Nickel 200 Alloy

Nickel 200 Alloy

The pure nickel has various features that are useful in the different applications such as chemical processing and electronics. The nickel alloy offers an excellent resistance to the caustic alkalies. It has large electrical and heat conductance. It is also comprised of high curie temperature and better magnetostrictive features. The annealed nickel loses its hardness though it has high ductility and malleability. These properties combined with the excellent welding character, make this metal ready to fabricate.

The nickel alloy has low performance hardening rate though it can be cold processed to get reasonably large strength level while maintaining its ductility. The **Nickel 200 alloy** is 99.6% pure wrought metal with better mechanical features and excellent resistance to corrosive conditions. The significant features of the alloy are its magnetic and magnetostrictive features, large thermal and electrical conductivity and lower gas concentration as well as vapor pressure.

Chemical composition of Nickel 200 Alloy

Nickel	Copper	Iron	Manganese	Carbon	Silicon	Sulfur
99.0 %	0.25 %	0.40 %	0.35 %	0.15 %	0.35 %	0.01 %

The resistance to corrosion of Nickel 200 is useful in maintaining the product's purity in the food processing, synthetic fibers, caustic alkalies and in the structural operations. It is also used in the chemical shipment drums, electric and electronic components, aeronautic and missile parts.

Physical properties of Nickel 200 Alloy

Density	8.89 g/cm3
Melting Range	2615-2635oF or 1435-1446oC
Specific Heat, J/kg•°C	456
Curie Temperature	680oF or 360oC

Thermal properties of annealed Nickel 200 alloy

Temperature oF	Coefficient of Expansion A 10(-6)in/in•oF	Electrical Resistivity ohm•circ•mil/ft	Thermal Conductivity Btu•in/ft 2•h•oF
-423	4.7	-	
-300	5.8	-	16
-200	6.2	533	26
-100	6.3	516	36

Nickel 200 Alloy

Modulus of elasticity

Temperature oF	Young's Modulus,10(3) ksi	Shear Modulus 10(3) ksi	Poisson's Ratio
78	29.7	11.55	0.29
200	29.1	11.30	0.29
400	28.3	11.00	0.29
600	27.4	10.66	0.29
800	26.4	10.27	0.29

Mechanical properties of Nickel 200 Alloy

Form	Tensile Strength,ksi	Yield Strength, ksi	Elongation%	Hardness, Rc
Wire, Cold-Drawn				
Annealed	55-85	15-50	50-30	-
No. 1 Temper	70-95	40-75	40-20	-
Spring Temper	125-145	105-135	15-2	-
Strip				
Spring	90-130	70-115	15-2	95 min
Annealed	55-75	15-30	55-40	64 max.

The torsional features of **Nickel 200 alloy** are shown in the below table. The breaking force is calculated by considering that the shear stress was same throughout the whole material during fracture.

Breaking Strength, ksi (MPa)	81.0 (558)
Twist, °/in (°/mm)	341 (13.4)

The results of shear stress analysis in the double shear on bars of different hardness are described in the below table:

Temper	Shear Strength	Tensile Strength	Hardness, Rc
Annealed	52.0 ksi	68.0 ksi	46
Half-Hard	58.0 ksi	79.0 ksi	90
Full-Hard	75.0 ksi	121.0 ksi	100

Fatigue strength of Nickel 200 Alloy

The fatigue strength and resistance to corrosion of **Nickel 200 alloy** are determined during an analysis when the pin diameter was developed smaller than the hole to get the wire fit tightly. The bearing strength properties are mentioned in the below table:

Condition	Bearing Strength	
	Ultimate strength, ksi	Yield Strength, ksi
Soft	125.5	50.3
Half-Hard	151.5	97.9
Hard	179.0	133.5

The highest weight to damage the hole and the weight essential for the permanent increase in the hole diameter by 2% are evaluated and ultimate yield strengths are calculated. The nickel metal is counted as one of the hardest metals and its hot rolled and annealed material are taken to calculate the maximum impact strength than the cold processing of metal.

