SGS-04-08

Generals on Storage Systems and Comments on J2579 (5.2.2.1)

Hydrogen Fuel Cell Vehicle (HFCV)

4th Meeting of the Subgroup on Safety (SGS)

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BAM-III.2

Purposes and Goals

The purpose of approval regulations is to guarantee users' safety and public safety at the respectively accepted risk levels.

The purpose of a GTR is to harmonise rules at the most stringent level in the most global extend for worldwide acceptance of tests and approvals without any need for regional supplements.

Purposes and Goals

The purpose of test procedures is to demonstrate that required safety (protection) goals are met.

1. The whole set of tests has to cover all safety relevant performance aspects in a representative manner (using NDT for 100% tests).
2. Technique of test procedures have to be frequently improved to follow the Progress in Science and Engineering (PSE).
3. Required test equipment has to be available in a sufficient number (e.g. at least three times per region).
4. Tests have to demonstrate properties such that they are representative for the whole production or shall be repeated and surveyed continuously during production (batch tests).

SAE J2579 Pneumatic Performance Test

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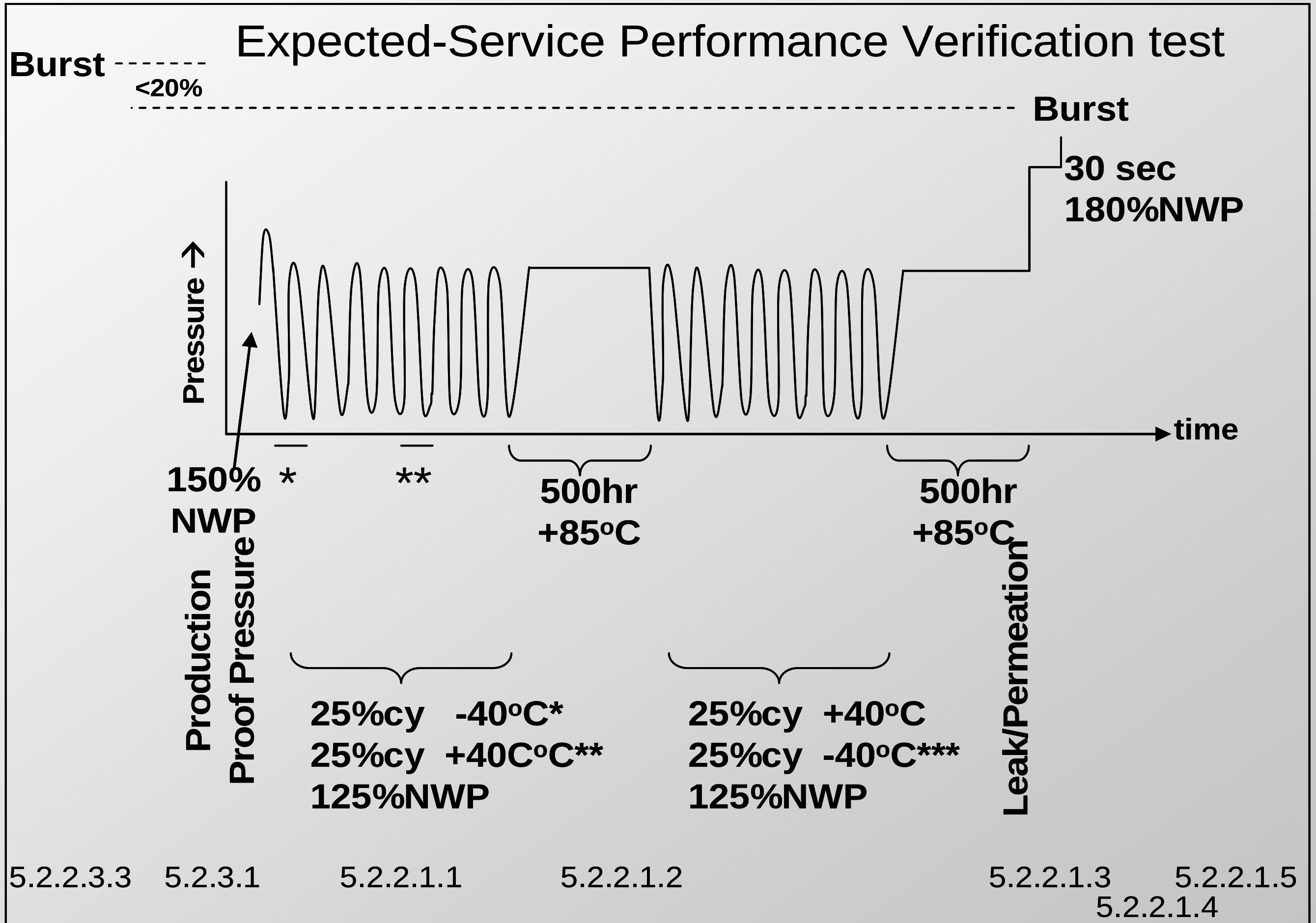
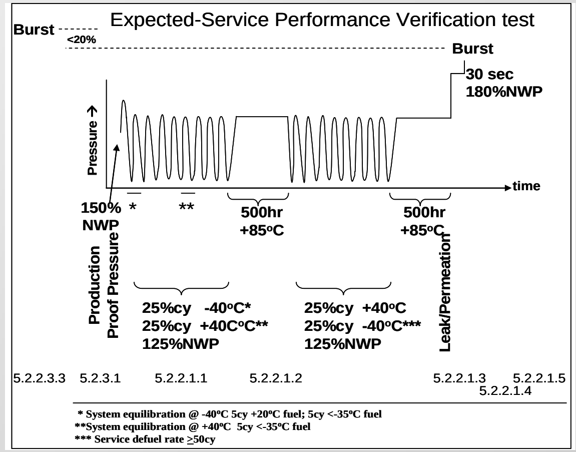
SAE: At least one hydrogen storage system shall demonstrate the capability to function through the expected cumulative exposures associated with worst-case conditions of fueling and de-fueling (pressure cycling at environmental temperature limits) and parking (sustained static pressure).



