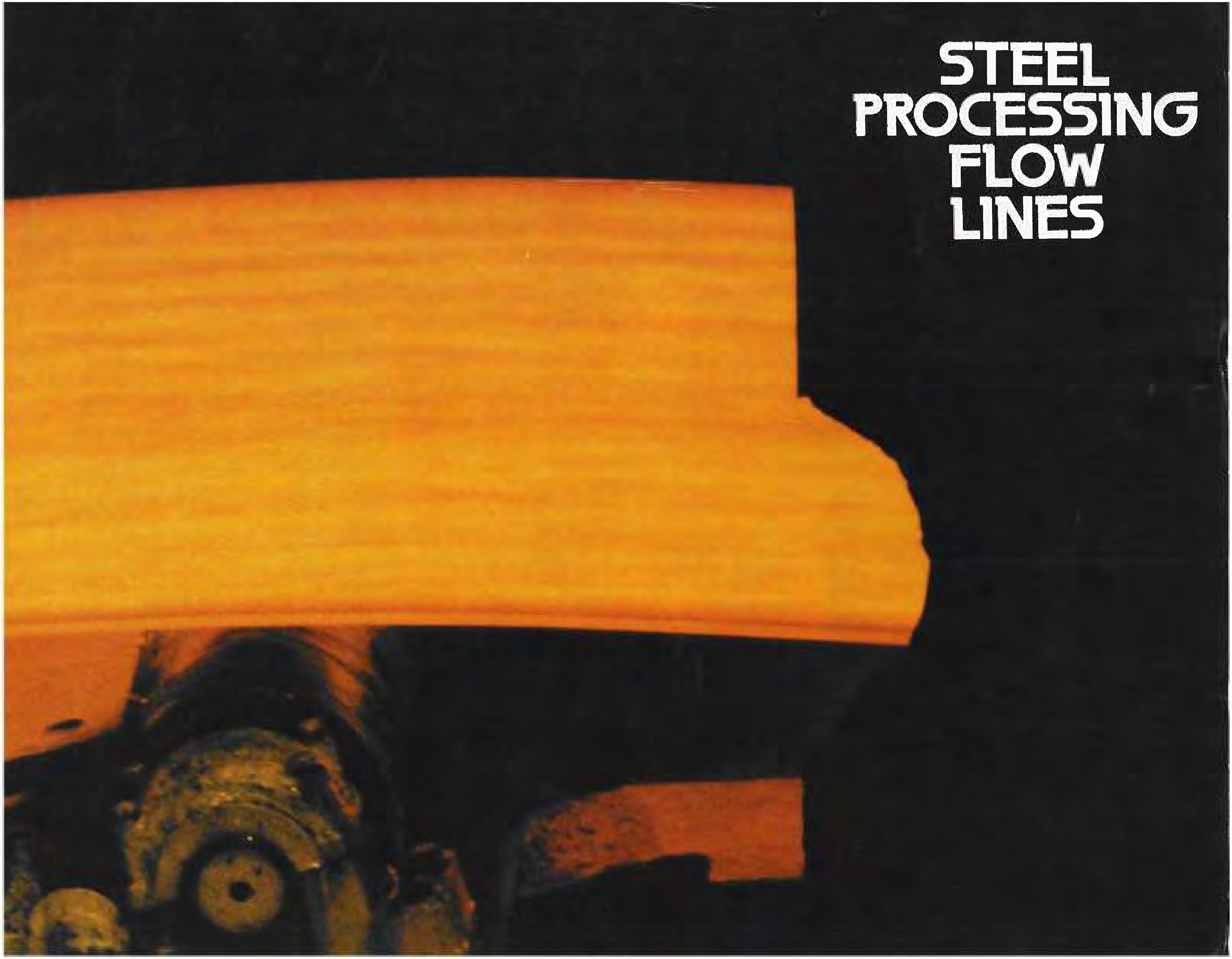
STEEL PROCESSING FLOW LINES



The flowlines in this booklet are designed to give viewers a graphic impression of how steel is processed. The drawings are not to scale or all-inclusive, but they offer teachers, students and others a simplified view of the world's most useful metal.

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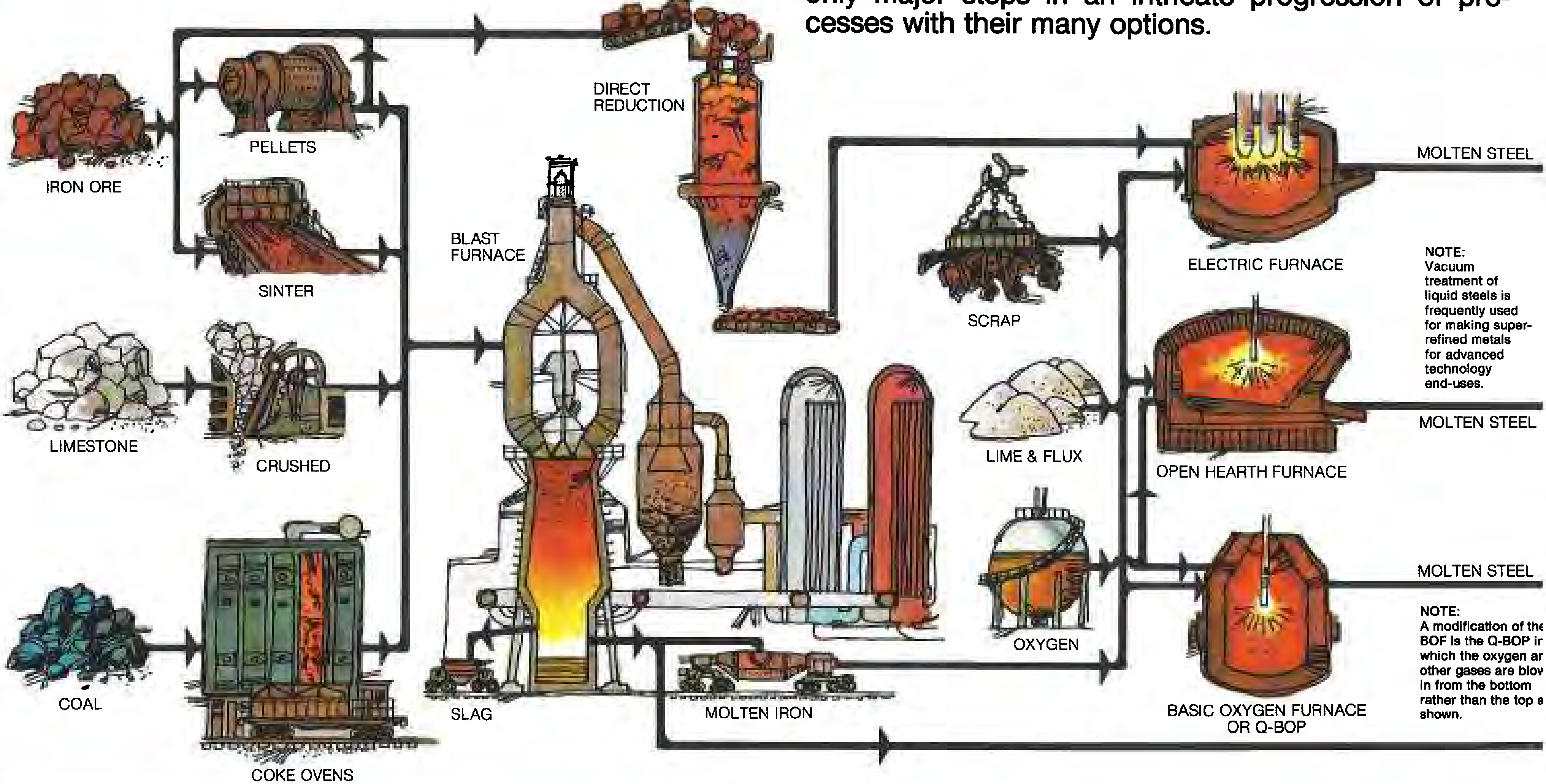
STEEL PROCESSING FLOWLINES

One way or another, steel figures into all of our lives. Day in and day out we take it for granted and yet it is the very basis of so much we see and do. Few people are aware of the full extent of human effort that is required. Steelmaking is a complicated procedure that requires an in-depth study before one can obtain a full understanding; however, a working knowledge of the basic steps can be acquired in a relatively short time.

This booklet of flowlines traces many of the steps involved in steel processing. An earlier published booklet entitled "Steelmaking Flowlines" is available which follows the steps to produce steel in its first solid forms.

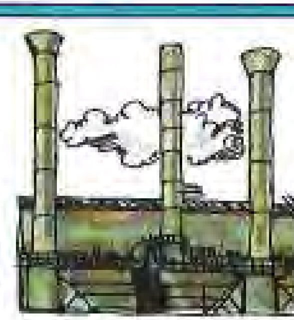
a flowline of steelmaking

From iron ore, limestone and coal in the earth's crust to space-age steels — this fundamental flowline shows only major steps in an intricate progression of processes with their many options.



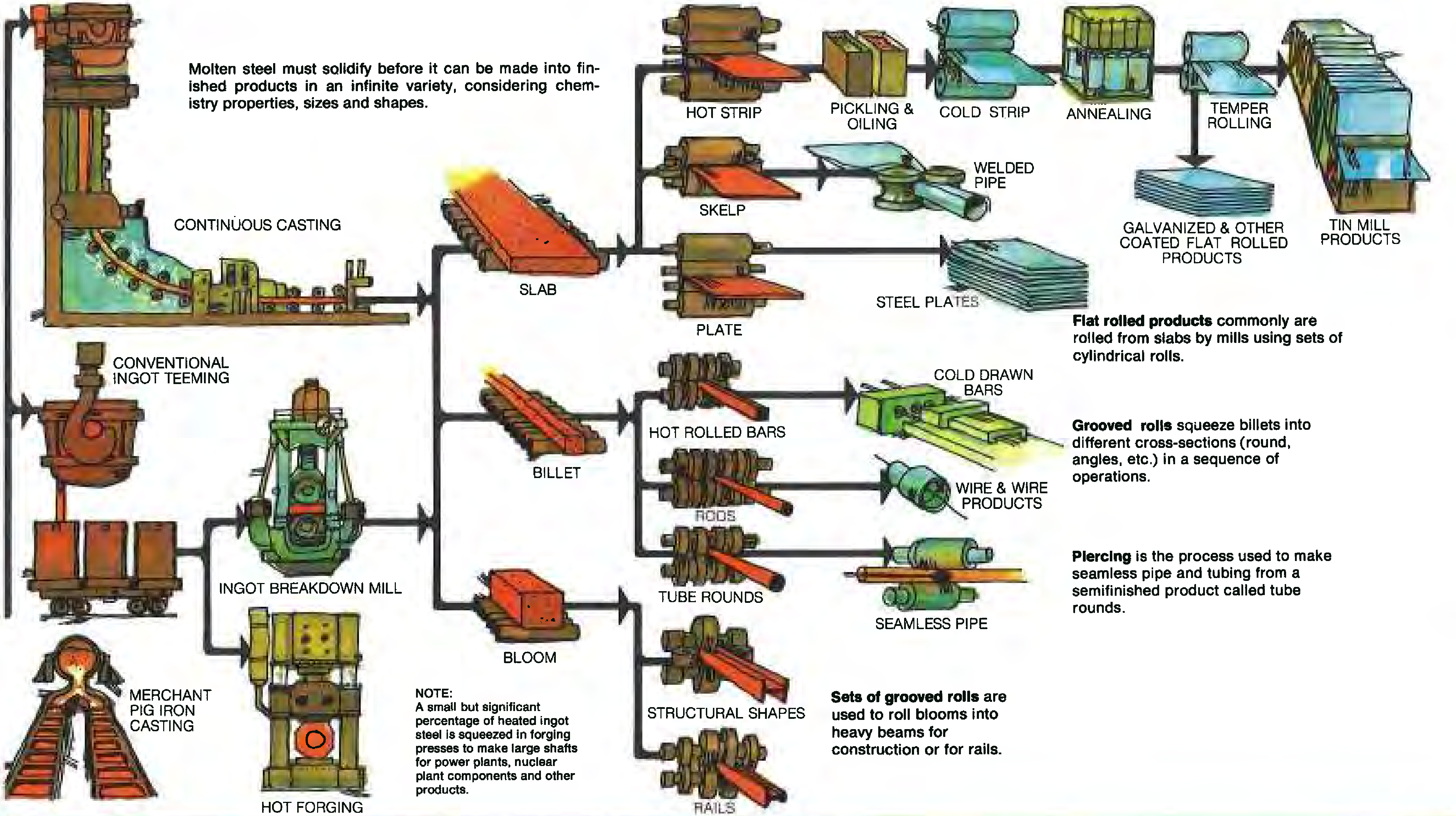
some environmental systems parallel to steelmaking

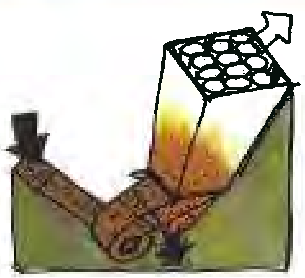
Land reclamation restores mines and quarries to natural state. Tree-planting is one method.



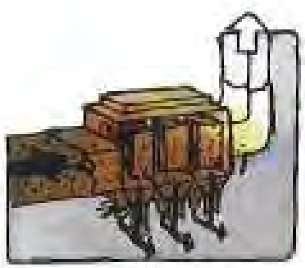
Stack cleaners capture dust from numerous steelmaking processes, keeping it out of the atmosphere.

Venturi scrubbers spray water into dust-laden gases. Recovered solid particles may often be recycled.





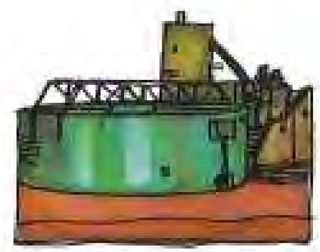
Bag houses use cloth bags like big vacuum cleaners to capture dust.



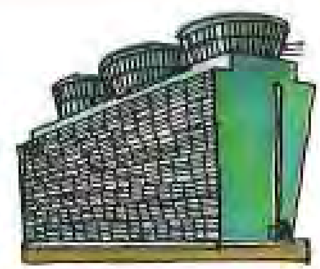
Electrostatic precipitators use electricity to remove dust.

Testing water from a steel plant is essential to know the effectiveness of pollution control measures.

Clarifiers are used to clean steel plant water by letting solids settle out.

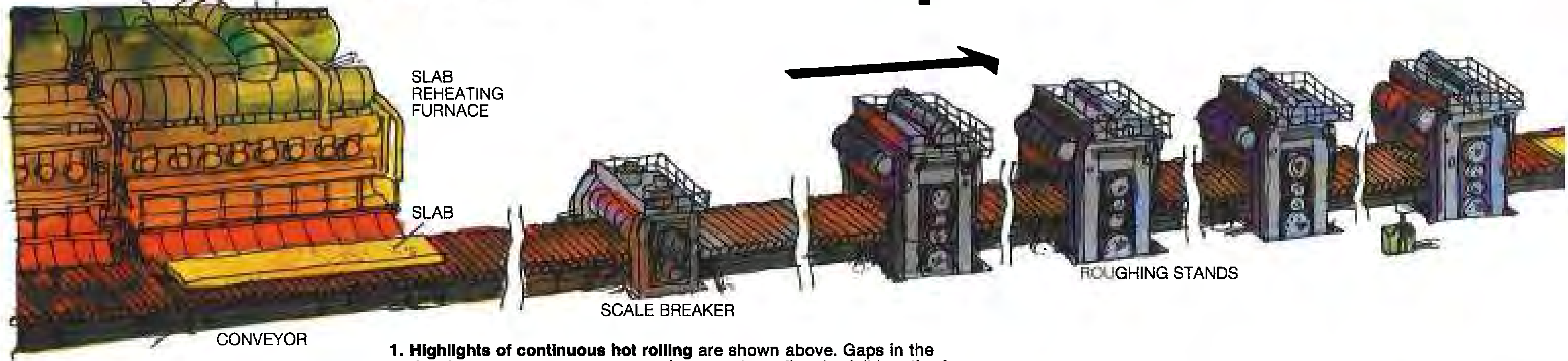


Acid Neutralization is an important part of treating water used in cleaning of steel.



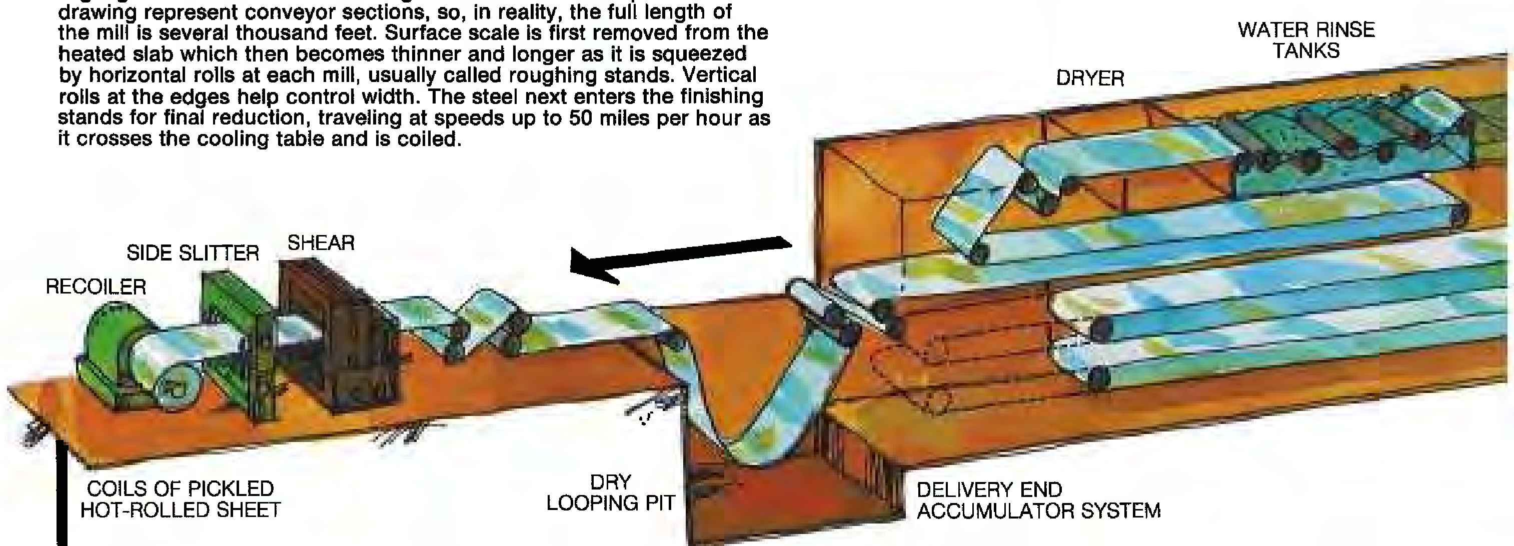
Cooling towers reduce temperature of cooling water so it can be used again and again.

