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IND2014-1039

EN 13445 – Unfired Pressure Vessels - A Useful Standard for Europe?

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This paper should be cited as follows:

Boehm, P., (2014) **"EN 13445 – Unfired Pressure Vessels - A Useful Standard for Europe?",** Athens: ATINER'S Conference Paper Series, No: **IND2014-1039**.

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Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm
Printed in Athens, Greece by the Athens Institute for Education and Research.

ISSN **2241-2891**
15/07/2014

EN 13445 – Unfired Pressure Vessels – A Useful Standard for Europe?

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Abstract

Since 2002 pressure vessels with a maximum acceptable operational pressure above 0,5 bar have to be constructed and produced in or for Europe according EG-Directive 97/23/EG (PED – Pressure Equipment Directive). From that on pressure vessels are marked by CE-sign and require a declaration of conformity. In dependence on the risk potential - category I to IV - the declaration of conformity has to be signed by a Notified Body. Before that each country as a member of the European Community (EC) produced those vessels according to their own technical guidelines. This fact causes a lot of problems as these guidelines contain many differences. Due to that problem many vessels in Europe – or produced outside of Europe for European operating companies – were produced in accordance to the US ASME Code. In 2003 a common harmonized European Standard – EN 13445 – was published to create the basis for all technical constructions and producing details. Nevertheless the pressure vessels are produced still by using the national guidelines. Only less companies are using the harmonized Standard. The reason: EN 13445 is a very complex and mighty Standard, hard to understand. Especially for the Asian market it would be more comfortable to use a common European Standard acting parallel to the world wide known ASME Code. The future development for European producers and operating companies has to be the awareness of the advantage of the EN 13445.

Acknowledgement: For technical assistance we would like to thank Mr. Stefan Jahn, Authorized Inspector of TÜV Süd, Industrial Service Ltd.

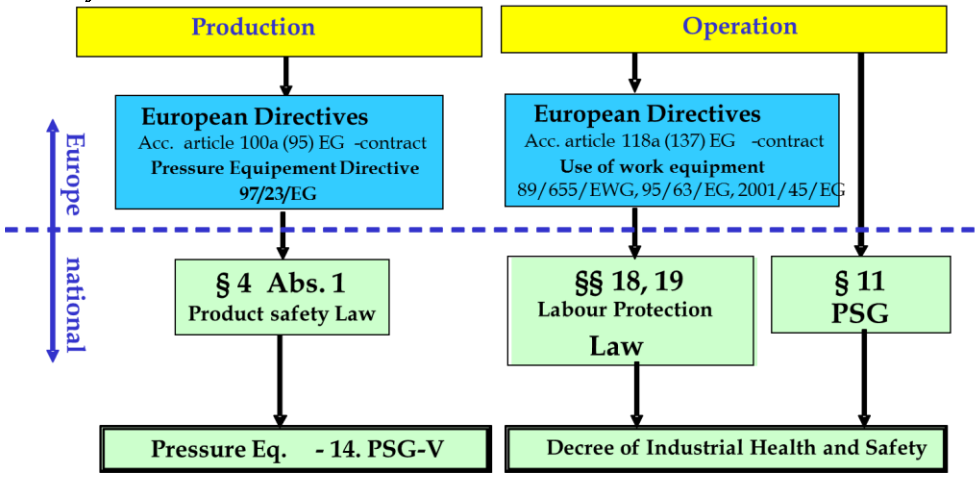
Introduction

The Pressure Equipment Directive (97/23/EC) was adopted by the European Parliament and the European Council in May 1997. It has initially come into force on 29 November 1999. From that date until 29 May 2002 manufacturers had a choice between applying the pressure equipment directive or continuing with the application of the existing national legislation. From 30 May 2002 the pressure equipment directive is obligatory throughout the EU. The directive provides, together with the directives related to simple pressure vessels (2009/105/EC), transportable pressure equipment (99/36/EC) and Aerosol Dispensers (75/324/EEC), for an adequate legislative framework on European level for equipment subject to a pressure hazard.

The PED Directive 97/23/EC (consolidated text) arises from the European Community's Program for the elimination of technical barriers to trade and is formulated under the "New Approach to Technical Harmonization and Standards". Its purpose is to harmonize national laws of Member States regarding the design, manufacturing, testing and conformity assessment of pressure equipment and assemblies of pressure equipment. It therefore aims to ensure the free placing on the market and putting into service of the equipment within the European Union and the European Economic Area. Formulated under the New Approach the directive provides for a flexible regulatory environment that does not impose any detailed technical solution. This approach allows European industry to develop new techniques thereby increasing international competitiveness. The pressure equipment directive is one of a series of technical harmonization directives for machinery, electrical equipment, medical devices, simple pressure vessels, gas appliances etc.

