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

BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

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BURST STRENGTH AS SAFETY CRITERIA FOR TYPE 4 COMPOSITE PRESSURE VESSELS

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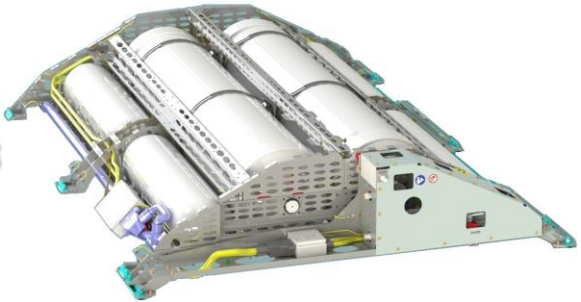
7th WG on rev GTR 13, Stuttgart

Safety aspects are independent from the kind of usage

No failures?
Hydrogen storage is currently not a real safety issue.

But, there is a request for weight and cost savings!



How to assess the intended reduction of “safety factors”?

Technical safety

Safety is achieved when …

…. the probability (frequency) of a failure during the service life is acceptable!

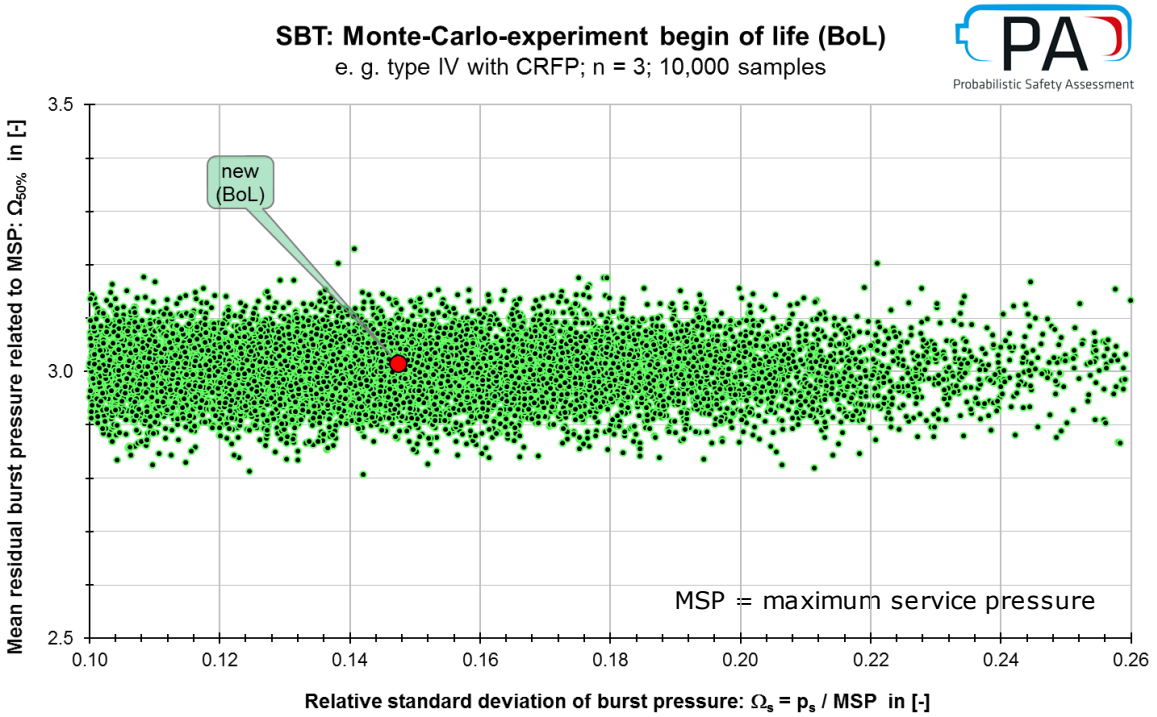
Or in other words:

We try to reduce the frequency of failures as good as possible (in the frame of acceptable effort).

Real life: “scattering”

