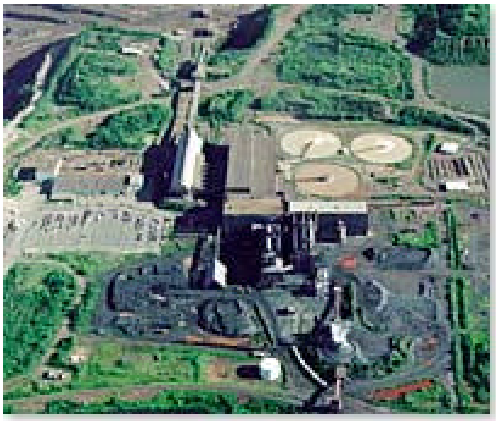
Iron Ore Processing for the Blast Furnace

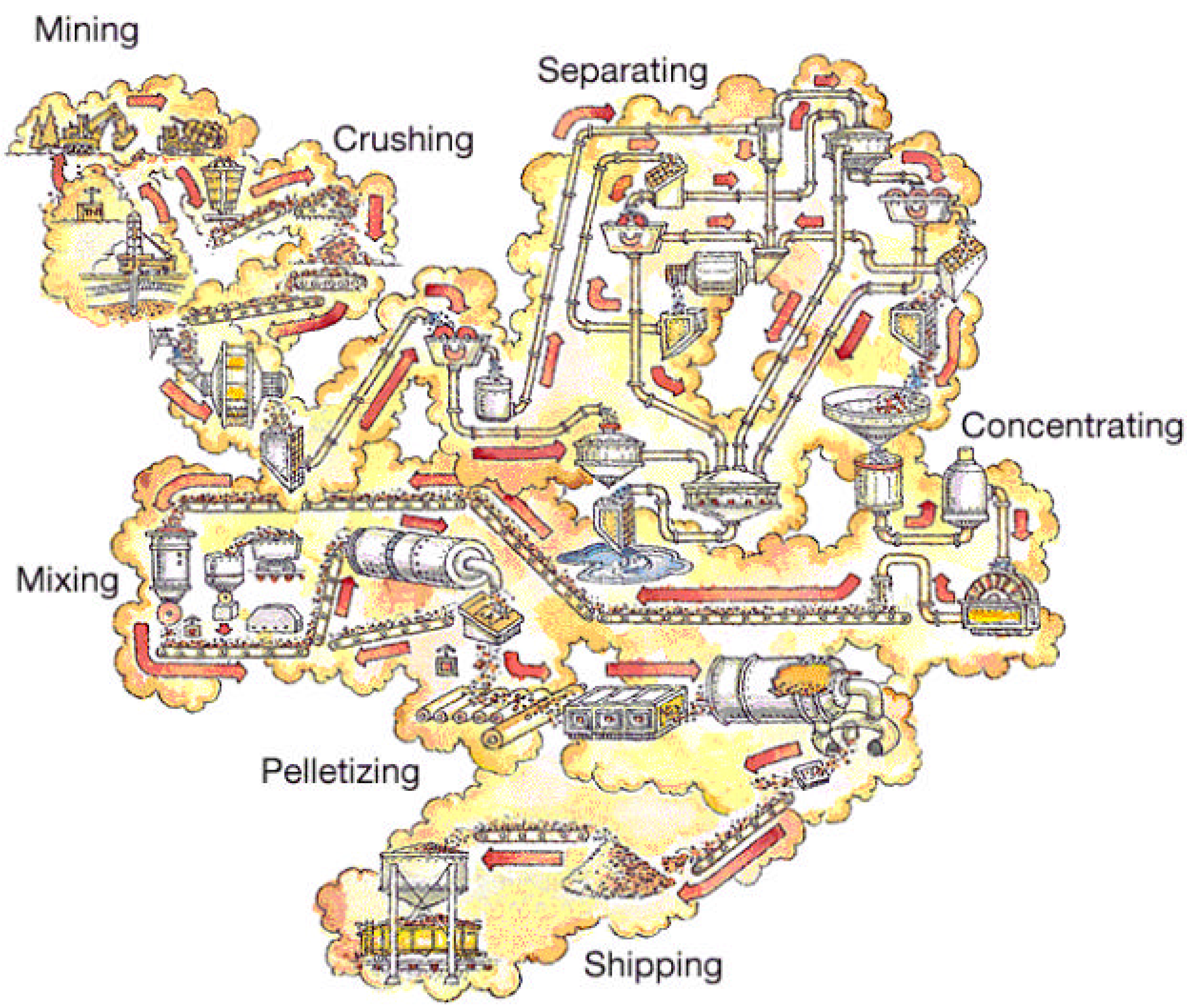
(Courtesy of the National Steel Pellet Company)

