4. FILLER METAL OF NICKEL BASED ALLOYS

4 .1 Lancaster Alloys Company can offer the following Nickel weld wire(1):

Table 4.1. Stock List of LAC for Nickel weld wire

LAC STOCK #	AMS SPECIFICATIONS	ALLOY NAME	AWS SPECIFICATIONS	AWS CLASS	UNS # (2)
5675	AMS 5675	FM 92	AWS A5. 14	ERNiCrFe-6	N07092
5676	AMS 5676	NICHROME V	N/A	N/A	N06003
5679	AMS 5679	FM 62	AWS A5. 14	ERNiCrFe-5	N06062
5778	AMS 5778	FM 69	N/A	N/A	N07069
5786	AMS 5786	W	AWS A5. 14	ERNiMo-3	N10004
5798	AMS 5798	X	AWS A5. 14	ERNiCrMo-2	N06002
5800	AMS 5800	RENE-41	N/A	N/A	N07041
5828	AMS 5828	WASPALLOY(3)	N/A	N/A	N07001
5829	AMS 5829	90	N/A	N/A	N07090
5832	AMS 5832	718	AWS A5. 14	ERNiFeCr-2	N07718
5837	AMS 5837	625	AWS A5. 14	ERNiCrMo-3	N06625
5838	AMS 5838	S	N/A	N/A	N06635
5872	AMS 5872	263	N/A	N/A	N07263
N100	N/A	B2	AWS A5. 14	ERNiMo-7	N10665
N112	N/A	FM 82	AWS A5. 14	ERNiCr-3	N06082
N113	N/A	617	AWS A5. 14	ERNiCrCoMo-1	N06617

1. Other Nickel alloys are also available upon request.
2. SAE/ASTM Unified Numbering System for metals and alloys.
3. Trade mark of United Technology Corp.

4.2 Chemical composition of Nickel weld wire.

Table 4.2 gives chemical composition for filler metals of Nickel alloys.

TABLE 4.2
Chemical composition requirements for Nickel alloy welding wire

Weight percent(a)

LAC STOCK #	C	Mn	Fe	P	S	Si	Cu	Ni(b)	Co	Al	Ti	Cr	Cb+ Ta	Mo	V	W
5675	0.08	2.00 to 2.70	10.00(c)	0.030	0.015	0.35	0.50	67.00 Min	1.00	-	2.50 to 3.50	14.00 to 7.00	-	-	-	-
5676	0.08 to 0.26	1.00	0.50	0.025	0.015	0.50	0.20	75.00 Min	1.00	-	-	19.00 to 21.00	-	-	-	-
5679	0.08	1.00	6.00 to 10.00	0.030	0.015	0.35	0.50	70.00 Min	1.00	-	-	14.00 to 17.00	1.50(d) to .00	-	-	-
5778	0.08	1.00	5.00 to 9.00	-	0.010	0.50	0.50	70.00 Min	1.00	0.40 to 1.00	2.00 to 2.75	14.00 to 17.00	0.70 to 1.20	-	-	-
5786	0.12	1.00	4.00 to 7.00	0.040	0.030	1.00	0.50	REM	2.50	-	-	4.00 to 6.00	-	23.00 to 26.00	0.60	1.00
5798(e)	0.05 to 0.15	1.00	17.00 to 20.00	0.040	0.030	1.00	0.50	REM	0.50 to 2.50	-	-	20.50 to 23.00	-	8.00 to 10.00	-	0.20 to 1.00
5800(f)	0.12	0.10	5.00	-	0.015	0.50	-	REM	10.00 to 12.00	1.40 to 1.60	3.00 to 3.30	18.00 to 20.00	-	9.00 to 10.50	-	-
5828(f, g)	0.02 to 0.10	0.10	2.00	0.010	0.010	0.10	0.10	REM	12.00 to 15.00	1.20 to 1.60	2.75 to 3.50	18.00 to 21.00	-	3.50 to 5.00	-	-
5829(h)	0.13	1.00	1.50	-	0.015	1.00	0.20	REM	15.00 to 18.00	1.00 to 2.00	2.00 to 3.00	18.00 to 21.00	-	-	-	-

TABLE 4.2
Chemical composition requirements for Nickel alloy welding wire (continued)

Weight percent(a)

