NICKEL 200

Nickel 200 (UNS N02200/W.Nr. 2.4060 & 2.4066) is commercially pure (99.6%) wrought nickel. It has good mechanical properties and excellent resistance to many corrosive environments. Other useful features of the alloy are its magnetic and magnetostrictive properties, high thermal and electrical conductivities, low gas content and low vapor pressure. Chemical composition is shown in Table 1.
The corrosion resistance of Nickel 200 makes it particularly useful for maintaining product purity in the handling of foods, synthetic fibers, and caustic alkalies; and also in structural applications where resistance to corrosion is a prime consideration. Other applications include chemical shipping drums, electrical and electronic parts, aerospace and missile components.

Physical properties

Physical constants and thermal properties are shown in Tables 2 and 3. Values for modulus of elasticity at various temperatures are in Table 4. The elastic properties were determined dynamically on annealed material.

Mechanical properties

- **Room-temperature properties**

Nominal mechanical properties of Nickel 200 are shown in Table 5. Figures 1 and 2 show the relationship between tensile properties and hardness of rod and strip.

Torsional Strength
The torsional properties of Nickel 200 are shown in Table 6. The breaking strength was computed with the assumption that at time of fracture the shear stress was equal across the entire section.
Shear Strength
Results of shear tests made in double shear on bars of varying hardness are shown in Table 7. The shear strength of rivet wire at various temperatures is shown in Table 8.
Compressive Strength
Compressive Strength is shown in Table 9.
Bearing Strength
The data given in Table 10 are from tests where the diameter of the pin was made only slightly smaller than the hole so as to have a tight fit. The maximum load for tearing out of the hole and the load required for a permanent enlargement of the hole diameter by 2% were determined and calculated to ultimate and yield strengths in bearing.
Impact Strength
Nickel is one of the toughest metals, as measured by Izod or Charpy impact tests. Both hot-rolled and annealed samples of Nickel 200 have higher impact strength than cold-worked material. The combination of good strength and impact properties is shown in Table 11. See also the section on low-temperature properties.

Fatigue and Corrosion Strength

Endurance limits for Nickel 200 rod in air and in fresh and salt water are shown in Table 12. The cold-drawn specimens used had an average tensile strength of 132.0 ksi (910 MPa) and the annealed specimens, 78.0 ksi (538 MPa). Although cold-worked material has a considerably higher endurance limit of 50.0 ksi (345 MPa) in air than annealed material of 33.0 ksi (228 MPa), the corrosion fatigue limits in fresh water and in salt water are very similar. Contrarily, the fatigue limits for cold-drawn rod are similar in air and in fresh water up to about 106 cycles. Also, a similarity in fatigue life up to about 106 x 4 cycles exists for annealed rod tested in air, fresh water and salt water.

- **High-temperature properties**

The mechanical properties of Nickel 200 at elevated temperatures are shown in Figures 3 and 4. However, Nickel 200 is normally limited to service at temperatures below 600°F (315°C). At higher temperatures Nickel 200 products can suffer from graphitization which can result in severely compromised properties. For service above 600°F (315°C), Nickel 201 is preferred. Nickel 200 and 201 are approved for construction of pressure vessels and components under ASME Boiler and Pressure Vessel Code Section VIII, Division 1. Nickel 200 is approved for service up to 600°F (315°C) while Nickel 201 is approved for service up to 1250°F (677°C).

- **Low-temperature properties**

Low-temperature tensile properties of Nickel 200 are shown in Tables 13 and 14. Figure 5 is a stress-strain diagram for the material from room to cryogenic temperatures. Fatigue and notch fatigue strengths appear in Figures 6 and 7; low-temperature impact strength is shown in Figure 8.

Metallography

Nickel 200 is a solid-solution alloy with a face-centered cubic structure. The microstructure typically exhibits a minor amount of nonmetallic inclusions, principally oxides, which are unchanged by annealing.

Corrosion Resistance

Nickel 200 is highly resistant to many corrosive media. Although most useful in reducing environments, it can be used also under oxidizing conditions that cause the development of a passive oxide film. The outstanding resistance of Nickel 200 to caustics is based on this type of protection. In all environments, when temperatures above 600°F (315°C) are involved, the preferred material is Nickel 201.

- **Atmosphere**

Nickel 200 normally remains bright in indoor atmospheres. Outdoors, the rate of attack is slow because of the formation of a thin protective film, usually a sulfate. This rate increases with increases in the sulfur dioxide content of the atmosphere (such as might occur in industrial areas). Corrosion rates in both marine and rural atmospheres are very low.
The results of two series of atmospheric-exposure tests are shown in Tables 15 and 16. In the 1957 tests, measurements of pit depths and losses in mechanical properties were practically nil.

- **Water**

The resistance of Nickel 200 to corrosion by distilled and natural waters is excellent. In distilled water, its corrosion rate has been found to be less than 0.01 mpy (0.0003 mm/a). Corrosion rates in domestic hot water up to 200°F (95°C) are normally less than 0.02 mpy (0.0005 mm/a) and only occasionally as high as 0.2 mpy (0.005 mm/a). Nickel 200 effectively resists water containing hydrogen sulfide or carbon dioxide. In distilled water saturated with 50:50 carbon dioxide and air at 160°F (71°C), its corrosion rate was less than 1 mpy (0.025 mm/a). It is used for oil well strainers where corrosion by hydrogen sulfide and brine must be combatted.
Nickel 200 gives excellent service in flowing sea water even at high velocity, but in stagnant or very low-velocity sea water severe local attack may occur under fouling organisms or other deposits.
In steam-hot water systems where the steam contains carbon dioxide and air in certain proportions, corrosion rates will be initially high but will decrease with time if conditions favor the formation of a protective film. Impurities such as iron corrosion products can interfere with the development of such a film, however. To prevent attack, such systems should include provisions for deaeration of the feedwater or venting of part of the noncondensables.

- **Acids**

Sulfuric
Nickel 200 can be used with sulfuric acid at low or moderate temperatures. Both aeration and increasing temperatures increase corrosion rates so that the principal use of Nickel 200 in sulfuric acid is in nonaerated solutions near room temperature. The presence of oxidizing salts will also accelerate corrosion. Some typical data are presented in Table 17.

Hydrochloric
According to the data available, Nickel 200 may be used in hydrochloric acid in concentrations up to 30%, either aerated or unaerated, at room temperature. An important reason for its success is that its corrosion product – nickel chloride – has a relatively low solubility in this range of concentration. Because of this reason, the material should be used only with caution when solutions are at high velocity. Also, both increasing temperature and aeration will accelerate corrosion. Its use in air-saturated hydrochloric acid above room temperature is usually limited to concentrations of less than 3-4%, but completely air-saturated solutions are not commonly used in industry. If oxidizing salts are present in any but very small amounts, corrosion will be increased. The behavior of Nickel 200 in various concentrations at approximately room temperature is shown in Figure 10. At less than 0.5% concentration, the material can be used satisfactorily up to 300°-400°F (150°-205°C).
Hydrofluoric
Nickel 200 has excellent resistance to anhydrous hydrofluoric acid even at elevated temperatures. In aqueous solutions, however, service is usually limited to below 180°F (80°C). Even at room temperature, 60-65% commercial-grade acid has been found to severely corrode Nickel 200. Some typical data are shown in Table 18.
Phosphoric
Nickel 200 has limited usefulness in commercial phosphoric acid solutions because they usually contain impurities such as fluorides and ferric salts that accelerate corrosion. In pure unaerated acid, corrosion rates are low for all concentrations at atmospheric temperatures. In hot or concentrated solutions, rates are usually too high for reasonable service life.

