FACULTY OF MECHANICAL ENGINEERING – SKOPJE

CAPE - Center for Assessment of Pressure Equipment

International Conference on

PRESSURE EQUIPMENT SECTOR IN EUROPE AND REFLECTIONS IN THE REPUBLIC OF MACEDONIA

- Quality assurance and integrity assessment –

TEMPUS PROJECT IB-JEP-16047-2001:

"Center for Assessment of Pressure Equipment (CAPE)"

Skopje, April 2005

EUROPEAN PRESSURE EQUIPMENT DIRECTIVE AND NON-DESTRUCTIVE EXAMINATIONS IN STRUCTURE INTEGRITY ASSESSMENT

M. Arsić, V. Aleksić, Institute for Materials Examination, Belgrade, Serbia and Montenegro
J. Kurai, CertLab.Co, Serbia and Montenegro

RESUME

Pressure equipment has to be designed, manufactured, inspected, equipped and installed in such manner to ensure safety when it is introduced in exploitation in accordance with manufacturer's guidelines and working conditions.

Non-destructive examinations of inseparable joints have to be carried out by skilled personnel.

Personnel who perform examinations of high class pressure equipment have to be authorized by the independent organization which is recognized by member countries.

Finial inspection can be applied to any part of the equipment, internally and externally, in suitable manufacturing phases, until it is believed to be necessary from the safety aspect.

This paper presents summary of new and general approach to standardization and technical harmonization of pressure equipment (Pressure Equipment Directive – PED), regarding to structure integrity i.e. basic safety demands, calculations, designing and strength examination with special emphasize of nondestructive examinations.

INTRODUCTION

Pressure equipment (PE) with its specific demands in designing, manufacturing, examination and safety, has to be designed with respect to all relevant influences in order to ensure safety during exploitation. Design of pressure equipment has to include adequate factors of safety. Allowable stresses have to be limited by possible mistakes in working conditions in order to completely eliminate uncertainty as a consequence of manufacturing conditions, calculation model, real exploitation conditions as well as properties and behavior of base metal and welded joints.

According to "new approach" in European Union regulatory rules, designing and manufacturing of pressure equipment is performed in conformity with established legal and technical rules whereby manufacturer is not obliged to apply harmonized standards, but if product is manufactured according to adequate standards it is consequently admitted to have guaranteed level of safety as well as people and environment protection. Enhanced responsibility of manufacturer implies in higher efficiency, better and modern approach and cost savings.

Calculation methods have to ensure demanded safety level. Demands could be fulfilled by using one of following methods, as it is suitable in given moment or if it is necessary as a supplement of other method:

- by using of formulas,
- by using of finite elements method,
- analysis,
- fracture mechanics parameters.

Design of equipment becomes valid, entirely or partially, when it is confirmed by the adequate examinations for specific equipment type or category. Priorities clearly determined in examination program have to be accepted by the authorized body which is responsible to evaluate design conformity. Where it is requested examination has to comprise examination of pressure equipment critical zones by using of precise instruments to record stress and strain.

1. DIRECTIVE 97/23/EC AND SUPPORTING HARMONIZED STANDARDS

Directive 97/23/EC consists of 21 articles and 7 annexes. Basic text contains legal fundamentals and general technical demands, categories of pressure equipment, clauses referring to "notified bodies" for conformity examination and sequence of proofing. Annexes determine/specify technical content of demands.

Directive is amended by the Recommendations of EU Expert Commission for Pressure Equipment, which don't have obligatory power, but they are supplement of the Directive and they refer to the application of Directive's demands.

Directive reclines on harmonized standards and supporting harmonized standards. Mutual position of Directive and standards is given in Fig. 1.

