ArcelorMittal USA

Plate

HARDWEAR® Plate: Premium abrasion-resistant steels "Introducing HARDWEAR® 550F"

Introduction

HARDWEAR®, a line of premium abrasion-resistant plate steels, is available in four grades – HARDWEAR 400F, HARDWEAR 450F, HARDWEAR 500F and HARDWEAR 550F – with nominal Brinell hardness of the number in the grade title. These grades are produced at facilities in Coatesville and Conshohocken, PA. as well as Burns Harbor, IN.

Each grade exhibits an excellent combination of hardness, abrasion resistance, formability, weldability, toughness and flatness to meet fabrication needs and end-use requirements. HARDWEAR steels are designed for through-thickness hardness while maintaining minimum carbon, alloy and carbon equivalent contents to improve weldability. All HARDWEAR grades are heat treated. Thicker HARDWEAR 400F and all other HARDWEAR grades are quenched and tempered. Thinner HARDWEAR 400F plates may be untempered.

The sulfur content is reduced to a maximum of 0.005% and the steels are calcium treated for inclusion shape control. These factors enhance the cold forming characteristics of the steels and thus the "F" in the grade names, for formable.

HARDWEAR 400F, 450F and 500F grades are available in thicknesses from 1/8 to 3 inches (3 mm to 76 mm). HARDWEAR 550F is available to 3/8" (9.5 mm). The availability of HARDWEAR grades to 1/8" (3 mm) thickness is a recent capability enhancement. Inquire with ArcelorMittal USA Plate offices for availability.

Applications

HARDWEAR plate steels are used in the original fabrication and repair of heavy equipment subject to severe abrasive wear. Their use is especially effective where formed transitions are preferred over welded joints for flowability in material handling equipment used in the mining, aggregate, pulp and paper, and construction industries. HARDWEAR's improved weldability enhances its attractiveness where field welding is often performed.

Most common applications are in the mining and construction markets with uses as liners for truck beds, buckets, hoppers, chutes, crushers and conveyor troughs. Concrete mixer drums, trash truck bottoms, bucket lips, street sweepers and dump trailers are among other applications.

Composition

HARDWEAR steels are designed with as low a carbon equivalent as possible, consistent with meeting surface and through-thickness hardness requirements. The chemistry range for each HARDWEAR grade is shown in Table 1. Figures 1 and 2 show the carbon equivalent results for a representative number of heats of steel produced for plates to 1 inch (25.4 mm) thick in grades 400F and 500F. More restrictive carbon equivalent levels are available for thinner plates.

Because of ArcelorMittal USA Plate mill's ladle refining practices, very precise and reproducible chemistries can be expected from these steels. The low sulfur and phosphorus levels for HARDWEAR plate steels are shown in the distributions in Figures 4 and 5. Lower sulfur and phosphorus specification levels are available when specified.

ArcelorMittal USA HARDWEAR Steels (1/8" to 3" thick)
Table 1: Chemistry (maximum unless range is shown)

Grade	C	Mn	P	S*	Si	Ni	Mo	Cr	B
400F	.12/.16	1.55	.025	.005	.35/.55	1.00	.55	.55	.0005/.005
450F	.20/.25	1.35	.025	.005	.35/.55	1.00	.65	.55	.0005/.005
500F	.25/.31	0.95	.025	.005	.35/.55	1.00	.65	.75	.0005/.005
550F	.31/.36	0.95	.025	.005	.35/.55	1.00	.65	.75	.0005/.005

** with calcium treatment for inclusion shape control, Fineline® Double-O-Five*

3/4 inch thick HARDWEAR 500F plates formed for truck bed liners being prepared for shipment from a service center.

Figure 1: ArcelorMittal USA HARDWEAR 400F Heat Chemistry Distribution
Carbon Equivalent Distribution for Thickness to 1 in. (25.4 mm)