The Directive concerns items such as vessels, pressurized storage containers, heat exchangers, steam generators, boilers, industrial piping, safety devices and pressure accessories. Such pressure equipment is widely used in the process industries (oil & gas, chemical, pharmaceutical, plastics and rubber and the food and beverage industry), high temperature process industry (glass, paper and board), energy production and in the supply of utilities, heating, air conditioning and gas storage and transportation.

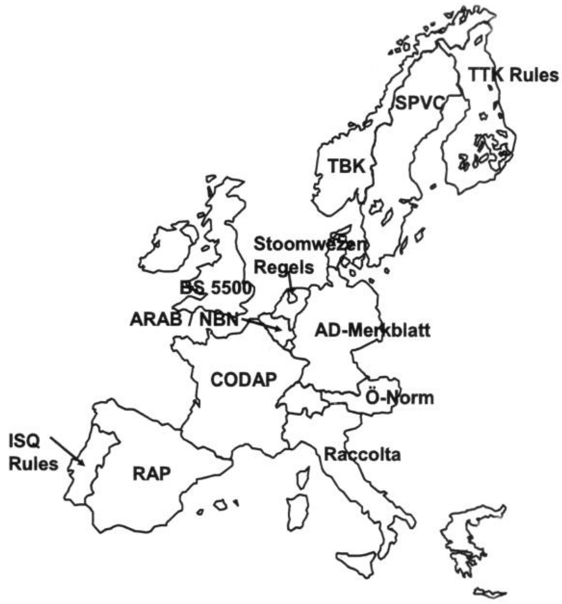
Figure 1. *Implementation of European Directives into National Law in Germany*



In all countries of the EC do exist basic technical national guidelines like the AD-Regelwerk, CODAP or BS (British Standard), fig. 2. More over several countries apply the US ASME Code. Especially US companies in the EC and their subcontractors preferred that Standard because of its world-wide acceptance. The main problem for producers of pressure vessels up to then persisted in the diversity of the different national technical guidelines. One day it has to be produced according to German AD-Regelwerk, another day according to ASME Code. In detail many problems occurred – f.e. AD-Regelwerk required an EN 473 certificate for NDT staff, ASME Code required an SNT-TC 1A certificate (Same problem does exist for the welding staff). After legal legality of the harmonized European EN 13445 new requirements due to design, production and testing appeared. In fact only a few number of production companies tried to convert to the new Standard. A lot of question for production companies as well as for classification bodies appeared:

- Do I have to test more or less compared to previous well known national guidelines?
- How can I deal with the EN 13445?
- Having less knowledge about the new Standard, to whom I can place questions?
- Can I make more profit using the EN 13445?
- Is the EN 13445 more complex than my previous national guideline?

Figure 2. *Different Technical Guidelines in the EC*



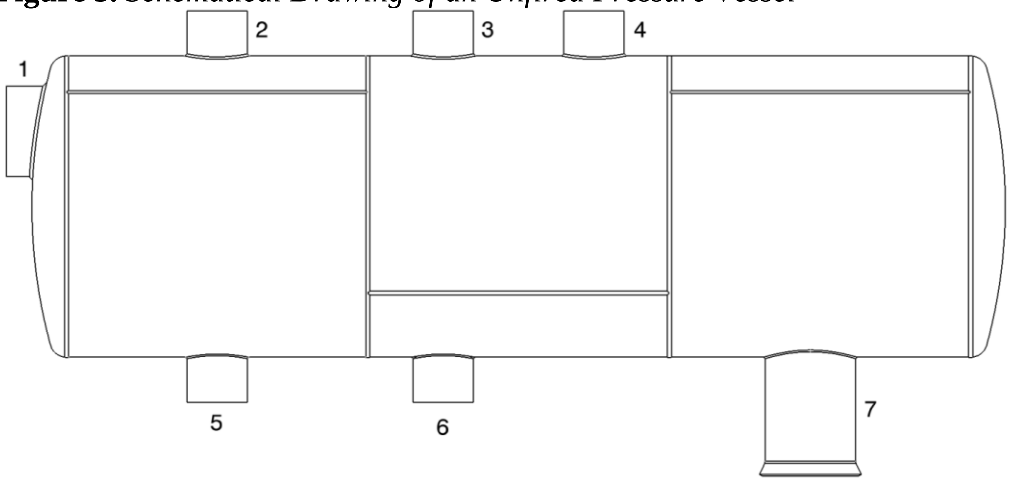
EN 13445 - Part 5 – Inspection and Testing – A Case Study
EN 13445 consists of 7 parts:

EN 13445-1 : Unfired pressure vessels - Part 1: General
EN 13445-2 : Unfired pressure vessels - Part 2: Materials
EN 13445-3 : Unfired pressure vessels - Part 3: Design
EN 13445-4 : Unfired pressure vessels - Part 4: Fabrication
EN 13445-5 : Unfired pressure vessels - Part 5: Inspection and testing
EN 13445-6 : Unfired pressure vessels - Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron
EN 13445-8 : Unfired pressure vessels - Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys

Test Zones of the NDT Methods at the Vessel

To understand the EN 13445 Standard a lot of training courses have been offered. Minimum time for the whole Standard is in many cases more than one week. We only deal in this particular example with part 5: Inspection and Testing. To get a better understanding how the Standard works one quite simple pressure vessel had been designed. The main task here consists in finding out the zones at the vessel which have to be tested by Non-Destructive Testing methods, fig. 3.

Figure 3. *Schematical Drawing of an Unfired Pressure Vessel*



Basic data

- material: 11MnNi5-3
- No serial vessel
- No cyclic load
- joint coefficient 0,85
- All fillet welds completely penetrated
- Vessel for compressed air
- operational pressure: 100 bar

Manhole 1:

- diameter: 600mm
- Wall Thickness: 25mm

Vessel shell:

- diameter: 2000mm
- Long. weld: 3x2000mm
- Wall Thickness: 25mm
- Circumferential weld: 6283mm

Nozzle 2-6:

- diameter: 400mm
- Wall thicknesss: 20mm

Nozzle 7:

- diameter: 600mm
- Wall thickness: 25mm
- Circumferential weld seam: Unidirectional welded

For pressure equipment, non-destructive tests of permanent joints must be carried out by suitable qualified personnel. For pressure equipment in categories III and IV, the personnel must be approved by a third-party organization (RTPO) recognized by a Member State pursuant to Article 13.

This means: Welding seams may only be inspected by NDT personnel, qualified and certified according to EN 473 (nowadays ISO 9712). Certificate has to include the industrial section “Welding seams” and has to be issued by a Recognized Third Party Organization according to Article 13 of the Pressure Equipment Directive. Additional the certificate has to contain the approval of the NDT personnel to be well trained on pressure vessel testing.

At first the material group has to be determined. Therefor the basic material 11 MnNi 5 3 can be found in EN 13445-2: Materials, fig. 4.

Figure 4. *Determination of Material Group*

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CR ISO 15608	Notes
39	plate and strip	EN 10028-4	low temperature properties	11MnNi5-3	1.6212	N,NT	0	80	9.1	
40	plate and strip	EN 10028-4	low temperature properties	[illegible]	[illegible]	N,NT	0	80	9.1	
41	plate and strip	EN 10028-4	low temperature properties	15NiMn6	1.6228	N,NT,QT	0	80	9.1	
42	plate and strip	EN 10028-4	low temperature properties	12Ni14	1.5637	N,NT,QT	0	80	9.2	
43	plate and strip	EN 10028-4	low temperature properties	X12Ni5	1.5680	N,NT,QT	0	50	9.2	
44	plate and strip	EN 10028-4	low temperature properties	X8Ni9+NT640	1.5662	N+NT	0	50	9.3	

Up to now the material group is identified to 9.1 and we can go forward to part 5 of the Standard. In part 5 we have to use the table 6.6.6.1-1 to determine the testing group. Additional to the knowledge of the material group we use the joint coefficient of 0,85 and the wall thickness of 25 mm. Operating with these data we can determine several testing groups, marked in fig. 5