The pairing of large strength and impact features of metal are shown in the below table:

Condition	Hardness	Izod, J	Charpy V, J	Charpy Torsion, J	Charpy Tension, J
Hot-Rolled	107	163	271	39	132
Cold-Drawn, 24% Reduction, Stress-Relieved	177	163	277	47	119
Cold-Drawn, Annealed at 1350°F (732°C)/3 hr	109	163	309	39	153

The endurance strength of Nickel 200 alloy in an air and salt water are described in the below table. The utilized cold treated samples offer an approximate tensile strength of 132.0 ksi and annealed material offers 78.0 ksi. The cold treated sample offers higher endurance limit about 50.0 ksi in air as compare to annealed metal that offers about 33.0 ksi. The corrosion fatigue values in the fresh water and salt are almost equal.

No. of Cycles	Cold-Drawn Rod in			Annealed Rod in		
	Air, ksi	Fresh water, ksi	Salt Water, ksi	Air, ksi	Fresh water, ksi	Salt Water, ksi
10(4)	109.0	110.0	-	-	-	-
10(5)	84.0	80.0	-	52.0	52.0	52.0
10(6)	63.0	56.0	54.0	40.0	39.0	37.0
10(7)	52.0	34.0	30.0	34.0	27.0	24.0
10(8)	50.0	26.0	23.0	33.0	23.0	21.0
10(9)	50.0	24.0	21.0	33.0	23.0	21.0

On the other side the fatigue strength of cold drawn alloy are similar in air and in fresh water about 106 cycles. The similarity in the fatigue strength exists for about 106 x 4 cycles for the annealed alloy in the air, fresh water and salt solution.

High temperature characteristics

Though nickel 200 is generally restricted to service at the temperatures about 600oF or 315oC. At the elevated temperatures, the **Nickel 200 alloy** can be attacked by the graphitization that causes wider alteration in its properties therefore **Nickel 201 alloy** is preferred.

The processing of alloy at temperatures more than 600oF or 315oC is recommended. The nickel 200 and 201 alloy are employed in manufacturing the pressure vessels and parts under ASME boiler and pressure vessel codes. The **Nickel 200 alloy** is used for service about 600oF or 315oC though nickel 201 is utilized at service temperature about 1250oF or 677oC.

Low temperature Characteristics

The tensile properties of **Nickel 200 alloy** at the lower temperatures are shown in the below table:

Temperature	Tensile Strength, ksi	Yield Strength, ksi	Elongation%
-423	110.0	37.5	60
-300	90.0	27.5	61
-200	78.0	24.0	57
-100	71.0	22.0	51
70	64.0	21.0	48

Nickel 200 Alloy

Microstructure

The Nickel 200 is a firm solution metal that occupies face centered cubic structure. The microstructure gains the nominal amount of nonmetallic additions, prime oxides that remain unaltered during annealing of alloy. The extended exposure of Nickel 200 at the temperature between 800oF to 1200oF causes precipitation to graphite. Due to this, the alloy 200 is not preferred for operations at temperatures between 600oF to 1200oF. So **nickel 201 alloy** is utilized.

Corrosion Resistance Characteristics

The nickel 200 alloy is extensively resistant to the various corrosive conditions. However it is widely used in the reduction conditions; it is also employed in the oxidizing environments that develop the passive oxide layer on the metal surface. The excellent resistance of **nickel 200 resistance wire** to caustics is based on this kind of security. In all kinds of conditions when the temperature is raised from 600oF, the nickel 201 alloy is preferably used rather than nickel 200.

The nickel 200 shows glowing surface when it is isolated from the external conditions. In the external conditions, the attack of atmosphere is lower due to the production of protective layer of sulfate on the metal surface. This rate is increased in the presence of sulfur dioxide in the atmosphere. The rate of corrosion in the sea and rural areas is also very nominal.

