
 MANNESMANN LINE PIPE <small>Ein Unternehmen der Salzgitter Gruppe</small>	Technical Standard	T 11.00.001_HS_Q Status 11/2017 Rev 0 Page 1 / 5
HFI-welded steel pipe for the transmission of compressed gaseous hydrogen		

HFI-welded steel pipe for the transmission of compressed gaseous hydrogen

Based on API 5L PSL 2 and/or ISO 3183 PSL 2
as well as IGC Doc 121/14 (EIGA Guideline)

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1 General

Longitudinally welded steel pipe from Mannesmann Line Pipe (MLP), manufactured using the high-frequency induction (HFI) welding process and intended for the transmission of compressed gaseous hydrogen (H₂), is made from manganese-alloyed carbon steels (FE, C, Mn). The pipes are available as normalized N variants and as thermo-mechanically rolled TM variants, both of which comply in principle with the requirements of API 5L PSL 2 and/or ISO 3183 PSL 2. Properties above and beyond these requirements with a view to the intended application, i.e. the transmission of compressed gaseous hydrogen, are described in detail in the following.

2 Basic standards

- API SPEC 5L: 2015-04 "Specification for Line Pipe"
- DIN EN ISO 3183: 2013-03 "Petroleum and natural gas industries - Steel pipe for pipeline transportation systems"
- EIGA (European Industrial Gases Association) Guideline IGC Doc 121/14 "HYDROGEN PIPELINE SYSTEMS"
- DIN EN ISO 148-1: 2017-05 "Metallic materials - Charpy pendulum impact test - Part 1: Test method"
- DIN EN ISO 6892-1: 2017-02 "Metallic materials - Tensile testing - Part 1: Method of test at room temperature"
- ASTM E 112: 2013 "Standard Test Methods for Determining Average Grain Size"
- DIN EN 10204:2005-01 "Metallic products - Types of inspection documents"

3 Geometry

3.1 Pipe geometry in the weld area


The as-delivered condition of MLP pipe is "inside surface free from weld upsets ". This is achieved by restricting the tolerances. MLP pipes thus meet the requirements of Annex M, Section M.6.2 of ISO 3183: The internal weld upset shall not protrude beyond the pipe contour more than $0.3 \text{ mm} + 0.05 * t$ (t = wall thickness) up to a maximum of 1.5 mm. Deviations as well as strip edge offsets permissible according to the applicable standard are reworked by grinding, always making sure that the minimum wall thickness is maintained.

The external weld upset is scraped off to the level of the pipe surface.

4 Materials

4.1 Normalized rolled N-steels

Here grades X42N and X52N are normally used. The MLP variants feature the following maximum alloying contents, which are partly further restricted compared to EIGA Guideline IGC Doc 121/14 for Hydrogen Pipeline Systems:

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Element	MLP H ₂ grade: N-steel	EIGA Doc 121/04	API 5L PSL2
Sulphur	≤ 0.006 % ^{*1}	≤ 0.010 %	≤ 0.015 %
Phosphorus	≤ 0.015 %	≤ 0.015 %	≤ 0.025 %
Carbon equivalent CE_{IIV}^{*2}			
X42N	≤ 0.36 %		
X52N	≤ 0.42 %	≤ 0.43 %	≤ 0.43 %
Other N-grades on request			

^{*1} By restriction of the sulphur content to values below those specified in EIGA Doc 121/04, a higher degree of purity is obtained, and the possible hazard of hydrogen attack is significantly reduced.

^{*2} $CE_{IIV} = \%C + \%Mn/6 + (\%Mo + \%Cr + \%V)/5 + (\%Ni + \%Cu)/15$

The guaranteed mechanical-technological properties can be taken from API 5L PSL 2 and/or ISO 3183.

4.2 Thermo-mechanically rolled TM steels

Alongside X42M and X52M, higher-strength steel grades such as X60M, X65M and X70M are also offered as thermo-mechanically rolled variants. The properties of MLP pipes in TM materials for the transmission of compressed gaseous hydrogen have been optimized beyond the requirements of API 5L. Essentially, they meet the requirements of EIGA IGC Doc 121/14 or even further restricted criteria. Higher-strength grades such as X70M have proved their suitability for the transmission of compressed gaseous hydrogen in tests and are offered in line with the above or other criteria to be agreed upon.

4.3 Alloying content

The alloying contents of TM variants are restricted compared to those specified in API 5L and in the EIGA Guideline. The table below provides an overview.


