

Economic Commission for Europe

Inland Transport Committee

Working Party on the Transport of Dangerous Goods

20 September 2016


Joint Meeting of the RID Committee of Experts and the
Working Party on the Transport of Dangerous Goods


Geneva, 19–23 September 2016

Partial Substitution of inspection By Statistical Methods

Georg W. Mair

The slide features a white background with a grey and red geometric design at the bottom. Logos for UNECE and BAM are in the top corners. The text is centered and includes the date, title, author, and meeting details.

 **UNECE**
Sicherheit in Technik und Chemie

 **BAM**
Bundesanstalt für
Materialforschung
und -prüfung


Sept, 20th 2016

**PARTIAL SUBSTITUTION OF INSPECTION
BY STATISTICAL METHODS**


Georg W. Mair

Joint Meeting
2016 Autumn-Meeting in Geneva

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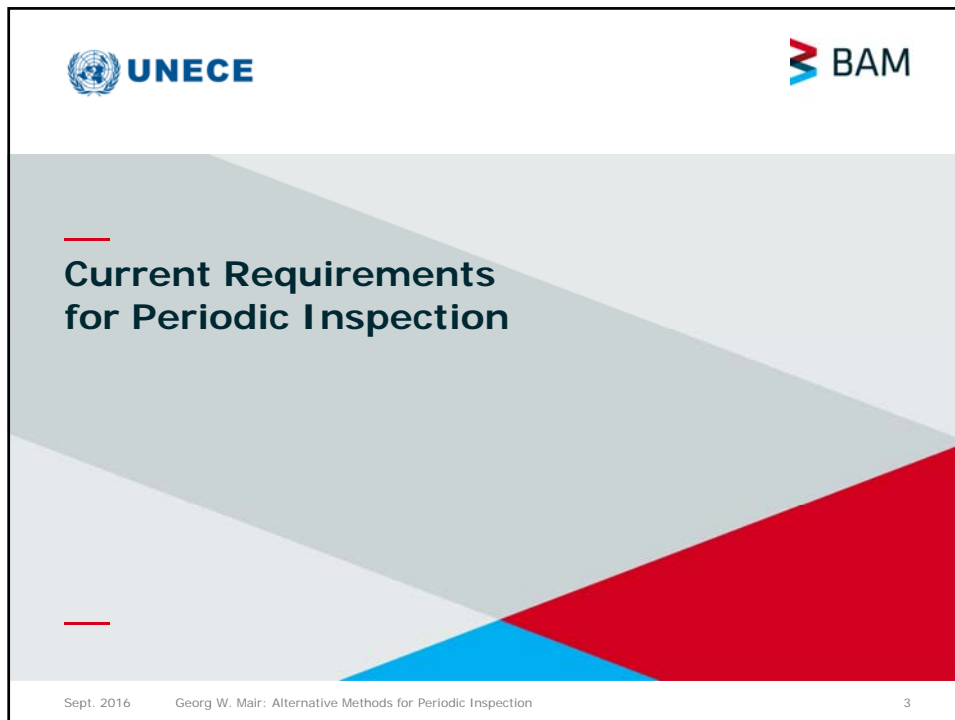
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Overview

