Industeel

ArcelorMittal

CryElso™ 7

CryElso™ 7: 7% nickel steel for equipment designed for cryogenic temperature service

CryElso™ 7 is an alloyed steel grade containing 7% nickel intended for the fabrication of storage tanks for Liquefied Natural Gas, Liquefied Ethylene Gas, Liquefied Ethane and other extra low temperature service equipment.
CryElso™ 7 is a quenched and tempered grade providing adequate tensile and toughness properties equivalent to those of classical 9% nickel steel.
CryElso™ 7 is manufactured via the electric arc furnace basic process, with deep dephosphorisation, followed by ladle refining processing including deep desulfurisation and vacuum degassing in order to provide a reproducible chemistry and a clean and homogeneous steel.
The use of special steelmaking practice provides high cleanliness combined with optimised chemical composition. **CryElso™ 7** produces excellent toughness at low temperature and good crack arrest properties. **CryElso™ 7** is currently being developed for LNG, ethylene and ethane storage tanks projects worldwide.
It can also find applications in cryogenic piping and ship board storage systems.

PROPERTIES

STANDARDS

> ASTM	A 553 Type III (UNS K61365)
> ASME	Code Case 2842 of BPVC for use in ASME VIII Div.1 and Div.2
> API 620	inclusion in Annex Q approved and sent to publication

CHEMICAL ANALYSIS - WEIGHT %

Chemical analysis is guaranteed as per Table I hereunder.

Table I (%)	C	Mn	Si	P	S	Ni	Cu	Cr	Mo	Al	Nb	V
Heat analysis	<0.06	0.30/0.80	<0.30	<0.005	<0.001	6.50/7.50	<0.10	<0.30	<0.30	>0.020	<0.030	<0.010

TENSILE PROPERTIES

One transverse tensile test specimen is sampled at both ends from each Quenched and Tempered plate.
Guaranteed tensile properties are given in Table II

Table II	$R_{p0.2}$ (MPa)	R_m (MPa)	A_{50} (%)
5 ≤ t ≤ 40 mm	585 mini	690 / 825	20 mini

IMPACT PROPERTIES

One set of three transverse Charpy V-Notch impact test specimens is sampled at one end from each Quenched and Tempered plate. More specimens can be extracted according to requirements. Guaranteed impact properties are given in Table III. As far as possible in relation with plate thickness, the largest sample size is being used.

Table III	Test temperature	Energy absorption		Lateral expansion	Shear fracture
		Average for a set	One specimen for a set	Each specimen	
10x10 mm specimen for plate thickness 10 mm and above	-196°C	100 J mini	75 J mini	0.38 mm mini	75% mini
10x7.5 mm specimen for plate thickness 7.5 mm to 9.99 mm		75 J mini	56 J mini		
10x5 mm specimen for plate thickness 5 mm to 7.49 mm		50 J mini	38 J mini		

HEAT TREATMENT

Water Quenching and Tempering treatment, with possible intermediate treatment. Heating at 820°C minimum before quenching and tempering at 540°C minimum. Intermediate quenching can be processed at 650°C minimum.

RESIDUAL MAGNETISM

CryElso™ 7 is guaranteed to be free of residual magnetism exceeding 50 Gauss.

INTERNAL SOUNDNESS

CryElso™ 7 is guaranteed to be free of lamination, porosity and inclusions exceeding the acceptance criteria of A578 Level C.
Upon special request ultrasonic examination can be carried out and more severe criteria can be guaranteed.

SURFACE CONDITION

CryElso™ 7 is supplied in the shot blasted condition. A protective paint coating can be applied, please enquire. CryElso™ 7 is guaranteed to be free of any injurious surface defects. Upper and lower surfaces are visually checked before shipment. Inherent surface imperfections are being checked according to the acceptance criteria of EN 10163, class B, sub class 2.