Nitric
Nickel 200 should be used in nitric acid only in solutions of up to 0.5% concentration at room temperature.
Organic
In general, Nickel 200 has excellent resistance to organic acids of all concentrations if aeration is not high. Some typical results are shown in Table 19. It has useful resistance to fatty acids such as stearic and oleic.

- **Alkalies**

The outstanding corrosion resistance characteristic of Nickel 200 is its resistance to caustic soda and other alkalies. (Ammonium hydroxide is an exception. Nickel 200 is not attacked by anhydrous ammonia or ammonium hydroxide in concentrations of 1%. Stronger concentrations can cause rapid attack.) There is a wide range of proven industrial applications for this material in plant processes involving alkalies. In caustic soda, Nickel 200 has excellent resistance to all concentrations up to and including the molten state. Below 50%, rates are negligible, even in boiling solutions. As concentration and temperature increase, corrosion rates increase very slowly. Examples of its performance under a variety of conditions is shown in Tables 20 and 21. The chief factor contributing to the outstanding performance of Nickel 200 in highly concentrated caustic soda is a black protective film that forms during exposure. This film – nickel oxide – results in a marked decrease in corrosion rates over long exposure under most conditions. Because the presence of chlorates in caustic increases corrosion rates significantly, every effort should be made to remove as much of them as possible. Oxidizable sulfur compounds also tend to increase the corrosivity of caustic to Nickel 200. Adding sufficient sodium peroxide to oxidize these sulfur compounds to sulfates will counteract this condition. Corrosion rates in caustic potash are shown in Table 22.

- **Salts**

Typical corrosion rates of Nickel 200 in a variety of salts are shown in Table 23. The metal is not subject to stress-corrosion cracking in any of the chloride salts and has excellent resistance to all of the nonoxidizing halides. Oxidizing acid chlorides such as ferric, cupric and mercuric are very corrosive and should be used with alloy 200 only in low concentrations. Stannic chloride is less strongly oxidizing, and dilute solutions at atmospheric temperature are resisted. The maximum safe limit for use of Nickel 200 in oxidizing alkaline chlorides is 500 ppm available chlorine for continuous exposure (see Table 24.) For intermittent exposure where a rinsing operation is included, concentrations of up to 3 gram/liter can be handled. In bleaching, sodium silicate (1.4 specific gravity) can be used as an inhibitor to corrosion; as little as 0.5 ml/liter of bleach has been found to be effective. Some very reactive and corrosive chlorides (phosphorus oxychloride, phosphorus trichloride, nitrosyl chloride, benzyl chloride and benzoyl chloride) are commonly contained in Nickel 200. It has excellent resistance to neutral and alkaline salt solutions. Even under severe exposure conditions, rates are usually less than 5 mpy (0.13 mm/a) (see Table 25).
In acid salts, rates may vary considerably, as shown in Table 26.

- **Fluorine and chlorine**

Although fluorine and chlorine are strong oxidizers that react with metal, Nickel 200 can be used successfully in such environments under certain conditions. At room temperature, Nickel 200 forms a protective fluoride film and is considered satisfactory for handling fluorine at low temperatures. At elevated temperatures, Nickel 201 is preferred. Nickel 200 effectively resists dry chlorine at low temperatures. Hydrogen chloride (formed from hydrogen and chlorine) when dry behaves similarly toward the metal. In wet chlorine at low temperature or wet hydrogen chloride at temperatures below the dew point, Nickel 200's performance is somewhat as in hydrochloric acid. It has been found that 0.25% moisture in hydrogen chloride did not affect corrosion rate of Nickel 200 – 0.3 mpy (0.008 mm/a) in both wet and dry gas at 400°F (205°C).

- **Bromine**

Nickel 200 was found to corrode at a rate of 0.04 mpy (0.001 mm/a) at room temperature in bromine commercially dried with sulfuric acid. In bromine saturated with water, corrosion rate was 2.5 mpy (0.064 mm/a). The material also resists attack from bromine vapor.

- **Phenol**

Phenol is commonly stored and transported in Nickel 200-clad steel tanks and tank cars because the alloy protects the phenol from contamination and discoloration.

Fabrication

- **Heating and Pickling**

Nickel 200 may be annealed over a wide range of temperatures above its recrystallization temperature. For heavily cold-worked material, temperature may be as low as 1100° to 1200°F (595° to 650°C), but from a practical viewpoint, the range is usually about 1300 to 1700°F (705° to 925°C). Because of the absence of a quantity of residual elements and secondary phases that tend to inhibit grain growth in more complex alloys, grain growth is rather rapid in Nickel 200 at elevated temperatures. Figure 11 shows the effect of various annealing temperatures on grain size. At higher temperatures, time at temperature must be carefully watched in order to exercise control over grain size. Batch annealing in box, retort, or open furnaces is usually performed in the range of 1300° to 1500°F (705° to 815°C) for about 30 minutes to 3 hours, depending on cross section and amount of contained cold work. Nickel 200 has relatively high thermal conductivity so that heating rate will be relatively rapid. Cooling rate is not critical, and quenching is not necessary except as a means to shorten the heat-treating cycle or to partially reduce any surface oxide developed during heating or cooling in an oxidizing atmosphere. This reduction is accomplished by quenching in water containing 2% alcohol. A soft oxide will remain which can be easily removed in standard pickling solutions. Continuous annealing in pusher-type, roller-hearth and conveyor-belt furnaces is usually done between 1450° and 1750°F (790° and 955°C) for about 15 to 45 minutes in the hot zone. Strip and wire may be strand-annealed at temperatures between 1600° and 1900°F (870° and 1040°C) from 5-10 minutes down to a few seconds in the hot zone. The fabricator should establish empirically specific heat treatments to provide proper control of grain size and properties by selecting the proper temperature range and running trials within that range to obtain the desired set of properties. A fine-to-medium grain necessary to maintain a smooth surface during forming is usually considered to be about 0.001 to 0.004 inch (0.025 to 0.10 mm), which corresponds to an ASTM grain size of 7½ to 3½. Annealing for periods of 1 hour or more at temperatures above 1700°F (925°C) will result in hardnesses of approximately 20 to 40 Rockwell B. This treatment, commonly called a dead-soft anneal, is used only in specialized applications such as burst diaphragms because of the low mechanical properties and coarse grain structure produced. Annealing should be performed in a reducing atmosphere to retain bright finishes. Dry hydrogen and dissociated ammonia are preferred, but less expensive atmospheres like partially burned natural gas will also provide adequate brightness. Heating in oxidizing atmospheres at high temperatures should be avoided because of the danger of intergranular oxidation. Nickel 200 is sensitive to intergranular attack from sulfur and metals such as lead, tin, zinc, and bismuth that have low melting points. Scrupulous care must be exercised to remove all traces of forming lubricants, marking paints and shop soil prior to heating.

Hot and Cold Forming

- **Hot Forming**

Nickel 200 can be readily hot-formed to practically any shape. Proper temperature during deformation is the most important factor in achieving hot malleability. The recommended temperature range for hot forming is 1200° to 2250°F (650° to 1230°C). All heavy forging should be done above 1600°F (870°C); the metal stiffens rapidly below this temperature. Light forging below 1200°F (650°C), however, will produce higher mechanical properties. Laboratory experiments on forged discs for ring applications have indicated that tensile properties at 1200°F (650°C) can be increased by upsetting the material 50% at 1200°F (650°C). The best temperature range for hot bending is 1600° to 2250°F (870° to 1230°C). In any operation, care should be exercised to avoid heating Nickel 200 above the upper temperature limit of 2250°F (1230°C). Furnaces for heating Nickel 200 should be designed so that fuel combustion occurs before the gases contact the hot metal. The preferred fuels are sulfur-free gas and oil. Fuel oils of low sulfur content (under 0.5%) will give good results if proper precautions are taken. Gas used for heating Nickel 200 must not contain more than 30 grains of total sulfur per 100 cu ft of gas (0.68 g/m^3) and preferably not more than 15 grains of total sulfur per 100 cu ft (0.34 g/m^3). A reducing atmosphere is necessary to avoid oxidation. The metal should be charged to a hot furnace, withdrawn as soon as the desired temperature is reached and worked rapidly. Steel rails, or other means of support, should be provided to prevent the metal from contacting the bottom or sides of the furnace. It may be necessary to protect the metal from roof spallings.

