Partial Substitution of inspection By Statistical Methods

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Overview

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
Current Requirements for Periodic Inspection

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.
The Current Requirements

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

Examples of Obvious Deficits of Current Inspection Methods
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.

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.
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)
Currently not clearly covered issues

<table>
<thead>
<tr>
<th>Item of inspection and its main intention: They cover aspects of individuals but no systematic ones!!</th>
<th>Related to individuals</th>
<th>Related to production batches</th>
<th>Related to a whole population</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) external visual inspection marking, etc.</td>
<td>yes</td>
<td>indirect</td>
<td>no</td>
</tr>
<tr>
<td>b) internal visual inspection, wall thickness etc.</td>
<td>yes</td>
<td>indirect</td>
<td>no</td>
</tr>
<tr>
<td>c) check of threads</td>
<td>yes</td>
<td>indirect</td>
<td>no</td>
</tr>
<tr>
<td>d) proof test</td>
<td>yes</td>
<td>indirect</td>
<td>no</td>
</tr>
<tr>
<td>e) check of service equipment</td>
<td>yes</td>
<td>indirect</td>
<td>no</td>
</tr>
</tbody>
</table>

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

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 **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!
Composite Cylinders
e.g. for medical oxygen

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

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!
How Statistics Works

How do statistics work?
1st step

Monitoring of individual results

Quantification of mean strength

Burst pressures of a small sample

Burst pressure of a small sample

average strength: 1153 bars
How do statistics work?

2nd step

Quantification of scatter value

Ranking of test results

Burst pressures of a small sample

average strength: 1153 bars

How do statistics work?

3rd step

Check of best fit line!!

GAUSSian probability net (normal distribution N(0))

Failure rate $p_F$ of design S: type IV, CTRP & PD, risk assessment.

How do statistics work?

4th step

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

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
Summary and Conclusion

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).
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.

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.
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