Industeel

ArcelorMittal

CromElso™ 91
SA 387 grade 91 class 2

CromElso™ 91: Special alloy steel (9Cr1 Mo 0.2V) with HIGH temperature creep resistance

CromElso™ 91 is an alloyed martensitic CrMoVNb steel designed for high temperature creep resistance up to about 600°C (1100°F). **CromElso™ 91** is manufactured via the electric arc furnace with dephosphorisation, ladle refining and vacuum degassing to provide reproducible, clean and homogeneous steel.

Combining use of special steel making practice and balance of chemical elements as well as controlled ratios of compositional elements permits to guarantee the strong martensitic structure. **CromElso™ 91** steel ensure enhanced weldability for pipe, boiler and pressure vessel fabrication, improved impact toughness properties in heat affected zone and high creep resistance properties.

CromElso™ 91 is available in plate form in thickness up to 150 mm. This steel is particularly suitable for supercritical steam piping for enhanced thermodynamical efficiency in energy generation processes, for heavy section components in thermal power plants and for pressure vessel applications typical of the refining and nuclear.

PROPERTIES

STANDARDS

- > EN10028-2 — 2X10CrMoVNb9-1 (1.4903)
- > ASTM/ASME — A/SA 387 grade 91 class 2 (UNS K90901)
- > ASME — Code Case 2864 (UNS K90901)

CHEMICAL ANALYSIS AND MICROSTRUCTURE

Typical values on heat (weight%).

C	S	P	Si	Mn	Cr	Mo	V	Nb	N	Al
0.10	0.002	0.018	0.3	0.4	9.00	1.00	0.2	0.08	0.05	0.010

The above chemistry is suitable for welded steam piping and can be adjusted according to intended use and product size.

The chemistry is specially balanced to combine low carbon for good welding and fabrication properties, being at the same time high enough to contribute to creep resistance. N/Al target ratio is in accordance with the stringent requirements recommended by the most advanced international studies and committees ensuring as well optimised mechanical features and creep strength.
This is fully tempered martensitic steel with a combination of composition and microstructure that contributes to the creep resistance.

MECHANICAL PROPERTIES

Transverse values at room temperature. According to applicable standards and customer specifications.
Minimum guaranteed values for as-delivered plates are per the following table.

Thickness (mm)	Rp 0.2 (MPa/ksi)	Rm (MPa/ksi)	A (%)	Kv (J) Average		
				-20°C (-4°F)	0°C (32°F)	+20°C (68°F)
t<60	445 (65)	585-730 (85-106)	18	27	34	40
60<t<150	435 (63)					

Typical strength of the material is generally targeted on the high-end when creep resistance is required.
The balanced low carbon martensite possesses sufficient toughness: for as-delivered conditions transverse Charpy-V impact strength values at -20°C can reach about 100 J.
Studies have shown a correlation between hardness and creep resistance: CromElso™ 91 can be guaranteed to possess an as-delivered conditions hardness of minimum 205 and no more than 250 HV10
Actual high temperature tensile properties can be provided upon request. For information, some of these are described in the material standards.

The internal soundness of the plates is guaranteed in accordance with international standard ASTM A 578 or EN 10160. Other standard can be used upon request.

The surface state delivery condition is generally shot blasted.

CREEP PROPERTIES

Creep resistance is the driving engineering property for choosing 9%Cr Creep Strength Enhanced Ferritic (CSEF) steel. It is provided by a finely tuned chemical analysis linked to a stringent control of the heat treatments. Creep properties of CromElso™ 91 are achieved by complex and multiscale microstructural features:

- **> fine and dispersed nitrides and carbo-nitrides**
- **> multiscale martensitic microstructure**
- **> distribution of dislocations and laths/packets interfaces**

Creep data are available on request.

PLATE PROCESSING

HEAT TREATMENT

A proper microstructure is achieved by either Normalisation and Tempering (NT) or Normalisation with Accelerate Cooling and Tempering (NACT).
Normalising temperature is in the range 1040-1080°C (1904-1976°F) and tempering between 730 and 800°C (1346 and 1472°F).
Tempering temperature must be confirmed with the mill, as a function of required mechanical properties and PWHT.

The total fabrication sequence of the final equipment may necessitate several cycles of heat treatments. The plate steel chemistry is specially designed to support that higher number of heat treatments cycles.
It is furthermore possible to adjust plate tempering parameters to minimize the equivalent time-temperature impact on the material while assuring the suitable level of properties of the welds.

