Structural Steel

We take steel beams for granted as the bones of new buildings, but how are they made?

TEXT BRADFORD MCKEE **PHOTOS** TIMOTHY HURSLEY

At the Nucor-Yamato Steel Co. plant outside Blytheville, Ark., small mountains of rusted scrap metal rise across a stretch of Mississippi River floodplain. Most of the material, sorted by size and type, is completely unrecognizable. Some piles contain thin sheet metal. Some have pieces of buildings or machines, and in spots you see lengths of pipe. The finest scrap, called shredded scrap or "frag," looks like metal garden mulch or tea.

Several heaps hold discarded tails from brand-new wide flange beams—generically called I-beams, though there are several different shapes. This is the basic unit of heavy steel construction for buildings. The 850-acre Nucor-Yamato plant, with its two gargantuan, parallel sheds, makes about 2.2 million tons of structural beams a year. In about four hours' time, 125 tons of the scrap in the yard here will be recycled into steel beams.

Inside the plant's hazy, Piranesian depths, 860 employees work 12-hour shifts—four days on, four days off. They tend exploding furnaces as big as brownstones, monster vats of molten steel, and more than a soccer field's worth of mills and presses that pound metal into shape. Out of the roaring machinery, ranks of near-perfect beams sidle off the line, glowing orange and gradually turning a cool gray.

Steel, the miracle metal of the industrial age, is iron alloyed to any of various elements to suit the desired purpose. That could be pipes, tubes, plates, rebar, bed frames, saucepans, or ship hulls—or, at the Nucor-Yamato plant, structural beams for building frames.

Steelmaking originally depended solely on the mining of iron ore. Yet because steel can be melted and remade almost infinitely, American industry recycles more steel than it does anything else. About 95% of the content in Nucor-Yamato's beams is metal that once existed as something else.

In Nucor-Yamato's scrap yard, piles of ferrous scrap, including discarded ends of beams and finely shredded metal fragments, lie ready for transporting into the plant, where they will be melted into liquid steel. Behind them stands the air-handling equipment that removes and treats hot, dusty exhaust from the melting operations.

The Scrap Yard

Usually, in Blytheville, making steel begins by unloading scrap on the river, though some scrap arrives by truck or train. Barges pull up to the plant's port from up and down the Mississippi and Ohio rivers. Loads vary, but a single barge may hold up to 1,400 tons of shredded scrap. It takes two hours to empty—using a crane-like mechanical claw, known as a grappler, and, sometimes, an enormous magnet—into a fleet of Komatsu hauling trucks with wheels 7 ft high.

In the scrap yard, another grappler is at work. Equipped with a scale, it weighs the scrap—and, sometimes, chunks of processed iron known as pig iron—while loading the piles into an armored vessel called a scrap charging bucket, which stands nearly 20 ft high and looks like a gigantic hand grenade. Nearly everything about the plant is audaciously large.

About 4,000 cu. ft of scrap fit in the bucket. It sits on wheels and, when full, is rolled into the plant and raised on an overhead crane affixed inside the plant's soaring roof structure. Traveling upward, it floats above the factory's maze of moving parts until its hinged clamshell bottom hangs over the lid of the furnace.

On the rails, a vessel known as a charging bucket arrives with a fresh load of scrap inside the plant's melting operation. It will be lifted by an overhead crane and carried to a spot above the electric arc furnace. The bucket's underside opens to drop the metal into the furnace for melting.

Once the steel is melted to about 3,000 °F and is ready for refining, it is "tapped" from the furnace down to a vessel called a ladle before being taken to the ladle metallurgy furnace. Employees in the control room, or tapping pulpit (at left), monitor the process.

