UN R134 Material Compatibility

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Background

- GTR13 material requirements were not included in Part 2 since not all CPs require them in their national legislation
- Test methods for evaluating material compatibility (metals) are included in Part 1, Section M
  - Fatigue life test, Slow strain rate tensile test
  - Humid gas stress corrosion test
- EC 79 (2009)/EU 406 material tests have sunset but included in [EU]2021/535 (Section F)

What is material compatibility?

- There is no general definition of ‘compatible’. Compatibility must be defined on a case-by-case basis and is determined by clearly defined requirements for a specific application (or applications).
- All of the materials of interest are susceptible to hydrogen embrittlement; thus, compatibility is a question of the requirements.
    - For example, Annex 8 effectively defines compatibility as no failure at 100,000 cycles (or 200,000 cycles). In contrast, materials compatibility for transportable cylinders (ISO 11114-4) is defined with fracture criteria. These criteria are not interchangeable (hence ISO 11114-4 should not be used for vehicle components).
- It is important to note also that materials for gas cylinders (Cr-Mo steel) and materials for vehicles components (316 and similar alloys) are all degraded in gaseous hydrogen environments.
- To reiterate, compatibility is not defined by whether the material is degraded (they all are degraded more or less). **Compatibility is defined by whether the material meets the intended service.**

What is the goal?

Goal: Establish testing metrics to show components are safe for hydrogen service. This can be achieved in (at least) two ways:

1. Demonstrate that the **material** is compatible with hydrogen for the design constraints of the component.
2. Demonstrate that the **component** does not fail under the 'worst-case' service environment defined by the requirements of the application.

>> Neither test can certify the material for any hydrogen service.

The two evaluation methods are not the same, **but both can be used to achieve the same goal** with proper definition.

How can goals be met?

Two possible options	UN R134 (OICA Proposal)
1. Demonstrate that the <u>material</u> is compatible with hydrogen for the design constraints of the component. **<u>OR</u>** 2. Demonstrate that the <u>component</u> does not fail under the 'worst-case' service environment defined by the requirements of the application.	1. Annex 8 [perform <u>material tests</u> or show acceptable published papers, standards, or technical reports demonstrating compliance] **<u>OR</u>** 2. Cycle test the <u>component</u> using gaseous hydrogen without failure [2x number of required cycles*]

** Recognizing that the required cycles are equivalent to the life of the component, 2x is therefore represents a 2x safety factor on component lifetime*

Understanding results

What is the materials test appropriate for?

- The materials test does **not** demonstrate the material is acceptable for **any** hydrogen service
- The materials test demonstrates performance of the ***material* within very specific constraints**.
- This material test method **does not guarantee the infinite life of components**. It can only show that the material has 'infinite life' for a specific maximum stress.

What is the component test appropriate for?

- The component test is an acceptance test for the ***component* within very specific constraints**.
- A component test assesses the performance of the component **and only the component in the specific configuration and service environment** of the component test.
- **BUT** a properly-defined component test demonstrates that **the design (including materials) is appropriate** for conservative test conditions and therefore is a reasonable way to 'accept' the component (within the constraint of the test conditions).

■ OICA's proposal

- 6.1(a) Pressure cycling test for TPRD :
  - ✓ Total 15,000 cycles
    (including 10,000 cycles at 20℃, 2MPa to 125%NWP)
- 6.2(c) Extreme temperature pressure cycling test for Check valve、
  Shut-off valve :
  - ✓ Total 15,000 cycles for Check valve
    (including 13,500 cycles at 20℃, 100%NWP)
  - ✓ Total 50,000 cycles for Shut-off valve
    (including 45,000 cycles at 20℃, 100%NWP)

Big difference between both number of cycles

■ The material compatibility test in draft UN R134, Annex 8 Part 1

- ✓ Option 1) Notched fatigue life test : 100,000 cycles at 20℃
- ✓ Option 2) SSRT test : Yield strength > 0.80 yield strength in air
  @The strain rate ≤ 5×10^{-5} s^{-1} at -45℃
  Smooth fatigue life test : 200,000 cycles at 20℃

Differences between materials and component tests

Materials test

- Goal – show the material has essentially infinite life for typical design stress
- Fatigue life of a conventional materials fatigue coupon > 100,000+ cycles to failure.
  - In gaseous hydrogen, at pressure > maximum service pressure (i.e., 1.25 x NWP)
  - Design stress = 1/3 tensile strength at RT

Component test

- Goal – show the component exceeds the required design life
- Pressure cycling of component: cycles > 2x intended life of the component (15,000+ cycles)
  - Simulated hydrogen service environment representing essentially full pressure cycles

- The goals of these two tests are different
  - The materials test shows essentially *infinite life*
    - greater 'safety' factor accounts for design constraints that are difficult to characterize (e.g., stress concentrations)
  - The component test shows *conservative life* (2x intended service)
    - smaller 'safety' factor is acceptable because there are no assumptions about stress (i.e., design unknowns are captured)