BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

June 28th-29th, 2021

BURST STRENGTH AND ITS SCATTER AS KEY POINTS OF SAFETY

G.W. Mair, R. Bock (Germany)

10th IWG on rev GTR 13, online

Overview

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2. Simulation of statistical behaviour
3. **Minimum burst pressure – requirement for design type testing; Proposal 1**
4. **Minimum burst pressure required for batch testing; Proposal 2**
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6. Surveillance of degradation
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1. Introduction

You might remember……. 2019 in Stuttgart

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Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

6th & 7th Nov. 2019

BURST STRENGTH AS SAFETY CRITERIA FOR TYPE 4 COMPOSITE PRESSURE VESSELS

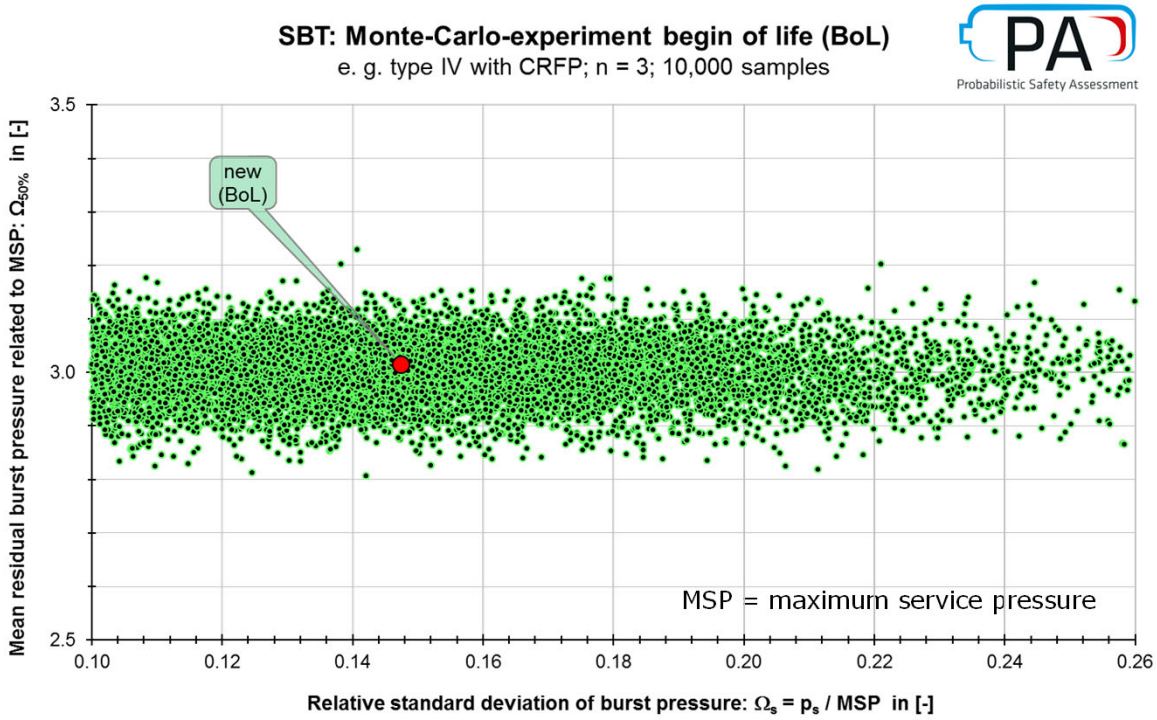
Dr. Georg W. Mair (Germany)

7th WG on rev GTR 13, Stuttgart

Stuttgart: Real life “scattering”

Experience shows that no CPV is identical to another: all properties scatter around the unknown, global properties of the basic population.

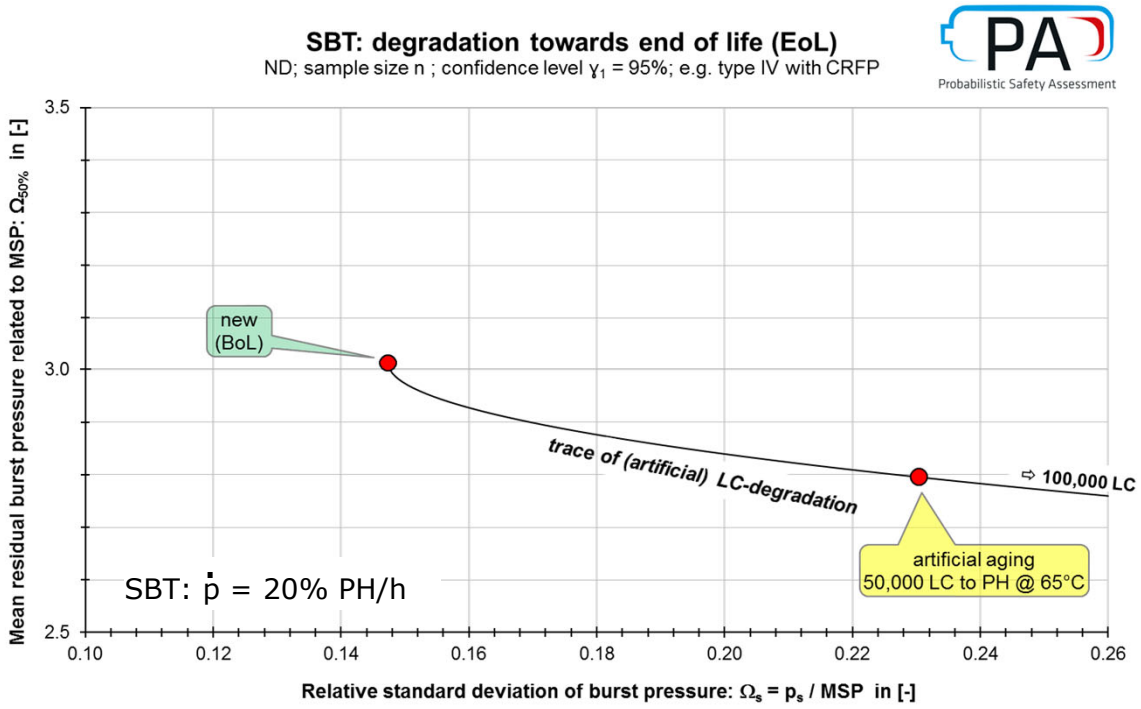
Right: e.g. properties of a simulated production of 30,000 CPV in 10,000 samples



