Keep on ROLLING

STORY AND PHOTOS BY GEOFF WEISENBERGER

An inside look at a modern, high-tech steelmaking operation.

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LATE LAST YEAR, Nucor-Yamato Steel's (NYS) mill in Blytheville, Ark., reached a significant milestone: a quarter-century of operation.

Since opening in 1988, it has produced an estimated 48 million tons of structural steel—all of it via the electric arc furnace (EAF) process. The short version is that the mill makes new steel products out of old steel products, melting down scrap and casting it into new wide-flange and other shapes. The long version is much more interesting.

The Right Mix

It all starts with scrap—lots of scrap. Thanks to the mill's strategic positioning on the Mississippi River, the majority of scrap arrives via barge and is typically sourced from within a 500-mile radius. (Blytheville is about an hour north of Memphis, Tenn., and the site was chosen for its central U.S. location, access to the river, reliable local electrical grid, regional scrap supply and proximity to a good transportation network of

▲ Steel on its way from rolling to final cutting.

◄ Slag being dumped from a ladle, after being emptied at the caster, into a slag pot.

▼ Graphite electrodes melt the steel at temperatures approaching 3,000 °F in the electric arc furnace. In this picture, the roof is swung open while the scrap bucket is emptied into the furnace.

railroads and highways.) A specialized crane, which looks like a giant claw, plucks the scrap from the barge and loads it into trucks.

All inbound scrap is run through a monitor, which basically looks like a yellow steel archway, that tests the scrap load for radioactive materials. In rare cases of detection, material that contains traces of radioactivity is moved to a confinement area before being hauled away. (Sometimes the trace amount of radiation is emitted by steel from demolished industrial facilities where radioactive processes were once used; in those cases the suspect scrap is segregated for further evaluation by trained radiation technicians.)

The scrap is then transported to the

Casting the steel. Two molten steel streams are fed into molds. Granulated powder is also continuously fed into the molds so that the steel doesn't stick—much like greasing a pan.

appropriate pile. The mill uses several different types of scrap, based on content and density, each with a certain percentage of iron and other residual elements: nickel, chromium, copper, tin, etc. For example, one type is composed of steel that was most recently used as structural steel, another type has the same chemical makeup but has already been shredded and yet another is composed of scrap that wasn't formerly structural elements but still has a high iron (ferrous) content (cars, appliances, roadside recycling, etc.). There is also a designation for "home scrap" that has been recycled from the steelmaking process at the facility.

The Blytheville facility has two rolling mills, which specialize in different products. Mill 1 focuses on wide-flange, angles (up to L10), S-sections (up to S24), channels (up to C18), H-piles and sheet piles. Mill 2, which opened in 1993, primarily produces heavy wide-flange sections and H-piles (up to HP16 and HP18). The range of W-shapes produced at the Blytheville facility is W6×15 to W14×730

Molten steel is fed directly into the caster from the ladle. It is at this point that it takes on its "dog bone" profile.

Scrap is dropped into the electric arc furnance from a charging bucket, which has a hatch at the bottom.

Steel exiting the breakdown mill (left) and being rolled in the universal rougher/edger mill (right).

After going through all three sets of rollers, each one further forming the shape, steel is ready for final cutting.

(with regard to foot-weight) and up to W44×335 (with regard to section depth).

While the EAFs are in the same building, the rolling mills are located in two different buildings on the facility's 850 acres, approximately 45 acres of which is under roof. Most of the facility runs 24-7, with four crews on a "four-on, four-off" schedule (meaning four 12-hour days in a row followed by four days off).

