Manufacturing of Steel

Jay Forni, Jr.
Clayton Simons

What is Steel?

Steel, or more specifically carbon steel, is a mixture made mostly of iron with small amounts of other elements.

When iron cools and becomes solid, its atoms arrange themselves in repeating geometric patterns called crystalline structures. This crystalline structure gives steel its properties of high strength and elastic deformation. The crystalline structures align with each other and form grains. The zone of mismatch between the grains is the grain boundary. The grain boundary is less dense than the grains which allow the alloying elements to diffuse more readily.

Fine grained steels have more boundary area per unit area than coarse grained steel.

The addition of other elements during the steel making process are designed to enhance these properties.

History of Steel

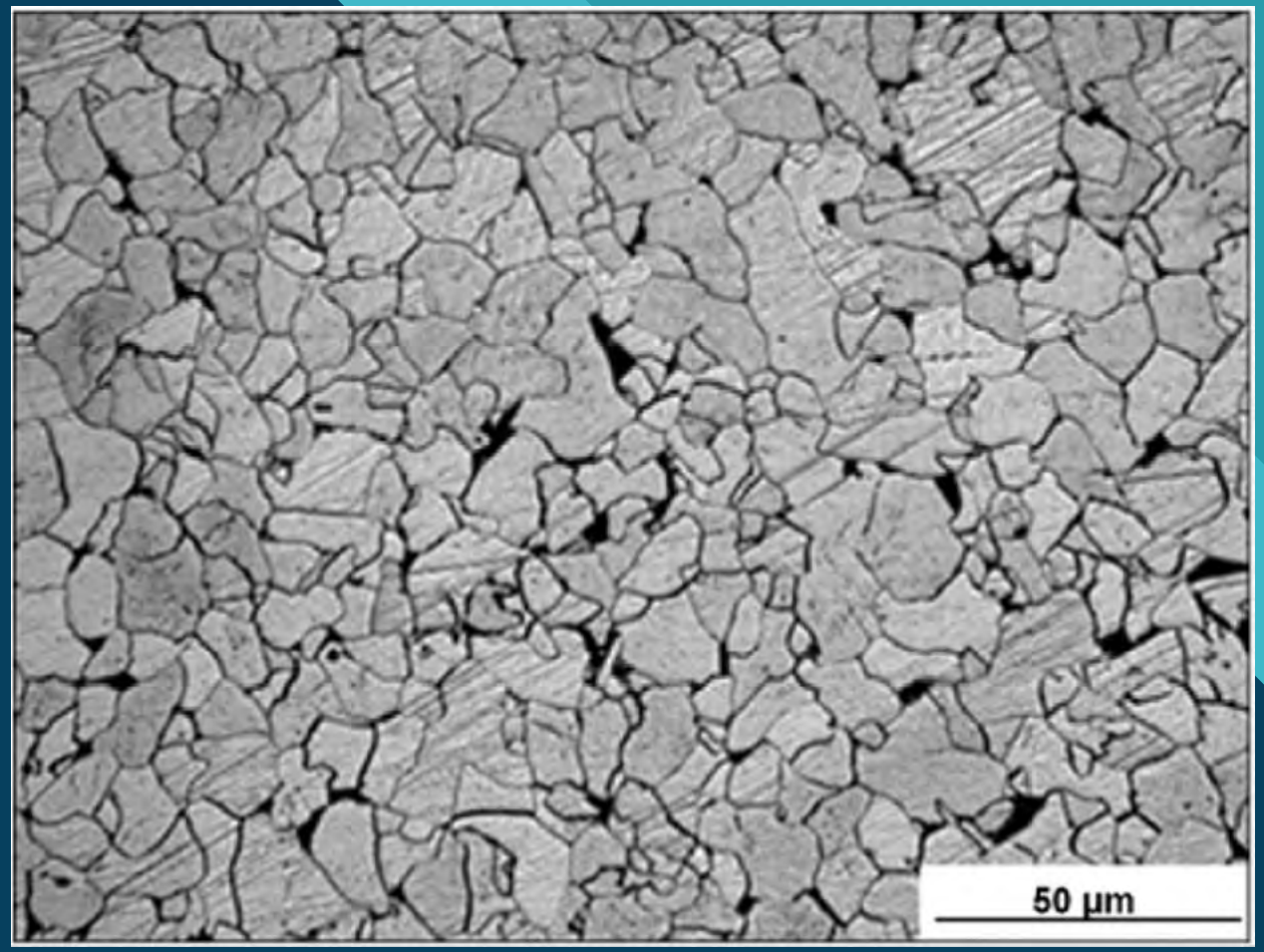
In the pipe industry, the most commonly used type of steel is called low carbon or mild steel. This type of steel is made up of more than 90% iron.

Small amounts of other elements are added to improve how the steel performs. One of the main elements added is carbon (but only in small amounts, less than 0.30%). Other possible alloying elements include manganese, molybdenum, vanadium, nickel, titanium, and several others.

Depending on which elements are added and how much, the steel can be made stronger, more flexible, or tougher. Because you can adjust its properties in so many ways, steel is one of the most useful and adaptable building materials in the world.