The following describes operations at the National Steel Pellet Company, an iron ore mining and processing facility located on the Mesabi Iron Range of Minnesota.

Creating steel from low-grade iron ore requires a long process of mining, crushing, separating, concentrating, mixing, pelletizing, and shipping. The process of mining low-grade iron ore, or taconite, requires massive resources. Heavy industrial mining equipment, expansive mines, and a skilled labor pool are all required. The equipment used includes diamond-bit rotary drills, hydraulic shovels and loaders, water wagons, production trucks and heavy-duty conveyors.



National Steel Pellet Company's plant is capable of producing 5.35 million tons of pellets each year. It employs approximately 500 workers.



Mining Iron Ore

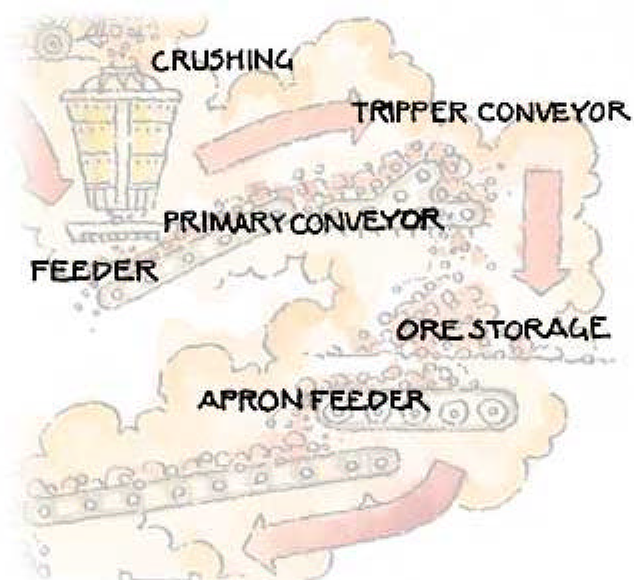
Mining iron ore begins at ground level. Taconite is identified by diamond drilling core samples on a grid hundreds of feet into the earth. Taconite rock comprises about 28 percent iron; the rest is sand or silica. These samples are analyzed and categorized so that mining engineers can accurately develop a mine plan.

To uncover taconite reserves, the mine area is first "stripped" of the overburden or glacial drift, comprised primarily of rock, clay and gravel. The overburden is loaded by large hydraulic shovels into production trucks, which haul it to contour dumps. These dumps are environmentally designed to match the surrounding area.

Once the taconite rock is exposed, large drilling rigs drill blast holes 16" in diameter by 40' deep, in some cases. Nearly 400 of these holes are drilled in a blast pattern. Before the blast, the holes are filled with a special mixture of blasting agents. Once prepared, the mine site is cleared of workers and equipment, and the blast is detonated. Each of the holes is detonated just a millisecond apart, resulting in a pile of crude taconite that is broken apart to a minus 6' x 6' size.

After blasting, hydraulic face shovels and larger loaders load the taconite into 205-ton or 240-ton production trucks, which haul it to crushers. The taconite is ground to a fine powder and mixed with water. A series of magnets is run over the mixture. The magnets grab the iron particles and the rest is discarded. For every ton of iron retained, two tons of waste, or tailings, are discarded.