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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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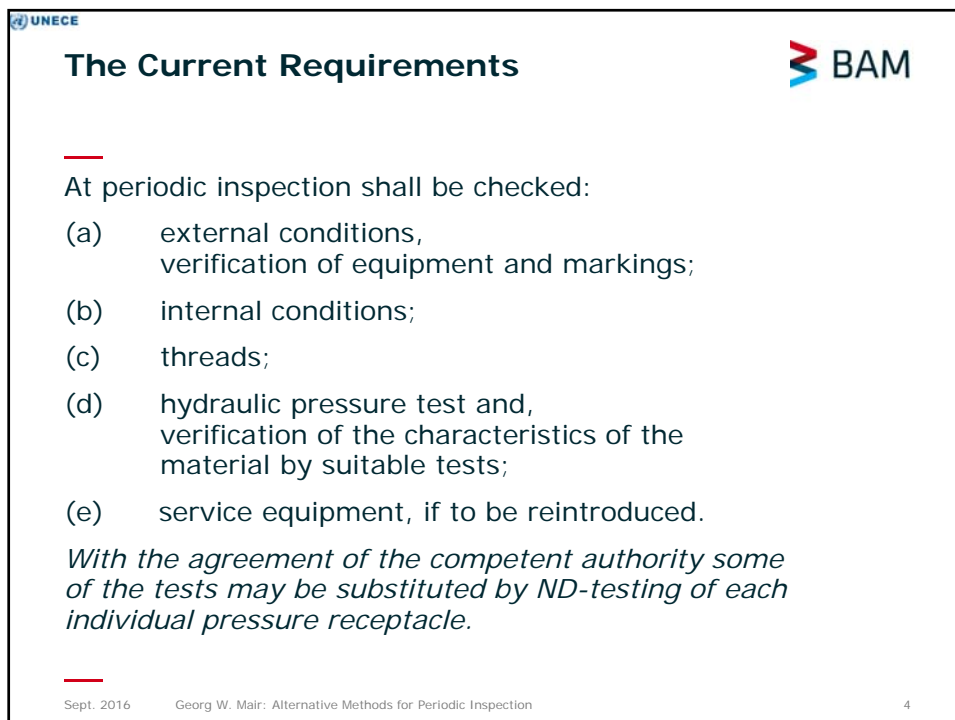
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Current Requirements for Periodic Inspection

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The Current Requirements


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

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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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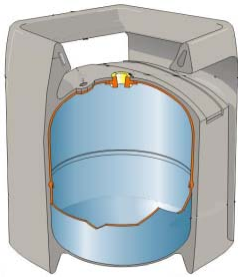
**Example A:
over-moulded cylinders...**

... 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 ...**

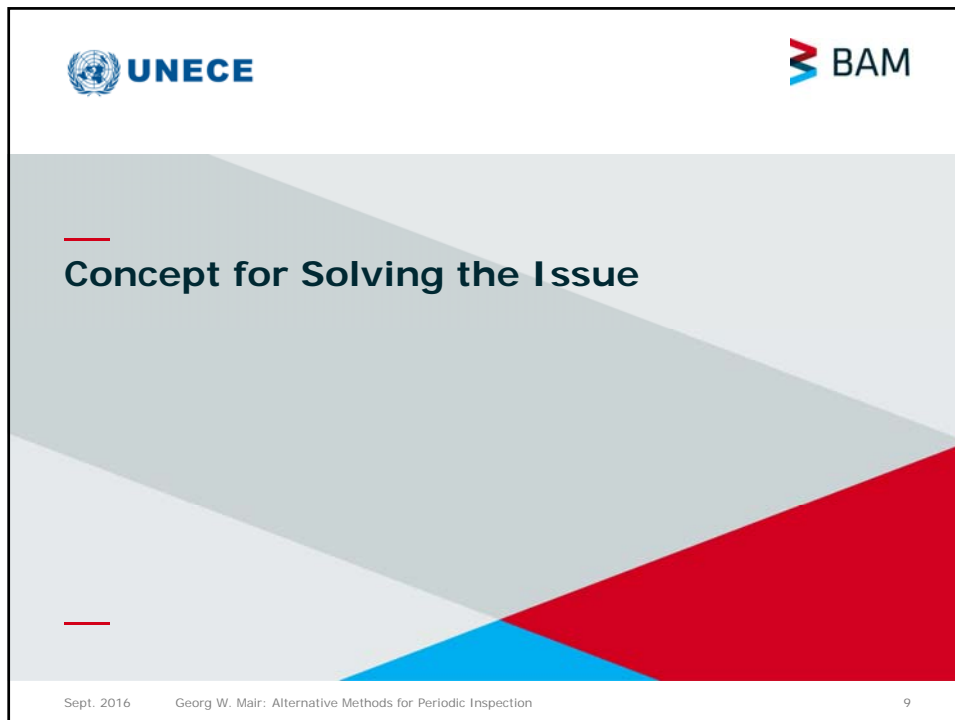
... are e.g. aluminium cylinders with a fully or hoop wrapped composite. Fibre pre-stress is the main issue for number of fillings to leakage.