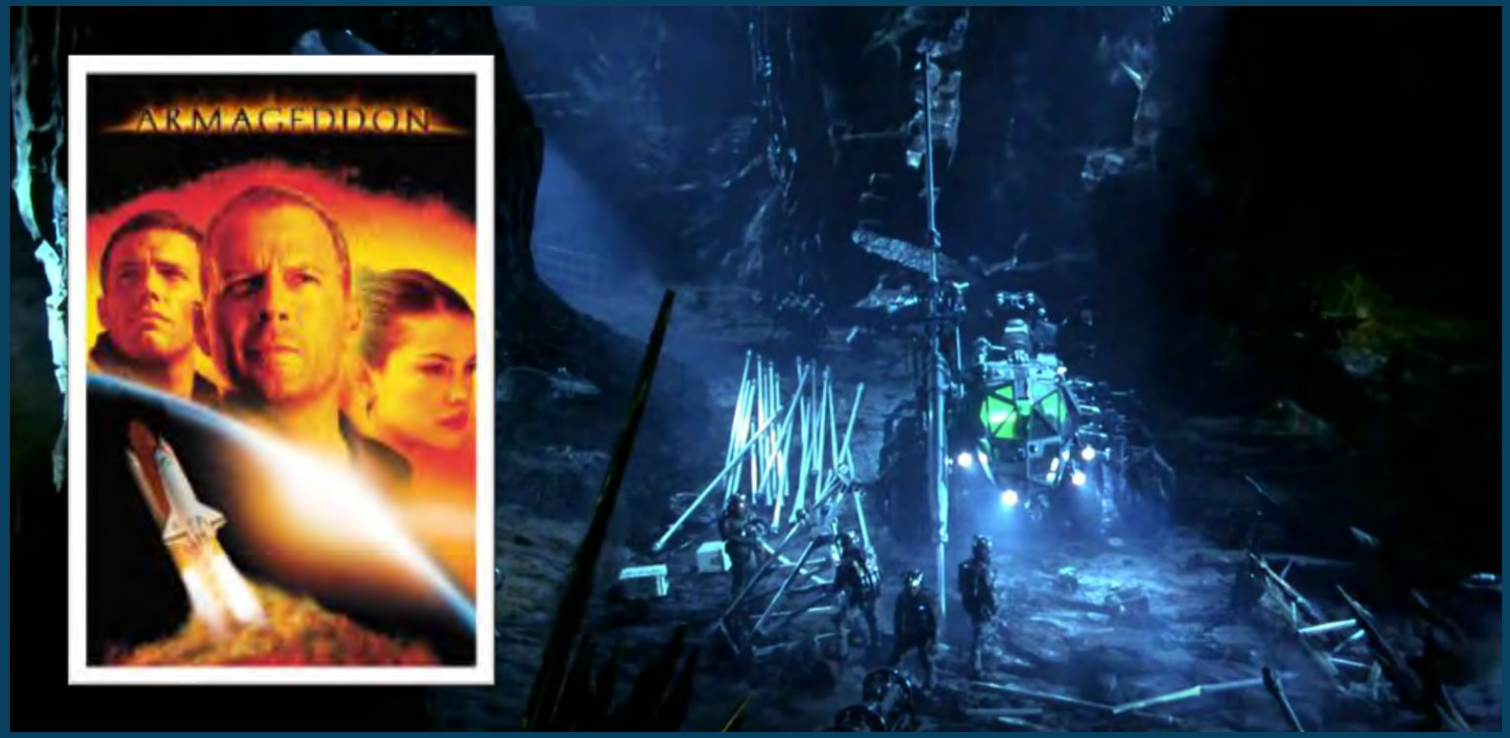
Micrograph of Steel

Fine grained steel
Grain boundaries are the darker areas



Iron is more than 90% of all metals mined in the world. Very little pure iron exists on the Earth. Most of the pure iron found on Earth is from fragments of meteorites.

The vast bulk of usable iron ore on the Earth is found as oxides such as magnetite or hematite. The countries that produce the largest amount of iron ore are Australia, Brazil, and China.



Iron is the fourth most abundant element in the Earth's crust. Most of the iron is bound in silicate or carbonate minerals which are difficult to smelt.

Iron is more than 90% of all minerals mined in the world.

The total amount of iron ore produced over the last 4 years averaged 2 billion tons per year.

“Iron Ore Mining”

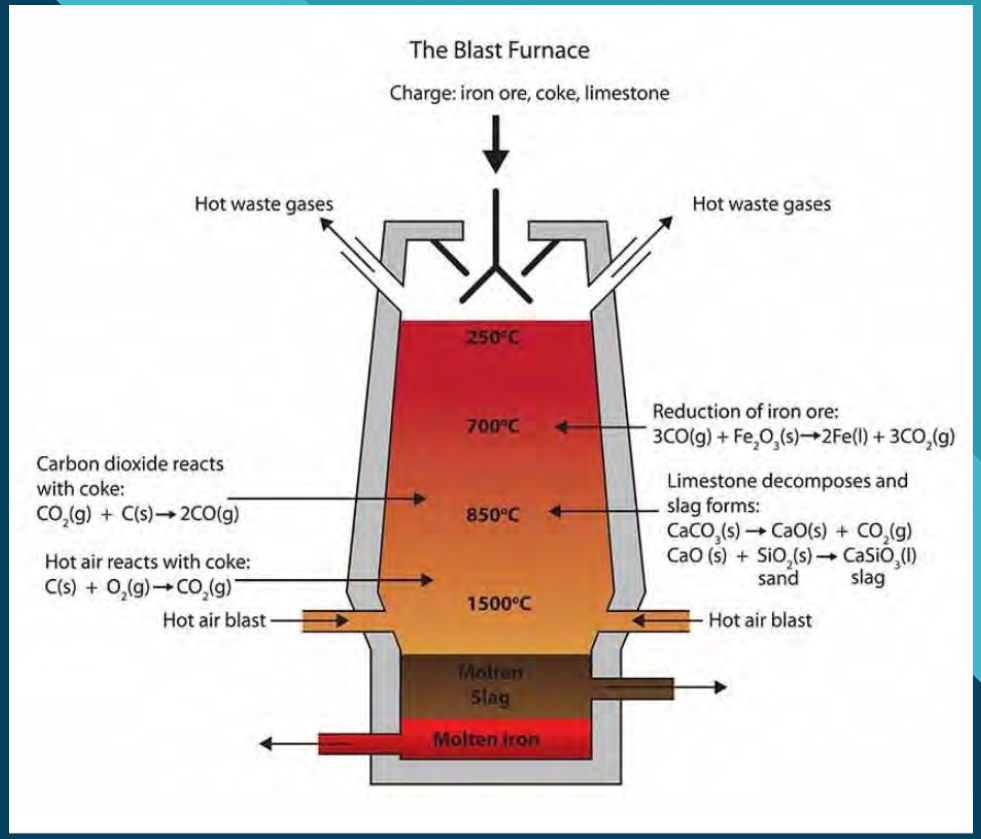
Iron, the precursor to steel, was referenced in ancient writings as far back as 2000 B.C.

The production of iron appears to have occurred as early as 1350 B.C. by burning iron ore (originally in the form of a meteorite), in charcoal, where the oxygen in the air combines with the burning charcoal to produce carbon dioxide, which combines with the hot carbon in the combustion zone to produce carbon monoxide. The hot carbon monoxide then reacts with the oxides in the iron ore (meteorite) to produce carbon dioxide and iron.

How Steel is Made

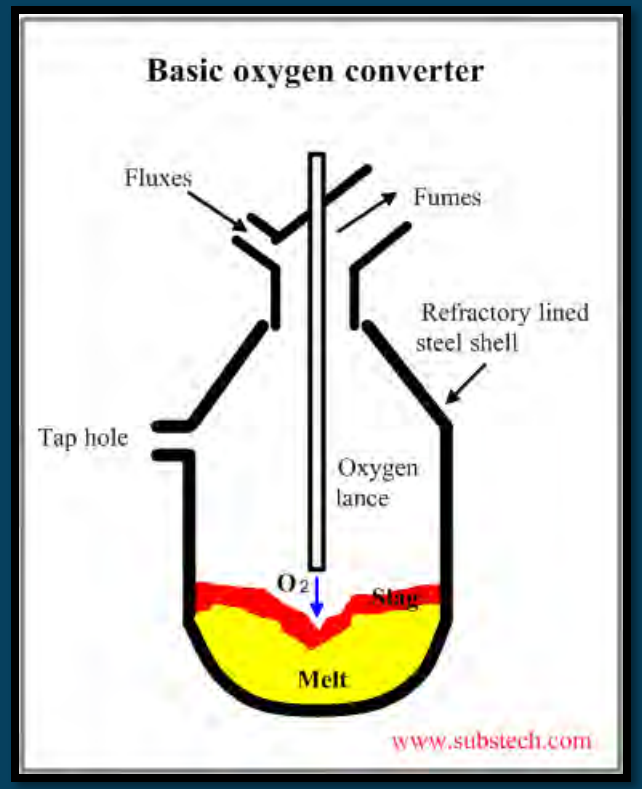
In order to produce iron, the iron oxide ore must be processed in a blast furnace. Modern blast furnaces now make a type of iron called pig iron, which is the main ingredient for making steel.