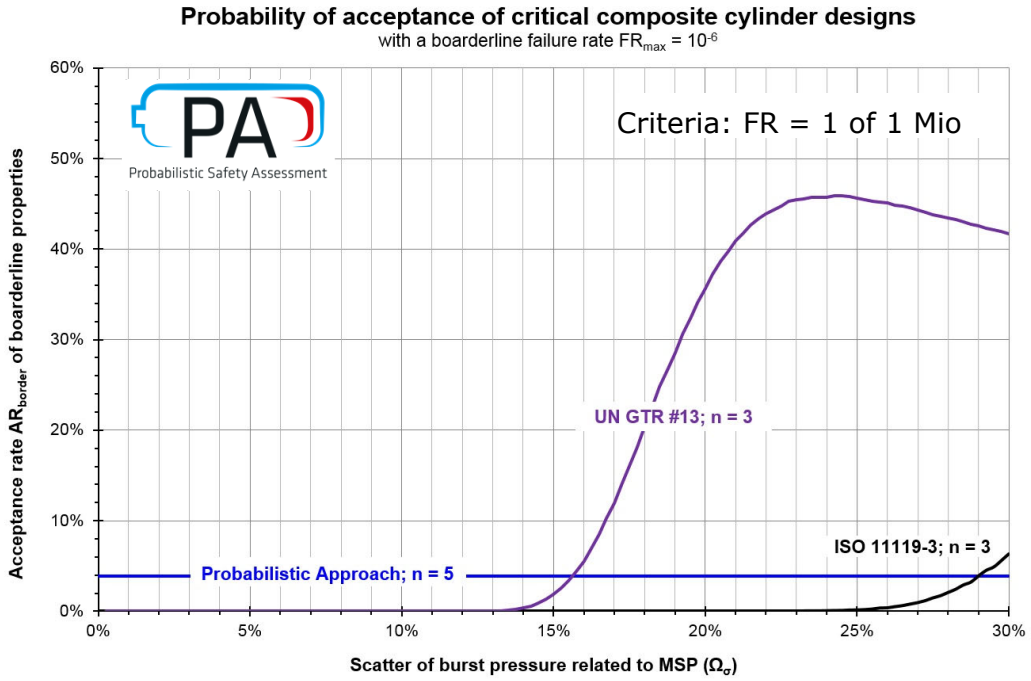
Stuttgart: Real life “ageing”

Experience shows that all properties change when becoming older (ageing).

Right: change of properties of samples from a type IV CF-PV design type tested with slow burst procedure; ageing by high temperature load cycling



Stuttgart: Probability of acceptance



- Left: Analysis of the probability accepting insufficient populations accord to current regulations by Monte-Carlo simulation.
- Outcome: The lower the BP_{min} is the lower the accepted production scatter must become.

TAnk HYdrogen Automotive „TAHYA“

2018-2021; EU Horizon 2020 research and innovation program

Partners:

