Allegheny Ludlum
An Allegheny Technologies Company

Technical Data BLUE SHEET

Allegheny Ludlum Corporation ◆ Pittsburgh, PA

Martensitic Stainless Steels
Types 410, 420, 425 Mod, and 440A

GENERAL PROPERTIES

Allegheny Ludlum Types 410, 420, 425 Modified, and 440A (see composition on Page 2) are hardenable, straight-chromium stainless steels which combine superior wear resistance of high carbon alloys with the excellent corrosion resistance of chromium stainless steels. Oil quenching these alloys from temperatures between 1800°F to 1950°F (982-1066°C) produces the highest strength and/or wear resistance as well as corrosion resistance. A range of as-quenched hardnesses is achieved in these alloys by varying the carbon level from .15% maximum in Type 410 to .60-.75% in Type 440A.

These alloys are used where strength, hardness, and/or wear resistance must be combined with corrosion resistance.

APPLICATIONS

A major use for these grades of heat treatable stainless steels is in cutlery. Depending on the customer's end-use requirements, cutlery alloys are usually selected with respect to heat treating response, mechanical properties and fabricating characteristics.

When sufficient amounts of carbon are added to straight- chromium stainless steels, the alloy then has the capability to transform its microstructure through proper heat treatment (hardening) into one that will possess optimum strength, hardness, edge retention, and wear resistance. The presence of sufficient chromium will impart the necessary corrosion resistance and form chromium carbide particles that enhance the wear resistance of the given alloy. The higher the carbon content, the greater the amount of chromium carbide particles, and the greater the strength and hardness for heat treatable straight-chromium stainless steels.

When blanking cutlery parts from annealed raw material stock, Types 410, 420, and their higher carbon versions (Types 410HC and 420HC) will usually exhibit hardness, yield strength, and tensile strength that are low enough for fine blanking purposes. However, Type 440A is not readily amenable to fine blanking due to its higher strength and hardness in the annealed condition; and therefore, could require more powerful presses to blank parts. In addition, the presence of large primary carbides in Type 440A would tend to reduce die life.

When buffing blanked parts, the higher hardness of Type 440A in the heat treated condition (hardened) would mean less residual buffing lines on the surfaces of parts but the large primary carbides could be dislodged during buffing which would produce scratches called “comet-tails”. Stainless steels lower in carbon content are essentially free of "comet-tails".

Other applications for these grades include dental and surgical instruments, nozzles, valve parts, hardened steel balls and seats for oil well pumps, separating screens and strainers, springs, shears, and wear surfaces.

PRODUCT FORM

These alloys are available as plate, sheet, strip and flat bars.

CHEMICAL COMPOSITION

Stainless Steels	Element in Weight Percent							
	Carbon	Manganese	Silicon	Chromium	Molybdenum	Nickel	Sulfur	Phosphorus
Type 410*	0.15 max	1.00 max	1.00 max	11.50-13.50	--	0.50 max	0.03 max	0.04 max
Type 420**	0.15-0.40	1.00 max	1.00 max	12.00-14.00	---	0.50 max	0.03 max	0.04 max
Type 425 Mod	0.50-0.55	1.00 max	1.00 max	13.00-14.00	0.80-1.20	0.50 max	0.03 max	0.04 max
Type 440A	0.60-0.75	1.00 max	1.00 max	16.00-18.00	0.75 max	0.50 max	0.03 max	0.04 max

*A higher carbon version of Type 410 is also available called Type 410HC (nominal 0.21% C).

**A higher carbon version of Type 420 is also available called Type 420HC (nominal 0.44% C).

MECHANICAL PROPERTIES

Typical compositions, annealed mechanical properties and hardening response for the various Allegheny Ludlum martensitic stainless steels are presented below.

