Technical Data Sheet
UGI® 4435H2

Chemical composition (%)

C	Si	Mn	Ni	Cr	N	Mo	P	S
≤ 0.030	≤ 1.0	≤ 2.0	13.0 – 14.0	17.0 – 18.0	≤ 0.1	2.5 – 3.0	≤ 0.045	≤ 0.015

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General presentation

UGI® 4435H2 is a molybdenum-alloyed austenitic stainless steel belonging to the 316L family. Its low carbon content provides good corrosion resistance, including in welded areas.
UGI® 4435H2 a highly reliable stainless steel grade for use in high pressure hydrogen gaseous environments. Its high nickel content and stable austenitic microstructure induces a very good resistance to hydrogen embrittlement.

Classification

Austenitic Stainless Steel with Molybdenum.

Designation

Material No.

Europe – EN		USA – UNS	Japan – JIS	World – ISO
1.4435	X2CrNiMo18–14–3	S31603	SUS316L	4435-316-91-I

Other material name

USA	France	Germany	UK	Sweden
AISI	**AFNOR**	**DIN**	**BS**	**S.S**
316L	X2CrNiMo18–14–3	1.4435		

Standards

EN	EN 10088-3
ASTM	ASTM A276 - ASTM A959
JIS	JIS G 4303 - JIS G 4308

Mechanical properties

Tensile data

	Yield stress	Tensile strength	Elongation	Reduction of Area
	Rp0,2% (MPa)	**Rm (MPa)**	**A (%)**	**Z (%)**
Solution annealed	≥ 200	500-700	≥ 40	
Ø ≤ 16 mm solution annealed + cold-drawn	≥ 400	600-950	≥ 25	
Ø > 16 mm solution annealed + cold drawn	≥ 235	500-850	≥ 30	

For specific mechanical properties requirements (for instance, cold work-hardened condition), please consult us.

Swiss Steel Group

Production sites: Ugitech SA
www.swisssteel-group.com

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Impact strength data

Temperature	Absorbed energy
T (°C)	**KV (J) longitudinal**
20	≥ 100

Physical properties

Temperature (°C)	Density	Elastic modulus	Thermal conductivity	Expansion coefficient From 20 to 200°C	Electrical resistivity	Specific heat
	(kg/dm^3)	(GPa)	(W.m^{-1}.K^{-1})	(10^6 K^{-1})	(µΩ.mm)	(J/kg.K)
20	8.0	200	15		0.75	500
100		194		16.0		
200		186		16.5		
300		179		17.0		
400		172		17.5		
500		165		18.0		

(Indicative values)

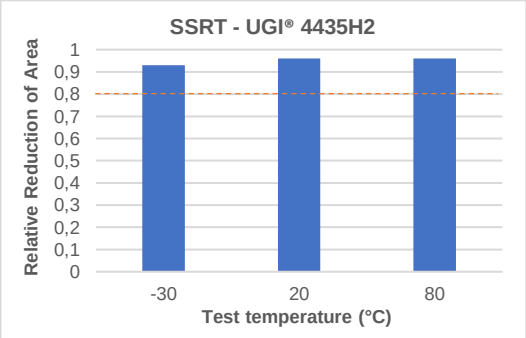
UGI® 4435H2 is non-magnetizable (amagnetic). Due to its high alloying content, UGI® 4435H2 remains non-magnetic after typical cold-forming operations (ie. cold-drawn bars). It usually contains ≤ 3% (by volume) magnetic phases (delta ferrite + strain-induced martensite).

Hydrogen compatibility

UGI® 4435H2 is more resistant to hydrogen-assisted fracture than most other stainless steels.

The high Ni content of UGI® 4435H2, Ni ≥ 13% or Ni_{eq}* ≥ 28.5% ensures a good resistance to gaseous hydrogen embrittlement, even at subzero temperatures.

Slow strain-rate tensile tests (SSRT) on smooth specimens under 100 bar of hydrogen show that the relative reduction of area RRA = Z_{H2} / Z_{air} is above 0.8 which means no significant loss of ductility. In addition, the fracture surfaces remain ductile.



