Welding of Nickel & Nickel Alloys

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Ever heard of MONEL, INCOLOY, INCONEL, NICROFER, NICROM or NIMONIC ?
Probably not, they are not the most common alloys encountered when doing maintenance welding onboard. When weld repairs are needed of items made of these alloys there is little information available.
This paper outlines information on the different alloys and realistic welding methods and procedures for performing maintenance welding onboard.

Introduction

The name "Nickel" originated in Germany. The copper ores being mined seemed to be contaminated and could not be reduced into workable copper. They attributed this to the power of "Old Nick". The contaminated ores came to be called Kupfer-nickel which can be translated into devil’s copper. Though first discovered in Germany the main deposits of nickel ores are in Canada. There are also deposits in New Caledonia, Cuba and Finland.

Nickel is similar to iron in most of its properties; it has slightly lower strength and hardness and is magnetic. In contrast to iron, nickel is very resistant to corrosion and is used for this purpose in industry. Nickel is widely used for plating steel components and in fact Chromium plating is often primarily nickel plated with a fine coating of chromium for hardness and brightness. Nickel is a very useful material but it is also very expensive and is therefore only used when it is of great importance to improve on metals work performance.

Nickel and nickel alloys are chosen because of their:

- Corrosion resistance
- Heat resistance and high temperature properties. For example, Inconel Alloy 625 with high strength and toughness up to 980°C (1800°F)
- Low temperature Cryogenic properties. For example, Inconel Alloy 718 can work from – 253°C to 750°C (-423°F to 1300°F)

Marine applications

Nickel alloys corrosion resistance makes them ideal in applications such as piping systems, pump shafts, seawater valves, trolling wire, and strainer baskets. They are also used for shackles for anchor ropes, water and fuel tanks, and for underwater applications. They are also used for propeller shafts and for keel bolts. Some alloys are completely non-magnetic and are used for anchor cable aboard minesweepers and for housings for magnetic-field measurement equipment.

Classification

Nickel alloys are designated by various designation systems however the alloys are usually identified according to their trade names.

There are four main groups of nickel alloys:

Pure nickel alloys

Commercially pure nickel is actually about 99,5% Nickel (Ni) + Cobalt (Co). Three-digit numbers (2xx, 3xx) are used as trade names of commercial nickel. This metal has good mechanical properties and excellent resistance to many corrosive environments. The alloy retains much of its strength at elevated temperatures and is tough and ductile at low temperature. The alloy contains up to 0,1% carbon (C). The lower the carbon content the lower the risk of work hardening and the higher the ductility.

Composition of some pure nickel

Designation	Cu,%	Al,%	Fe,%	Mn,%	Ti,%	Ni,%
200	0.25 max.	-	0.40 max.	0.35 max.	-	99.0 min.
270	0.001	-	0.003	0.001	-	99.9 min.
301	0.25 max.	4.0-4.75	0.6 max.	0.5 max.	0.25-1.0	balance

Nickel Alloys

Nickel alloys are alloys with nickel as principal element**.** The Nickel alloys can be grouped according to the principal alloying elements. Although there are National and International designations for the alloys, tradenames such as Inconel and Hastelloy, are more commonly used.

Nickel-copper alloys

These alloys contain about 30% of copper, which form solid solution with nickel. The accepted trade name of Nickel-Copper Alloys is Monel or Nicorros (67% Ni and 33% Cu). The Monel alloys provide excellent service in seawater and is highly resistant to attack by chlorinated solvents, most acids, and practically all alkalis. Nickel-Copper Alloy, containing aluminum and titanium as additional alloying elements (Monel K-500), is heat-treatable and may be strengthened by precipitation hardening. Precipitation hardening and solid solution to be explained later.

Chemical compositions of some nickel-copper alloys

Designation	Cu,%	Al,%	Ti,%	Fe,%	Mn,%	Si,%	Ni,%
Monel 400	28-34	-	-	2.5 max.	2.0 max	-	63 min.
Monel 405	28-34	-	-	2.5 max.	2.0 max	0.5 max.	63 min.
Monel K-500	27-33	2.3-3.15	0.35-0.85	2.0 max.	1.5 max.	-	63 min.