* System equilibration @ -40°C 5cy +20°C fuel; 5cy <-35°C fuel
**System equilibration @ +40°C 5cy <-35°C fuel
*** Service defuel rate ≥50cy

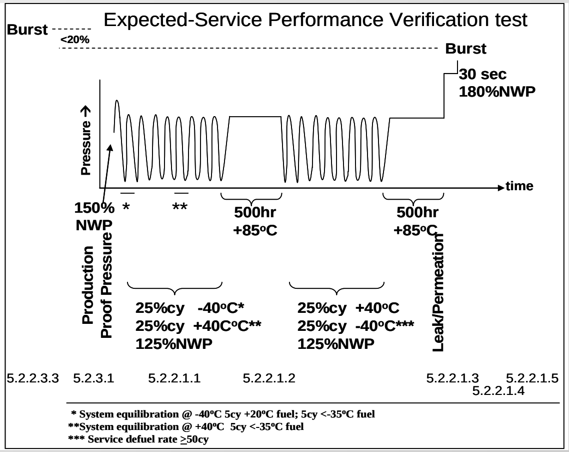


5.2.2.1 “Extr. temp. gas cycle test”

This test concept can be supported as best method for simulation the composite degradation process during use, if the following questions can be affirmed:

1. **Is the filling procedure at fuelling stations harmonised enough to enable a description of test parameters such that the most critical degradation aspects are covered?**
2. **Does the ultimate criteria of 180% of NWP cover reliably the specific scatter of UTS of all cylinders with CFRP or other fibres?**
3. **How to ensure that one specimen can present the behaviour of all containers?**
4. **How to prevent a sudden burst during gas cycling such that the test facilities can be built up like a hydraulic test facility?**