Crushing the Ore



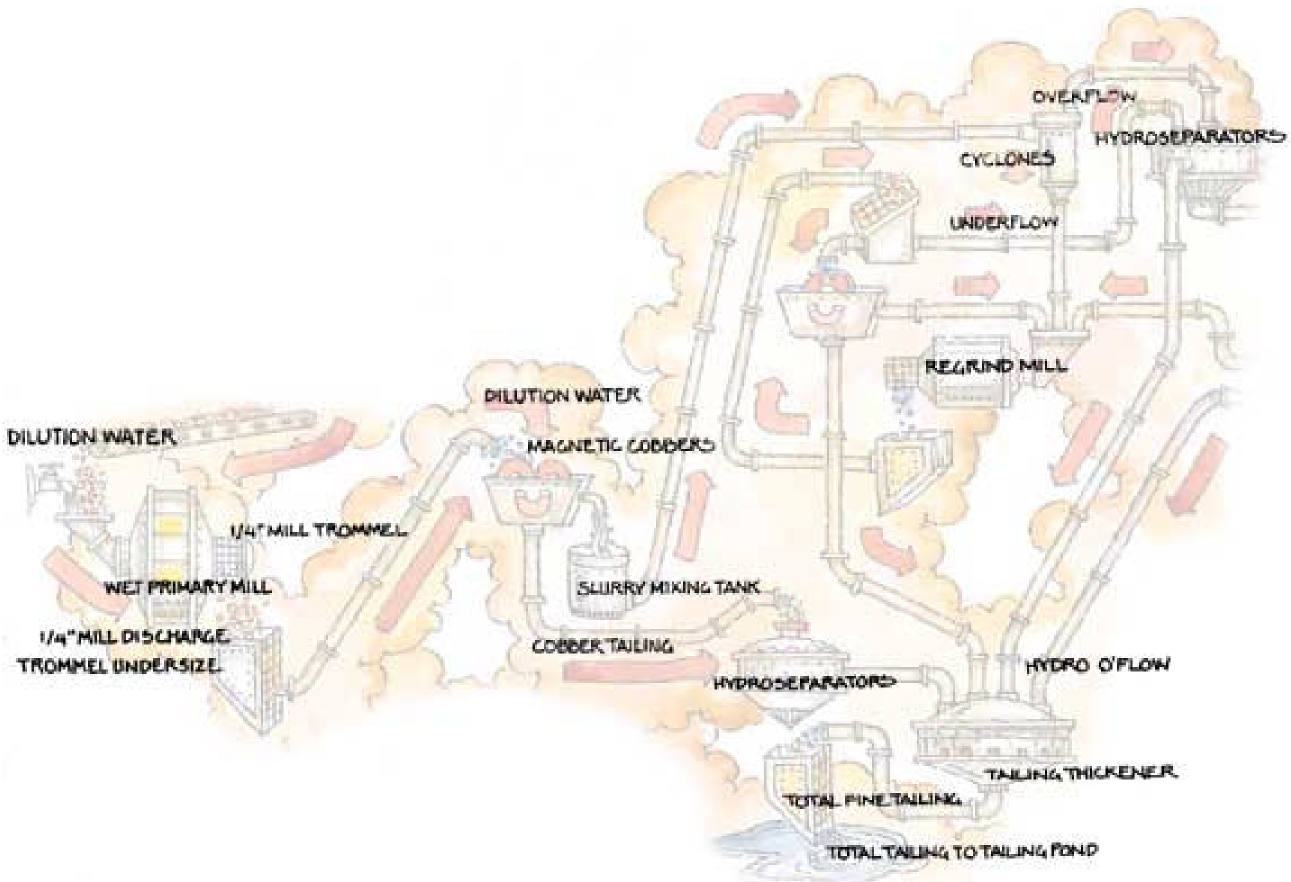
The crude taconite is delivered to large gyrator crushers, where chunks as large as five feet are reduced to six inches or less. More than 6,000 tons of taconite can be crushed in one hour.

The crushed material is transferred by belt to an ore storage building, which holds up to 220,000 tons of taconite. An apron feeder sends the ore to the concentrator building for grinding, separating, and concentrating.