The consequences of exposures of nickel 200 are shown in the below table:

Site	Corrosion Rate, mpy
Heavy Railroad – Industrial (Altoona, PA)	0.222
Urban – Industrial (New York City, NY)	0.144
Rural (State College, PA)	0.0085
Semi-arid – Rural (Phoenix, AZ)	0.0015

Resistance to Water Corrosion

The resistance to corrosion by the nickel 200 alloy to the distilled and natural fresh water is incomparable. The corrosion rate in the distilled water is slightly less than 0.01 mpy than the fresh water. The rate of corrosion in the municipal hot water of 95oC or 200oF is less than 0.02 mpy and slightly higher by 0.2 mpy. The Nickel 200 alloy resists the water corrosion comprising of hydrogen sulfide or carbon dioxide. In the distilled water saturated in 50 to 50 ratio to carbon dioxide and air at the temperature of 160oF or 71oC, it offers resistance to corrosion slightly lesser than 1 mpy.

The **Nickel 200 alloy** is utilized for oil well applications to resist corrosion by the hydrogen sulfide and brine. It offers superior performance in the sea water moving with high velocity though in the almost static sea water the alloy 200 is attacked by the fouls due to organisms or other causes. In the steam hot water systems that has steam comprises of carbon dioxide and air in the particular ratios, the rate of corrosion is extensively higher though it decreases with the times if the alloy forms a protected layer. The contaminants like ferrous corrosive products can resist the formation of protected layer. So, to avoid such attacks, the systems should include alternatives for deaeration of feedwater.

Resistance to acidic Corrosion

The **nickel 200 alloy** can be employed in the operations that include sulfuric acid at the lower or intermediate temperature ranges. However the corrosion rate increases with an increase in temperature and aeration, therefore the metal should be used in the nonaerated solutions at the room temperature only.

The presence of oxidizing salts also increases the rate of corrosion. The below table shows the typical corrosion rate at the different concentrations of acid.

Acid Concentration %	Temperature oF	Corrosion Rate	
		Unaerated mpy	Air-saturated mpy
1	86	-	49
2	70	2	-
5	65	2.2	-
10	140	-	89
20	70	4	-
25	180	-	83
48	158	18	-

The nickel 200 alloy may be employed in the hydrochloric acid conditions that have concentration about 30% in the aerated or deaerated form at the room temperature. The reason that the alloy successfully works in such conditions is the formation of nickel chloride that is apparently less soluble in such concentration. Due to this, the alloy should be employed cautiously in the high velocity solutions.

Also with the increasing temperature and aeration the corrosion rate is improved. Therefore the Nickel alloy is rarely or not employed in the highly concentrated acidic solutions. Also the presence of oxidizing salts accelerates the rate of corrosion. At the acidic concentration less than 0.5%, the alloy can be employed to get the satisfactory performance at temperature range about 300oF to 400oF. The **Nickel 200 alloy** offers extended resistance to anhydrous hydrochloric acid even at the high temperature limits. In the aqueous solution, the performance of alloy is combated at temperature lower than 180oF or 80oC. Also at the room temperature the concentration of acid about 60 to 65% causes corrosion of the nickel 200 alloy. The following table shows the testing conditions and corrosion rate of alloy 200.

Test Conditions	Temperature oF	Corrosion Rate, mpy
Inlet side of preheater channel. Liquid conc: 79-92% hydrofluoric acid; 0.8-2.5% water; residue, isobutane and acid dissolves in oil.	120- 135	1.1
Top of regeneration column just below vapor outlet. conc: 90-95% hydrofluoric acid and 5-10% isobutane. Acid phase: 90- 95% hydrofluoric acid, 0.5-2.5% water, 1.0-5.0% oil. Pressure, 120-150 psi (0.83-1.0 MPa).	275- 300	13
Top of regeneration column. conc: Equal parts of 93% hydrofluoric acid and isobutene vapor.	215- 220	14
Bottom of regeneration column, acid tar containing 1-10% hydrofluoric acid and water in 1:1 ratio.	250 ave.	11
Bottom of regeneration column, beneath grid plate. Feed to column contains 85.2% hydrofluoric acid, 1.6% water and oils.	220- 250	18

The **Nickel 200 alloy** offers controlled performance in the industrial phosphoric acidic solutions due to the presence of contaminants in them like fluorides and ferrite salts that increase the corrosion. In the pure unaerated acid, the corrosion rate is reduced for the whole acidic amounts at the normal temperatures. The corrosion rate is apparently higher in the hot or high concentration solutions.