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

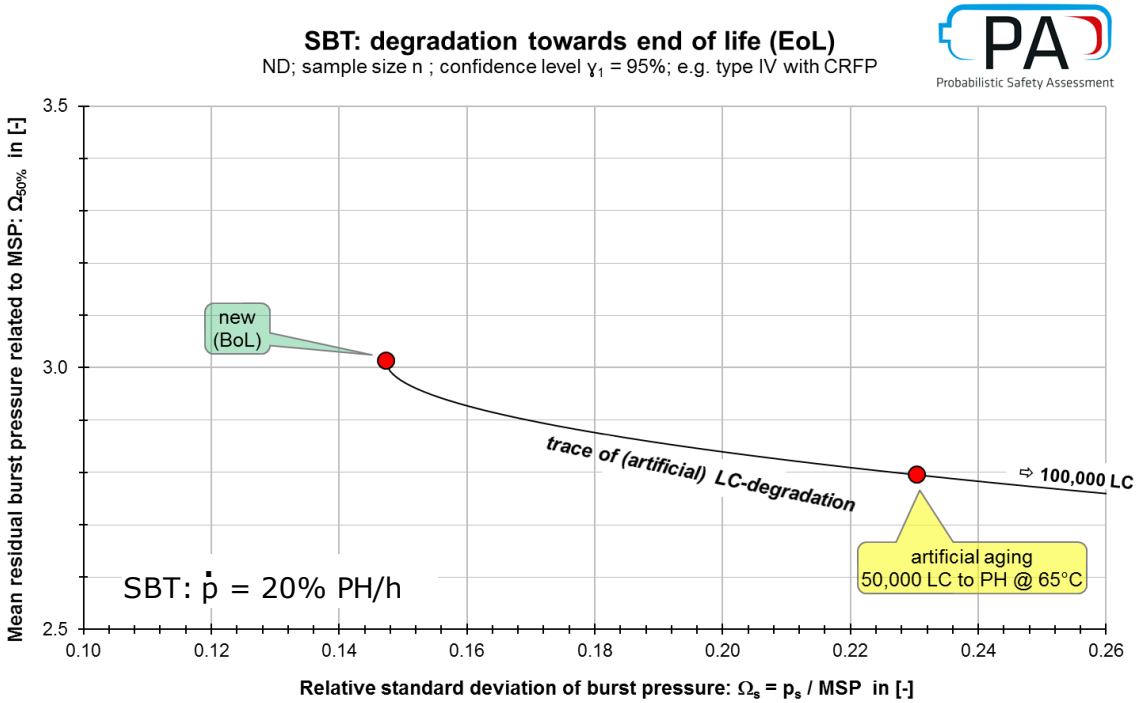
Right: e.g. properties of a simulated production of 30,000 CPV in 10,000 samples



Real life: “ageing” i.e. strength degradation

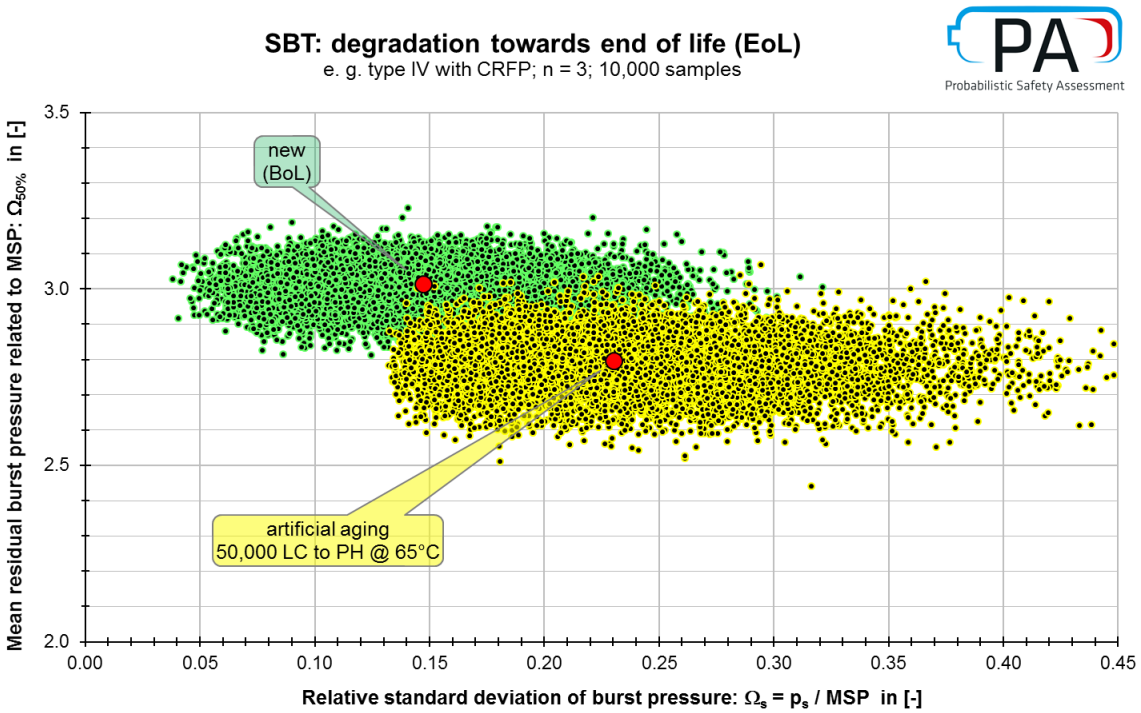
Experience shows that all properties change when becoming older (ageing).