Slow strain rate test results under 100 bar H_2 / air

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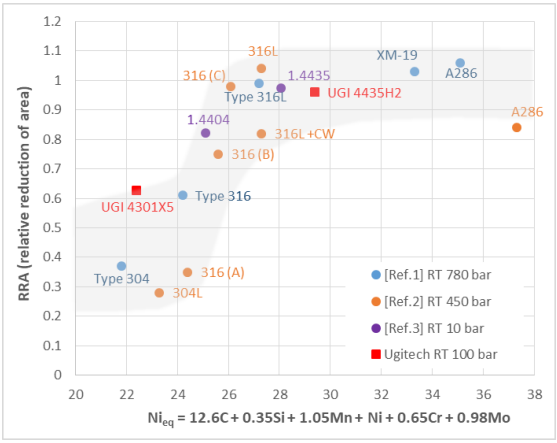
Influence of Ni_{eq} on hydrogen embrittlement of various austenitic stainless steels



In addition, UGI® 4435H2 is a “Premium Grade” melted with a specific process to ensure a good and consistent micro-cleanliness to prevent leakages on components submitted to high pressures of hydrogen.

Alternative materials can also be used in contact with H_2:

- UGI® 4435X4 : similar to UGI® 4435H2 with Ni ≥ 12.5% and slightly better machinability
- UGI® 209 / XM-19 for higher mechanical strength

** : Ni_{eq} (wt%) = Ni + 0,65Cr + 0,98Mo + 1,05Mn +0,35Si +12,6C*

Corrosion resistance

Uniform corrosion

The increase of molybdenum provides UGI® 4435H2 with a better uniform corrosion resistance than the conventional austenitics 1.4307 (304L) and 1.4404 (316L) in reducing mineral acids.

Localized corrosion

Pitting corrosion and crevice corrosion

UGI® 4435H2 has a very good corrosion resistance behavior for a great majority of natural exposures (rural, urban and industrial). This grade, with high molybdenum content, offers among the best pitting and crevice corrosion resistance of the austenitic family.

Intergranular corrosion

Due to its low carbon content, this grade resists intergranular corrosion after welding and after sensitizing heat treatment as specified in the standards (ASTM A262-75 Practice E; DIN EN ISO 3651-2).

The use of UGI® 4435H2 is compatible with all the fluids, lubricants, oils and greases used in the machining industry. Optimum corrosion resistance is obtained where a surface is free from all residual machining oil or foreign particles (iron for example).

Environment	Behavior
Nitric acid	Good
Phosphoric acid	Average
Sulfuric acid	Average
Acetic acid	Good
Sodium carbonate	Average
NaCl (Saline mist)	Good
Humidity	Excellent
Gasoline	Good
Sea water	Good

The corrosion resistance of a stainless steel depends on many factors related to the composition of the corrosive atmosphere (chloride concentration, presence or absence of oxidizing agents, temperature, pH, agitation or no agitation, etc.), as well

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as to the preparation of the material (surfaces free from metal particles, surface finish such as hardening, polishing, etc.). Precautionary measures should be taken for certain tests such as the saline mist test (ISO 9227): for example marking labels (that might cause corrosion run-outs and reduce the test resistance time) should not be used on the sample.

Heat treatment

The solution annealing heat treatment of UGI® 4435H2 consists of exposing the material at least half an hour in the temperature range between 1020°C and 1120°C, followed by air or water cooling. This solution annealing heat treatment removes all traces of strain-hardening whilst providing the steel with its lowest level of mechanical properties.

Hot working

Forging

UGI® 4435H2 can be hot-worked between 900°C and 1250°C and then cooled rapidly, in water or air (priority will be given to water cooling for large charges ; avoid cooling stacked forgings in air).

Hot forming is generally followed by a solution annealing heat treatment (see recommendations in the corresponding section).

Cold working

Wire drawing

UGI® 4435H2 grade has good cold forming capability. Its high work-hardening rate compared with non-austenitic grades may induce the use of appropriate tools. Only heavy cold working can make the grade slightly magnetizable through the formation of strain-induced martensite.

Bending – Forming

Good bending and forming capability.