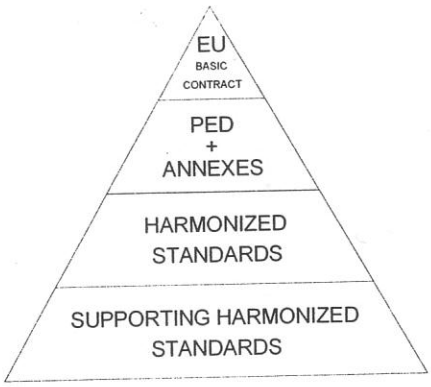

Figure 1. Mutual position of Directive and standards

1.1 Harmonized standards

Harmonized standards are standards concerning the same subject, approved from different standardization bodies, which enable interchange of products, processes and services or mutual accepting of examination results or giving information according to JUS/ISO/IEC/ standards, Guideline 2:2001.

Harmonized standards specify technical demands and determine examination methods. Minimal safety conditions demanded by Directive are fulfilled by application of harmonized standards. Harmonized standards for the equipment comprised by Directive are given in respect to equipment category, at present just in form of recommendation:

• Pressure vessels that aren't heated	pr EN 13445 parts 1-6
• Boilers with large water space	pr EN 12953 parts 1-12
• Boilers with water heating pipes	pr EN 12952 parts 1-15
• Industrial pipes, pipelines	pr EN 13480 parts 1-6
• Safety equipment	doesn't exist
• Equipment exposed to pressure	doesn't exist
• Mounting units	doesn't exist

1.2 Supporting harmonized standards

Harmonized standards referring to wide area of supporting harmonized standards, which define demands regarding specific elements and methods details. They are grouped to:

- NDT Standards
- Standards which define welding and similar procedures
- Standards for materials
- Standards for products (pipelines, forgings…)
- Standards for coiling connections

Standards about NDT methods principles:

- RT Radiographic testing EN 1330-3:1997
- PT Liquid penetrant testing EN ISO 12706:2000
- UT Ultrasonic testing EN 1330-4:2000
- AT Acoustic emission testing EN 1330-9:2000
- ET Eddy current testing EN 1330-5:1998
- LT Leak tightness testing EN 1330-8:1998
- MT Magnetic particles testing pr EN ISO 12707
- VT Visual testing pr EN 1330-10

Standards for NDT of welded joints

- VT Visual examination EN 970:1997
- ET Eddy current examination of welds EN 1711:2000
- MT Magnetic particle examination of welds EN 1290:1997; EN 1291:1998
- PT Penetrant testing of welds EN 1289:1998
- RT Radiographic examination of welded joints EN 1435:1997; EN 12517:1998
- UT Ultrasonic examination EN 1713:1998; EN 1712:1997

Review of harmonized supporting standards in the field of non-destructive testing appeared till now is given in Table 1.

Table 1. Harmonized supporting standards in the field of non-destructive testing

No.	Designation	Title
1.	EN 473:2000	Non-destructive testing. Qualification and certification of NDT personnel. General principles.
2.	EN 583-1:1998	Non-destructive testing. Ultrasonic examination: Part 1. General principles.
3.	EN 1289:1998	Non-destructive examination of welds. Penetrant testing of welds. Acceptance levels.
4.	EN 1291:1998	Non-destructive examination of welds. Magnetic particle testing of welds. Acceptance levels.
5.	EN 1593:1999	Non-destructive testing. Leak testing. Bubble emission techniques.
6.	EN 1711:2000	Non-destructive examination of welds. Eddy current examination of welds by complex plane analysis.
7.	EN 1713:1999	Non-destructive examination of welds. Ultrasonic examination. Characterization of indications in welds.
8.	EN 12517:1998	Non-destructive examination of welds. Radiographic examination of welded joints. Acceptance levels.
9.	EN 1779:1999	Non-destructive testing. Leak testing. Criteria for method and technique selection.

We can conclude from the exposed above that a number of observations, interpretations and supplements of legal and technical rules should be expected before users and notified bodies could use Directive 97/23/EC /1/ with certainty.