Figure 5. *Determination of Testing Group*

Table 6.6.1-1 — Testing groups for steel pressure vessels

Requirements	Testing group [a]						
	1		2		3		4 [b,j]
	1a	1b	2a	2b	3a	3b	
Permitted materials [g]	1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Extent of NDT for governing welded joints [e,h]	100 %	100 %	100 % - 10% [c]	100 % - 10 % [d]	25 %	10 %	0 %
NDT of other welds	Defined for each type of weld in Table 6.6.2-1						
Joint coefficient	1	1	1	1	0,85	0,85	0,7
Maximum thickness for which specific materials are permitted	Unlimited [f]	Unlimited [f]	30 mm for groups 9.1, 9.2 16 mm for groups 9.3, 8.2 [i], 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	30 mm for groups 9.2, 9.1 16 mm for groups 8.2, 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	12 mm for groups 1.1, 8.1
Welding process	Unlimited [f]	Unlimited [f]	Fully mechanical welding only [c]		Unlimited [f]	Unlimited [f]	Unlimited [f]
Service temperature range	Unlimited [f]	Unlimited [f]	Unlimited [f]	Unlimited [f]	Unlimited [f]		Limited to (-10 to +200) °C for group 1.1 (-50 to+300) °C for group 8.1

In testing group 1a 100 % NDT of all welded joints is required. In group 2a also 100 % for an initial pressure vessel is requested . The percentage can be lowered if satisfactory experience can be verified. We assume that our pressure vessel is a single vessel designed and produced for the first time. In testing group 3a only 25 % extent of NDT for governing welded joints has to done. Related to costs and competitive situation a producer will often decide for a minimum of inspecting efforts and he will deal in that case with testing group 3a.

After the determination of the testing group you get more information in detail in table 6.6.2.-1 by mentioning how to deal with the separate type of welded joints, fig. 6.

Figure 6. *Determination of the Extent of NDT*

Table 6.6.2-1 — Extent of non-destructive testing

TYPE OF WELD [a, p]			TESTING [b]	EXTENT FOR TESTING GROUP [c]						
				1a	1b	2a [i]	2b [i]	3a	3b	4
				EXTENT FOR PARENT MATERIALS [l,m,n]						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1[illegible], 1.2, 8[illegible]	1.1, 8.1
Full penetration butt weld	1	Longitudinal joints	RT or UT MT or PT	100 % 10 %	100 % 10 % [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	1[illegible] % 1[illegible] % [d]	0 0
	2a	Circumferential joints on a shell	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	1[illegible] % [c] 1[illegible] % [d]	0 0

In case of less than 100 % required testing, the extent and location of non-destructive testing shall be determined at all intersections of longitudinal and circumferential butt joints. The minimum length to be tested shall be 200 mm. Where the inclusion of all intersections exceeds the percentage in Table 6.6.2-1 then this higher value will apply. If necessary to attain the percentage required in Table 6.6.2-1, additional randomly selected locations on the butt welded joint shall be subject to non-destructive testing.

The length of the longitudinal joint is 2000 mm. The vessel possesses three longitudinal joints of the same length. To shorten up the procedure in our example we inspect only by volumetric methods like Ultrasonic (UT) or Radiographic Testing (RT) and leave open the surface methods like MT or PT. 25 % of 2000 mm gives an extent of 500 mm testing zone. The circumferential joints have to be tested only by 10 % which effects a testing area of about 628 mm (10 % of 6283 mm length).

To determine the extent of non-destructive testing of nozzles and branches attached to the vessel (butt welds), the total number of nozzles and branches which have full penetration butt welds shall be grouped as follows:

1) for 100 % non-destructive testing: the size of the group is 1 (i.e. every individual nozzle and branch) ;
2) for 25 % non-destructive testing: the size group size is 4 (i.e. at least one complete nozzle or branch for each group of 4) ;
3) for 10 % non-destructive testing: the size of the group is 10 (i.e. at least one complete nozzle or branch for each group of 10).

