GM	WORLDWIDE ENGINEERING STANDARDS	Material Specification	GMW17177

Selection and Use of Metallic Materials used for High Pressure Hydrogen (H_2) Applications in Fuel Cell Vehicles

1 Scope

1.1 Material Description. This standard applies to all metallic materials exposed to direct contact with high pressure gaseous hydrogen (H_2) especially in fuel cell powered vehicles. This standard describes engineering measures and materials specifications to avoid hydrogen-induced brittle fracture and defines suitable materials.

Note: Nothing in this standard supersedes applicable laws and regulations.

1.2 Symbols. Not applicable.

1.3 Applicability. This standard applies to all metallic materials exposed to direct contact with high pressure gaseous hydrogen (H_2). Typical automotive applications are Fuel Cell Vehicles.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ANSI/CSA CHMC 1	EN 755-2	EN 10228-7	ISO 3506-3
ASTM B 637	EN 1301-2	EN 10270-3	ISO 3506-4
ASTM B 805	EN 10088-2	EN 10272	ISO 14343
DIN 17753	EN 10088-3	EN 10296-2	ISO 17672
DIN 50602	EN 10095	EN 10297-2	SAE J2579
EN 485-2	EN 10151	ISO 643	
EN 573-3	EN 10216-5	ISO 3506-1	
EN 752-2	EN 10217-7	ISO 3506-2	

2.2 GM Standards/Specifications.

GMW3059

2.3 Additional References.

- AD 2000 Merkblatt W 2 - Austenitic and austenitic-ferritic steels
- AD 2000 Merkblatt W 6/1 - Aluminium and alluminium alloys; Wrought materials
- AD 2000 Merkblatt W 10 - Materials for low temperatures; Ferrous materials

3 Requirements

3.1 Hydrogen-Induced Crack Formation or Brittle Fracture. This standard defines hydrogen-induced crack formation or hydrogen-induced brittle fracture as material damage resulting from diffusion of atomic hydrogen into the material. The damage is triggered by tensile stresses or residual tensile stresses in the component.

The embrittlement index represents a measure for the material suitability at hydrogen-exposure and is defined as the ratio H_2/air of the percentage reduction of area of tensile tests.

Only unnotched tensile test specimens shall be used for the determination of the values. In case of plate or sheet materials, specimens shall be machined perpendicular to the rolling direction. The test procedure is described in ANSI/CSA CHMC 1.

Materials exposed to hydrogen that exhibit an embrittlement index < 0.9 shall not be used.

3.2 Design Requirements. The components shall be dimensioned such that the local loads remain as low as possible. In particular, notches shall be avoided to the extent possible.

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3.3 Manufacturing Requirements. Since rough surfaces promote hydrogen embrittlement under mechanical loads, surface roughness shall be as low as possible.

3.4 Suitable Materials.

3.4.1 Austenitic Stainless Steels. For applications exposed to hydrogen the steel types according to Table 1 shall be used exclusively.

Table 1: Selection of Austenitic Stainless Steels for Applications in Hydrogen Gas Pressure Range from 0.1 MPa to 1 MPa

Steels Suitable for Welding	Steels Not Suitable for Welding
Applicable over the entire temperature range	
1.4433	1.4439
1.4435	--
1.4438	--
No application in the temperature range of -20 °C to -100 °C	
1.4306	1.4401
1.4404	1.4406
1.4430	1.4429
1.4571 Note 1	1.4434

Note 1: Not for wall thicknesses < 1 mm

Based on the current state of knowledge there exist no further limitations for the supply conditions of materials listed in Table 1.

Table 2: Selection of Austenitic Stainless Steels for Applications in Hydrogen Gas Pressure Range from 0.1 MPa to 70 MPa

Steels Suitable for Welding	Steels Not Suitable for Welding
Applicable over the entire temperature range	
1.4433	1.4529
1.4435 Note 1	1.4539
1.4438	--
1.4539	--
1.4980	--

Note 1: The minimum nickel content shall be ≥ 13% by mass.

Steels with reduced carbon content < 0.03% (low carbon steel) shall be preferred to Ti-stabilized steels.

The usage of steel types not listed in Tables 1 and 2 shall be approved by the respective GM Engineering Department.

As regards the mechanical properties and the chemical compositions of the steel types listed in Table 1 and Table 2 the standards for semi-finished products according to Table 3 are applicable.

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Table 3: Standards for Semi-Finished Products

Tubes	Strip and sheet	Bar and wire	Pressure vessels
EN 10216-5 EN 10217-7 EN 10296-2 EN 10297-2	EN 10228-7 EN 10088-2	EN 10088-3 EN 10272	AD 2000 Merkblatt W2 AD 2000 Merkblatt W10

3.4.2 Conventional Steels. Conventional steels are all steels with a body centered cubic (bcc) crystal structure, i.e., ferritic, pearlitic, bainitic and martensitic steels and all combinations thereof. The usage of such steels shall be approved by the respective GM Engineering Department.

3.4.3 Aluminum and Aluminum Alloys. All 6000 series aluminum alloys can be used.

From aluminum alloys of 7000 series, only alloy 7075 shall be used.

The use of 5000 series alloys is currently being investigated.

For cryogenic applications, the alloys listed in Table 4 shall be used preferably, and can be used over the entire temperature and pressure range.

Table 4: Selection of Aluminum and its Alloys for Cryogenic Applications in the Pressure Range 0.1 MPa to 70 MPa

7000 series alloys	6000 series alloys
EN AW-7075 Note 1	EN AW-6060
	EN AW-6061
	EN AW-6082

Note 1: This alloy shall not be used in corrosive environments.

With respect to the chemical compositions of the aluminum alloys listed in Table 4, EN 573-3 is applicable.

With respect to the mechanical properties the respective standards for semi-finished products according to Table 5 are applicable.

Table 5: Standards for Semi-Finished Products

Strip and Sheet	Drawn Bar	Extruded Bar	Wire	Pressure Vessels
EN 485-2	EN 752-2	EN 755-2	EN 1301-2	AD 2000 Merkblatt W6/1 AD 2000 Merkblatt W10

3.4.4 Magnesium Alloys. Alloy AZ31 is released without restrictions over the entire temperature and pressure range. It shall be ensured that the components are not exposed to corrosive environments.

3.4.5 Copper and Copper Alloys. All copper alloys up to a maximum operating temperature of ≤ +500 °C can be used.

3.4.6 Pure Nickel and Nickel-Based Alloys.

3.4.6.1 Pure Nickel Alloys. In the annealed condition, at pressure loading and at electrolytic loading in the vehicle-relevant temperature range, pure nickel alloys exhibit a significant reduction of the ductility and of the static and dynamic strength due to hydrogen embrittlement. Therefore, pure nickel alloys in the annealed condition shall not be used.

3.4.6.2 Nickel-based Alloys. For nickel-based alloys the composition of the alloy and the heat treatment have a significant influence on hydrogen embrittlement. The suitability for each alloy and heat treatment condition shall be proven in each case.

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