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Partial Substitution of inspection By Statistical Methods

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Sicherheit in Technik und Chemie

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PARTIAL SUBSTITUTION OF INSPECTION BY STATISTICAL METHODS

Georg W. Mair

Joint Meeting

2016 Autumn-Meeting in Geneva

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Overview

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1. Current requirements for periodic inspection
2. Examples of obvious deficits of current inspection methods
3. Concept for solving the issue
4. How statistics works
5. Summary and conclusion

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Current Requirements for Periodic Inspection

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The Current Requirements

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At periodic inspection shall be checked:

(a) external conditions,
verification of equipment and markings;

(b) internal conditions;

(c) threads;

(d) hydraulic pressure test and,
verification of the characteristics of the material by suitable tests;

(e) service equipment, if to be reintroduced.

With the agreement of the competent authority some of the tests may be substituted by ND-testing of each individual pressure receptacle.

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The Current Requirements

Can we be sure that these methods provide always sufficient knowledge necessary for safety assessment?

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Examples of Obvious Deficits of Current Inspection Methods

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The Deficits of Current Procedures

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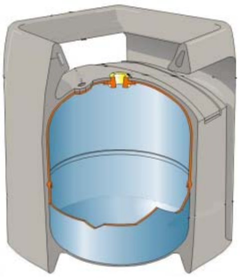
Example A:
over-moulded cylinders…

… are steel cylinders with a robust permanent cover.

Its adhesion is similar to the one of a coating.

This means with respect to retest procedures:

External corrosion and a leak would not be detectable by proof testing or visual inspection.



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The Deficits of Current Procedures

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Example B:
composite cylinders …

… are e.g. aluminium cylinders with a fully or hoop wrapped composite. Fibre pre-stress is the main issue for number of fillings to leakage.

This means with respect to retest procedures:

The fibre pre-stress cannot be quantified or observed by any of the currently required methods for periodic inspection.

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Concept for Solving the Issue

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General Aspects for Solving the Issue

1. **Mandatory procedures that do not serve their purpose within the periodic inspection have to be substituted.**

2. **In this case, the reason(s) for not detectable failures shall be analysed.**

3. **It has to be differentiated between:**
   a) safety aspects of individuals (e.g. mistreatment)
   b) production faults (i.e. mainly related to batches)
   c) inherent problems of new cylinder concepts (mainly related to the age of a population)

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Currently not clearly covered issues

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Item of inspection and its main intention: **They cover aspects of individuals but no systematic ones!!!**	related to individuals	related to production batches	related to a whole population
a) external visual inspection marking, etc.	yes	indirect	no
b) internal visual inspection, wall thickness etc.	yes	indirect	no
c) check of threads	yes	indirect	no
d) proof test	yes	indirect	no
e) check of service equipment	yes	indirect	no

Just in cases of frequent abnormalities there might be a trace back to the batch → deficit

Just in the rare case of abnormalities related to several batches a general problem might be recognised → deficit

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Over-Moulded Cylinders OMC

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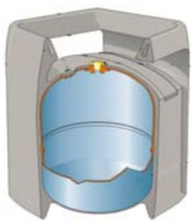

A leakage of steel cylinder is probably caused by **welding defects** in the inner cylinder. Most probable reason for external corrosion of the inner cylinder is a **week adhesion** between steel and over-mould. Both is mostly expected as a consequence of **production faults relevant for groups of cylinders**.

Due to the over-mould even a leakage of inner cylinder is **not detectable** by current checks of periodic testing. OMCs with leaking inner cylinders often stay tight during filling.

Statistics on residual burst strength and adhesion are the most appropriate test method for detection of such critical effects!

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Composite Cylinders

e.g. for medical oxygen

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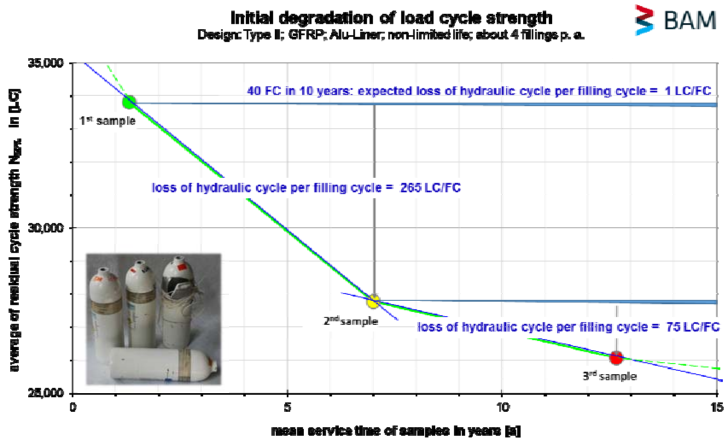
This tremendous reduction of life time is related to the whole population and not to individual cylinders.



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Composite cylinders

e.g. for medical oxygen

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This tremendous **reduction of life time** cannot be tested during approval process nor it is detectable by current checks of periodic testing.

Proof testing usually shows no (hydraulic) leakage as long as the cylinders stays **tight during filling**. I.e. **rupture or leakage during service** is much more probable than a negative proof test result.

Statistics on residual load cycles is the best method for detection of critical loss of life time;
- compare latitude of judgement for **UN-service life checks**!