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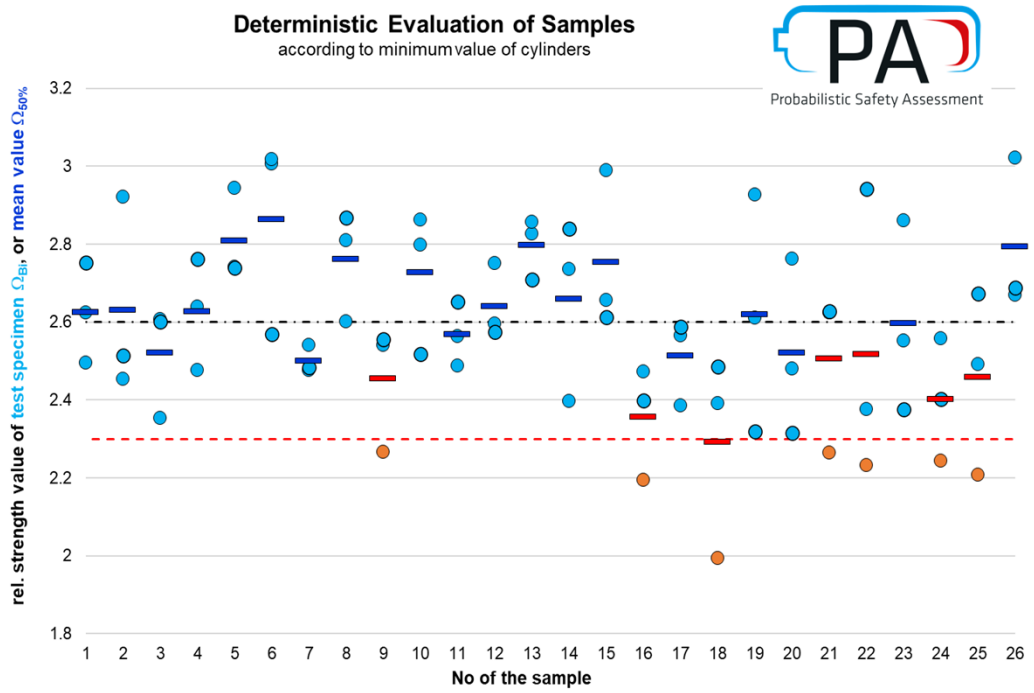
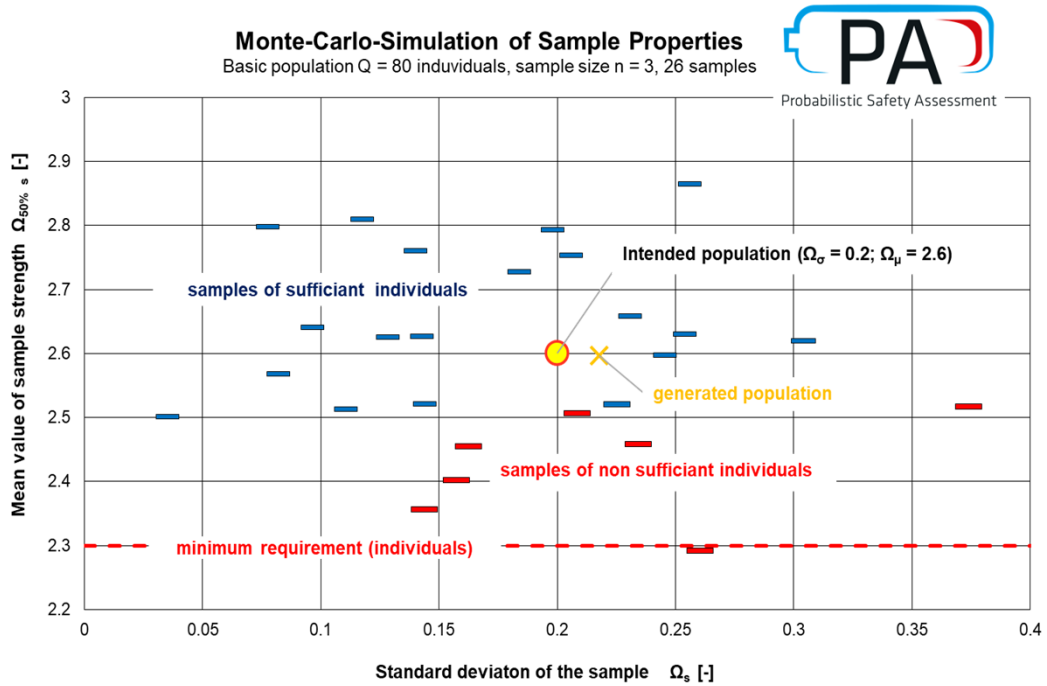
2. Simulation of statistical behaviour

Simple example of how Monte-Carlo-Simulation “MCS” works



The generated properties of individuals in each sample (here 3) can be checked against a minimum requirement, which allows to count how many batches would not pass.