Non-heat-treatable nickel-chromium-iron alloys

The major alloying elements of these alloys (15-22% of chromium and up to 46% of iron) form solid solution with nickel. The alloys may be hardened by cold work. The non-heat-treatable Nickel-Chromium-Iron Alloys are identified according to their trade names Inconel, Incoloy and Hastelloy.

Chemical compositions of some non-heat-treatable nickel-chromium-iron alloys

Designation	Cr,%	Fe,%	Mo,%	Al,%	Ti,%	C,%	Others,%	Ni,%
Inconel 600	14-17	6-10	-	-	-	-	-	72 min.
Inconel 625	20-23	5 max.	8-10	-	-	-	Nb3.15-4.15	58 min.
Incoloy 800	19-23	39.5 min.	-	0.15-0.6	0.15-0.6	0.1 max.	-	30-35
Incoloy 800HT	19-23	39.5 min.	-	0.15-0.6	0.15-0.6	0.06-0.1	-	30-35
Hastelloy X	20.5-23	17-20	8-10	-	-	0.05-0.15	W 0.2-1Co 0.5-2.5	30-35

Heat-treatable nickel-chromium-iron alloys

These alloys may be strengthened by precipitation hardening due to presence of additional alloying elements: aluminum, titanium, silicon.
Nimonic, Inconel X-750, Udimet, Waspaloy, Rene, Astroloy are some of the trade names of heat-treatable Nickel-Chromium-Iron Alloys.

Chemical compositions of some heat-treatable nickel-chromium-iron alloys

Designation	Cr,%	Fe,%	Mo,%	Al,%	Ti,%	Co,%	Others,%	Ni,%
Nimonic 80A	18-21	3 max.	-	1.0-1.8	1.8-2.7	-	-	69 min.
Nimonic 115	14-16	1 max.	3-5	4.5-5.5	3.5-4.5	13-15.5	B=0.01-0.025 C=0.12-0.2	54 min.
Inconel X-750	14-17	5-9	8-10	0.4-1.0	2.25-2.75	-	Nb=0.7-1.2	70 min.
Waspaloy	18-21	2 max.	3.5-5	1.0-1.5	2.6-3.25	12-15	C=0.02-0.1 Zr=0.02-0.12 B=0.003-0.008	balance
Rene 41	18-20	5 max.	9-10.5	1.4-1.6	3.0-3.3	10-12	C=0.06-0.12 B=0.003-0.01	balance

Some of the mentioned nickel–chromium alloys are also referred to under the name **Super-alloys.** A super-alloy, or high-performance alloy, is an alloy that exhibits several key characteristics: excellent mechanical strength, resistance to thermal creep deformation at very high temperature, good surface stability, and resistance to corrosion or oxidation. The crystal structure is typically face-centered cubic austenitic. Examples of such alloys are Hastelloy, Inconel, Waspaloy, Rene alloys, Incoloy, MP98T, TMS alloys, and CMSX single crystal alloys. The primary application for such alloys is in turbine engines, both aerospace and marine.

Monel	Ni- Cu alloys	400, 401, 404,R-405, K-500
Incoloy	Fe- Ni- Cr alloys	800,800T,800HT,803,825,832…
Nimonic	Ni- Cr and Ni- Cr- Co alloys	75, 80A, 91, 115, 901, PE11….
Inconel	Ni- Cr- Fe alloys	600,601,617,625,718,X750…
Nilo	Ni- Fe alloys	36, 42, 48, 365, K,
Hastelloy	Ni- Cr- Mo- W alloys	B2, B3, C4, C22,C276,X….

Registered nickel trade names:

HASTELLOY is a registered trade name of Haynes Intl.

INCOLOY, INCONEL, MONEL and NIMONIC are registered trade names of the INCO family of companies.

INVAR is a registered trademark of Imphy S.A.

MU-METAL is a registered trademark of Telcon Metals Ltd

NICORROS and NICROFER are registered tradenames of Krupp UM GmbH

Nickel alloys most common in Marine Engineering:
MONEL® alloy 400, MONEL® alloy R-405, MONEL® alloy K-500, INCONEL® alloy 625, INCONEL® alloy 625LCF®, INCONEL® alloy 686, INCONEL® alloy 718, INCONEL® alloy 725, INCOLOY® alloy 825, INCOLOY® alloy 25-6MO, INCOLOY® alloy 27-7MO

In terms of their weldability, the Nickel alloys can be classified according to the means by which the alloying elements develop the mechanical properties, namely solid solution alloys and precipitation hardened alloys:

1) Solid Solution Alloys

(A solid solution is a solid-state solution of one or more solutes for example Copper in a solvent like for example Nickel. The different chemical components remain in a single homogeneous phase.