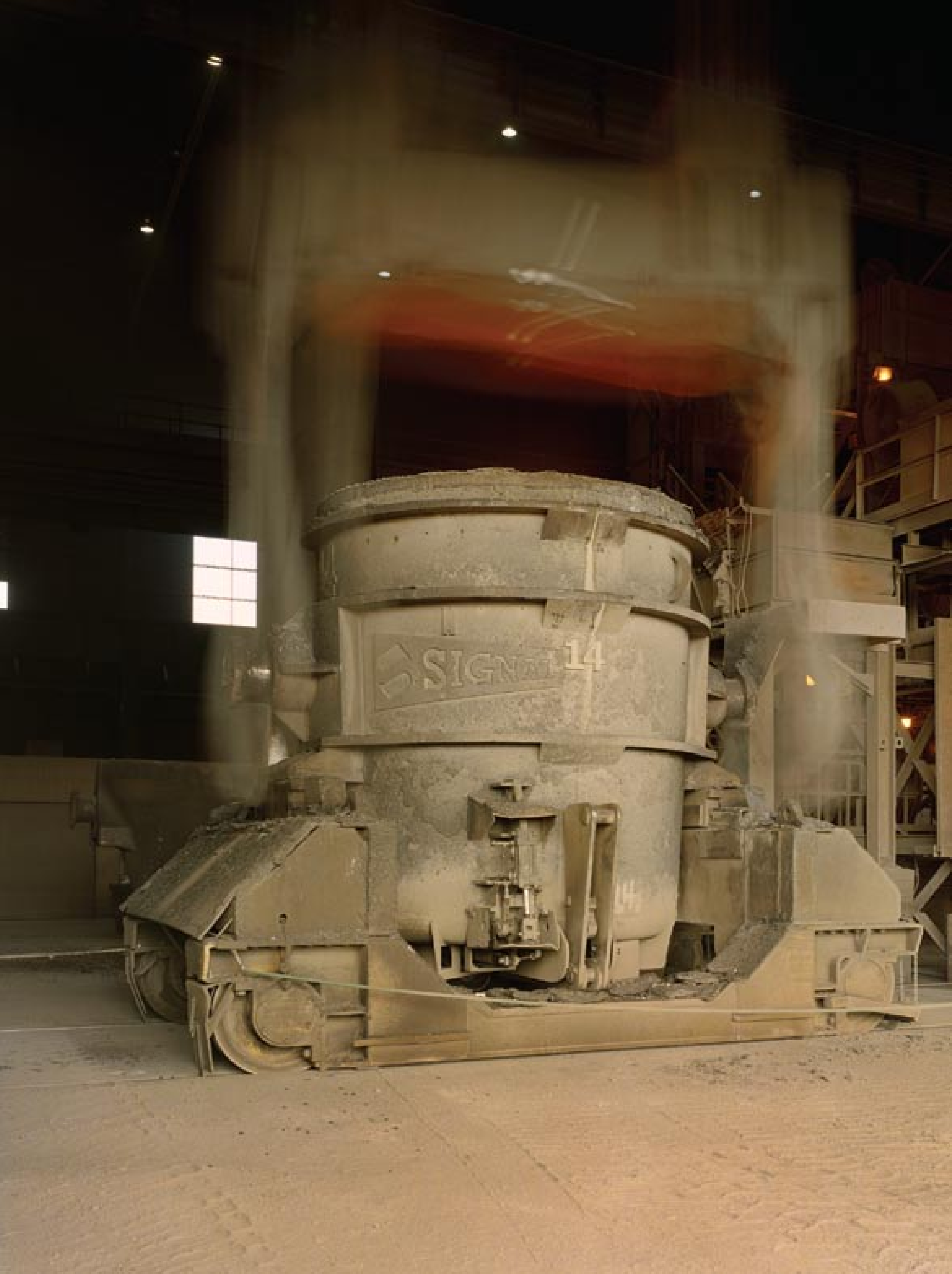
The Electric Arc Furnace

Nucor-Yamato relies on a method of steelmaking called electric arc furnace, or EAF technology. The electric arc furnace proper is a big, dirty cauldron of fire. Its inner lining of refractory brick protects the rest of the furnace from melting in the heat.

When the furnace's roof pivots open, the charging bucket's hinged bottom doors fall open. The scrap crashes into the glowing orange void with a thunderous impact, and flames erupt above the furnace. The roof swings closed.