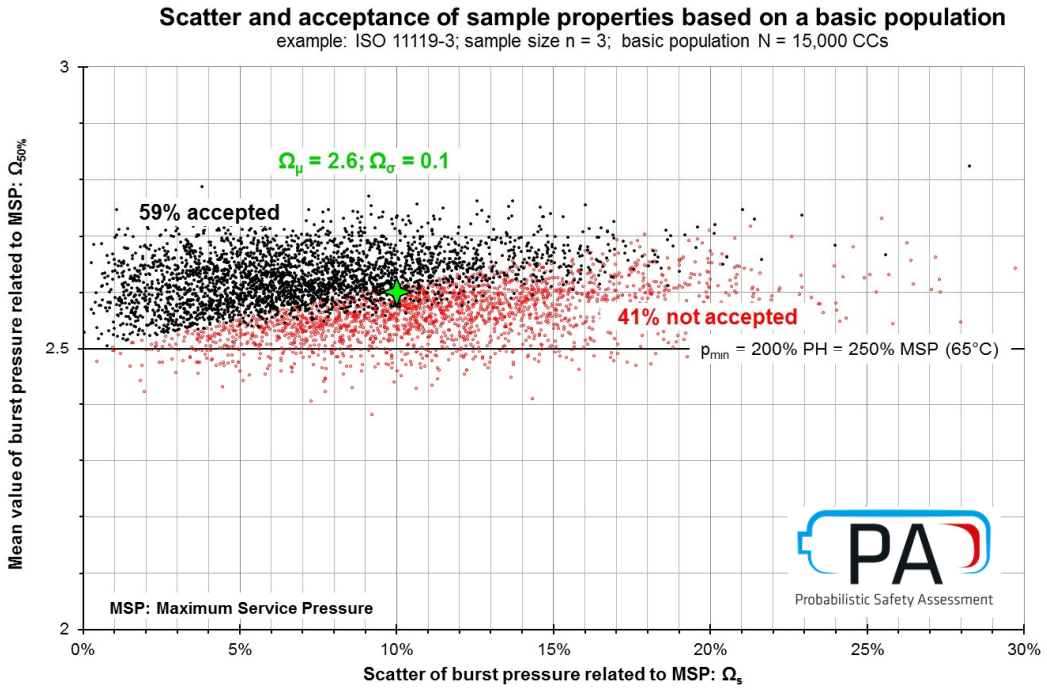
How the sample evaluation works



The information about passing the minimum requirement and the mean strength of the batch links the two different worlds of deterministic and probabilistic.

This enables to calculate the likelihood for passing a legal requirement and the probability of failure under normal load.

Example for a larger population

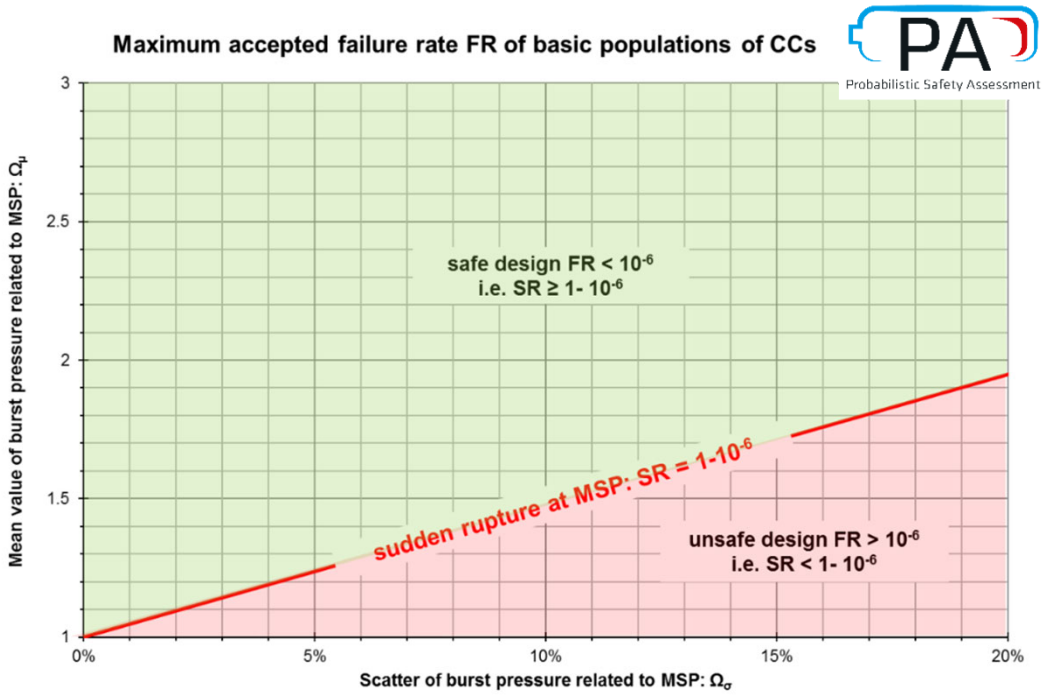


When you ask for a minimum burst pressure on the basis of a small amount of CPVs to be tested there is always a high influence of chance in the test result.

(real properties of the basic population are green; accepted samples of this population are black; rejected samples are red)