LAC STOCK #	C	Mn	Fe	P	S	Si	Cu	Ni(b)	Co	Al	Ti	Cr	Cb+ Ta	Mo	V	W
5832(i)	0.08	0.35	REM	0.015	0.015	0.35	0.30	50.00 to 55.00	1.00	0.20 to 0.80	0.65 to 1.15	17.00 to 21.00	4.75 to 5.50	2.80 to 3.30	-	-
5837	0.10	0.50	5.00	0.015	0.015	0.50	0.50	58.00 Min	1.00	0.40	0.40	20.00 to 23.00	3.15 to 4.15	8.00 to 10.00	-	-
5838(j)	0.02	0.30 to 1.00	3.00	0.020	0.015	0.20 to 0.75	0.35	REM	2.00	0.10 to 0.50	-	14.50 to 17.00	-	14.00 to 16.50	-	1.00
5872(k)	0.04 to 0.08	0.60	0.70	0.015	0.007	0.40	0.20	REM	19.00 to 21.00	0.30 to 0.60	1.90 to 2.40	19.00 to 21.00	-	5.60 to 6.10	-	-
N100	0.02	1.00	2.00	0.040	0.030	0.10	0.50	REM	1.00	-	-	1.00	-	26.00 to 30.00	-	1.00
N112	0.10	2.50 to 3.50	3.00	0.030	0.015	0.50	0.50	67.00 Min	-	-	0.75	18.00 to 22.00	2.00(d) to 3.00	-	-	-
N113	0.05 to 0.15	1.00	3.00	0.030	0.015	1.00	0.50	REM	10.00 to 15.00	0.80 to 1.5	0.60	20.00 to 24.00	-	8.00 to 10.00	-	-

Please refer to footnotes on next page

Notes to table 4.2:

a. Single values are maximum, except where otherwise specified
b. Includes incidental cobalt.
c. Iron- 8.00 maximum per AWS specification
d. Tantalum- 0.30 maximum, when specified
e. Boron is 0.010 maximum
f. Boron is 0.003 to 0.010.
g. Zirconium- 0.04 maximum
h. Zirconium- 0.15 maximum; Boron- 0.02 maximum; Lead 0.002 maximum.
i. Boron is 0.006 maximum; Silver- 0.0005 maximum; Bismuth- 0.0001 maximum
j. Lanthanum- 0.01 to 0.10; Boron- 0.015 maximum
k. Titanium +Aluminum- 2.40 to 2.80; Boron- 0.005 maximum.

4.3 Nickel and High-Nickel alloys General information.

Nickel, in some aspects, bears a marked similarity to iron, it's close neighbor in the periodic table. Nickel is only slightly denser than iron, because its magnetic and mechanical properties are similar to those of iron. The crystalline structure of nickel, however, is quite different from that of iron, so the metallurgy of nickel and nickel alloys differs too.

Unlike iron, nickel has an unchanging crystalline structure up to its melting point. In that respect, nickel and nickel alloys are similar to the austenitic stainless steels. Since the nickel alloys do not undergo a crystalline or phase change, the grain size of base metal or weld metal is not refined by heat treatment alone.

Because nickel has wide solubility for a number of other elements, many greatly different commercial alloys are produced. Nickel and copper have complete solid solubility. Iron and cobalt are soluble in nickel to a very high degree. The limit of solubility of chromium is 35% to 40%, and of molybdenum about 20%. Addition of these major alloying elements, that is copper, chromium, molybdenum, iron and cobalt, have no adverse effect and in most cases a beneficial effect on weldability, whereas nickel-chromium alloys behave more like the austenitic stainless steels.

In relatively small amounts, manganese, silicon, carbon, chromium, aluminum and titanium are either beneficial or have no effect on weldability. But those elements can, as can the major alloying elements, include hot-cracking of the weld if their respective critical tolerances are exceeded. Manganese, in amounts between 3% to 9%, are commonly added to nickel-copper and nickel-chromium weld metals to impart cracking resistance to heavy, highly restrained welds.

Sulfur, phosphorus, lead, zirconium and boron are practically insoluble in nickel and nickel alloys and can undergo eutectic reactions,causing hot cracking of welds. Boron and zirconium in extremely small controlled amounts, are added to certain nickel-base alloys to improve their high-temperature performance, but weldability is decreased. The harmful effects of sulfur on ductility are controlled by the addition of small amounts of magnesium to wrought products and to filler wires, for the gas shielded-arc processes. In shielded metal-arc welding, the loss of magnesium across the arc is so great that ineffectively small amount of magnesium are recovered. Under those circumstances, control of sulfur is accomplished by other elements such as columbium, titanium, and aluminum, which can be recovered in substantially greater amounts than can magnesium.

