Nonlinear Design Rules

Theoretical, Engineering and Experimental Validation Program

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Table of Content

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. Objectives

- help all the users of EN Standards on Pressure Equipment: EN 13445 for Vessels [6], EN 13480 for Piping System [7] and EN 12952-53 for Boilers [8] to perform design analyses
- review format and content of EN 13445, EN 13480 and EN12952-53 in term of Failure Mode and potential Degradation Mechanisms
- 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 adapted to Innovation
- develop some experimental R&D program to support some rule validation
- analyze all the uncertainties associated to Failure Modes and Degradation Mechanisms
- propose a set of typical Benchmarks to assure applicability of the new rules
- compare EN Standards with similar other International Codes & Standards, as: ASME BPVC Section VIII-Division 1-2-3 and ASME-B31, JSME, BS, JSME…
- prepare some rewrite proposals of parts of EN13445, EN13480 and EN 12952-53 in connection with corresponding CEN Technical Committees
- 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 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 .
- "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
- "Different CEN cooperation working products": ES, TS, TR, Gu, CWA [5] https://www.cen.eu/work/products/cwa/pages/default.aspx

4. EPERC TG4- Detailed Proposed Working Program

4.1. Project Introduction

The major objective is to consider how "Nonlinear Design Rules" of Failure Modes and Degradation Mechanisms, can help to solve some particular difficulties, 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. List of Work Packages and Tasks covered in the Project

4.2.1. Work Package 1: Failure Modes

- Task 1.1: Plastic collapse
- Task 1.2: Plastic Instability
- Task 1.3: Local Failure- Decohesion
- Task 1.4: Buckling
- Task 1.5: Creep

4.2.2. Work Package 2: Degradation Mechanisms

- Task 2.1: Fatigue
- Task 2.2: Plastic Shakedown and Ratchetting
- Task 2.3: Creep- Fatigue
- Task 2.4: Corrosions

4.2.3. Work Package 3: Flaw Tolerance

- Task 3.1: Crack growth: fatigue, corrosion, creep
- Task 3.2: Critical Crack Size
- Task 3.3: Leak Before Break
- Task 3.4: Local Approach of Failure

4.2.4. Work Package 4: Specific Mechanical cases

- Task 4.1: Nozzle Reinforcement rules
- Task 4.2: Elastic Follow-up in piping systems
- Task 4.3: Bolted Flange and Sealing
- Task 4.4: Dynamic loads: Seismic and Water Hammer
- Task 4.5: HDPE piping systems

4.2.5. Work Package 5: Materials and associated welds mechanical Properties

- Task 5.1: Metallic materials: carbon steels, low alloys steels, stainless steels, nickel based alloys
- Task 5.1: Non Steel materials: Nickel, Copper….
- Task 5.1: Non-metallic materials: HDPE, composite…
- Task 5.1: New materials for innovative applications and new operating conditions
- Task 5.1: Thermal Ageing
- Task 5.1: Environment attack

4.2.6. Work Package 6: Project Synthesis and Conclusion

4.3. Step by Step proposals for each Work Package

1. Definition

2. Existing Elastic codified Rules
3. **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

4.4. Management, Synthesis and Conclusion of the Project

- Chairman and list of members
- Detailed program of each task
- 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. Work Package 1: Monotonic Load Failure Modes

5.1. Task 1.1: Plastic Collapse

5.1.1. Definition

- No excessive deformation- globally elastic – no plasticity except in local stress concentration

5.1.2. Existing Codified Rules

5.1.2.1. General

5.1.2.2. Elastic Approach

5.1.2.3. Nonlinear existing rules

5.1.3. Nonlinear Design Rules – WP1 proposal

5.1.3.1. General

5.1.3.2. Limit Load Analysis

5.1.3.3. Elastic-plastic Analysis

5.1.4. Experimental Program

5.1.4.1. Tests

- to be confirmed in term of Test Security – stopped the test… or other proposals can be done
- a preliminary review of existing tests will be done

2 types of potential tests:

- Reinforced piping nozzle to vessel under pressure loads
- Reinforced piping to piping tees under pressure loads and piping loads

Development of a detailed test program with associated instrumentation and criteria to **safely stopped** the tests, material properties measurements and data collection to compare Test results and Analyses results.