2. CAPABILITY OF IMPERFECTIONS DETECTION BY NON-DESTRUCTIVE METHODS

Examination of inseparable joints, in a great deal depends on the possibility of detection and the specification of the imperfection category, position and magnitude. Non-destructive examinations are mainly used for that purpose. Liquid penetrants, magnetic particles and eddy currents are used for the detection of surface imperfections, and radiographic and ultrasonic testing are used for the detection of internal imperfections.

Assessment of pressure equipment condition during exploitation by using of NDT methods could be separated in eight different fields:

1. detection of imperfections and their estimation,
2. testing of leak tightness and its assessment,
3. measuring of dimensions and their assessment,
4. macrostructural characterization,
5. establishing of mechanical and physical properties,
6. determination of critical stresses and the dynamic response,
7. designation and type identification,
8. determination of chemical composition.

Selection of the most adequate NDT method or the combination of NDT methods demands clear comprehension of the problem.

Non-destructive method is usually characterized by its capability to detect a tiny imperfection with the requested certainty level, which makes difficulties in the application of non-destructive examination, taking in respect that data evaluation in a great deal depends on objective circumstances but also on operator's mistakes.

Distribution of imperfections magnitude in relation to the capability of their detection by using of non-destructive methods is shown on Fig. 2.

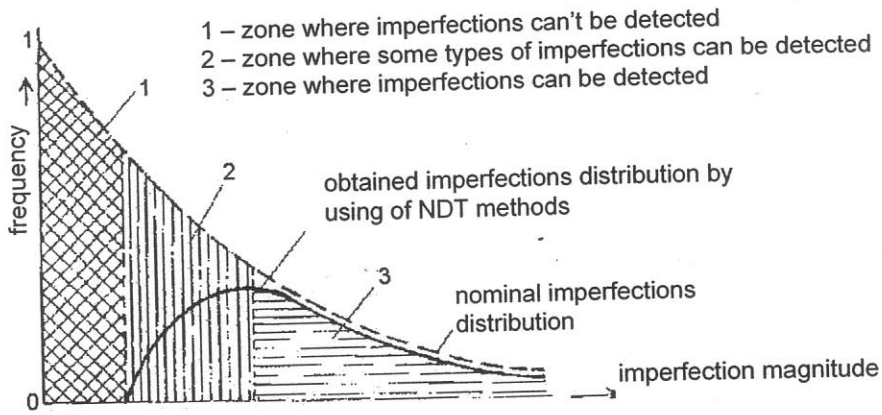

Figure 2. Distribution of imperfections magnitude frequency in relation to the capability of their detection

Once when imperfection is detected it should be decided is it necessary to repair it, since the presence of imperfections in welded joints, as it has been mentioned, doesn't always mean lack of working ability or applicability of welded structure, pressure equipment in this case. It is necessary to analyze imperfection types, their magnitude and frequency in respect to the category of pressure equipment and the character of loading. Before the decision is made we have to considerate probable loading, structure's environment, danger of fracture and its possible consequences. Approach which determines these factors is usually called "usage readiness" and its advantage over empirical indicators lies in following reasons:

- Repairs could be expensive, especially when mounting and exploitation of pressure equipment are late
- Lifetime of "repair" could be lower than the lifetime of former version, taking into consideration that repairs more frequently are performed by removing of imperfection and repeated welding. Repaired weld could contain new imperfections, its toughness could be lower and welding could introduce some additional residual stresses, due to the fact that the treatment of thermal relaxation is usually inconvenient on local level and also is expensive to be applied to complex equipment.

Approach of exploitation readiness based on imperfections assessment in previous practice has been comprised in multistage procedure:

- Imperfections are characterized regarding their magnitude and position. That includes direct measuring of imperfection magnitude by using of non-destructive examination methods, and upon this making of corresponding conclusions along with certain assumptions.
- Local stress spectrum is determined.
- Calculation of fatigue crack growth is applied and upon this consideration of probability that crack won't grow.
- Determination of critical size for imperfection growth before it cause fracture.
- If calculations show that critical imperfection size will be reached before next inspection, reparation is necessary.