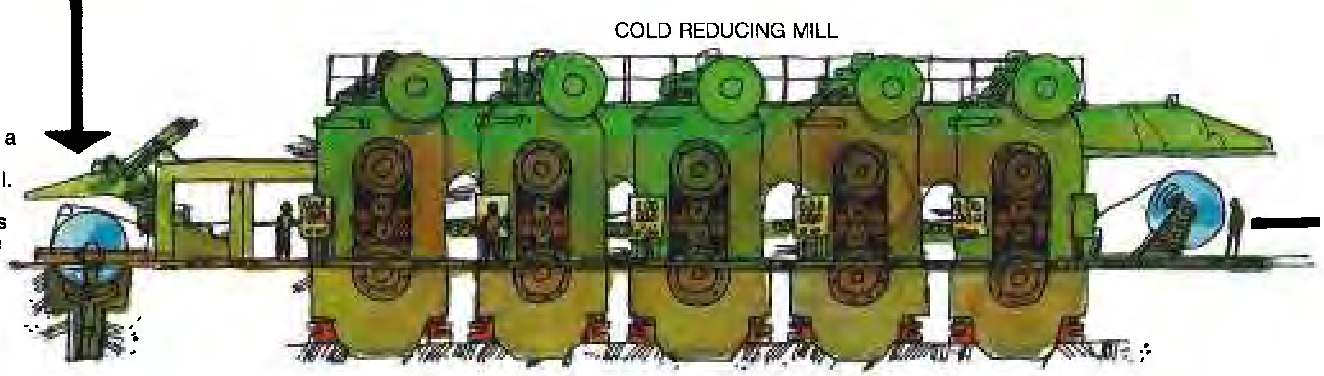
hot- & cold-rolled sheet mill products



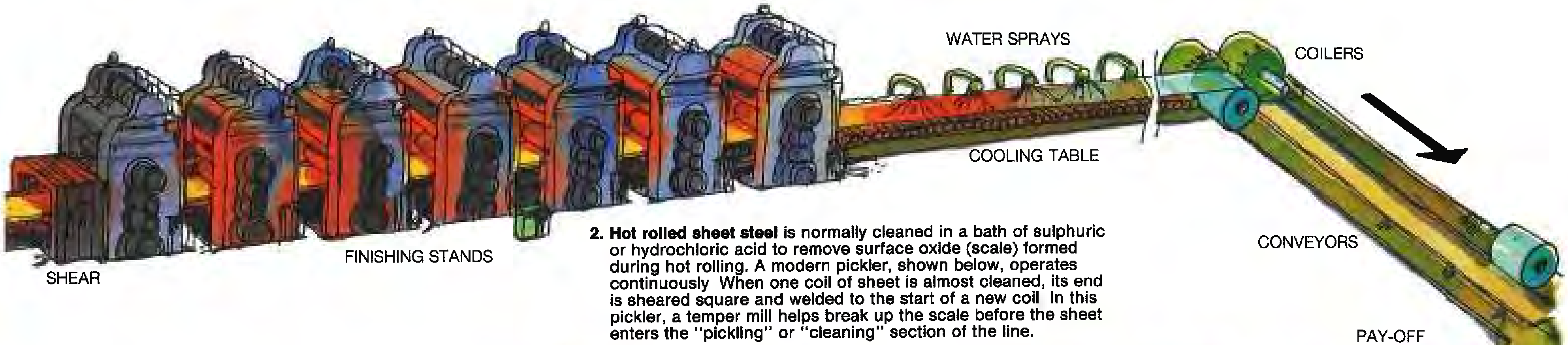
1. Highlights of continuous hot rolling are shown above. Gaps in the drawing represent conveyor sections, so, in reality, the full length of the mill is several thousand feet. Surface scale is first removed from the heated slab which then becomes thinner and longer as it is squeezed by horizontal rolls at each mill, usually called roughing stands. Vertical rolls at the edges help control width. The steel next enters the finishing stands for final reduction, traveling at speeds up to 50 miles per hour as it crosses the cooling table and is coiled.

In a few minutes the continuous hot strip mill diagrammed here can turn a glowing slab of steel into a coil of thin sheet more than a quarter of a mile long That coil may be shipped to customers, or it may be cleaned, as shown in the second diagram, and cold rolled (lower left) to make products. More than one-third of all steel shipped annually is the product of sheet mills and is made into appliances, auto bodies and a wide variety of other products.

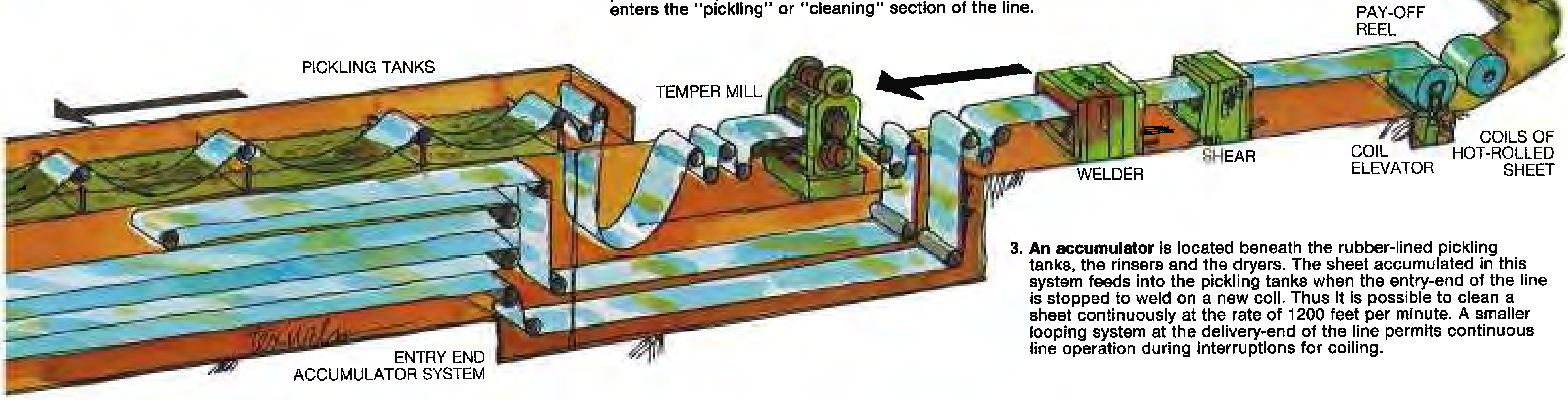




4. Coils of cleaned, hot-rolled sheet may be cold rolled to make a product thinner and smoother. This process gives steel a higher strength-to-weight ratio than can be made on a hot mill. A modern five-stand tandem cold reducing mill may receive sheet about 1/10-inch thick and ¾ of a mile long; two minutes later that sheet will have been rolled to 0.03-inch thick and be more than two miles long.



2. Hot rolled sheet steel is normally cleaned in a bath of sulphuric or hydrochloric acid to remove surface oxide (scale) formed during hot rolling. A modern pickler, shown below, operates continuously When one coil of sheet is almost cleaned, its end is sheared square and welded to the start of a new coil In this pickler, a temper mill helps break up the scale before the sheet enters the "pickling" or "cleaning" section of the line.



3. An accumulator is located beneath the rubber-lined pickling tanks, the rinsers and the dryers. The sheet accumulated in this system feeds into the pickling tanks when the entry-end of the line is stopped to weld on a new coil. Thus it is possible to clean a sheet continuously at the rate of 1200 feet per minute. A smaller looping system at the delivery-end of the line permits continuous line operation during interruptions for coiling.

5. The cold-rolling process hardens sheet steel so that it usually must be heated in an annealing furnace to make it more formable. In the furnace at the left, coils of cold-rolled sheets are stacked on a base. Covers are placed over the stacks to control the annealing atmosphere and then the furnace is lowered over the covered stacks. The heating and re-cooling of sheet may take five or six days.

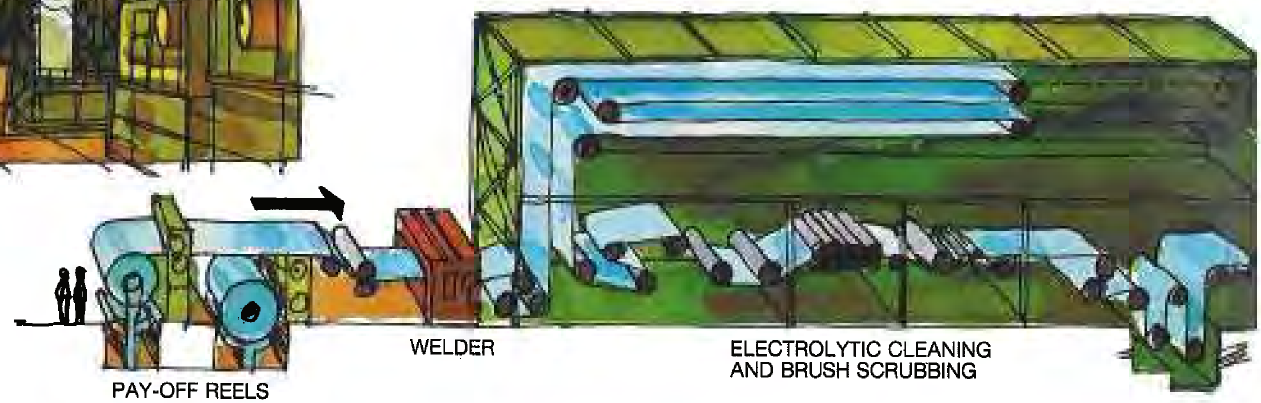
6. After the steel has been softened in the annealing process, a temper mill is used to give the steel the desired flatness, metallurgical properties, and, surface finish. The product may be shipped to consumers as coils or further side-trimmed or sheared into cut lengths.

coated sheet steel products

galvanizing

The huge, complicated facility shown at the right is used to coat sheet steel with zinc, continuously, at the rate of several hundred feet per minute. Once coated, this galvanized product is highly versatile. For example, it is used in the underbody parts of automobiles, and in making air ducts, garbage cans, culverts, storage tanks, and wherever corrosion resistance is required. A large amount of the galvanized sheet and strip made each year is painted. This adds to the corrosion resistance and gives the product a pleasing, colorful appearance. Painted galvanized sheets are frequently used for roofing and siding for industrial buildings, gutters, downspouts, or for interior cabinets, appliances and many other eye-catching applications.

1. **In the continuous hot-dip** galvanizing line diagrammed here, steel moves through the process generally from left to right. Once past the welder and accumulator, the steel surfaces are cleaned to make the zinc stick better. In the continuous annealing furnace, the steel strip is radiant-heated in a controlled atmosphere at temperatures which develop the desired metallurgical properties in the steel.



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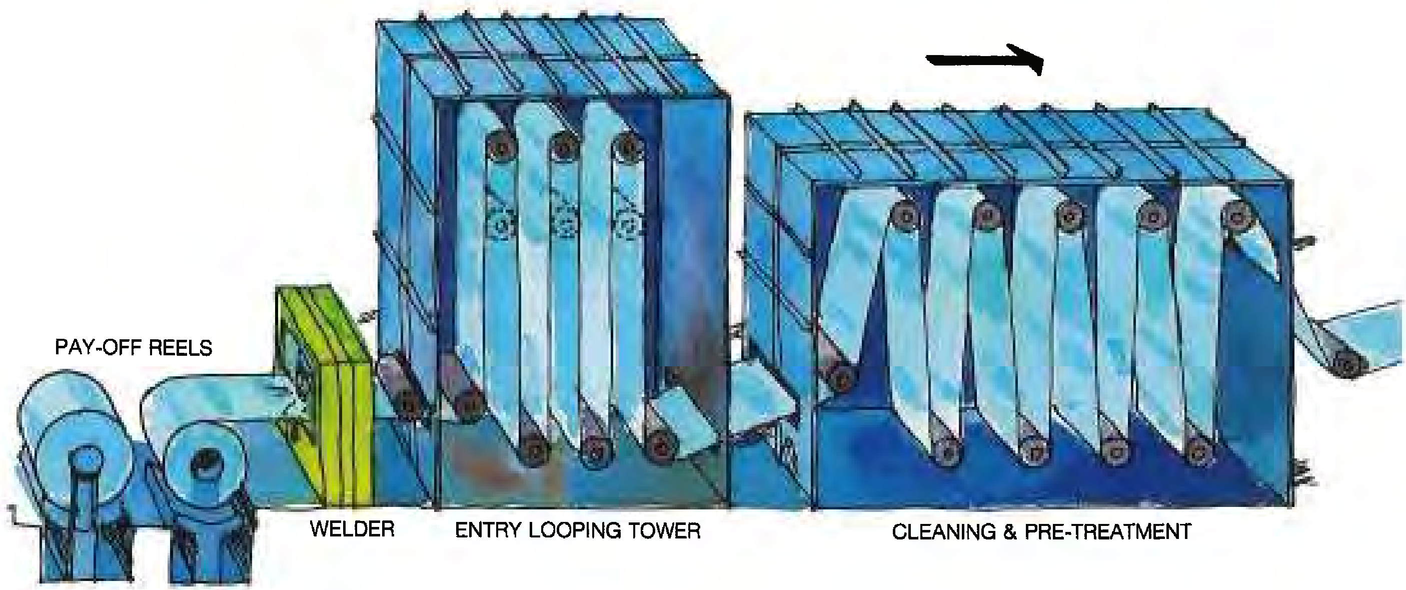
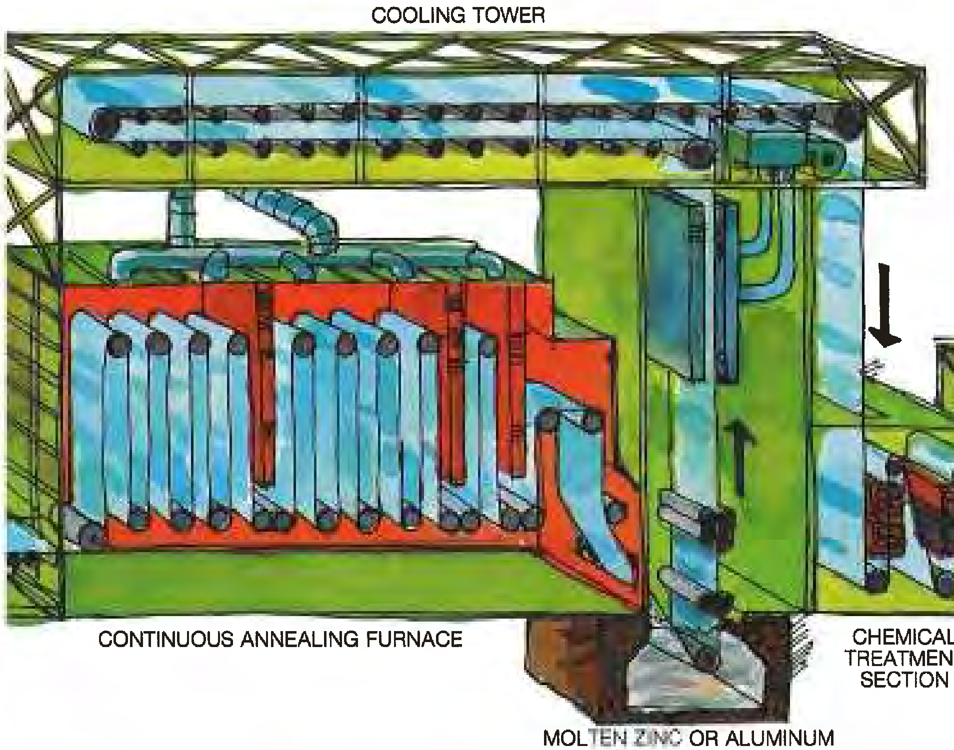
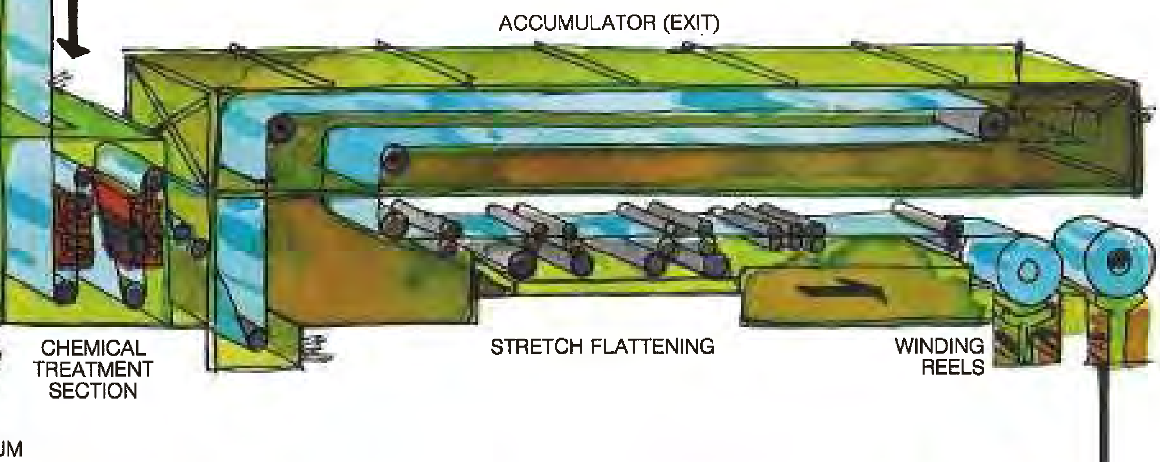
painting

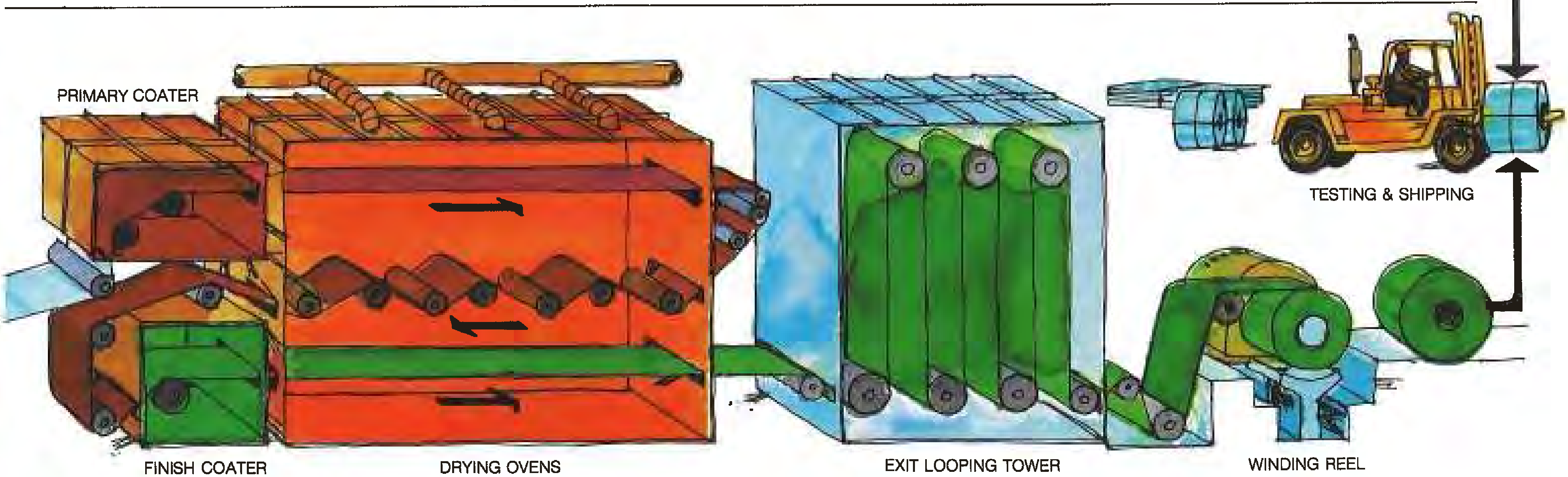
In the continuous paint coating line shown at the right, steel strip moves from a pay-off reel into an entry accumulator, or looping tower, and then into a cleaning and pre-treatment section where the surface is prepared for painting. The strip then moves to the first paint coater where a primer is applied to the top and bottom surfaces with reverse roller coaters. The primer-coated strip passes into a baking oven to cure the primer and then into a cooling zone. The strip is then conveyed to the second paint coater where the finish coating is applied to both surfaces with reverse roller coaters. The strip then enters another oven for curing and cooling.





2. From the furnace, the strip enters the molten zinc coating bath which is contained in a steel or refractory-lined pot. As the strip emerges from the molten zinc, an air (or steam) wipe is used to control the zinc coating thickness. The strip then continues upward into a cooling tower where the zinc coating solidifies. Next, a chemical treatment can be applied to the zinc-coated sheet to minimize surface staining in initial outdoor exposure. The strip then passes through another accumulator before it is stretch-flattened. Finally, it is coiled and removed from the line for shipping.