Main Comment on SAE J2579



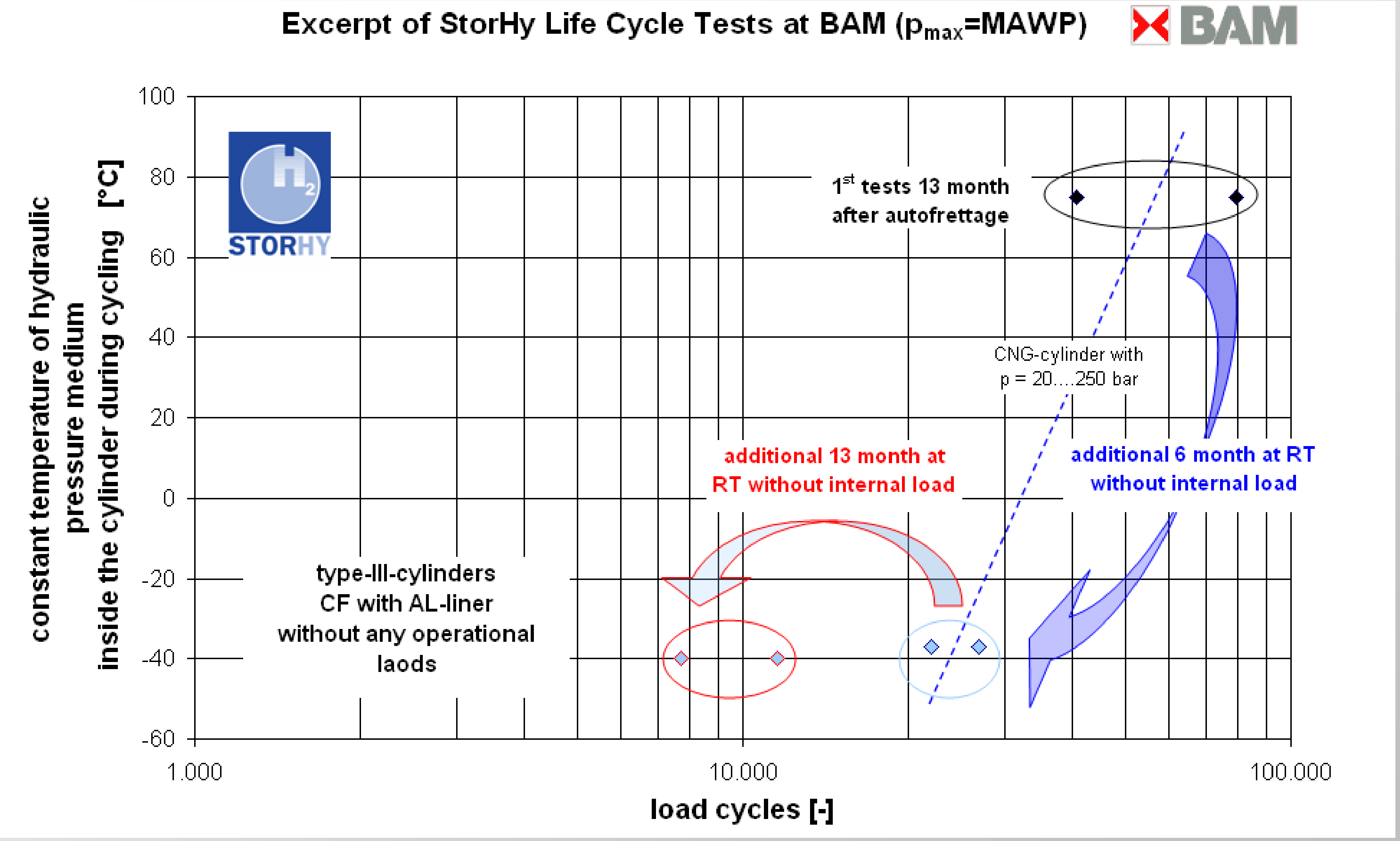
5.2.2.1 “Extr. temp. gas cycle test”

This test concept seems to be the best method to simulate the composite degradation process during use. But….

6. **… the test is extreme expensive to be performed on an adequate number of samples or to be repeated periodically during production.**
7. **… the necessary test equipment (extreme ambient temperatures during filling procedure gas cycling) is commercially not available in an adequate number.**
8. **… the concept of final burst tests in general may be appropriate for type IV-cylinders; It is not sufficient for cylinders with load sharing liners. At those the remaining strength of fatigue strength (scatter of cycles) or a critical change of residual stresses can not be detected.**

Some further impressions on problematic aspects …

Hydraulic Cycle Conditions of Type III



Hydraulic Cycle Conditions of Type III

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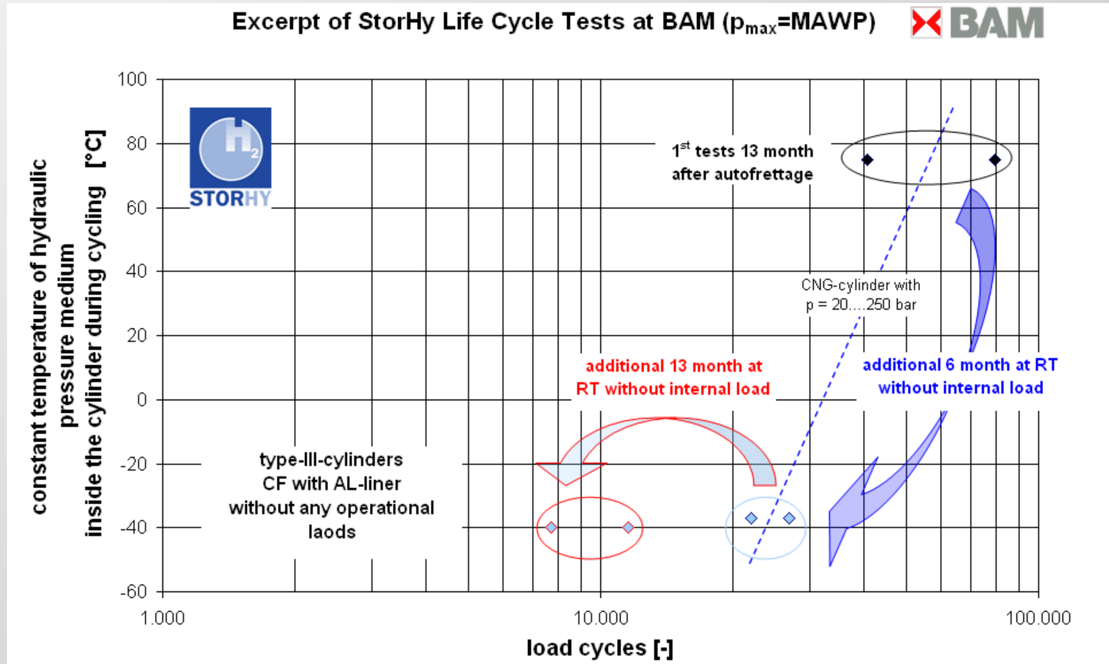
These test results show …