Nickel-Copper alloys (Ni-Cu alloys)

Nickel-Chromium alloys (Ni-Cr alloys)

Nickel-Ferrum-Chromium alloys (Ni-Fe-Cr alloys)

Nickel-Molybdenum alloys (Ni-Mo alloys)

Nickel-Chromium-Molybdenum alloys (Ni-Cr-Mo alloys)

2) Precipitation-Hardening alloys

Precipitation hardening, also called age hardening or particle hardening, is a heat treatment technique used to increase the yield strength of malleable materials, including nickel alloys. A fine distribution of particles like Aluminum (Al), Titanium (Ti) or Niobium (Nb), formerly Columbium, are elements used in a nickel-rich matrix. Precipitation hardening alloys include Ni-Cu-Al-Ti, Ni-Cr-Al-Ti and Ni-Cr-Fe-Nb-Al-Ti. These alloys may be susceptible to post-weld heat treatment cracking.

Solid Solution Nickel base alloys	Precipitation-Hardening Nickel base alloys
HastellyN	3MR 235
HastelloyS	Inconel 702
HastelloyX	IN 713C
Haynes 230	In 739
Inconel 600	In 738
Inconel 601	Inconel 722
Inconel 617	Inconel 706
Inconel 625	Inconel 718
	Inconel X-750
	Incoloy 901
	Rene 41
	Waspalloy
	M252
	Udimet 700
	Haynes 214

Solid Solution Iron* base alloys	Precipitation-Hardening Iron* base alloys
16-25-6	A286
17-14 CUMO	Discolloy
19-9 DL	Haynes 556
Incoloy 800H	Incoloy 903
Incoloy 802	Incoloy 909

*Iron= Ferrum (Fe)

Solid Solution Cobalt (Co) base alloys

Haynes 25
Haynes

How to identify nickel alloys?

Magnetic Test*: Nickel 200,201 are magnetic.

Alloys 400,R-405 may be magnetic depending on composition variations.

All other are non-magnetic.

Spark Test: Sparks are thin and very short, they are dark-red in color, and do not fork

Color: Nickel is silver white in color when the metal is in its natural form. Nickel alloys can express in blue, green and yellow

Relative weight: Slightly heavier than steel.

*The three main magnetic elements are: iron (Fe), nickel (Ni), and cobalt (Co). Never the less nickel -chromium and nickel -chromium-iron wrought and cast alloys do not contain ferrite and do not exhibit magnetic response. NB. The rare earth metal Gadolinium is also magnetic.

Surface Preparation

Nickel and nickel alloys are susceptible to embrittlement by lead, sulphur, phosphorus, and other low-melting-point elements.
These materials can exist in grease, oil, paint, marking crayons or inks, forming lubricants, cutting fluids, shop dirt, and processing chemicals.
Work-pieces must be completely free of foreign material before they are heated or welded.
Shop dirt, oil and grease can be removed by either vapor degreasing or swabbing with acetone or another nontoxic solvent.
Paint and other materials that are not soluble in degreasing solvents may require the use of methylene chloride, alkaline cleaners, or special proprietary compounds.
If alkaline cleaners that contain sodium carbonate are used, the cleaners themselves must be removed prior to welding.
Spraying or scrubbing with hot water is recommended.
Marking ink can usually be removed with alcohol.
Processing material that has become embedded in the work metal can be removed by grinding, abrasive blasting, and swabbing with 10% HCl solution, followed by a thorough water wash.
Oxides must also be removed from the area involved in the welding operation, primarily because of the difference between the oxide and base metal melting points. Oxides are normally removed by grinding, machining, abrasive blasting or pickling.
Grinding must be done with an aluminium oxide or silicon carbide wheel.

Weld design

The groove angle must be large enough to permit proper manipulation of the filler metal because Nickel base alloys has lower flowability and wetting capacity than stainless steel weld metals.

