HMG Opinion of Metal Material Compatibility Test

■ Today ' s situation on material compatibility

- Recommendations for materials to be used in the hydrogen environment are existing
  (e.g. Table B2 in SAE J2579 or Table A5.8 in NASA NSS1740.16)

- The test procedure worked out by SAE and submitted by Japan to the IWG (GTR13-6-04) is very time consuming (2~3 Months) and not feasible for regulatory provisions as the proposed tests (SSRT and Fatigue test) can currently not be conducted on comercial level, as the test facilities are very limited and mainly available for research work only.

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- **Example from NASA NSS1740.16. The steels and aluminums in the table below are proven materials with regard to hydrogen embrittlement, and are generally used in the aerospace area where the operating environment is more severe**

National Aeronautics and Space Administration

SAFETY STANDARD FOR HYDROGEN AND HYDROGEN SYSTEMS

Guidelines for Hydrogen System Design, Materials Selection, Operations, Storage, and Transportation

		Slightly embrittled		
304 ELC Stainless Steel	0.87	----	----	----
305 Stainless Steel	0.89	----	----	----
Be-Cu Alloy 25	0.93	----	----	----
Titanium	0.95	----	----	----
		Negligibly embrittled		
310 Stainless Steel	0.93	----	----	----
A286	.97	----	----	----
7075-T73 Aluminum Alloy	.98	----	----	----
316 Stainless Steel	1.00	----	----	----
OFHC Copper	1.00	----	----	----
NARloy-Z[c]	1.10	----	----	----
6061-T6 Aluminum Alloy	1.10	----	----	----
1100 aluminum	1.40	----	----	----

[a] Chandler, W. T. and R. J. Walter. "Testing to Determine the Effect of E
Environments on the Mechanical Properties of Metals," in *Hydrogen Em*

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- **Example from SAE J2579. The steels and aluminums in the table below are proven materials with regard to hydrogen embrittlement**

Material	NWP	Material Composition and Processing	Design Guidance at 1.5xNWP
Steel: [a,b] S31603, S31608 (China) DIN 1.4401 (Germany) DIN 1.4404 (Germany) DIN1.4435 (Germany) UNS S31600/AISI 316 (USA) UNS S31603/AISI 316L (USA)	≤70 MPa	No restrictions except note b	No significant degradation under hydrogen service for infinite life design [d]
Steel [a,b] SUS304 (Japan) SUS316 (Japan) SUS316L (Japan)	≤70 MPa	Austenitic Stainless with solid-solution heat treatment	No significant degradation under hydrogen service for infinite life design [d]
Steel: [a,b] S31603, S31608 (China) DIN 1.4401 (Germany) DIN 1.4404 (Germany DIN 1.4435 (Germany) UNS S31600/AISI 316 (USA) UNS S31603/AISI 316L (USA)	≤70 MPa	≥13% Ni [c] ≤0.25% N [c] Note b	No significant degradation under hydrogen service
Steel: [a,b] DIN 1.4433 (Germany) UNS S31703/DIN 1.4438 DIN 1.3952 (Germany) UNS N08926/DIN 1.4529 UNS N08904/DIN 1.4539	≤70 MPa	No restrictions except note b	No significant degradation under hydrogen service
Aluminum [e,f] A6061-T6 A6061-T62 A6061-T651 A6061-T6511	≤70 MPa	No restrictions	No significant degradation under hydrogen service

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- Proposal for further procedure in GTR13
  - General provision to use those (stainless steel or aluminium) materials tabled in NASA NSS1740.16 or SAE J2579
  - Providing the possibility to further certify/test materials according to test procedure SAE J2579. This is used as an engineering screen standard for newly developed materials (e.g carbon steel, low alloy, etc.)
  - Evalute in parallel the feasability of this test procedure in (national) round robin tests. They are in the progress and the decision on the test should be done after finalization of the round robin tests
  - Further update of the standard for the evaluation method is needed (e.g. specimen size and process method, equipment specification etc.)
  - Alternative, less complicated and time consuming test methods have to be worked out and should be considered. We allready started that process internally and are willing to consider it together