- **Cold Forming**

Nickel 200 can be worked by all conventional cold-forming methods. Generally, the alloy will behave similarly to mild steel, except that, because of the higher elastic limit of Nickel 200, greater power will be required to perform the operations. Thus, manual operations such as spinning and hand hammering are limited to simple shapes. Severe work can be done manually only with the assistance of frequent anneals to restore softness. Cupping and deep-drawing dies are made of gray iron, chilled iron, and alloy castings. Chromium-plated hardened steel, tungsten-carbide or diamond dies are used for wire and rod drawing. All die surfaces should be highly polished. Tallow, soap, sulfur-based oil, lard oil and similar heavy lubricants are used in connection with cold-working operations. Cold-rolled sheet and strip may be bent to a greater degree in the direction where the bend axis is perpendicular to the direction of rolling. In either the annealed or stress-relieved temper, Nickel 200 condenser tubes can be readily expanded into tube sheets for heat exchangers. The use of soft-temper material generally will yield the most satisfactory results in drawing and severe forming operations. Cold-rolled (not stretcher-leveled) and annealed sheet is in the best condition for spinning and other manual work.

- **Machining**

Nickel 200 can be machined satisfactorily at commercial rates providing that the practices outlined in the Special Metals publication “Machining” are carefully followed. This material tends to flow under pressure of the tool cutting edge and form long stringy chips. To avoid a built-up edge, tools should be ground with very high positive rake angles; 40° to 45° rake angles have been used in some instances. High-speed-steel or cast-alloy tools should be used. Chip action is substantially better with material in the harder tempers, so that cold-drawn rod in the as-drawn or stress-relieved temper will offer an improvement over annealed material.

NICKEL 201

Nickel 201 (UNS N02201/W.Nr. 2.4061 and 2.4068) is the low-carbon version of Nickel 200. Composition is shown in Table 28. Typical applications are caustic evaporators, combustion boats, plater bars, and electronic components.
Nickel 201, because of its low base hardness and lower work-hardening rate, is particularly suited for spinning and cold forming. It is preferred to Nickel 200 for applications involving exposure to temperatures above 600°F (315°C).

Physical properties
Some physical constants and thermal properties are shown in Tables 29 and 30.

Mechanical properties
Nominal mechanical properties of Nickel 201 are shown in Table 31.

High-temperature properties
The mechanical properties of Nickel 201 at elevated temperatures are shown in Figures 12, 13 and 14. Due to its low carbon content, Nickel 201 is resistant to graphitization so it can be used at temperatures above 600°F. Nickel 201 is approved for construction of pressure vessels and components under ASME Boiler and Pressure Vessel Code Section VIII, Division 1. Nickel 201 is approved for service up to 1250°F.

Corrosion Resistance
Nickel 201 has the excellent corrosion resistance characteristic of Nickel 200. Because it is a low-carbon material (0.02% max.), alloy 201 is not subject to embrittlement by intergranularly precipitated carbon or graphite when held at temperatures of 600° to 1400°F (315° to 760°C) for extended times, provided carbonaceous materials are not in contact with it. It is, therefore, preferred to Nickel 200 in all cases where temperatures exceed 600°F (315°C). Nickel 201 is used for laboratory crucibles that must be capable of withstanding oxidizing furnace atmospheres up to 2000°F (1100°C). The material is subject to intergranular embrittlement by sulfur compounds at temperatures above 600°F (315°C).

- **Caustic Soda**

Nickel 201 is very widely used to handle caustic soda. In the isocorrosion chart shown in Figure 15, at only above 75% caustic concentration and near the boiling point, did the corrosion rate start to go above 1 mpy (0.025 mm/a). Like Nickel 200, Nickel 201 forms an oxide film that protects it in caustic. For example, specimens in a caustic solution (2 kg technical-grade flake caustic in 500 cc water) at 790°-830°F (420°-445°C) corroded 21 mpy (0.53 mm/a) in 24 hr. By that time they had developed an oxide coating. At the end of a week, corrosion rate dropped to 2.8 mpy (0.07 mm/a) for an additional week when the test was concluded. Results of laboratory tests in sodium hydroxide solutions of varying concentrations are shown in Figure 16. The typical thin black oxide film was found on some of the samples in the tests at boiling temperature. Chlorates in caustic will accelerate corrosion and as much of them as possible should be removed. Oxidizable sulfur compounds are also harmful, but, by adding sodium peroxide to change them to sulfates, their effect can be minimized. In certain high-temperature caustic applications where sulfur is present, ALLOY 600 is used rather than Nickel 201 because of its greater resistance to sulfur embrittlement.

- **Fluorine and Chlorine**

In comparison with other commercial metals and alloys, Nickel 201 has outstanding resistance to dry fluorine. Some typical corrosion rates are shown in Table 32.
Nickel 201 and ALLOY 600 are the most practical alloys for service in chlorine or hydrogen chloride at elevated temperatures. Table 33 shows temperatures at which various corrosion rates were exceeded and a suggested upper temperature limit for continuous service. These limits are believed to be conservative since longer testing times will show the effect of a protective chloride developed. For instance, in 500-hr laboratory corrosion test in anhydrous hydrochloric acid gas at 930°F (500°C), Nickel 201 corroded only 3 mpy (0.08 mm/a).
Studies have shown the effect of 0.25% moisture in hydrogen chloride on corrosion of Nickel 201 at 1000°F (540°C); see Table 34.
Nickel 201 has been successfully used for chlorination equipment at temperatures up to 1000°F (540°C) and for cylindrical retorts for the sublimation of zirconium chloride at temperatures of 800° to 1000°F (425° to 540°C).

- **Hydrofluoric Acid**

Nickel 201 can be used effectively in hydrofluoric acid provided there are no conditions of flowing under which its protective fluoride film would be removed. Aeration or the presence of oxidizing chemicals will also increase corrosion rates. As an example of its performance, corrosion rate in anhydrous hydrogen fluoride (hydrofluoric acid gas) at temperatures of 930°-1100°F (500°-595°C) was 36 mpy (0.91 mm/a).

Fabrication

Nickel 201 can be readily formed by most commercial practices. The same procedures should be used as for Nickel 200, with consideration made for a slightly lower range of mechanical properties. Annealing temperatures should be 50° to 100°F (30° to 55°C) lower or times-at-temperature 10 to 20% shorter than for Nickel 200.

Table 1 - Limiting Chemical Composition, %

Nickel (plus cobalt)	99.0 min.
Copper	0.25 max.
Iron	0.40 max.
Manganese	0.35 max.
Carbon	0.15 max.
Silicon	0.35 max.
Sulfur	0.01 max.