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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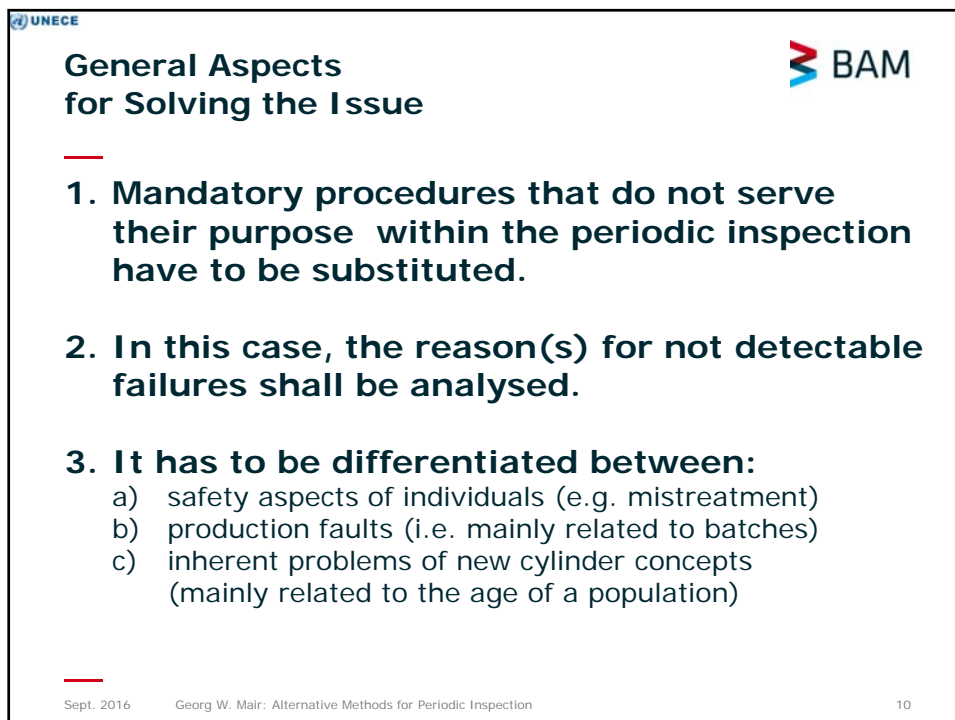
Slide 9 features the UNECE logo on the top left and the BAM logo on the top right. The main content area is a large light gray triangle pointing downwards, with a smaller blue triangle at its base and a red triangle to its right. The text 'Concept for Solving the Issue' is centered within the gray triangle. At the bottom, there is a white footer bar containing the text 'Sept. 2016', 'Georg W. Mair: Alternative Methods for Periodic Inspection', and the number '9'.

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Concept for Solving the Issue

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Slide 10 features the UNECE logo on the top left and the BAM logo on the top right. The text 'General Aspects for Solving the Issue' is positioned at the top left. Below it is a list of three numbered points. The third point includes three sub-points labeled a), b), and c). At the bottom, there is a white footer bar containing the text 'Sept. 2016', 'Georg W. Mair: Alternative Methods for Periodic Inspection', and the number '10'.

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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

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

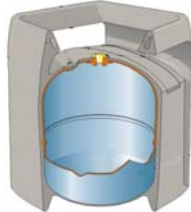
Just in the rare case of abnormalities related to several batches a general problem might be recognised → deficit

