

CryElso™ 9Q

CryElso™ 9Q: A steel for Pressure Equipment designed for extra low temperature service

CryElso™ 9Q is:

- > an alloyed steel grade containing 9% nickel intended for the fabrication of storage tanks and transport ships for liquefied natural gas (LNG)
- > a Quenched and Tempered grade, to provide better tensile and toughness properties
- > a high clean steel manufactured via the electric arc furnace, with dephosphorisation, ladle refining with desulfurization and vacuum degassing basic process.
- > a homogeneous steel with reproducible and optimized chemistry

CryElso™ 9Q shows:

- > excellent toughness at very low temperature and very good crack arrest properties.
- > safe use for LNG storage tank projects worldwide
- > a design optimised for use in pressure vessels, cryogenic piping and ship storage and transportation systems.

It is further recognized by all the world-renowned engineering companies as a steel grade suitable for the construction of very safe Liquefied Natural Gas storage tanks.

PROPERTIES

STANDARDS

- > EN 10028-4 X7Ni9 (1.5663)
- > EN 10028-4 X8Ni9+QT680 (1.5662+QT680)
- > ASTM/ASME A/SA 553 Type I (UNS K81340)
- > JIS G3127 SL9N590Q

Combined certifications are possible on request.

CHEMICAL ANALYSIS - WEIGHT %

Heat analysis

C	Mn	Si	P	S	Ni	Cu	Cr	Mo	Al	Nb	V
<0.06	0.30/0.80	<0.30	<0.005	<0.002	8.70/9.40	<0.12	≤0.10	≤0.10	≥0.020	≤0.010	≤0.010

TENSILE PROPERTIES

Transverse tensile test specimens are sampled from each Quenched and Tempered plate.
Guaranteed tensile properties are:

Plate thickness (mm)	YS/R _{p0.2} min (MPa)	TS/R _m (MPa)	E5.65√So min (%)	E ₅₀ min (%)
5 ≤ t ≤ 50	590	690 / 820	18	20
50 < t ≤ 100		680 / 820		

PROPERTIES

IMPACT PROPERTIES

Charpy V-Notch impact test specimens are sampled in transverse direction from each Quenched and Tempered plate. Guaranteed impact properties are:

Specimen size (mm)	Test temperature (C°)	Energy absorption (J)		Lateral expansion (mm)	Shear fracture (%)
		Average for a set min	One specimen min	Each specimen min	
10 x 10	-196	100	75	0.64	75
10 x 7.5		75	56		
10 x 5		50	38		

Drop Weight Test: previous qualification records can be supplied. Test may be performed also upon request, for thickness 16 mm and above, according to ASTM E 208. Testing frequency are to be agreed. Guaranteed criteria is Double No Break at -196°C.

HEAT TREATMENT

Water Quenching and Tempering treatment. Heating at 820°C minimum before quenching and tempering at 570°C minimum.

INTERNAL SOUNDNESS

CryElso™ 9Q is guaranteed with internal health encompassed in the acceptance criteria of A578 Level C. Upon special request ultrasonic examination can be carried out with more severe criteria.

RESIDUAL MAGNETISM

Residual magnetism of CryElso™ 9 is guaranteed to not exceed 50 Gauss.

DELIVERY CONDITIONS

AVAILABLE SIZES

CryElso™ 9Q can be produced in thicknesses from 5 mm up to 100 mm (3/16" up to 4").

Max. plate weight: 20 tonnes

Industeel proposes the following available sizes:

Thickness (mm)	Width (mm)	Max. Length (mm)
4.75 to 5.99	1200 to 2700	12000
6.00 to 6.99	1200 to 3000	12000
7.00 to 7.99	1200 to 3400	12000
8.00 to 8.99	1200 to 3600	12000
9.00 to 9.99	1200 to 3940	12000
10.00 to 100.00	1200 to 3940	16000

Thickness up to 125 mm can be considered on request. Other sizes may also be delivered.

SURFACE CONDITION

CryElso™ 9Q is supplied shot blasted Sa 2.5 as per EN 8501. Upper and lower surfaces of plates are guaranteed in accordance with criteria of EN 10163, class B, sub class 2.