The **Nickel 200 alloy** can also be used in the presence of nitric acid solution of 0.5% concentration. It offers supreme resistance to the entire organic acid concentrations with the reasonable aeration.

Resistance to alkalines

The nickel 200 alloy offers tremendously high resistance to the caustic soda and other alkaline solutions except ammonium hydroxide since nickel is not corroded by the anhydrous ammonia or ammonium hydroxide in the 1% concentrated solution but the higher concentrations of alkalies can immediately attack the metal. The nickel 200 alloy is extensively used in the several industrial operations that include alkalies.

It offers broad resistance to the caustic soda in all concentrations as well as melting caustic soda. Even the concentration less than 50% doesn't attack much in the boiling state. But the rate of corrosion increases with an increase in the concentration and temperature such as the performance of Nickel alloy in the different conditions is shown in the below table:

Temperature oF	Pressure	Duration, hours	Corrosion Rate, mpy
86	Atmos.	120	0.06
86	Atmos.	24	0.3
195	Atmos.	24	0.55
212	610 mm	24	0.7
212	610 mm	240	0.07
212	620 mm	264	0.5
266	Atmos.	720	1.1

The prime factor that contributes in the excellent performance of nickel 200 alloy in the highly concentrated solution of caustic soda is the formation of black protected layer that is produced during vital exposure of metal. The layer is basically a nickel oxide that reduces the corrosion rate during the prolonged exposure of metal. The presence of chlorates in the caustic soda tends to improve the corrosion rate so the attempts should be made to discard such factors. The oxidized sulfur compounds also improve the corrosion rate of nickel 200 alloy. At this time, the inclusion of adequate amount of sodium peroxide oxidizes the sulfur compounds to reduce the corrosion rate.

The rate of corrosion of **nickel 200 alloy** in the caustic potash is shown below:

Temperature oF	Pressure	Duration, hours	Corrosion Rate, mpy
86	Atmos	120	0.06
86	Atmos	24	0.3
195	Atmos	24	0.55
212	610 mm	24	0.7
212	610 mm	240	0.07

The corrosion rate of nickel 200 alloy in the different salt solutions is shown in the below table:

Test Conditions	Temp.	Corrosion Rate
Analysis in mixture of arsenic trichloride (72-100%) and sulfur monochloride (0.28%) with vapor & condensate	248-266 oF	1.3 mpy
Analysis, evaporating 37% manganous chloride, sample partially submerged	210-225 oF	30 mpy
Analysis in phosphorus pentachloride	169 oF	0.2 mpy
Analysis mixture of phosphoric, hydrochloric & cresylic acids & phosphorus oxychloride. Test spool at liquid line.	180 oF	17 mpy
Analysis in evaporator concentrating a mixture of magnesium & calcium chloride brines to 50% chlorides under vacuum	Boiling	3 mpy

The **Nickel 200 alloy** is not corroded in the stress corrosion cracking in the chloride salts and offers superior resistance to non oxidizing halides.

Resistance to Corrosion by salts

The oxidizing acid chlorides like ferric, cupric and mercuric salts are highly corrosive and utilized with the **Nickel 200 alloy** in the minimum concentration. The stannic chloride is less oxidizing and dilute solutions at the atmospheric temperature are opposed.

The highest protection limit for using nickel 200 alloy in the oxidizing alkaline chloride is 500 ppm for rapid exposure. This is shown in the below table:

Available Chlorine, ppm	Corrosion Rate mpy
35	0.1
100	0.3
500	0.8

For the irregular exposure where the rinsing operation is considered, the concentration of about 3 gm per liter can be maintained. The sodium silicate is utilized as an inhibitor to corrosion as minimum as 0.5 ml per liter bleaching is considered valuable. Few salts are very hasty and corrosion chlorides like phosphorus oxychloride, phosphorus trichloride, nitrosyl chloride, benzyl chloride and benzoyl chloride are primarily resisted by nickel 200 alloy.