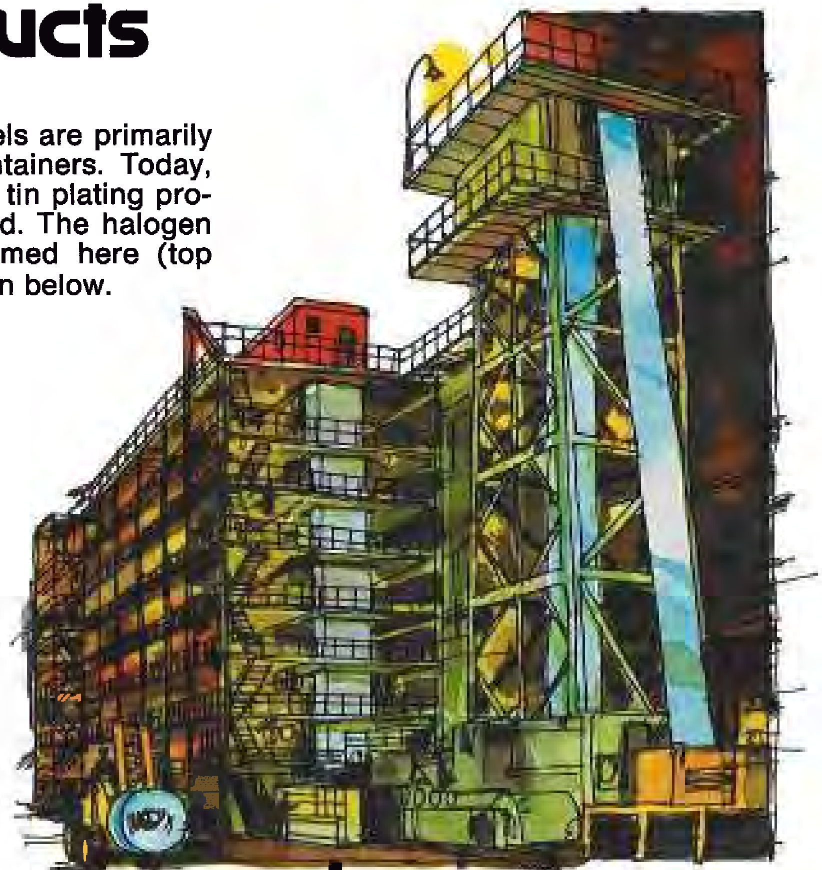
tin mill products

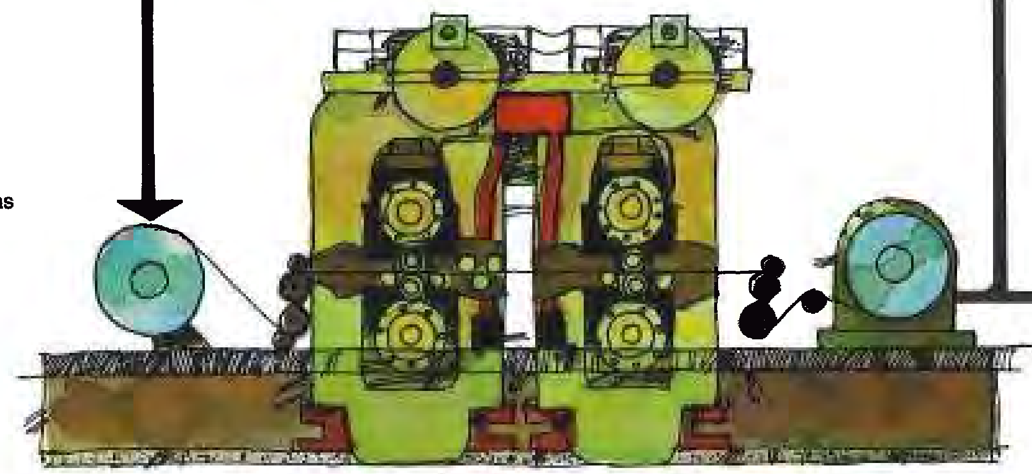
Tin plate and chromium-coated steels are primarily used to make cans and other containers. Today, there are three types of continuous tin plating processes — alkaline, halogen and acid. The halogen tin plating line has been diagrammed here (top right). A chrome-plating line is shown below.

1. **Much of the steel** for making tin mill products goes from a cold reduction mill through a continuous annealing facility. As the strip uncoils and passes through the annealing furnace, it is subjected to heat which softens it in preparation for further processing.

2. **Coils from continuous annealing** go either to a temper mill, where the strip is rolled just enough to give it proper hardness and surface properties, or they go to a double cold reduction mill which can further reduce the thickness up to 50 percent.

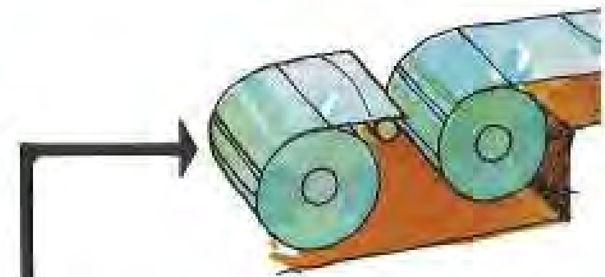
3. **The double cold reduced product** has greater strength than material that has been temper rolled, and is thinner. Either single or double reduced product is ready for coating as tin mill products. (The product at this stage is referred to as black plate.)





4. **At the start of the line,** the front end of one coil of steel, referred to as blackplate, is welded to the back end of the coil ahead to maintain continuous operations. The steel is washed and cleaned in a dilute acid. It then enters a plating solution where it is electroplated. In the plating section, tin leaves the positively charged tin anodes and is deposited on the negatively charged steel. The coating may be as thin as 0.000006 inch on a side.

halogen tinning line

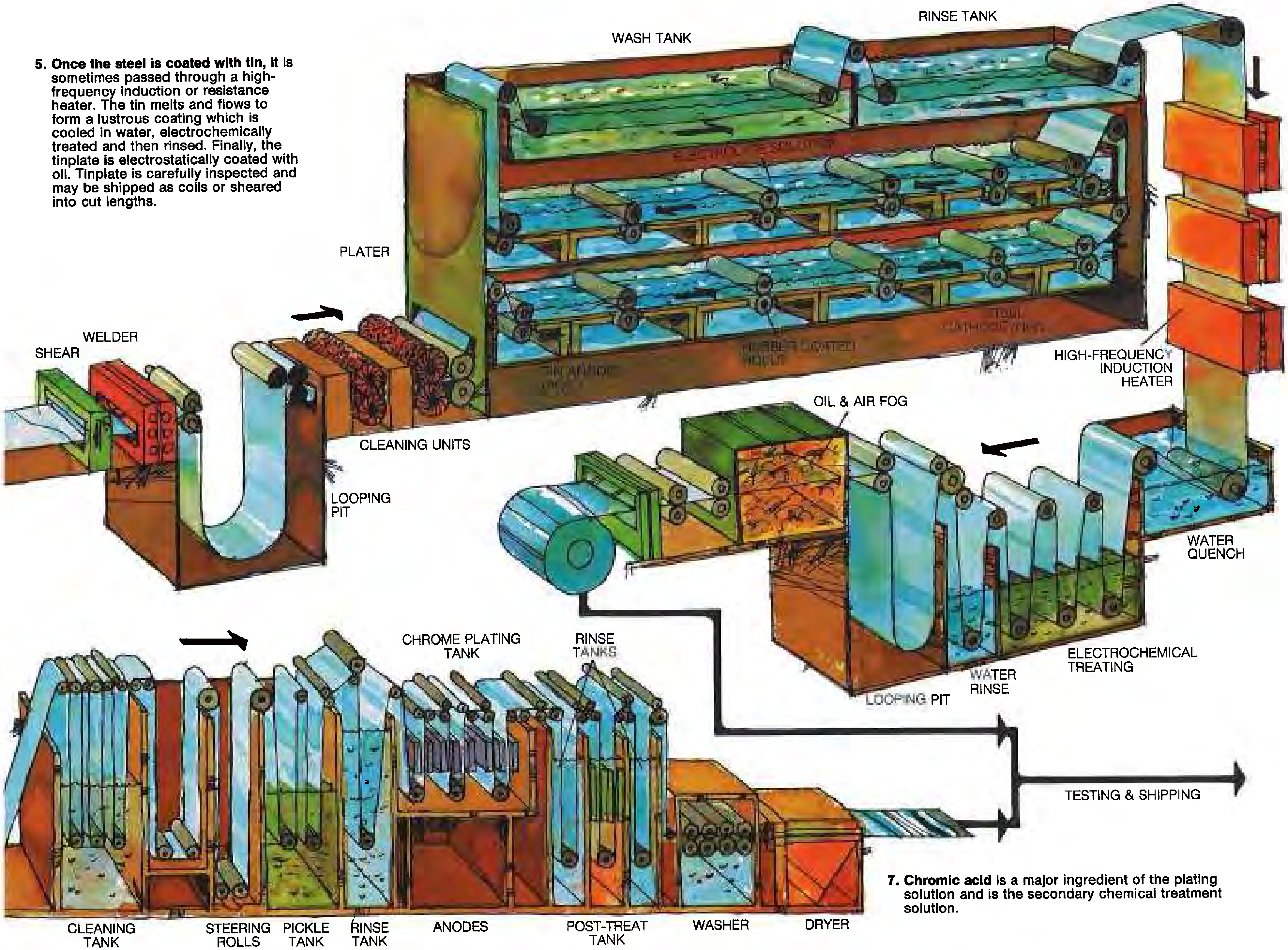


6. **"Tin-free steels"** are a chromium-coated product. Chromium plating processes use insoluble anodes in a plating solution from which chromium is electro-deposited onto the negatively charged sheet moving through the plating tank.

Reading from left to right on the diagram below, the steel sheet is cleaned, pickled in dilute acid, rinsed, chromium plated. In some processes a second chemical post treatment completes the coating. After this, the sheet is rinsed, dried and oiled.

chrome plating line

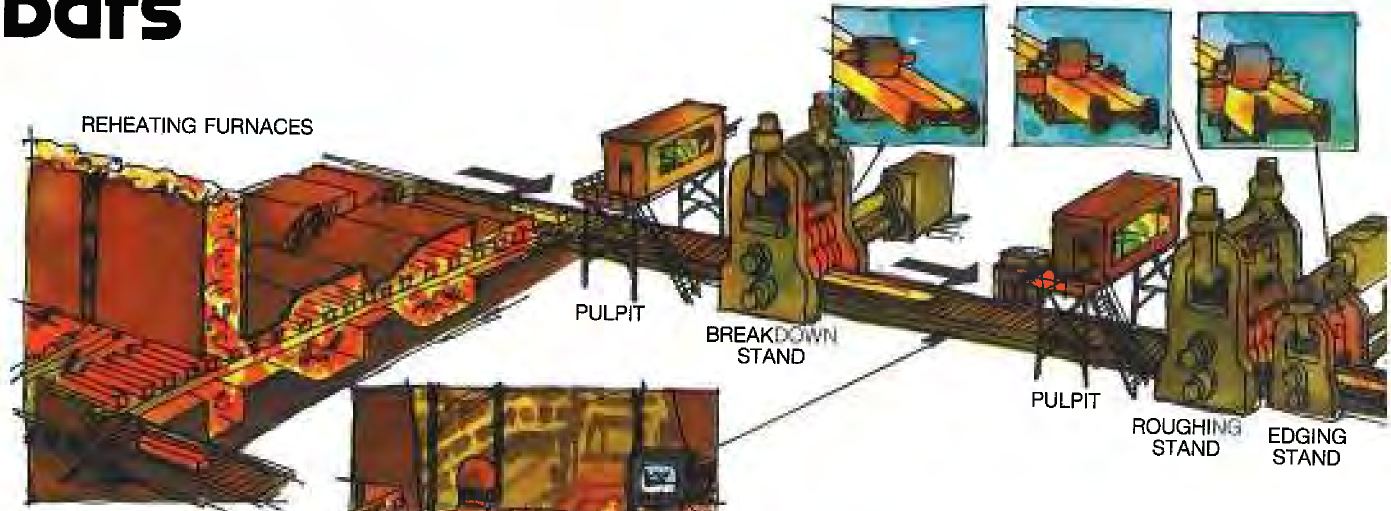
5. Once the steel is coated with tin, it is sometimes passed through a high-frequency induction or resistance heater. The tin melts and flows to form a lustrous coating which is cooled in water, electrochemically treated and then rinsed. Finally, the tinplate is electrostatically coated with oil. Tinplate is carefully inspected and may be shipped as coils or sheared into cut lengths.



7. Chromic acid is a major ingredient of the plating solution and is the secondary chemical treatment solution.

structurals & bars

Buildings and bridges require structural and other shapes rolled by mills similar to those shown at right. Among the most familiar products are the beams and angles shown being rolled in the top sketch. Many other shapes are available, largely for the construction industry. Smaller shaped sections are also produced on the bar mill shown in the bottom sketch.



structural & shape mill

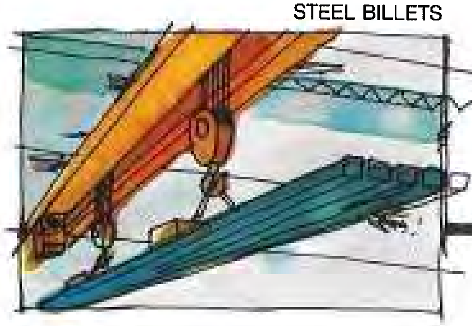
1. **Steel blooms or billets** ready for rolling are brought to uniform temperature in a reheating furnace. Then they enter a breakdown stand where grooved, adjustable, horizontal rolls squeeze the steel in sequences designed to produce various end products. The inset drawings show how the steel is shaped at each rolling stand. A change of rolls in the same stand produces numerous shapes ranging from I-beams to sheet piling.

2. **From elevated pulpits,** operators control the passes of the hot steel through the stands. The product may be passed back and forth several times (except at the finishing stand) reducing it to smaller cross sections. Edging stand rolls are retracted from the line when not in use.

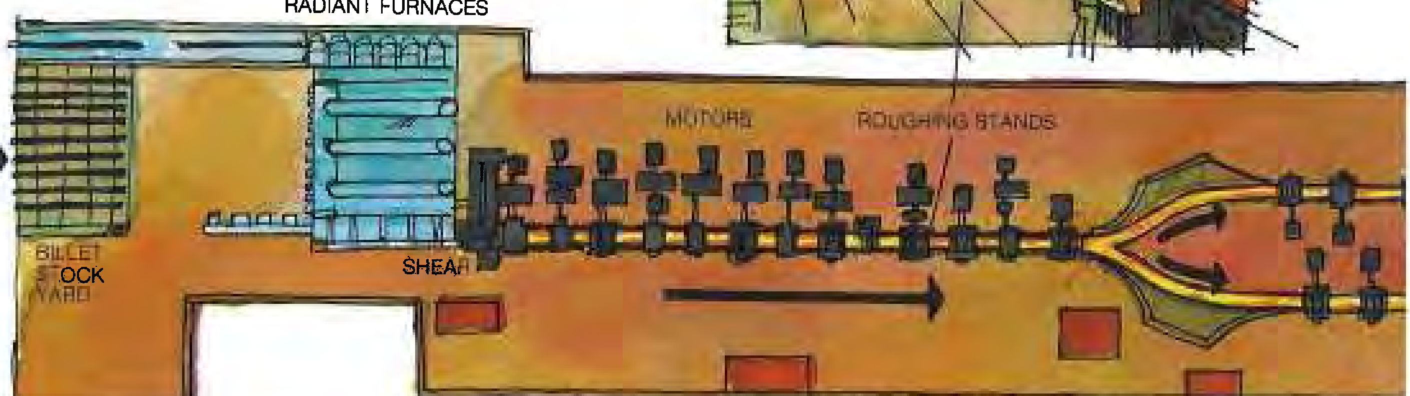
bar mill

4. **A bird's-eye schematic** of a bar mill is shown at the bottom of these pages. Two perspective drawings are presented separately, along with a diagram showing how grooved rolls shape the hot billets into one type of bar.

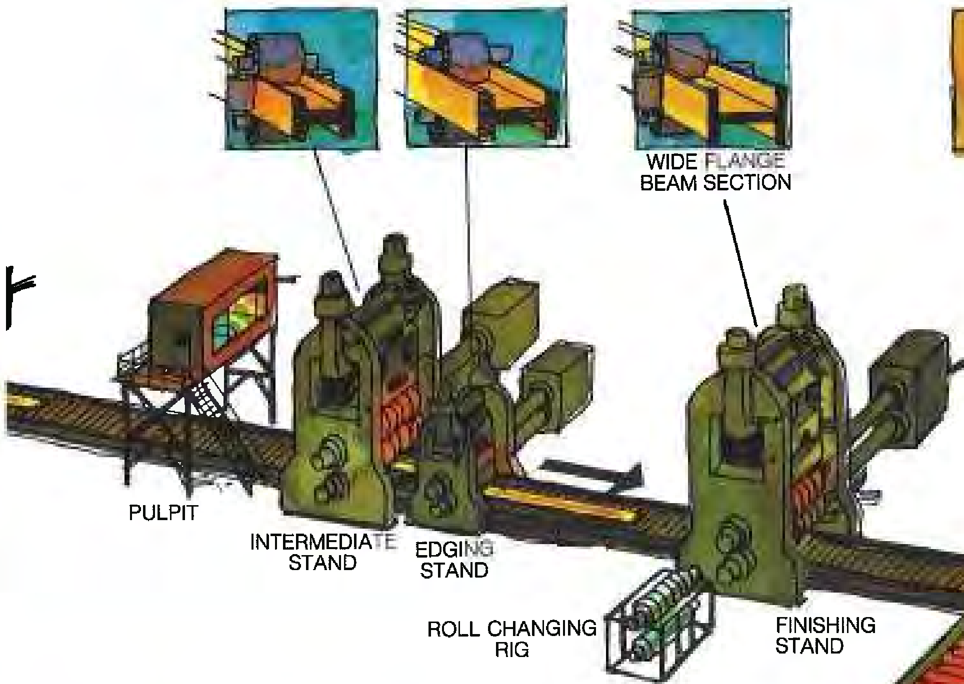
6. **Roughing and intermediate** reducing stands of rolls alternately exert pressure horizontally and vertically to produce twist-free bars.



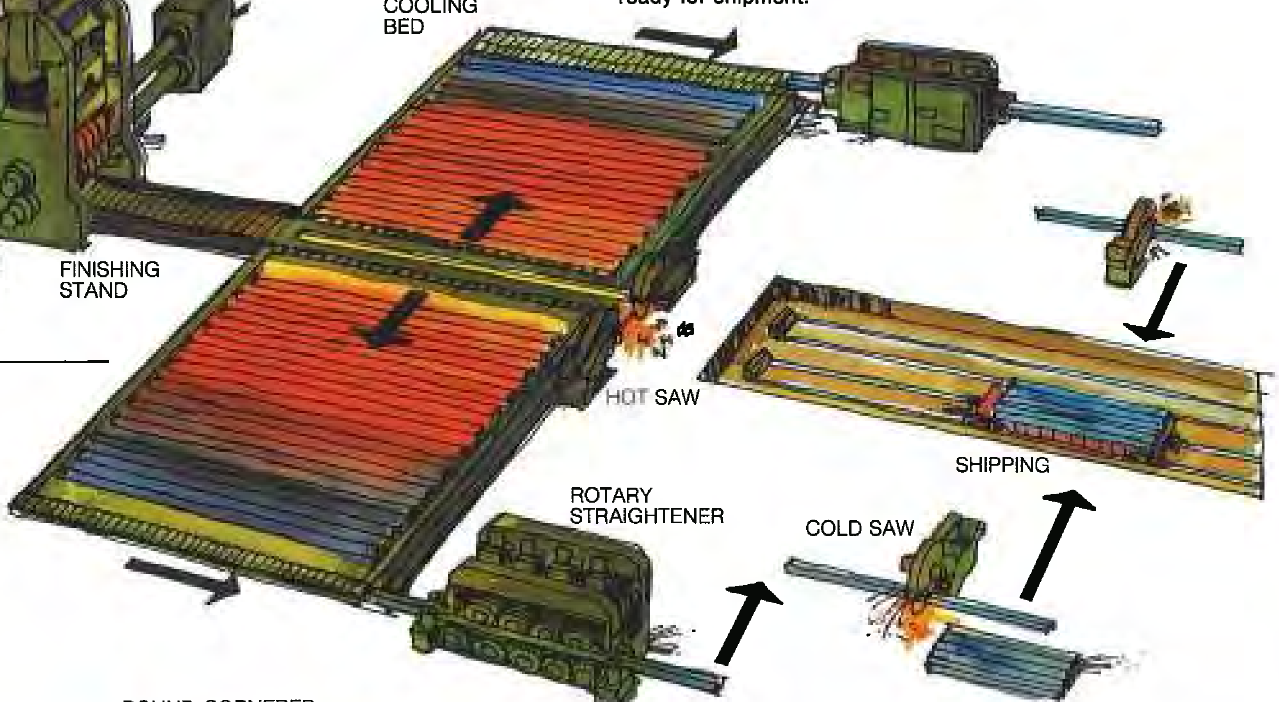
5. **Billets** are stocked in special yards. Inspection devices can detect possible internal flaws and external imperfections. In the bar mill, reheat furnaces bring the billets to rolling temperature at individually controlled rates.