Figure 7. *Determination of the Extent of NDT*

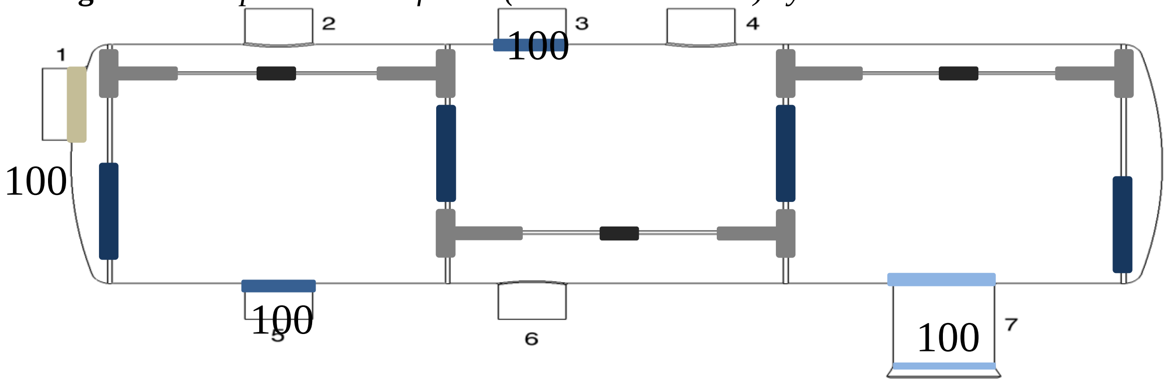
Nozzle or branch [e]	15	With full penetration d_i> 150 mm or e > 16 mm	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-25) % 10 %	(25-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	[illegible]
	16	With full penetration $d_i \le$ 150 mm and e $\le$ 16 mm.	RT or UT MT or PT	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
	17	with partial penetration for any d_i a > 16 mm (see figure 6.6.2-2)	RT or UT MT or PT [j]	100 % 10 %	25 % 10 % [d]	(100-25) % 10 %	(25-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	18	with partial penetration d_i > 150 mm. a $\le$ 16 mm.(see figure 6.6.2-2)	RT or UT MT or PT [j]	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
	19	With partial penetration $d_i \le$ 150 mm. a $\le$ 16 mm.(see figure 6.6.2-2)	RT or UT MT or PT [j]	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0

In our study case the vessel consists of 5 nozzles of the same type (nozzle no.2 to no. 6). For the 25 % NDT inspection the group size is 4 which results the conclusion to test 2 complete nozzles (e.g. the welded joints). Nozzle no. 7 is designed in a different way, therefor he has to be treated like one single group with the effect of complete testing of the welded joints. Also the manhole has to be treated in the same way.

The whole extent of NDT (volumetric method) is shown in fig. 8. A total of mm has to be tested.

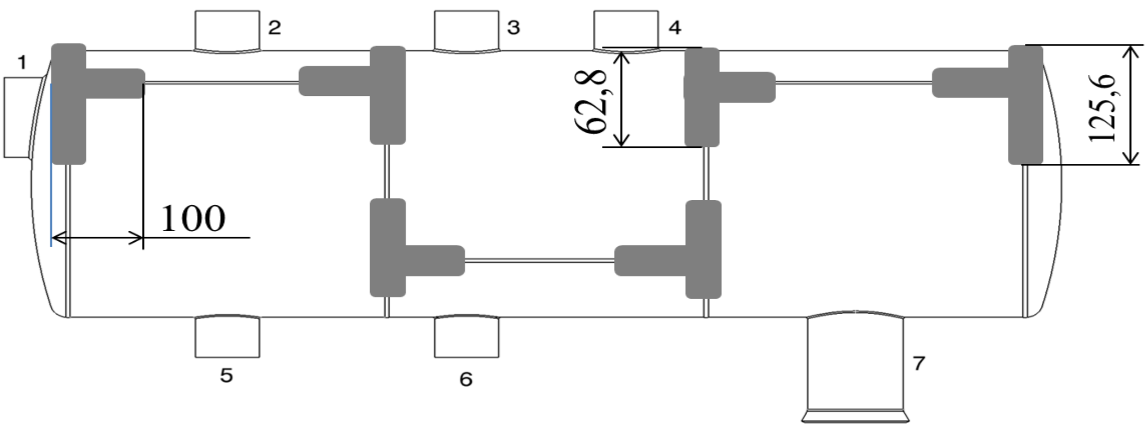
- 1500 mm of the longitudinal joints
- 2412 mm of the circumferential joints
- 2400 mm 2 nozzles joint (type no. 2 to no. 6)
- 1200 mm nozzle joints no. 7

Figure 8. *Complete Extent of NDT (volumetric method) by EN 13445*



A comparison to the German AD-Regelwerk shows a different extent of NDT, fig. 9. Not in any case it has to be tested with a larger extent by using the EN 13445. It depends on many parameters like wall thickness, kind of material, welding process, temperature, etc. In addition using the AD-Regelwerk an authorized inspector has to observe the NDT and can influence the production and testing process directly on site. This fact is not necessary according to EN 13445. The Notified Body has to check the results of NDT measurements. The discussion if the Notified Body is allowed to check for example the Radiographic films of the joint welds and evaluate by himself is still going on.