The **Nickel 200 alloy** offers outstanding resistance to neutral and alkaline salt solutions. In fact under the typical exposure conditions the rate of corrosion is less than 5 mpy. This is shown in the below table:

Conditions	Temperature	Corrosion Rate
Cobalt acetate in evaporator	225 oF	4 mpy
Sodium metasilicate in evaporator concentrating solution to 50%	230	0.02
Sodium sulfate, saturated solution, pH 9-10, in slurry tank	170	0.8
Sodium hydrosulfide, 45% solution in storage tank	120	0.1

The corrosion rate in the acidic salts varies significantly as shown in the below table:

Conditions	Temperature oF	Corrosion Rate, mpy
Aluminum sulfate, quiet immersion in 25% solution in storage tank	95	0.6
Aluminum sulfate in evaporator concentrating solution to 57%	240	59
Ammonium chloride in evaporator concentrating solution from 28 to 40%	216	8.4
Ammonium sulfate, saturated solution containing 5% sulfuric acid in suspension tank during crystallization	106	3.0
Manganese chloride plus some free hydrochloric acid, immersed in boiling 11.5% solution in flask equipped with reflux condenser	214	8.7
Manganese sulfate in evaporator concentrating solution from 1.250-1.350 specific gravity	235	2.9

Resistance to Fluorine and Chlorine

The fluorine and chlorine are the powerful oxidizing agents that react with the metallic material rapidly, the **nickel 200 alloy** can be employed productively in these conditions under certain effects. At the room temperature, it creates protective fluoride layer and suits effectively in handling fluorine at the low temperatures.

The nickel 201 alloy is recommended for using in the high temperature applications. It resists dry chlorine at the reduced temperatures. The arid hydrogen chloride acts in the same way towards the metal alloy. However in the hydrated chlorine at the reduced temperature or at temperature lower than the dew point, the **nickel 200 alloy** offers similar functionality as it shows with hydrochloric acid. Moreover the hydrogen chloride with moisture concentration up to 0.25% doesn't influence the rate of corrosion in the hydrated and dehydrated forms at the temperature of 400oF or 205oC.

The nickel 200 alloy is attacked by the corrosion at the rate of 0.04 mpy at the room temperature in the bromine solution that is dehydrated by the sulfuric acid.

Heating and pickling of Nickel 200 Alloy

The **Nickel 200 alloy** can be annealed at the different temperature ranges more than its recrystallization temperature. For the severely cold processed alloy, the temperature can be lowered to 1100oF to 1200oF or 595oC to 650oC though from the practical sight, the temperature limit is about 1300oF to 1700oF or 705oC to 925oC. Due to absence of residual materials and secondary phases that cause the growth of grain in the complex alloy materials, the grain development is quick in the nickel 200 material at the high temperatures.

In the elevated temperatures, the temperature span should be cautiously considered to monitor the grain size. The annealing in the box, retort or open furnaces are often made at the temperature of 1300oF to 1500oF or 705oC to 815oC for half an hour to three hours on the base of cross section area and the quantity of cold processing. The **nickel 200 alloy** offers good thermal conductance to increase the heating rate. However the cooling rate is not crucial, except to reduce the heat processing cycle or partially decrease the surface oxide while heating or cooling in the oxidizing atmosphere.

This cut back is obtained by cooling in water that consists of 2% alcohol. The soft oxide is persistent that can be eradicated in the standard pickling solution. The rapid annealing in the pusher kind, roller hearth and conveyor belt furnaces is often performed at temperature limits between 1450oF to 1750o or 790oC to 955oC. The annealing is done for 5 to 10 minutes in the hot region. The fabricator should create the empirical specific heat processing to offer the complete control of grain size and the features by choosing the proper temperature limits and the tests in a range to receive the required features of alloy.

The good to intermediate grain size is essential to maintain the soft surface while the production is counted to be 0.001 to 0.004 inch or (0.025 to 0.10 mm), that is an ASTM standard grain size. The annealing of **nickel 200 alloy** for one hour or more at the temperature limits of more than 1700oF or 925oC produces toughness of about 20 – 40 Rc. This processing is normally known as dead soft annealing and followed solely in the special operations like burst diaphragm due to the limited mechanical features and coarse grain structure created. The annealing should be done in the reducing conditions to maintain the glowing finish. The arid hydrogen and dissociated ammonia are recommended though cost effective conditions such as moderately burned natural gas also offers appropriate glow. The heating of **Nickel 200 alloy** in the oxidizing conditions at the elevated temperatures should be discarded due to the risk of intergranular oxidation of nickel.