In MIG welding (GMAW) process the arc do not easily get deflected from straight line, so the joint design should permit the movement of the arc.

A V-preparation with an included angle of 70 – 80˚ is usually adequate but consider changing to a double-V or single-U preparation with an included angle of 30 – 40˚ at sections thicker than 13 mm (0,5").

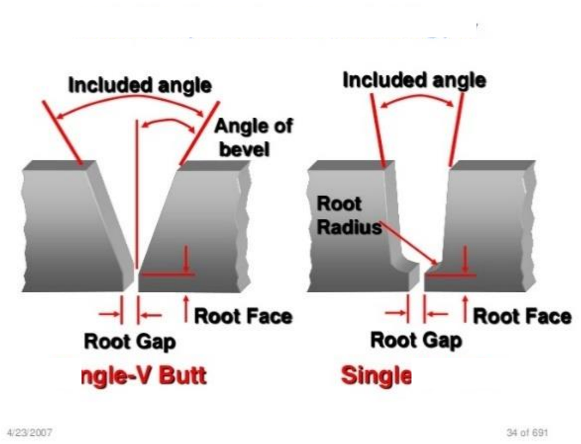


Plate thickness up to 13mm (0,5"): Single-V Butt
Included angle: 70 - 80 °
Root gap: 0,8mm-2,3mm (0,03"-0,93")
Root face: 1,6mm-2,4mm (0,062"-0,093")
(Same values for Double-V Butt)
Plate thickness over 13mm (0,5"): Single-U Butt
Included angle: 30 °
Root gap: 1,6mm-3,2mm (0,062"-0,125")
Root face: 1,6mm-2,4mm (0,062"-0,093")
Root radius: 6,4mm (0,25")
(Same values for Double-U Butt)

So, Nickel alloy joints have wider bevel, narrower root face and wider root opening than steel.

Heat Considerations

High heat input while welding Nickel and Nickel base alloys may result in constitutional liquidation, carbide precipitation or other metallurgical phenomenon which may lead to cracking.

The extent of the changes which takes place in the base material is determined by the heat input of the process and the inter pass temperature.

Interpass temperature (measured 50mm (2") from the joint should not be allowed to rise above 150°C (302°F) although some alloy suppliers recommend an interpass as low as 100°C (212°F) for certain alloys such as Alloy C276. Heat input should be limited to approx. 8-12Kj/cm.

The Precipitation hardening alloys require special welding procedures because of their susceptibility to cracking. Cracks can occur in the base-metal heat-affected zone (HAZ) upon aging or in service at temperatures above the aging temperature, as a result of residual welding stress and stress induced by precipitation. Before welding these alloys, a full-solution anneal is usually performed. After welding, the appropriate aging heat treatment is performed. To further improve alloy properties, a full anneal after welding, followed by a post weld heat treatment, can be incorporated in the welding procedure.

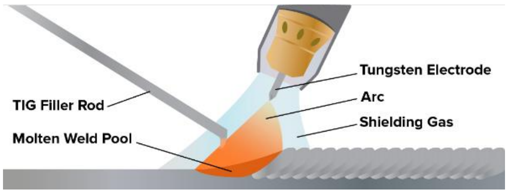
For Solid Solution Alloys preheat is not required, but it is desirable to have the surface temperature above 16°C (60°F), to avoid moisture condensate. Post-weld heat treatment is not usually needed to restore corrosion resistance.

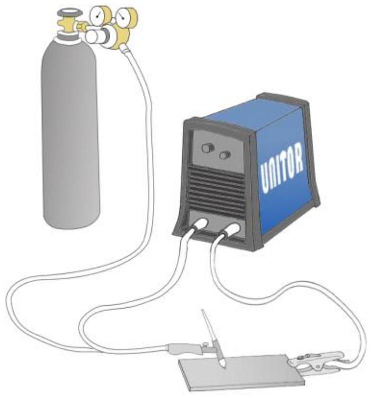
Welding Processes

Most nickel alloys can be fusion welded using gas shielded processes like TIG (Tungsten Inert Gas) or MIG (Metal Inert Gas).