3. TECHNICAL REQUESTS AND TECHNICAL RECOMMENDATIONS

Taking into consideration that the basic purpose of the Directive 97/23/EC is to assure safety of products which belong to pressure equipment, i.e. their compliance in designing and manufacturing with technical requests, question how to regulate tracking of pressure equipment in exploitation is asked.

Answer to that question is not given by the *Regulations about technical requests for pressure equipment* because it proposes only technical requests which have to be fulfilled in designing, manufacturing and compliance assessment of pressure equipment.

On the basis of mentioned above and the fact that the application of harmonized and other standards according to the Directive is not obligatory for pressure equipment manufacturers, we can conclude that tracking of pressure equipment in exploitation should be performed according to certain technical recommendations. Technical recommendations could come from common work of professional organizations and equipment users.

Example of recommendation which is harmonized in this way in Serbia and Montenegro is "Inspection and examination of spherical tanks made of microalloyed steels during exploitation" /2/. Outline of this recommendation is given hereinafter.

3.1 Technical recommendation for inspection and examination of spherical tanks made of microalloyed steels during exploitation

Technical recommendation originated from the need due to the fact that massive damages in the form of different cracks have been detected during regular inspections of spherical tanks made of microalloyed steels (yield stress more than 450 MPa).

Taking this into consideration regular inspection periods have been shortened, and examinations have been extended with ultrasonic and magnetic particles examination. Those examinations have been performed on free will without any established order.

In order to avoid mentioned situation and to establish certain order in this field, procedure for inspection and examination of spherical tanks made of microalloyed steels during exploitation has been proposed and adopted.

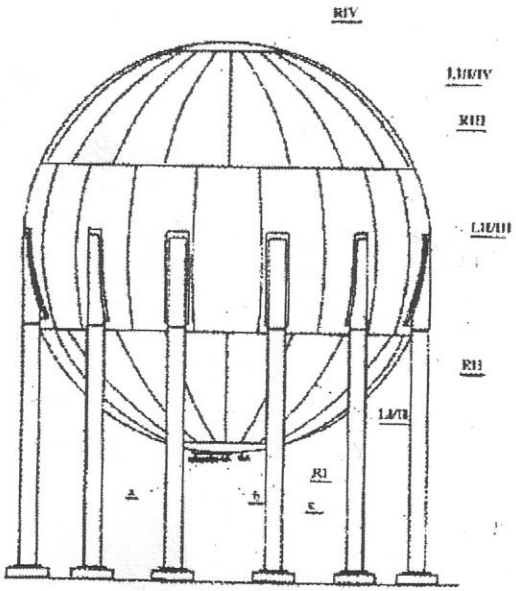

Figure 3. Spherical tank

3.1.1 Beginning of Examination

Examination can be performed after the Program of examination has been made and certified by authorized organization. Program has to comprise analysis of previous examinations findings.

Operators who perform particular NDT method have to be qualified according to JUS ISO 9712, level II for ultrasonic examinations and level I for other NDT methods.

3.1.2 Places of Examination

Examination is performed by non-destructive methods on the inner side of the tank at following places:

- on welded joints and base metal at the distance of 100 mm on both sides of the joint,

- in zones of supporting columns joint,
- at all places where imperfections have been detected in previous examinations.

3.1.3 Preparation for Examination

When conditions for entry are ensured, tank is examined from inner side. Zones of 100-200 mm wide from both sides of all butt and fillet welded joints, and also all places mentioned in 4.1.2 should be marked, as it is defined in the Program of examination.

All mentioned zones should be cleaned to metallic glow.