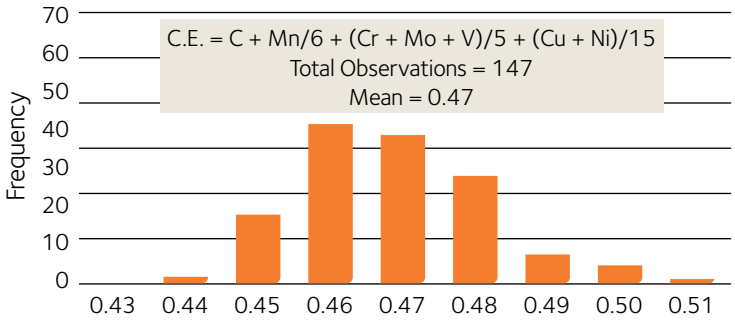


Figure 2: ArcelorMittal USA HARDWEAR 500F Heat Chemistry Distribution
Carbon Equivalent Distribution for Thickness to 1 in. (25.4 mm)

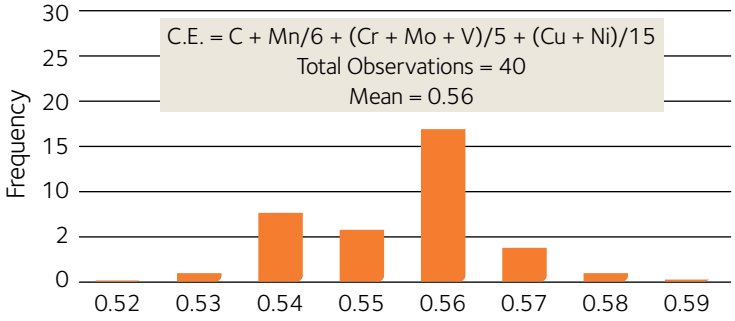


Figure 3:
3/8" thick ArcelorMittal USA HARDWEAR 450F formed with 3T bend radius parallel to the rolling direction

Figure 4: ArcelorMittal USA HARDWEAR 400F Plate Sulfur Levels for 336 Heats

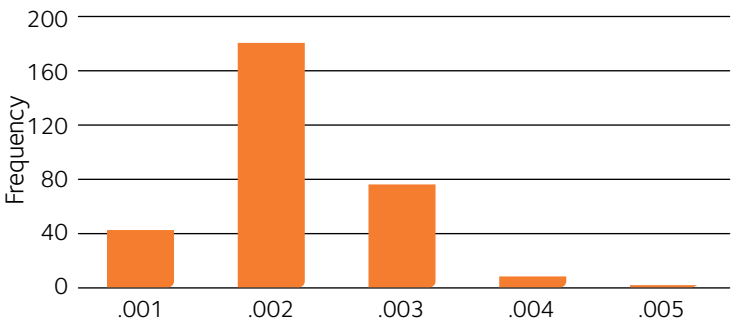
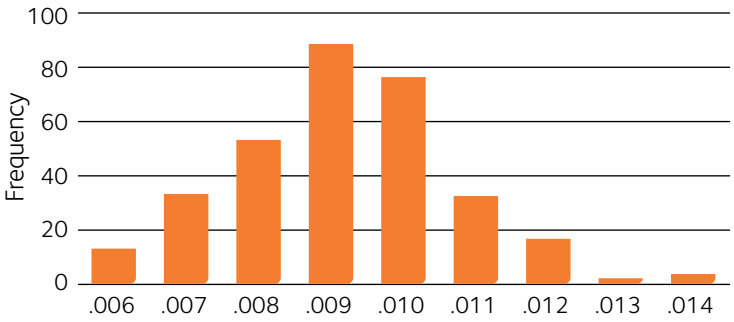


Figure 5: ArcelorMittal USA HARDWEAR 400F Plate Phosphorus Levels for 336 Heats



Hardness

The primary ordering requirement for HARDWEAR steels is minimum surface hardness. The hardness distributions of almost 60,000 HARDWEAR 400F plates and approximately 8,000 HARDWEAR 500F plates are shown in Figures 6 and 7. The Brinell hardness (HB) ranges of the HARDWEAR grades are:

HARDWEAR Grade	Hardness Range (HB) *
400F	360-444
450F	429-495
500F	460-544
550F	510-590

** Inquire with ArcelorMittal USA Plate offices if more restrictive hardness levels are required.*

Figure 6: ArcelorMittal USA HARDWEAR 400F Plate Hardness Distribution To 3/4" (19 mm) Thickness