It is prone to the intergranular corrosion by sulfur and metals like lead, tin, zinc and others that are comprised of lower melting point. The process of pickling is based on the condition of nickel 200 alloy.

Hot and cold formation

The **nickel 200 alloy** is readily hot formable to any specification. The complete temperature for deformation is not an essential factor in obtaining the hot malleability of material. The preferred temperature limit for hot processing is 1200oF to 2250oF or 650oC to 1230oC. The rigorous forging is preferred at temperature limits more than 1600oF or 870oC. The alloy stiffens immediately at the lower temperature ranges.

The slight forging is done at lower temperature than 1200oF or 650oC though it offers superior mechanical features. The laboratory tests on the forged discs are made in the ring applications that have shown that the tensile properties at 1200oF or 650oC can be enhanced by subjecting the alloy at the temperature of 1200oF or 650oC. The excellent temperature for the hot bending is 1600oF to 2250oF or 870oC to 1230oC.

While the alloy is in operation, care is made to avoid heating of nickel more than 2250oF or 1230oC. The furnace conditions for heating of **Nickel 200 alloy** are made in such a way to begin the burning of fuel prior to contact gases with the warm metal. The recommended fuels are sulfur free gas and oil. The fuel oil consisting of limited sulfur concentration offers the better outcomes if the process is undertaken carefully.

The gaseous utilized for alloy's heating should not possess more than 30 grains of whole sulfur per 100 cu feet of gas and recommended size should not be more than 15 grains of total sulfur per 100 cu ft. The reduction atmosphere is essential to discard the oxidation. The metals should be subjected to the hot furnace, withdrawn quickly upon reaching the required temperature and processed immediately. The steel rails should be offered to avoid the metal to contact the base or walls of the furnace. It is essential to secure the nickel metals from the roof spalling.

The **Nickel 200 alloy** can be processed by following the standard cold formation techniques. The alloy reacts like the mild steel though it has large elastic limit value so large power is needed to accomplish the operation. The manual tasks like spinning and hand hammering are followed for the simple configurations. Rigorous working is performed manually just with the support of periodic annealing to maintain the softness of alloy. The cupping and deep drawing dies are formed of gray iron, chilled iron and alloy casting.

The chromium plated toughened steel, tungsten carbide or diamond dies are utilized for wire and rod drawing of Nickel alloy. The die surfaces are superiorly polished. The tallow, soap, sulfur based oil, lard oil and other severe lubricants are utilized during the cold working.

The cold rolled sheet and **Nickel 200 strip** can be bent to large degree in the direction where the bend axis is vertical to the direction of rolling. In the annealing or stress relieving temper, the nickel condenser tubers can be readily expanded to the tube sheets for heat exchanger. The soft temper alloy material offers the desired end results in drawing and rigorous forming applications.

Machining of Nickel 200 and 201 Alloy

The Nickel 200 alloy can be machined adequately at the industrial rate by following the particular machining processes. The tools are grounded to high positive rake angles up to 40o to 45o to prevent the built up edges. The high speed or cast alloy equipments should be utilized. The chip performance is considerably better with the toughening temperatures.

The cold processed Nickel 200 rod shows enhancement in the annealed specimen.

Welding of Nickel 200 and 201 Alloy

The Nickel 200 alloy can be welded through traditional welding, soldering and brazing methods. Improved features can be obtained in the welded points. Obtaining the clean surface from the unwanted materials is essential to do welding smoothly.

The popular welding methods for Nickel 200 alloy are mentioned as following:

1. Shielded Metal-Arc Welding
2. Gas Tungsten-Arc &
3. Gas-Metal-Arc Welding
4. Nickel Welding Electrode 141
5. Nickel Filler Metal 61

The Nickel 200 alloy can also be welded to steel by Nickel Welding Electrode 141 and Nickel Filler Metal 61.