A protective paint coating can be applied, as per project need.

STAMPING

CryElso™ 9Q is stamped in accordance with the relevant standard. All plates are low stress die-stamped for traceability directly after rolling and before any heat treatment. This procedure guarantees no under thickness and contributes to removing eventual crack-starting risks.

PREFABRICATED PIECES

By special agreement, e.g. for Liquid Natural Gas 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 (see Annex).

COLD FORMING

CryElso™ 9Q is suitable for cold forming operation up to a very high level of deformation such as 33% (example of a bending on a mandrel with a diameter that equals two times the plate thickness).

In case of very high deformation level, before cold forming, light chamfering or grinding of edges is mandatory to avoid cracking.

Heat treatment are to be foreseen in accordance with rules of plastic deformation, as follow:

Cold Deformation Ratio (%)	Heat Treatment Recommendation
≤ 5	No further heat treatment needed
5 < CDF ≤ 10	Stress Relief heat treatment can be applied
> 10	Quenching and Tempering mandatory to regenerate mechanical properties. Soaking time and temperature are same as mentioned on the Mill test certificate.

Recommended Stress Relief / Post Weld Heat Treatment	
Heating and cooling rate	according to furnace capability with max rate as per design code
Soaking temperature	570°C ± 10°C
Soaking time	2 min/mm of thickness with a minimum of 20 minutes

HOT FORMING

CryElso™ 9Q 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 with parameters as mentioned on the Mill test certificate

CUTTING

Shear and sawing mechanical or thermal gas or plasma cutting can be used.

In case of thermal cutting, the Heat Affected Zone hardness is guaranteed below 360 HV 10. 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 low hardness increase, even in the non-tempered condition.

WELDING CONDITIONS

CryElso™ 9Q 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 or mandated by some rules, preheating and PWHT are not necessary.

The quality of welded joint is assured by the heat input and inter-pass temperature, which must be under control. Inter-pass temperature shall be limited to 150°C maximum.

If for any reason Post Weld Heat Treatment must be carried out, parameters are same as for Stress Relief.



HAZ PROPERTIES

Even in the As-Welded condition the structure in the Heat Affected Zone is a very tough martensite, due to the very low carbon content. Hardness is limited to acceptable level and crack arrest properties give a full confidence in CryElso™ 9Q when properly welded with Heat Input in the range to 2.5 kJ/mm.

Typical impact tests and CTOD tests results are shown in next table.

Plate thicknesses have been selected:

- to cover the range from the first ring of thick shell and one of the last ring of thin shell
- to cover both welding processes SMAW 3G vertical up for the longitudinal seams and SAW 2G for the circumferential seams.

Circumferential weld - 38.1 mm - SAW (approx. 1.0 kJ/mm) - 2G position

Location	Charpy V - Notch impact tests at -196 °C		CTOD Tests at -163 °C		
	Average (J)	Individual min. (J)	Individual (mm)		
Base Metal	185	165			
Weld Metal	122	118	δm: 0.716 mm	δm: 0.429 mm	δu: 0.458 mm
10° bevelled side					
Fusion Line (FS)	113	103	δu: 0.548 mm	δu: 0.481 mm	δu: 0.322 mm
FL + 2 mm	281	252			
FL + 5 mm	183	180			
45° bevelled side					
Fusion Line (FS)	140	124	δu: 0.382 mm	δu: 0.309 mm	δu: 0.213 mm
FL + 2 mm	179	154			
FL + 5 mm	181	174			

Longitudinal weld - 14 mm - SAW (approx. 1.0 kJ/mm) - 3G up position

Location	Charpy V - Notch impact tests at -196 °C		CTOD Tests at -163 °C		
	Average (J)	Individual min. (J)	Individual (mm)		
Base Metal	194	184			
Weld Metal	100	94	δm: 0.518 mm	δm: 0.563 mm	δu: 0.543 mm
Straight side					
Fusion Line (FS)	87	62	δu: 0.406 mm	δu: 0.458 mm	δu: 0.347 mm
FL + 2 mm	349	330			
FL + 5 mm	213	202			
45° bevelled side					
Fusion Line (FS)	137	122	δu: 0.570 mm	δu: 0.614 mm	δu: 0.558 mm
FL + 2 mm	166	144			
FL + 5 mm	195	180			

FILLER MATERIALS

CryElso™ 9Q can be welded with consumables such as ferrite base type, austenitic stainless-steel type, Ni-base alloy type and Fe-Ni base alloy type. Incoloy 625 and Hastelloy C276 are the most known high-strength nickel base alloys consumables.