Three white-hot carbon electrodes, each 2 ft in diameter, descend through openings at the roof's center and strike an arc of electricity into the scrap. A storm begins: Clouds of fire and sparks burst out of gaps in the furnace roof as the electrodes subdue the steel into a blindingly hot porridge. A safe distance away, in a windowed, heat-shielded control room or "pulpit," a worker known as a first helper watches several computer screens that report the status of the melting batch, known as a heat. The first helper tracks the temperature as it rises to about 3,000 °F. He also calculates carbon levels, which fall as oxygen levels rise. Higher carbon content makes steel more brittle. He waits for the carbon to reach a desired low of about 0.1% of the molten steel.

As the steel cooks, its foamy by-product, slag (consisting largely of lime), floats to the top and is skimmed off into a cone-shaped slag pot for processing into an aggregate for roadbeds. When the steel has melted, it is time for the "tap." A slot opens at the furnace's underside to empty the liquid into a wheeled vessel beneath it, known as a ladle.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Perfecting the Mix

The molten steel filling the ladle is like a blank canvas; other elements, such as silicon, manganese, vanadium, and niobium, are added to create the specific chemistry desired for the final product. For structural beams, Nucor-Yamato makes a grade of steel known as A992, which, since it was first standardized in 1998, has been supplanting other grades (primarily one known as A36) as the standard for building frames because of its high yield strength and tensile strength, especially under seismic stress.

From the electric arc furnace, the ladle of molten steel is moved to the ladle metallurgy furnace for fine chemical tuning. The ladle has a porous plug at its base for pumping argon gas up through the liquid steel, causing it to bubble and stir, much as salad dressing is shaken to mix its ingredients.

When the batch is believed ready (after about 40 minutes), a sample about the size of a silver dollar is taken, cooled, and analyzed in an optical emission spectrometer. The spectrometer provides a kind of fingerprint showing the amounts of various elements. If they seem to fall in the correct range, the batch is ready to cast.

Jim Schoen, a plant metallurgist, has seen the ladle do its work countless times in more than 20 years of making steel. As he stands in the pulpit above the ladle and watches the steel agitate, he marvels at the consistency of the process, which runs 24 hours a day.

The steel mixtures "fall out of spec," as he says, once maybe every two months.

The ladle of liquid steel rolls into the ladle metallurgy furnace (right in photo), and its chemistry is corrected according to the type of final steel product needed. Once this process is complete, an overhead crane (left) will carry the steel and pour it into the continuous caster for forming into rough beams.

A ladle metallurgy furnace operator (right) in front of a steel ladle trolley.


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Red-hot wide-flange beams (facing page) roll from the finishing mill, which gives them their final shape, toward large saws (at rear) to be cut into customized lengths for shipping. The saws can cut beams into lengths of up to about 125 ft. Some semifinished "beam blanks" (above) are set aside and stored in a large stockpile within the plant for future reheating and rolling into finished beam sections.

Casting

When the ladle rolls away from the second furnace, a pair of giant hooks lift it—still full of liquid steel—40 ft high, beyond a layer of gray stairs and catwalks, to be poured into its molds for crude shaping. Steel is poured from the ladle into a tub that divides it into two streams (another caster in the plant has four streams), each of which flows down a long mold, forming as a strand, before being cut to length by automatic gas torches at the bottom. The steel is alive, red-hot, and now in the rough form of a beam, called a beam blank or bloom.

Members of the technical staff know the temperature of the steel at all times. Just after casting, the steel registers near 1,800 °F. Sprays of water hit the beam blanks to help cool them to a solid state within minutes.

Some of the cooled ones are stockpiled for finishing later. Some go back in for reheating and final milling.

Finishing Touches

The beam blanks are sent into a 10-ft-deep gas oven and brought to about 2,100 °F. When hot again, they slide into the "breakdown mill," where they are rolled violently back and forth like missiles within flatbed channels, and then through a series of fearsome machines that press them into the correct sizes.

The flanges of the nearly complete beams must be cooled to promote their ductility. A finishing mill evens them out, and a straightener prevents any bow, sweep, or camber along their 27-ft spans. With a terrific grind and a nebula of sparks, the beams are cut to lengths measuring anywhere from 30 ft to 80 ft. Finally, they are taken for shipping to steel fabricators, who ready them for construction.

The steel beam, mighty yet plastic, has been melted, muscled, and sculpted into a new life. "Remember," Schoen points out, "this started out as a piece of scrap." **MSC**

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