Concentrating

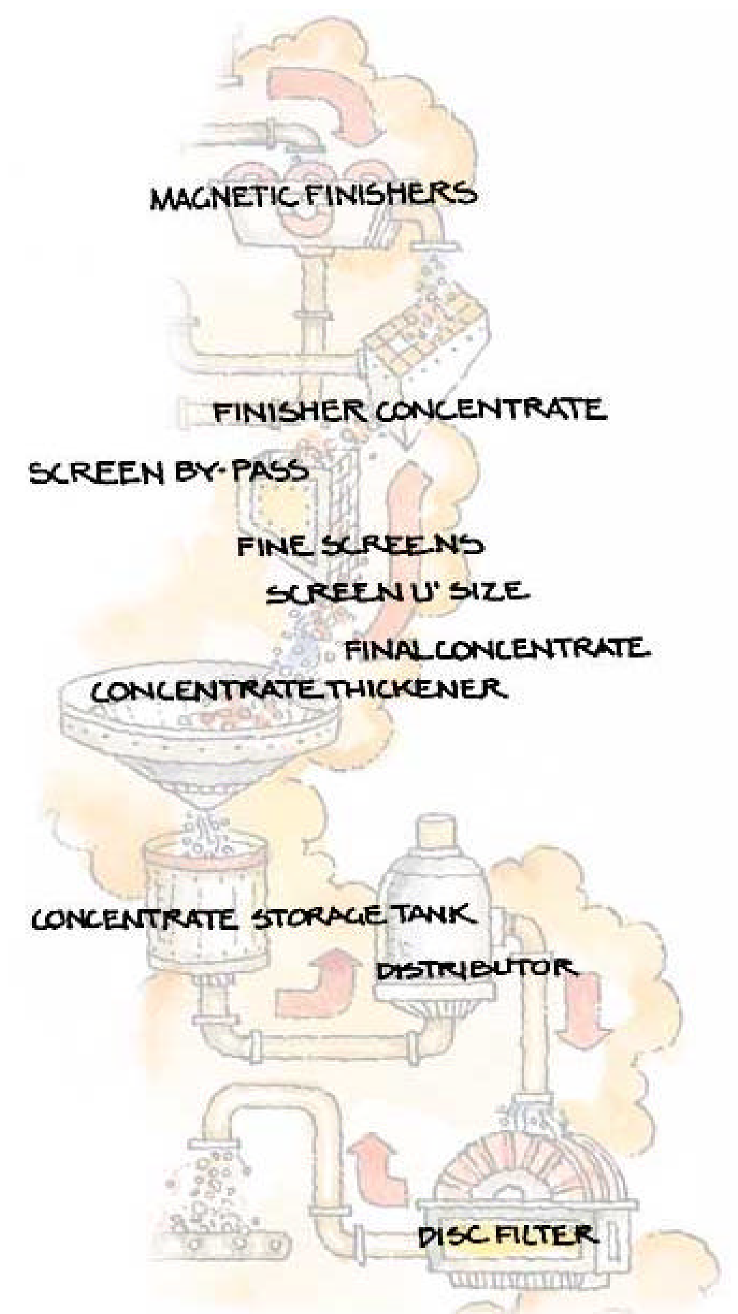
The crude taconite is now roughly the size of a football or smaller. A series of conveyor belts continuously feed the ore into ten large 27-foot-diameter, semi-autogenous primary grinding mills. Water is added at this point to transport it (94 percent of the water is recycled, while the rest is lost through evaporation).

Each primary mill contains several 4" steel balls that grind the ore as the mills turn. When the ore is reduced to 3/4" or less, it moves out of the mill in a slurry solution. The mill discharge is screened at 1/4" on trommel screens attached to the mill. Ore smaller than 1/4" is pumped in slurry solution to the wet cobber magnetic separator, which begins the process of separating the iron from the non-iron material. The magnetic iron ore is then laundered in two slurry surge tanks while the non-magnetics (silica/sand) go to the tailings disposal area.



Most of the material continues to be finely ground in one of five secondary ball mills, which are powered by electric motors ranging from 2,500 hp to 4,000 hp and are charged with 1-1/2" chrome grinding balls. Fine grinding is achieved using these smaller mills, bringing the ore to a similar grind as that found in face powder. The screen undersize is then moved to hydroseparators, where silica is floated off the top.

The hydroseparator underflow is pumped to the finisher magnetic separators. Once again, the magnetic separators grab the iron and discard the silica and sand. Thus, the ore is "concentrated" by removing the waste materials. The concentrate from the separators is pumped to fine screening.