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



Real life: ageing and degradation

Right: schematic and exemplary simulation of the change of sample properties of a population of 30.000 CPVs grouped in 10.000 samples after ageing.



Technical safety

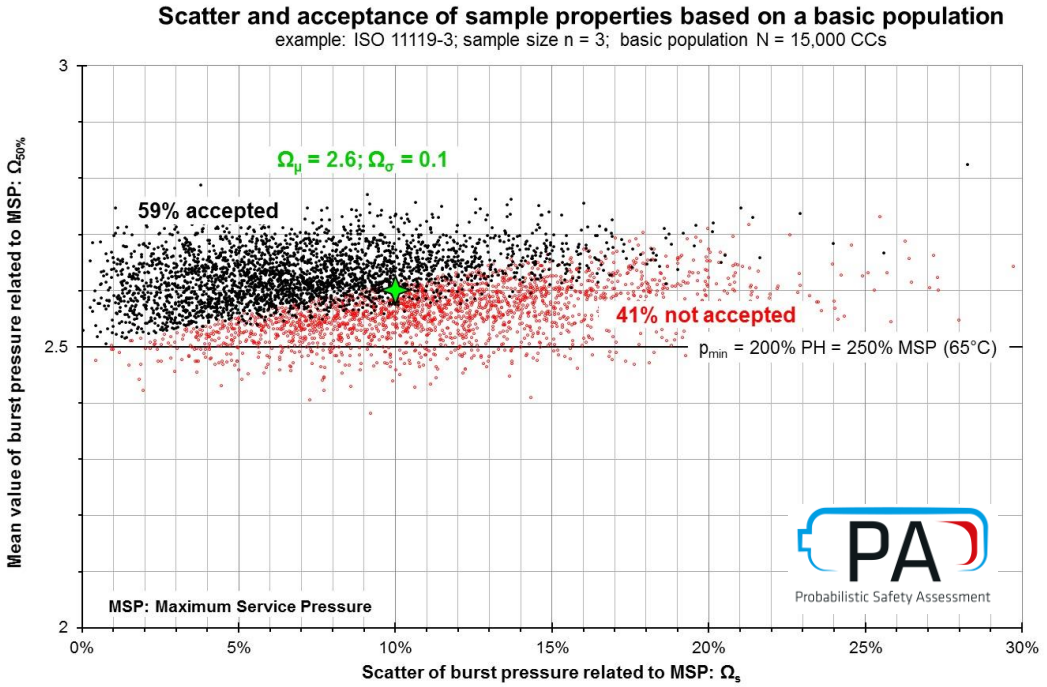
The key point of technical safety is to ensure that …

> **…. the probability (frequency) of a failure at the end of life experienced under normal conditions is still acceptable!**

But there are aspects making life complicate:

- **Mean and scatter of the population age during service**
- **The way and quantity of ageing depends on the design type behaviour, the production and the service conditions**

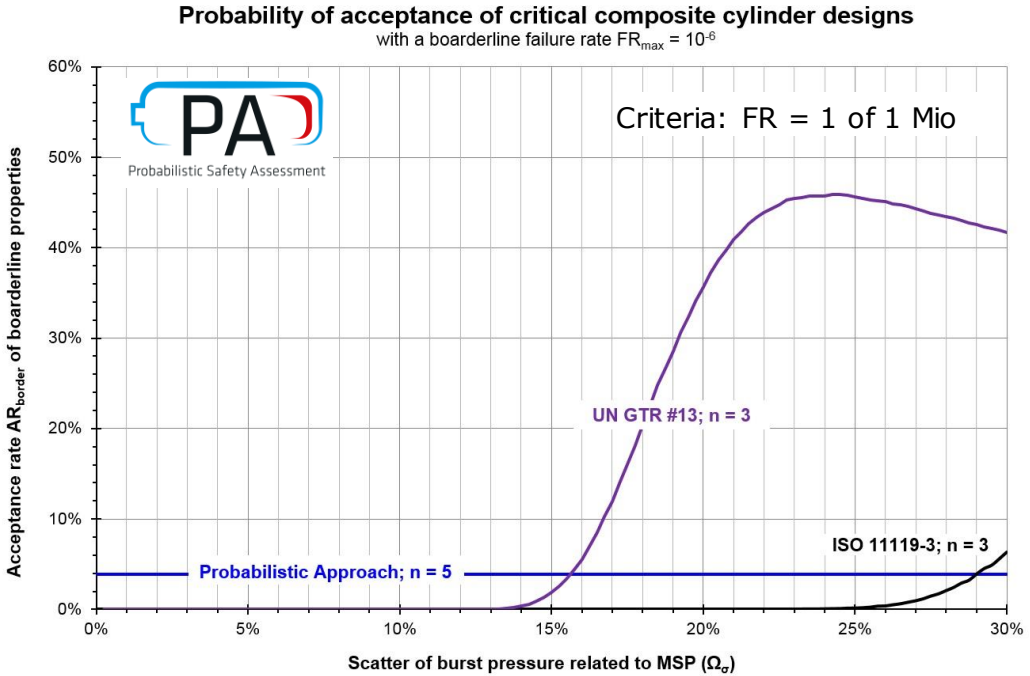
What we currently do (BoL)