Table 2 - Physical Constants

Density, lb/in³	0.321
g/cm³	8.89
Melting Range, °F	2615-2635
°C	1435-1446
Specific Heat, Btu/lb•°F	0.109
J/kg•°C	456
Curie Temperature, °F	680
°C	360

Table 3 - Thermal Properties of Annealed Nickel 200

Temperature	Coefficient of Expansion	Thermal Conductivity	Electrical Resistivity
°F	10^{-6} in/in•°F	Btu•in/ft²•h•°F	ohm•circ mil/ft
-423	4.7	–	–
-300	5.8	–	16
-200	6.2	533	26
-100	6.3	516	36
0	–	499	48
70	–	487	58
200	7.4	463	76
400	7.7	426	113
600	8.0	389	164
800	8.3	389	204
1000	8.5	404	228
1200	8.7	421	248
1400	8.9	437	269
1600	9.1	455	289
1800	9.3	472	306
2000	9.5	–	323
°C	µm/m•°C	W/m•°C	µΩ•m
-200	10.1	–	–
-100	11.3	75.5	0.050
20	–	70.3	0.096
100	13.3	66.5	0.130
200	13.9	61.6	0.185
300	14.2	56.8	0.260
400	14.8	55.4	0.330
500	15.3	57.6	0.365
600	15.5	59.7	0.400
700	15.8	61.8	0.430
800	16.2	64.0	0.460
900	16.6	66.1	0.485
1000	16.9	68.2	0.510
1100	17.1	–	0.540

Table 4 - Modulus of Elasticity

Temperature	Young's Modulus	Shear Modulus	Poisson's Ratio	Temperature	Young's Modulus	Shear Modulus	Poisson's Ratio
°F	10³ ksi	10³ ksi		°C	GPa	GPa	
78	29.7	11.55	0.29	26	205	79.6	0.29
200	29.1	11.30	0.29	100	200	77.9	0.28
400	28.3	11.00	0.29	200	195	75.8	0.29
600	27.4	10.66	0.29	300	190	73.8	0.29
800	26.4	10.27	0.29	400	183	71.4	0.28
1000	25.2	9.80	0.29	500	177	69.0	0.28

Table 5 - Nominal Mechanical Properties

Form	Tensile Strength		Yield Strength (0.2% Offset)		Elongation in 2 in. (51 mm), %	Hardness	
	ksi	MPa	ksi	MPa		Brinell (3000 kg)	Rockwell B
Rod and Bar							
Hot-Finished	60-85	415-585	15-45	105-310	55-35	90-150	45-80
Cold-Drawn	65-110	450-760	40-100	275-690	35-10	140-230	75-98
Cold-Drawn, Annealed or Hot-finished, Annealed	55-75	380-520	15-30	105-210	55-40	90-120	45-70
Plate							
Hot-Rolled	55-100	380-690	20-80	140-550	55-35	100-150	55-80
Hot-Rolled, Annealed	55-80	380-550	15-40	105-275	60-40	90-140	45-75
Sheet							
Hard	90-115	620-795	70-105	480-725	15-2	–	90 min.
Annealed	55-75	380-520	15-30	105-210	55-40	–	70 max.
Strip							
Spring	90-130	620-895	70-115	480-795	15-2	–	95 min.
Annealed	55-75	380-520	15-30	105-210	55-40	–	64 max.
Tubing							
Stress-Relieved	65-110	450-760	40-90	275-620	35-15	–	75-98
Annealed	55-75	380-520	12-30	85-210	60-40	–	70 max.
Condenser and Evaporator Tubing							
Annealed	55-75	380-520	15-30	105-210	60-40	–	65 max.
Stress-Relieved	65-110	450-760	40-90	275-620	35-20	–	75-98
Wire, Cold-Drawn							
Annealed	55-85	380-580	15-50	105-345	50-30	–	–
No. 1 Temper	70-95	485-655	40-75	275-520	40-20	–	–
Spring Temper	125-145	860-1000	105-135	725-930	15-2	–	–

Table 6- Torsional Properties of Cold-Drawn Nickel 200 Rod (1-inch diameter)

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

Table 7 - Shear Strength of Nickel 200 Bar

Temper	Shear Strength, (Double Shear)		Tensile Strength		Hardness, Rockwell B
	ksi	MPa	ksi	MPa	
Annealed	52.0	359	68.0	469	46
Half-Hard	58.0	400	79.0	545	90
Full-Hard	75.0	517	121.0	834	100

Table 9 - Compressive Strength of Nickel 200

Property	Hot-Rolled		Cold-Drawn 24%		Annealed	
	ksi	MPa	ksi	MPa	ksi	MPa
Compressive Data						
Yield Strength (0.2% offset)	23.0	159	58.0	400	26.0	179
Tensile Data						
Breaking Strength	710	490	87.0	600	73.0	503
Yield Strength (0.2% offset)	24.0	165	62.0	427	27.0	186
Hardness						
Brinell (3000 kg)	107		177		109	

Table 8- Shear Strength of Nickel 200 Rivet Wire

Property	Temper			
	Soft		1 B&S No.	
	ksi	MPa	ksi	MPa
Shear Strength				
Room Temperature	41.0	283	45.0	310
1/2 hr at temperature				
600°F (315°C)	39.5	272	42.5	293
800°F (430°C)	34.0	234	37.0	255
1000°F (540°C)	26.5	183	28.5	197
24 hr at temperature				
800°F (430°C)	35.5	245	36.5	252
1000°F (540°C)	27.0	186	29.0	200
Yield Strength (0.2% offset)	46.5	321	67.5	465
Tensile Strength	65.0	448	73.5	507
Elongation in 2 in. (51 mm), %	36		12	

Table 10 - Bearing Strength of Nickel 200 Sheet

Condition	Tensile Strength		Yield Strength (0.2% offset)		Elongation in 2 in. (51 mm) %	Bearing Strength				Ratio of Bearing to	
						Ultimate Strength (Tearing out)		Yield Strength[b]		Tensile Strength	Yield Strength
	ksi	MPa	ksi	MPa		ksi	MPa	ksi	MPa		
Soft	59.6	411	28.7	198	39.0	125.5	865	50.3	346	2.11	1.75
Half-Hard	67.6	470	55.5	383	30.0	151.5	1045	97.9	675	2.24	1.77
Hard	99.0	683	88.9	613	18.0	179.0	1234	133.5	920	1.81	1.50

Table 11 - Impact Properties of Nickel 200

Condition	Hardness, Brinell (3000 kg)	Izod				Charpy V		Charpy Torsion			Charpy Tension			
		ft-lb	J	ft-lb/ sq in.	J/ mm^2	ft-lb	J	ft-lb	J	Twist, °	ft-lb	J	Elong. in 3.54 in. (89.9 mm), %	Reduction of Area, %
Hot-Rolled	107	120	163	932	1.95	200	271	29	39	103½	98	132	20.0	83.1
Cold-Drawn														
24% Reduction, Stress-Relieved	177	120	163	966	2.03	204	277	35	47	102	88	119	19.5	71.2
Cold-Drawn														
Annealed at 1350°F (732°C)/3 hr	109	120	163	980	2.06	228	309	29	39	103	113	153	33.0	75.1

Table 12 - Fatigue and Corrosion Fatigue of Nickel 200 Rod

No. of Cycles	Stress to Cause Failure											
	Cold-Drawn Rod in						Annealed Rod in					
	Air		Fresh Water		Salt Water		Air		Fresh Water		Salt Water	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
10^4	109.0	752	110.0	758	–	–	–	–	–	–	–	–
10^5	84.0	579	80.0	552	–	–	52.0	359	52.0	359	52.0	359
10^6	63.0	434	56.0	386	54.0	372	40.0	276	39.0	269	37.0	255
10^7	52.0	359	34.0	234	30.0	207	34.0	234	27.0	186	24.0	165
10^8	50.0	345	26.0	179	23.0	159	33.0	228	23.0	159	21.0	145
10^9	50.0	345	24.0	165	21.0	145	33.0	228	23.0	159	21.0	145