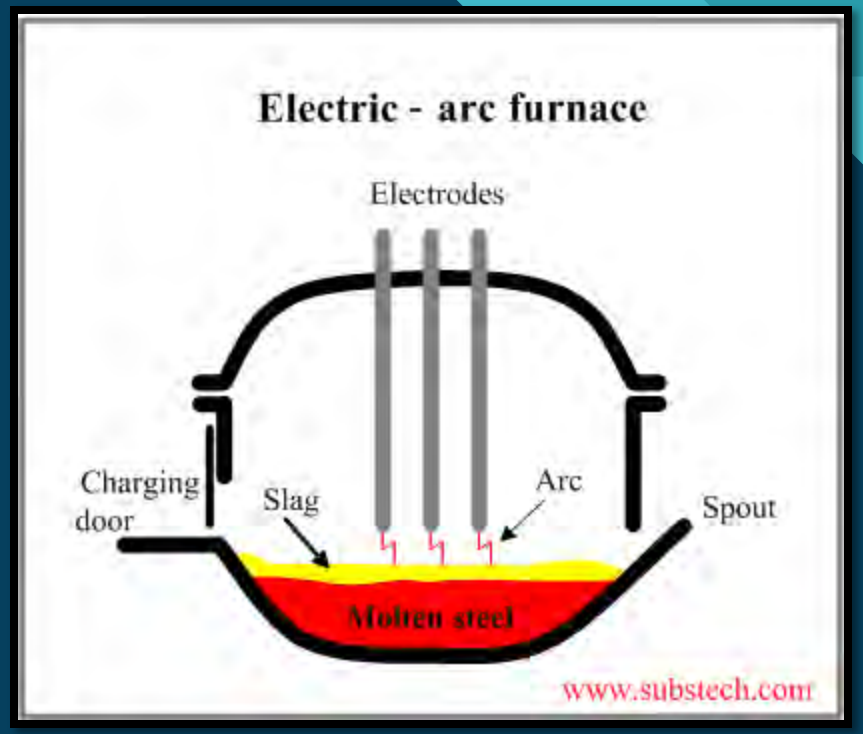
The first step in making steel is to produce pig iron. This happens in a blast furnace, where iron ore is mixed with coke (a type of carbon fuel) and other materials. Hot air is blown in from the bottom, and as the ore drops down, chemical reactions turn it into molten iron. This liquid iron can be sent straight to the next step while still hot — called “hot metal” — or cooled into solid pieces called pig iron. The molds resemble a litter of suckling pigs, so the individual pieces of iron are referred to as pigs.



How Steel is Made

To turn pig iron into steel, it's melted again — sometimes with scrap steel — in furnaces such as the Basic Oxygen Furnace (BOF) or the Electric Arc Furnace (EAF).

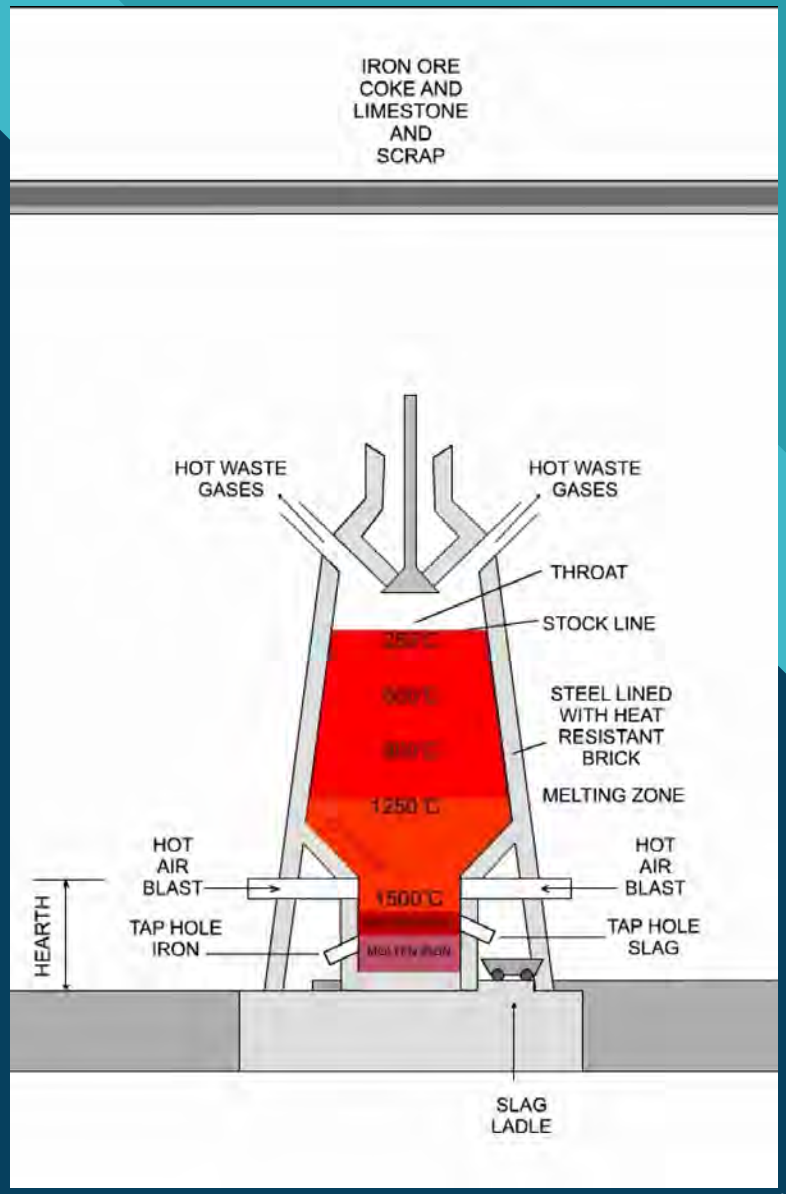




How Steel is Made

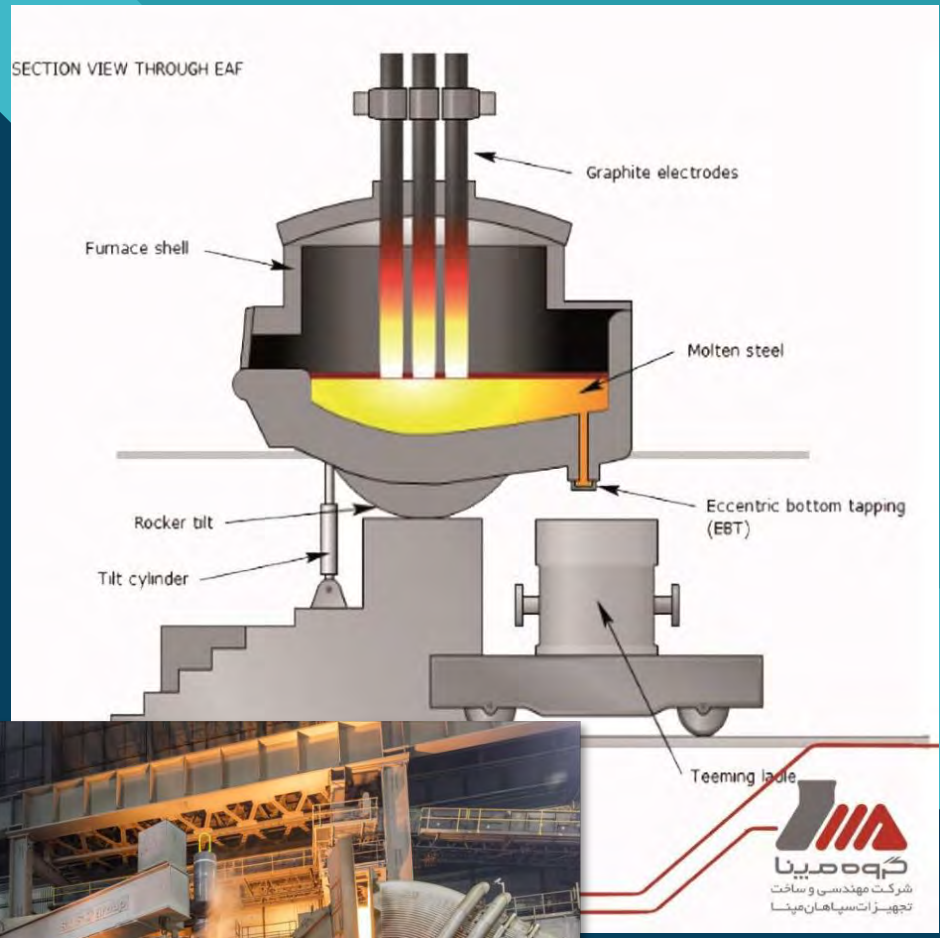
The blast furnace process is continuous. Blast furnaces range in capacity from 1,000 to 15,000 tons per day. The largest blast furnace in the world, located in South Korea, produces 6,000,000 tons per year.