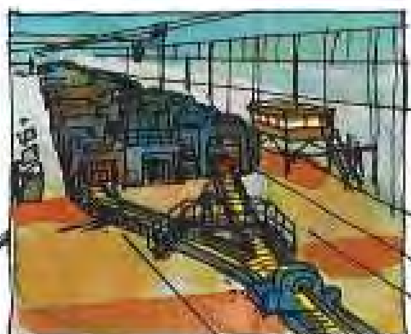


OVERHEAD DIAGRAM OF BAR MILL

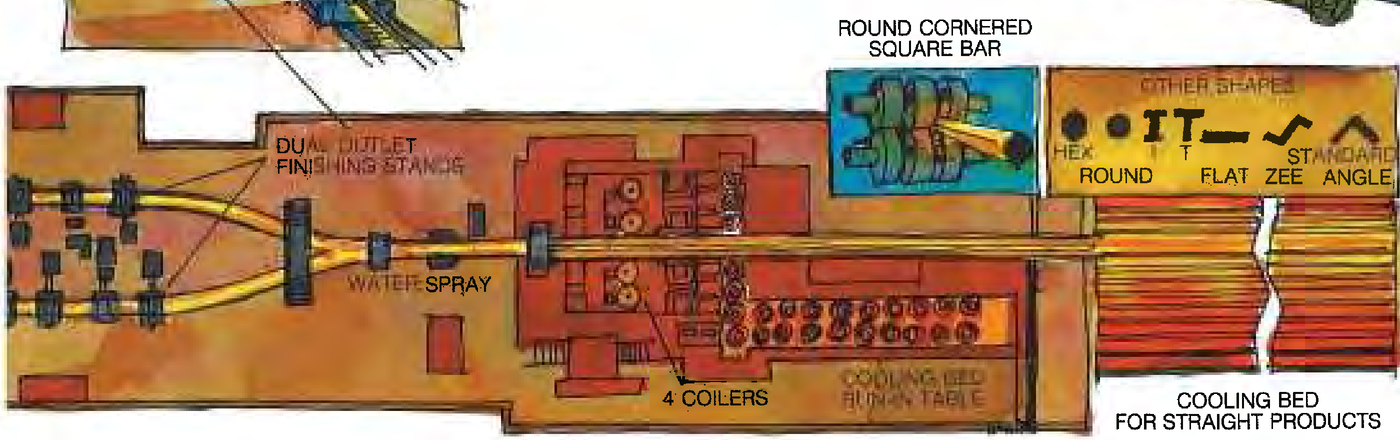


3. Products leaving the finishing stand are generally but not always, front-end cropped by a hot saw. Successive sections are moved along the cooling bed. When they reach either outside extreme, they are processed by a rotary straightener and cut to the length specified by customers. The products are then ready for shipment.





7. Unique to this particular mill are the dual outlet finishing stands. While one set of stands is working, the rolls can be changed in the other to make a different size or shape of bar.



8. Steel bars that are hot rolled into the many kinds of rounded or flat-sided cross sections, such as oval or hexagonal, are ordered in sizes ranging from a fraction of an inch to several inches in diameter. Many of the small-diameter bars are coiled. The coils may weigh up to two tons. Large-diameter bars are pushed out onto cooling beds and cut to length in straight sections. Standard shapes and special sections (for example, small channels or U-bars) rolled on these mills are water sprayed and moved onto the cooling beds. Many hot rolled bars require additional processing within the steel plant before being shipped to customers.

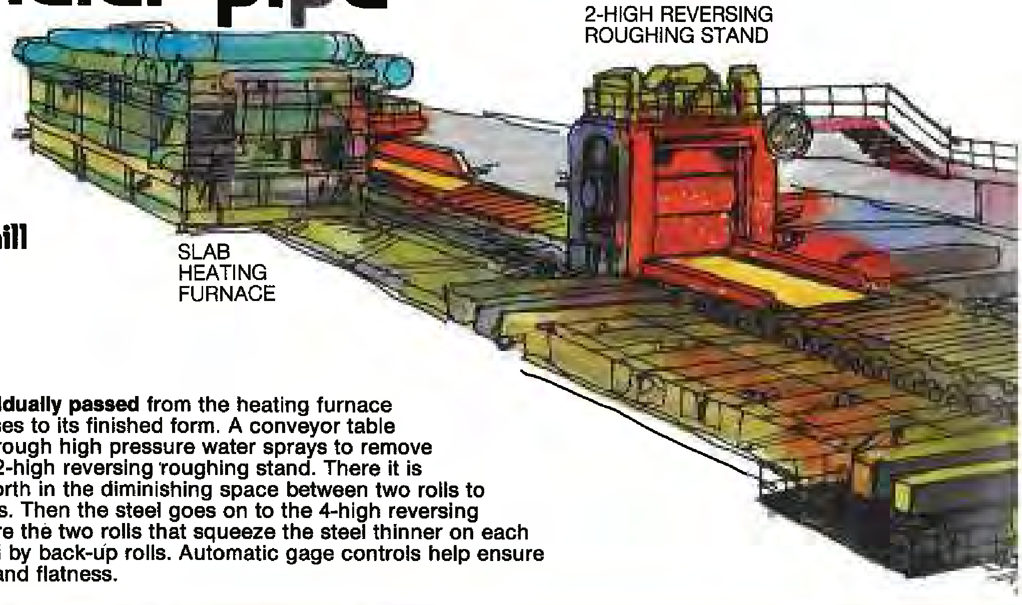
All bars are inspected. Special treatment such as sizing, turning and centerless grinding are required for many applications. Cold drawing of bars through special dies produces bars for applications where great strength and precise dimensions are necessary.

steel plate & large diameter pipe

A flat-rolled product that may range in thickness from less than one-quarter of an inch to more than one foot, steel plate serves the public in many essential ways. It is fabricated, both by platemakers and their customers, for various uses such as buildings, bridges, nuclear reactor vessels, industrial equipment, ships, machines and railroads, to name only a few. As a single example of a steel company plate-forming operation, the manufacturer of large O.D. (outside diameter) pipe is shown here. Welded girders or circles formed into domed "heads" for pressure vessels are among other plate product processes that might have been shown had space permitted.

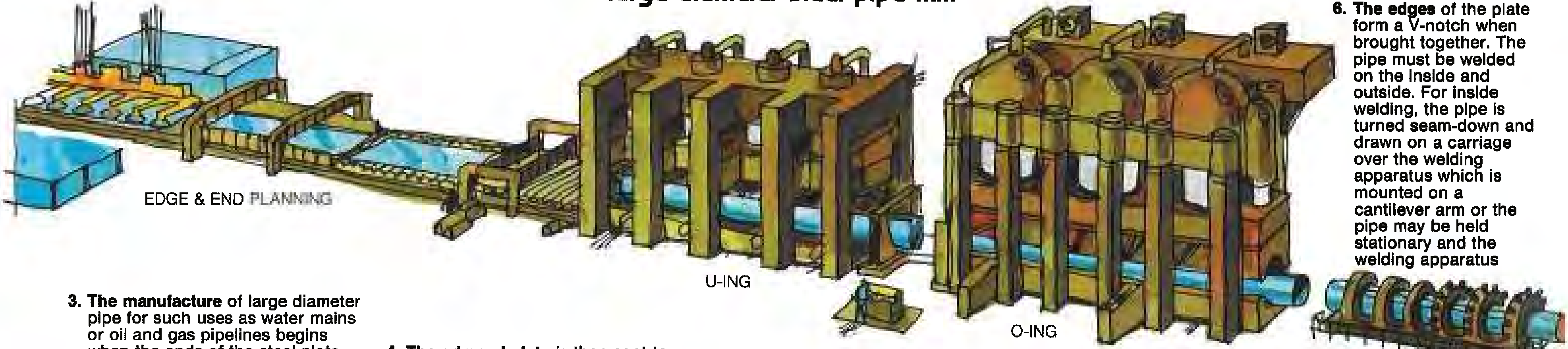
Most plates are rolled from slabs. The mill stands shown at the right reduce the thickness of the steel without controlling the straightness of the edges, which can be trimmed by shears or cutting torches.

steel plate mill



1. **Hot slabs are individually passed** from the heating furnace through all processes to its finished form. A conveyor table carries the steel through high pressure water sprays to remove scale and into the 2-high reversing roughing stand. There it is passed back and forth in the diminishing space between two rolls to reduce its thickness. Then the steel goes on to the 4-high reversing finishing stand. Here the two rolls that squeeze the steel thinner on each pass are supported by back-up rolls. Automatic gage controls help ensure uniform thickness and flatness.

large diameter steel pipe mill

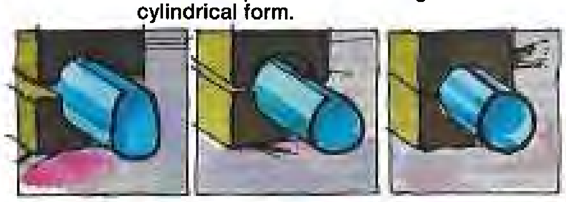


6. **The edges** of the plate form a V-notch when brought together. The pipe must be welded on the inside and outside. For inside welding, the pipe is turned seam-down and drawn on a carriage over the welding apparatus which is mounted on a cantilever arm or the pipe may be held stationary and the welding apparatus

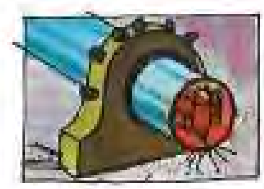
3. **The manufacture** of large diameter pipe for such uses as water mains or oil and gas pipelines begins when the ends of the steel plate are cut square and the edges are beveled and made parallel. The edges are then shaped or bent either with rolls (above) or with a hydraulic press.

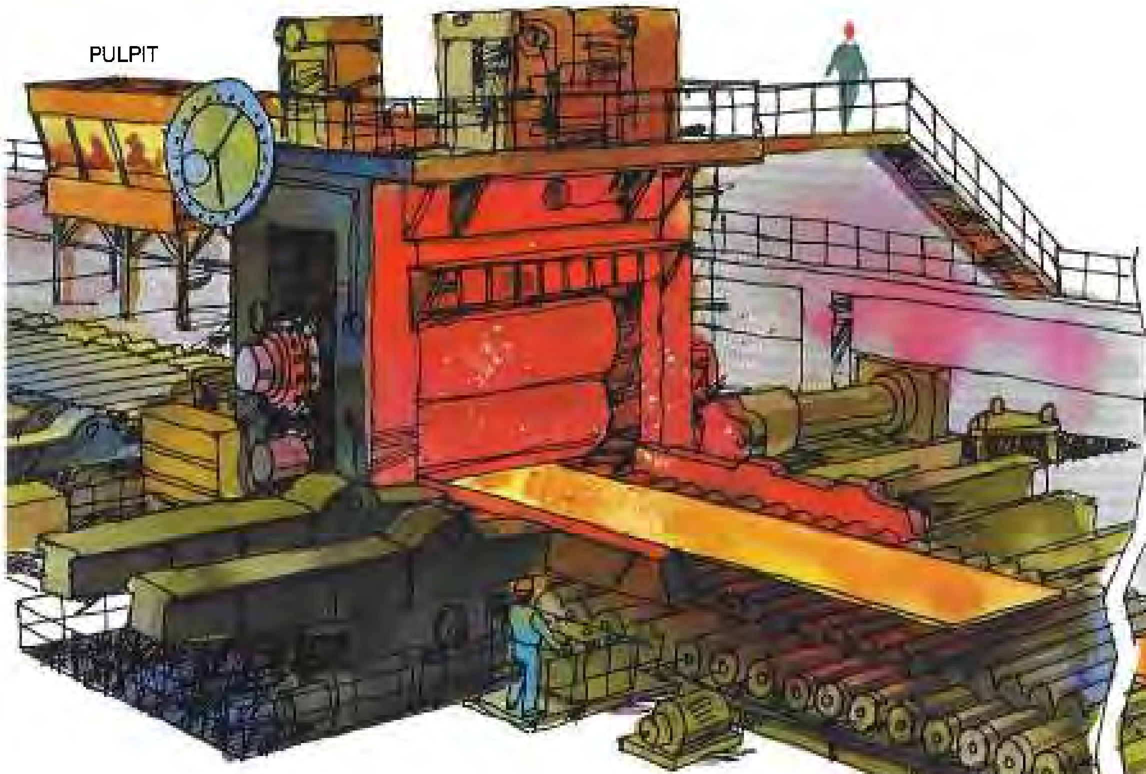
4. **The crimped plate** is then sent to the U-ing press where a U-shaped die forces the steel down between rocker rolls. The curved die is as long as the plate and forms half the pipe circumference.

5. **The O-ing press** takes a plate which has been shaped by the U-ing press, and, using much greater force, completes the bending to cylindrical form.

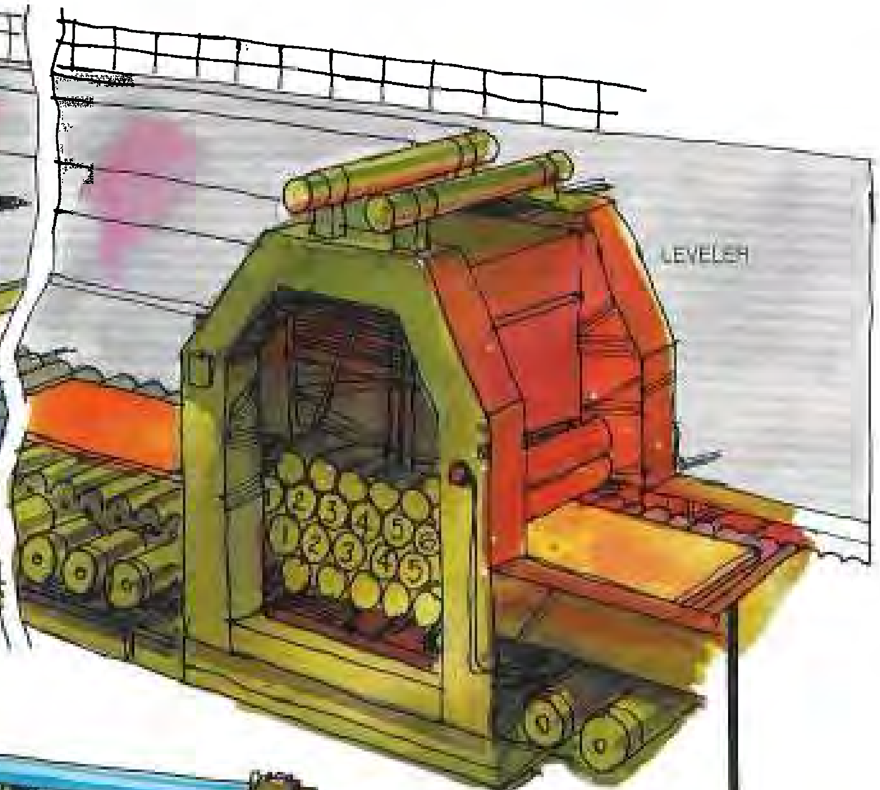


INSIDE
SEAM WELDING



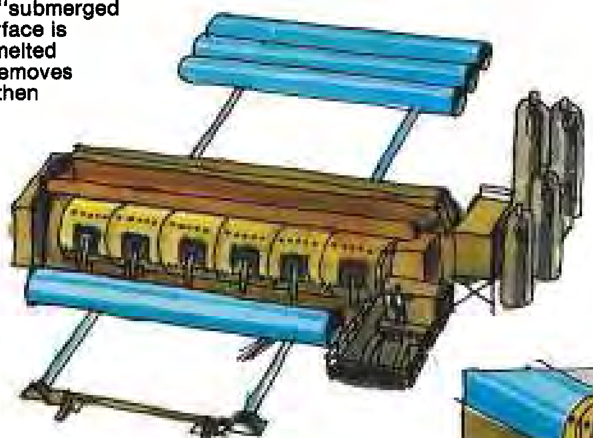


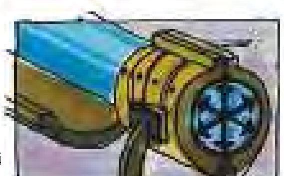
2. A leveler is commonly used to improve flatness of the plate. The schematic drawing below shows a 6-over-5 backed-up leveler, so called because of the arrangement of the power driven rolls and the other rolls which squeeze the steel evenly.



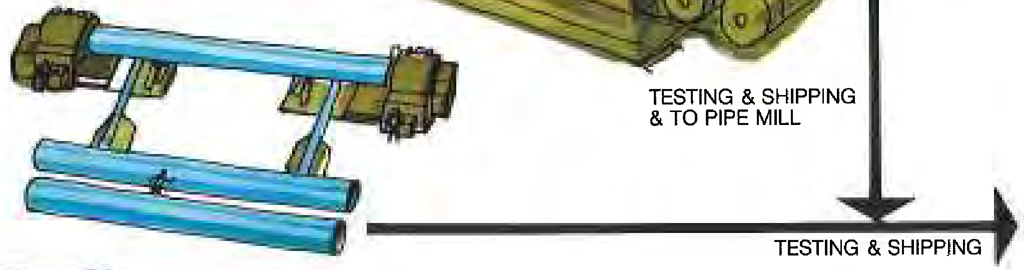
drawn through the pipe. In the welding process, the notch is filled with molten metal produced by applying electrical current through welding wire which fuses the plate edges together. The process shown is called "submerged arc-welding" because the surface is covered with a flux which is melted by the heat. A vacuum later removes the flux. A similar process is then used to produce a weld seam on the outside.

OUTSIDE
SEAM WELDING





COLD EXPANSION AND
HYDROSTATIC TESTING

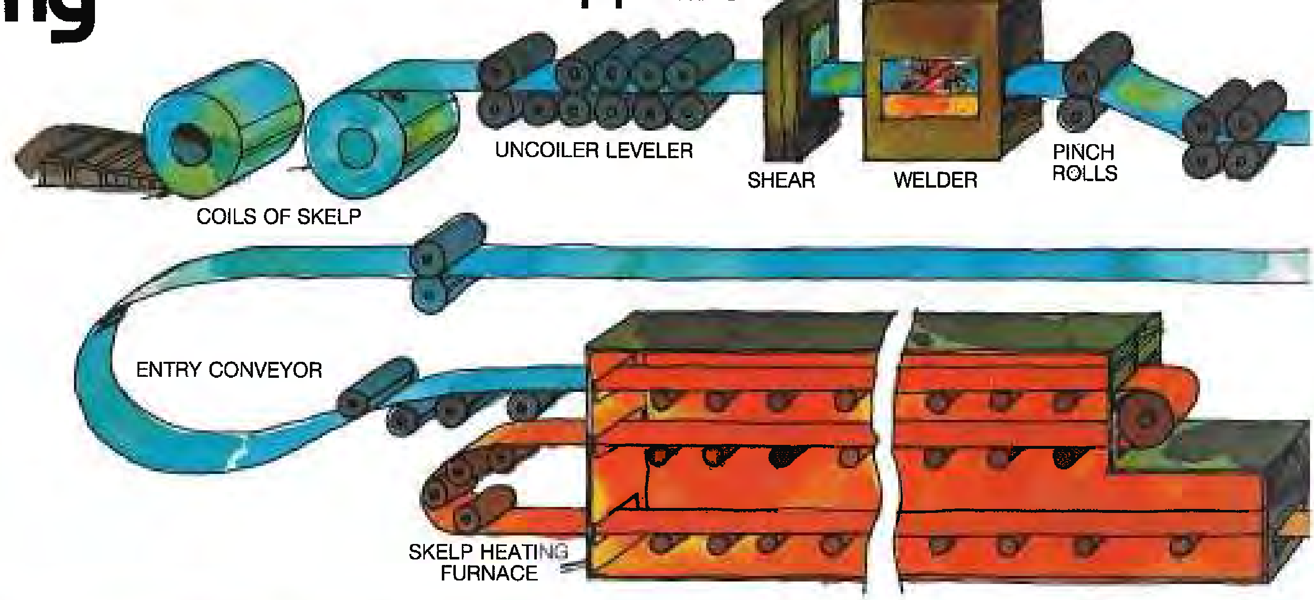


7. Expanding steel pipe to give it additional strength and improved dimensions requires complex, costly equipment. The welded pipe is put into hinged dies with a circumference slightly larger than itself, and the ends of the pipe are sealed. Water is pumped in until the hydraulic pressure expands the pipe (as much as one percent) out to the restraint of the dies.