- … a significant influence of the **temperature** during cycles.
- … unexpected influence of the **storage time** before cycling.



But it is currently not possible to confirm that the conclusion on the first view (it looks like a strong degradation of fatigue life without any pressure loads) is correct!

But we should have a stronger look on the long term impacts on residual stresses and consequences ……

Type III: Residual Stresses

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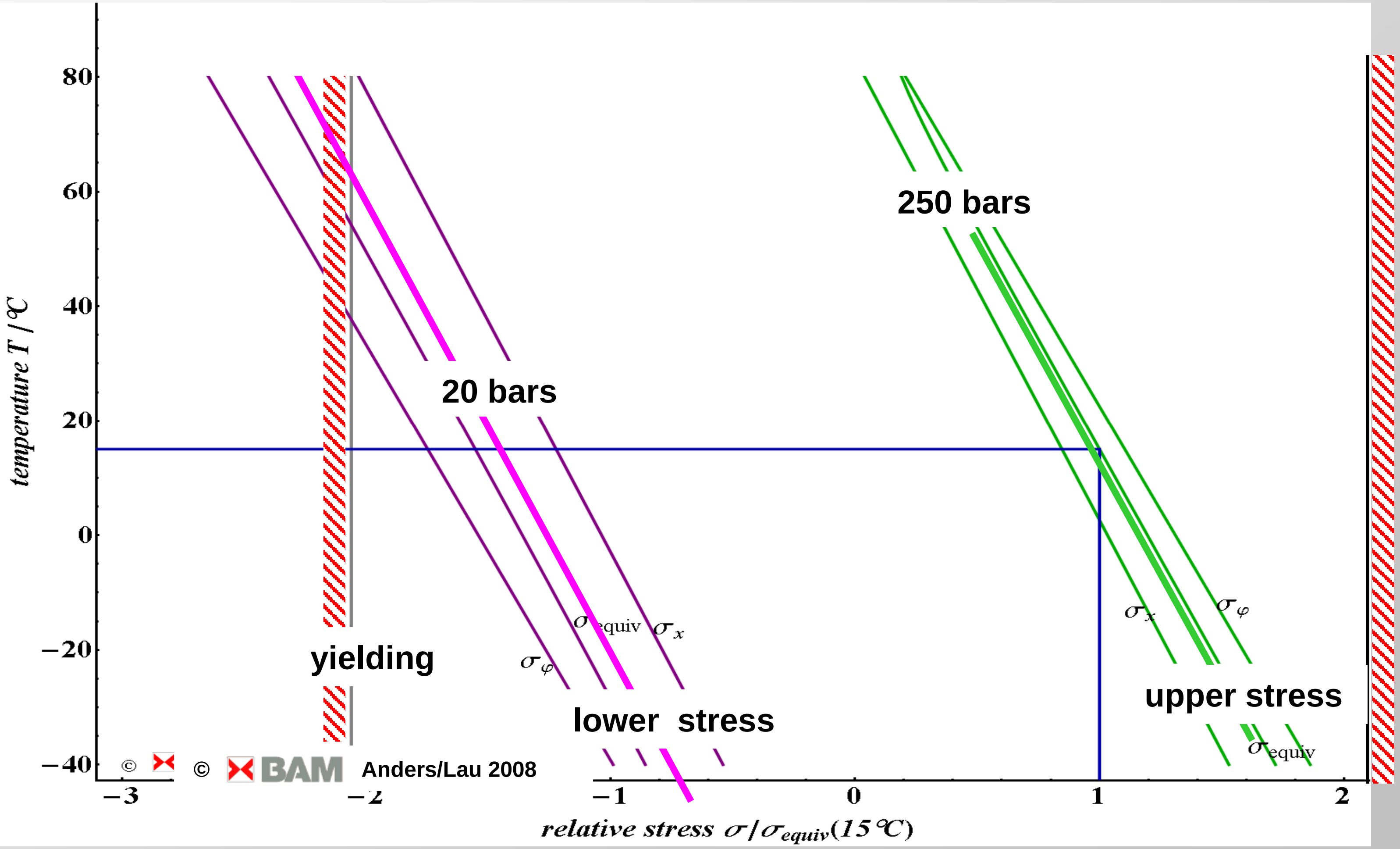
The upper and the lower stress levels (v. Mises) of a load sharing liner depends on temperature more than mostly estimated today.