Basic Oxygen Furnace (BOF): Pure oxygen is blown into the molten iron and scrap mix to remove carbon and other impurities, making low-carbon steel. This takes less than an hour and produces about 60% of the world's steel. Furnace sizes typically range from 250 to 400 tons.



Electric Arc Furnace (EAF): Uses electricity to melt mostly scrap metal. In the U.S., about 70% of steel is made this way. It's more eco-friendly, producing only about a third of the greenhouse gases compared to making steel from ore, but recycling scrap can increase unwanted elements like copper. Copper is difficult to remove, and excess copper content can cause surface cracking during forming and welding, called "hot-shortness". Adding pig iron helps dilute the copper. Furnace sizes vary from about 100 to 300 tons. Electric arc furnaces are an integral part of mini mills.

Today, around 90% of U.S. steel comes from recycled metal, but making new steel still requires some mined iron ore.



Alloying Elements

The process of alloying steel is adding additional elements to improve or change physical characteristics. In general, the low alloy steel specifications listed in AWWA C200 have yield strengths of 30,000 to 50,000psi, 18 to 22% ductility and moderate toughness for temperatures for a range of -30 to 250F.

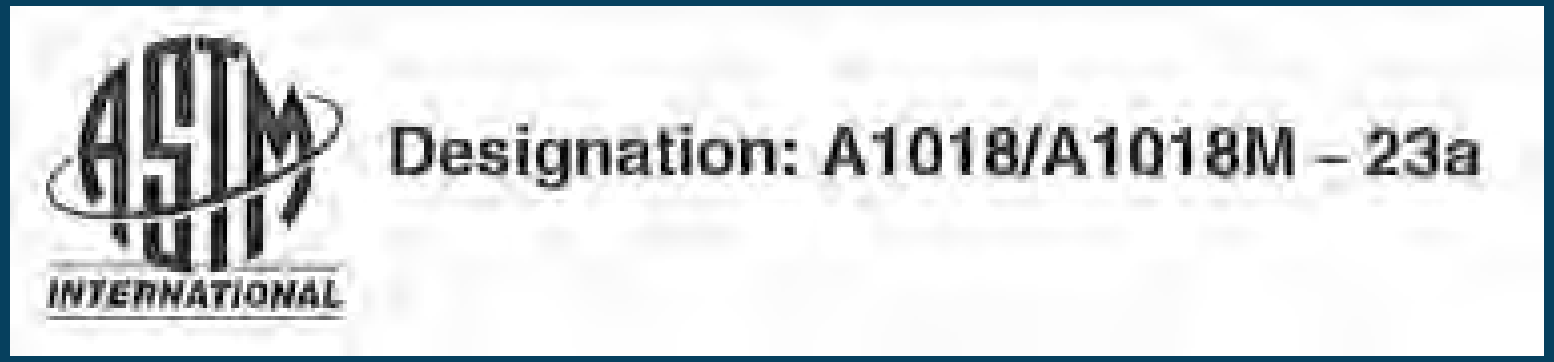
Typical elements and their effects are below:

Aluminum	A deoxidizer to limit grain growth aka “killed steel”
Manganese	Improves hardenability, ductility and wear resistance
Molybdenum	Increases hardenability and strength
Niobium	Increases yield strength
Phosphorus	Improve machinability and strength
Silicon	A deoxidizing agent to limit grain growth
Sulfur	Improves machinability
Vanadium	Promotes fine grain structure

Alloying Elements

Most of these elements are added in minute amounts (far less than 0.5%), yet can have a dramatic effect on the properties of the final product.

Additionally, copper content is typically limited to 0.20 to 0.40%.



Designation: A1018/A1018M – 23a

1. Scope*

1.1 This specification covers hot-rolled, heavy-thickness coils beyond the size limits of Specification A1011/A1011M.

1.2 The product is available in six designations: Commercial Steel, Drawing Steel, Structural Steel, High-Strength Low-Alloy Steel, High-Strength Low-Alloy Steel with Improved Formability, and Ultra-High Strength Steel.

1.3 This material is available only in coils described as follows:

Product	Size Limits, Coils Only	
	Width, in. [mm]	Thickness, in. [mm]
Strip	Over 8 to 12, incl [Over 200 to 300]	0.230 to 1.000, incl [From 6.0 through 25]
Sheet	Over 12 [Over 300]	0.230 to 1.000, incl [From 6.0 through 25]

NOTE 1—The changes in width limits with the publication of A635/A635M – 06a result in a change in tensile testing direction for material

NUCOR STEEL - ARKANSAS
A Division of Nucor Corp
7301 East County Road 142
Blytheville, AR 72315
Telephone: 870/762-2100

METALLURGICAL TEST Total Wgt: 219,170 LBS Date Printed: 8/03/22 Page 1 of 4

Sold To

Ship To

Order/Line	H448494-1	Product	HOT BAND ✓	B/L #	1262020
P/O Number	9100254355	Dimensions	.4900 MIN x 60.0000 MIN (INCHES)	Vehicle #	BN686407
Description	A1018-18 SS GR36 TYPE 2 ✓		Charpy Testing	Ticket #	1352377
				Issue Date	8/01/22

With the following modifications:
"Continuous Cast,fully killed,fine austentic grained"

Customer Part Number 44438

Heat 2123943 Coil ID 1777518.0000
58,000.00 Lbs

Heat 2123944 ✓ Coil ID 1777525.0000
56,980.00 Lbs

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca	Sb
2123943	.22	.50	.009	.0028	.03	.12	.04	.05	.01	.006	.04	.003	.001	.007	.002	.000	.001	.002
2123944 ✓	.22	.51	.010	.0035	.02	.12	.04	.06	.01	.006	.04	.002	.001	.007	.001	.000	.001	.001
2123943	CEV: .3343																	
2123944	CEV: .3343																	

Coil	Test	Val	UOM	Test	Val	UOM	Test	Val	UOM
1777518.0000	T YIELD	45.9	KSI	T TENSILE	75.2	KSI	T ELONGATION	29	%
	T CHARPY 1	21	Ft/Lbs	T CHARPY 2	34	Ft/Lbs	T CHARPY 3	25	Ft/Lbs
	T CHARPY AVG.	26	Ft/Lbs	T CHARPY SHEAR % 1	40		T CHARPY SHEAR % 2	40	
	T CHARPY SHEAR % 3	40		T CHARPY SHEAR % AVG	40		T CHARPY TEMP DEGREES	10	F
	T CHARPY TEST SIZE	8	MM						
1777525.0000	T YIELD	49.2	KSI	T TENSILE	75.3	KSI	T ELONGATION	32	%

All goods are sold subject to the description, specifications and terms and conditions set forth on the face and reverse side, or otherwise provided with, Nucor Steel's order acknowledgement.
Tensile specimens are tested in accordance with ASTM A-370 specification: standard rectangular test configuration (Figure 3) with 2 inch gauge length and a 0.2% offset yield method. Steel is aluminum killed and produced to a fine grain practice.
This material has been produced in compliance with the chemistry and established rolling practices of the ordered specification. If material is ordered to a chemistry only, testing is not performed by producer.
Materials certified to most current revision of ASTM specifications.
We hereby certify the above is correct as contained in the records of the corporation.