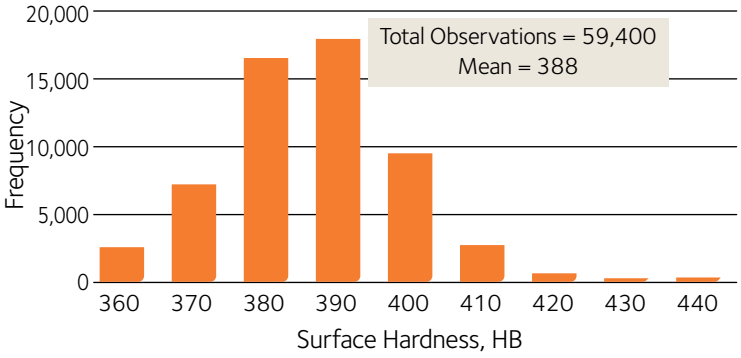
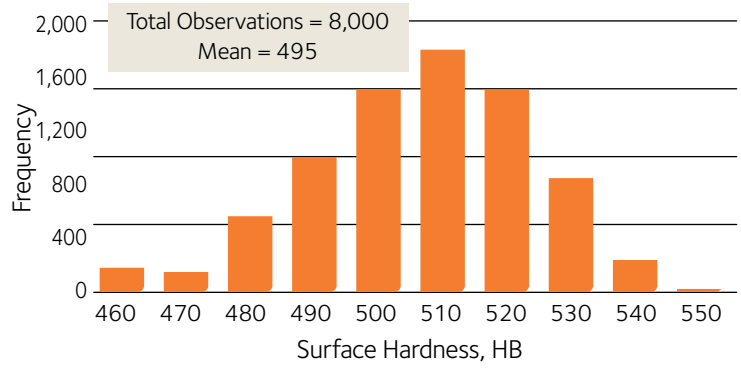


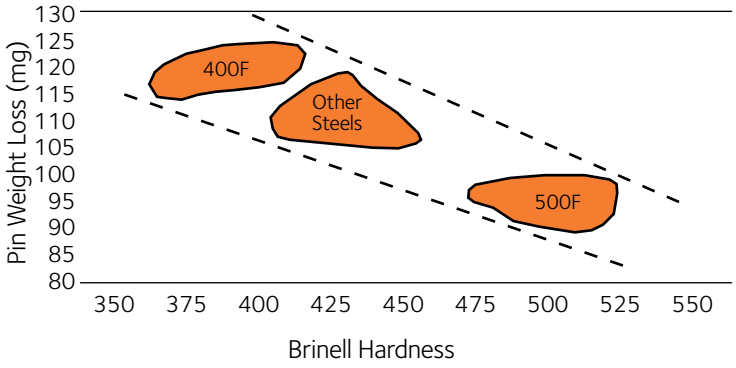
Figure 7: ArcelorMittal USA HARDWEAR 500F Plate Hardness Distribution To 3/4" (19 mm) Thickness



Pin Abrasion

The Pin Abrasion test is used to compare abrasion resistant steels. A standard test pin, machined from the steel to be tested, is abraded by a 150-mesh garnet abrasive cloth under specified laboratory conditions and the pin's weight loss, in milligrams, is measured. The results of testing conducted by ArcelorMittal USA Plate metallurgists, comparing the pin weight loss with corresponding hardness of the HARDWEAR grades, are shown in Figure 8.

Figure 8: ArcelorMittal USA HARDWEAR 'F' Series Plate Pin Abrasion Test vs. Hardness



Mechanical Properties

While HARDWEAR steels are normally specified by Brinell hardness, it is of interest to know other mechanical properties of these steels.

Tensile Strength

ArcelorMittal USA Plate facilities does not guarantee tensile properties of HARDWEAR grades. However, for information purposes, Figures 9 and 10 show typical yield and tensile strength behavior of grades 400F and 500F as a function of thickness. The transverse values shown approximate those in the longitudinal direction. Furthermore, both steels exhibit fairly consistent strength, independent of thickness.

Please note the tensile specimens used for this study had a 1 inch gauge length. The reported elongation values are greater than those obtained with longer gauge lengths.