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How Statistics Works

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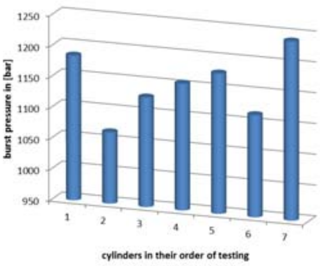
How do statistics work?
1st step

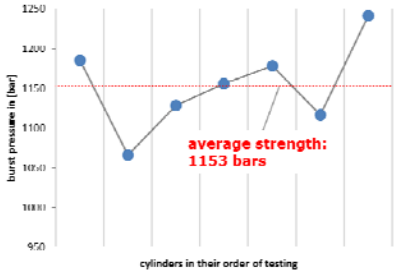
Monitoring of individual results

Burst pressures of a small sample



Quantification of mean strength

Burst pressure of a small sample



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How do statistics work?
2nd step

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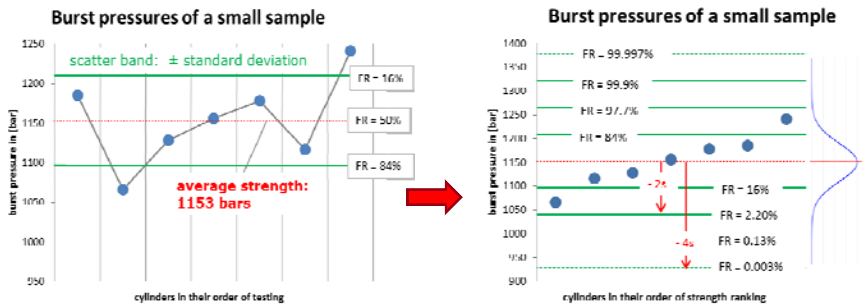
Quantification of scatter value | **Ranking of test results**



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How do statistics work?
3rd step

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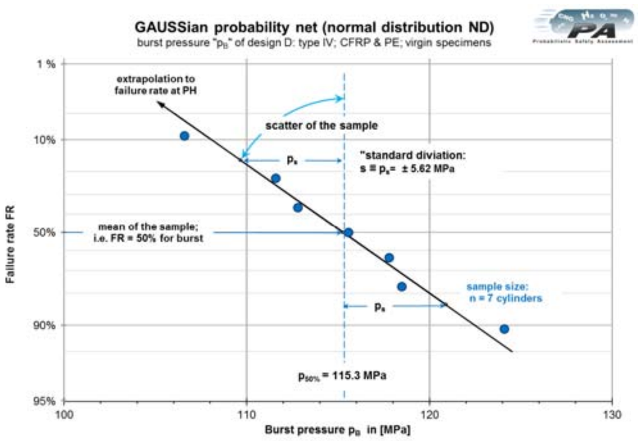
Check of best fit line!!



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How do statistics work?
4th step

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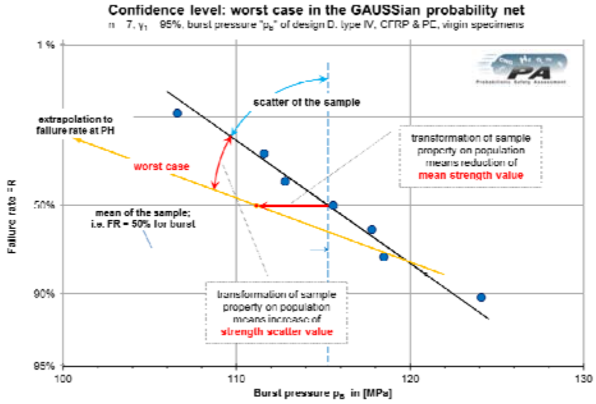
Considering the uncertainty of limited test samples by using a “penalty function”



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How do statistics work?
5th step

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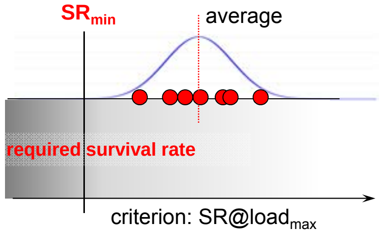
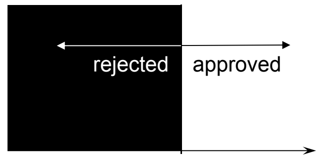
Comparison of test results with minimum requirements

(e.g. accepted failure rate FR
i.e. required survival rate SR)

Quantitative property-check



Simple 100% yes/no-check



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Summary and Conclusion

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Summary

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- Defects and degradation can be detected by destructive tests if they are related to major parts of a population (i.e. aging)
- The properties of a group of cylinders is known by testing. They can be described by mean strength and its scatter.
- The scatter function is based on a best fit analysis.
- The properties of the whole population can be estimated (number of specimens and the required confidence level).

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Concept for Solving this Issue

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1) In some cases some of the currently required retest methods provide not the expected safety relevant information.

2) In this case alternatives to these retest methods have to be used for ensuring safety.

3) If none appropriate NDT method is available destructive tests may be used for substitution.

4) Destructive tests cannot be operated on a major part of a population.

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Concept for Solving this Issue

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5) Destructive tests have to be extrapolated on the whole population by statistical methods.

6) Destructive tests are appropriate when deficits of individuals can reliably be detected by the remaining 100%-checks.

7) If neither a NDT nor a destructive test is appropriate for substitution of a meaningless retest method the relevant design concept of a pressure receptacle cannot be accepted for approval.

8) Precondition: performance of a pre-fill inspection before each filling

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Concept for Solving this Issue

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9) All decisions on alternative methods

either related to 100 % NDT or destructive sample testing

and the decision on the relevant type of a pressure receptacle

needs a detailed description in the ADR / RID und depends completely on a decision of the Joint Meeting

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Thank you for your attention!

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