100% MELTED AND MANUFACTURED IN THE USA ✓

Andrew Nix
Hot Mill Metallurgist

METCHTT

Rev. 12/13/13 FRM-014-HM

Designation: A1018/A1018M – 23a

5.1.3 *Structural Steel*—(SS Grades 30[205], 33[230], 36[250] Types 1 and 2, 40[275], 45[310], 50 [340], and 55 [380]).

5.1.4 *High Strength, Low Alloy Steel*—(HSLAS Grades

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METALLURGICAL TEST Total Wgt: 219,170 LBS Date Printed: 8/03/22 Page 1 of 4

Sold To

Ship To

Order/Line	H448494-1	Product	HOT BAND		B/L #	1262020	Ship Date	8/03/22
P/O Number	9100254355	Dimensions	.4900	MIN x 60.0000 MIN (INCHES)			Vehicle #	BN686407
Description	A1018-18 SS GR36 TYPE 2			Charpy Testing			Ticket #	1352377
							Issue Date	8/01/22

With the following modifications:
"Continuous Cast,fully killed,fine austentic grained"

Customer Part Number 44438

Heat 2123943 Coil ID 1777518.0000
58,000.00 Lbs
Heat 2123944 Coil ID 1777525.0000
56,980.00 Lbs

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca	Sb
2123943	.22	.50	.009	.0028	.03	.12	.04	.05	.01	.006	.04	.003	.001	.007	.002	.000	.001	.002
2123944	.22	.51	.010	.0035	.02	.12	.04	.06	.01	.006	.04	.002	.001	.007	.001	.000	.001	.001
2123943	CEV: .3343																	
2123944	CEV: .3343																	

Coil	Test	Val	UOM	Test	Val	UOM	Test	Val	UOM
1777518.0000	T YIELD	45.9	KSI	T TENSILE	75.2	KSI	T ELONGATION	29	%
	T CHARPY 1	21	Ft/Lbs	T CHARPY 2	34	Ft/Lbs	T CHARPY 3	25	Ft/Lbs
	T CHARPY AVG.	26	Ft/Lbs	T CHARPY SHEAR % 1	40		T CHARPY SHEAR % 2	40	
	T CHARPY SHEAR % 3	40		T CHARPY SHEAR % AVG	40		T CHARPY TEMP DEGREES	10	F
	T CHARPY TEST SIZE	8	MM						
1777525.0000	T YIELD	49.2	KSI	T TENSILE	75.3	KSI	T ELONGATION	32	%

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Rev. 12/13/13 FRM-014-HM

Designation: A1018/A1018M – 23a

Comparing Spec To MTR Table 1

"Items you do not want in your recipe for steel"

A1018/A1018M – 23a

TABLE 1 Chemical Requirements: Cu, Ni, Cr and Mo for Commercial Steels, Structural Steels, High-Strength Low-Alloy Steels, and High-Strength Low-Alloy Steels with Improved Formability

		% Heat Analysis, Element Maximum Unless Otherwise Shown			
Designation	Limits	Cu[A,B]	Ni[B]	Cr[B,C]	Mo[B,C]
CS:					
Grades 1002–1095, 1515–1566	A	0.20	0.20	0.15	0.06
	B	0.40	0.40	0.30	0.12
SS:					
All grades	A	0.20	0.20	0.15	0.06
	B	0.40	0.40	0.30	0.12
HSLAS:					
All grades and classes except for Grade 70 [480]	A	0.20	0.20	0.15	0.06
	B	0.40	0.40	0.30	0.12
Grade 70 [480] Class 1 and Class 2	A	0.20	0.20	0.15	0.16
	B	0.40	0.40	0.30	0.16
HSLAS-F:					
Grades 50 [340] and 60 [410]	A	0.20	0.20	0.15	0.06
	B	0.40	0.40	0.30	0.12
Grade 70 [480] and 80 [550]	A	0.20	0.20	0.15	0.16
	B	0.40	0.40	0.30	0.16

[A] When copper bearing steel is specified, the minimum limit for copper is 0.20 %. When copper bearing steel is not specified, the maximum limit for copper is as shown in the table.
[B] For Limits B steels, the sum of copper, nickel, chromium and molybdenum shall not exceed 1.00 % on heat analysis. When one or more of these elements are specified by the purchaser, the sum does not apply; in which case, only the individual limits on the remaining elements shall apply.
[C] For Limits B steels, the sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining elements shall apply.

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Comparing Spec To MTR

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METALLURGICAL TEST Total Wgt: 219,170 LBS Date Printed: 8/03/22 Page 1 of 4

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A1018/A1018M – 23a

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Grades 1002–1095,	A	0.20	0.20	0.15	0.06
1515–1566	B	0.40	0.40	0.30	0.12
SS:					
All grades	A	0.20	0.20	0.15	0.06
	B	0.40	0.40	0.30	0.12

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58,000.00 Lbs
Heat 2123944 ✓ Coil ID 1777525.0000
56,980.00 Lbs

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca	Sb
2123943	.22	.50	.009	.0028	.03	.12	.04	.05	.01	.006	.04	.003	.001	.007	.002	.000	.001	.002
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	T CHARPY SHEAR % 3	40		T CHARPY SHEAR % AVG	40		T CHARPY TEMP DEGREES	10	F
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Rev. 12/13/13 FRM-014-HM

Designation: A1018/A1018M – 23a

Comparing Spec To MTR Table 3

“Recipe for steel”

TABLE 3 Chemical Requirements

Structural Steels, High-Strength Low-Alloy Steels, and High-Strength Low-Alloy Steels with Improved Formability

	% Heat Analysis, Element Maximum Unless Otherwise Shown									
Designation	C	Mn	P	S	Al	Si	V	Cb/Nb[A]	Ti	N
SS										
Grade 30 [205]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 33 [230]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 36 [250] Type 1	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 36 [250] Type 2	0.25	[C]	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 40 [275]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 45 [310]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 50 [340]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 55 [380]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
HSLAS[D]										
Grade 45 [310] Class 1	0.22	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 45 [310] Class 2	0.15	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 50 [340] Class 1	0.23	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 50 [340] Class 2	0.15	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 55 [380] Class 1	0.25	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 55 [380] Class 2	0.15	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 60 [410] Class 1	0.26	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 60 [410] Class 2	0.15	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 65 [450] Class 1	0.26	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 65 [450] Class 2	0.15	1.50	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 70 [480] Class 1	0.26	1.65	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 70 [480] Class 2	0.15	1.65	0.04	0.04	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
HSLAS-F[D]										
Grade 50 [340]	0.15	1.65	0.025	0.035	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 60 [410]	0.15	1.65	0.025	0.035	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 70 [480]	0.15	1.65	0.025	0.035	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]
Grade 80 [550][C]	0.15	1.65	0.025	0.035	[B]	[B]	0.005 min	0.005 min	0.005 min	[E]

[A] The names Columbium (Cb) and Niobium (Nb) for Periodic Table Element 41 are considered interchangeable within A01 Product specifications.

[B] There is no specified limit, but the analysis shall be reported. See Table 1 for requirements for Cu, Ni, Cr, and Mo.

[C] For SS Grade 36 Type 2 greater than 0.75 in. [20 mm] in thickness, the manganese requirement is 0.80 % to 1.20 %. For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 % for SS Grade 36 Type 2 and to a maximum of 1.90 % for HSLAS-F Grade 80.

[D] HSLAS and HSLAS-F steels contain the strengthening elements columbium (niobium), vanadium, and titanium added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.