3.1.4 Scope of Non-destructive Examination Before Pressure Test

When requests from 4.1.3 are fulfilled, tank is examined from inner side as follows:

- Visual examination of the tank (scope 100%).
- Magnetic particles examination of welded joints and zones up to 100 mm of basic metal from both sides of welded joints, and also the zones defined in 4.1.2 (scope 100%).
- If mentioned examinations show defects and damages, in order to define the nature and the cause of their appearance, it is necessary to take the marks of characteristic damages and in case of need to perform the examination by using of other methods (ultrasonic, metalographic, penetrants, hardness measuring, deposit analysis, control calculation, measuring of residual stresses).
- If surface imperfections and damages which affect to certainty of examinations results are detected, those imperfections have to be removed or repaired before examinations are performed.
- If on the occasion of examination according this recommendation there is no legal obligation for pressure test, further examination of that tank is performed as it is quoted in 4.1.6.

3.1.5 Pressure Test

Cold water pressure test is performed on the conditions which are proposed in Yugoslav regulations and standards. This test can be performed without throwing out the scaffoldings, but in that case is necessary to ensure agreement of certified designer.

3.1.6 Scope of Non-destructive Examination After Pressure Test

When tank is discharged and cleaned, tank is examined from inner side as follows:

- Visual examination of the tank (scope 100%).
- Magnetic particles examination of zones quoted 4.1.2 (scope 100%).
- Ultrasonic examination of butt welded joints by using 2 different incident angles, in dependence from quality level of welded joint in defined scope. This examination should comprise places which previous examinations have pointed as imperfectioned and damaged.
- In the case that defects are detected by these examinations, third clause from 4.1.4 is applied .

3.1.7 Acceptance Criteria

All imperfections detected by NDT methods have to be recorded. Acceptance criteria for welded joints have to be in accordance with JUS ISO 5817.

Volumetric imperfections, undercuts and rippling which originated during tank manufacturing should be recorded and traced in order to state possible changes and a need of adequate repair.

3.1.8 Repair of Damaged Places

In the case that examinations before and after of the pressure test detect defects, repair of the tank has to be performed according the Program of repair which is approved by the authorized organization.

Detailed report about performed repair has to be made.

4. HARMONIZATION OF TECHNICAL REGULATIONS IN SERBIA AND MONTENEGRO WITH EU DIRECTIVES (INSTEAD OF CONCLUSION)

Technical regulations in Serbia and Montenegro (in the form of technical norms, orders about obligatory certifying, quality norms), are legislated by the federal minister, on the basis of new Standardization Law. Beside the changes concerning competence in technical regulation legislation, innovation lies also in the content of technical regulations since they contain clauses about certification of products, processes and services.

Harmonization of technical regulations in Serbia and Montenegro with European Directives should be observed so that technical requests proscribed in technical regulations are identical with European Directives.

However, proceeding from the assumption that legislated technical regulation should be applied without exceptions, question of economic ability remains unanswered, on one side, and on the other side there is a question how to allow application of process which is not as safe as in European countries, or appearance of products which safety are unconfirmed could be allowed.

When we consider questions of people safety and environmental protection, nobody could have privileges toward the technical regulation proscribed requests, which implies the conclusion that regulations in Serbia and Montenegro have to be harmonized with international technical regulations, which is not done as yet. It is just a question of time, taking into consideration that Standardization Law has been passed long time ago, and numerous changes have been occurred in the fields of accreditation and certification of processes, products and personnel, which have not been adopted properly in our legislative.

Actual situation is that Certification Law, Accreditation Law and the Metrology Law have been done and their adoption is expected in the first half of this year. Technical regulations are considered by the professional organizations and users of pressure equipment. Recommendations from the field of NDT are point of interest of Serbian Society for Non-destructive Testing, and the Society for Structural Integrity and Life is engaged in preparation of recommendation from the domain of pressure equipment strength and integrity.

REFERENCES

[1] Pressure Equipment Directive 97/23/EC (PED) with annexes
[2] Technical Recommendation for the Inspection and Examination of Spherical Tanks Made of Microalloyed Steel During Exploitation.