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Over-Moulded Cylinders OMC

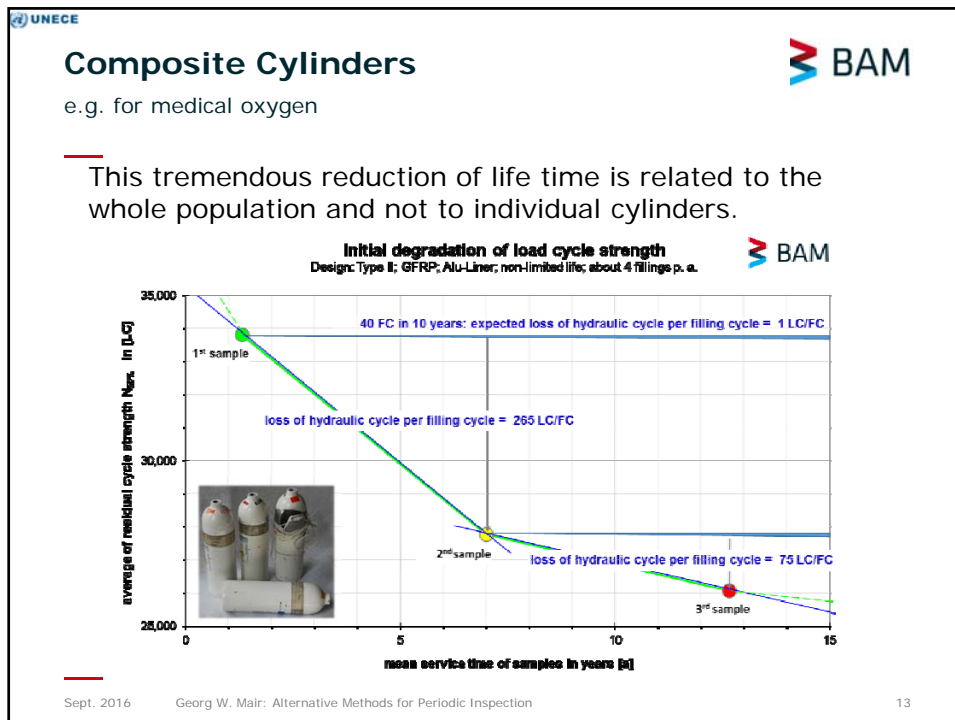
A leakage of steel cylinder is probably caused by **welding defects** in the inner cylinder. Most probable reason for external corrosion of the inner cylinder is a **weak adhesion** between steel and over-mould. Both is mostly expected as a consequence of **production faults relevant for groups of cylinders**.



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** 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

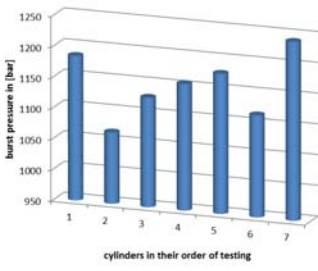
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How do statistics work? 1st step

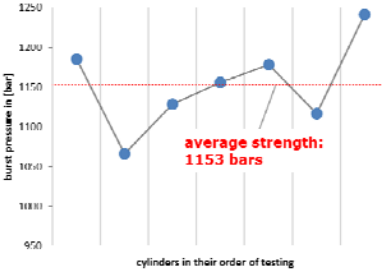
Monitoring of individual results

Burst pressures of a small sample



Quantification of mean strength

Burst pressure of a small sample



average strength:
1153 bars

➔

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How do statistics work?

2nd step

Quantification of scatter value

Burst pressures of a small sample

scatter band: \pm standard deviation

average strength: 1153 bars

FR = 16%

FIT = 50%

FR = 84%

cylinders in their order of testing

Ranking of test results

Burst pressures of a small sample

FR = 99.997%

FR = 99.99%

FIT = 97.77%

FIT = 81%

FR = 16%

FR = 2.20%

FR = 0.13%

FR = 0.003%

cylinders in their order of strength ranking

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How do statistics work?

3rd step

Check of best fit line!!

GAUSSian probability net (normal distribution ND)
burst pressure "p₀" of design D: type IV; CFRP & PE; virgin specimens

Failure rate FR

1%

10%

50%

90%

95%

100

110

120

130

Burst pressure p_0 in [MPa]

extrapolation to failure rate at PH

scatter of the sample

standard deviation: $s = \pm 5.62$ MPa

mean of the sample; i.e. FR = 50% for burst

$p_0 = 115.3$ MPa

sample size: $n = 7$ cylinders

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How do statistics work?

4th step

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

Confidence level: worst case in the GAUSSIAN probability net
n = 7, γ_1 = 95% burst pressure " p_D " of design D, type IV, CFRP & PC, virgin specimens

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How do statistics work?

