

Workshop on Regulations, Codes and Standards (RCS) for H₂/FC Technologies

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Hydrogen-related Research on RCS Issues

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Overview



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1. Introduction of BAM
2. Technical Progress (TP) – AE as a QM-Tool 
3. TP – Extreme Temperature Cycles 
4. TP – Improvement of public safety and regulations
5. Transport of Dangerous Goods  
6. Probability Aspects 
7. Summary and Future Work

1. Introduction of BAM

- ✓ **The BAM is a federal institute, mainly financed by the Federal Ministry of Economics and Labour of Germany.**
- ✓ **Our main task is to watch and control the level of public safety.**
- ✓ **We are a permanent adviser of the Federal Ministry of Transport, Building and Housing on issues of the transport of dangerous goods, even on UN-level.**
- ✓ **We are the competent authority of Germany with respect to a lot of aspects of the transport of dangerous goods.**
- ✓ **We are extensively involved in CEN- and ISO-standardisation work which is an essential basics of transport approvals.**
- ✓ **We are concentrating on research aspects which are directly linked to the public safety.**

2. TP: AT as a QM-Tool

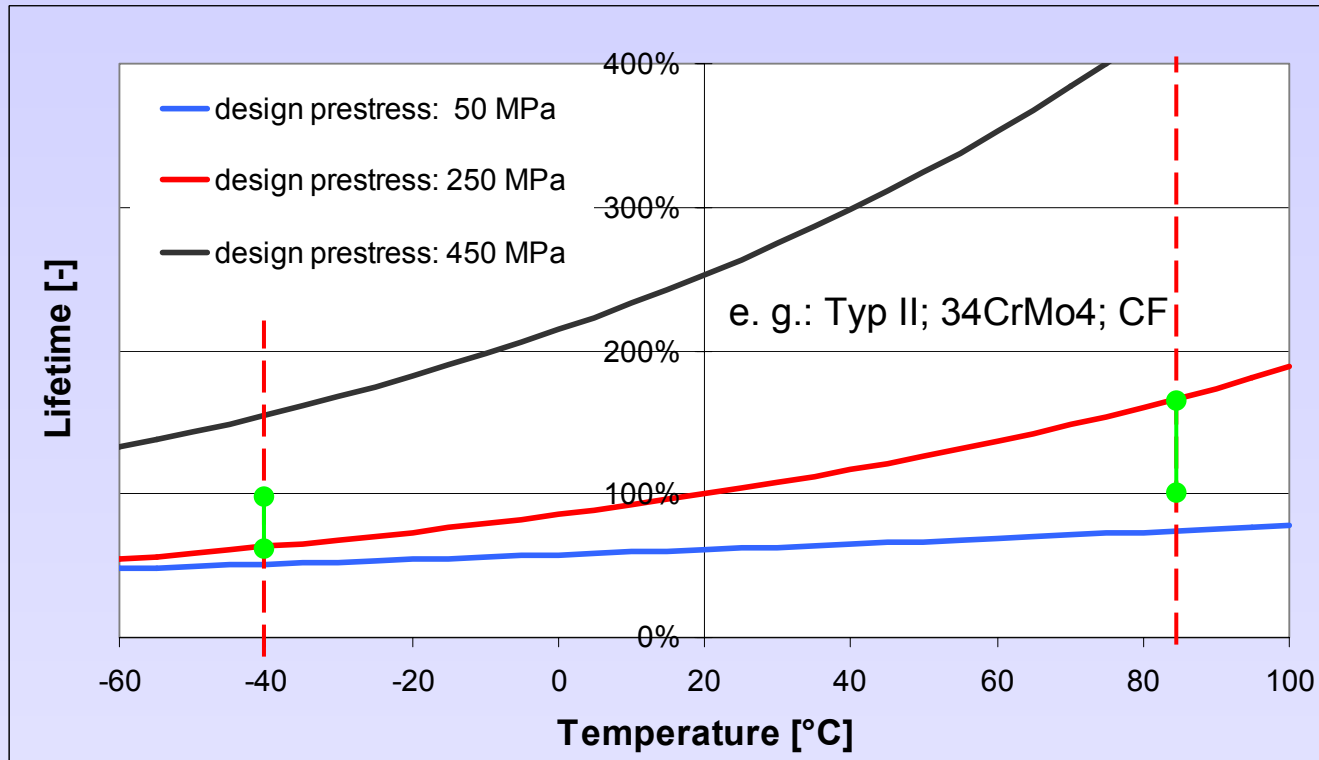
**The renunciation of periodic inspection requires a higher level of Quality Management (QM):
e. g. by using Acoustic Emission Testing (AT)**