5.1.4.2. Analyses

2 phases in Tests analysis

- pre-test analyses: with Codified existing elastic and nonlinear elastic-plastic rules
- post-test analyses: with Codified existing elastic and nonlinear elastic-plastic rules

5.1.4.3. Synthesis on Plastic Collapse Tests Analyses

- synthesis and recommendation for Codified rules and nonlinear approaches
- material property needs
- criteria and safety factors

5.1.5. Benchmarks

- To be defined with EPERC-TG4 members

5.1.6. Conclusion and Code Case proposal

- Code Case (non-mandatory Clause) proposal to improve existing EN Standard (Vessel and Piping)

5.1.7. Practical examples

- To be defined by TG4 with Codes & Standards and Industry representative

5.1.8. Document to be produced on Collapse Analyses

- General introduction to this Project Work Package (WP1) with Definitions, Existing rules, Rules proposed, material properties needed, criteria (Report 1)
- Test program and Material properties to collect: definition (Reports 2)
- Test results and Comparison with Analyses Rules and Criteria (Report 3)
- Benchmark report: definition and result analyses (Reports 4 & 5)
- Practical examples (Report 6)
- WP Synthesis and recommendation for Codified rules using nonlinear approach (Report 7)

5.2. Task 1.2: Plastic Instability

5.2.1. Definition

- large plastic deformation with striction up to burst of the PE…

5.2.2. Existing Codified Rules

5.2.2.1. General

5.2.2.2. Elastic Approach

5.2.2.3. Nonlinear existing rules

5.2.3. Nonlinear Design Rules- WP1 proposal

5.2.3.1. General

5.2.3.2. Limit Load Analysis

5.2.3.3. Elastic-plastic Analysis

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5.3. Task 1.3: Local Failure without Crack

5.3.1. Definition

- Stress Triaxiality limitation to prevent rupture (without initial)

5.3.2. Existing Codified Rules

- Elastic: limitation of the sum of the principal stresses

5.3.3. Nonlinear Design Rules – WP1 proposal

5.3.3.1. Elastic-plastic Analysis

5.3.4. Experimental Program

- **To be defined by RINA on the basis of the Report presented in Milan TG Conference**
- **Or any other proposal by anyone…**
- to be confirmed in term of Test Security – stopped the test… or other proposals can be done
- a preliminary review of existing tests will be done

Development of a detailed test program with associated instrumentation and criteria to **safely stopped** the tests, material properties measurements and data collection to compare Test results and Analyses results.

5.3.4.1. Analyses

2 phases in Tests analysis

- pre-test analyses: with Codified existing elastic and nonlinear elastic-plastic rules
- post-test analyses: with Codified existing elastic and nonlinear elastic-plastic rules

5.3.4.2. Synthesis on Local Failure Tests Analyses

- synthesis and recommendation for Codified rules and nonlinear approaches
- material property needs
- criteria and safety factors

5.3.5. Benchmarks

- To be defined with EPERC-TG4 members

5.3.6. Conclusion and Code Case proposal

- Code Case (non-mandatory Clause) proposal to improve existing EN Standard (Vessel and Piping)

5.3.7. Practical examples

- To be defined by TG4 with Codes & Standards and Industry representative

5.3.8. Document to be produced on Collapse Analyses

- General introduction to this Project Work Package (WP) with Definitions, Existing rules, Rules proposed, material properties needed, criteria (Report 1)
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- Practical examples (Report 6)
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5.4. Task 1.4: Buckling

5.4.1. Definition

- sudden change in shape of a structural component under load
- such as the bowing of a column under compression or the wrinkling of a plate under shear…
- mechanical and thermal loads

5.4.2. Existing Codified Rules

5.4.2.1. Elastic buckling

5.4.2.2. Elastic-plastic buckling

5.4.3. Nonlinear Design Rules – WP4 proposal

5.4.3.1. General

5.4.3.2. Elastic-plastic "bifurcation" Analysis

5.4.4. Experimental Program

- Selection of existing tests; supplementary tests if necessary
- test analyses
- comparison, synthesis and recommendation

5.4.5. Benchmarks

- To be defined with EPERC-TG4 members

5.4.6. Conclusion and Code Case proposal

- Code Case (non-mandatory Clause) proposal to improve existing EN Standard (Vessel and Piping)

5.4.7. Practical examples

- To be defined by TG4 with Codes & Standards and Industry representative

5.4.8. Document to be produced on Collapse Analyses

- General introduction to this Project Work Package (WP) with Definitions, Existing rules, Rules proposed, material properties needed, criteria (Report 1)
- Test program and Material properties to collect: definition (Reports 2)
- Test results and Comparison with Analyses Rules and Criteria (Report 3)
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- Practical examples (Report 6)
- WP Synthesis and recommendation for Codified rules using nonlinear approach (Report 7)