[E] The purchaser has the option of restricting the nitrogen content. It should be noted that, depending on the microalloying scheme (for example, use of vanadium) of the producer, nitrogen may be a deliberate addition. Consideration should be made for the use of nitrogen binding elements (for example, vanadium, titanium).

Designation: A1018/A1018M – 23a

Comparing Spec To MTR Table 3

"Recipe for steel"

NUCOR STEEL - ARKANSAS | METALLURGICAL TEST | Total Wgt: 219,170 LBS | Date Printed: 8/03/22 | Page 1 of 4

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TABLE 3 Chemical Requirements

Structural Steels, High-Strength Low-Alloy Steels, and High-Strength Low-Alloy Steels with Improved Formability

Designation	% Heat Analysis, Element Maximum Unless Otherwise Shown									
	C	Mn	P	S	Al	Si	V	Cb/Nb[A]	Ti	N
SS										
Grade 30 [205]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 33 [230]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 36 [250] Type 1	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 36 [250] Type 2	0.25	[C]	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 40 [275]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 45 [310]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014
Grade 50 [340]	0.25	1.50	0.035	0.04	[B]	[B]	0.008	0.008	0.025	0.014

Heat 2123943 Coil ID 1777518.0000
58,000.00 Lbs

Heat 2123944 ✓ Coil ID 1777525.0000
56,980.00 Lbs

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca	Sb
2123943	.22	.50	.009	.0028	.03	.12	.04	.05	.01	.006	.04	.003	.001	.007	.002	.000	.001	.002
2123944 ✓	.22	.51	.010	.0035	.02	.12	.04	.06	.01	.006	.04	.002	.001	.007	.001	.000	.001	.001
2123943	CEV: .3343																	

[A] The names Columbium (Cb) and Niobium (Nb) for Periodic Table Element 41 are considered interchangeable within A01 Product specifications.
[B] There is no specified limit, but the analysis shall be reported. See Table 1 for requirements for Cu, Ni, Cr, and Mo.
[C] For SS Grade 36 Type 2 greater than 0.75 in. [20 mm] in thickness, the manganese requirement is 0.80 % to 1.20 %. For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 % for SS Grade 36 Type 2 and to a maximum of 1.90 % for HSLAS-F Grade 80.
[D] HSLAS ... minimum requireme...
[E] The pur... n) of the producer, nitrogen may be a deliberate addition. Consideration should be made for the use of nitrogen binding elements (for example, vanadium, titanium).

"Coil is less than 0.75" thick. This clause is not applicable."

1777525.0000 T YIELD 49.2 KSI T TENSILE 75.3 KSI T ELONGATION 32 %

All goods are sold subject to the description, specifications and terms and conditions set forth on the face and reverse side, or otherwise provided with, Nucor Steel's order acknowledgement.
Tensile specimens are tested in accordance with ASTM A-370 specification: standard rectangular test configuration (Figure 3) with 2 inch gauge length and a 0.2% offset yield method. Steel is aluminum killed and produced to a fine grain practice.
This material has been produced in compliance with the chemistry and established rolling practices of the ordered specification. If material is ordered to a chemistry only, testing is not performed by producer.
Materials certified to most current revision of ASTM specifications.
We hereby certify the above is correct as contained in the records of the corporation.

100% MELTED AND MANUFACTURED IN THE USA ✓

Andrew Nix
Hot Mill Metallurgist

Rev. 12/13/13 FRM-014-HM

Designation: A1018/A1018M – 23a

Comparing Spec To MTR Table 5

“Recipe Results, The Mechanical Properties”

TABLE 5 Mechanical Property Requirements[A] for Hot Rolled Heavy Thickness Coils

Designation	Yield Strength min ksi [MPa]	Tensile Strength min[B] ksi [MPa]	Elongation in 2 in. [50 mm], min, %	Elongation in 8 in. [200 mm], min, %
Designations SS, HSLAS, and HSLAS-F				
SS				
Grade 30 [205]	30 [205]	49 [340]	22	17
Grade 33 [230]	33 [230]	52 [360]	22	16
Grade 36 [250] Type 1	36 [250]	53 [365]	21	15
Grade 36 [250] Type 2[B]	36 [250]	58 to 80 [400 to 550]	21	18
Grade 40 [275]	40 [275]	55 [380]	19	14
Grade 45 [310]	45 [310]	60 [410]	18	13
Grade 50 [340]	50 [340]	65 [450]	17	12
Grade 55 [380]	55 [380]	70 [480]	15	10
HSLAS				
Grade 45 [310] Class 1	45 [310]	60 [410]	22	17
Grade 45 [310] Class 2	45 [310]	55 [380]	22	17
Grade 50 [340] Class 1	50 [340]	65 [450]	20	16
Grade 50 [340] Class 2	50 [340]	60 [410]	20	16
Grade 55 [380] Class 1	55 [380]	70 [480]	18	15
Grade 55 [380] Class 2	55 [380]	65 [450]	18	15
Grade 60 [410] Class 1	60 [410]	75 [520]	16	14
Grade 60 [410] Class 2	60 [410]	70 [480]	16	14
Grade 65 [450] Class 1	65 [450]	80 [550]	14	12
Grade 65 [450] Class 2	65 [450]	75 [520]	14	12
Grade 70 [480] Class 1	70 [480]	85 [590]	12	10
Grade 70 [480] Class 2	70 [480]	80 [550]	12	10
HSLAS-F				
Grade 50 [340]	50 [340]	60 [410]	22	16
Grade 60 [410]	60 [410]	70 [480]	16	14
Grade 70 [480]	70 [480]	80 [550]	12	10
Grade 80 [550]	80 [550]	90 [620]	12	10
UHSS				
Grade 90 [620] Types 1 and 2	90 [620]	100 [690]	10	8
Grade 100 [690] Types 1 and 2	100 [690]	110 [760]	10	8

[A] For coil products, testing by the producer is limited to the end of the coil. Mechanical properties throughout the coil shall comply with the minimum values specified.
[B] A minimum and maximum tensile strength are specified for SS Grade 36 Type 2.

Designation: A1018/A1018M – 23a

Comparing Spec To MTR Table 5

"Recipe Results, The Mechanical Properties"

NUCOR STEEL - ARKANSAS
A Division of Nucor Corp
7301 East County Road 142
Blytheville, AR 72315
Telephone: 870/762-2100

METALLURGICAL TEST Total Wgt: 219,170 LBS Date Printed: 8/03/22 Page 1 of 4

Sold To

Ship To

Order/Line	H448494-1	Product	HOT BAND ✓	B/L #	1262020	Ship Date	8/03/22
P/O Number	9100254355	Dimensions	.4900 MIN x 60.0000 MIN (INCHES)			Vehicle #	BN686407
Description	A1018-18 SS GR36 TYPE 2 ✓		Charpy Testing			Ticket #	1352377

With

Heat

Heat

Heat

21

21

21

21

A1018/A1018M – 23a

TABLE 5 Mechanical Property Requirements[A] for Hot Rolled Heavy Thickness Coils

Designations SS, HSLAS, and HSLAS-F

Designation	Yield Strength min ksi [MPa]	Tensile Strength min[B] ksi [MPa]	Elongation in 2 in. [50 mm], min, %	Elongation in 8 in. [200 mm], min, %
SS				
Grade 30 [205]	30 [205]	49 [340]	22	17
Grade 33 [230]	33 [230]	52 [360]	22	16
Grade 36 [250] Type 1	36 [250]	53 [365]	21	15
Grade 36 [250] Type 2[B]	36 [250]	58 to 80 [400 to 550]	21	18
Grade 40 [275]	40 [275]	55 [380]	19	14
Grade 45 [310]	45 [310]	60 [410]	18	13
Grade 50 [340]	50 [340]	65 [450]	17	12

