

# Bolted Flange and Sealing

## Theoretical, Engineering and Experimental Validation Program

EPERC TG3 preliminary chairman

Claude Faidy

[Claude.faidy@gmail.com](mailto:Claude.faidy@gmail.com)

### Table of Content

- 1. Introduction .....2**
  - 1.1. European Regulation (PED) and consequences.....2
  - 1.2. Needs of EN standards .....2
- 2. Major Objectives of EPERC TG3.....2**
- 3. Potential EU Research Support .....3**
- 4. EPERC TG3- Detailed Proposed Working Program .....3**
  - 4.1. Project Introduction .....3
  - 4.2. Potential Topics .....3
  - 4.3. List of Work Packages and Tasks.....3
    - 4.3.1. Work Package 1: Overview of existing International Standards.....3
    - 4.3.2. Work Package 2: Gaps and Needs evaluation.....3
    - 4.3.3. Work Package 3: Non-Metallic / Metallic Seal Technology .....4
    - 4.3.4. Work Package 4: R&D Test Program .....4
    - 4.3.5. Work Package 5: Benchmarks .....4
    - 4.3.6. Work Package 6: Recommended Practices.....4
    - 4.3.7. Work Package 7: Practical Cases.....4
    - 4.3.8. Work Package 8: Project Synthesis and Conclusion.....4
  - 4.4. Final Reports and Conclusion .....4
  - 4.5. Management, Synthesis and Conclusion of the Project.....4
- 5. EC proposal for TS, TR, Guides or CWA.....5**
  - 5.1. Proposal preparation.....5
  - 5.2. Detailed Work Package Developments .....5
    - 5.2.1. Work Package 1: Overview of existing International Standards.....5
    - 5.2.2. Work Package 2: Gaps and Needs evaluation.....5
    - 5.2.3. Work Package 3: Non-metallic and Metallic Seal Technology.....5
    - 5.2.4. Work Package 4: R&D Test Program .....5
    - 5.2.5. Work Package 5: Benchmarks .....5
    - 5.2.6. Work Package 6: Recommended Practices and Code Cases.....5
    - 5.2.7. Work Package 7: Practical Examples.....5
    - 5.2.8. Work Package 8: Knowledge Transfer, Synthesis, Conclusion.....5
  - 5.3. Deliverables, planning and meetings .....5
  - 5.4. Meetings and Preliminary Budget.....5
    - 5.4.1. TG3 Project Meetings.....5
    - 5.4.2. TG3 Budget .....5
- 6. References .....6**

## 1. Introduction

### 1.1. European Regulation (PED) and consequences

The essential safety requirements laid down in this Directive [1] are **mandatory**. The obligations following from those essential safety requirements apply only if the corresponding hazard exists for the pressure equipment in question when it is used under conditions which are "reasonably foreseeable" by the manufacturer.

The manufacturer is under an obligation to analyze the hazards and risks in order to identify those which apply to his equipment on account of pressure; he shall then design and construct it taking account of his risk analysis

Pressure Equipment shall be designed for adequate strength associated to pressure loads and for loadings appropriate to its intended use and other reasonably foreseeable operating conditions. In particular, different degradation mechanisms shall be taken into account, as: fatigue, ratcheting, creep-fatigue, corrosion and erosion...

Consequently:

- some margins have to be justified in front of the basic pressure equipment failure modes, as: plastic collapse, plastic instability, local failure without crack, buckling, creep...
- potential degradation that can affect the pressure boundary has to be considered at the design stage: no thinning, no loss of material properties (material strength and toughness), no cracks, associated to do different degradation mechanisms, as fatigue, plastic shakedown, corrosions or thermal ageing...
- in some cases, the "flaw tolerance" of the pressure equipment has to be evaluated at design level to assure safe operation life of the equipment

### 1.2. Needs of EN standards

- assure "easy to use" Standards, sufficiently explain, justified, at the state of the art technical level
- assure "competitiveness" with similar international standard to assure relevance of the European pressure equipment designs: security and cost of Construction (Design, Fabrication, Protection, Tests)
- anticipate "specific or future needs" of European Pressure Equipment industry on the future Clean Energy market and other innovative Pressure Equipment application.

## 2. Major Objectives of EPERC TG3

- help all the users of EN Standards on Pressure Equipment: EN 15492-15493 for Boilers, EN 13445 for Vessels and EN 13480 for Piping System to design pressure equipment bolted flange
- review format and content of EN 12952-12953, EN 13445, EN 13480, EN1591 and EN13555 in term of Bolted Flanges, using reference [11]
- compare EN Standards with similar other International Codes & Standards, as: ASME BPVC Section VIII-Division 1-2-3 and ASME-B31, API682, KTA/ADM, BS, Japan, Korea... and ISO Standards
- collect all the references that support and justify all the proposal available inside the standards
- identified gaps and needs to remain competitive at the State Of the Art Level and new needs associated to innovation use of Pressure Equipment (pressure, temperature, environment), in connection with CEN-TC 74 Business Plan on "Flanges and their Joints" [6]
- analyze all the uncertainties associated to Failure Modes of Flanges and Leak Tightness
- propose a set of typical Benchmarks to assure applicability of the new rules
- prepare some recommended practice proposals of parts of EN 12952-12953 [7], EN13445 [8], EN13480 [9] and EN1591 [10] /EN 13555 [11]
- develop a set of practical examples on typical cases for the more complex rules
- develop a dedicated Road Map for regular reviews of Project and Tasks advancement
- Reports and knowledge dissemination closely connected, including participation to Workshop and Conferences, training courses or Master Classes proposals