Table 13 - Low-Temperature Tensile Properties of Annealed Nickel 200 Bar

Temperature		Diameter		Tensile Strength		Yield Strength		Elongation %	Reduction of Area %
°F	°C	in.	mm	ksi	MPa	ksi	MPa		
-423	-255	1.00	25.4	–	–	–	–	–	–
		0.750	19.0	110.0	758	37.5	259	60	70
-300	-185	1.00	25.4	100.0	690	28.5	197	53	75
		0.750	19.0	90.0	621	27.5	190	61	75
-200	-130	1.00	25.4	82.5	569	27.0	186	46	78
		0.750	19.0	78.0	538	24.0	165	57	68
-100	-75	1.00	25.4	76.0	524	27.0	186	43	72
		0.750	19.0	71.0	490	22.0	152	51	65
0	-20	1.00	25.4	70.0	483	24.5	169	44	75
		0.750	19.0	66.0	455	21.5	148	49	65
70	21	1.00	25.4	65.0	448	25.0	172	42	78
		0.750	19.0	64.0	441	21.0	145	48	66

Table 14 - Low-Temperature Tensile Properties of Nickel 200

Condition	Temperature		Tensile Strength		Yield Strength (0.2% offset)		Elongation in 2 in. (51 mm) %	Reduction of Area %	Hardness Rockwell C
	°F	°C	ksi	MPa	ksi	MPa			
Hot-Rolled	-310	-190	103.0	710	–	–	51.0	–	–
	-292	-180	98.0	676	28.0	193	–	–	–
	-112	-80	76.4	527	27.5	190	–	–	–
	Room	Room	65.6	452	24.6	169	50.0	–	–
Cold-Drawn	-110	-79	112.3	774	101.8	702	21.5	60.9	22
	Room	Room	103.4	713	97.4	672	16.3	66.9	19

Table 15 - Effect of Atmospheric Exposure on Corrosion of Nickel 200 (20-yr study begun in 1931).

Site	Corrosion Rate	
	mpy	mm/a
Heavy Railroad - Industrial (Altoona, PA)	0.222	0.0056
Urban - Industrial (New York City, NY)	0.144	0.0036
Rural (State College, PA)	0.0085	0.0002
Semi-arid - Rural (Phoenix, AZ)	0.0015	0.00004

Table 16 - Effect of 2-yr Atmospheric Exposure (1957) on Corrosion of Nickel 200

Site	Weight Loss, gram	Corrosion Rate	
		mpy	mm/a
East-Coast Marine (Kure Beach, NC)	0.23	0.012	0.0003
Industrial (Newark, NJ)	1.50	0.079	0.0020
West-Coast Marine (Point Reyes, CA)	0.13	0.007	0.0002
Rural (State College, PA)	0.22	0.012	0.0003

Table 17 - Corrosion of Nickel 200 in Sulfuric Acid (Lab Tests)

Acid Concentration, %	Temperature		Velocity		Corrosion Rate			
					Unaerated		Air-saturated	
	°F	°C	fpm	m/min	mpy	mm/a	mpy	mm/a
1	86	30	15.5	4.7	–	–	49	1.2
	172	78	15.5	4.7	–	–	110	2.79
2	70	21	None	None	2	.051	–	–
5	65	18	None	None	2.2	.056	–	–
	86	30	16.0	4.9	9	0.23	61	1.55
	140	60	None	None	10	0.25	–	–
	140	60	15.5	4.7	–	–	88	2.2
	160	71	16.0	4.9	–	–	103	2.62
	170	77	None	None	21	0.53	–	–
	172	78	15.5	4.7	30	0.76	200	5.08
10	70	21	None	None	1.7	0.43	–	–
	140	60	15.0	4.7	–	–	89	2.3
	170	77	None	None	12	0.30	–	–
	176	80	None	None	–	–	120	3.05
20	70	21	None	None	4	0.10	–	–
25	180	82	26.0	7.9	–	–	83	2.1
48	158	70	None	None	18	0.46	–	–
50	86	30	16.0	4.9	–	–	16	0.41
70	100	38	15.5	4.7	29	0.74	–	–
93	86	30	15.5	4.7	–	–	10	0.25
	149	65	None	None	146	3.71	–	–
95	70	21	None	None	71	1.8	–	–

Table 18 - Plant Corrosion Tests of Nickel 200 in Hydrofluoric Acid Alkylation Processes

Test Conditions	Temperature (Ave. to max.)		Corrosion Rate	
	°F	°C	mpy	mm/a
Inlet side of preheater channel. Liquid composition: 79-92% hydrofluoric acid; 0.8-2.5% water; Remainder, isobutane and acid-soluble oil.	120-135	50-55	1.1	0.03
Outlet side of preheater channel. Composition, same as above.	235-260	115-125	3.5	0.09
Top of regeneration column just below vapor outlet. Composition: 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	135-150	13	0.33
Top of regeneration column. Composition: Equal parts of 93% hydrofluoric acid and isobutane vapor.	215-220	100-105	14	0.36
Bottom of regeneration column, acid tar containing 1-10% hydrofluoric acid and water in 1:1 ratio.	250 ave.	120 ave.	11	0.28
Bottom of regeneration column, beneath grid plate. Feed to column contains 85.2% hydrofluoric acid, 1.6% water and oils.	220-250	105-120	18	0.46
Bottom of dehydrator column beneath bottom plate. Feed contains 89.3% hydrofluoric acid 1.6% water.	225-250	105-120	68	1.7
Top of hydrofluoric acid stripper column above top tray. Composition of vapor: 10% hydrofluoric acid, 90% light hydrocarbons.	110-150	45-65	0.7	0.02

Table 19 - Corrosion of Nickel 200 by Organic Acids

Test Conditions	Temperature °F	Temperature °C	Corrosion Rate mpy	Corrosion Rate mm/a
99% acetic anhydride, 1% acetic acid in a still	310	155	0.2	0.005
60% acetic anhydride, 40% acetic acid in a still	284	140	0.6	0.015
Acetic acid, air-saturated				
0.10% solution	Room	Room	10	0.25
5% solution	Room	Room	40	1.02
85% solution	Room	Room	400	10.2
Distillation of butyric acid				
Liquid	230-265	110-130	36	0.91
Vapor	212-250	100-120	9	0.2
2% butyric acid, liquid	Room 160	Room 70	2.3 5.4	0.06 0.14
Laboratory immersion test in 2% citric acid	Room 160	Room 70	0.8 5.5	0.02 0.14
Laboratory aerated test in 2% citric acid	180	80	34	0.86
Laboratory test in 5% citric acid				
Immersed	86	30	5	0.13
Aerated	86	30	15	0.38
Immersed	140	60	20	0.51
Laboratory immersion test in 58% citric acid	Boiling	Boiling	17	0.43
90% formic acid in storage tank				
Liquid	Room	Room	4	0.10
Vapor	Room	Room	7	0.18
90% formic acid in a still				
Liquid	212	100	18	0.45
Vapor	212	100	7	0.18
Laboratory immersion test in 50% hydroxyacetic acid	86 Boiling	30 Boiling	0.3 7.6	0.008 0.19
Laboratory immersion test in 2% lactic acid	Room 160	Room 70	2.1 3.4	0.05 0.09
10-22% lactic acid in vacuum evaporator	130	55	51	1.3
Laboratory immersion test in 85% lactic acid	Room	Room	2.7	0.07
Up to 85% lactic acid in vacuum evaporator	120-180	50-80		
Liquid phase			10	0.25
Vapor phase			11	0.28
66% propionic, 17% iso-butyric, and 17% n-butyric acids in reboiler liquid	300	150	24	0.61
57% tartaric acid in vacuum evaporating pan	130	55	7.5	0.19