Coil	Test	Val UOM	Test	Val UOM	Test	Val UOM
1777518.0000	T YIELD	45.9 KSI	T TENSILE	75.2 KSI	T ELONGATION	29 %
	T CHARPY 1	21 Ft/Lbs	T CHARPY 2	34 Ft/Lbs	T CHARPY 3	25 Ft/Lbs
	T CHARPY AVG.	26 Ft/Lbs	T CHARPY SHEAR % 1	40	T CHARPY SHEAR % 2	40
	T CHARPY SHEAR % 3	40	T CHARPY SHEAR % AVG	40	T CHARPY TEMP DEGREES	10 F
	T CHARPY TEST SIZE	8 MM				
1777525.0000	T YIELD	49.2 KSI	T TENSILE	75.3 KSI	T ELONGATION	32 %

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Tensile specimens are tested in accordance with ASTM A-370 specification: standard rectangular test configuration (Figure 3) with 2 inch gauge length and a 0.2% offset yield method. Steel is aluminum killed and produced to a fine grain practice.
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100% MELTED AND MANUFACTURED IN THE USA ✓

Andrew Nix
Hot Mill Metallurgist

METCHTT

Rev. 12/13/13 FRM-014-HM

Designation: A1018/A1018M – 23a

Results

NUCOR STEEL - ARKANSAS
A Division of Nucor Corp
7301 East County Road 142
Blytheville, AR 72315
Telephone: 870/762-2100

METALLURGICAL TEST Total Wgt: 219,170 LBS Date Printed: 8/03/22 Page 1 of 4

Sold To

Ship To

Order/Line	H448494-1	Product	HOT BAND	B/L #	1262020
Ship Date	8/03/22				
P/O Number	9100254355	Dimensions	.4900 MIN x 60.0000 MIN (INCHES)		
Vehicle	BN686407				
Description	A1018-18 SS GR36 TYPE 2	Charpy Test		Ticket #	1352377
					8/01/22

PASSED

With the following modifications:
"Continuous Cast,fully killed, [illegible]"

Heat 2123943 Coil ID 1777[illegible]
58,0[illegible]
Heat 2123944 Coil ID 1777[illegible]
56,98[illegible]00 Lbs

Heat	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	V	Nb	N	Ti	B	Ca	Sb
2123943	.22	.50	.009	.0028	.03	.12	.04	.05	.01	.006	.04	.003	.001	.007	.002	.000	.001	.002
2123944	.22	.51	.010	.0035	.02	.12	.04	.06	.01	.006	.04	.002	.001	.007	.001	.000	.001	.001
2123943	CEV: .3343																	
2123944	CEV: .3343																	

Coil	Test	Val	UOM	Test	Val	UOM	Test	Val	UOM
1777518.0000	T YIELD	45.9	KSI	T TENSILE	75.2	KSI	T ELONGATION	29	%
	T CHARPY 1	21	Ft/Lbs	T CHARPY 2	34	Ft/Lbs	T CHARPY 3	25	Ft/Lbs
	T CHARPY AVG.	26	Ft/Lbs	T CHARPY SHEAR % 1	40		T CHARPY SHEAR % 2	40	
	T CHARPY SHEAR % 3	40		T CHARPY SHEAR % AVG	40		T CHARPY TEMP DEGREES	10	F
	T CHARPY TEST SIZE	8	MM						
1777525.0000	T YIELD	49.2	KSI	T TENSILE	75.3	KSI	T ELONGATION	32	%

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Hot Mill Metallurgist

Rev. 12/13/13 FRM-014-HM

Alloying Elements

A downside of increasing the alloying elements is the decreasing weldability of the steel. All of these additives have the same effect on welding as increasing the carbon content.

This is expressed as the “carbon equivalent” or CE. Generally, the maximum value for the Carbon Equivalent is 0.45.

The accepted formula for CE per ASTM A1018 is as follows:

$$CE = \%\ carbon + \frac{\%\ manganese}{6} + \frac{(\%\ chromium + \%\ molybdenum + \%\ vanadium)}{5} + \frac{(\%\ nickel + \%\ copper)}{15}$$

Alloying Elements

It is noticeable that many of the alloying elements limit grain growth and many steel specifications refer to “fine” grained steel. As mentioned earlier, fine grained steels have more boundary area per unit area of steel.

At the typical operating temperature range for steel, the grain boundaries interfere with plastic deformation which is an increase in strength and ductility.

Alloying Elements

Q. So how do you get fine grained steel?

A. You kill the steel!

Killing steel means a deoxidizer (Aluminum) is added at the time the steel is poured to stop (kill) the chemical reaction, which prevents the grain size from increasing. A steel is considered fully killed if the heat analysis shows the aluminum content is not less than 0.020%.

What is Green Steel?

The production of steel from iron ore and/or scrap is an extremely energy-intensive process, responsible for an estimated 7–9% of all global greenhouse gas emissions. Because of this, steelmaking is a major target for decarbonization.

Many steel producers have turned to Electric Arc Furnaces (EAFs), which use electricity instead of coal to provide the heat to melt metal. EAFs can process scrap steel, direct reduced iron (DRI), and hot briquetted iron (HBI), and they produce roughly 75% less carbon emissions than a traditional blast furnace combined with a Basic Oxygen Furnace (BOF). EAFs are also more energy-efficient because they can be turned off and on quickly, unlike blast furnaces and BOFs, which take a long time to shut down or restart.

What is Green Steel?

Steel companies are promoting “Green Steel” in several ways. The term “Green” refers to several items including:

- Purchasing carbon offsets
- Sequestration of the carbon dioxide generated during the steelmaking process
- Using less energy to produce steel
- Using low carbon or carbon free sources of energy
- Producing lower amounts or eliminating harmful byproducts.

What is Green Steel?

Technology claims – Some steel producers like Nucor, highlight their low-carbon production using EAFs and recycled scrap, often publishing Environmental Product Declarations (EPDs) to prove emissions reductions.

Partnerships and buyer platforms – Steel producers sign supply deals with customers (Primarily automakers) to guarantee future demand for low-carbon steel. Industry platforms also connect buyers to certified green steel suppliers.

What is Green Steel?

Branding and certification – Some companies label their products as “fossil-free,” “low-carbon,” or “sustainable steel” to appeal to customers and investors focused on climate impact. Governments and Owners are also starting to define and track green steel. These types of standards encourage investment in cleaner technology and give buyers a way to compare products. There are third party organizations such as Building Transparency with the mission of managing and maintaining Embedded Carbon Data (EC3) and Environmental Product Declarations (EPDs).

What is Green Steel?

With steel demand expected to grow by 30% by 2050, these combined efforts from industry and government are critical to reducing the environmental footprint of one of the world's most essential materials.