### 3. Potential EU Research Support

A dedicated Report has been proposed by CEN-CENELEC:

- "How to Link Standardization with EU research projects" [2] can be found on [www.cencenelec.eu/research](http://www.cencenelec.eu/research).
- "Horizon 2020" December 2019 [3] on <https://ec.europa.eu/programmes/horizon2020/en/background-material>
- "Strategic Plan" December 2019 [4] on [https://ec.europa.eu/info/files/strategic-planning-process-and-strategic-plan\\_en](https://ec.europa.eu/info/files/strategic-planning-process-and-strategic-plan_en)
- "Different CEN cooperation working products": ES, TS, TR, Gu, CWA [5] <https://www.cen.eu/work/products/cwa/pages/default.aspx>

### 4. EPERC TG3- Detailed Proposed Working Program

#### 4.1. Project Introduction

The major objective is to consider how leak tightness of bolted can be assured with efficient Design and Installation rules, and how existing standards can help to solve some particular situation, to justify more simple engineering rules, to help in margins understanding associated to major uncertainties on Methods, Data, Parameters and Material properties used in each analysis. Identification of essential variables for each Work Package will be covered.

#### 4.2. Potential Topics

- comparison of International Codes and Standards for Bolted Flange Design: EN Standards EN 12952-53, 13445, 13480; ASME, JSME, China, Russia, BS....
- review background and consistency of EN 12952-53, 13445, 13480, 1591 and associated standards as EN 1092-1759-1514
- identification of Gaps and Needs, in particular to support innovation (high pressure, high/low temperature, different environment as hydrogen..., new materials...
- concerning the bolted flange assembly, the major questions are around the flange, the bolts, the seal, the leak tightness (no leak or fugitive emission), under complex loads (pressure, bending temperature, thermal transient, dynamic loads...), tolerances and surface finished are also to be considered, the contact metal-metal, the tightening procedure, the pressure classification...
- non-metallic flanges (HDPE-HDPE or HDPE- steel pipe) are associated to particular questions
- in term of innovation the compact flanges and the clamps with particular metallic sealing will be considered to be introduced has alternative in EN Standards....
- Leak tightness and bolted flange tests will be selected and performed
- different typical tests associated to parametric nonlinear analyses (plasticity, creep-relaxation, contact and friction factors...) will be also performed in the Project
- proposed improvement of existing EN Standards rules will be proposed to TC 74

#### 4.3. List of Work Packages and Tasks

##### 4.3.1. Work Package 1: Overview of existing International Standards

- Task 1.1: General Introduction
- Task 1.2: Flange Design Rules and historical background
- Task 1.3: Different seal technology: metallic and non-metallic
- Task 1.4: Leak Tightness performance and fugitive emission consideration
- Task 1.5: Bolt relaxation and tightening procedure
- Task 1.5: Particular cases: high pressure, high/ low temperature, different liquid or gas environments, different materials...

##### 4.3.2. Work Package 2: Gaps and Needs evaluation

- Task 2.1: Design analyses: engineering rules and detailed nonlinear analysis
- Task 2.2: Seal properties and Seal qualification
- Task 2.3: Leak tightness and fugitive emission
- Task 2.4: Flange and Bolt tightening procedure

- Task 2.5: Innovation and new operating conditions

#### **4.3.3. Work Package 3: Non-Metallic / Metallic Seal Technology**

##### **4.3.3.1. Non-Metallic Seal**

- Task 3.1: Flange Design Rules & Gasket Characterization Methods
- Task 3.2: EN 1591 and EN 13555 Application Reducing Fugitive Emissions

##### **4.3.3.2. Metallic Seal**

- Task 3.3: Status and Overview of different application and associated design rules
- Task 3.4: Compact Flanges and Clamps with metallic seals

#### **4.3.4. Work Package 4: R&D Test Program**

- Task 4.1: Seal qualification and leak tightness on specific experimental facilities
- Task 4.2: Bolted Flange Tests in different operating conditions
- Task 4.3: Pre-test analyses
- Task 4.4: Post-test analyses
- Task 4.3: Dynamic loads: Seismic and Water Hammer
- Task 4.4: HDPE bolted flange tests and analyses