3. Minimum burst pressure - requirements design type testing

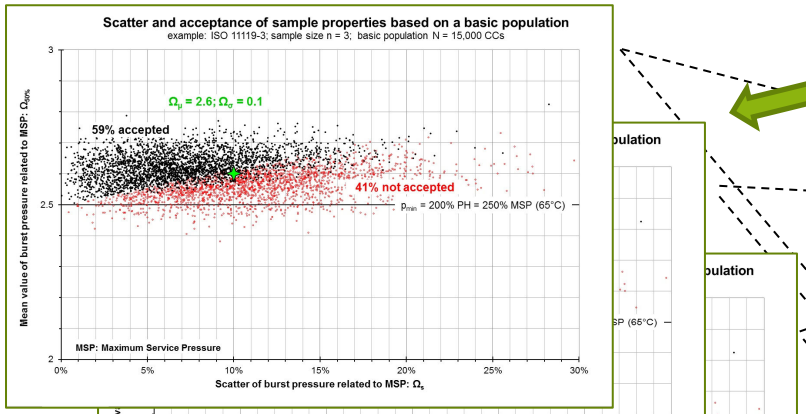
The probabilistic safety criterion

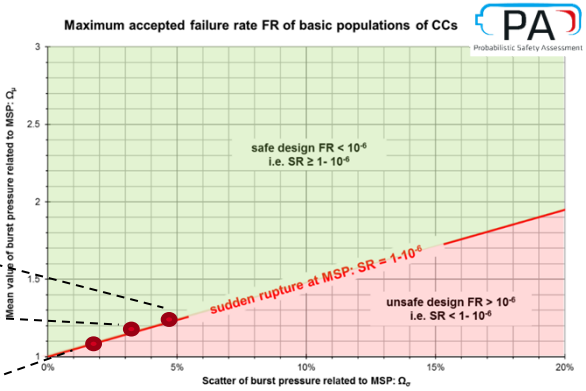


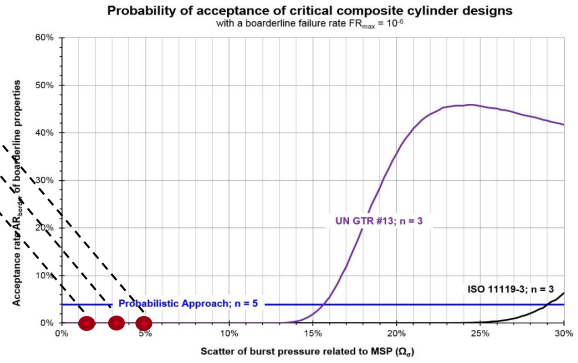
When the data are verified the sample properties (either tested or simulated) need to get checked against the minimum requirement (e.g. 1 of 1 Mio), which depends on the pressure-volume-product (pV).

For the TAHYA-design $2 \cdot 10^{-7}$ (1 of 5 Mio) has been determined.

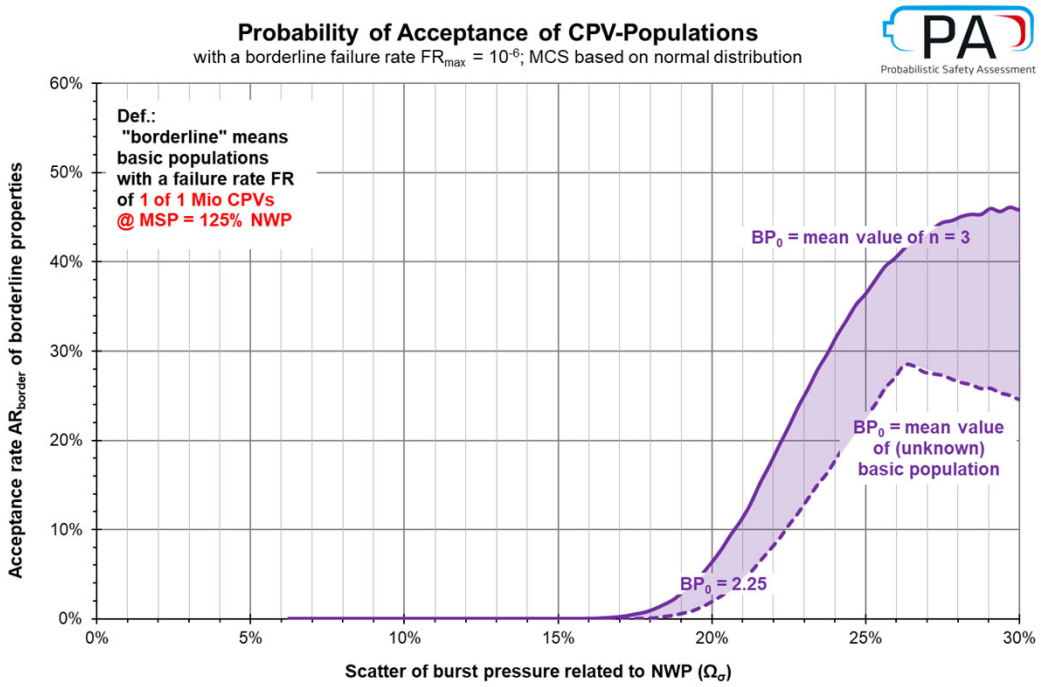
Effect of minimum burst pressure required for design type testing







