

ATI 500-MIL™ High Hard Specialty Steel Armor

INTRODUCTION

ATI 500-MIL High Hard Specialty Steel is wrought Ni-Cr-Mo specialty steel for armor plate. The balanced composition of the alloy lends itself to excellent toughness relative to other “high-hard” alloys while maintaining ballistic resistance that meets the MIL-DTL-46100E standard. The alloy’s high toughness results in good blast properties.

Due to the processing practices utilized for ATI 500-MIL steel, residual stresses are low; and plate exhibits minimal distortion after mechanical cutting. Thermal cutting may produce some distortion, but this typically will be much less than would be seen for liquid-quenched materials.

CHEMICAL COMPOSITION

Element	Composition* (weight %)
C	0.22 – 0.32
Ni	3.50 – 4.00
Cr	1.60 – 2.00
Mo	0.22 – 0.37
Mn	0.80 – 1.20
Si	0.25 – 0.45
P	0.020 (max)
S	0.005 (max)
Fe	Balance residual elements per MIL-A-46100D requirements

*Composition shown is typical; specifics can vary.

MECHANICAL PROPERTIES

Typical mechanical property data for ATI 500-MIL specialty steel is included below. This data represents an average of results for 0.275 in. (7 mm) and 0.199 in. (5 mm) plate.

HARDNESS

Steel will re-harden in the 477 to 534 BHN range.

FLATNESS

ATI 500-MIL specialty steel exceeds the flatness requirement referenced in section 3.2.8.3 of the MIL-DTL-46100E specification per ASTM A6.

TENSILE PROPERTIES (at room temperature)

Tensile Strength: 260,000 psi (1792 MPa)
Yield Strength: 150,000 psi (1034 MPa)
Elongation: 13%

CHARPY V-NOTCH IMPACT PROPERTIES (typical)

	0.200" (5mm)	0.275" (7mm)
Room Temp		
Energy (ft/lbs):	24	28
Lateral Exposure:	0.005" (0.1mm)	0.005" (0.1mm)
-40°F (-40°C)		
Energy (ft/lbs):	20	20
Lateral Exposure:	0.004" (0.1mm)	0.004" (0.1mm)

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 herein.

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PHYSICAL PROPERTIES

Density:
7.850g/cm³ (0.285lbm/in³)

Coefficient of Thermal Expansion:

°F (68°F-212°F): 6.5x10⁻⁶
°C (20°C-100°C): 11.6x10⁻⁶

BALLISTIC PROPERTIES					
ATI 500-MIL plate is designed to meet or exceed the ballistic requirements of MIL-DTL-46100E.					
Size		Threat Level	MIL-DTL-46100E BL(P)		BL(P)
inches	mm		fps	mps	
0.199"	5.06	.30 cal AP	1901	579.4	Exceeds Spec
0.250"	6.35	.30 cal AP	2237	681.8	Exceeds Spec
0.315"	8.00	.50 cal AP	1873	570.9	Exceeds Spec
0.375"	9.52	.50 cal AP	2073	631.9	Exceeds Spec
0.500"	12.70	.50 cal AP	2440	743.7	Exceeds Spec
0.625"	15.87	14.5mmB32	2428	740.1	Exceeds Spec
0.750"	19.05	14.5mmB32	2679	816.6	Exceeds Spec
1.00"	25.40	14.5mmBS41	2822	860.1	Exceeds Spec

AP ~ Armor Piercing cal ~ caliber fps ~ feet per second mps ~ meters per second BL (P) ~ V50 protection ballistic limit

FABRICATION

CUTTING

Abrasive, water-jet and saw cutting are acceptable methods that typically do not create a heat affected zone (HAZ). Thermal cutting methods such as plasma, laser, and torch cutting may create a HAZ. Refer to section 3.2.10.3.1 of the MIL-DTL-46100E specification for additional information on how to handle plate that has been thermally cut.

ATI 500-MIL plate may not be amenable to shearing due to its high strength and toughness. Attempts to shear this material could create a safety hazard so user should take appropriate safety precautions.

MACHINING

ATI 500-MIL plate can be drilled in the hardened condition by using high speed or carbide tipped drill bits. Because ATI 500-MIL plates have a high work hardening rate, it is important that the work piece be rigidly supported to insure that positive feed pressure is maintained continuously. Interrupted feed pressure will allow work hardening thereby rendering drilling more difficult. Heavy feeds and slow speeds are preferred.

COLD FORMING

Cold forming can be performed with the proper techniques and suitable equipment in a highly controlled environment. Given the high strength nature and material properties of ATI 500-MIL plate, set up should be thoroughly evaluated before cold forming. Although cold forming is not recommended, it is possible. ATI 500-MIL plate up to 0.375" gauge has been successfully cold formed. The following precautions should be taken when cold forming this material:

1. Grind edges, grind outside surface which will be in tension and grind to create round corners.
2. Use lubricant.
3. Nearly five times as much power is required compared with mild steel.
4. Forming across grain direction is preferred but not mandatory.
5. Allow for greater "spring-back" due to higher yield strength.