#### **4.3.5. Work Package 5: Benchmarks**

- Task 5.1: Benchmarks definition and data collection
- Task 5.2: Benchmark result analyses
- Task 5.3: Synthesis and recommendations

#### **4.3.6. Work Package 6: Recommended Practices**

- Task 5.1: Leak Tightness and Fugitive Emission
- Task 5.2: Seal qualification
- Task 5.3: Engineering versus detailed nonlinear analyses Design Rules
- Task 5.4: Innovative applications and new operating conditions

#### **4.3.7. Work Package 7: Practical Cases**

- Task 7.1: Case number 1: complete design analysis of selected bolted flange
- Task 7.2: Case number 2: complete design analysis of selected bolted flange

#### **4.3.8. Work Package 8: Project Synthesis and Conclusion**

- Knowledge transfer
- Project Synthesis
- Project Conclusion

## **4.4. Final Reports and Conclusion**

Topics to be covered through contribution of different Work Packages:

1. Introduction and Definition
2. Existing Elastic Codified Rules
3. Detailed Nonlinear Design Rules
4. Experimental Program: definition, performance, pre- and post-test analyses
5. Benchmarking
6. Code Case Proposal
7. Practical Examples
8. Knowledge Transfer
9. List of Document produced in the Task

## **4.5. Management, Synthesis and Conclusion of the Project**

- Election of Chairman and definition of members list
- Detailed "Roadmap" of R&D program and each tasks
- Periodic updated Planning and Roadmap review
- Report: review by Project members and selected International Key Actors of the domain
- All the documents of each Work Package will be released to: all the sponsors and EPERC TG4 members

## 5. EC proposal for TS, TR, Guides or CWA

### 5.1. Proposal preparation

These detailed description of the Work Package have to be filled up with TG3 members (or potential members) to prepare a CEN Committee proposal for a ES (European Standards), TS (Technical Specification), TR (Technical Reports), Gu (Guides) or CWA (CEN Workshop Agreement) (<https://www.cen.eu/work/products/guides/Pages/default.aspx> )

### 5.2. Detailed Work Package Developments

To be defined with TG3 members

- 5.2.1. Work Package 1: Overview of existing International Standards
- 5.2.2. Work Package 2: Gaps and Needs evaluation
- 5.2.3. Work Package 3: Non-metallic and Metallic Seal Technology
- 5.2.4. Work Package 4: R&D Test Program
- 5.2.5. Work Package 5: Benchmarks
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- 5.2.8. Work Package 8: Knowledge Transfer, Synthesis, Conclusion

### 5.3. Deliverables, planning and meetings

To be defined later with TG Chairman and Work Package Leaders...

**A first SKYPE meeting with volunteers will take place before end of June 2020**

### 5.4. Meetings and Preliminary Budget

#### 5.4.1. TG3 Project Meetings

- To be defined later with Chairman and Work Package Leaders...
- **Max of web-meetings: SKYPE or ZOOM video conference**
  - o At WP level
  - o At TG3 Project level with TG3 Chairman and WP Leaders
  - o 1 EPERC workshop per year

#### 5.4.2. TG3 Budget

- To be defined later with Chairman and Work Package Leaders...

## 6. References

1. DIRECTIVE 2014/68/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 May 2014 on the harmonization of the laws of the Member States relating to the "making available on the market of pressure equipment"
2. "How to Link Standardization with EU research projects" can be found on [www.cencenelec.eu/research](http://www.cencenelec.eu/research) and <https://www.cen.eu/work/products/cwa/pages/default.aspx>
3. "Horizon 2020" December 2019 on <https://ec.europa.eu/programmes/horizon2020/en/background-material>
4. "Strategic Plan" December 2019 on [https://ec.europa.eu/info/files/strategic-planning-process-and-strategic-plan\\_en](https://ec.europa.eu/info/files/strategic-planning-process-and-strategic-plan_en)
5. "Different CEN cooperation working products": ES, TS, TR, Gu, CWA  
<https://www.cen.eu/work/products/cwa/pages/default.aspx>
6. CEN TC 74 Business Plan – Flanges and their Joints; 2014 01 17  
<https://standards.cen.eu/BP/6057.pdf>
  - o WG 1 Basic terminology standards,
  - o WG 2 Steel flanges (PN and Class),
  - o WG 3 Cast iron flanges (PN),
  - o WG 4 Copper alloy flanges (PN and Class),
  - o WG 5 Aluminum alloy flanges (PN and Class),
  - o WG 8 Gaskets (dimensions, testing and determination of gasket factors),
  - o WG 9 Bolting,
  - o WG 10 Calculation methods.
7. EN 12952- 12953 Boilers
8. EN 13445 Vessels
9. EN 13480 Piping
10. EN 1591 Flange
11. EN 13555 Flanges and Seal Parameters
12. F. Lidonnici, "Design of Bolted Flange Connections- Status of EN Standards", Sant'Ambrogio, May 2018 (available on EPERC website TG3)