Figure 9: ArcelorMittal USA HARDWEAR 400F Plate - Tensile Strength

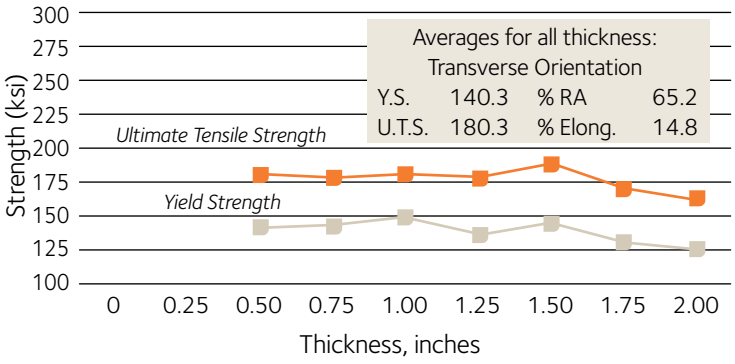
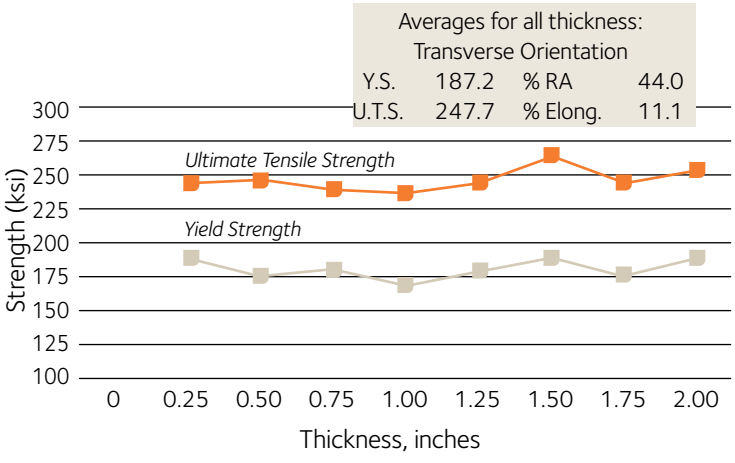


Figure 10: ArcelorMittal USA HARDWEAR 500F Plate - Tensile Strength



Charpy V-Notch Impact Toughness

The results of extensive Charpy V-Notch impact testing are summarized in Figures 11 and 12. ArcelorMittal USA Plate facilities can guarantee impact properties of any HARDWEAR grade when specified.

Figure 11: ArcelorMittal USA HARDWEAR 400F Plate Transverse CVN Toughness, 7/16" - 2" Thick Plates

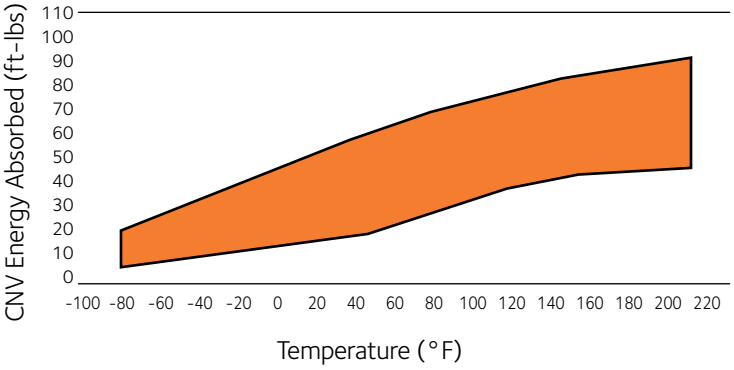
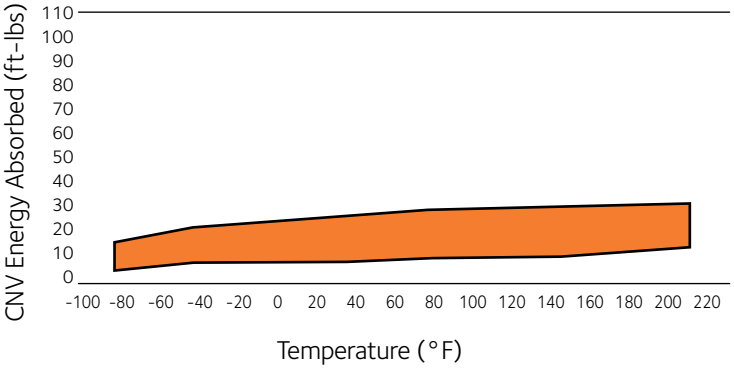


Figure 12: ArcelorMittal USA HARDWEAR 500F Plate Transverse CVN Toughness, 7/16" - 2" Thick Plates



Fabrication Guidelines for HARDWEAR

General information on fabrication with plate steels is given in "Guidelines for Fabricating and Processing Plate Steel" book. For guidelines specific to HARDWEAR grades, the following information is provided.