2021: a deeper view on BPmin = 2.25

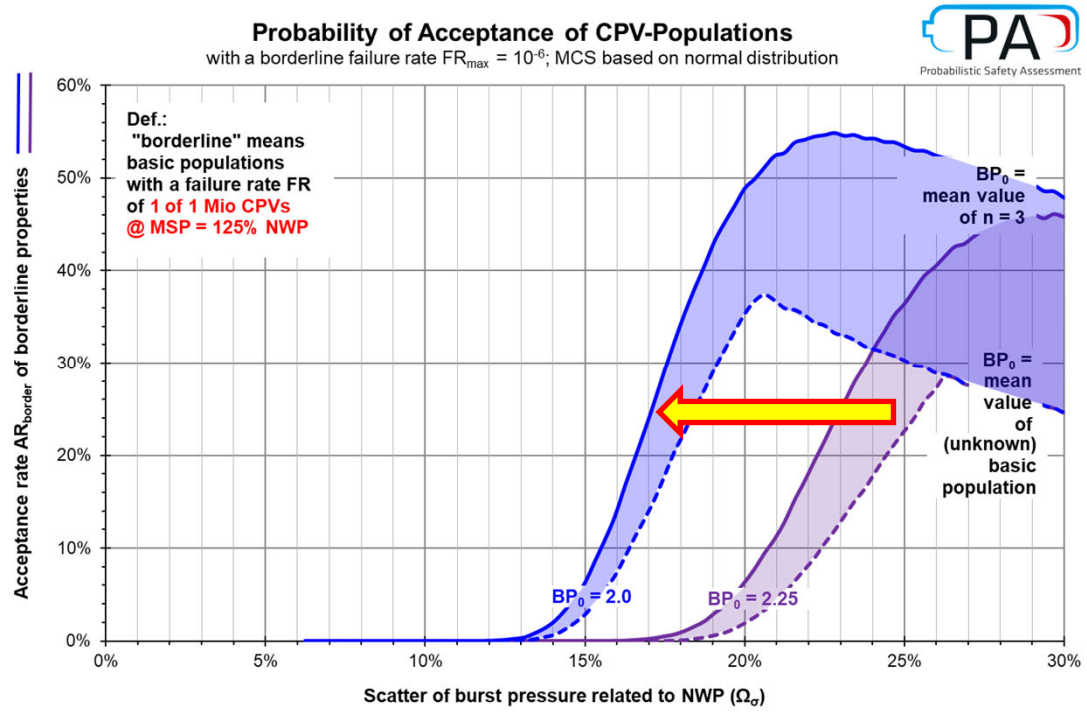


When following the red line (previous slide) the acceptance rate of populations with borderline properties according to any requirement can get checked.

The acceptance rate should go above 5 %.

Compare discussion on "confidence levels"!

Consequence of the reduction of BPmin



The newly agreed reduction of the minimum burst strength leads to a much lower scatter value at which the acceptance of critical designs increases.

This makes it necessary to treat the scatter more restrictively!

Proposal 1: BPmin and scatter range

1. Increase the number of burst tests for approval from 3 to 5 pressure vessels.

   This creates a higher confidence in test results.

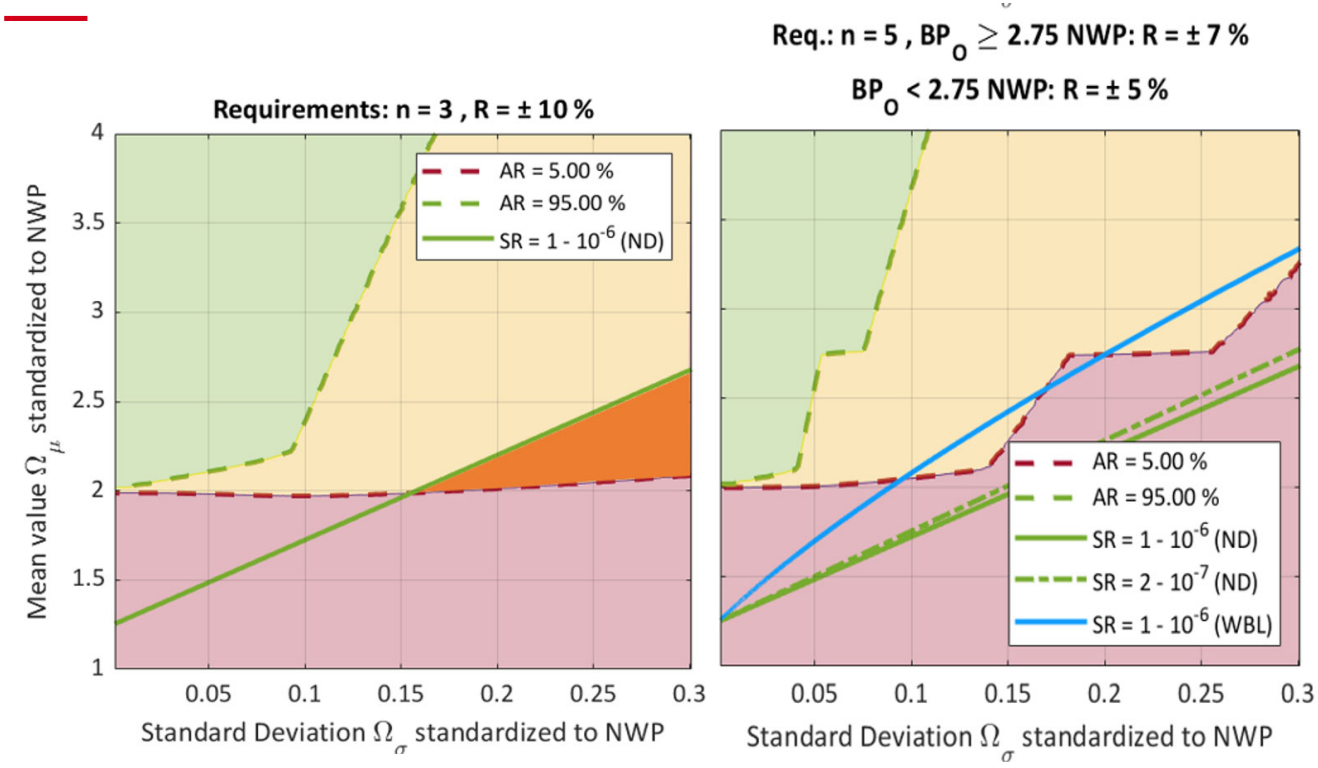
2. Require a scatter value of ±5% BP_O instead of ±10% BP_O

   This prevents the acceptance of designs with too high scatter in production.

3. Accept an increased scatter value of ±7% BP_O if $BP_O \geq 2.75$ NWP

   This enables the approval of designs with a higher production scatter.

