

The Aperam logo is positioned in the top right corner of the page. It consists of the word "aperam" in a white, lowercase, sans-serif font. The background of the entire page is a close-up photograph of a fractured, translucent material, likely a metal alloy, showing a complex network of cracks and a blueish-grey color palette.

aperam

Nickel Alloy - INVAR M93

For cryogenic applications down to - 269° C

About us

Aperam is a global player in the production of stainless, specialty, and electrical steels and a world leading producer of cobalt and nickel based alloys.

From our patenting of the groundbreaking nickel-iron alloy INVAR to developing the field of precision metallurgy, Aperam Alloys Imphy has been providing innovative, high-performing, quality alloys for over a century. Today, we offer a portfolio of over 200 grades and numerous patents, meaning Aperam Alloys Imphy has an alloy for every need.

Our INVAR is available in different forms: cold rolled strips, plates, bars, wire rods and draw wires.

Cryogenics is the condition of low temperature, when gas become liquid, and is a clever feature used for transport, distribution and storage function's for several markets as power generation, chemistry, space, etc...

The use, transport and storage of certain media under cryogenic conditions requires careful handling and particular attention to safety.

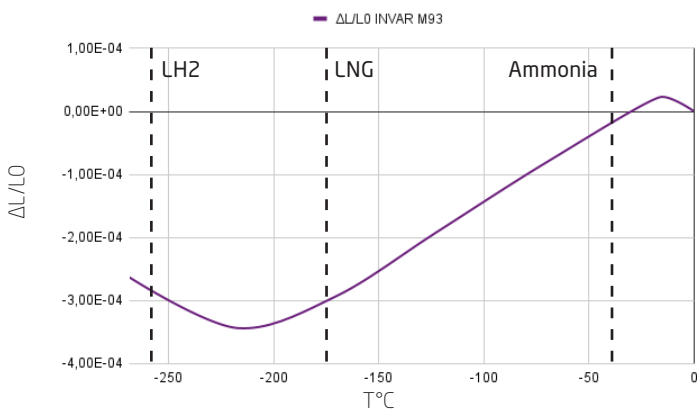
For example, special care must be paid to the materials that are in direct contact with these substances. Low boiling temperatures and embrittlement must be taken into account when selecting materials.

Our INVAR SERIES, includes INVAR M93 - strip, plate and bar - and INVAR M93T/TS - wire rod - offer the appropriate solution for such applications.



INVAR M93 for cryogenic requirements

Coefficient of Thermal Expansion (CTE) and Cryogenic Point of LH2, LNG and Ammonia



Invar M93, chemistry: FeNi36 + dedicated elements, offers good formability: deep drawing, folding, bending, etc...

Standard dimensions and tolerances are available.

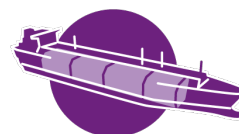
Our specialists and R&D center are at the customer disposal to support your project. Please contact us with questions or to learn more about cryogenic applications.

Finding the right solution for your application

Application type...	Our solution...
Liquefaction onshore and offshore	INVAR SERIES
Regasification onshore and offshore	
Pipe in Pipe	
Tankers for liquid cryogenic materials	
Aircraft fuel tanks	

Invar M93TS, welding wire:

To perfectly meet cryogenics requirements, INVAR M93TS (patented) has been developed for overmatching by optimizing the Ni/Ti ratio without altering the other properties such as toughness and fatigue behavior.



1. Low CTE & Young modulus

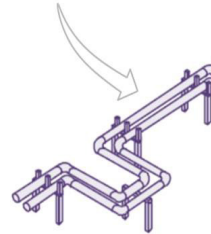
CTE of INVAR M93

Very low CTE is at the core of cryogenic application condition to ensure safety and to manage thermal expansion.

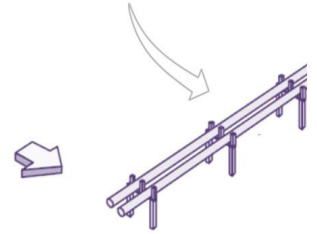
INVAR M93 answers this need by exhibiting low CTE, even down to liquid helium (-269°C).

Our INVAR M93 Pipe-in-Pipe solution for transfer lines eliminates all thermal expansion compensation systems, bellows and lyses, resulting in a similar CAPEX while significantly reducing OPEX.

Austenitic Stainless Steel



INVAR M93



CTE according to temperature

T °C	0	-16	-71	-123	-171	-217	-269
INVAR M93	0.00E+00	2.30E-05	-8.12E-05	-1.92E-04	-2.94E-04	-3.44E-04	-2.63E-04
Al 5083-T0	~5,00E-04	~8,50E-04	~2,00E-03	~3,00E-03	~3,70E-03	~4,00E-03	~4,10E-03
9% Ni	Between -196 to 21°C, Mean Coefficient of Expansion = 4.90E-06						

Young modulus of INVAR M93

Low young modulus is also a key point for cryogenic need by avoiding any deformation and specifically for storage by improving the boil off to avoid any losses.

By showing no physical mechanism change below -196°C, INVAR M93 is the material of choice, even up to -269°C.

Young modulus in kMPa according to temperature

T °C	0	-16	-71	-123	-171	-217	-269
INVAR M93	140	139	138	135	133	132	131
Al 5083-T0	~72	~73	~76	~78	~79	~80	~81
9% Ni	At -196°C, the Young's modulus is at 209 kMpa						

2. Stability at cryogenic temperatures

Cryogenic applications require guaranteed structure integrity, still with a security approach.