- ✓ **There are some good basic studies which demonstrate good prospects of success to detect the most relevant points of quality reduction by controlling the manufacturing process by AT.**
- ✓ **The equipment is available.**
- ✓ **The AT shall be done during the autofrettage-process.**
- ✓ **AT is relevant for all kinds of storage containments.**
- ✓ **Further fundamental studies are in preparation and have to be transferred to every design type.**

3. TP: Extreme Temp. Cycles



Influence of the receptacle's temperature on the number of cycles before leakage (liner)



3. TP: Extreme Temperature Cycle

The result of the life-time prediction in comparison with the current relevant standards (drafts):

- **The current procedure requires the cycling at extreme thermal conditions to a life-time relevant number of cycles combined with a rupture test, all with the same specimen.**
- **The given diagram of the interaction of pre-stress, temperature and life-time-calculation demonstrates that there is a significant effect in the liner of cancelling out each other.**
- **Due long liner cracks before leakage and the ability of local balancing of stress concentrations this concept is not expected to work with the necessary reliability.**

4. Technical Progress...

.....with respect to the public-technical safety and regulations

- **Well-known Engineering Rules (WER)**
- **State of the Art (SA)**
- **State of the Art of Safety Technology (SAST)**
- **Progress in Science and Engineering (PSE)**

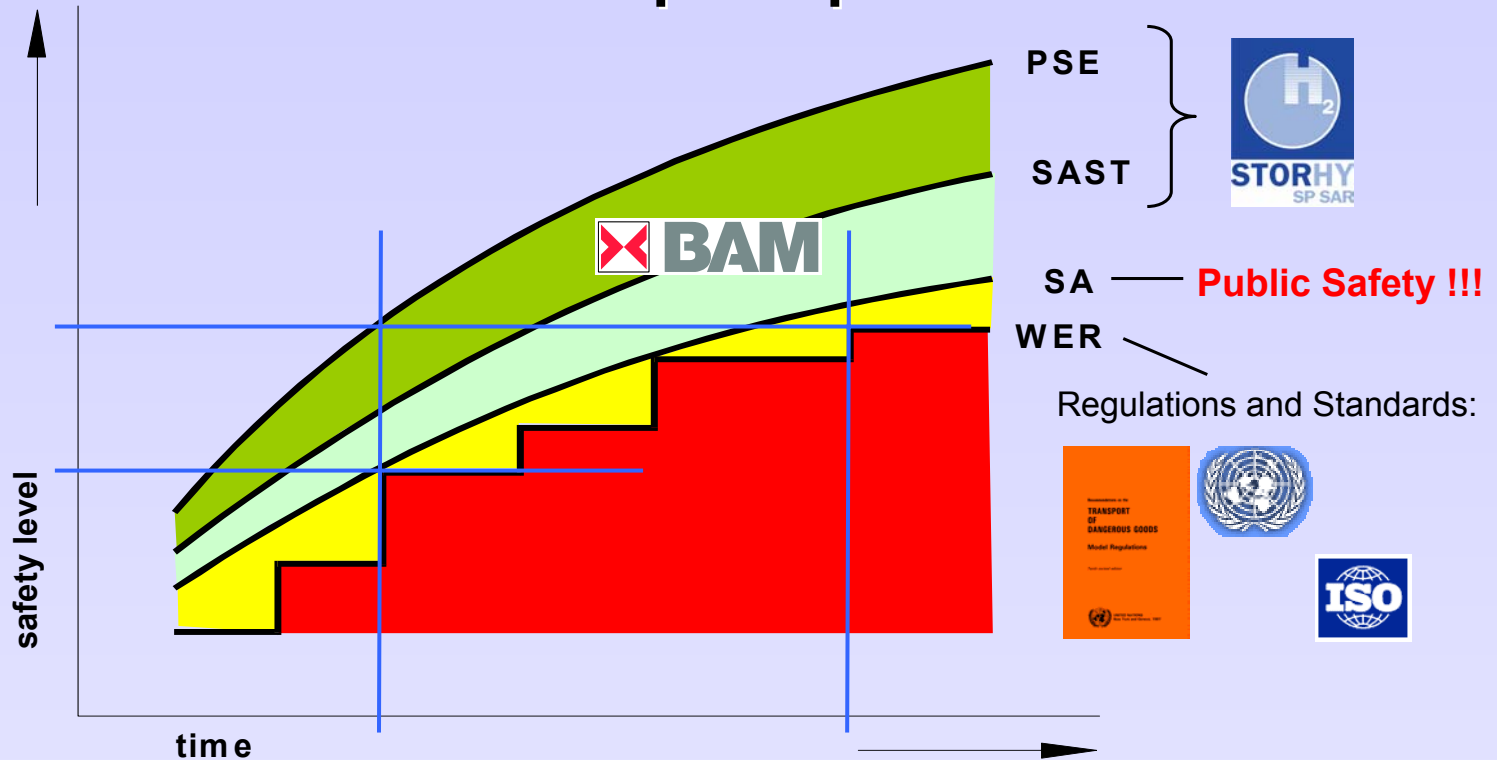
Result of the “Kalkar” (atom energy plant) decision by the German Federal Constitutional Court (1978; compare Seveso II Directive):