STAMPING

CryElso™ 7 is stamped in accordance with the relevant ASTM standard. All plates are low stress die-stamped for traceability directly after rolling and before any heat treatment .This procedure contributes to removing eventual crack-starting risks. No under thickness is produced by this procedure.

DELIVERY CONDITIONS

PREFABRICATED PIECES

By special agreement, e.g. for storage tanks projects, prefabricated pieces can be delivered according to drawings. The following operations can be done: bevelling, bending, rolling of shell to radius, cutting to shape, fabrication of stiffeners and annular plates, pre-welding and temporary warehousing.

AVAILABLE SIZES

CryElso™ 7 is available in thicknesses from 5 mm up to 40 mm (3/16" up to 1 ½"). Industeel can supply plates up to 12.5 tonnes unit weight at widths between 1500 and 3680 mm as a standard, the maximum width depending on thickness. Please enquire for other sizes as the product capability range is under constant development .

COLD FORMING

CryElso™ 7 is suitable for cold forming operation.

> **If cold deformation does not exceed 5%, no further heat treatment is needed.**

> **If cold deformation exceeds 5%, but is less than 10%, a Stress Relief heat treatment can be applied according to the following recommendation.**

> **If cold deformation exceeds 10%, the mechanical properties are to be regenerated by Quenching and Tempering. Soaking time and temperature are mentioned on the Mill test certificate.**

Recommended Stress Relief Treatment	
Heating rate	according to furnace capability
Soaking temperature	550°C ± 10°C
Soaking time	2 min/mm of thickness with a minimum of 20 minutes
Cooling rate	in still air

HOT FORMING

CryElso™ 7 is suitable for hot forming operation.
A temperature not exceeding 1150°C is recommended. After hot forming, the mechanical properties must be regenerated by Quenching and Tempering and eventual intermediate quenching. Soaking times and temperatures are mentioned on the Mill test certificate.

CUTTING

Shear cutting or sawing may be applied. Also, gas cutting or plasma cutting can be used. After a light grinding in order to obtain a bright metal finish, the Heat Affected Zone hardness is guaranteed below 360 HV10. Less than 0.2 mm metal removal is needed to achieve this. The low carbon martensite which is produced in the Heat Affected Zone remains very tough with limited hardness increase, even in the non-tempered condition.

WELDING CONDITIONS

CryElso™ 7 can be welded using all usual welding processes such as GMAW, GTAW, SMAW and SAW. Usual Heat Input, typically in the range from 1.0 kJ/mm to 2.5 kJ/mm, can be used. Unless the construction is heavily restrained, preheating is not necessary. Interpass temperature shall be limited to 150°C maximum. Unless the construction is heavily restrained or unless mandated by some rule, Post Weld Heat Treatment is not necessary. If for any reason Post Weld Heat Treatment has to be carried out, the following parameters apply.

Recommended Post Weld Heat Treatment	
Heating rate	according to furnace capability
Soaking temperature	550°C ± 10°C
Soaking time	2 min/mm of thickness with a minimum of 20 minutes
Cooling rate	in still air

Please enquire for further recommendations on PWHT.

HAZ PROPERTIES

Thanks to a very low carbon content, the structure in the Heat Affected Zone is a very tough martensite; even in the As-Welded condition. Hardness is limited to below 360 HV10, and good crack arrest properties give a full confidence in CryElso™ 7 when properly welded with a Heat Input up to 2.5 kJ/mm. Table IV gives typical welding tests results. Other data is available upon request .