- 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.

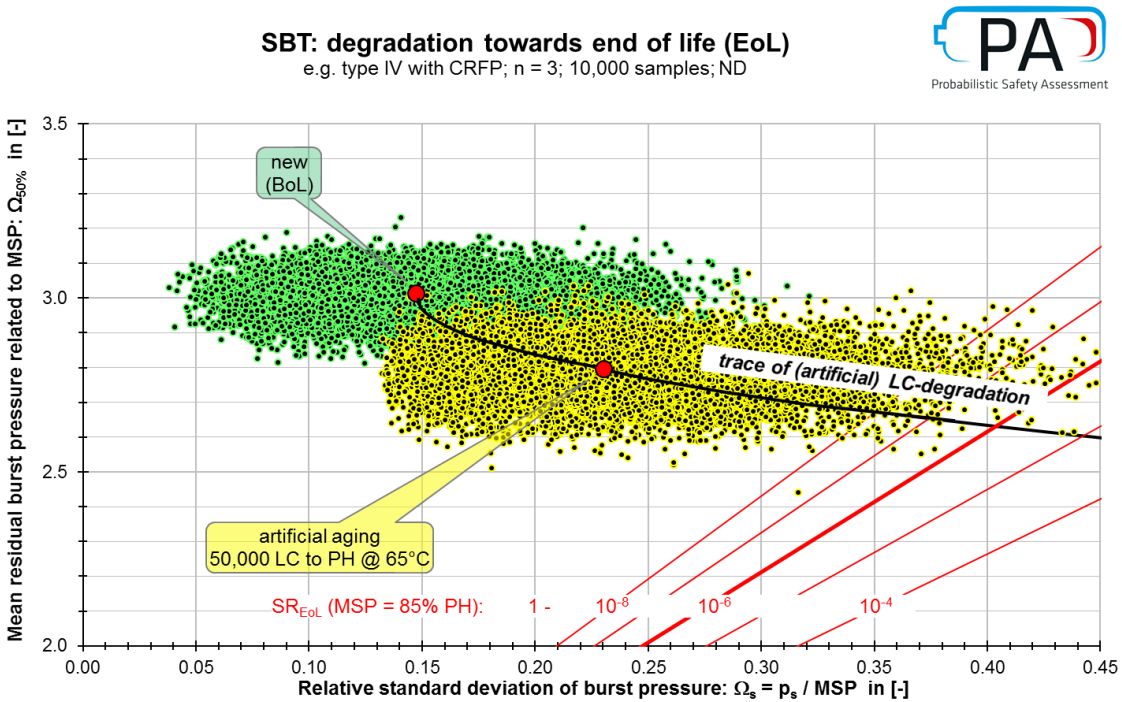
(real properties of the basic population (BB) are green; accepted samples of this BB black; rejected samples red)

What we currently do (BoL)



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

What we should do (EoL)



We are not able to describe the real properties of a basic population:
not at BoL and
surely not at EoL

Nevertheless, we have to avoid parts of the population with an unaccepted failure rate.

What we do / should do

Currently

- Minimum burst pressure
- Det. average burst pressure
- Limitation of scatter of initial burst pressure
- Artificial ageing with accepting a lowered min burst ratio

Future

- Maximum failure rate at MSP of burst pressure
- Survey of production scatter
- Maximum failure rate subse-quent to artificial ageing
- Check of in-service degradation

Conclusions

- Currently, we focus on the properties at begin of life on the basis of a few test specimens usually from pre-production and not from mass production.
- This is accompanied by certain tests on individuals, which simulate artificial ageing but do not reflect influences on scatter.
- The impact of a reduction of initial burst strength on the guaranteed EoL reliability of populations of composite cylinders has not been demonstrated up to now.
- The scatter of production and the in-service degradation should be considered somehow.
- Can we really anticipate this during the design type approval process? How?

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Thank you for your attention!

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Probabilistic Safety Assessment