5.5. Task 1.5: Creep

- **To be defined with EPERC TG6 Creep**
- Existing Code Comparison
- Gaps and needs identification
- New needs associated to innovative PE application: elastic-visco-plastic analysis rules for "particular" needs
- Procedure to develop and use elastic-visco-plastic material constitutive equation

6. Work Package 2: Degradation Mechanisms under cyclic loads

6.1. Task 2.1: Fatigue

6.1.1. Definition

- Usage factor for Crack Initiation and Through Wall Crack

6.1.2. Existing Elastic Codified Rules

- for vessel, piping, pump, valves and support
- for crack like defect situation
- for bolt
- for bellows…

6.1.3. Nonlinear Design Rules – WP2 proposal

6.1.3.1. General and required material properties

- Basic material thermo-mechanical properties: E, α, λ, μ
- Monotonic and cyclic stress-strain curves
- Fatigue curves of the material
- All with temperature dependence

6.1.3.2. Simplified Elastic-Plastic Analyses

- factors to correct elastic strain amplitude with plasticity level
- Based on K_e (strain amplification due to plasticity and secondary stresses)and K_υ (υ value modification due to plasticity 0.3 ➔ 0.5)
- 2 objectives:
  - Confirm validity of existing codified factors
  - Develop a direct evaluation procedure for particular cases

6.1.3.3. Elastic-plastic Analysis

- Cycle by cycle analyses
- Dedicated material constitutive equations: model calibration, model validation
- model application procedure on component

6.1.4. Experimental Program

- review and selection of existing tests
- typical potential test: piping thickness variation or valve body….
  Under Pressure and Thermal Shock Loads
- pre-test analyses
- post-test analyses
- synthesis and recommendation

6.1.5. Benchmarks

- To be defined with EPERC-TG4 members

6.1.6. Conclusion and Code Case proposal

- Code Case (non-mandatory Clause) proposal to improve existing EN Standard (Vessel and Piping)

6.1.7. Practical examples

- To be defined by TG4 with Codes & Standards and Industry representative

6.1.8. Document to be produced on Collapse Analyses

- General introduction to this Project Work Package (WP) with Definitions, Existing rules, Rules proposed, material properties needed, criteria (Report 1)
- Test program and Material properties to collect: definition (Reports 2)
- Test results and Comparison with Analyses Rules and Criteria (Report 3)
- Benchmark report: definition and result analyses (Reports 4 & 5)
- Practical examples (Report 6)
- WP Synthesis and recommendation for Codified rules using nonlinear approach (Report 7)

6.2. Task 2.2: Plastic Shakedown

6.2.1. Definition

- the steady state is a closed elastic-plastic loop, with no net accumulation of plastic deformation
- ratcheting behavior is one in which the steady state is an open elastic-plastic loop, with the material accumulating a net strain during each cycle

6.2.2. Existing Codified Rules

- Elastic approach: 2 S_y criteria
- Bree Diagram

6.2.3. Nonlinear Design Rules – WP2 proposal

6.2.3.1. General

6.2.3.2. Engineering approach based on elastic-perfectly plastic material

6.2.3.3. Elastic-plastic Analysis

- Cycle by cycle analyses with a model that can develop progressive deformation
- model calibration, model validation
- procedure to apply the model selected to a component

6.2.4. Experimental Program

- Review of existing tests
- Develop one set of simple tests for different materials, as traction-torsion test of bar
- Perform validation tests on 2 major materials

6.2.5. Benchmarks

6.2.6. Conclusion and Code Case proposal

- Code Case (non-mandatory clause) proposal to improve existing EN Standard

6.2.7. Practical examples

- To be defined by TG4 with Codes & Standards and Industry representative

6.2.8. Document to be produced on Collapse Analyses

- General introduction to this Project Work Package (WP) with Definitions, Existing rules, Rules proposed, material properties needed, criteria (Report 1)
- Test program and Material properties to collect: definition (Reports 2)
- Test results and Comparison with Analyses Rules and Criteria (Report 3)
- Benchmark report: definition and result analyses (Reports 4 & 5)
- Practical examples (Report 6)
- WP Synthesis and recommendation for Codified rules using nonlinear approach (Report 7)

6.3. Task 2.3: Creep Fatigue interaction

- **To be defined with EPERC TG6 on Creep**
- Existing Code Comparison
- Gaps and needs identification
- New needs associated to innovative PE application
- Procedure to develop and use elastic-visco-plastic material constitutive equation