Thanks to its fully austenitic structure at all temperatures, INVAR M93 offers good ductility and toughness without any risk of embrittlement at cryogenic temperatures.

Volume fraction of martensite (%)	20	25	30	35	40
Plastic deformation at -196°C (%)	0.00	0.05	0.15	0.80	1.20

3. Mechanical properties

Systems and their components are usually exposed to large dynamic loads and cyclic stresses at low temperatures. For example, tanks and other containers confronted to frequent pressure fluctuations are subject to stresses.

INVAR M93 maintains a high ductility and a high strength down to nitrogen, hydrogen and even at helium liquid temperature (-269°C), maintaining good behaviour in YS, TS, and El% with minimal difference in both directions.

INVAR M93 - thickness = 3 mm		Long direction			Transverse direction		
Conditions	Temperature (C°)	0.2%YS (Mpa)	TS (Mpa)	El%	0.2%YS (Mpa)	TS (Mpa)	El%
RT	24	360	520	35	350	510	36
N2 Liq temp.	-196	680	980	35	700	970	40
H2 Liq temp.	-253	850	1140	40	860	1130	40
He Liq temp.	-269	870	1140	40	890	1130	40

4. Impact strength

Materials used for applications at very low temperatures require a very good notched impact strength.

This is essential for preventing rapid fracture with low energy absorption. If defects are present, a crack can grow to critical size through cyclic loading.

INVAR M93 subjected to charpy impact demonstrate high ductility and high mechanical properties at -196°C at KCV > 200 J/cm².

INVAR M93 - thickness = 3 mm	KCV (J/cm ²)	
	Long direction (C°)	Transvers direction %
He Liq temp.	160	130

5. Fatigue limit

INVAR M93 fatigue limit typical values (thickness= 0.7 mm, GASTM grain size= 9)

T°C	25	-196
Fatigue Limit	300 MPa	700 MPa

An important issue associated with cryogenic applications is their structural integrity. This is essential to ensure their operating life and safety, but also for certain applications in thermal and cyclic loading. In this case, the fatigue performance is considered to be of particular importance.

INVAR M93's fatigue limit at ambient temperature and at -196 °C is over 250 MPa and 700 MPa respectively. Because this fracture stress limit over a great number of cycles (> 10⁶ cycles) is close to the yield strength (0.2%YS) of the material. We can assume that INVAR M93's fatigue limit is tailored to cryogenic environments.

Having supplied INVAR M93 for over 40 years during which time it has been exposed to the sloshing of LNG carriers, has always proven the fatigue limit of our product.

6. Corrosion resistance

In accordance with the various tests carried out by Aperam, the INVAR M93 has a good resistance to corrosion, especially in a marine environment with affected depth in marine atmosphere estimated < 10µ/month.

Maximum puncture depths (µ/month)						
Pollutant-free humid atmosphere (HR = 98% ; 55°C)	Natural marine atmosphere	Natural marine atmosphere U-folding (~1800MPa) (Kure Beach)	Simulated marine atmosphere (HR = 98% ; 38°C)	72 hours in soil. NaCl 20g/l + Humid atmosphere (HR = 98% ; 55°C)	Salt Fog (5% NaCl ; 35°C)	
< 1 Average over 2000h	2 Average over 12 Months	7 Average over 35 months	2 Average over 1 month	6 Average over 2000h	70 Average over 3 months	63 Average over 1000h


7. Weldability

When a cryogenic application requires welding, the filler metal's coefficient of thermal expansion must be as close as possible to the base material at ambient and cryogenic temperature.

INVAR M93TS is a filler metal defined to achieve the very best compromise in terms of performance required by cryogenic applications. That's because its chemical composition is adjusted in Ni and Ti, which allows overmatching in both cryogenics and at the ambient temperature.

Our experience has enabled us to offer a grade that is perfectly adapted to automatic and manual welding processes.

Welding Procedure		PAW Automatic	GTAW Automatic	GTAW Manuel
Base Metal		INVAR M93TS		
Filler metal		INVAR M93TS (Ø = 1.2 mm)		INVAR M93TS (Ø = 1.2 mm) (twist joint)
Gas	Plasmagene(I/mn)	Ar + 2%H2 (3 to 5)	-	-
	Annular (I/mn)	Ar + 5%H2 (20 to 40)	- Ar + 30%He (15 to 40) - Ar + 5%H2 (15 to 30)	Ar (10 to 20)
	Backing (I/mn)	Ar (20 to 40)	-	-
Electrical Characteristics	Current (A) : DC (-)	150 to 250	150 to 250	140
	Voltage (V)	25 to 30	10 to 20	14 to 16
	Heat input (kJ/cm)	9 to 23	4 to 15	10 to 20
Technique	Initial and interpass cleaning	grinding - brushing		
	Travel speed (cm/mn)	20 to 25	20 to 25	7 to 10
	Filer metal speed (cm/mn)	100 to 300	50 to 150	10 to 15



What is required in cryogenics?

- Sensitive safety management
- Adaptation for a large temperature range
- Long life duration

Our material offers all of this

- › Very low thermal expansion under cryogenic conditions
- › Chemical composition fit for the cryogenic environment
- › Good fatigue behavior and managed corrosion

**That's INVAR M93
by Aperam**



Contact us

www.aperam.com

www.e-aperam.com

nickel.alloys@aperam.com



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Aperam Alloys Imphy

BP1 - 58160 Imphy - FRANCE

T + 33 (0)3 86 21 30 00