NB. Most of the precipitation hardening alloys are subject to strain age cracking. The higher the Aluminium (Al) and Titanium (Ti) content the higher the risk for cracking. If Niobium (Nb), formerly Columbium is substituted in place of Aluminum (Al) the ageing reaction is reduced, consequently the Heat Affected Zone (HAZ) may remain sufficiently ductile during the Post Weld Heat Treatment (PWHT) and stain age cracking may be prevented.

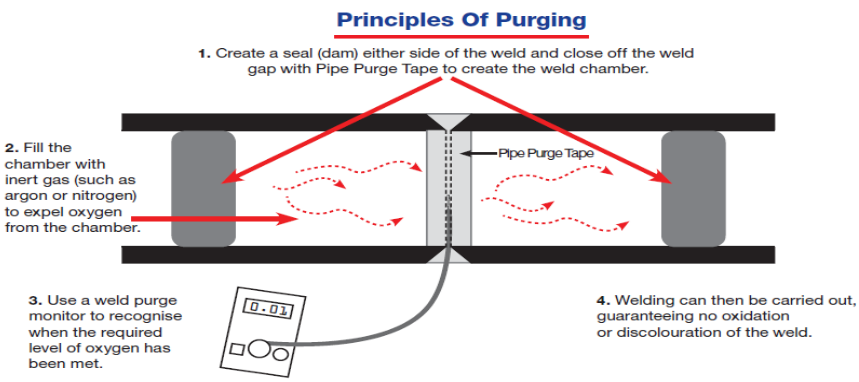
TIG (GTAW) welding is best suited for precipitation hardening alloys because it provides excellent protection against oxidation and the precipitation hardening alloys (Al, Ti, Nb)





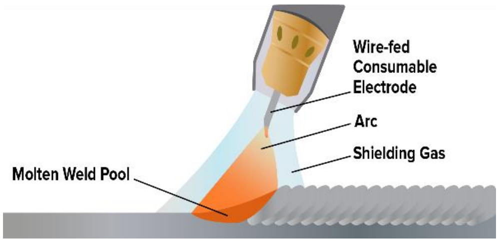
Direct current (DC) with TIG torch connected to negative (-) polarity. Arc stability is best if the Tungsten (W) electrode is ground to a point with approximately angle 30^{O} to 40^{O}. Use as large a ceramic shroud as possible together with a gas lens fitted in the TIG torch.

It goes without saying that gas purging of the root is essential when depositing a TIG root pass.



Argon (Ar) or a mixture of the Argon + Hydrogen (H2) are used as purging gas

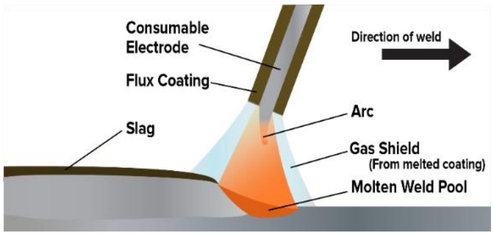
MIG (GMAW) welding can be used on all of the Solid Solution strengthened alloys. Wire diameters 0,9mm (0,035”), 1,2mm (0,047”) and 1,6mm (0,063”) are generally used.

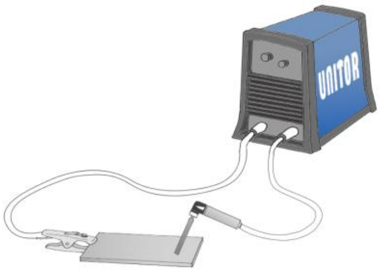


Arc length 6mm (0,236 “) and Spray arc mode. Spray arc has deeper penetration weld bead.

Argon (Ar) or Argon + Helium (He) are normally used as shielding gas. An addition of 15 to 20% of He increases bead width and decreases penetration.

MMA Electrode/Stick (SMAW) welding is primarily used for welding commercially pure Nickel and solid Solution strengthened alloys. Precipitation hardening alloys are not preferable for this welding process because the alloying elements contributing to hardening are difficult to transfer across the arc.