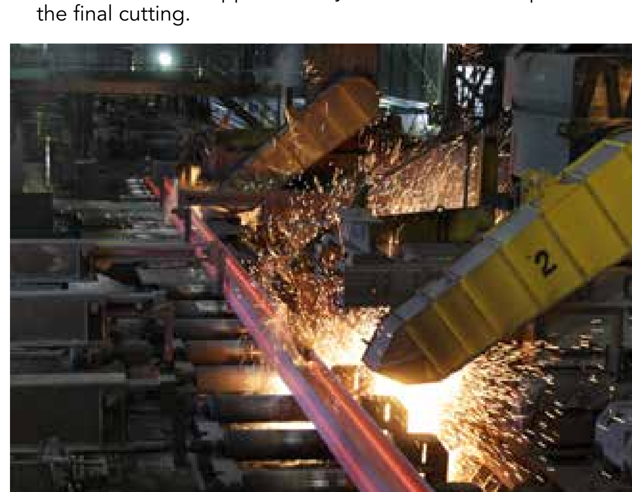
Steelmaking via the EAF process is much like baking, and you can think of each scrap type as a specific ingredient and the various scrap piles as the pantry. For the most part, each product uses the same scrap recipe or blend (that is, a measured tonnage of each scrap type, loaded into the scrap buckets). Once the bucket is loaded, the scrap is dumped into one of the mill's two EAFs, where it will be melted down at temperatures approaching 3,000 °F. Each batch is called a "heat" and the scrap mix is added to the furnace in two buckets or "charges." The first charge, typically 90 to 95 tons, is melted, then the second charge of 40 to 45 tons is added and melted; the variation in tonnage depends on the scrap density. In addition to the scrap, lime is added for flux, as is charge carbon as an additional heat source; at this facility, charge carbon is also substituted with shredded tires. Each heat takes approximately 35 minutes and there are typically 36 heats per furnace per day; a good yield from a heat is 120 tons of molten steel.

Observing the melting process is a powerful experience, akin to being close to a volcano while it's erupting—a lot of noise, a lot of smoke and an intensity that you can feel throughout your body, especially when standing on a metal catwalk several stories above the ground. The furnace is lined with refractory bricks, which keeps the furnace itself from melting, and the melting is performed by three 24-in.-diameter graphite electrodes that are lowered through the roof of the furnace. When the electrodes first hit the steel, there's a loud pop followed by a continuous rumbling. Once the heat is completed, the furnace is "tapped" and the molten steel, which looks like lava, is extracted for the next step in the process. Slag, materials that rise to the surface, is skimmed from the top and separated—much like skimming the cream at a dairy—and sold, typically as road aggregate. A vacuum or "bag house" above the furnace removes emissions, and the particulates are sent to a recycling facility.

Next, the molten steel is transported via giant ladles to the ladle metallurgy furnace (LMF). Here, the steel is reheated, using electrodes similar to the EAF, deoxidized, desulfurized and further re-

Beam blanks after being cut by the oxygen torch.

Two circular saws (approximately 84 in. in diameter) perform the final cutting.



Most scrap arrives at the facility via barge. From here it is transferred, via trucks, to the proper scrap pile to await melting.

Scrap is separated into multiple types. A consistent "recipe" of steel from the various piles is used to create the products.

fined with the addition of various other alloys to bring it to the perfect mix before it is cast. It is at this stage that the chemistry is adjusted to create a specific end product. For example, too many alloys for a light product will cause the mechanical properties to be too high for the specification, while too few alloys for a heavier product will cause the mechanical properties to be too low for the specification. Basically, the chemistry is fine-tuned to specific, tight, internal specifications within a general specification such as ASTM A992 or ASTM A588.

"Without this step, it would be like a cake without flour," says Jim Schoen, one of the plant's metallurgists. "Basically, the steel would be of little use because it could not meet the intended properties without deoxidation, desulfurization and alloying."

At the LMF, an operator takes a sample of the steel, which cools into a small shape resembling a lollipop, and tests it with an optical emission spectrometer.

"This machine tells you the chemical composition of the sample," explains Schoen. "Sometimes the LMF operators achieve the procedural aim for the end product with the first addition."

If not, the proper proportions of specified alloys are further added until the perfect mix is achieved.

Casting Call

At this point, the ladle is transported to the caster, where the steel will be cast into long shapes called beam blanks or "dog bones"—as this is what the cross section resembles—which will then be cut and rolled into finished products. As the liquid steel flows out from a ceramic gate in the ladle bottom, it is guided into the caster in perfect strands. Granulated powder, which is designed to melt at a specific temperature for NYS products, is continuously fed into the bottomless caster mold so that the solidified steel shell that forms along the mold wall doesn't stick to it—much like greasing a pan. The emergence from the caster is where the steel first begins to take on the look of a finished product—a cast beam with a web and two flanges (in the case NYS' main products, W- and HP-shapes). However, there are a few products produced at rolling Mill 1 that come from a "bloom" with a rectangular cross section.