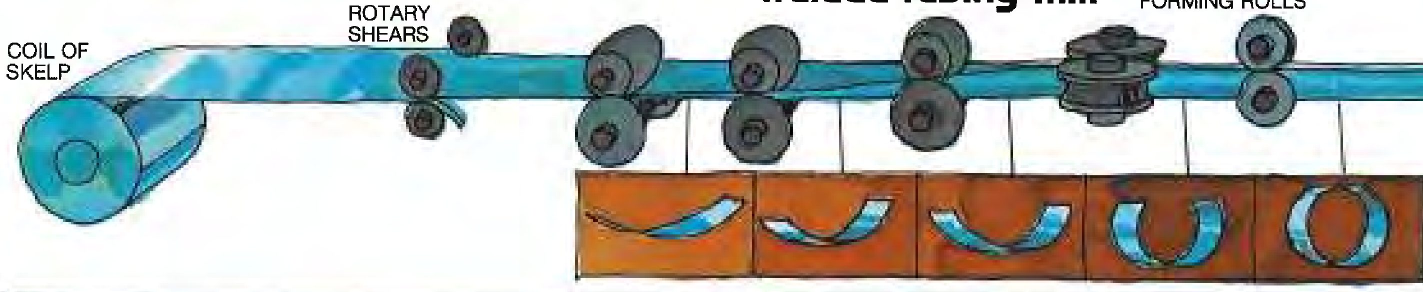
other pipe & tubing

Three ways by which steelworkers make most of their pipe and tubing are illustrated here. They are different from each other and from the method of forming large diameter pipe described earlier in this series. Each process has advantages for producing certain kinds of end products. For example, the continuous butt-weld pipe mill (right) makes much of the standard pipe used in plumbing. The electric-resistance welded tubing mill (below) is often employed to make products of relatively high diameter/wall thickness ratios. Seamless tubing is made by the mandrel type mill (at bottom). Seamless products are used by the oil, gas and chemical industries and also for boiler tubing.

continuous butt-weld pipe mill

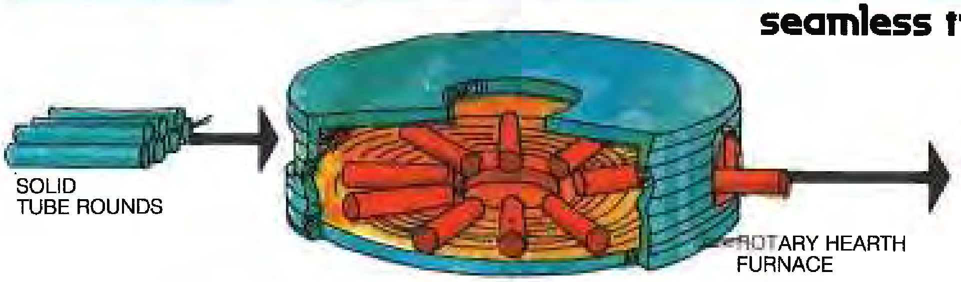


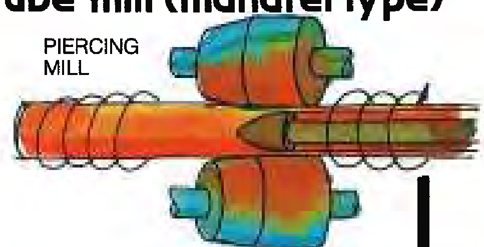
welded tubing mill



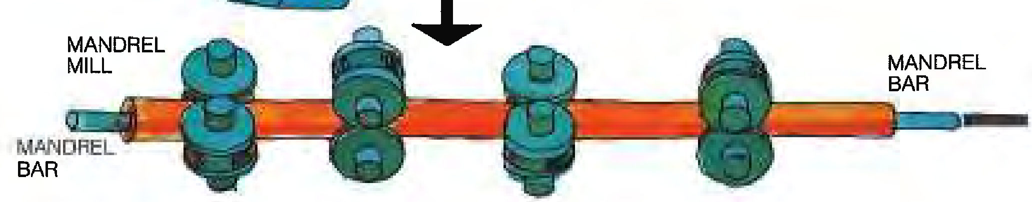
2. The second process, the electric-resistance welded tubing mill, begins when rotary shears trim the edges of skelp parallel. The contour of the forming rolls forms tubing step by step. Carefully guided by rolls, the tube edges are electrically welded together by pressure and the heat caused by steel's resistance to

seamless tube mill (mandrel type)



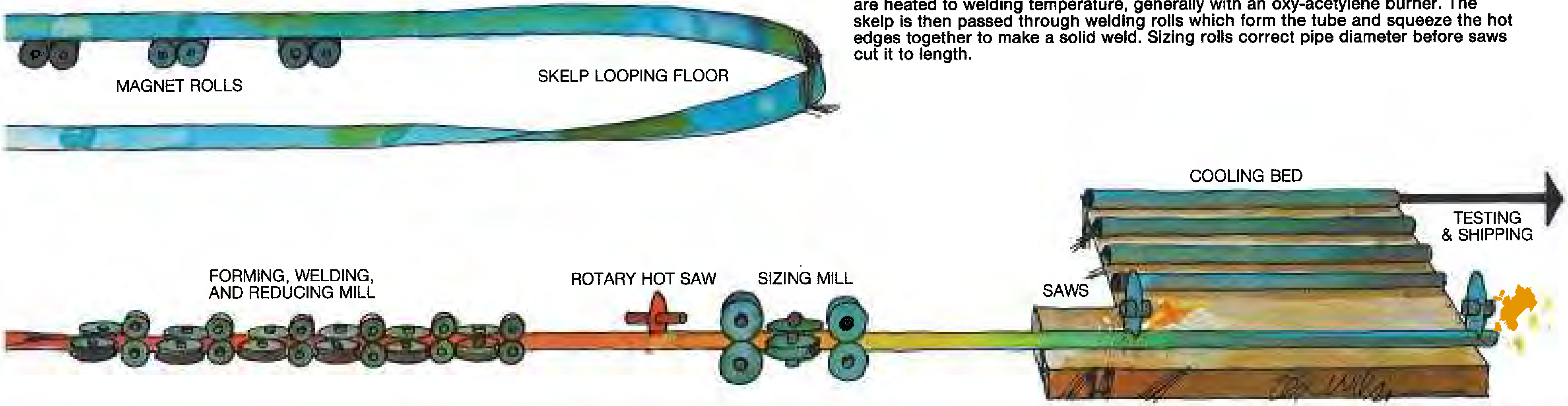


4. Once through the mandrel mill, the seamless tubing is reheated in either a reheat furnace or an induction heater. The lengths are then rolled to very precise sizes either on a sizing mill or on a stretch reducing mill. In the latter, each pair of rolls rotates faster than the pair preceding it, thus stretching the steel and reducing the tubes' diameter and wall thickness simultaneously.

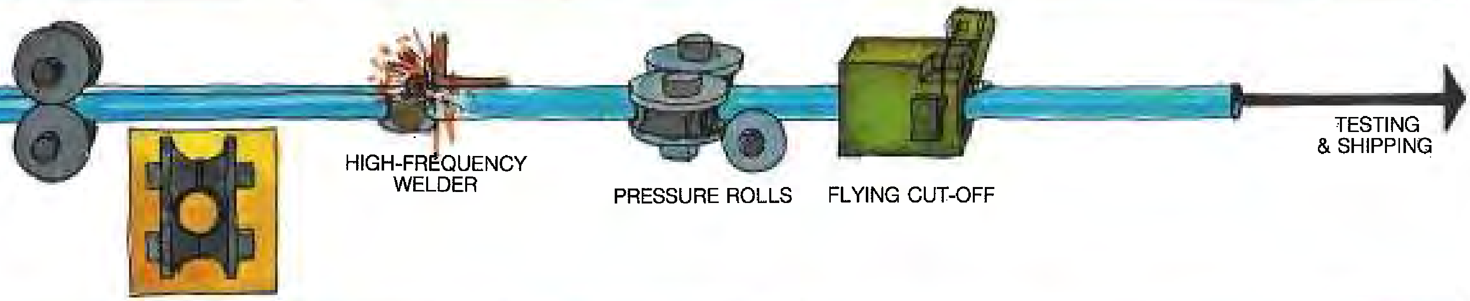


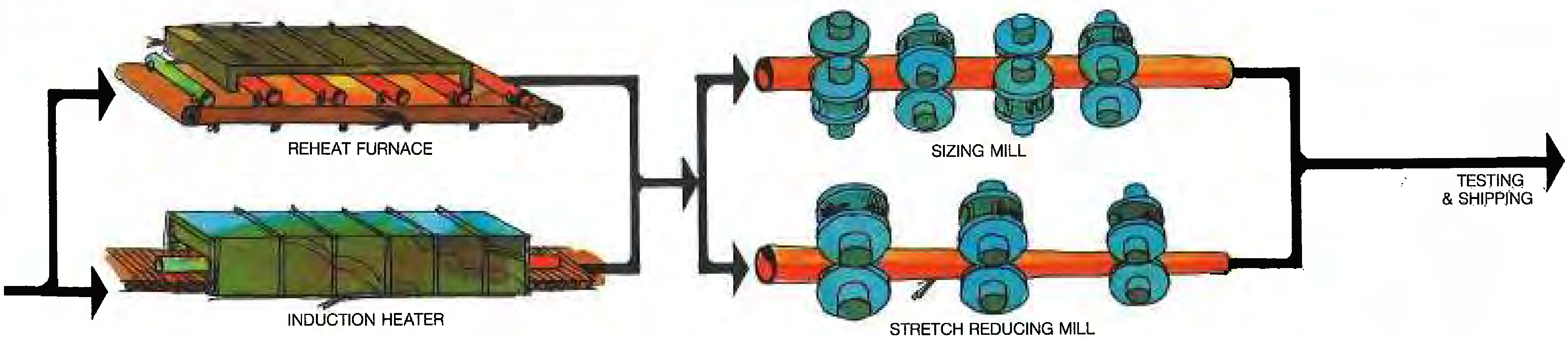
3. Round steel billets, often called tube rounds, are first heated to a uniform rolling temperature. A piercing mill rotates the steel under extreme pressure, which causes the metal to open up in the center of the round, permitting the mandrel to enter and pierce. Then a cylindrical mandrel bar is inserted into the pierced shell. The desired diameter, wall thickness and length are obtained as the shell with the bar inside it progress through successive stands of the mandrel mill.

1. Following the flow of the continuous butt-weld pipe mill (left) a coil of flat-rolled steel called skelp is drawn through the line by pinch rolls. A long loop of skelp is created as a reserve so that pipemaking can continue while the trailing end of one coil is welded to the leading end of a new one. The skelp is heated to forming temperature as the steel winds through a long furnace. After exiting the furnace, the skelp edges are heated to welding temperature, generally with an oxy-acetylene burner. The skelp is then passed through welding rolls which form the tube and squeeze the hot edges together to make a solid weld. Sizing rolls correct pipe diameter before saws cut it to length.



electricity. The welder wheel has two copper discs, one positive and the other negative in charge. In continuous operation, provision is made to weld the square-cropped end of the coil to the leading end of the next without stopping the progress of forming and welding.





specialty steel tubing

Specialty tubing is more economically suited to the tasks required of it than any other form of steel or other material.

The products range from boiler tubes to aircraft hydraulic lines and hypodermic needles. In all cases, the chemistry, metallurgy, size and shape of specialty tubing are controlled with extra care. Most of the product is made by the seamless tube mills or the electric welded tubing mills as shown in the flow chart "Pipe and Tubing."

Other methods of making specialty tubing are sometimes used for special products which require precision. Four of these methods are briefly diagrammed here. All are suited to making small quantities of very high quality tubing.

hot extrusion

1. **In this process,** a billet (or round) has a pilot hole drilled along its axis or is pierced in a vertical piercing press. When reheated, the billet is wrapped in glass wool which melts to become a lubricant. It is then placed in the container of the extrusion press. A stem, through which runs a glass-wrapped mandrel, now comes into play. The mandrel extends through the hollow billet and out through the center of a die that is lubricated with strongly reinforced glass. During extrusion the stem forces the steel out between the die walls and the mandrel, forming a tube in two or three seconds.

FURNACE

ROUNDS (OR BILLETS)

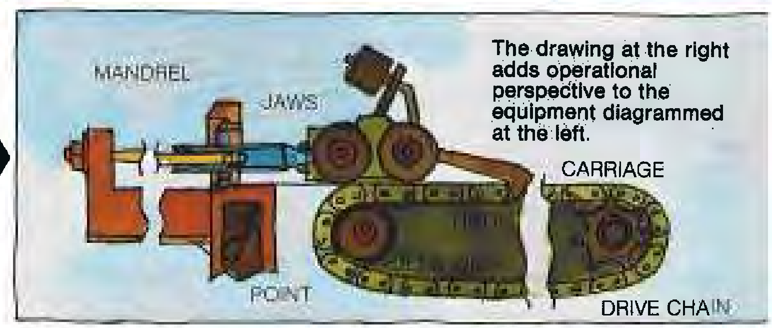
cupping and drawing

2. **Cupping and drawing,** which is also called "piercing and drawing," is a process that has some features in common with hot extrusion, but is less commonly used. The piercing mandrel is not forced entirely through the hot billet, and thus forms a thick-walled cup. This cup is placed on the end of a long mandrel that forces the steel through a series of progressively smaller dies. This action forces the metal back over the advancing mandrel, forming a tube with one closed end which is later sawed off.

PICKLING (CLEANING) TUBES

cold drawing

3. **Cold drawing involves** pulling tubing through a die, but much preparation of the steel precedes that operation. Tubing from a hot mill or weld mill is carefully inspected, cleaned, annealed and lubricated. One end is swaged, or pointed, to fit easily through the die so that the jaws on the draw-head (carriage) can grip it. A hook from the carriage engages a link in the chain drive on the draw bench (far right) and the tubing is cold drawn through the die. When there is no mandrel (plug) inside the tubing being drawn, the diameter is reduced, but the wall thickness is unaffected. With plugs or a rod inside, both the outside diameter and wall thickness of the tubing is reduced.

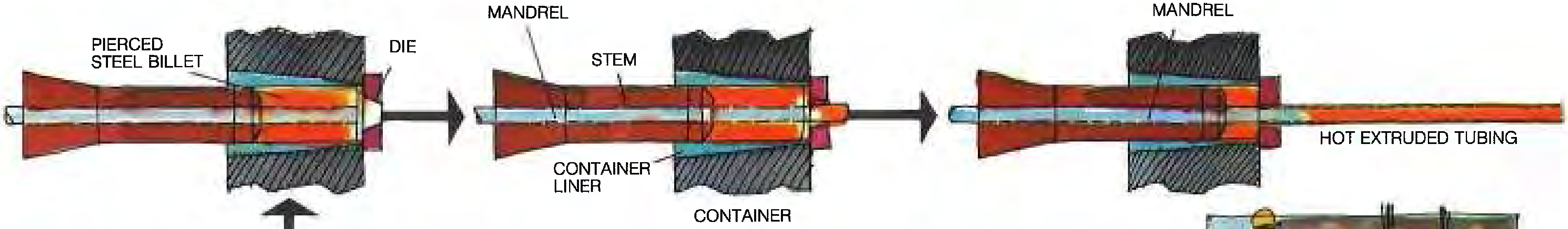


The drawing at the right adds operational perspective to the equipment diagrammed at the left.

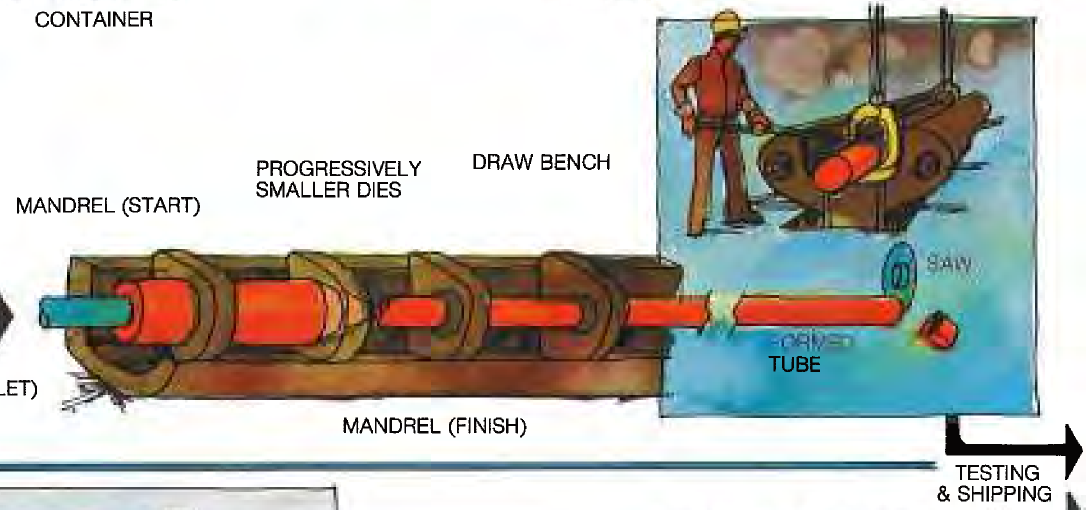
tube reducing

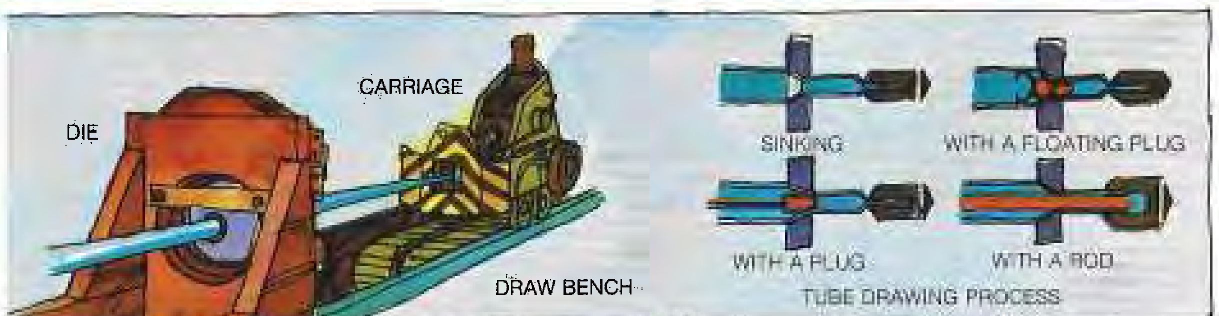
4. **Tube reducing** involves a machine that uses matched tapered grooves, or dies, mounted in facing rolls to reduce the tubing over a stationary tapered mandrel. Large reductions are possible. The "saddle" formed by the rolls works the outside of the tubing, and the mandrel works the inside, as the result of the compressive force. The tapered grooves rock back and forth over the tube surface, reducing the steel at the taper. The steel is fed forward through the machine after each rocking action, and is also turned slightly to prevent the formation of "ribs" between opposing die surfaces.