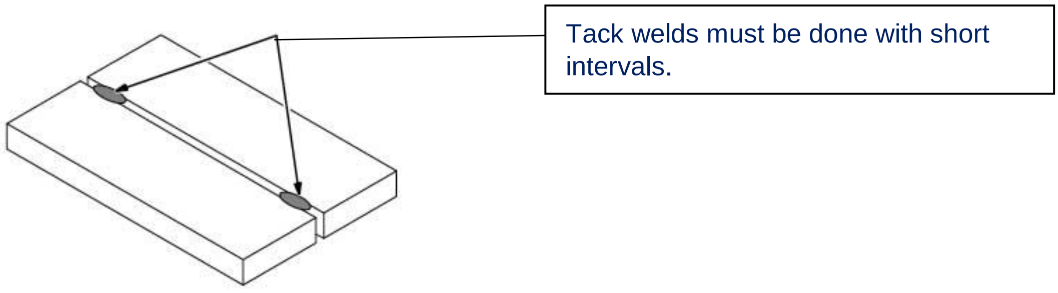
Direct current (DC) with electrode holder connected to positive (+) polarity. Electrode diameter of 3,2mm (0,126”) is suitable for welding in all positions. NB. Electrodes must be re-dried to 350°C (662°F) for 2 hours before use.

Electrodes/wires/ rods chemical composition should be similar to base material being welded.

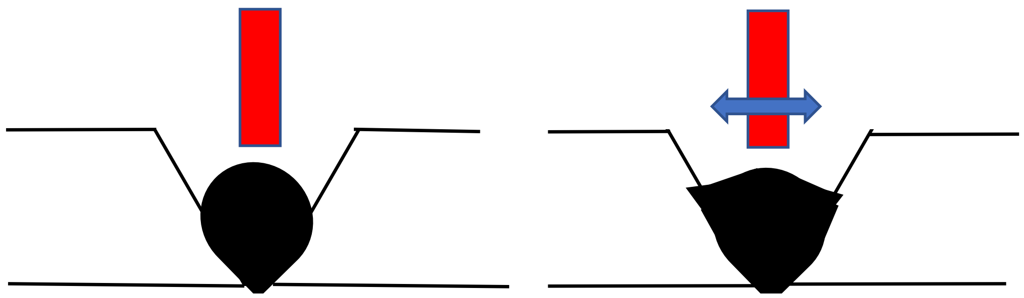
Recommended welding machine for MIG, TIG or MMA (Electrode/ Stick) welding of nickel and nickel alloys: **Weco Micro Pulse 302MFK**. This is a 3-phase robust designed Inverter for Synergic, Pulse Synergic and Double Pulse Synergic MIG/MAG welding, MMA and TIG Lift Arc welding. Easy to transport, compact and only 24kg, it is a most suitable machine for maintenance and repair welding of nickel and nickel alloys onboard. It can also with good results be used for other metals like steel, stainless steel and aluminum.

Practical welding hints

Nickel and its alloys are similar in many respects to the austenitic stainless steels; welding procedures are likewise also similar.



Nickel, however, has a coefficient of thermal expansion less than that of stainless steel so distortion and distortion control measures are similar to those of carbon steel. The weld pool, in addition to the surface film, is also sluggish and does not flow freely as with a carbon or stainless steel. This may result in a lumpy and very convex weld bead and a poor toe blend unless the welder manipulates the weld pool to avoid such defects.



Although stringer beads are recommended, a slight weave to assist the weld metal to wet the side walls of the preparation is beneficial. If waving the oscillation should be limited to 2,5 X the core diameter of the electrode.

A further characteristic of nickel alloys is that the amount of penetration is less than with a carbon or stainless steel. Increasing the welding current will not increase penetration. The implication of this is that the root face thickness in single sided full penetration welds should be less than with a stainless steel. It is recommended that the thickness of the root face should not be greater than 1.5mm (0,059”) in a zero gap TIG butt weld.

Removable backing strips are very useful to control root bead shape. These can be made from copper, stainless steel or a nickel alloy. Carbon or low alloy steel backing strips must be avoided.

Imperfections and degradation

Nickel and its alloys are readily welded but it is essential that the surface is cleaned immediately before welding. The normal method of cleaning is to degrease the surface, remove all surface oxide by machining, grinding or wire brushing (stainless steel wire brush) and finally degrease.