Exemplarely calculation of a type-III-cylinder for CNG with CRP and A6061T6



For assessment of fatigue safety it is necessary to have a look on statistical aspects:

Normal-distribution represented by a parameter for the spread of distribution “Streuspanne” (T_N)

$$T_N \equiv N_{90} / N_{10}$$

means

ratio of LC @ 90% survival rate to LC@10% survival rate

Confidence in Fatigue Tests

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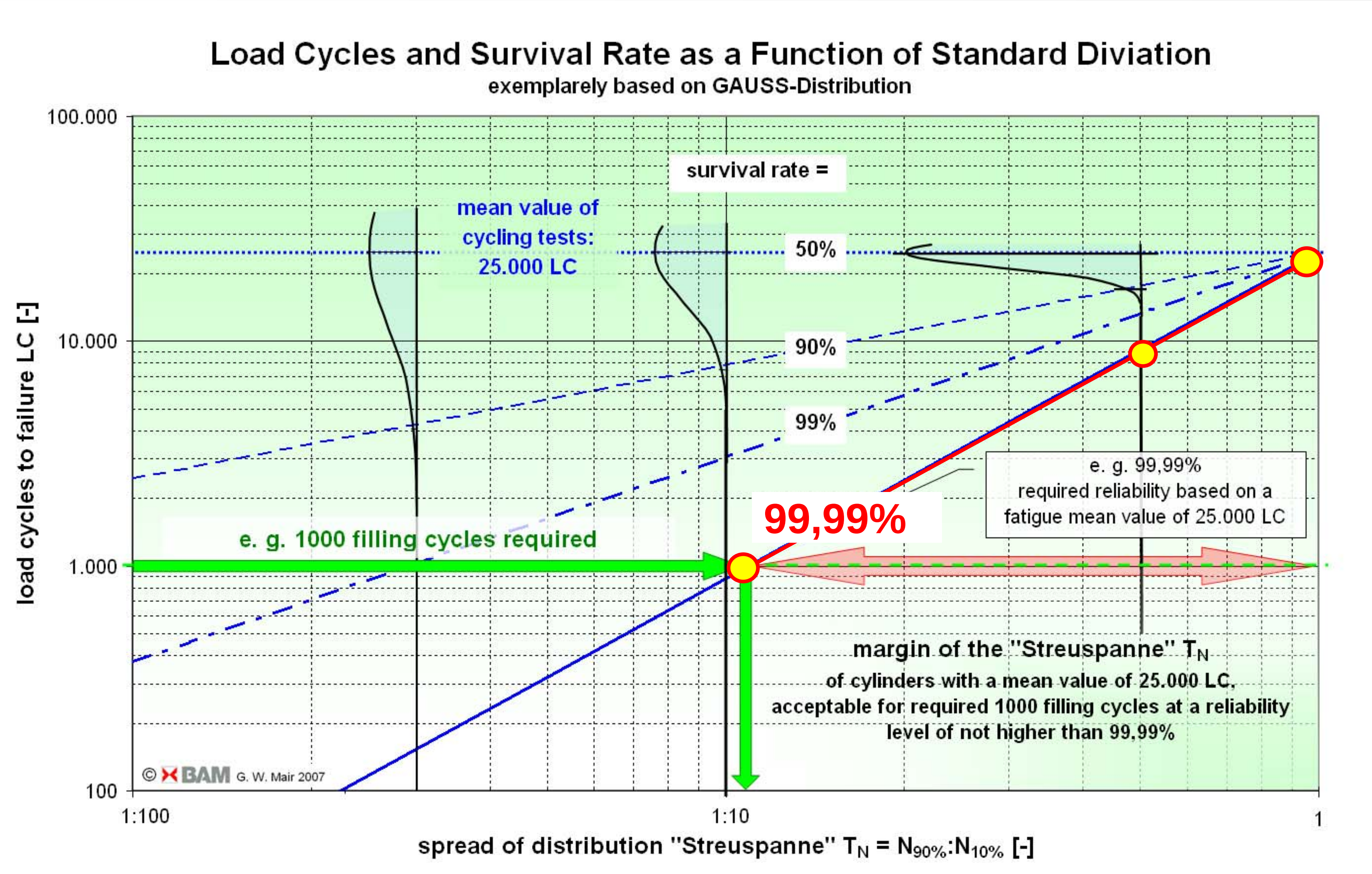
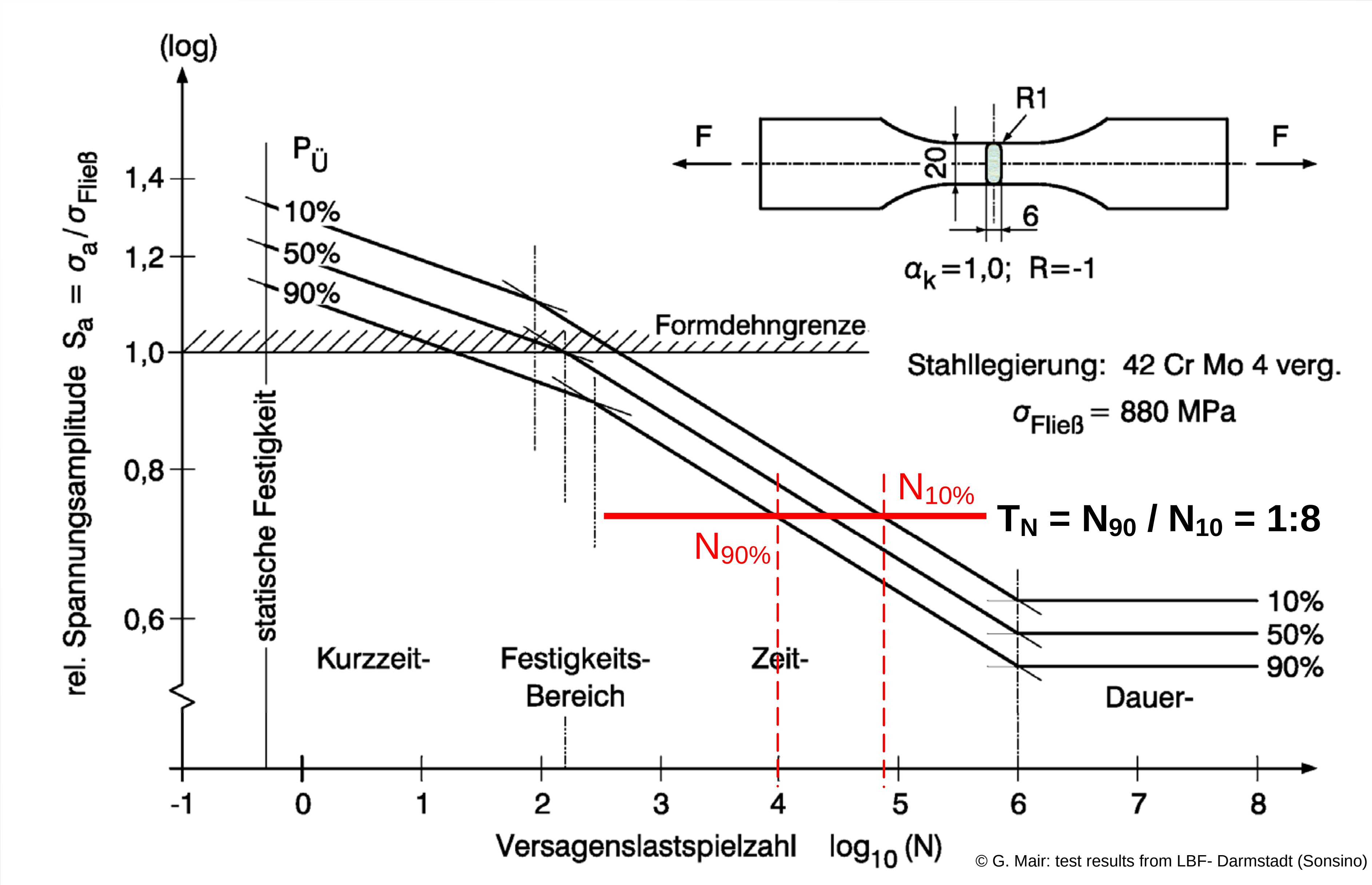
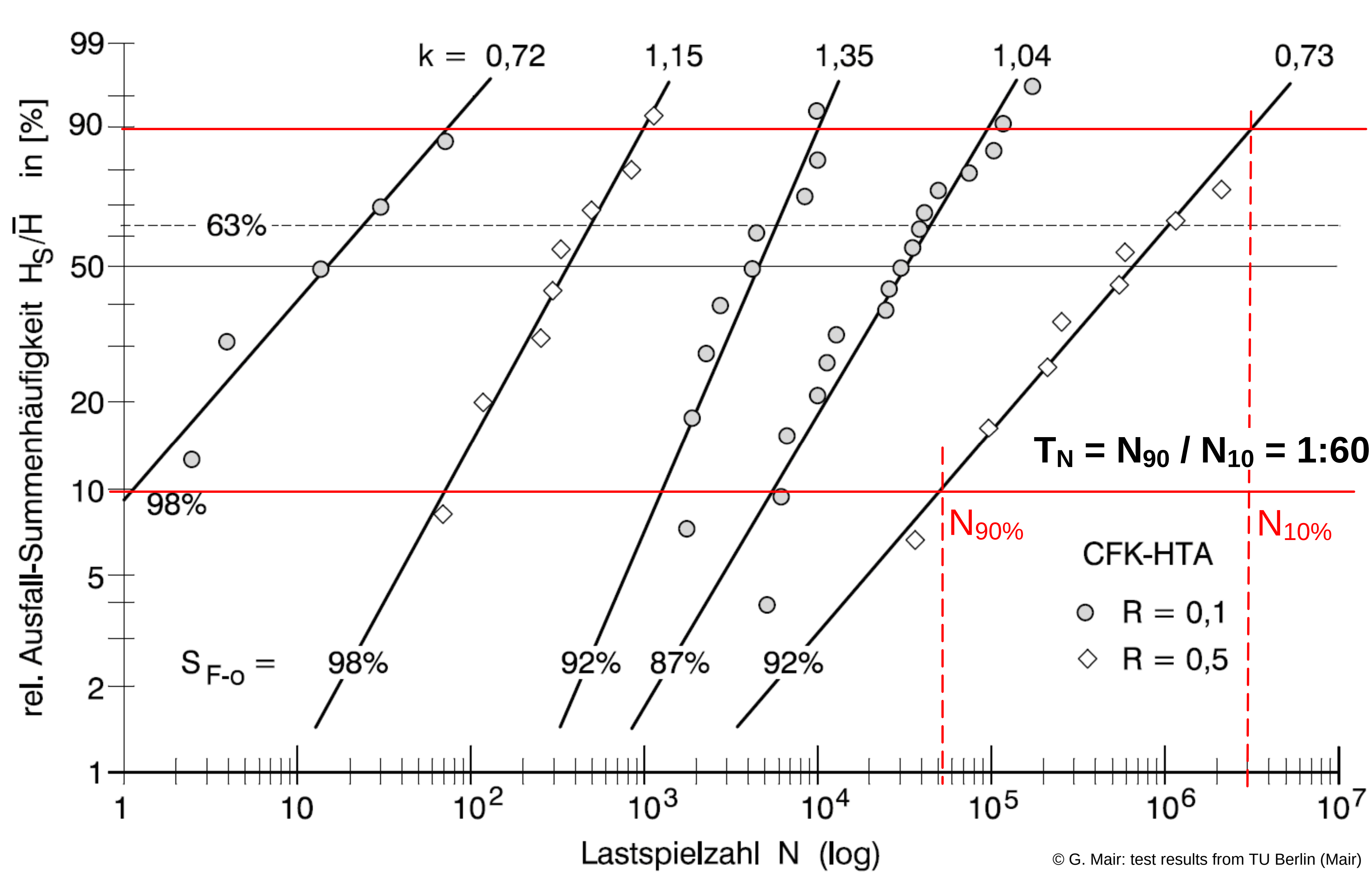