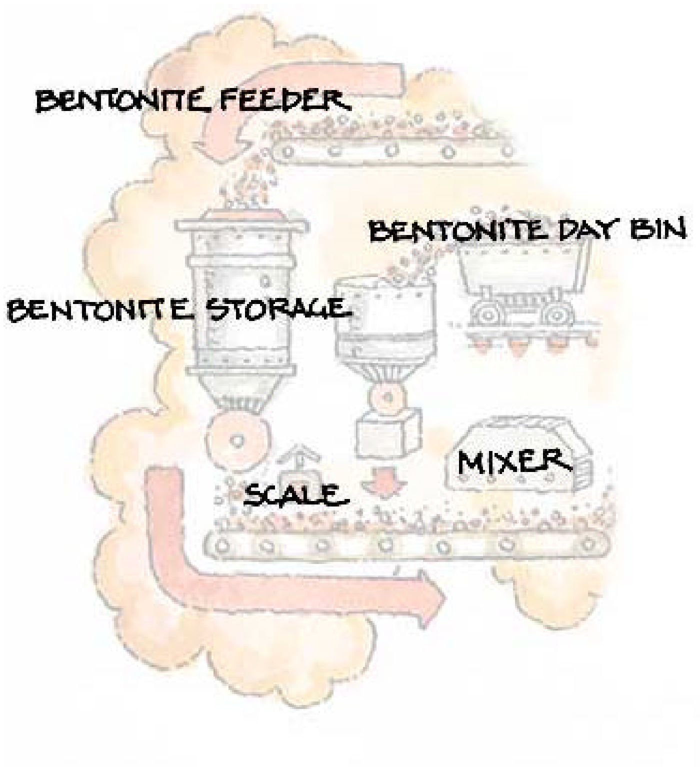


The oversize material is returned to the balls mills, while the undersize (with the most impurities removed) becomes the final concentrate. Waste from the circuit goes to the tailings basin and the final concentrate travels to thickeners located in the pellet plant. The underflow from the thickeners is pumped to a storage tank and then to disc filters for dewatering.

The product is called “filter cake”, and is now ready for mixing with the binding agent.

Mixing with the Binding Agents

Once the filter cake is complete, it is deposited into a surge bin. It then travels onto a feeder belt and from there to a conveyor where bentonite, a bonding agent, is added. Bentonite is a clay from Wyoming used to help iron ore concentrate stick together when rolled into pellets. About 16 pounds of Bentonite are added to every ton of iron ore concentrate.