Stainless Steels	Typical Composition (Weight Percent)			Typical Annealed Properties				Hardening Response HRC
	C	Cr	Mo	HRB	0.2% Offset Yield Strength Ksi (MPa)	Tensile Strength Ksi (MPa)	Elongation, Percent in 2" (51 mm)	
Type 440A	0.64	16.5	--	95	62 (427)	104 (717)	20	57-60
Type 425 Mod	0.55	13.5	1.0	93 89*	55 (379) 45 (310)	94 (648) 86* (593)	24 25*	57-60
Type 420HC**	0.44	13.0	--	88	45 (310)	87 (600)	28	56-59
Type 420	0.38	13.0	--	87	45 (310)	85 (586)	29	53-57
Type 410HC**	0.21	12.5	--	83	43 (310)	78 (538)	30	45-52
Type 410	0.14	12.5	--	82	42 (290)	74 (510)	34	38-45

* Fine blanking quality
**HC means higher carbon version of standard grade

Data are typical and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown herein.

Data shown below give typical mechanical properties of martensitic stainless steels obtained with various drawing temperatures after austenitizing at 1800-1950°F (982-1066°C) followed by an oil quench and a two hour temper. Heat-to-heat variations can be anticipated.

Modulus of Elasticity

29 x 10^6 psi (200 GPa)

Typical Mechanical Properties of Heat Treated Martensitic Stainless Steels

Heat Treatment	T410 (0.14 %C) Hardened 1800°F (982°C)			T420 (0.25 %C) Hardened 1900°F (1038°C)			T425 Mod (0.55 %C) Hardened 1900°F (1038°C)			T440A (0.62 %C) Hardened 1900°F (1038°C)		
	Rockwell Hardness	0.2% YS, Ksi (MPa)	UTS, Ksi (MPa)	Rockwell Hardness	0.2% YS, Ksi (MPa)	UTS, Ksi (MPa)	Rockwell Hardness	0.2% YS, Ksi (MPa)	UTS, Ksi (MPa)	Rockwell Hardness	0.2% YS, Ksi (MPa)	UTS, Ksi (MPa)
Annealed*	81 HRB	45.4 (313)	80.4 (554)	85 HRB	51.5 (355)	85.8 (592)	90 HRB	57.4 (396)	86.3 (595)	94 HRB	51.6 (354)	108.4 (747)
Hardened+ Tempered 400°F (204°C)	43 HRC	156.1 (1076)	202.9 (1399)	48 HRC	190.1 (1311)	255.2 (1759)	53 HRC	200.9 (1385)	270.9 (1868)	54 HRC	229.0 (1579)	293.3 (2022)
Hardened+ Tempered 550°F (288°C)	40 HRC	148.3 (1022)	187.0 (1289)	44 HRC	176.0 (1213)	229.6 (1583)	50 HRC	197.2 (1360)	250.8 (1729)	50 HRC	220.2 (1518)	272.6 (1879)
Hardened+ Tempered 600°F (316°C)	40 HRC	148.8 (1026)	186.1 (1283)	45 HRC	179.0 (1234)	232.9 (1606)	53 HRC	196.0 (1351)	245.1 (1690)	53 HRC	222.0 (1531)	273.2 (1883)
Hardened+ Tempered 800°F (427°C)	41 HRC	132.9 (916)	188.5 (1300)	46 HRC	185.6 (1280)	236.0 (1627)	53 HRC	210.6 (1452)	255.1 (1759)	53 HRC	233.6 (1610)	272.8 (1881)
Hardened+ Tempered 900°F (482°C)	41 HRC	122.6 (845)	188.3 (1298)	46 HRC	179.3 (1236)	233.0 (1606)	52 HRC	198.4 (1368)	234.8 (1619)	52 HRC	212.6 (1466)	269.5 (1858)
Hardened+ Tempered 1000°F (538°C)	35 HRC	127.9 (882)	154.3 (1063)	36 HRC	137.9 (951)	158.5 (1093)	43 HRC	176.6 (1218)	208.0 (1434)	41 HRC	147.0 (1013)	177.5 (1224)
Hardened+ Tempered 1200°F (649°C)	98 HRB	85.5 (589)	111.2 (767)	23 HRC	94.6 (652)	121.6 (838)	29 HRC	107.8 (743)	135.7 (936)	31 HRC	105.5 (727)	135.4 (933)

*See Heat Treatment section for annealing information

Data are typical and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown herein.