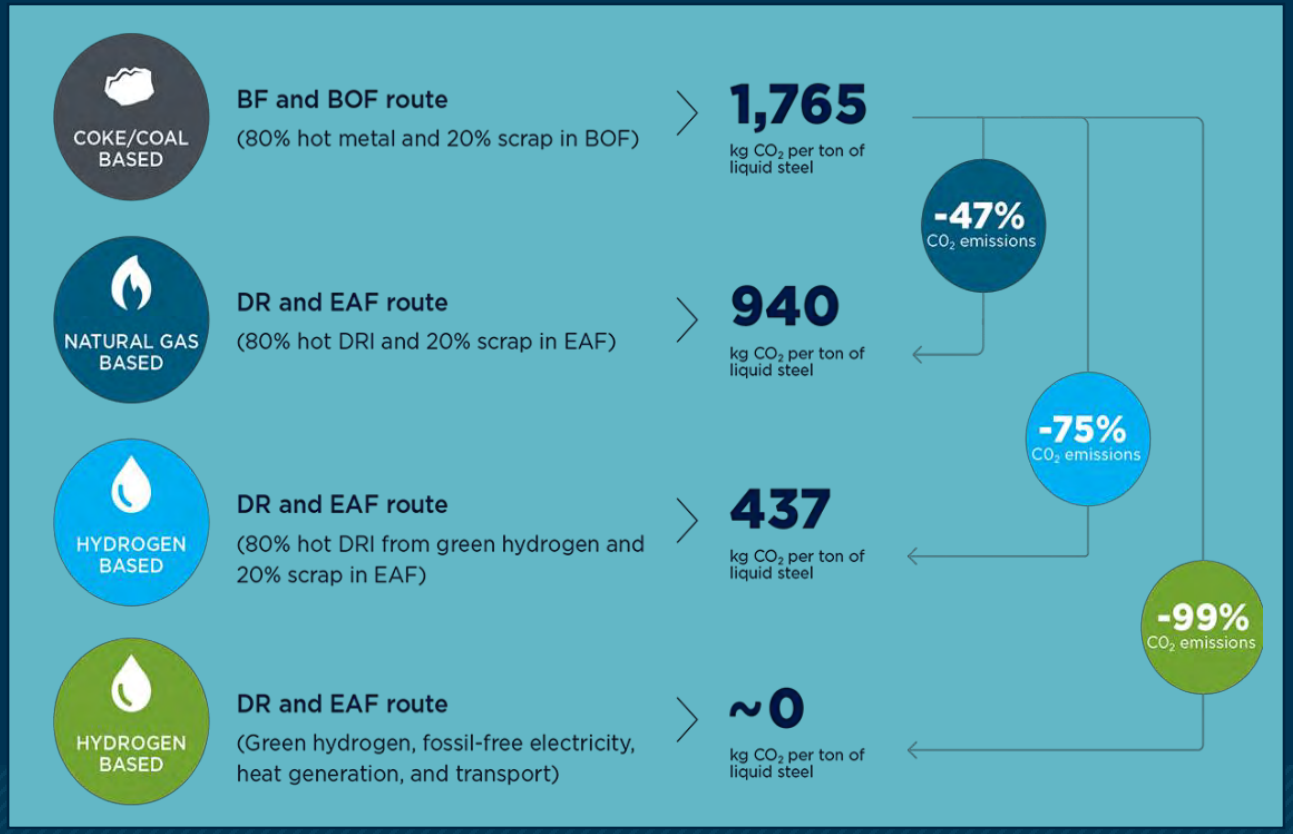
Key:

BF Blast Furnace

BOF Basic Oxygen Furnace

DRI Direct Reduced Iron

EAF Electric Arc Furnace



Some new processes to reduce greenhouse gas emissions

Molten Oxide Electrolysis, where an inert anode is immersed in an electrolyte containing iron ore. When current is applied, the cell heats to 2,900°F and the electrons split the bonds in the iron oxide in the ore and molten metal is produced. Carbon is eliminated from the process and the only byproduct is oxygen. This process is expected to reach production with Boston Steel by 2026.

Nucor is partnering with ExxonMobil at their Direct Reduced Iron (DRI) plant to remove the carbon dioxide and sequester it.

NUCOR®

ExxonMobil

Some new processes to reduce greenhouse gas emissions

Arcelor Mittal is using a DRI process that eliminates the use of nitrogen in the process that eliminates the nitrous oxide (NOX) emissions. NOX is a smog forming compound.

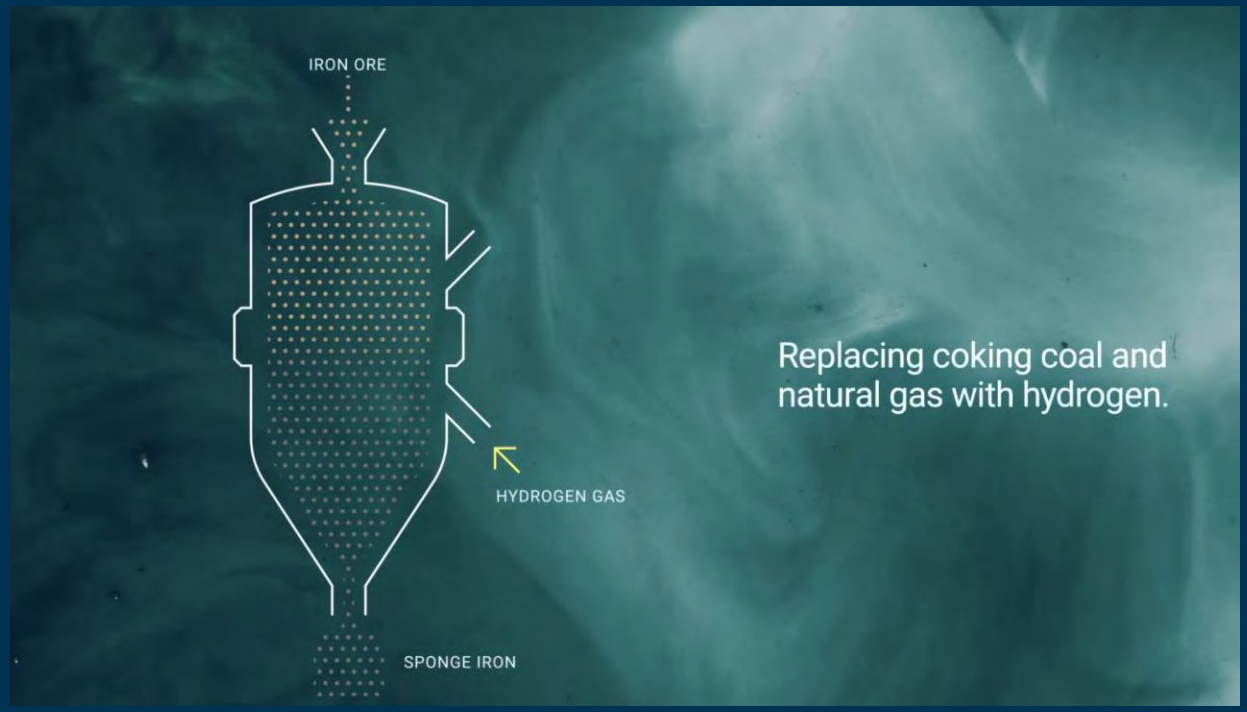
Also, Arcelor Mittal is recycling blast furnace waste gasses at a plant in Belgium into methanol which is used in place of fossil sourced natural gas to power the blast furnace process.

Some new processes to reduce greenhouse gas emissions

Cleveland-Cliffs is converting some of their furnaces in Middletown, OH to hydrogen fuel to lower its carbon footprint.

SSAB has developed a process called Hybrit, which is a direct reduction of iron ore using fossil free hydrogen fuel which emits water only.

They are also marketing a scrap-based steel called SSAB Zero which is produced with fossil free electricity and renewable natural gas.



Points to Remember

- ✓ Steel is an extremely versatile material made mostly from iron
- ✓ The processing of iron ore to steel is very energy-intensive and emits large amounts of greenhouse gases
- ✓ Steel used in the manufacture of pipe is a low carbon, low alloy fine grained material
- ✓ New steel is primarily made in a minimill from scrap with some pig iron used to dilute the copper present in the scrap. Excess copper can result in poor welding performance.
- ✓ Most steel is typically made to a particular (Common) standard and not to a unique specification.
- ✓ The versatility of steel allows steel made to different standards to fulfill a specific set of requirements.

Thank You

STI SPFA®