Table 20 - Laboratory Corrosion Tests of Nickel 200 in 50% Caustic Soda

Temperature °F	Temperature °C	Pressure	Velocity fpm	Velocity m/min	Duration of test, hr	Corrosion Rate mpy	Corrosion Rate mm/a
86	30	Atmos.	–	–	120	0.06	0.0015
86	30	Atmos.	–	–	24	0.3	0.008
195	90	Atmos.	15	4.6	24	0.55	0.014
212	100	610 mm	–	–	24	0.7	0.018
212	100	610 mm	–	–	240	0.07	0.0018
212	100	620 mm	–	–	264	0.5	0.013
266	130	Atmos.	–	–	720	1.1	0.028
302	150	Atmos.	–	–	336	0.4	0.010
310	155	Atmos.	–	–	672	0.5	0.013
310	155	5 psi (260 mm)	75	23	20	1.2	0.030

Table 21 - Corrosion of Nickel 200 in Caustic Soda Solutions

Environment	Temperature °F	Temperature °C	Corrosion Rate mpy	Corrosion Rate mm/a
Lab tests in 4% solution	Room	Room		
-Quiet immersion			0.05	0.001
-Air-agitated immersion			0.05	0.001
-Continuous alternate immersion			0.50	0.010
-Intermittent alternate immersion			0.60	0.015
-Spray test			0.05	0.001
Plant tests in 14% solution in first effect of multiple-effect evaporator	190	90	0.02	0.0005
Plant tests in 23% solution in tank receiving liquor from evaporator	220	105	0.16	0.004
Plant tests in single-effect evaporator concentrating solution from 30 to 50%	179	80	0.10	0.0025
Plant tests in evaporator concentrating to 50% solution	–	–	0.1	0.003
Lab tests during concentration from 32 to 52% (vacuum, 640 -685 mm Hg)	185-196	85-90	1.3	0.03
Tests in storage tank containing 49-51% solution	131-167	55-75	0.02	0.0005
Lab tests in 75% solution	250 400	120 205	1.0 0.8	0.025 0.02
Plant tests in 70% electrolytic solution in receiving tank	194-239	90-115	0.1	0.003

Table 22 - Laboratory corrosion tests of Nickel 200 in Caustic Potash

Environment	Temperature °F	Temperature °C	Corrosion Rate mpy	Corrosion Rate mm/a
30% solution, saturated with potassium chloride, 0.05% potassium chlorate	Boiling	Boiling		
Liquid			0.2	0.005
Vapor			0.3	0.008
47% solution, saturated with potassium chloride, 0.078% potassium chlorate	Boiling	Boiling		
Liquid			0.1	0.003
Vapor			0.3	0.008
50% solution, Velocity:				
21.6 ft/min (6.58 m/min)	300	150	(Gain)	(Gain)
348 ft/min (106 m/min)	300	150	(Gain)	(Gain)
70% solution, Velocity:				
21.6 ft/min (6.58 m/min)	300	150	0.4	0.010
348 ft/min (106 m/min)	300	150	1.6	0.041

Table 23 - Corrosion of Nickel 200 in Salts

Test Conditions	Temperature		Corrosion Rate	
	°F	°C	mpy	mm/a
Plant test in mixture of arsenic trichloride (72-100%) and sulfur monochloride (0.28%) with some vapor & condensate	248-266	120-130	1.3	0.033
Plant test, evaporating 37% manganous chloride, specimen half submerged	210-225	100-110	30	0.76
Laboratory test in phosphorus pentachloride	169 302	75 150	0.2 0.3	0.005 0.007
Plant test in mixture of phosphoric, hydrochloric & cresylic acids with phosphorus oxychloride. Test spool at liquid line.	180	80	17	0.43
Plant test in evaporator concentrating a mixture of magnesium & calcium chloride brines to 50% chlorides under vacuum	Boiling	Boiling	3	0.08
Plant test in distillation of crude tin tetrachloride. Specimen below liquid.	220-240	105-115	3.9	0.10

Table 24 - Corrosion of Nickel 200 in Sodium Hypochlorite Sterilizing Solutions at 77°F (25°C)

Available Chlorine, ppm	Corrosion Rate	
	mpy	mm/a
35	0.1	0.003
100	0.3	0.008
500	0.8	0.020

Table 25 - Corrosion of Nickel 200 by Solutions of Neutral and Alkaline Salts

Test Conditions	Temperature		Corrosion Rate	
	°F	°C	mpy	mm/a
Cobalt acetate in evaporator	225	110	4	0.10
Sodium metasilicate in evaporattor concentrating solution to 50%	230	110	0.02	0.0005
Sodium sulfate, saturated solution, pH 9-10, in slurry tank	170	75	0.8	0.020
Sodium hydrosulfide, 45% solution in storage tank	120	50	0.1	0.003

Table 26 - Corrosion of Nickel 200 in Solutions of Acid Salts

Test Conditions	Temperature		Corrosion Rate	
	°F	°C	mpy	mm/a
Aluminum sulfate, quiet immersion in 25% solution in storage tank	95	35	0.6	0.015
Aluminum sulfate in evaporator concentrating solution to 57%	240	115	59	1.50
Ammonium chloride in evaporator concentrating solution from 28 to 40%	216	102	8.4	0.21
Ammonium sulfate, saturated solution containing 5% sulfuric acid in suspension tank during crystallization	106	41	3.0	0.076
Manganese chloride plus some free hydrochloric acid, immersed in boiling 11.5% solution in flask equipped with reflux condenser	214	101	8.7	0.22
Manganese sulfate in evaporator concentrating solution from 1.250-1.350 specific gravity	235	115	2.9	0.074
Zinc chloride in evaporator concentrating solution from 7.9 to 21% under 26-28 in. (6.5-7.0 kPa) vacuum	100	40	4.6	1.12
Zinc chloride in evaporator concentrating solution from 21 to 69% under 15-18 in. (3.7-4.5 kPa) vacuum	240	115	40	1.02
Zinc sulfate, saturated solution containing trace of sulfuric acid in evaporating pan, vigorous stirring	225	110	25	0.64

Table 27 - Resistance Spot Welding of Nickel 200

Weld Time, cycles	Shear Strength	
	lb	N
2	1125	5004
3	1128	5017
4	1170	5204
5	1280	5693

Table 28 - Limiting Chemical Composition, %

Nickel (plus cobalt)	99.0 min.
Copper	0.25 max.
Iron	0.40 max.
Manganese	0.35 max.
Carbon	0.02 max.
Silicon	0.35 max.
Sulfur	0.01 max.