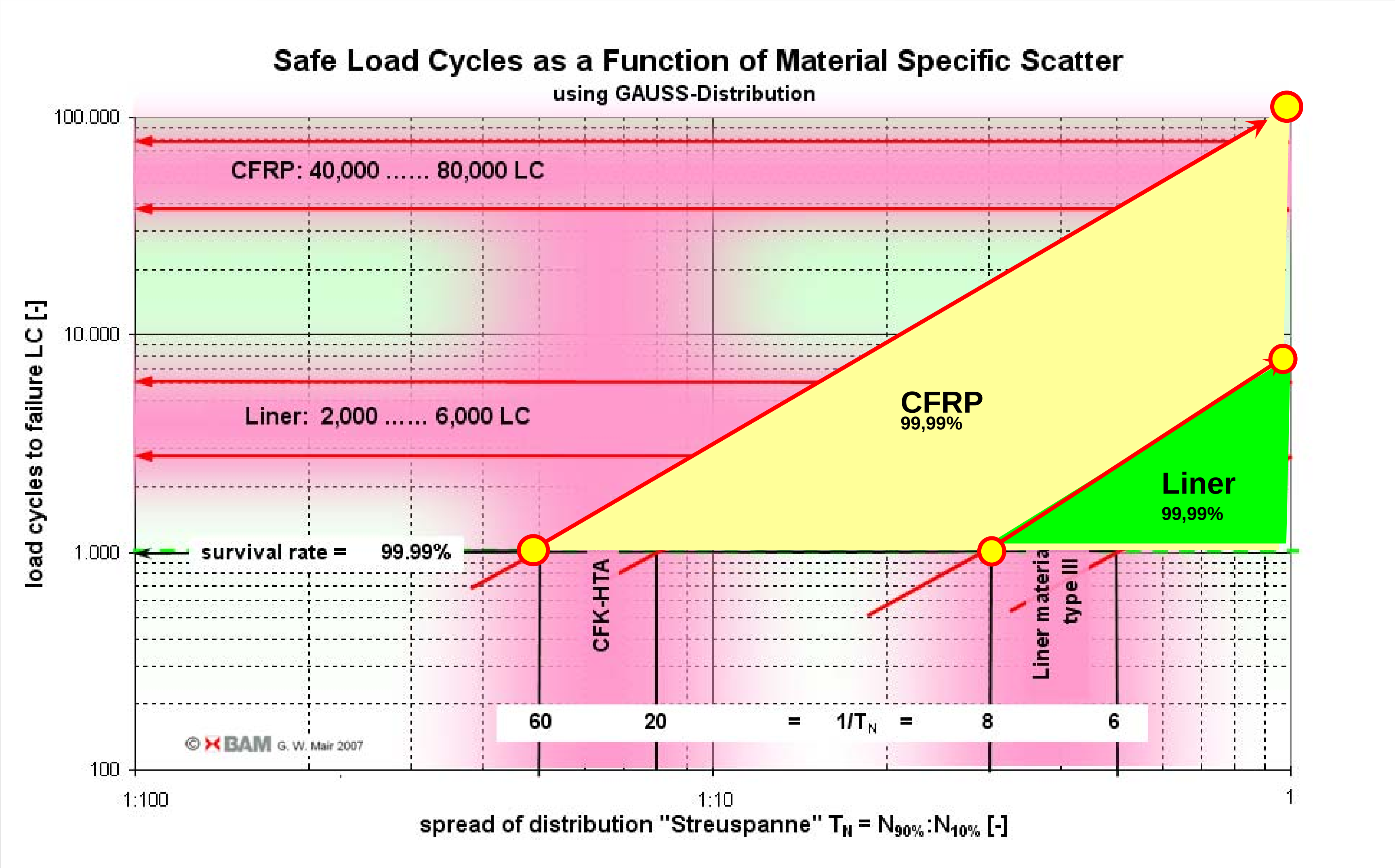
Fatigue Strength of 34CrMo4



Fatigue Strength of CFud



Confidence in Fatigue Tests



Comment: Shown material properties are based on simple specimen and are not necessarily representative for manufactured pressure cylinders

Conclusions on Fatigue Tests

So it will be necessary to assess the fatigue reliability (static and cycling) with focus on containers' first (leakage) and fatal failure (burst) in future.

For this purpose it will stay necessary to cycle a sample of containers hydraulically up to leakage or at least to a minimum number of cycles – depending on the material. Therefore the reproducibility of hydraulic tests has to be improved.

In addition in the GTR a possibility should be given to use probabilistic tools for safety assessment instead of fixed safety margins – when the production volume increases significantly.

Further information are available: georg.mair@BAM.de

Conclusions concerning SAE J2579

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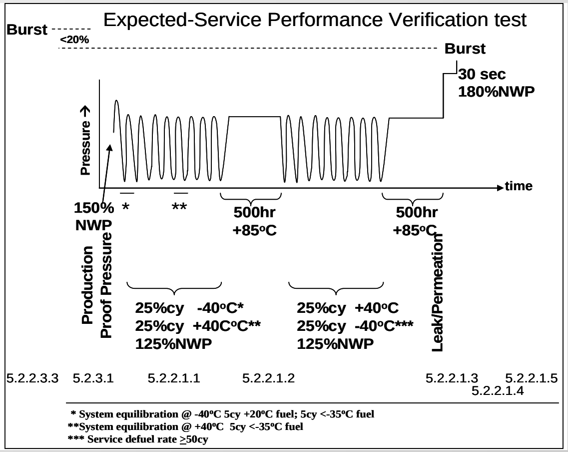
5.2.2.1 “Extr. temp. gas cycle test”



This test concept (including final burst for type IV and final cycling for type III) is recommended to be performed as reference test for operational degradation, which should be described in details (filling parameters etc.) and compared with hydraulic test results by extensive use of NDT (AT, X-ray etc.) to scale up hydraulic sustained load and cycle tests, which easily can be performed on a significant number of specimen and statistically assessed.