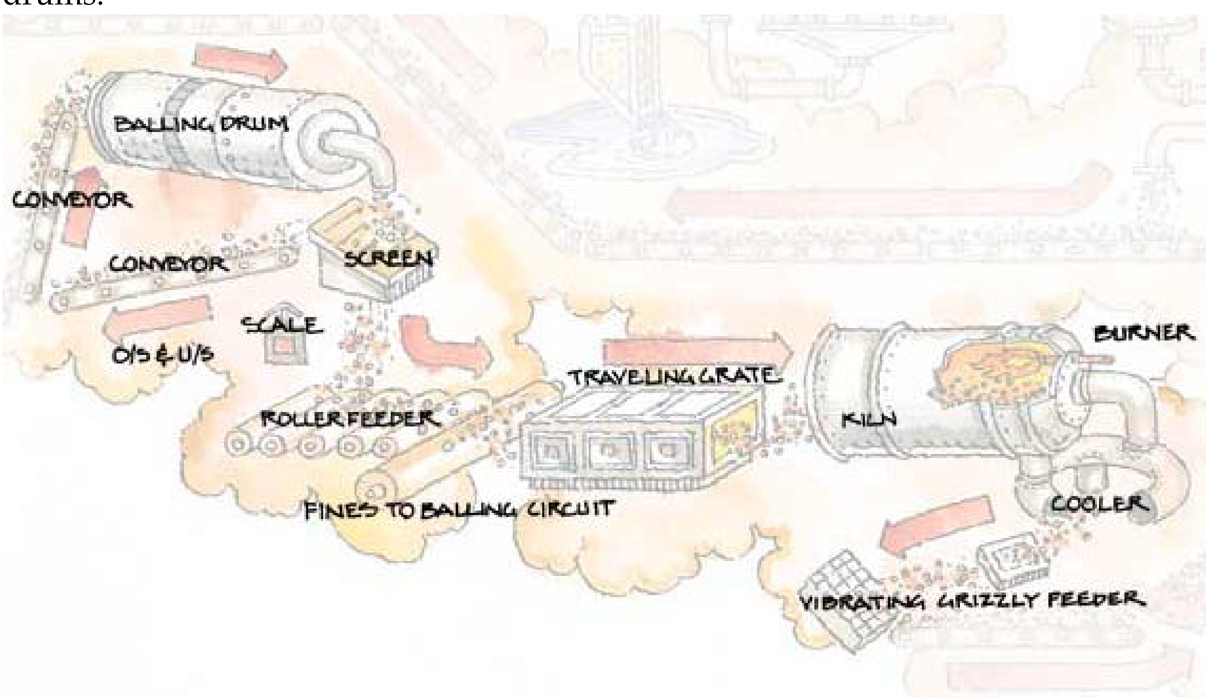


Small amounts of limestone (1%) are also added and mixed with the concentrate at this point. Limestone is added to meet the requirements of steel customers in the blast furnace process.

The iron ore concentrate is now mixed and ready for the pelletizing process.

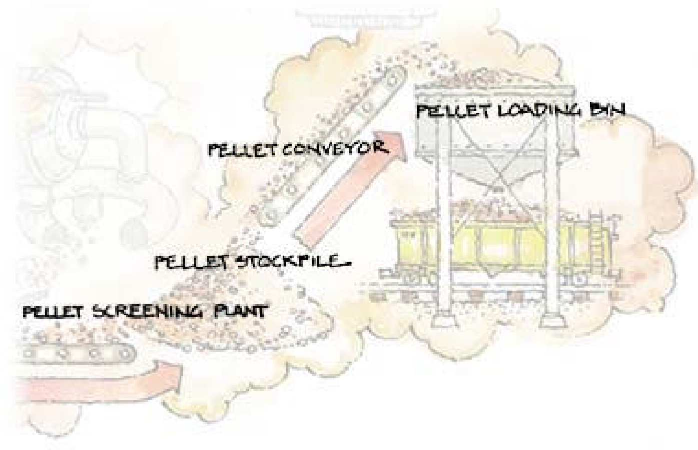
Pelletizing

A pellet plant contains a series of balling drums where the iron ore concentrate is formed into soft pellets, in much the same manner that one rolls a snowball, to make a pellet about the size of a marble (between 1/4" and 1/2"). Pellets are screened to meet the size specification, with undersized or oversized pellets crushed and returned to the balling drums.



The soft pellets are then delivered to the roller feeder for final removal of the fines, which are also returned to the balling circuits. Now the soft pellets, correctly sized, are delivered to the traveling grate furnace for further drying and preheating. The grate is fired by natural gas.

From this point, the pellets are charged into the large rotary kiln where they are heat-hardened at 2,400 degrees Fahrenheit. The pellets are discharged into the revolving cooler and then moved to the pellet screening plant, onto the pellet loadout system. The whole process consumes energy in the form of electricity and natural gas. Over the past several years, millions of dollars have been spent to improve energy efficiency and to recoup waste heat and re-use it in the process. These efforts have significantly reduced expenditures on energy.



The pelletizing process has now been completed. The pellets are run through a final screening to remove those not meeting size specifications or those that are chipped or broken into fines. Pellets that meet the necessary standards are conveyed to the pellet stockpile, which holds about 30,000 tons.

Pellet Loadout and Shipping

The pellets are now ready for shipping by train to customers or to ore docks. They are sent to blast furnaces and steel mills, where they will be turned into finished steel.

A trainload of iron ore pellets bound for the blast furnace

National Steel Pellet Company's iron ore pellets have the following characteristics (FOB Mine):

Total Iron: 65.85%
Silica (SiO_2): 4.5%
Lime (CaO): 0.68%
Phosphorous: 0.010

Size: %+1/4" 96.5% (after tumble)
Compression Strength: 560 pounds

AISI wishes to thank the National Steel Pellet Company for use of this article.