Surface treatment

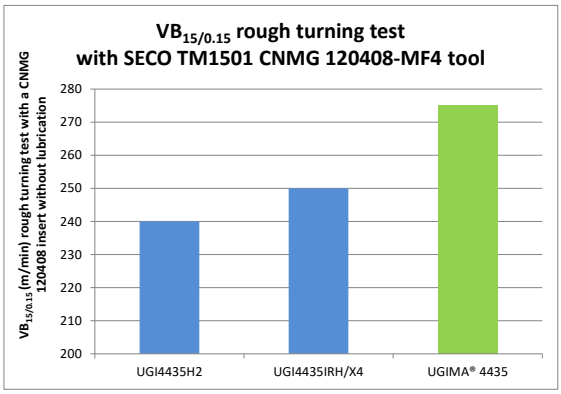
Type	Medium	Comments
Pickling	6 - 25% HNO_3 + 0.5 - 8% HF	In the annealed state only and at high temperature
Passivation	20 - 50% HNO_3	At high temperature

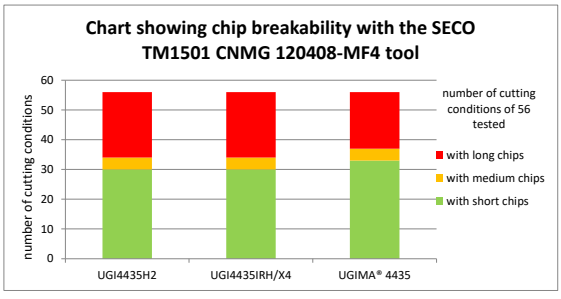
Machinability

The machinability of UGI® 4435H2 is close to that of UGI® 4435IRH/X4 thanks to its intermediate sulfur content and its high Ni content. Nevertheless, it is lower than that of a UGIMA® 1.4435 as shown in the graphs below.

In the first graph below, the $VB_{15/0.15}$ which is a normalized test gives a good idea of the difference between the grades in terms of potential productivity in a turning operation. The higher, the better.

In the second graph below, the chip breakability charts give a good idea of the potential difficulties to manage the chip breaking. The lower the red conditions, the better the grade.





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To obtain the maximum benefit from the machining potential of this grade, please contact our Technical Support department (machining.support@UGI®tech.com).

Welding

UGI® 4435H2 can be resistance welded (spot or seam welding) by any type of arc process (MIG, TIG, submerged arc, covered electrode), by laser, electron beam, etc.

UGI® 4435H2 is balanced to be on the boundary of primary ferritic solidification in order to ensure a minimum of residual ferrite in the welding region while limiting the risk of crack formation at high temperature during arc welding. In laser welding, the risk of crack formation at high temperature is greater than with arc welding, and the welding parameters should be adjusted as well as possible on a case by case basis to limit this risk.

Where a filler wire is used to weld UGI® 4435H2 to itself, preferably choose an ER316L(Si) - 1.4430 wire.

The protection gases in arc welding should preferably be:

In MIG: Ar (+ possibly He) + 2% to 3% O_2 or CO_2

In TIG: Ar (+ possibly He)

No preheating or post-welding heat treatment is required. Interpass temperatures not exceeding 150°C should be complied with.

Available products

Product	Shape	Surface finish	Tolerance	Dimensions	
Bar	Round	Rolled and descaled	12 to13	22 to 130	mm
	Round	Turned and polished	9 to 11	22 to 130	mm
	Round	Drawn	8 to 9	1.8 to 55	mm
	Round	Ground	7 to 9	1.8 to 80	mm
	Hexagonal	Drawn	11	3 to 55	mm
Drawn wire	Round	Mat		1 to 14	mm

For other sizes, please contact us

Applications

- Hydrogen-wetted components in FCEV (Fuel Cell Electric Vehicule): on-tank valve, shut-off valve, check valve, pressure regulators, thermal-relief valve…
- Hydrogen pressure sensors, temperature sensors
- Hydrogen refueling stations : nozzle, break-away
- Hydrogen injectors, rails for hydrogen combustion engines
- Production, storage and distribution of hydrogen: flow control systems, valves, fittings, sensors