Proposal 1:
make BP_{min} dependent on scatter value

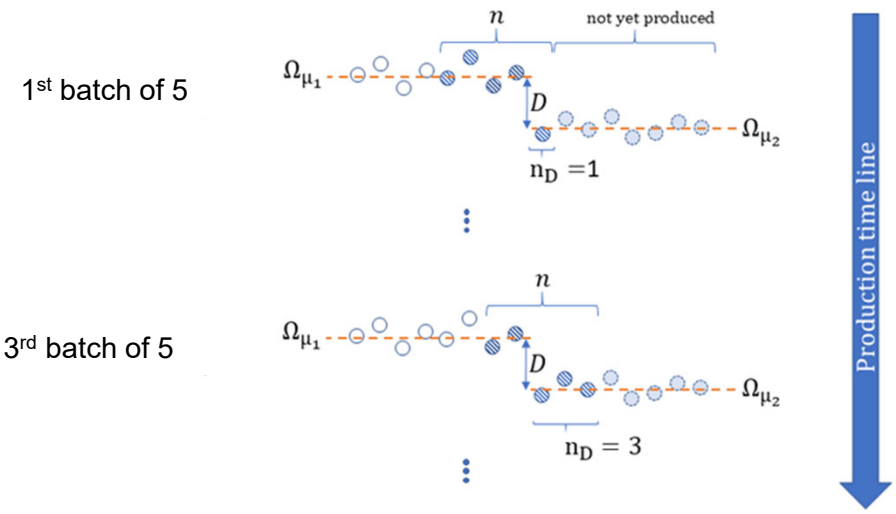


Current situation is not satisfying (left).

Proposal (right) for a sufficient requirement

4. Minimum burst pressure - requirements for batch testing

Today: a deeper view on 2.25



Batch testing is not able to detect single individuals with a production false (testing 1 of 200 or 1 of 1000).

Batch testing focus on the question:

Is the produced population a “copy” of the design type?

Proposal 2:
introduce batch test requirements

1. Introduce a requirement: each batch test result must be above BP_{min}

   This is state of the art in most of standards for composite pressure vessels (CPVs).

2. Require a running mean value of the last 10 results that shall surpass 90% BP_O.

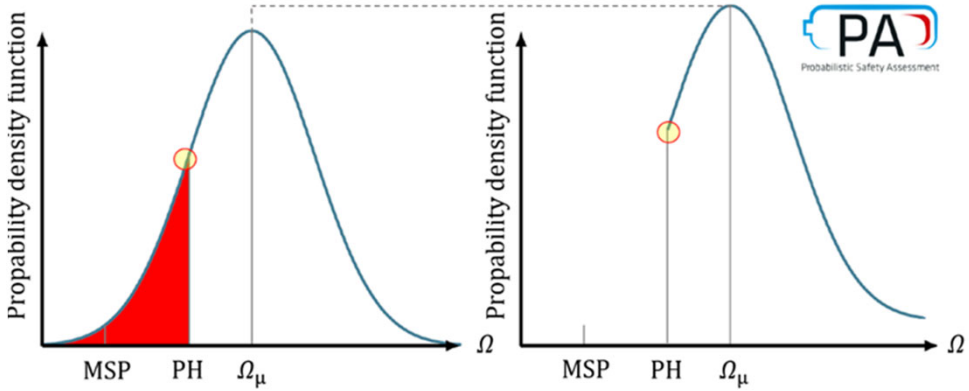
   This running mean shows how the production fits with the initial BP_o.

3. Check continuously the mean value of the increasing group of tested CPVs and check each new test results concerning outliers.

   This enables to check the real BP_o in comparison with the initial estimation.