For maximum hardness and strength, a hardening heat treatment is necessary. The stainless steel alloys shown in the table on Page 3 were heated as sheet samples for 60 minutes per inch of thickness at 1800°F (982°C) for Type 410 and at 1900°F (1038°C) for Types 420, 425 Modified, and 440A, and then air cooled to room temperature. The as-quenched structure of fresh martensite must be tempered to restore some ductility. The samples depicted in the table were tempered at temperatures from 400°F (204°C) to 1200°F (649°C) for two hours; note that their hardnesses and strengths changed very little with increases in tempering temperature up to 900°F (482°C).

PHYSICAL PROPERTIES

The values reported below are typical for the alloys in the annealed condition.

Property	Type 410	Type 420	Type 425 Mod	Type 440A
Specific Gravity	7.65	7.73	7.72	7.74
Density Lbs / in^3	0.276	0.278	0.278	0.279
Specific Heat Btu/lb. • °F	.11	.11	.11	.11
Thermal Conductivity at 212°F (100°C) Btu/(hr • ft • °F) W/m•K	14.4 24.9	14.0 24.2	14.0 24.2	14.0 24.2
Electrical Resistivity Microhm-cm 68°F (20°C)	56	56	61	62
Coefficient of Thermal Expansion 68 - 392°F, in/in°F 20-200°C, cm/cm/°C 68-1112°F, in/in/°F 20-600°C, cm/cm/°C	5.9×10^{-6} 10.5×10^{-6} 6.5×10^{-6} 11.6×10^{-6}	6.2×10^{-6} 11.2×10^{-6} 7.0×10^{-6} 12.5×10^{-6}	6.5×10^{-6} 11.6×10^{-6} 7.1×10^{-6} 12.8×10^{-6}	8.3×10^{-6} 15.0×10^{-6} 9.1×10^{-6} 16.8×10^{-6}
Melting Range	2700-2790°F 1482-1532°C	2650-2750°F 1454-1510°C	2600-2750°F 1427-1510°C	2550-2750°F 1399-1510°C

Data are typical and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown herein.

CORROSION RESISTANCE

Types 410, 420, 425 Mod, and 440A exhibit good corrosion resistance to atmospheric corrosion, potable water, and to mildly corrosive chemical enviroments because of their ability to form a tightly adherent oxide film which protects their surfaces from further attack. Their exposure to chlorides in everyday type activities (e.g., food preparation, sport activities...) is generally satisfactory when proper cleaning is performed after exposure to use. See additional comments on corrosion properties under the section "Surface Preparation".

General Corrosion Behavior Compared With Other Nonaustenitic Stainless Steels*

5% Test Solution at 120°F (49°C)	Corrosion Rate in Mils per Year and Millimeters per Year (mm/a)					
	Type 409	**Type 410**	**Type 420**	**Type 425 Mod**	**Type 440A**	**Type 430**
Acetic Acid	0.88 (0.022)	0.079 (0.002)	1.11 (0.028)	4.79 (0.122)	2.31 (0.0586)	0.025 (0.0006)
Phosphoric Acid	(0.059 (0.002)	0.062 (0.002)	0.068 (0.002)	0.593 (0.015)	0.350 (0.009)	0.029 (0.001)

*Hardened martensitic grades were tested after tempering at 400°F (204°C).

As shown in the above table, these alloys have good corrosion resistance to low concentrations of mild organic and mineral acids.

Effect of Chlorides on the Anodic Polarization Behavior Compared With Other Nonaustenitic Stainless Steels*

Test Solution at 75°F (24°C), pH 5	Breakthrough Pitting Potential [Volts vs SCE] in Sodium Chloride Solution					
	Type 409	**Type 410**	**Type 420**	**Type 425 Mod**	**Type 440A**	**Type 430**
100 ppm Chloride	0.439	0.502	0.581	0.619	0.598	0.590

*Hardened Martensitic grades were tested after tempering at 400°F (204°C). Test samples had ground surfaces.