For any special need or application, our specialist will help and assist, please consult.

FABRICATION AND WELDING CONDITIONS

Cutting of the material can be executed by shear or plasma cutting, or any other suitable method. Care should be taken not to introduce hydrogen in the material, through the gases or the presence of humidity.
Thermal cutting will harden the heat affected zone close to the cut edge. Normal practice however does not embrittle the material, but further machining (e.g. bevelling of the edges before welding) may prove to be more demanding on the bevelling tools. A pre-heating at 200°C (392°F) and post-heating at same temperature for at least 2 hours are advisable.
Oxycutting is not preferred due to the high chromium content of the grade.

When cold deformation exceeds 5% and no heat treatments are further scheduled in the processing of the CromElso™ 91 plates, a regeneration heat treatment according to the parameters indicated in the materials certificate is recommended. A short stress-relieve cycle may be applied when cold deformation is between 3 and 5%.

Welding consumables should preferably be of chemically matching composition. The following table summarizes typical acceptable standards.

	SMAW	GTAW - GMAW	FCAW	Wire-Flux combination SAW	
				wire	flux
AWS	A5.5: E901x-B9 E901x-G	A5.28: ER90S-B9 (GTAW) E90C-B9 (GMAW metal cored)	A5.29: E91T1-B9	A5.23: EB9	A5.23: F9PX
EN/ISO	EN ISO 3580-A: E CrMo 91 B 42 H5	EN ISO 21952-A W CrMo 91 G CrMo 91		EN ISO 24598-A: S CrMo91	EN ISO 14174: SA FB 2 55

The following consumables have been considered by Industeel and are available from various suppliers. This list is not intended to be limitative. Please consult your welding consumable supplier for updates and advice.

	SMAW	GTAW GMAW	FCAW	SAW	
				Wire	Flux
AIR LIQUIDE	Cromocord 91 Cromo E91	Carbord CrMo91		OE-S1 Cromo91	OP 90W
BÖHLER	Thermanit Chromo 9V	Thermanit MTS 3		Thermanit MTS 3	Marathon 543
ESAB	OK 76.98	OK Tigrod 13.38			
KOBELCO	CM-9Cb CM-95B9 CM-96B9	TG-S9Cb MG-S9Cb		US-9Cb (AC) US-90B9 (DC-EP)	PF-200S (AC) PF-90B9 (DC-EP)
METRODE	Chromet 9-B9 (Techtig B91C) Chromet 9MV-N (Techtig B91) Chromet 9MNN+ (Techtig B91+)	9CrMoV (Techtig B91C) 9CrMoV-N (Techtig B91)	Supercore F91 (Techcore B91)	9CrMoV-N	LA 490 (Techmerge F LA490)

Preheating should be at least 200°C (392°F) whereas interpass temperature should remain below 325°C (617°F).

Suggested heat input range is between 1.0 and 2.0 kJ/mm to limit the risks of cold and hot cracking. Care should be taken to avoid hydrogen pick-up in the weld zone. Care should also be exerted when considering temporary attachments. In order to ensure full martensitic transformation, welds should be cooled below 100°C (212°F) prior to PWHT.
PWHT should be sufficient to remove welding stress while at the same time avoiding a drop of mechanical properties below the minimum of the required standards. A temperature of 750-760°C (1382-1400°F) for at least 2 hours plus an extra hour for each 25 mm thickness above 50 mm can be recommended.

APPLICATIONS

CromElso™ 91 is suitable for superheated/supercritical steam piping of power and co-generation plants. As it is a plate material, it allows for fabricating larger pipes than the usual seamless materials. It is also very suitable to fabricate the pipe support systems.

Due to its proved high resistance to High Temperature Hydrogen Attack (HTHA) the grade can be recommended for pressure vessel applications and for certain valve systems in the oil & gas.
Other chemical and processing industry, solar and renewable thermal power generation systems will use successfully this steel.

Furthermore, it is a potential candidate material for vessel fabrication in nuclear power plants as well as future radioactive waste disposal nuclear reactor designs or parts of nuclear fusion reactors. Its low molybdenum and nickel contents compared to standard austenitic stainless steels make it less prone to activation under irradiation.
CromElso™ 91 is in use all over the World, from Europe, to North America, to Eastern Asia.

For any information for specific applications, please consult.

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