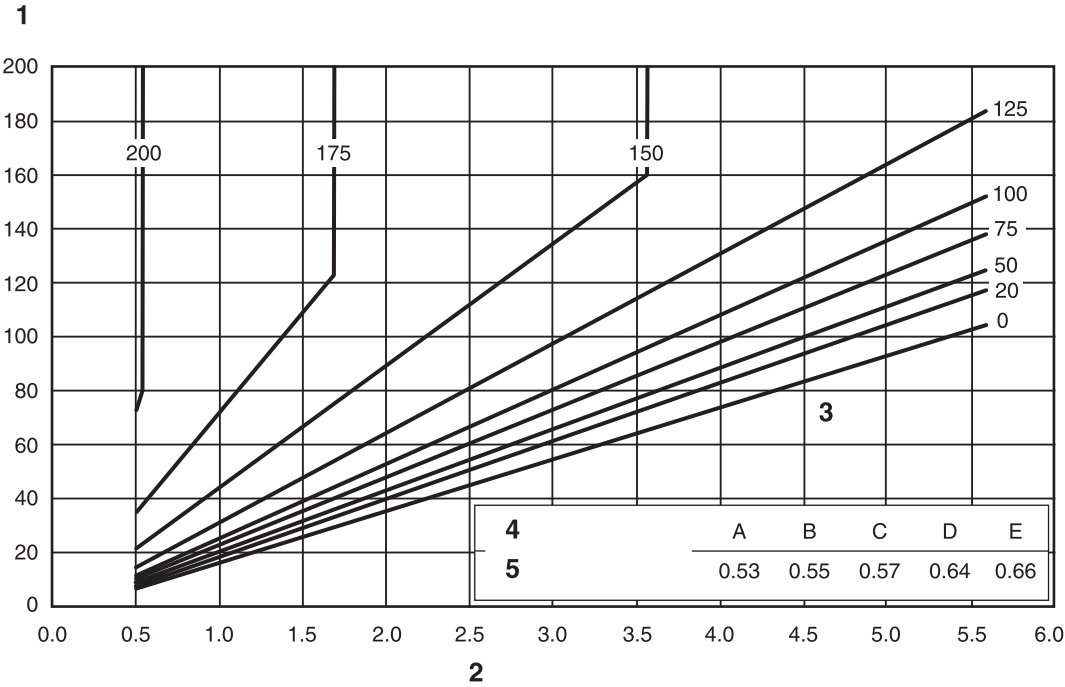


Figure 2j)

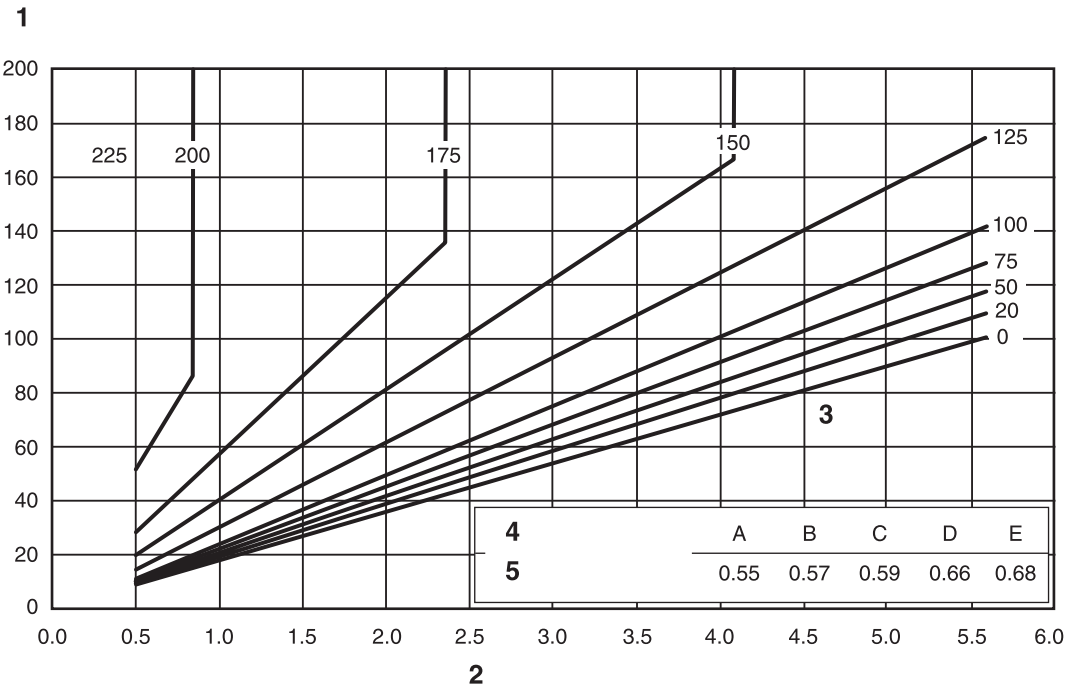


Figure 2k)

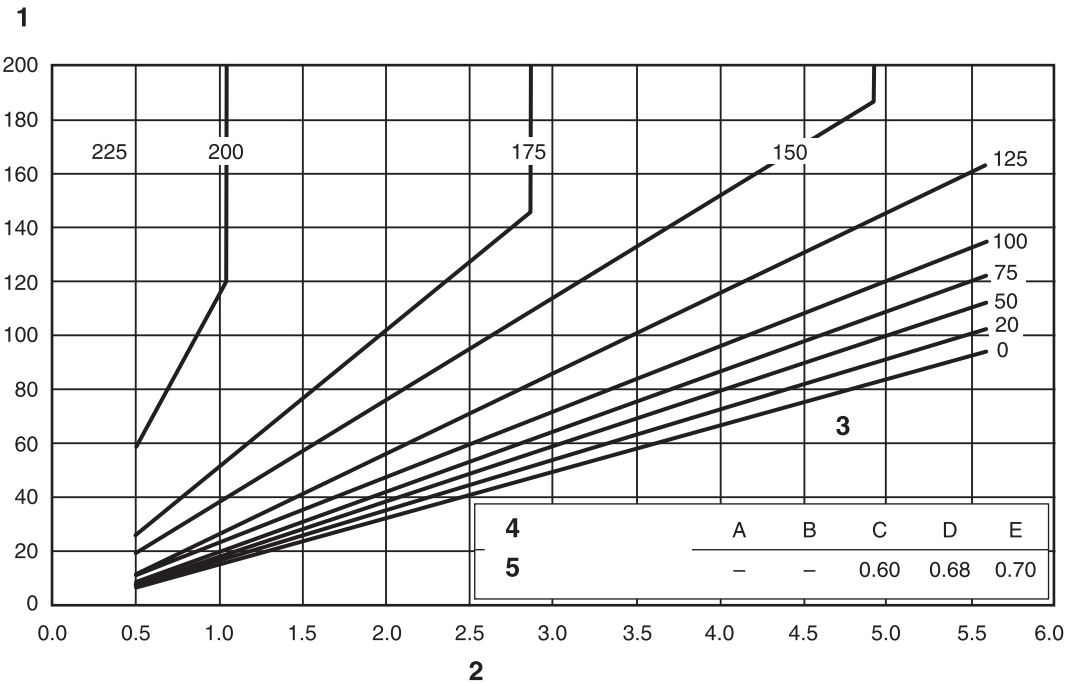


Figure 2l)