Common imperfections found on welding are:

- porosity
- oxide inclusions and lack of inter-run fusion
- weld metal solidification cracking
- micro fissuring

Additionally, precautions should be taken against post-welding imperfections such as:

- post-weld heat treatment cracking
- stress corrosion cracking

Porosity

Porosity can be caused by oxygen and nitrogen from air entrainment and surface oxide or by hydrogen from surface contamination. Careful cleaning of component surfaces and using a filler material containing deoxidants (aluminum and titanium) will reduce the risk. When using argon in TIG and MIG welding, attention must be paid to shielding efficiency of the weld pool including the use of a gas backing system. In TIG welding, argon-hydrogen gas mixtures tend to produce cleaner welds. Gas backing using argon with up to 10% H2 as a backing gas helps to prevent porosity. Bubbles of hydrogen that form in the weld pool gather the diffusing hydrogen. Too much hydrogen (>15%) in the shielding gas can result in the hydrogen porosity.

Oxide inclusions and lack of inter-run fusion

As the oxide on the surface of nickel alloys has a much higher melting temperature than the base metal, it may remain solid during welding. Oxide trapped in the weld pool will form inclusions. In multi-run welds, oxide or slag on the surface of the weld bead will not be consumed in the subsequent run and may cause lack of fusion imperfections. Before welding, surface oxide, particularly if it has been formed at a high temperature, must be removed by machining or abrasive grinding; it is not sufficient to wire brush the surface as this serve only to polish the oxide. During multipass welding, surface oxide and slag must be removed between runs.

Micro fissuring

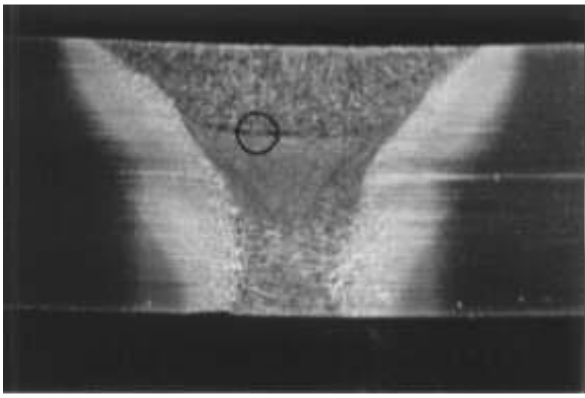
Similar to austenitic stainless steel, nickel alloys are susceptible to formation of liquation cracks in reheated weld metal regions or parent metal HAZ. This type of cracking is controlled by factors outside the control of the welder such as grain size or impurity content. Some alloys are more sensitive than others. For example, some cast super alloys are difficult to weld without inducing liquation cracks.

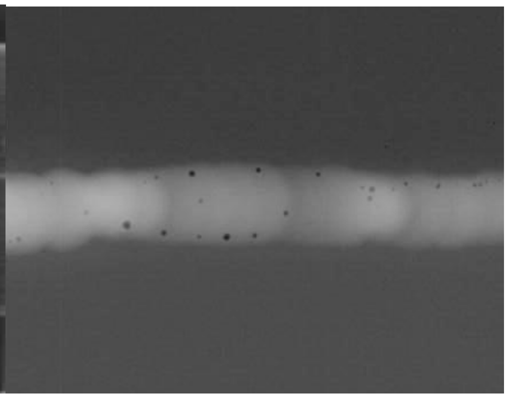
Post-weld heat treatment cracking

This is also known as strain-age or reheat cracking. It is likely to occur during post-weld ageing of precipitation hardening alloys but can be minimized by pre-weld heat treatment. Solution annealing is commonly used but over ageing gives the most resistant condition. Alloy 718 alloy was specifically developed to be resistant to this type of cracking.

Stress corrosion cracking

Welding does not normally make most nickel alloys susceptible to weld metal or HAZ corrosion. However, when Alloy 400 will be in contact with caustic soda, fluosilicates or HF acid, stress corrosion cracking is possible. For such service, thermal stress relief is applied after welding. Stress corrosion can also occur in Ni-Cr alloys in high temperature water. High chromium filler metal has been developed for welds and overlays in this environment.





Lack of inter-run fusion **Porosity**

Filler/Consumable alloys

Filler composition normally matches the parent metal. However, most fillers contain a small amount of titanium, aluminum and/or niobium to help minimize the risk of porosity and cracking. Filler metals for gas shielded processes (TIG and MIG) are covered in BS EN 18274:2004 and in the USA by AWS A5.14. Recommended fillers from UTP brand (voestalpine Bohler Welding) for selected alloys are given in the table.