Bend Formability

HARDWEAR steels were specifically designed for improved formability. ArcelorMittal USA Plate metallurgist's plane strain bend testing of HARDWEAR 400F, HARDWEAR 450F, HARDWEAR 500F and HARDWEAR 550F led to the forming guidelines presented in Table 2. Plate in the thinner part of the thickness range, and bent less than 90º may allow tighter bends (see Figure 3).

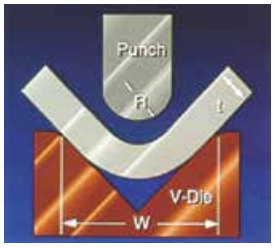
These guidelines are based on forming at typical shop temperatures over +60°F*. We caution that bend forming of these hard steels should be carried out using shop practices which include, but are not limited to, using hardened V-dies with a liberal radius (See Table 2). It is recommended that adequate lubrication, grinding of thermal cut or sheared plate edges and applying the load in a smooth, steady manner be utilized. Particular caution should be used in applying the "bump and move" technique to control the depth and number of bends.

HARDWEAR steels are not intended for hot forming applications, unless reheat treatment of the part is included. Consult ArcelorMittal USA Plate offices for heat treatment guidelines.

Table 2: ArcelorMittal USA HARDWEAR 400F, 450F, 500F and 550F Plate

Grade	Thickness Range*	Severity Ratios for Single Stroke Bend to 90°			
		Bend Transverse to Rolling Direction		Bend Parallel to Rolling Direction	
	Inches (mm)	R/t	W/t	R/t	W/t
400F	1/8 – 3/4 (3 – 19)	3	13.5	4	14.5
450F	1/8 – 3/4 (3 – 19)	4	14	5	15
500F	1/8 – 1/2 (3 – 13)	6	16	6	16
550F	1/8 – 3/8 (3 – 9.5)	8	20	10	20

** Consult ArcelorMittal USA Plate offices for greater thicknesses*



Punch Bend Forming Severity Ratio – R/t

Punch Bend Forming Severity Ratio – W/t

*Bend Load Requirement Formulas (for nominal strength levels) **

P = estimated press load, tons L = length of plate to bend, inches	
400F $P = (150 \times t^2 \times L)/W$	500F $P = (200 \times t^2 \times L)/W$
Example: 400F plate 0.5-inch thick by 48-inches wide with a die W of 7 inches P = (150 x 0.52 x 48)/7 = 257 tons needed for forming	

** loads for 450F are between these shown*

Machinability

Due to their high hardness levels, HARDWEAR steels, as are all abrasion resistant grades, are inherently more difficult to machine when compared to normal structural steels. Also, the cleanliness, low sulfur and inclusion levels of HARDWEAR steels influence chip breakage behavior. Therefore, machining these steels requires the use of cobalt-alloyed, high speed steel (HSS) tools or carbide tips, using a generous supply of cutting fluid. In milling operations, the 400F and 500F grades require cutting speeds of 45% and 35%, respectively, of the speeds for milling A572-50. The following parameters have been found effective in the drilling of HARDWEAR steels (See Table 3). Carbide tips are required for machining HARDWEAR 550F using the 500F guidelines..

Table 3: ArcelorMittal USA HARDWEAR 400F, 450F and 500F Plate

Grade	Drill Speed, rpm			
	Cutting Speed, In./Min.	0.4 Inch. Dia.*	0.8 Inch Dia.*	1.2 Inch. Dia.*
400F	250-450	300	150	100
450F	200-300	215	110	70
500F	150-250	130	65	40

** Feed rate In./Rev. .004, .008, .012, respectively*

Thermal Cutting

ArcelorMittal USA HARDWEAR 400F, 450F, 500F and 550F plates can be thermally cut with conventional oxygen-fuel and plasma-cutting techniques. The minimum plate temperature prior to thermal cutting should be +60°F for all grades. It is further recommended that HARDWEAR 400F and 450F plates greater than 2 in (51 mm) thick and HARDWEAR 500F plates greater than 1 inch (25.4 mm) thick be preheated to 300°F to prevent edge cracking. Use of reduced cutting speeds with other proper cutting parameters may also be used for thicker plates.