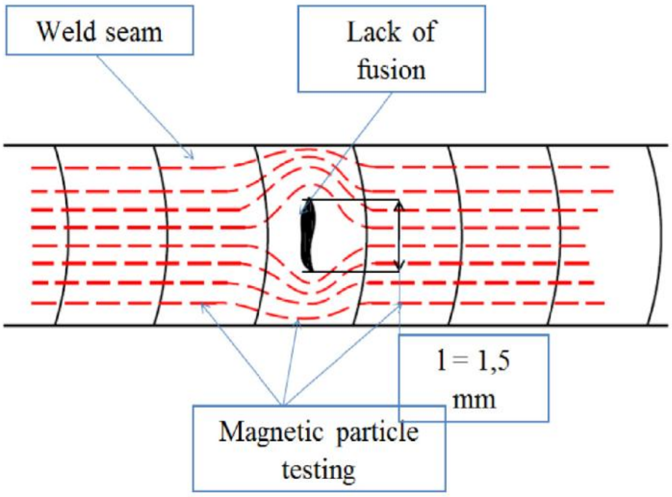
Figure 9. *Complete Extent of NDT (volumetric method) by AD-Regelwerk*



Evaluation of Detected Indications

To find out how the EN 13445 and the AD-Regelwerk are dealing with indications we assume that the NDT staff had found indication in the surface of a welded joint by Magnetic Particle Inspection (MT), fig. 10.

Figure 10. *Indication in a Welded Joint Detected by MT*



This indication – a lack of fusion – holds a length of 1,5 mm. For the classification to flaw indication EN 13445 refers to another harmonized Standard, EN 1291, table 1: Non-destructive examination of welds – Magnetic Particle Testing of welds – Acceptance Levels. In EN 13445 it is advised to classify the indication by indication level 2X. Level 2 specified with a suffix "X" shall be assessed to level 1.

Figure 11. *EN 1291 – NDT of Welds - MT*

Table 1: Acceptance levels for indications

Dimensions in millimetres

Type of indication	Acceptance level 1)		
	1	2	3
Linear indication l = length of indication	l ≤ 1,5	l ≤ 3	l ≤ 6
Non-linear indication d = major axis dimension	d ≤ 2	d ≤ 3	d ≤ 4

1) Acceptance levels 2 and 3 may be specified with a suffix "X" which denotes that all linear indications detected shall be assessed to level 1. However, the probability of detection of indications smaller than those denoted by the original acceptance level can be low.

The acceptance level of AD-Regelwerk, HP 5/3 follows own regulations to evaluate flaw indications:

Linear indications, based on material cuts are not allowed. Surface pores are valid to rare appearance (AD HP 5/3).

In fact the detected indication would be valid according to EN 13445 eg. EN 1291 and would not be allowed by AD-Regelwerk. So it can be point out that both Standards cannot be compared anywhere. Each Standard influences the design, the production and the testing in its own way.

Conclusions

Not in any case the EN 13445 in comparison to other national technical guidelines – in our study case to the German AD-Regelwerk - offers a larger extent of testing. It strongly depends on the type of pressure vessel and its whole parameters. The EN 13445 seems to be more complex and shows more details. The reason for the complexity: the responsibility is shifted more into the direction of the producer. In Germany the AD-Regelwerk requires the presence of an authorized inspector of the third-party authority during production and testing. According to EN 13445 it is no longer necessary. The evaluation of indications detected by NDT-methods are basing in many cases upon the harmonized Standards, in EN 13445 as well as in AD-Regelwerk. But the German AD-Regelwerk follows additionally own classification rules for indications.

In comparison to AD-Regelwerk more and additional design calculation methods are offered. In some cases pressure vessels can be designed by a lower wall thickness, in other cases the vessel has to be designed by a higher wall thickness. Many pressure vessel producing companies do not rise the occasion at that moment to find out the advantages of the EN 13445 due to potential savings. Only big concerns are able to insert project teams to deal with the EN 13445 over a longer period with regard to the high personnel costs of training. The way the EN 13445 will tend to be successful as a really common Code opposite to previous national technical guidelines will strongly be influenced by these big concerns. If they realize some advantages in cost saving the market will follow them within a short period. BASF announced two years before to convert from AD-Regelwerk to EN 13445. This process is still going on.

Moreover it will be a combat between the European Standards and the US ASME Code with regard to the world-wide leadership. If the Europeans will not be able to work with their harmonized Standards, they will lose that battle.

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