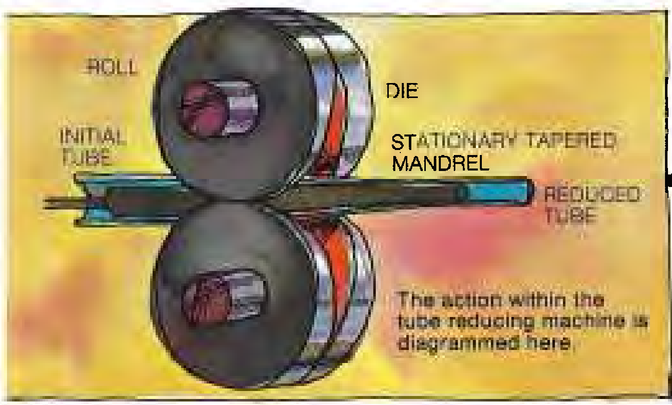
TUBE REDUCING MACHINE



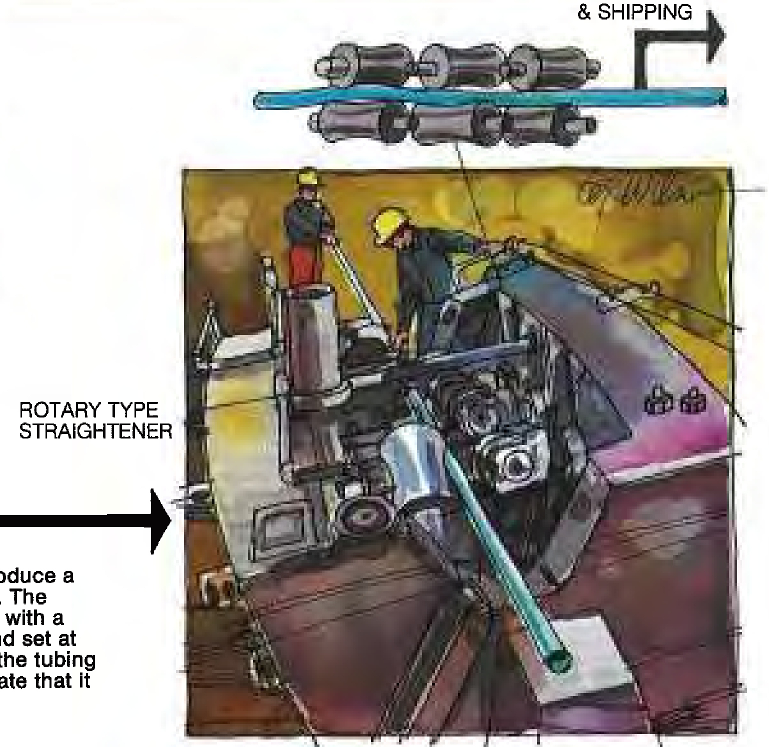
The drawing at the right indicates how a piercing mandrel forms a cup. Although different equipment may be used, a similar process, carried entirely through the billet, is applicable to hot extrusion (above).







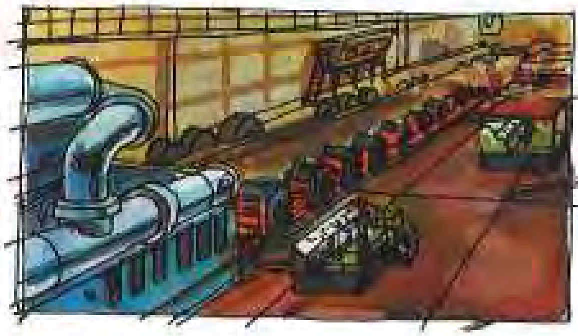
5. Cold drawing and tube reducing usually produce a product requiring a straightening operation. The rotary type machine is shown at right along with a diagram illustrating how rolls are shaped and set at angles to each other in order to straighten the tubing without crushing it. Some tubing is so delicate that it is hand-straightened.



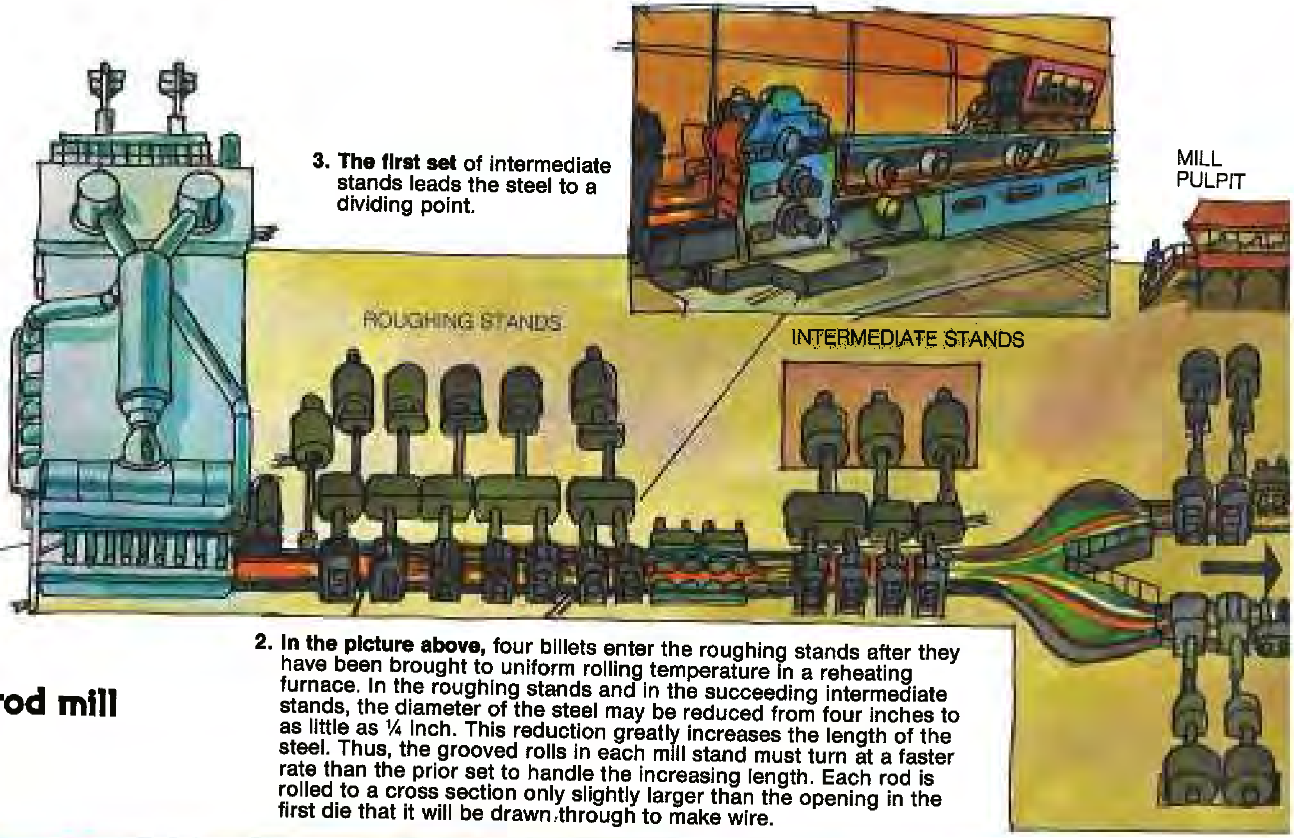
steel rods & wire

Billets, rolled into steel rods, are the semi-finished products from which wire is made. Rods are much like small diameter bars, and are produced in coils. These coils are then unwound as the rods are drawn through one or more dies which reduce their diameter to make wire. It has been estimated that there are more than 100,000 uses for wire.

1. The perspective drawing below shows the area where the billets leave the furnace and enter the roughing stands.



rod mill

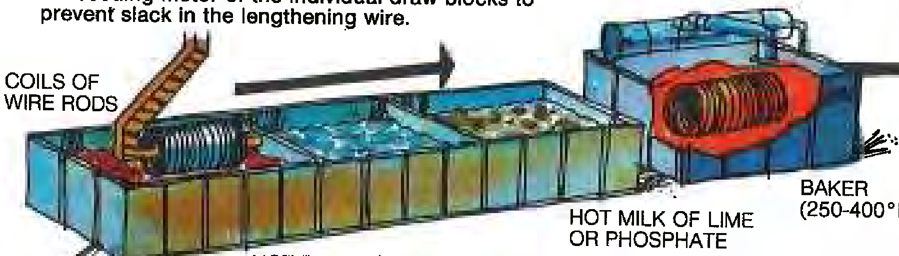


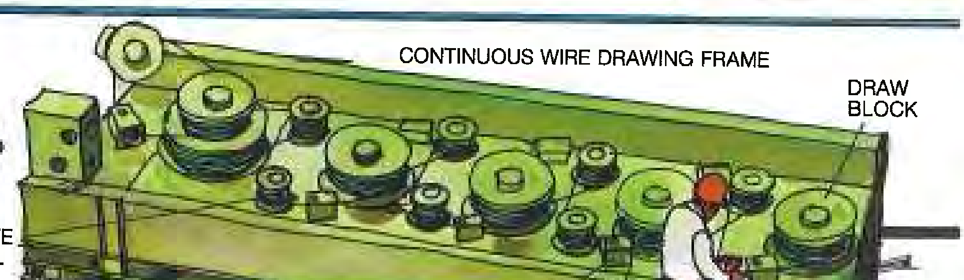
3. The first set of intermediate stands leads the steel to a dividing point.

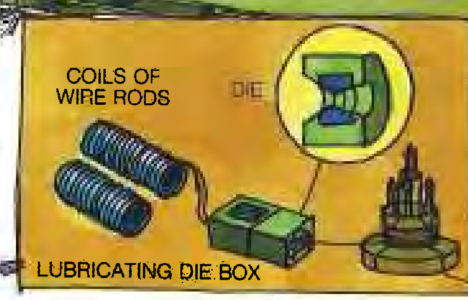
2. In the picture above, four billets enter the roughing stands after they have been brought to uniform rolling temperature in a reheating furnace. In the roughing stands and in the succeeding intermediate stands, the diameter of the steel may be reduced from four inches to as little as ¼ inch. This reduction greatly increases the length of the steel. Thus, the grooved rolls in each mill stand must turn at a faster rate than the prior set to handle the increasing length. Each rod is rolled to a cross section only slightly larger than the opening in the first die that it will be drawn through to make wire.

wiremaking

5. Steel rods are prepared for drawing in various ways. Here, acid cleans the surface; water rinses it; lime acts as a neutralizer for any residual acid. Mechanical descaling can also be used. To be a good carrier for a lubricant, the lime coating on the rods must be thoroughly dried in a baker. A phosphate coating is also used. The coated and baked rods are then taken to a drawing machine. Once a rod is drawn through a die it is called wire. In a continuous wire drawing machine, wire properly prepared and lubricated, goes through a series of dies. Sheave wheels control the tension between blocks. They also control the speed of each succeeding motor of the individual draw blocks to prevent slack in the lengthening wire.

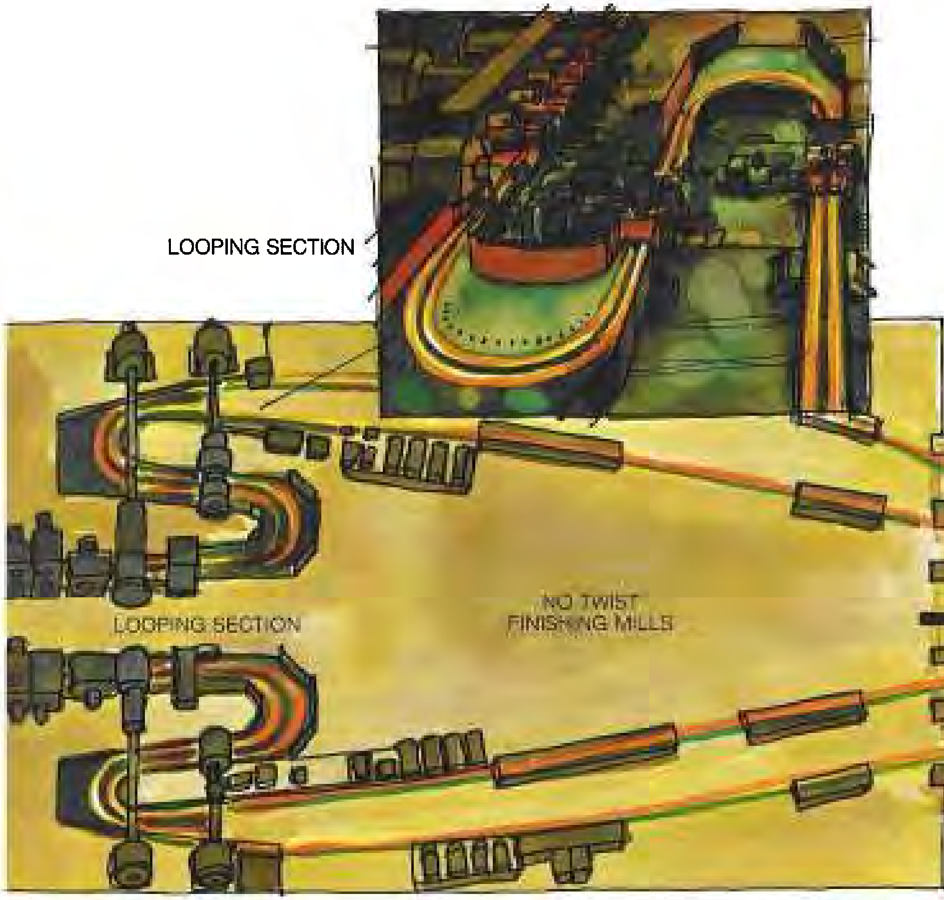






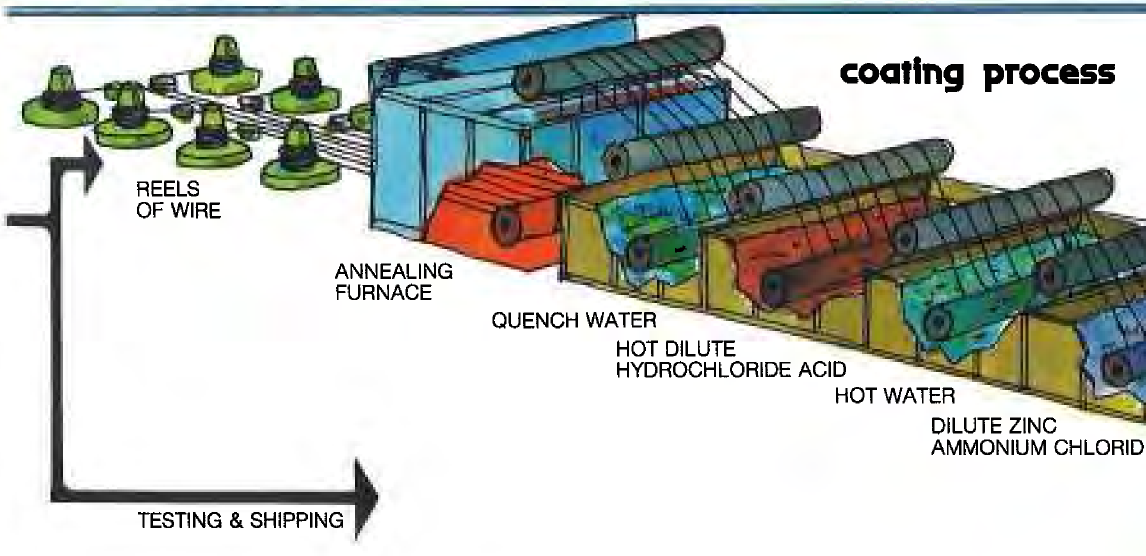
6. Schematic cross section (not to scale) of a single-hole wire drawing die employing a nib of sintered carbide mounted in a circular steel holder.

DRAW BLOCK

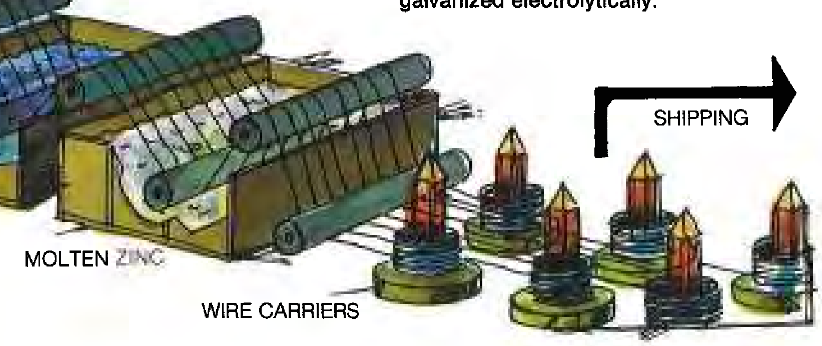


4. The looping section of the rod mill offers various economies in power usage and speed for certain kinds of rods. The finishing mills roll individually, which prevents the steel from twisting. In the mill shown here, rods slightly less than ¼ inch in diameter are delivered to the laying cones for coiling at the rate of about 8500 feet per minute; larger sizes are rolled more slowly.

coating process



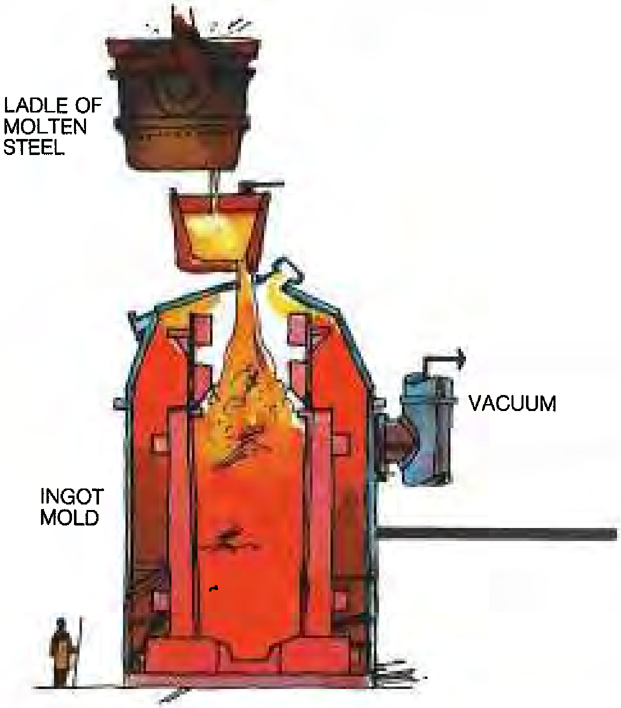
7. Once the rod is drawn to wire, its treatment may differ greatly, depending on the intended use. Heat treatment is common. An estimated one-third of all steel wire is coated. The hot galvanizing process (left) coats steel wire with a protective layer of zinc. The wire is water-cooled, cleaned with acid, hot water rinsed and then fluxed with a solution of dilute zinc ammonium chloride. The wire next goes through molten zinc which metallurgically reacts with the steel surface, producing a tight bond. The coated wire is then wiped and reeled for shipment. Wire is also galvanized electrolytically.



forging hot steel

Whenever a steel part is to be subjected to high stresses in service, designers consider a forging process to make it stronger. Whether the part is a turbine shaft of well over 100 tons, or a conveyor roller weighing a few pounds, forging it is likely to squeeze or hammer more strength for less bulk into the product than if one of the higher-tonnage-making processes were used. Steel for forging can be made in any steelmaking furnace, and it may also be degassed or vacuum melted. In addition to the important forging processes shown here, others can well claim advantages in making certain products. All methods, including extrusion, mechanical forging, upsetting and roll forging, "knead" the original steel into a denser structure and bring it so close to its finished shape that it requires minimal cutting with machine tools so that very little metal is lost as scrap.

Compared with the amount of steel rolled by mills into useful shape, forging accounts for a small tonnage — but the products of the forging processes are indispensable. Some steel plants operate forge shops and many more sell billets and bars of forging quality steel to an independent forging industry that has sales exceeding a billion dollars annually.