7. Work Package 2: Degradation Mechanisms with surface interaction

7.1. Task 2.4: Corrosions

To be defined with EPERC TG7 on Fitness for Service

7.1.1. Introduction

7.1.1.1. General Corrosion

- Manage through general design rules
- Major parameter: thinning rate

7.1.1.2. Flow induced corrosion – Corrosion Erosion

- Consequences: Local Thinning Areas
- Major parameter: localization and thinning rate for different materials
- Less sensitive material: EN Standards and other international Codes

7.1.1.3. Local Thinning area

7.1.1.3.1. Engineering Approach

- Existing Code Development Comparison
- Gaps and needs identification
- New needs associated to innovative PE application

7.1.1.3.2. Nonlinear Analysis

- Procedure to develop and use nonlinear rules
- Limit load or elastic plastic FE analysis
- Level and influence of local Residual Stresses

7.1.1.4. Stress Corrosion cracking

7.1.1.4.1. Engineering Approach

- Existing Code Development Comparison
- Gaps and needs identification
- New needs associated to innovative PE application
- Engineering methods

7.1.1.5. Nonlinear Analysis

- Based on Fracture Analyses
- Level and influence of local Residual Stresses

7.1.2. Experimental Program

7.1.2.1. Residual Stress Measurement and Evaluation

7.1.2.2. Local Thinning Area

7.1.2.3. Stress Corrosion Cracking

7.1.3. Conclusion and Code Case proposal

- Code Case (non-mandatory clause) proposal to improve existing EN Standard

7.1.4. Practical examples

- To be defined by TG4 with Codes & Standards and Industry representative

7.1.5. Document to be produced on Corrosion Analyses

- General introduction to this Project Work Package (WP) with Definitions, Existing rules, Rules proposed, material properties needed, criteria (Report 1)
- Test program and Material properties to collect: definition (Reports 2)
- Test results and Comparison with Analyses Rules and Criteria (Report 3)
- Benchmark report: definition and result analyses (Reports 4 & 5)
- Practical examples (Report 6)
- WP Synthesis and recommendation for Codified rules using nonlinear approach (Report 7)

8. Work Package 3: Flaw Tolerance

To be defined with EPERC TG7 on Fitness for Service

8.1. Introduction

8.2. Task 3.1: Crack Growth

8.2.1. Fatigue Crack Growth

- with ΔJ instead of ΔK
- level and influence of residual stresses

8.2.2. Corrosion crack growth

8.3. Task 3.2: Critical Crack Size

8.3.1. Definition

- Minimum Charpy value / toughness level
- Brittle/ Ductile Conditions: Rupture with K for Brittle and J for Ductile
- Leak Before Break (LBB)

8.3.2. Existing Codified Rules

- Engineering approaches:
  - K handbook,
  - J-K relationship
  - Corrosion-Fatigue crack growth material data
  - Leak Before Break: through wall critical crack, crack area and flow rate

8.3.3. Nonlinear Design Rules

8.3.3.1. Introduction

- international codes comparisons
- Gaps and needs

8.3.3.2. Reference stress method for J evaluation

- For surface and sub-surface cracks
- For through wall crack

8.3.3.3. Finite Element Analysis

- recommendation for cracked component

8.3.3.4. Local Approach

8.3.4. Experimental Program

- **Selection of existing tests**
- **supplementary tests if necessary to be defined**
- test analyses on vessels and piping (carbon/law alloys steel; stainless steel; other materials…)
- analysis, synthesis and recommendations

8.4. Task 3.3: Leak Before Break

8.4.1. Critical Through Wall Crack

8.4.2. Crack area and leak flow rate for LBB

8.5. Task 3.4: Local Approach of Rupture

- Gurson, BEREMIN, Rousselier models
- Master curve approach: T_0 toughness curve indexation instead of RT_{NDT}

8.6. Work Package 3: Synthesis and Conclusions

8.6.1. Conclusion and Code Case proposal

- proposal to improve existing EN Standard in Design Flaw Tolerance and Operation Standards

8.6.2. Practical examples

- To be defined with Codes & Standards and Industry representative
- Leak before Break and Incredibility of Failure

9. Work Package 4: Specific Mechanical Cases

9.1. Task 4.1: Nozzle Reinforcement rule

9.2. Task 4.2: Elastic Follow-up

9.3. Task 4.3: Bolted Flange and model with seal and leak evaluation

(To be defined with EPERC TG4 on Bolted Flange)

- International Code Comparison
- Gaps and needs
- Innovative clamp and compact flange with metallic seal
- Non-metallic seal nonlinear properties