As far as a potential high consequence of an accident is not excluded (damage to life, health and physical assets) the courts require an safety level which is not only represented by the WER (standards and approval rules). At least the SA is required.

4. Technical Progress



Improvement of technique and regulation in principle



4. Technical Progress

The assessment of today's safety level has a lot of different aspects:

- ✎ **Most of the strength relevant testing procedures are not build to present a quantitative safety value.**
- ✎ **The given “to go or not to go” decision of the standards are not sufficient for a differentiating assessment of safety properties.**
- ✎ **Some tests are created in such a way that effects cancel out each other.**
- ✎ **The current tests of the standards are mainly not appropriate for a probabilistic safety approach (PSA).**

5. Transport of DG

The historical roots of lightweight receptacles are the transport of dangerous goods

- Today's situation is:

- ✓ **Composite-Cylinders are mainly used for the transport of Hydrogen mounted on trailer.**
- ✓ **The periods of retesting and lifetimes are to be fixed by the competent authority; this avoids a fixed link to the WER.**
- ✓ **The acceptance of new standards can be anticipated by the competent authorities – to keep close the gap between WER and SA as much as possible.**

6. Probability Aspects

The sum of these aspects guides to new proposals of testing procedures in future, which have to be evaluated before – even with respect to PSA:

- ✓ **Fire Engulfment Test**
(pressure to be monitored; maybe without PRD)
- ✓ **Accelerated Stress Rupture Test**
(as a High Temperature Creep Burst Test)
- ✓ **Extreme Temperature Pressure Cycling Test**
(until leakage; no Ambient Temp. Cycle Test)
- ✓ **Impact Damage Test (instead of Drop Test)**
- ✓ **Permeation Test (alternative methods)**

Summary

- ✓ **The use of Hydrogen will increase. Therefore the safety of their containment techniques shall be improved, too.**
- ✓ **To guarantee a more safe use of hydrogen some new approaches concerning QM control and design requirements are necessary.**
- ✓ **Even the necessity to evaluate the state of the art of safety, within the IP StorHy, and the additionally addressed Probability Safety Assessment (PSA) require modifications of test procedures.**
- ✓ **The PSA will give the manufacturers a better tool to meet the SA (State of the Art) or SAST.**
- ✓ **An extensive exchange on European level of experience of the different kinds of the use of gas storage and transport systems will be necessary and provides a better efficiency of the research effort.**

Future Work

- 👍 **The safety level has to be built in a dynamic manner – dependent on the number of systems in use.**
- 👍 **The aspects of system integrity and of modularity have to be taken into consideration for a appropriate safety.**
- 👍 **The approach of design properties and QM has to be improved and changed step by step to PSA.**
- 👍 **The similarity to the Hydrogen transport in terms of the Transport of Dangerous Goods can be used for a higher efficiency.**

The final step should be a regulation stipulating end results in terms of safety / probability and not in terms of required testing procedures!



**Thank you for your
attention**