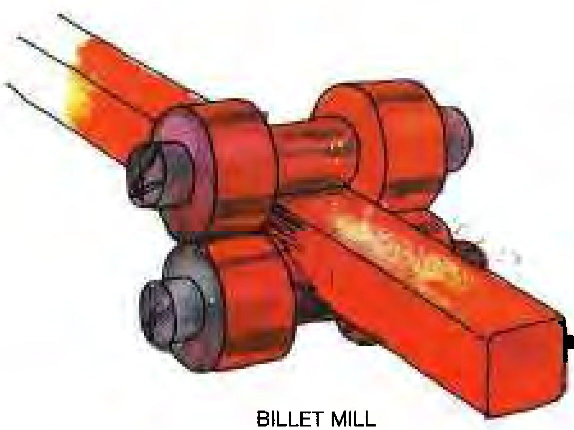


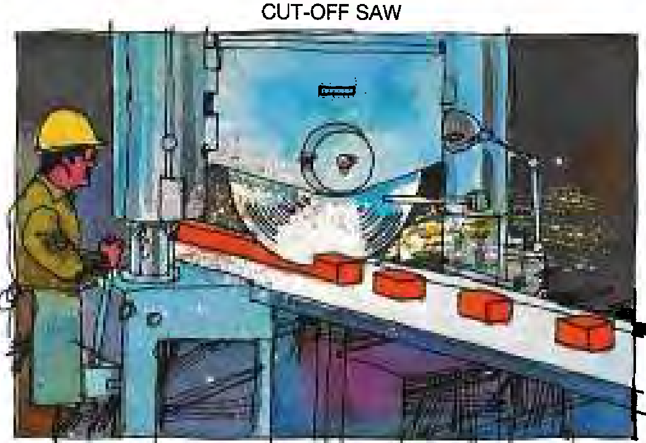
open die forging

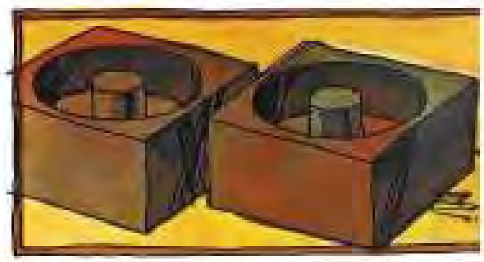
closed die forging

2. Many hot forgings are made from billets, which are the product of either rolling mills or strand casters. In the example shown here, a section of round-cornered, 4½-inch square billet is cut by the saw. Special dies, with the half shape of the desired product machined into each, are set for use in a steam hammer.

3. The steel is placed between the two dies which are hammered together. The hot metal inside the closed dies flows to fill both halves. Then, machine tools provide the finishing touches to a new conveyor roller.

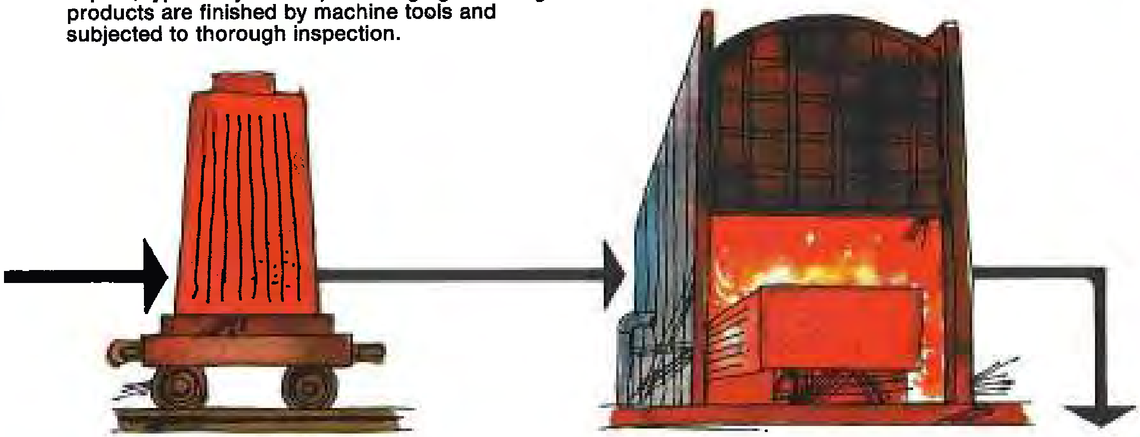






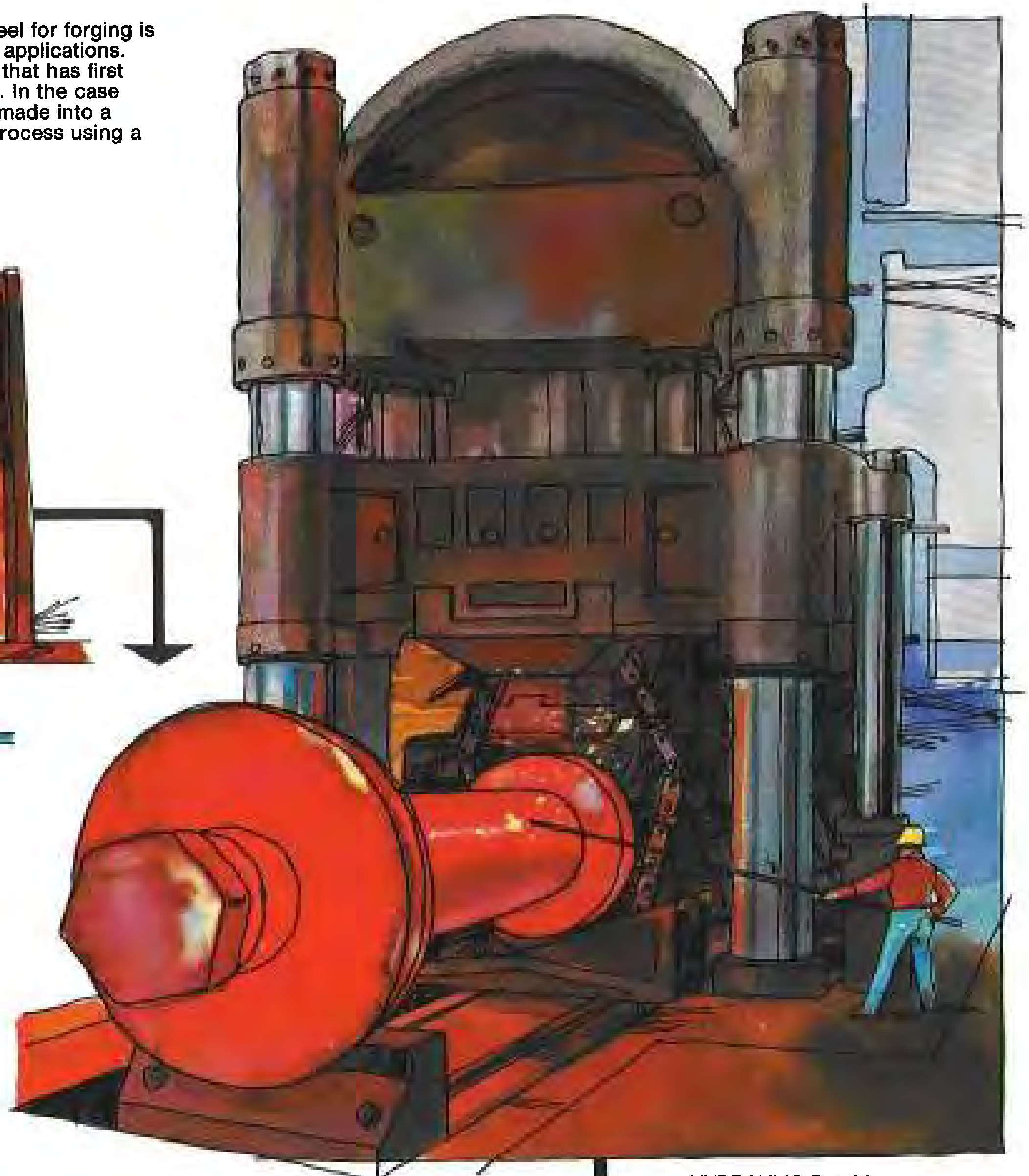
1. As a spectacular example of open die hot forging, an ingot (below) of alloy steel — vacuum processed for purity and uniformly heated throughout — is forged in an hydraulic press to make a huge turbine shaft. A piston-driven, flat-faced upper die is forced down on to the steel ingot which is moved and turned on the bottom die between reheating sessions. Open die forging is also done on semi-finished products such as blooms, billets or rounds. Squeezing rather than impact, typifies hydraulic press forging. The forged products are finished by machine tools and subjected to thorough inspection.

Although vacuum processing of steel for forging is common, it is not necessary for all applications. Most forgings are made from steel that has first been rolled into semi-finished form. In the case shown below, a section of billet is made into a conveyor roller by the closed die process using a steam hammer.

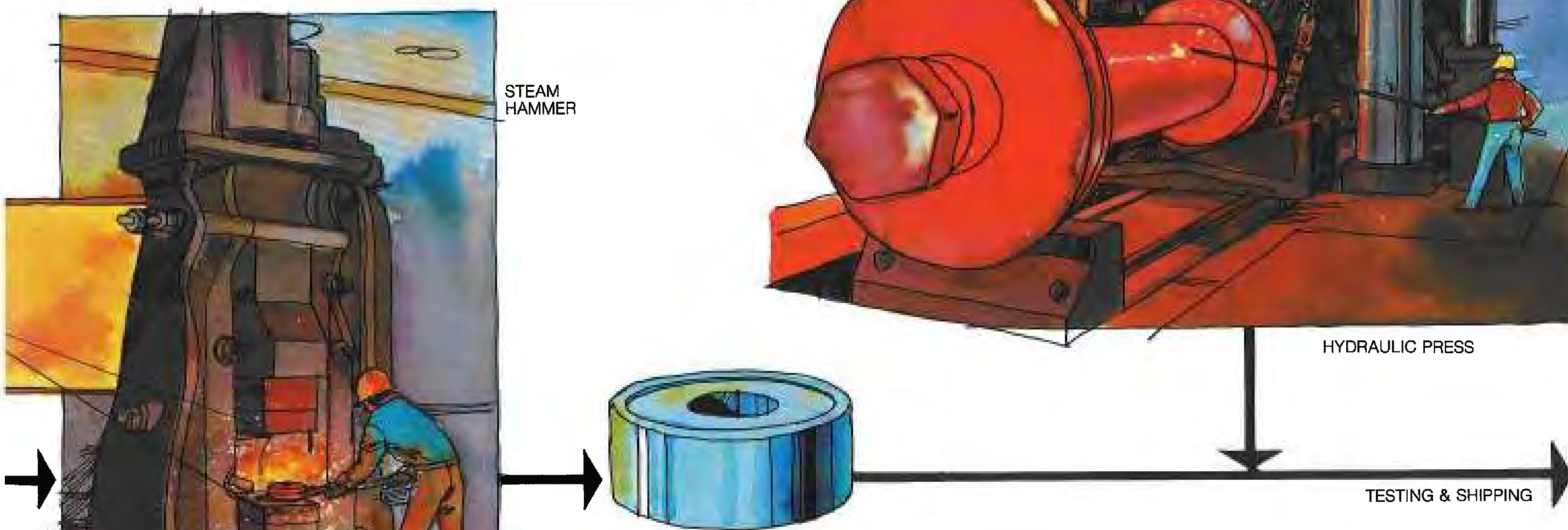


INGOT

HEATING FURNACE



HYDRAULIC PRESS



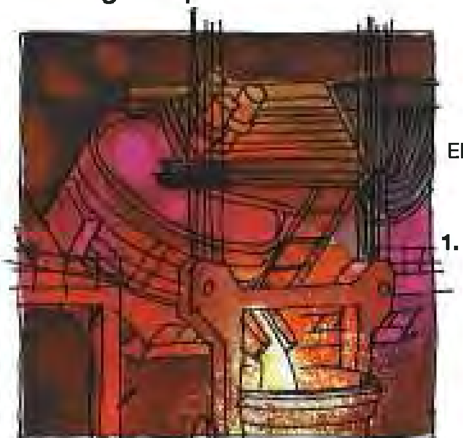
STEAM HAMMER

MACHINED PRODUCT

TESTING & SHIPPING

stainless steels

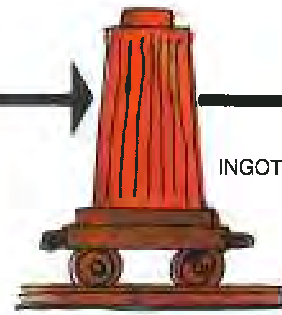
Because its resistance to corrosion is superior to that of carbon steels and other alloy steels, the family of stainless steels is important for food handling equipment, energy conversion equipment, hospital and laboratory facilities and other applications which must be cleaned with solutions. Corrosion resistance generally increases with increased chromium content. Steels containing 10 percent or more of chromium with at least 50 percent iron are designated as stainless rather than alloy steels. One of the most common grades contains 18 percent chromium. A wide range of mill products is produced from stainless steels, and many of the making, shaping and treating practices resemble those for carbon and alloy steels. This steel processing flowline emphasizes some of the procedures characteristic of stainless steel plants.

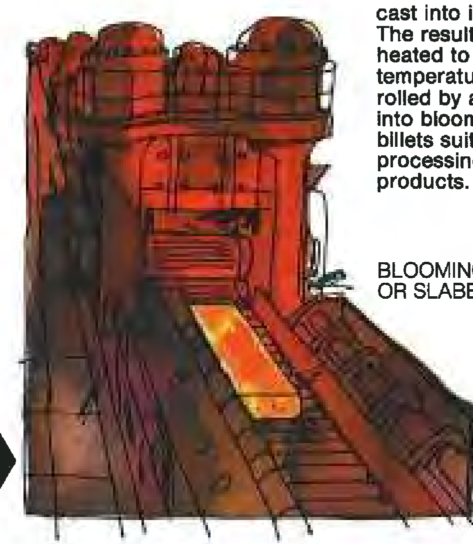


1. **Most stainless steels** are melted and refined in electric furnaces where close control of the chemical analysis is maintained. The major raw materials charged into the furnace are carefully selected scrap, fluorspar and lime or limestone. Alloy additions are made as required.

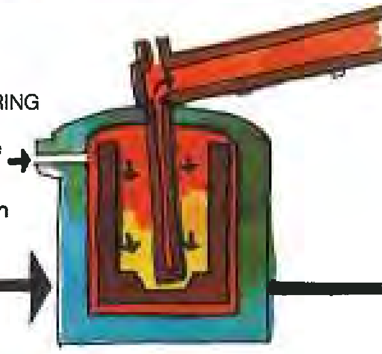
2. **Stainless steels** are often further refined by an argon-oxygen decarburization process. In the process, the molten, unrefined steel is transferred from the electric furnace into a separate vessel. Oxygen, gradually replaced by argon, is blown through the molten steel eliminating impurities.

3. **An alternate way** of pumping gaseous impurities from molten metal contained in a stainless ladle-furnace is to use vacuum oxygen decarburization. The metal is heated and stirred by an induced electrical current. Oxygen is introduced through a water-cooled lance and solid additions are made through a hopper.

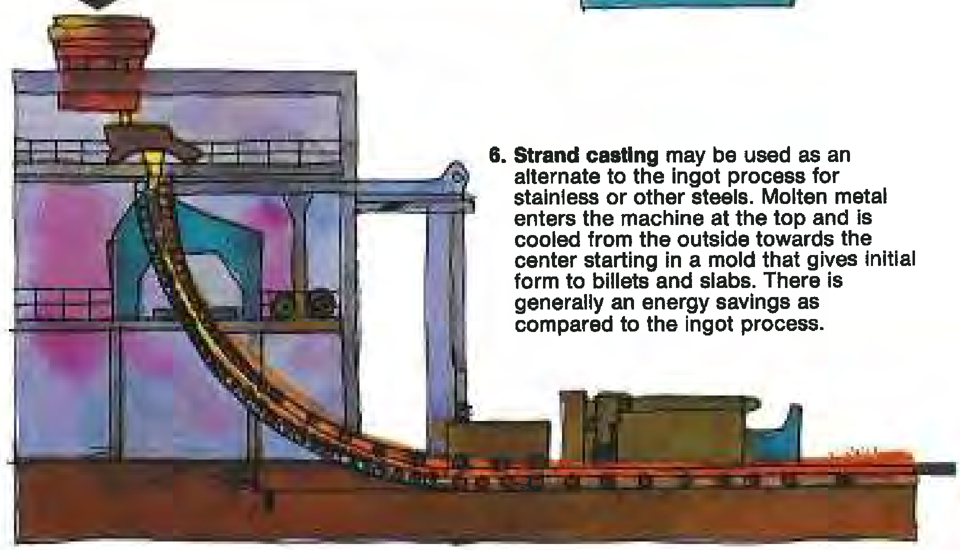




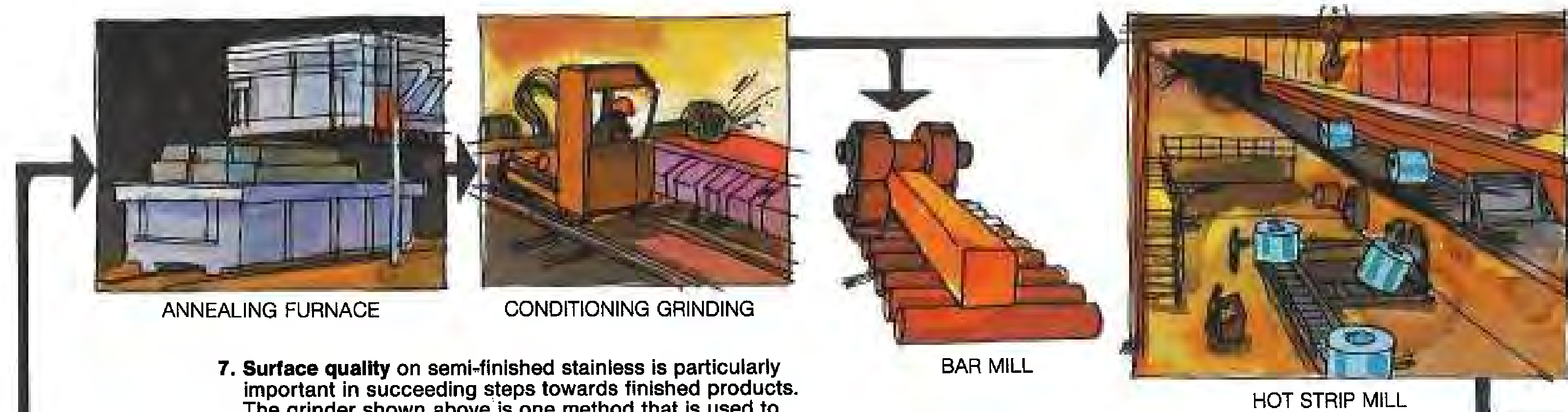
4. **Most stainless steel** is cast into ingot molds. The resulting ingots are heated to a uniform temperature and then rolled by a roughing mill into blooms, slabs or billets suitable for further processing into finished products.



5. **Another way to produce slabs** is by pressure pouring, which is a process that utilizes air pressure to force molten steel up a tube into a smooth, carbon-lined mold that is filled with an inert gas. The result is a smooth slab of improved surface quality.