At this point, the steel needs to be cut, as it emerges from the caster in lengths of up to 40 ft. Still orange-hot, the dog bones are cut with an oxygen torch, then cooled slightly with water so magnets can move them to storage if they are not going to be taken directly to the rolling mill. All water used at the plant is pulled from wells and is recirculated as many times as possible through a closed-loop system, then treated before being released. The mill is working toward zero discharge into the local groundwater and sewage systems and is currently using some of its treated, nutrient-rich discharge to irrigate adjacent farmland.

Nucor-Yamato's riverfront property provides fertile ground for grazing cattle owned by nearby farms.

Following cutting, beam blanks are cooled with water.

While steel is tracked through the facility from the very beginning, it is at this point where each beam blank or bloom, while still at the caster torch tables, receives a physical tag. The time frame from scrap melting to cutting is around two hours: 35 minutes for the heat in the EAF, 10 minutes or so in transit, 40 minutes in the LMF and 40 minutes for the casting operation.

On a Roll

Once ready for rolling, the beam blanks are placed in reheat furnaces, which can handle up to 32 blanks at a time depending on the size. Reheating typically takes two hours and brings the steel up to around 2,400 °F. The tracking tags are burned off during the reheating process and new ones are added back on after rolling and cutting (steel is tracked continuously via computers throughout the mill).

When it's heated back to the proper temperature and is once again orange-hot, the steel goes through three sets of rollers, each one further forming the steel until it becomes a usable member, ready for fabrication.

"Think of it as rolling out batter or pulling taffy," Schoen says.

The first set, the breakdown rolls, shapes the beam blank to the approximate section depth and flange width. The number of passes through this set varies by product; the steel we witness today will become HP16x121 and takes 11 passes, moving through the breakdown rolls forward and back a total of 11 times, then advancing to the universal rougher/edger mill after the 11th pass.

This second set of rollers further works the beam blank to the desired flange width and section depth. It is also at this point that temperature is controlled to achieve yield strength as well as CVN (Charpy V-notch) properties; 15 passes are required for this particular product.

The third and final set of rolls, the universal finishing mill, determines the final dimensions and requires just one pass.

Rolls need to be substituted based on the product requirements, maintenance needs and production schedule. They can be changed in about 45 minutes and can withstand thousands of production hours before being replaced. The company is currently building a robotic roller storage rack, adjacent to one of the mill buildings, which will increase the efficiency of rebuilding stands and replacing rolls.

Following rolling, the steel is cut to length via massive circular saws that send out a shower of sparks (old saw blades are turned into home scrap and eventually new steel products). Samples are cut periodically to check the dimensions of the product. Additionally, samples are cut to be tested for strength and other properties, at frequencies

After cooling, beam blanks are often stored outside before they are ready to be reheated and rolled into shape.

Now final products, steel members cool before they are stored outside and eventually shipped to customers.

A Bigger Furnace

The two-charge method of adding scrap to the EAF is dictated by having to melt down the first charge in order to make room for the second one; if the scrap was piled up past the top edge of the furnace, the lid wouldn't fit on. A good compromise, it would seem, would involve only having to use one charge while getting the same yield as the two-charge system. But how to do this?

In a nutshell: Make the furnace larger. And that's just what Nucor-Yamato is in the process of doing. The upgrade involves a new gantry system, scrap bucket, lower shell, spray-cooled upper shell and spray-cooled roof. The benefits will be a safer working environment, lower operating costs and improved shop logistics.