Table IV

> 7% Ni welded joint - FCAW - 3G (25 mm thick.)
> ENiCrMo-3 filler metal
> Tensile Test at Room Temperature

Plate thickness (mm)	Process / Position	Testing Temperature (°C)	TS (MPa)	Fracture location
25	FCAW 3G	RT	698	BM
			701	

Charpy V-Notch impact test (transverse direction)

Plate thickness (mm)	Process / Position	Testing Temperature (°C)	Location of specimen	Notch position	E (J)		LE (mm)		Testing Temperature (°F)	E (ft.lbf)		LE (in.)	
					ind.	av.	ind.	av.		ind.	av.	ind.	av.
25	FCAW	- 196	1/16" under top surface	WM	81	84	1.45	1.453	-321	60	62	0.057	0.057
					89		1.55			66		0.061	
					83		1.36			61		0.054	
				FL	61	91	0.76	0.993		45	67	0.030	0.039
					110		1.03			81		0.041	
					103		1.19			76		0.047	
				FL + 1 mm	86	90	0.97	1.050		63	67	0.038	0.041
					75		0.94			55		0.037	
					110		1.24			81		0.049	
				FL + 3 mm	222	220	1.75	1.730		164	162	0.069	0.068
					210		1.76			155		0.069	
					227		1.68			167		0.066	
				FL + 5 mm	261	254	2.04	1.940		193	188	0.080	0.076
					253		1.95			187		0.077	
					249		1.83			184		0.072	
API 620 Q					22	27	0.381			16	20	0.0150	

FILLER MATERIALS

CryElso™ 7 can be welded with metals of types 625, C276 or other high-strength nickel base alloys.
Table V overviews some of the consumables classification.

Table V	SMAW	GMAW	FCAW	SAW Wire + Flux
AWS	SFA 5.11 ENiCrMo-3 (625) ENiCrMo-4 (276) ENiCrMo-6 (620)	SFA 5.14 ERNiCrMo-3 (625) ERNiCrMo-4 (276)	A5.34 ENiCrMo-3 T1-4 (625)	SFA 5.14 ERNiCrMo-3 (625) ERNiCrMo-4 (276)
EN	ISO 14172 E Ni 6625 (625) E Ni 6276 (276) E Ni 6620	ISO 18274 S Ni 6625 (625) S Ni 6276 (276) S Ni 6620	ISO 14172 E Ni 6625 (625) E Ni 6276 (276) E Ni 6620	ISO 18274 S Ni 6625 (625) S Ni 6276 (276) S Ni 6620
JIS	Z3224 DNiCrMo-3 (625) Z3225 D9Ni-2	Z3332 YGT9Ni-2		Z3333 YS9Ni + FS9Ni-F YS9Ni + FS9Ni-H

Table VI lists a non-exhaustive list of suitable filler materials in alloy type 625:

Table VI	SMAW	GMAW	FCAW	SAW	
				Wire	Flux
ESAB	OK 92.45	OK Autrod 19.82		OK Autrod 19.82 SAW	OK 10.16
LINCOLN	Blue max NiCro 60/20	Blue max LNM NiCro 60/20		Blue max LNS NiCro 60/20	Blue max 2000
OERLIKON	Freezal 625				
T-PUT	Thermanit 625	Thermanit 625		Thermanit 625	Marathon 104
UTP	6222Mo	A6222Mo	AF6222Mo	UP6222Mo	FX UP6222Mo

Table VII lists a non-exhaustive list of suitable filler materials in alloy type C276:

Table VII	SMAW	GMAW	SAW	
			Wire	Flux
OERLIKON			Freezal S276	OP77
UTP	776Kb	A776	UP776	FX UP776

Table VIII lists some other types of available nickel-based filler materials (ENiCrMo-6):

Table VIII	SMAW	GMAW	FCAW	SAW	
				Wire	Flux
ESAB	OK 92.55				
LINCOLN	Blue max Nyloid 2				
OERLIKON	Freezal ENi9				
UTP	Soudonel D				
KOBELCO (other Hastelloy type)	NIC-1S	TGS-709S	DWN-70S	US-709S	PFN-3 or PFN-4

APPLICATIONS

The present trend is to increase cryogenic storage and transportation of LNG, ethylene and ethane for which CryElso™ 7 is an interesting alternate or complementary solution to CryElso™ 9Q traditional 9%Ni steel. CryElso™ 7 can also find further applications where cryogenic properties and limitation of weight are of importance, like piping, pressure vessels and storage spheres, floating storage tanks, etc.

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