Consumable classification - short overview:

	SMAW	GMAW	FCAW	SAW Wire + Flux
AWS	SFA5-11 ENiCrMo-3 (625) ENiCrMo-4 (276) ENiCrMo-6	SFA 5-14 ERNiCrMo-3 (625) ERNiCrMo-4 (276)		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

Non-exhaustive list of suitable filler materials in alloy type 625:

	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	6222 Mo	A6222Mo	AF6222Mo	UP6222Mo	FX UP6222Mo

Non-exhaustive list of suitable filler materials in alloy type C276:

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

Other types of available nickel-based filler materials (ENiCrMo-6):

	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

CryElso™ 9Q has been used for several decades to build LNG tankers. Small Scale LNG high development due to necessary flexibility in storage and transport continue to require thin and high resistant plates.

The current trend is the use of new technologies and new energy sources. For this purpose, new design requires thicker plates, used with pressure vessel design codes, which continue to keep this Ni Alloy steel on top interest of designer and fabricators.

These applications are Liquid Air Energy Storage (LAES), Hydrogen and CO₂ capture, storage and use for power purpose.



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Technical data and information are to the best of our knowledge at the time of printing. However, they may be subject to some slight variations due to our ongoing research programme on steels. Therefore, we suggest that information be verified at time of enquiry or order. Furthermore, in service, real conditions are specific for each application. The data presented here are only for the purpose of description, and considered as guarantees when written formal approval has been delivered by our company. Further information may be obtained from the address opposite.

READY TO ASSEMBLY PHILOSOPHY

Our Industeel Dunkirk unit developed over the years a high level of know-how and became an undisputed partner for the delivery of project parts direct on site.

Unit is located on the quay allowing the loading on barge, has a connection with the railway and a fast connection to the motorway.

Main special prefabrication operations and standard tolerances are shown hereafter:



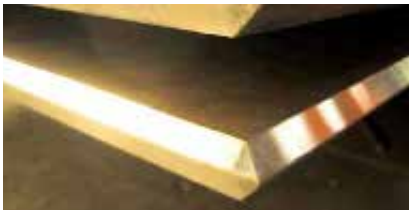
CUTTING

from 4 to 250 mm



MECHANICAL BEVELING:

straight or angle bevel with max length of 16



COLD FORMING:

Max thickness: 105 mm
Max width: 10 000 mm



TRANSPORT:

Special pack



SHELL AND THERMAL CORNER PROTECTION		
Measuring	tolerance	Measuring profile
Width : W (before bending)	+/-1,5mm	
Lenght : L (before bending)	+/-1,5mm	
Diagonal : C1-C2 (before bending)	≤3mm	
Bevel angle	+/-2,5°	
Root face : N,M	0/+1mm	
Deviation from roundness :X	0 to 3 mm	
Warpage : Y 2 M measurements has 200mm extremities of the plate	11mm	
SECONDARY/PRIMARY ANNULAR + STIFFENERS + EMBEDDED PLATE + TEST PLATE		
Measuring	tolerance	Measuring profile
Width : W	+/-1,5mm	
Lenght : L	+/-1,5mm	
Diagonal : C1-C2	≤3mm	
Bevel angle	+/-2,5°	
Root face	0/+1mm	
Deviation on tempate radius	+/-3mm	
INNER AND SECONDARY BOTTOM (other laping assembly)		
Measuring	tolerance	Measuring profile
Width : W (before bending)	0/+20mm	
Lenght : L (before bending)	0/+20mm	

Additional services like Mechanical drilling, Surface preparation, Non-destructive inspection, Welding, etc may be considered, please consult us.

Big storage facility is available, for just in time delivery.