All nickel alloys can be classified into one of two big groups: (1) Sold-solution-strengthened or (2) precipitation-hardened. Theoretically the solid-solution-strengthened alloys are not strengthened by heat treatment, whereas the precipitation-hardened alloys are strengthened to a large degree by heat treatment . In actual practice, some of the alloys classified as solid-solution alloys may have minor amounts of elements such as titanium, aluminum and columbium, and their presence can cause some strengthening when the alloys are heat-treated such as alloy 625(LAC stock # 5837). Consequently , the classification of a few alloys is somewhat arbitrary.

In the past, the identification of a particular nickel alloy has been by trade name, military or technical society material specifications. More recently some manufacturers of the wrought nickel alloys have employed a three-digit numbering system, grouping the alloys as follows:

TABLE 4.3.
Numerical numbering system for Nickel alloy groups

NUMBER SERIES	ALLOY GROUP
200	Nickel solid-solution
300	Nickel, precipitation-hardenable
400	Nickel-Copper, solid-solution
500	Nickel-Copper, precipitation-hardenable
600	Nickel-Chromium, solid-solution
700	Nickel-Chromium, precipitation-hardenable
800	Nickel-Iron-Chromium, solid-solution
900	Nickel-Iron-Chromium, precipitation-hardenable

4.4 Filler metal selection.

4.4.1. General welding considerations.

Nickel and high nickel alloys are weldable by all of the processes commonly used for steel and other materials. Welded joints can be produced to stringent quality requirements in the precipitation-hardenable as well the solid-solution alloys. Though the precipitation-hardenable alloys, because of the possibilities of hardening and the formation of refractory oxides during welding, require closer control of welding variables.

Cleanliness is the single most important requirement for successful welding. Nickel alloys are susceptible to embrittlement by sulfur, lead, phosphorus and other low-melting-point materials. Since those elements are often present in oils, paints, cutting fluids, shop dirt, etc., it is essential to thoroughly clean all surfaces of the metal that will be heated by welding. Oxides having a considerably higher melting points than the base metals, should be thoroughly removed from the surface, since these oxides can be barriers to complete fusion. Lancaster Alloys Company can guarantee that its weld wire surface is absolutely free from all substances mentioned above, including oxides.

In most cases, a filler metal should be selected that is as close in composition to the base metal as possible and which exhibits comparable corrosion resistance in most environments.

Postweld thermal treatments are usually not needed to restore the corrosion resistance of nickel, nickel-copper, nickel-chromium, or nickel-iron-chromium alloys. Some notable exceptions are the stress-relieve treatments required for nickel-chromium alloy 600 for fused-caustic service, and for nickel-copper alloy 400 for hydrofluoric acid service.

The nickel-chromium and nickel-iron-chromium alloys, like some austenitic stainless steels, can exhibit carbide precipitation in the heat-affected zone. Some alloys are stabilized by the addition of titanium or columbium, such as alloys 625, 801, 825 and 20Cb3.

The heat-affected zones of nickel-molybdenum and nickel-silicon alloys can influence their corrosion resistance. Generally, these alloys should receive a postweld solution-annealing treatment to restore the corrosion resistance of the heat-affected zone .

4.4.2 Selection of filler metal.

Filler metals for the age-hardenable alloys have compositions similar to those of the base metals with which they are used. The weld deposits will respond to age-hardening treatments under the same conditions as the base metal, but the resulting properties are generally lower than those attainable with fully heat-treated base material.

Alloys such as Rene-41 are commonly welded with solid-solution filler metals such as 5837 (alloy 625) and 5786 (alloy W) to minimize processing difficulties. As a result, mechanical properties are reduced, particularly in heavy sections where weld dilution is low.

The following are some typical applications for the most widely used nickel based filler metals that Lancaster Alloys Company has to offer.

5675

This filler metal is used for cladding steel with nickel-chromium-iron weld metal and for joining steel to nickel base alloys with the gas tungsten arc, gas metal arc, submerged arc , and plasma welding processes. This filler metal is especially useful when welding with the gas shielded processes under conditions which might impair the effectiveness of the gas shielding. The weld metal precipitation will harden on heat treatment. The degree to which it hardens depends on the temperature and the time at the temperature.

5697

This alloy is used for welding nickel-chromium-iron alloys (ASTM B163, B166, B167, and B168, all of which have UNS number N06600) with the gas tungsten arc, gas metal arc, submerged arc, and plasma processes. The higher columbium content of the filler metal is intended to minimize cracking where high welding stresses are encountered, as in thick base metal.