Table 29 - Physical Constants

Density, lb/in^3	0.321
g/cm^3	8.89
Specific Heat, Btu/lb•°F	0.109
J/kg•°C	456
Curie Temperature, °F	680
°C	360
Modulus of Elasticity (Tension), 10^3 ksi	30
GPa	207

Table 30 - Thermal Properties of Annealed Nickel 201

Temperature	Coefficient of Expansion	Thermal Conductivity	Electrical Resistivity
°F	10^{-6} in/in•°F	Btu•in/ft^2•h•°F	ohm•circ mil/ft
-320	–	–	10
-300	–	662	–
-200	–	630	19
-100	–	598	29
0	–	569	43
80	–	550	51
200	7.3	512	71
300	7.6	485	89
400	7.7	460	110
500	7.9	433	135
600	8.1	408	160
800	8.4	392	209
1000	–	410	232
1200	–	428	253
1400	–	445	274
1600	–	463	291
1800	–	480	308
°C	µm/m•°C	W/m•°C	µΩ•m
-100	–	88.3	0.040
20	–	79.3	0.085
100	13.2	73.4	0.125
200	13.9	66.3	0.175
300	14.4	59.9	0.250
400	14.9	56.1	0.330
500	–	58.2	0.375
600	–	60.6	0.405
700	–	62.8	0.435
800	–	65.1	0.465
900	–	67.7	0.490
1000	–	69.9	0.515

Table 31 - Nominal Mechanical Properties of Nickel 201

Form	Tensile Strength		Yield Strength (0.2% Offset)		Elongation in 2 in. (51 mm), %	Hardness	
	ksi	MPa	ksi	MPa		Brinell	Rockwell B
Rod and Bar							
Hot-Finished and Hot-Finished, Annealed	50-60	345-415	10-25	70-170	60-40	75-100	–
Cold-Drawn	60-100	415-690	35-90	240-620	35-10	125-200	–
Cold-Drawn, Annealed	50-60	345-415	10-25	70-170	60-40	75-100	–
Plate							
Hot-Rolled	50-70	345-485	12-35	83-240	60-35	–	–
Hot-Rolled, Annealed	50-70	345-485	12-35	83-240	60-40	–	–
Tube and Pipe (Seamless)							
Cold-Drawn, Annealed	50-70	345-485	10-28	70-195	60-40	–	62 max.
Stress-Relieved	60-105	415-725	30-85	205-585	35-15	–	70-95

Table 32 - Corrosion of Nickel 201 in Dry Fluorine

Temperature		Corrosion Rate	
°F	°C	mpy	mm/a
752	400	8.4	0.21
842	450	22.8	0.579
932	500	61.2	1.55
1112	600	348	8.84
1202	650	192	4.88
1292	700	408	10.4

Table 33 - Corrosion of Nickel 201 in Dry Chlorine & Dry Hydrogen Chloride

Given Corrosion Rate, mpy	Dry Chlorine		Dry Hydrogen Chloride	
	Approx. Temperature at Which Given Corrosion Rate is Exceeded in Short-time Tests			
	°F	°C	°F	°C
30	950	510	850	455
60	1000	540	950	510
120	1100	595	1050	565
600	1200	650	1250	675
1200	1250	675	1300	705
Suggested upper temperature limit for continuous service				
	1000	540	950	510

Table 34 - Corrosion of Nickel 201 in Hydrogen Chloride at 1000°F (540°C)

Time, hr	Corrosion Rate			
	Wet Gas		Dry Gas	
	mpy	mm/a	mpy	mm/a
4	120	3.05	–	–
8	70	1.78	–	–
20	28	0.71	37	0.94

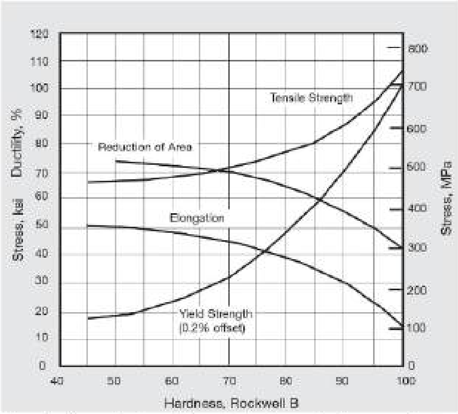

Figure 1 - Approximate relationship between tensile properties and hardness of Nickel 200 rod.

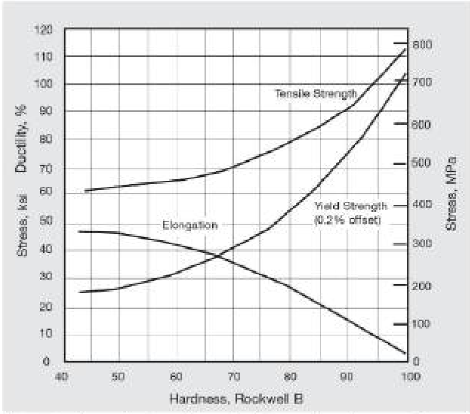

Figure 2 - Approximate relationship between tensile properties and hardness of Nickel 200 sheet and strip.

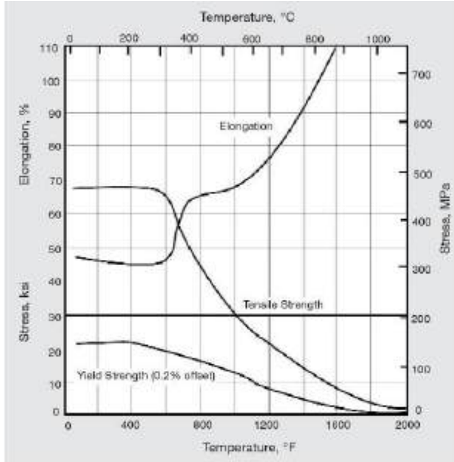

Figure 3 - High-temperature tensile properties of annealed Nickel 200.

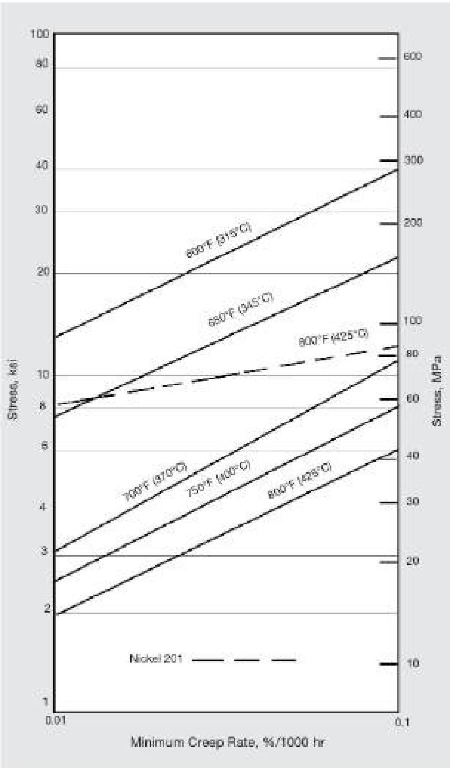

Figure 4 - Typical creep strength of annealed Nickel 200.

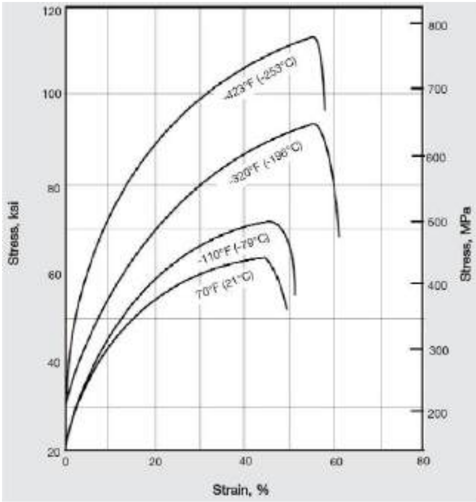

Figure 5 - Stress-strain diagram for annealed 0.750-in. (19-mm) Nickel 200 bar at low temperatures.

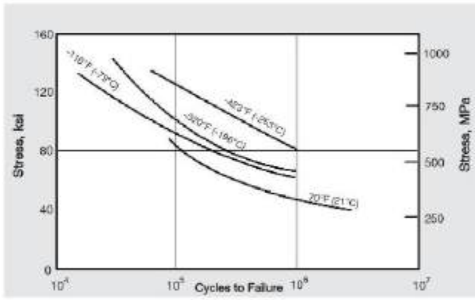

Figure 6 - Low-temperature fatigue strength of annealed Nickel 200 sheet, 0.021 in. (0.53 mm) thick. (Tested in completely reversed bending; tensile strength of material, 61.6 ksi (425 MPa).)