Potentiodynamic anodic polarization measurements, as shown above, can be used to determine the relative resistance of a stainless steel to the initiation of localized chloride attack (pitting and crevice corrosion). With this technique the "breakdown potential" is measured, and is defined as the potential at which the anodic current increases rapidly due to initiation of localized attack. The more positive or noble the breakdown potential the more corrosion resistant the alloy. The above table presents the average breakdown potential for the hardenable alloys as well as Types 430 and 409 for comparison.

The anodic polarization results show that alloys such as Type 425 Mod, Type 440A, and Type 430 with their higher chromium or combination of chromium and molybdenum contents are more resistant to localized chloride attack.

FABRICATING PROPERTIES

Machining

These alloys should be machined in the annealed condition using surface speeds of 60 to 80 feet (18.3-24.4 m) per minute.

Surface Preparation

For maximum corrosion resistance to chemical environments, it is essential that the stainless steel surface be free of all heat tint or oxide formed during forging, annealing, or heat treating. All surfaces must be ground or polished to remove any traces of oxide and surface decarburization. The parts should then be immersed in a warm solution of 10-20% nitric acid to remove any residual iron. A thorough water rinse should follow the nitric acid treatment.

Structure

In the annealed condition, Types 410, 420, 425 Mod, and 440A consist of ferrite and carbides. Higher carbon and higher chromium material such as Type 440A in the annealed condition will also contain large scattered primary carbides. When these alloys are heat treated at high temperatures [1800°F-1950°F (982-1066°C)] austenite will form and transform to martensite upon cooling to room temperature (i.e., air cool or oil quench). The hardness of the martensite will increase with increasing carbon content to a point where the martensite becomes saturated with carbon, hence Type 440A will exhibit a higher as-quenched hardness than Type 410. Carbon also combines with carbide formers such as chromium to form chromium carbides which are dispersed throughout the micro-structure to provide added wear resistance, as does higher hardness.

Forging

The suggested initial forging temperature range for Types 410, 420 and 425 Mod is 2000-2200°F (1093-1204°C) and 1900-2200°F (1038-1204°C) for Type 440A. Forging or hot working should always be followed by annealing to avoid stress cracking.

HEAT TREATING

To anneal these alloys, heat to 1550°F-1650°F (843-899°C) for Types 420, 425 Mod, and 440A or 1500°F-1550°F (815-842°C) for Type 410 and hold for one hour per inch of thickness and furnace cool to room temperature. Such annealing should produce a Brinell hardness of 126-192 HB in Type 410 material. The higher carbon alloys, Types 420, 425 Mod, and 440A, will have somewhat higher hardness values.

A hardening heat treatment is necessary to bring out the maximum hardness and wear resistance. Since these materials absorb heat very slowly, they should be heated gradually and allowed to remain at temperature long enough to ensure uniform temperature in thick sections. For maximum strength, hardness, and corrosion resistance, slowly heat the alloy to 1800°F (982°C) for Type 410 and to 1850°F-1950°F (1010-1066°C) for Types 420, 425 Mod, and 440A and quench to room temperature in oil. For thin sections, air cooling can be substituted for the oil quench. If retained austenite is known to be present after the austenitizing and quench to room temperature, additional hardening response may be achieved by sub-zero cooling to about -100°F (-73°C). The as-quenched structure of fresh martensite is quite brittle and should be stress-relieved or tempered at approximately 400°F to 500°F (204-260°C) to restore some ductility. During tempering between approximately 300°F (149°C) and 600°F (316°C), a relaxation of the martensite structure occurs whereby the volumetric stresses associated with the formation of martensite upon quenching are relieved. As a result, the martensite still exhibits its high hardness and wear resistance properties but some ductility is introduced at the loss of a few points of hardness.

Allegheny Ludlum's staffs of research and development engineers and mill product metallurgists welcome the opportunity to discuss your technical requirements during the design and specification stage. To access this technical assistance, please call:

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