5786

This filler metal is used for welding nickel-molybdenum base metal to itself, to steel ,to other Nickel base alloys, and for cladding steel with nickel-molybdenum weld metal by the gas tungsten arc, gas metal arc, plasma arc, and submerged arc welding processes.

5798

This alloy is used for welding nickel-chromium-molybdenum base metal (ASTM B366, B435, B567 and B572, all UNS number N060002) to itself, to steel, to other nickel-base alloys, and for cladding steel with nickel-chromium-molybdenum weld metal by the gas tungsten arc, gas metal arc and plasma arc welding processes.

5832

This filler wire is used for gas tungsten arc welding of nickel-chromium-columbium-molybdenum alloy (ASTM B637, AMS 5589, UNS NO7718). The weld metal will precipitation harden during heat treatment.

5835

Filler metal 5835 is used for welding nickel-chromium-iron alloys for the clad side of joints in steel clad with nickel-chromium-iron alloy, for surfacing steel with nickel-chromium-iron weld metal, and for joining steel to nickel base alloys. Typical specifications for the nickel-chromium base metal are ASTM B163, B166,B167 and B168, all of which have UNS number N06600. This filer metal can be used with the gas tungsten arc, gas metal arc, submerged arc and plasma arc welding processes.

5837

This alloy is used for welding nickel-chrominum-molybdenum base metal (ASTM B443, B444, and B446 all UNS number N06625) to itself, to steel, to other nickel base alloys, for cladding steel with nickel-chrominum molybdenum weld metal, and for welding the clad side of joints in steel with nickel-chrominum-molybdenum alloys. The welding processes are gas tungsten arc, gas metal arc, submerged arc and plasma arc.

N100.

Filler metal N100 is used for welding nickel-molybdenum base metal (ASTM B333 and B335, UNS number N10665) and for cladding steel with nickel-molybdenum weld metal by the gas tungsten arc and gas metal arc processes.

N113.

This filler metal is used for welding nickel-chrominum-cobalt-molybdenum base material(UNS NO6617), using the gas tungsten arc and gas metal arc welding processes.

4.4.3. Mechanical properties of welds.

Table 4.4 and 4.5 gives some typical mechanical properties of gas metal-arc and gas tungsten-arc butt-welds.

TABLE 4.4

Mechanical properties of gas metal-arc butt welds

(short-circuiting transfer)

ALLOY AND MATERIAL THICKNESS, IN.	JOINT TYPE	WELD METAL DIAMETER AND TYPE	TENSILE STRENGTH PSI	YIELD STRENGTH PSI	ELONGA TION %	REMARKS
INCONEL alloy 600 0.048 sheet	Square	0.030-in 5835	98,120	-	33.0	As-welded.Fractured in base metal.
INCONEL alloy 600 0.048 sheet	Square	0.030-in 5675	99,040	-	34.0	As-welded.Fractured in base metal.
INCONEL alloy 600 0.500 plate	Single-V	0.030-in 5835	99,880	-	35.0	Ground flush Fractured in base metal
INCONEL alloy 718 0.250 plate	Single-V	0.035-in 5832	185,000	150,000	16.0	Welded+annealed +aged
INCONEL alloy 718 0.250 plate	Double-U	0.035-in 5832	184,500	152,000	12.0	Welded+annealed +aged
INCONEL alloy 718 0.250 plate	Single-V	0.035-in 5832	172,000	138,000	7.0	Welded+aged
INCONEL alloy X-750 0.750 plate	Double-U	0.035-in 5832	154,500	116,000	12.0	Welded+annealed +aged

TABLE 4.5
Nominal Mechanical properties of gas tungsten arc butt welds

ALLOY	JOINT TYPE	WELD METAL	TENSILE STRENGTH $PSIx10^3$	YIELD STRENGTH $PSIx10^3$	ELONGATION %	REMARKS
INCONEL alloy 600	Single-V	5679	96.0	60.5	39.5	As-welded all-weld-metal specimen
INCONEL alloy 600	Single-V	5835	99.0	62.0	43.5	As-welded all-weld-metal specimen
INCONEL alloy 718	Single-V	5832	164.0	143.0	10.0	Annealed+Welded +aged
INCONEL alloy 718	Single-V	5832	123.0	80.0	34.0	Annealed+aged +welded
INCONEL alloy 718	Single-V	5832	185.0	148.0	14.5	Welded+annealed +aged
INCONEL alloy X-750	Single-U	5832	168.0	119.5	35.0	Welded+annealed +aged
RENE 41	Single-V	5800	171.0	144.0	4.0	Welded+annealed +aged