5. Initial proof testing by quasi-static loading

Effect of initial proof testing

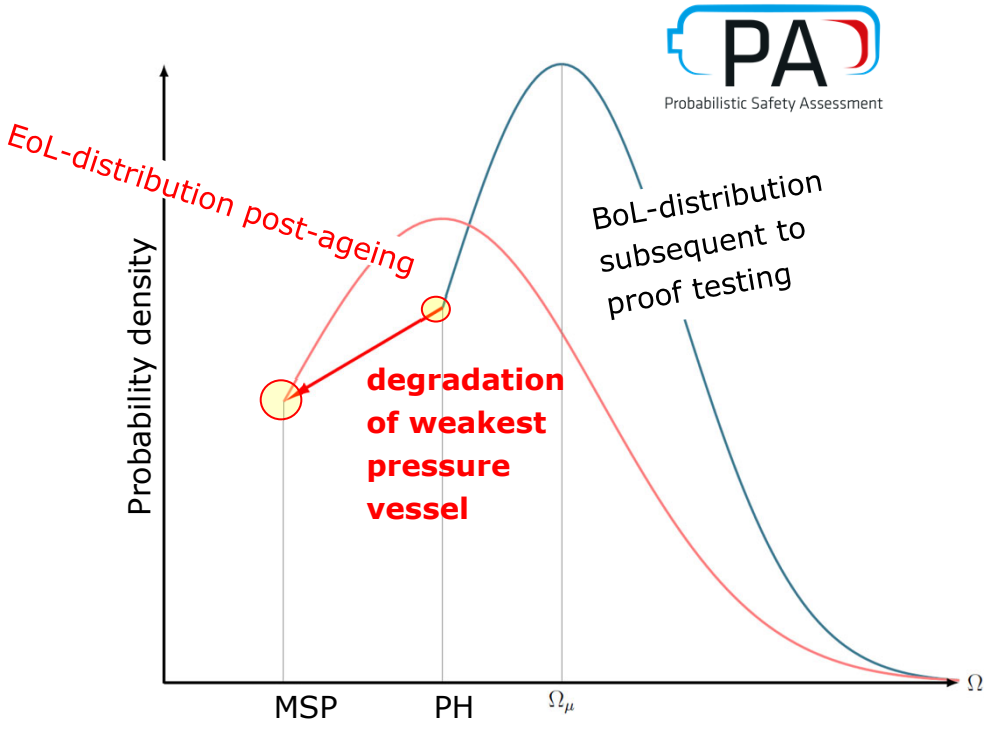


Since the test pressure (150% NWP) is above the maximum service pressure (125% NWP), the weakest part of the population is eliminated by proof testing.

Effect of initial proof testing

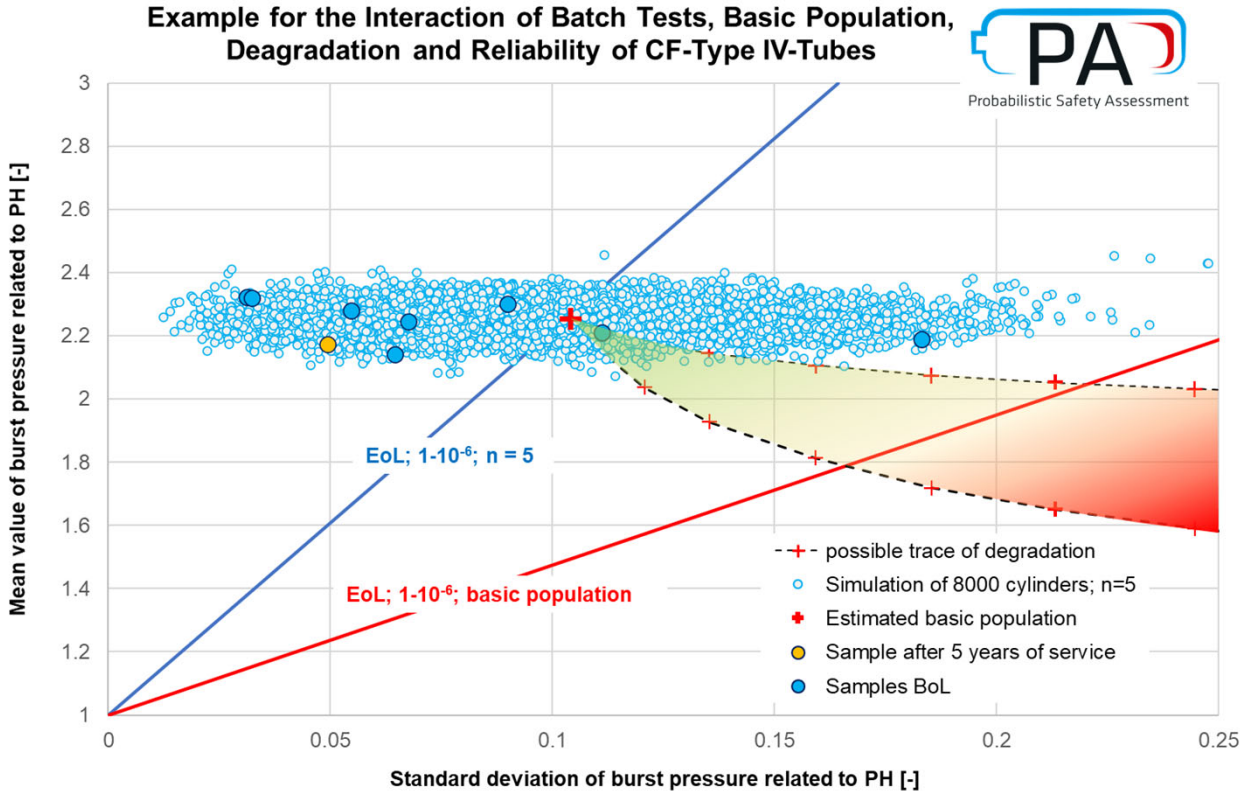
Caused by the degradation the individua of the remaining population will loss strength.

The question is just: “when will the first become critical?”



6. Surveillance of degradation

Summary



Since the degradation in service cannot be tested preliminary to approval tests, it is still necessary to care for the degradation of the population of 8000 cylinders, displayed in samples of 5 cylinders (blue cloud).

7: Summary

Summary: Proposals

1. Increase the number of burst tests for approval from 3 to 5 pressure vessels.
2. Require a scatter value of ±5% BP_O instead of ±10% BP_O
3. Accept an increased scatter value of ±7% BP_O if $BP_O \geq 2.75$ NWP

4. Introduce a requirement: each batch test result must be above BP_{min}
5. Require a running mean value of the last 10 results that shall surpass 90% BP_O.
6. Check continuously the mean value of the increasing group of tested CPVs and concerning outliers.

BAM is a senior scientific and technical Federal institute with responsibility to Federal Ministry for Economic Affairs and Energy.

Thank you for your attention.

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