9.4. Task 4.4: Dynamic Loads: Seismic and Water Hammer

- Elastic approach
- Nonlinear time history analyses
- Cumulative strain criteria
- Maximum load or fatigue-ratchet failure mode

9.5. Task 4.5: HDPE piping systems

- Large diameter pipe and fittings for different type of plants
- Underground – Trench – Above ground installation
- Fusion Joint: butt-fusion or electrofusion or mechanical
- Material properties: base metal, heat affected zone and weld
- Installation and defect tolerances
- Connection flange= HDPE – metallic piping design rules
- Crack analyses with a visco-elastic model of material
- A dedicated experimental program has to be proposed
- Code case proposal for EN 13480

10. Work Package 5: Material Properties for PE Design rules

10.1. Task 5.1: Metallic materials

- carbon steels, low alloys steels, stainless steels, nickel based alloys

10.2. Task 5.2: Non Steel materials

- Aluminum, Nickel, Copper….

10.3. Task 5.3: Non-metallic materials

- HDPE, composite…

10.4. Task 5.4: New materials for innovative applications

- new operating conditions:
- As Additive Manufacturing Materials… **(To be defined with EPERC TG5 on Additive Manufacturing)**

10.5. Task 5.5: Thermal Ageing

- as martensitic steels
- or Duplex cast stainless steels
- including welds under high temperature

10.6. Task 5.6: Environmental attack

- Fatigue resistance under water
- Hydrogen environment, as High Temperature Hydrogen Attack…
- Other environments

11. Work Package 6: Project Synthesis and Conclusion

- Knowledge transfer
- Project Synthesis
- Project Conclusion

11.1. Final Reports and Conclusion

Topics to be covered through contribution of different Work Packages:

10. Introduction and Definition
11. Existing Elastic Codified Rules
12. Detailed Nonlinear Design Rules
13. Experimental Program: definition, performance, pre- and post-test analyses
14. Benchmarking
15. Code Case Proposal
16. Practical Examples
17. Knowledge Transfer
18. List of Document produced in the Task

11.2. Management, Synthesis and Conclusion of the Project

- Chairman and list of members
- 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

12. EC proposal for TS, TR, Guides or CWA

12.1. Proposal preparation

These detailed description of the Work Package have to be filled up with TG4 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)

12.2. Detailed Work Package Developments

To be defined with TG4 members

12.2.1. Work Package 1: Failure Modes

- Task 1.1: Plastic collapse
- Task 1.2: Plastic Instability
- Task 1.3: Local Failure- Decohesion
- Task 1.4: Buckling
- Task 1.5: Creep

12.2.2. Work Package 2: Degradation Mechanisms

- Task 2.1: Fatigue
- Task 2.2: Plastic Shakedown and Ratchetting
- Task 2.3: Creep- Fatigue
- Task 2.4: Corrosions

12.2.3. Work Package 3: Flaw Tolerance

- Task 3.1: Crack growth: fatigue, corrosion, creep
- Task 3.2: Critical Crack Size
- Task 3.3: Leak Before Break
- Task 3.4: Local Approach of Failure

12.2.4. Work Package 4: Specific Mechanical cases

- Task 4.1: Nozzle Reinforcement rules
- Task 4.2: Elastic Follow-up in piping systems
- Task 4.3: Bolted Flange and Sealing
- Task 4.4: Dynamic loads: Seismic and Water Hammer
- Task 4.5: HDPE piping systems

12.2.5. Work Package 5: Materials and associated welds mechanical Properties

- Task 5.1: Metallic materials: carbon steels, low alloys steels, stainless steels, nickel based alloys
- Task 5.1: Non Steel materials: Nickel, Copper….
- Task 5.1: Non-metallic materials: HDPE, composite…
- Task 5.1: New materials for innovative applications and new operating conditions
- Task 5.1: Thermal Ageing
- Task 5.1: Environment attack

12.2.6. Work Package 6: Project Synthesis and Conclusion

12.3. 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

12.4. Meetings and Preliminary Budget

12.4.1. TG4 Project Meetings

- To be defined later with Chairman and Work Package Leaders…
- **Max of web-meetings: SKYPE or ZOOM video conference**
  - At WP level
  - At TG4 Project level with TG4 Chairman and WP Leaders
  - 1 EPERC workshop per year

12.4.2. TG4 Budget

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

13. 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 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
5. "Different CEN cooperation working products": ES, TS, TR, Gu, CWA https://www.cen.eu/work/products/cwa/pages/default.aspx
6. EN 12952- 12953 Boilers
7. EN 13445 Vessels
8. EN 13480 Piping