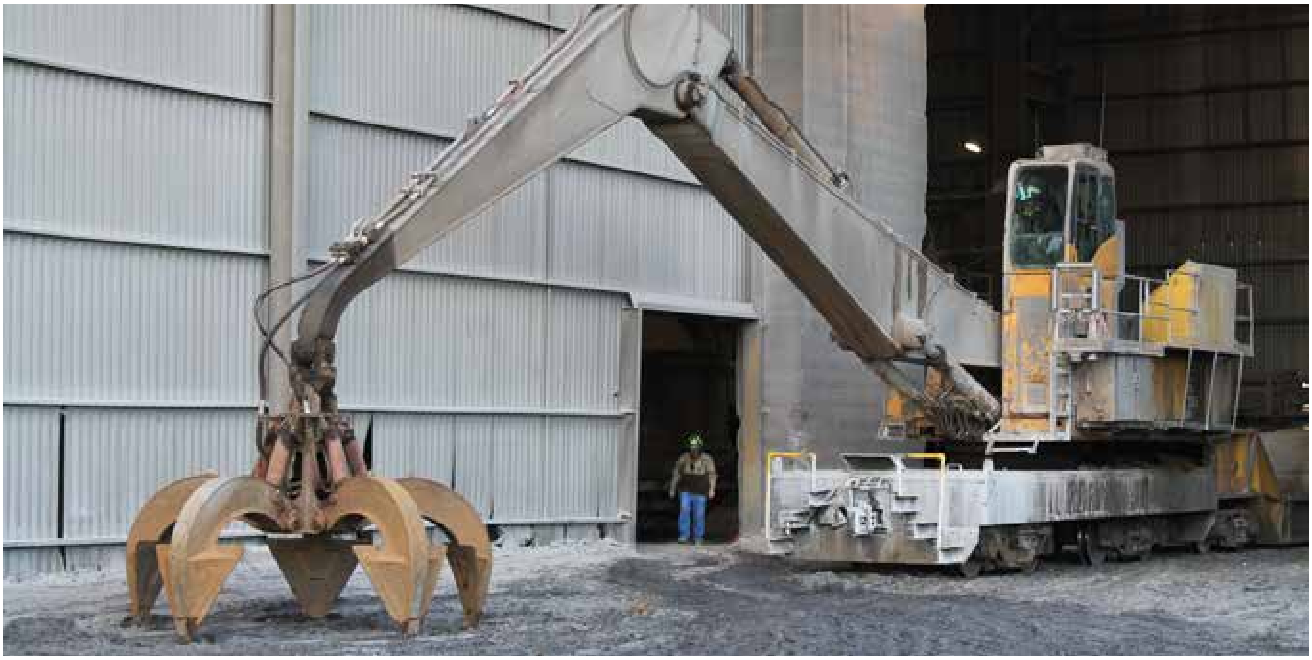
The modifications to EAF 2 are expected to be completed this spring, and modifications to EAF 1 are planned to be completed a year later.

➤ Specialized grapple cranes are used for transferring scrap.

▼ Proprietary software provides real-time data from every operation in the facility.

◀ Cutting a beam blank via oxygen torches.

▼ One of the many "pulpits" throughout the mill, command centers from which operators can monitor their processes.



A "lollipop" sample from the ladle metallurgy furnace following testing via the optical emission spectrometer.

It goes with the territory.

determined by the specifications. The testing NYS performs on its steel could warrant an entire other article, but includes tensile, yield, elongation and CVN properties, when ordered.

Maintaining Control

While the steelmaking process involves a lot of what could be considered massive hardware, it is monitored and controlled by proprietary software that gives operators throughout the mill and offices precise, up-to-the-minute information on each step. Sitting at Schoen's desk, we can see the location, temperature and other vital statistics for every steel member currently being produced at the mill.

At each process, there is a "pulpit" or enclosed area where mill personnel can monitor their operation—a cool, enclosed oasis of sorts amidst the high temperatures and heavy industrial goings-on of the mill. This network of command centers is the nerve center of the mill, providing a bird's-eye view of the action and housing control equipment and multiple monitors; there are cameras throughout the mill that provide operators an up-close look at what's happening. Some of the pulpits, especially the one for the oxygen cutting operation, resemble the bridge on the Starship Enterprise, complete with captain's chair. And captain is an apt descriptor.

"Operators 'own' their departments," says Schoen. "The decisions and discoveries they make in their areas can make their processes more efficient, which will lead to better efficiency and innovation for the facility and company as a whole."

One example of innovation is NYS' use of "smart start" technology on the four locomotives that transport steel off-site, which has significantly reduced fuel consumption and emissions. Another innovation involves diapers. NYS found that it could use an absorbent dust (which might normally be landfilled) from a diaper manufacturer in the region to help solidify some of the sludge that accumulates in the mill's water treatment vessels.

All of this monitoring, testing, control, ownership and innovation leads to a precision-made—and safely made—final product, ready to ship to one of the mill's hundreds of customers (for wide-flange steel, this typically means a steel service center or structural steel fabricator). The facility can currently produce 2.4 million tons of steel per year—and is ready to take on another quarter-century of service. ■