5th step

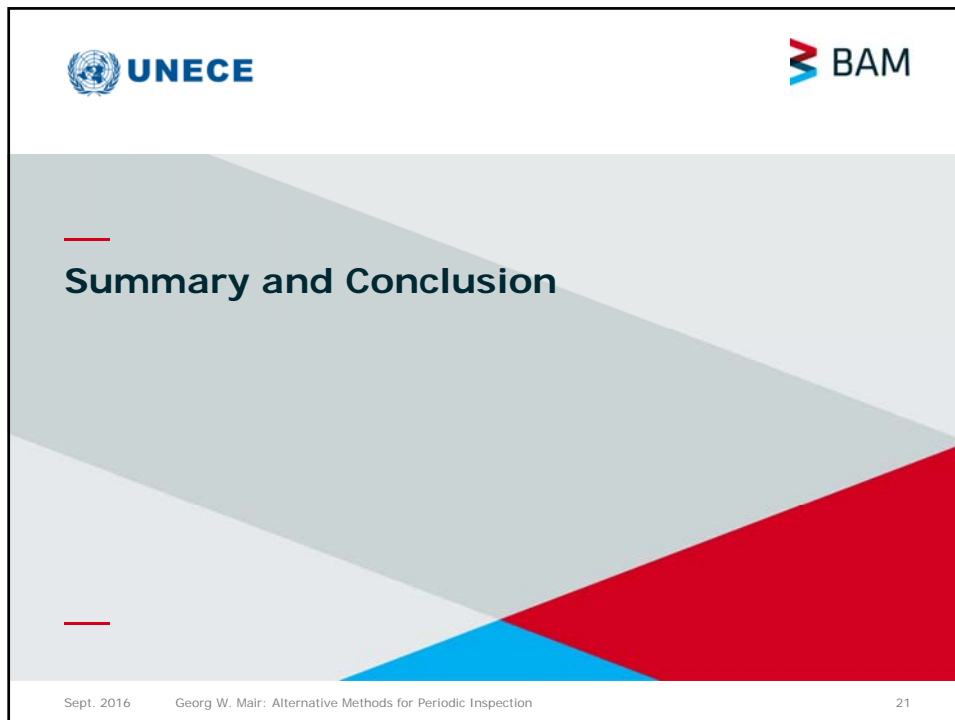
Comparison of test results with minimum requirements

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

Quantitative property-check

Simple 100% yes/no-check

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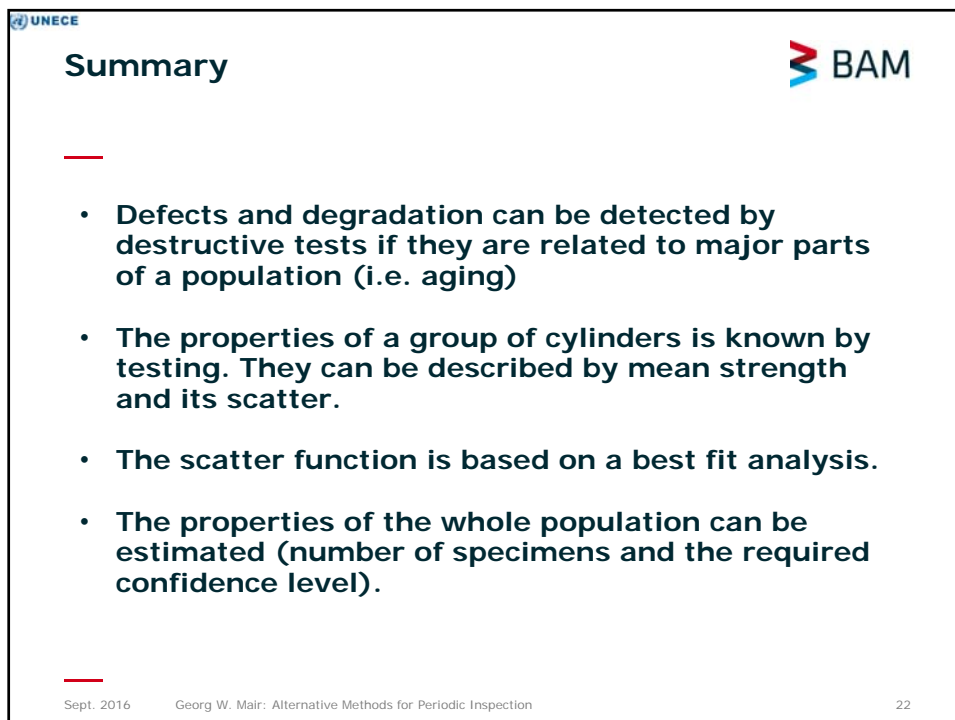
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Summary and Conclusion

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Summary

- 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** 



- 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** 

- 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



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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