Element	MLP H ₂ grade TM-steel	EIGA Doc 121/04/E	API 5L PSL2
Sulphur	≤ 0.005 %	≤ 0.010 %	≤ 0.015 %
Phosphorus	≤ 0.015 %	≤ 0.015 %	≤ 0.025 %
Carbon equivalent CE_{PCM}^{*3}	≤ 0.18 %	≤ 0.2 %	≤ 0.25%

^{*3} To improve the suitability for welding, the carbon content has been reduced ($C \leq 0.12\%$) to values below those of N-steels. Therefore, a different basis is used for calculating the carbon equivalent:

$$CE_{PCM} = \%C + (\%Mn + \%Si + \%Cu + \%Co)/20 + \%Ni/60 + \%Mo/15 + \%V/10 + \%B*5$$

4.4 Ring flattening test

Ring flattening test specimens serve for continuous quality monitoring of the base material and the weld. For this purpose, a ring is cut off a pipe. This is placed between two plates with the HFI weld being positioned in line with the relevant specifications (either in 12 o'clock or in 9 o'clock position). Then the two plates are continuously pressed together to a specified distance. When a plate distance equal to 0.5 x pipe diameter has been reached, the HFI weld must still be in perfect condition, i.e. no crack or opening is permitted.

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4.5 Charpy pendulum impact test

The Charpy pendulum impact test is carried out in accordance with DIN EN ISO 148-1 at a test temperature of 0 °C. Per heat, one set of specimens is tested in the transverse and longitudinal direction. In the case of pipes whose outside diameter (OD) is too small to permit transverse specimens to be produced to standard requirements, the testing of longitudinal specimens shall suffice. The minimum Charpy toughness values according to EIGA Doc 121/04 are listed in the table below.

Specimen size	Transverse		Longitudinal	
	Mean value in J	Single value in J	Mean value in J	Single value in J
Full-size	94	71	118	88
³ / ₄	71	53	88	67
¹ / ₂	35	35	58	43

When determining the percent shear areas, the mean value of three specimens must be at least 75 %, and no single value must fall below 60 %.

4.6 Tensile test

The tensile test is carried out at room temperature in accordance with DIN EN ISO 6892-1. As shown in the table below, the upper limits of the yield strength (YS) and tensile strength (TS) ranges have been reduced compared with the limits as per API 5L.

Grade	Yield strength YS in N/mm ²	Tensile strength TS in N/mm ²
X42M	290 – 462	415 - 587
X52M	360 – 525	460 - 625
X60M	415 – 535 ^{*4}	520 - 670 ^{*4}
X65M	450 - 570 ^{*4}	535 - 685 ^{*4}
X70M	485 - 605 ^{*4}	570 - 720 ^{*4}

^{*4} EIGA Doc 121/04 specifies no restrictions for high-strength grades above X52. Hence, as assured by MLP, the upper limits have been restricted as per API 5L PSL 2 starting from grade X60M.

4.7 Ferrite grain size


Grain size determination as per ASTM E 112 is conducted in line with the requirements for metallographic specimens of the weld area. Regarding the maximum permissible grain size, the values specified in ASTM 8 shall be applicable.

4.8 Hardness

Hardness measurements according to Vickers are taken across the wall thickness in the weld, in the heat-affected zone (HAZ), and in the base material (BM). The maximum permissible hardness for grades X42M and X52M is 220 HV 10 (= 95 HRB).

5 Lengths

The pipe lengths are as defined in the order specifications. The typical length tolerance is - 0 / +300 mm. The pipe lengths are supplied without butt welds.

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6 Test certificates

The pipes are supplied with a type 3.1 acceptance inspection certificate according to DIN EN 10204.

7 Marking

The pipes shall be marked in accordance with the requirements of the applicable standards. Normally, the marking is die-stamped at one pipe end and indicates the manufacturer's symbol, the pipe number, the applicable standard, the pipe material, the pipe diameter and the wall thickness. Alternatively, pipes may also be marked with a weather-proof adhesive label.

8 Ultrasonic test

The HFI-weld is subjected to ultrasonic testing over its full length.

9 Corrosion test

9.1 Slow strain-rate test

For each order the results of two slow strain-rate tests are submitted for documentation of the influence of H₂ on hydrogen embrittlement. One specimen is tested in air and one in compressed gaseous hydrogen (usually dry H₂ at room temperature and 100 bar). The tests are carried out at the Salzgitter Mannesmann Research Institute (SZMF).

9.2 Other tests

On the customer's request, other tests according to Appendix B of EIGA IGC Doc 121/14 can be carried out. The costs involved are charged to the customer.