HOT FORMING

Hot forming is recommended with the following guidelines:

1. Plate should be heated to the 1550°F to 1650°F (843°C to 899°C) temperature range prior to forming.
2. To maintain ballistic quality, toughness, and metallurgical integrity, the temperature of the plate should not exceed 1650°F (899°C.)
3. Grind edges and create round corners.
4. After forming allow steel to cool uniformly with unrestricted air flow (still air recommended) to the top and bottom of plate until plate temperature is <300°F (149°C.) Do not cool using water quenching or forced air cooling methods. Steel will re-harden to approximately 500 BHN.

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WELDING

ATI 500-MIL specialty steel is readily weldable using standard techniques. The steel plate may be gas metal arc welded (GMAW) with no preheating necessary. The alloy may also be welded using other welding techniques in accordance with section 6.3 of the MIL-DTL-46100E specification. An example of the GMAW welding procedure is provided below. Surfaces to be welded must be clean and dry. Employ practices which minimize hydrogen pick up.

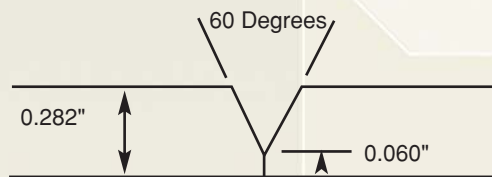
Example of GMAW Welding Procedure

Process:	Gas Metal Arc Welding
Thickness:	0.282" (7.2mm)
Welding Position:	1G (Flat)
Preheat Temp:	Room Temperature
Weld Joint:	Butt with no gap
Groove Type:	Single-V
Groove Details:	0.060" Land, 60° Included Angle
Weld Passes:	One
Filler Wire:	AWS SFA5.28, ER100S-1, 0.063" (1.6mm) diameter
Filler Metal Transfer Mode:	Spray
Shielding Gas:	98%Ar / 2%O ₂
Backing Gas:	None
Shielding Gas Flow Rate:	40 cfh
Gas Nozzle I.D.:	0.5" (12.65mm)
Contact Tip-to-Work Distance:	0.6875" (17.5mm)

Example Welding Parameters

Voltage:	27.5 volts (DCEP)
Wire Feed Speed:	170 ipm (431.8 cmp)
Resulting Current:	310-315 amps
Travel Speed:	12.5 ipm (31.75 cmp)
Calculated Heat Input:	41.3 kJ per inch

Cross Section of GMAW Plate Weld



HEAT TREATMENT

ATI 500-MIL plate is delivered in the fully hardened condition. A low temperature (300°F (149°C) maximum) tempering treatment may be used if increased toughness is desired.

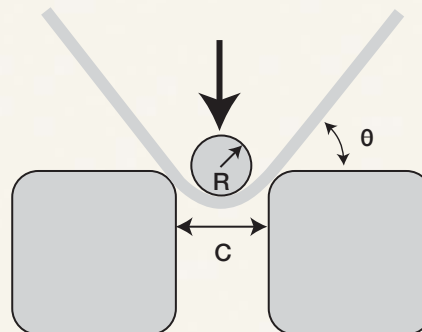
ATI 500 plate can be supplied in the as-annealed condition if stipulated but hardening of the material to achieve ballistic performance then becomes the sole responsibility of the user.

BEND TEST DATA

ATI 500-MIL plate has been tested in accordance with the bend test parameters set forth under section 3.2.6 of the MIL-DTL-46100E specification. Additional testing has also been performed with results shown below.

R/t	C (in.)	(mm)	R (in.)	(mm)	t (in.)	(mm)	01	02	Spring-back
6.0	3.00	76.20	1.25	31.75	0.213	5.41	75°	62°	13°
4.7	2.64	67.06	1.00	25.40	0.213	5.41	79°	62°	17°
4.4	3.40	86.36	1.25	31.75	0.286	7.26	68°	58°	10°
3.5(a)	2.14	54.36	0.75	19.05	0.213	5.41	31°	25°	6°
3.5(b)	2.14	54.36	0.75	19.05	0.213	5.41	80°	67°	13°

NOTE: 0.375" gauge material has been successfully bent to a 2T radius (in the transverse direction) at ambient conditions however an alternative methodology is required to minimize the possibility of cracking. For more information on this methodology please contact an ATI Defense representative.



AVAILABLE FORMS

ATI 500-MIL specialty steel is available in standard mill plate gauges from 0.1875" to 2.0" (4.762mm to 50.8mm.) Please inquire for sheet gauges.

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