WELDING CONSUMABLES FOR NICKEL & NICKEL ALLOYS

UTP PRODUCT	APPLICATION	MMA	MIG	TIG	F/C WIRE
80Ni **A80Ni**	For joining and surfacing on commercial pure nickel grades. **VDM Alloy** / **Inco Alloy** Nickel 99.2 / Nickel 200 LC Nickel 99.2 / Nickel 201	■	■	■	
80M **A80M**	For joining and surfacing on nickel copper alloys and clad steel grades. **VDM Alloy** / **Inco Alloy** Nicorros/Nicorros AL / Monel 400/ Monel K-500 Also used for joining steel to copper and nickel copper alloys.	■	■	■	
4225 **A4225**	For joining and surfacing Ni alloys of similar composition. Ideal in chemical industry for equipment exposed to sulphuric and phosphoric acid. **VDM Alloy** / **Inco Alloy** Nicrofer 4221 / Incoloy 825 Also for joining Alloy 28 and Alloy 904L	■	■	■	
068HH **A068HH**	A fully austenitic alloy used mainly in high grade plant engineering, also for the welding and repair of 9% nickel steels. **VDM Alloy** / **Inco Alloy** Nicrofer 3220 C / Incoloy 800 Nicrofer 3718 / Incoloy DS Nicrofer 3220 Nicrofer 3228 NbCe / AC 66	■	■	■	
7015 **A068HH**	For overlaying and joining nickel base materials. **VDM Alloy** / **Inco Alloy** Nicrofer 6023 / Inconel 600 Nicrofer 7216 H / Inconel 600H	■	■	■	

AF7015	Nicrofer 7216 LC — Inconel 600 Nicrofer 7520 — Nimonic 75 Also for joints between austenitic and ferritic steels.				■
7015Mo **A068HH**	For joining and surfacing on high temperature resistant nickel base materials. **VDM Alloy** — **Inco Alloy** Nicrofer 3220 — Incoloy 800 Nicrofer 3220H — Incoloy 800H Nicrofer 3220LC — Incoloy 800L Nicrofer 3718 — Incoloy DS Also for joints between austenitic and ferritic steels.	■	■	■	
6222Mo **A6222Mo** **AF6222Mo**	For welding matching nickel base alloy 625 (NiCr22Mo9). Developed specially where high strength, corrosion resistance and high temperatures are involved, such as in the following materials. **VDM Alloy** — **Inco Alloy** — **Avesta** Nicrofer 6020 — Inconel 625 — 254SMo Nicrofer 4221 — Incoloy 825 — (6 Moly) Nicrofer 3220H — Incoloy 800H Also for overlaying on carbon steels and dissimilar joints	■	■	■	■
6170Co **A6170Co**	For joining and surfacing alloys of similar composition as follows: **VDM Alloy** — **Inco Alloy** Nicrofer 5520CoSo — Inconel 617 ***Oxidising media at high temperature***	■	■	■	
6225AL **A6225AL**	For joining base materials of similar composition. **VDM Alloy** — **Inco Alloy** Nicrofer 6025HT — 602 CA Nicrofer 6125 GT — 603GT Nicrofer 6023(H)	■		■	
776Kb **A776**	For joining matching base material (NiMo16Cr15W) C-276, for chemical processes exposed to highly corrosive media. **VDM** — **Inco Alloy** Nicrofer 5716hMoW — Hastelloy C-276	■	■	■	
759Kb **A759**	Welding of matching base material (Alloy 59) **VDM Alloy** — **Cabot Alloy** Nicrofer 5923 — Hastelloy C-22*	■	■	■	

	Used on components in the chemical industry with highly corrosive media * Not matching filler				
6202Mo **A6202Mo**	For joining material subject to very high corrosive media. Such as Ni Mo 28 alloy B2 and Ni Mo 29 Cr alloy B4	■	■	■	

MMA Manual Metal Arc (Stick Electrodes)

TIG Tungsten Inert Gas Welding

MIG Metal Inert Gas Welding

F/C Flux Cored Arc Welding