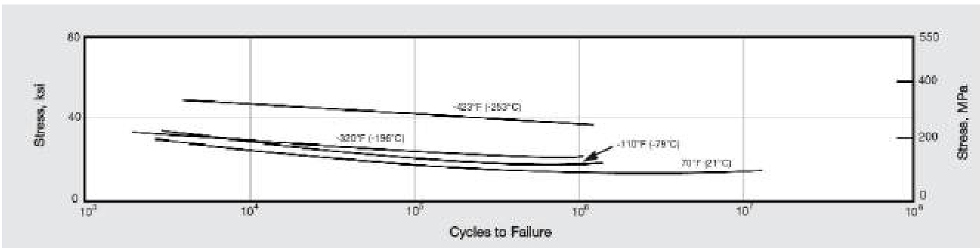

Figure 7 - Low-temperature notch-fatigue strength of annealed Nickel 200 sheet, 0.021 in. (0.53 mm) thick. (Tested in completely reversed bending; tensile strength of material, 61.6 ksi (425 MPa); notch concentration factor (K_t), 3.0.)

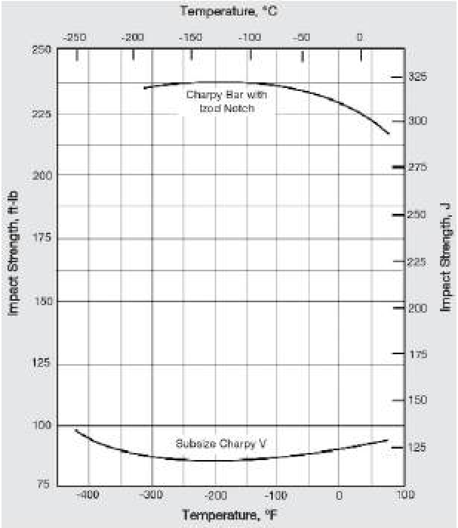

Figure 8 - Impact strength of annealed Nickel 200 bar at low temperatures.

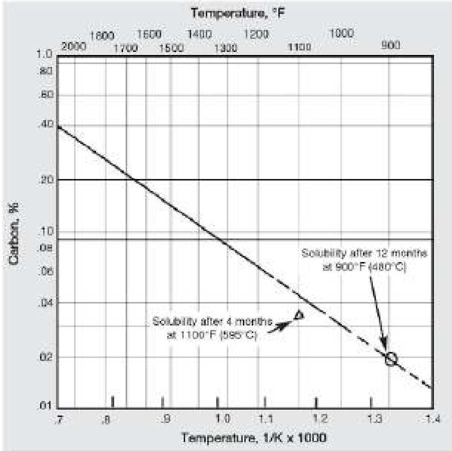

Figure 9 - Solubility of carbon in nickel. Data for the solid portion of the curve were obtained by heating DH 499 (99.9%) nickel in wet hydrogen for 2 hr at 1832°F (1000°C) and then in a mixture of 75% hydrogen, 25% methane for 1 hr at experimental temperature. The triangle and circle symbols represent tests on commercial melts; samples were annealed at 2400°F (1315°C) before testing.

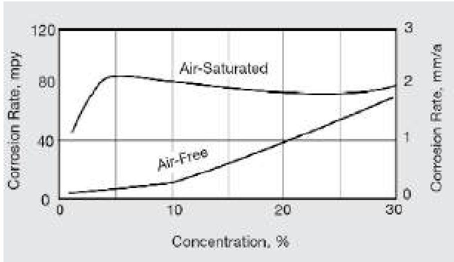

Figure 10 - Corrosion of Nickel 200 in hydrochloric acid at 86°F (30°C). (The air-free media were nitrogen-saturated.)

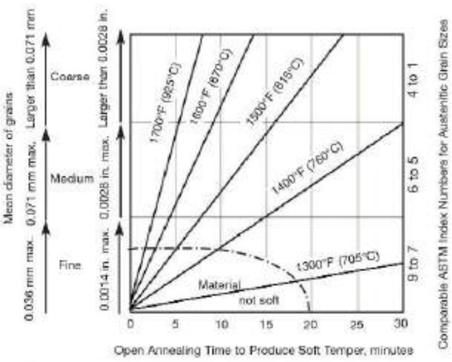

Figure 11 - Effect of open-annealing conditions on grain size of Nickel 200.

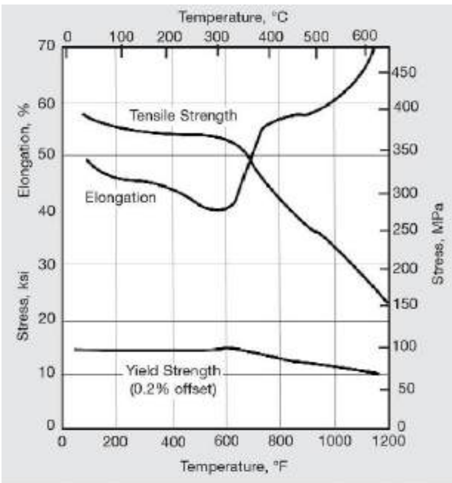

Figure 12 - High-temperature tensile properties of annealed Nickel 201.

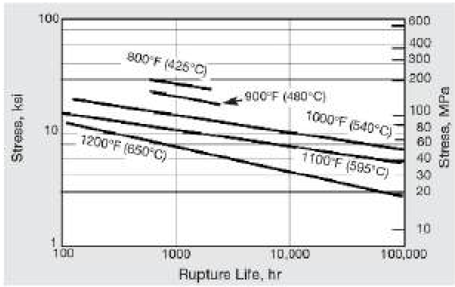

Figure 13 - Typical rupture strength of annealed Nickel 201.

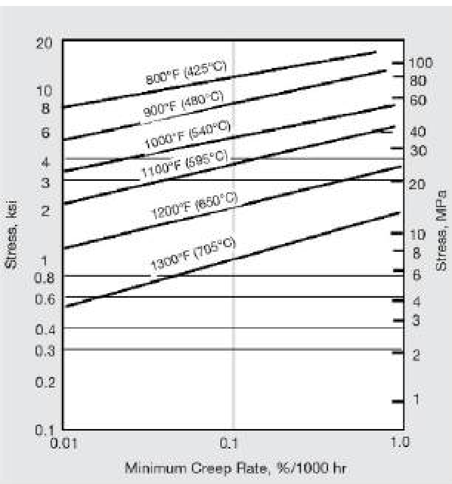

Figure 14 - Typical creep strength of annealed Nickel 201.

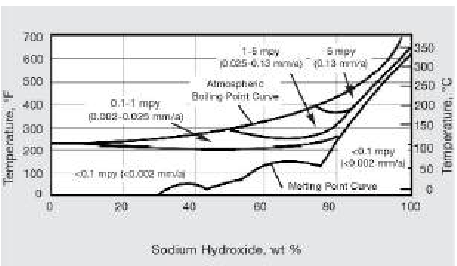

Figure 15 - Isocorrosion chart of Nickel 201 in caustic soda.

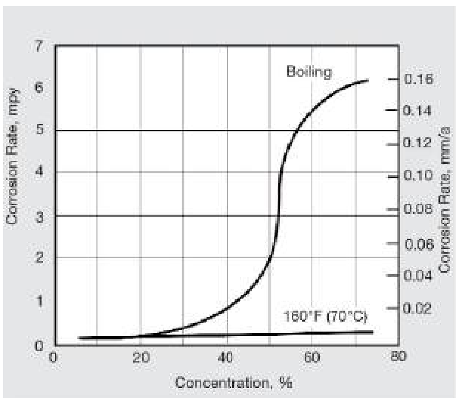

Figure 16 - Corrosion of Nickel 201 in sodium hydroxide.