Cylindrical sections of "top hat" crusher liners formed from 3/4 inch thick HARDWEAR 500F

The welded conical portion of this reducing hopper formed from 3/8 inch thick HARDWEAR 400F

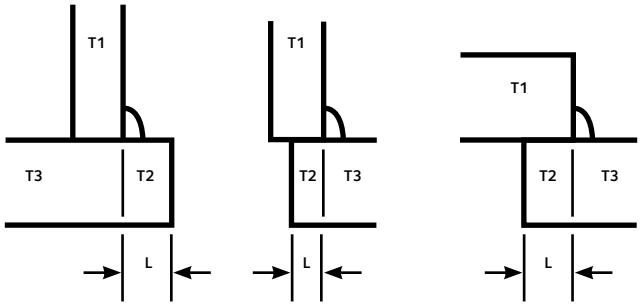
Weldability

ArcelorMittal USA Plate mill's HARDWEAR steels may be welded by any of the conventional welding processes such as SMAW, GMAW and SAW, provided proper precautions and low-hydrogen welding practices are employed. ArcelorMittal USA Plate facilities welding guidelines for HARDWEAR 400F, 450F and 500F are summarized in the Table 4 shown below. The guidelines were developed using the "Y" groove weldability test specimen. For joints under less restrained conditions, some fabricators have found lower preheat temperatures may be used. If the humidity level in the work area is high and/or the weldment is highly restricted, higher preheat temperatures may be required. Pre/Postweld heat treatment above 400°F should not be applied to the steels if the original hardness levels are to be maintained.

Welding guidelines for HARDWEAR 550F should use those of 500F.

Table 4: Welding Preheat Guide for ArcelorMittal USA HARDWEAR Plate Recommended Minimum Preheat (60°F)

Combined Plate Thicknesses	HARDWEAR 400F Heat Input (KJ/Inch)					HARDWEAR 450F Heat Input (KJ/Inch)				HARDWEAR 500F/550F Heat Input (KJ/Inch)			
T1 + T2 + T3	30	35	40	45	>45	30	35	40	45	30	35	40	45
3/4 Inch	60	60	60	60	60	60	60	60	60	200	200	200	200
1	60	60	60	60	60	60	60	60	60	250	200	200	200
1-1/4	60	60	60	60	60	60	60	60	60	300	250	200	200
1-1/2	60	60	60	60	60	200	200	60	60	350	300	250	200
2	60	60	60	60	60	250	250	200	200	400	350	300	300
2-1/2	60	60	60	60	60	300	300	250	250	400	350	300	300
3	200	200	200	60	60	350	350	300	300	400	400	350	350
4	250	250	250	200	200	400	400	350	350	400	400	400	400



If L is Less Than or Equal to 1/2 T2, Consider T2 = 0

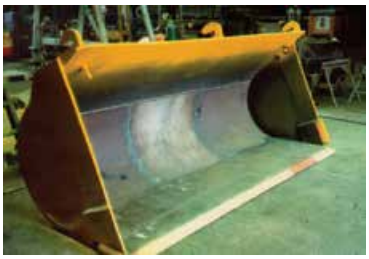
Notes:

- *Preheat temperature is based on SMAW process and E7018 electrode.*
- *E7018 electrodes must be stored in an oven at 250°F +25°F. Maximum exposure – four hours out of the can or out of the oven.*
- *Preheat minimum temperature may be reduced by 50°F (but not less than 50°F) using GMAW process, ER70S-3 electrode and AR-Co_2 gas.*
- *Maximum preheat and interpass temperatures should be 400°F to retain hardness properties.*
- *35 KJ/inch represents approximately a 1/4 inch fillet weld (SMAW).*

Additional Information

For Technical questions about this product, please contact John Kross at ArcelorMittal USA at +1 610 383 2306 or email john.kross@arcelormittal.com.

For Sales Customer Service call +1 800 641 7506.



ArcelorMittal USA
Corporate Office
1 South Dearborn Street
18th Floor
Chicago, IL 60603-9888
USA

T +1 800 422 9422
usa.arcelormittal.com

ArcelorMittal USA
Plate
ARC Building
139 Modena Road
Coatesville, PA 19320-0911
USA

T +1 800 966 5352
usa.arcelormittal.com

ArcelorMittal USA
Plate
250 West U.S. Highway 12
Burns Harbor, IN 46304-9745
USA

T +1 800 422 9422
usa.arcelormittal.com

September 2017