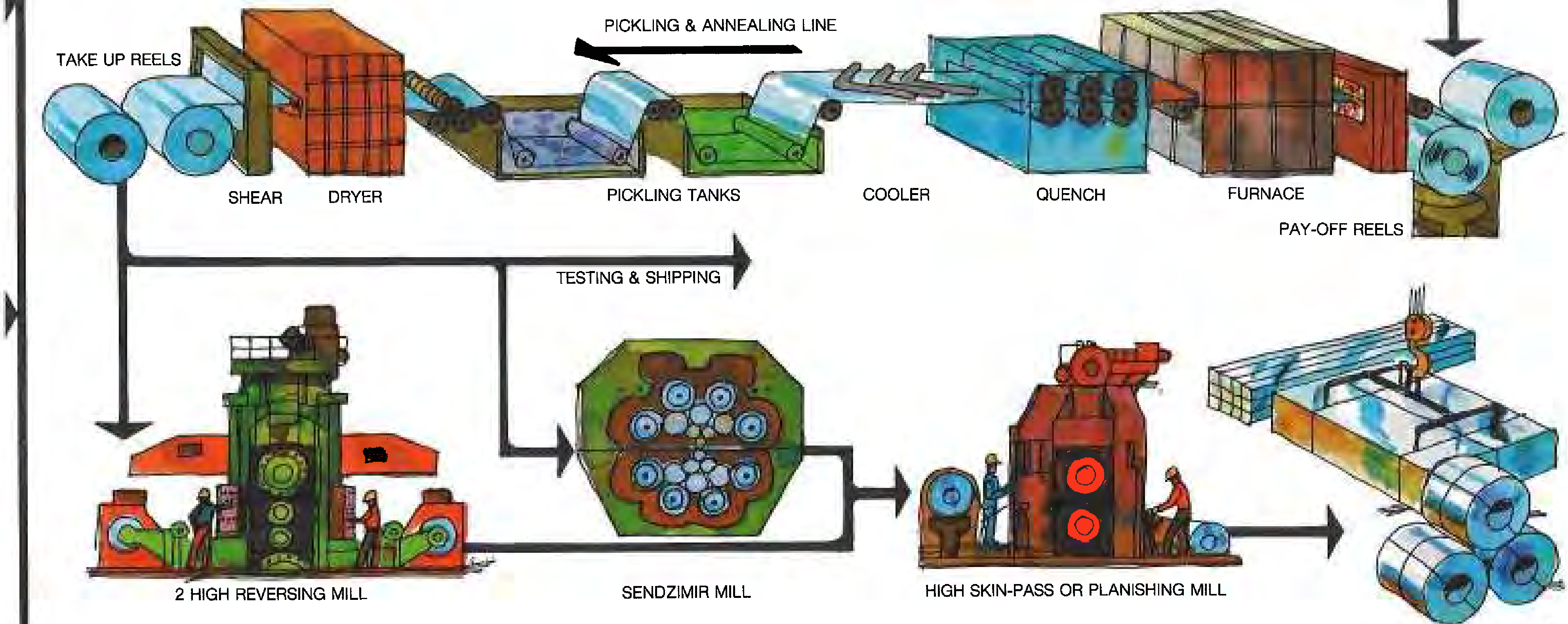


6. **Strand casting** may be used as an alternate to the ingot process for stainless or other steels. Molten metal enters the machine at the top and is cooled from the outside towards the center starting in a mold that gives initial form to billets and slabs. There is generally an energy savings as compared to the ingot process.



7. Surface quality on semi-finished stainless is particularly important in succeeding steps towards finished products. The grinder shown above is one method that is used to remove imperfections before they can be rolled into the steel. Conditioning is done after annealing.

8. About 60 percent of all stainless is shipped in the form of hot- and cold-rolled sheet and strip. Many stainless steels require greater roll-pressure to roll than most carbon and alloy steels, and their cross sections are reduced more gradually, than most other steels.
Great care is taken to preserve a good surface during the heating, cleaning and rolling processes so the final surface will have good stainless quality.



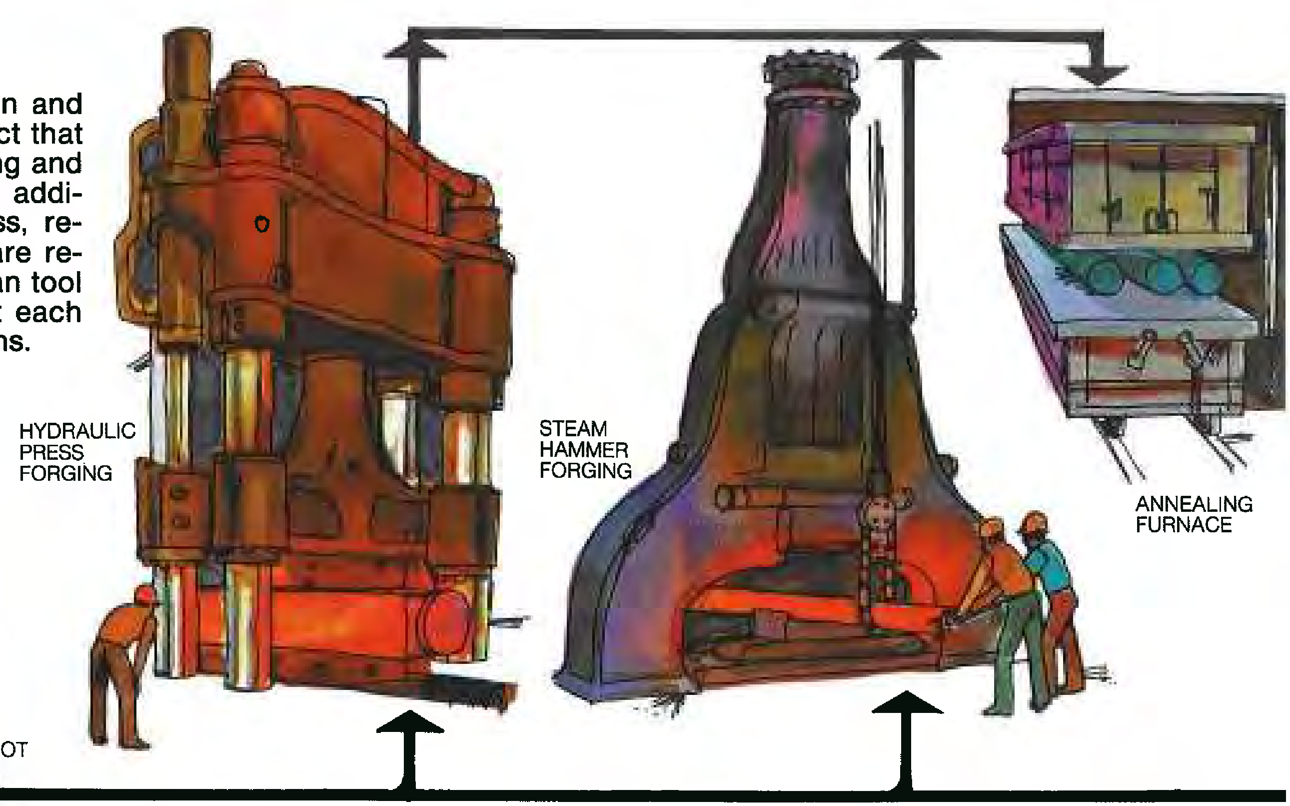
9. Cold-rolled stainless strip is made from the hot-rolled and pickled product, generally on a four-high reversing mill. The coils unwind from one reel and are moved through the work rolls which reduce the thickness and increase the length of the sheet before it is recoiled. Then the process is reversed until the required thickness and/or strength is achieved.

10. Another way to cold-reduce stainless steel is with a Sendzimir mill. Here small work rolls, heavily reinforced by clusters of back-up rolls, enable the Sendzimir mill to control gage better than another type of mill at less capital equipment cost and to roll thinner strips.

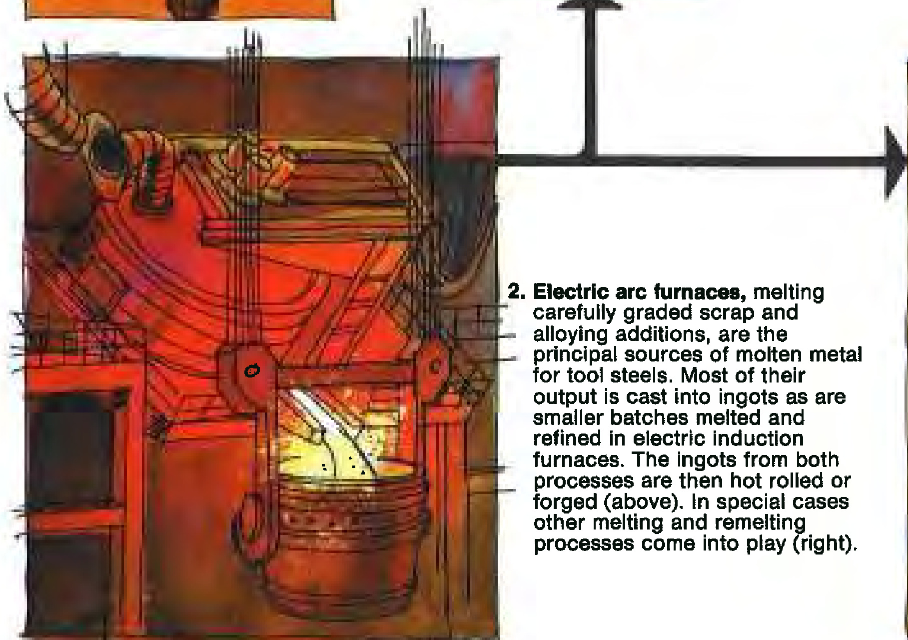
11. Cold-rolled stainless steel sheets are produced in several kinds of finishes. A "skin-pass" between highly polished rolls produces one of the more frequently used rolled surfaces. Such surfaces are often polished with fine abrasives and buffers to make extremely fine or decorative surfaces.

tool steels

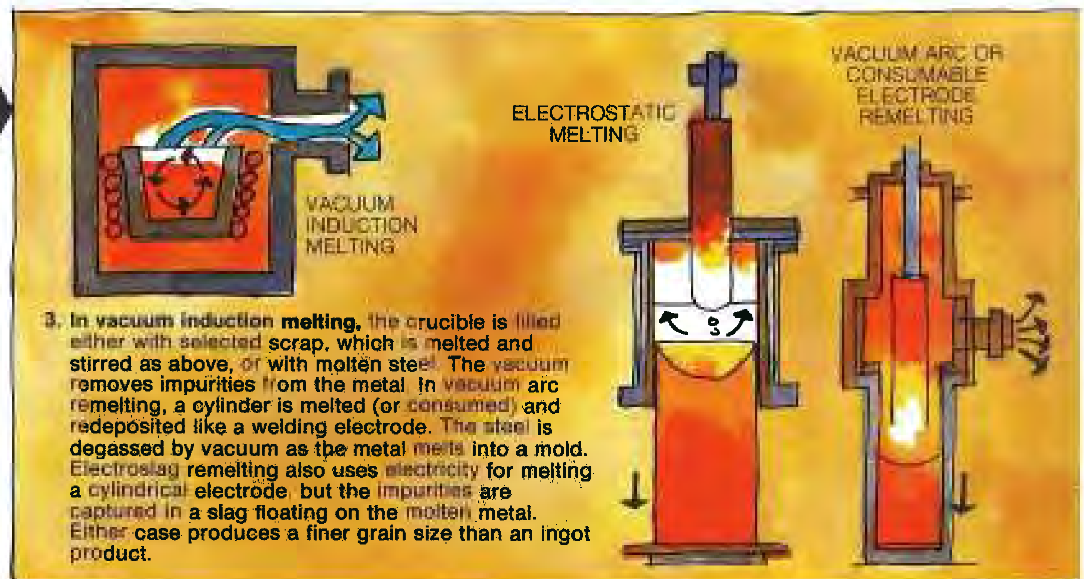
Tool steels are highly sophisticated high carbon and alloy materials which get their name from the fact that they are used mostly for cutting, shaping, forming and blanking steels and other materials. They have additional applications in which strength, toughness, resistance to wear and other special properties are required. An outstanding characteristic of American tool steel manufacture is the extreme care taken at each step to meet very high metallurgical specifications.



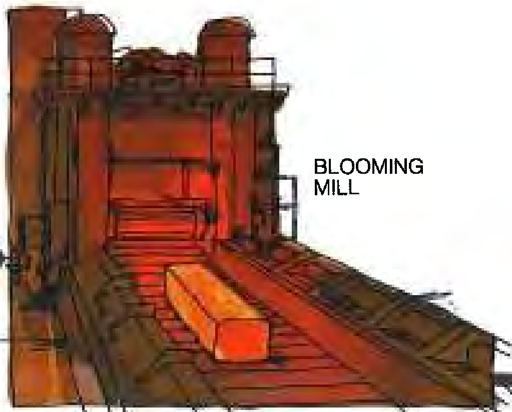
1. **Tool steel ingots** are cast from electric arc furnace or induction furnace steel. Hot ingots are rough rolled or forged to shape the metal and improve its properties. The care used to obtain high surface quality and uniformly sound steel cannot be shown in detail in this simplified flowchart, but it is a vital part of the process.



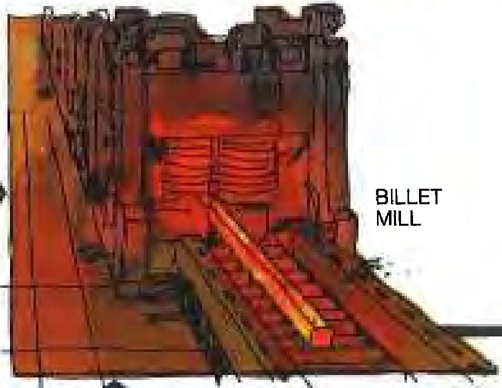
2. **Electric arc furnaces,** melting carefully graded scrap and alloying additions, are the principal sources of molten metal for tool steels. Most of their output is cast into ingots as are smaller batches melted and refined in electric induction furnaces. The ingots from both processes are then hot rolled or forged (above). In special cases other melting and remelting processes come into play (right).



3. **In vacuum induction melting,** the crucible is filled either with selected scrap, which is melted and stirred as above, or with molten steel. The vacuum removes impurities from the metal. In vacuum arc remelting, a cylinder is melted (or consumed) and redeposited like a welding electrode. The steel is degassed by vacuum as the metal melts into a mold. Electroslag remelting also uses electricity for melting a cylindrical electrode, but the impurities are captured in a slag floating on the molten metal. Either case produces a finer grain size than an ingot product.



BLOOMING MILL

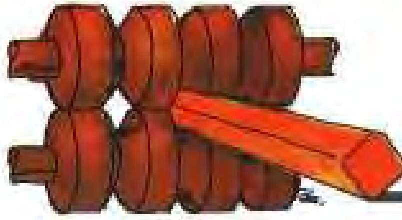


BILLET MILL

HEATING

4. Solid steel from the remelting processes is reheated and then formed like the ingots of electric furnace steel. Surface chemistry and temperature control are important factors in tool steel product manufacture.

HOT-ROLLED BARS



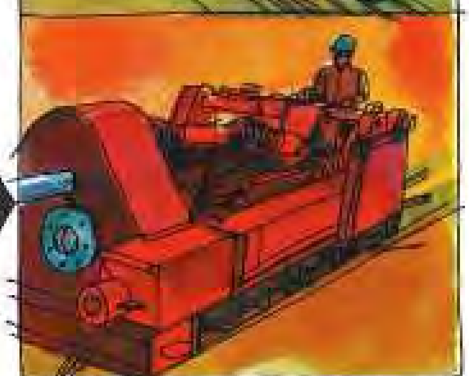
CONDITIONING GRINDER

5. Surface conditioning of semi-finished tool steel is careful and time-consuming work. About 80 percent of tool steel products leave the mills as bars and rods, mostly in the hot rolled form. A tool steel bar mill reduces the cross section of billets gradually. Temperature of the steel is controlled at certain levels to bring out various properties in the steel. Plates, sheets, strip, wire and forgings are also shipped by tool steel manufacturers. Further finishing of some mill products is often required and four major methods are sketched at right. Numerous machining and heat treating operations may be used by fabricators of finished products.

6. Centerless grinding removes the entire surface of round sections of tool steels such as drill rods. This process produces an accurate finish.

7. Machining or planing flat surfaces provides a high quality surface.

8. Cold finishing bars are hot rolled and annealed bars that are drawn through dies that are smaller in diameter than the rolled cross section, thus stretching the steel throughout and providing a smooth surface.

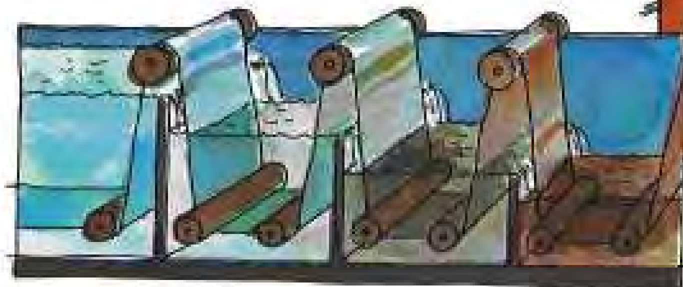


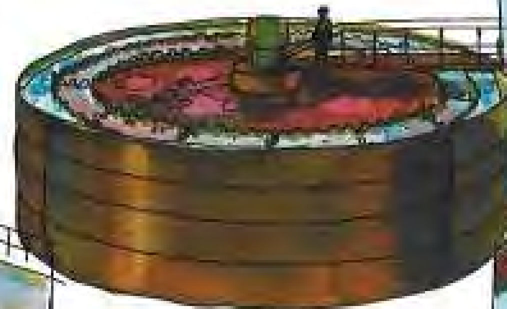
9. Straightening involves a machine with specially positioned rolls to remove possible bends in certain products — principally bars.

TESTING & SHIPPING

environmental systems

Environmental control systems within the steel industry involve a variety of operations from cleaning water to covering conveyor belts. Illustrated here are some of the major processes used to clean air and water in the steelmaking process.





Clarifiers are round basin devices used for a two-step water cleaning system. In the first step, chemicals are added to waste water causing particulate matter to cluster into heavy particles. During the second step, these heavy particles settle and are removed from the bottom; clear water overflows. Remaining oils are skimmed from the top of the clarifying basin.

Oil skimmers recover oils which float to the surface of waste water streams.

Scale pits are settling basins are used to remove solid materials and oil from the water used on rolling mills. These solids are mostly mill scale, the flakes and particles of iron oxide that form on steel during heating. The solids settle to the bottom of the basin, from which they can be dredged for recycling. Oil rising to the surface of the basin can be skimmed off and reprocessed.

Cascade rinse involves water usage in rinsing operations. The amount of water needed is minimized by re-using rinse water from each stage in the next. This reduces the effluents and reduces the purification required.

Bag houses are devices which function on the same principle as a vacuum cleaner. Exhaust air is pulled through large cloth or fiberglass bags. There may be over 5,000 bags in one facility. By reversing the air flow, the bags are emptied and the dust collected for disposal.

testing & research

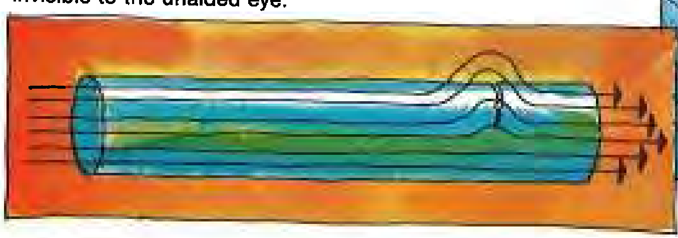
Many types of testing including those shown here are used by the steel industry to improve product quality and uniformity. Brief descriptions of each type of testing shown are provided although the technology involved is very complex.

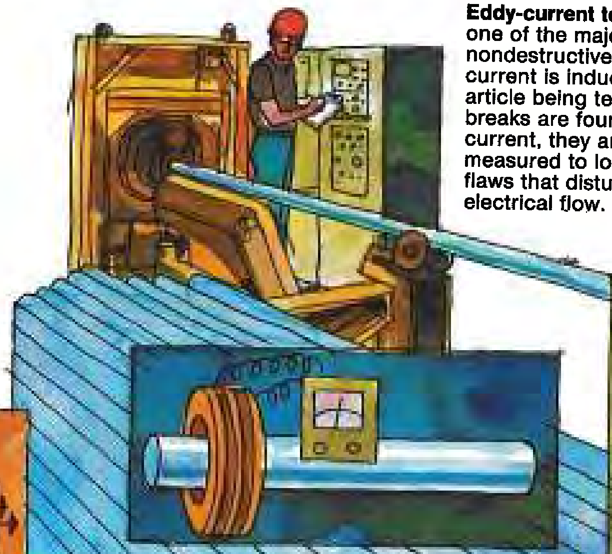
Eddy-current testing is one of the major nondestructive tests. A current is induced in the article being tested. If breaks are found in that current, they are measured to locate the flaws that disturbed the electrical flow.

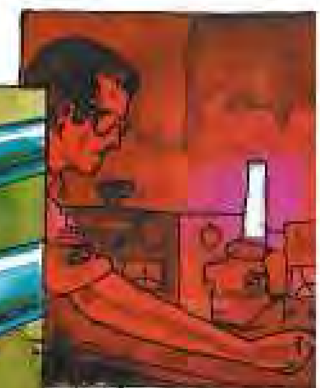
Hydrostatic testing involves water pressure. Pipe ends are sealed and high-pressure water is pumped in at specific pressure. A significant drop in the measured test pressure can indicate leaks.

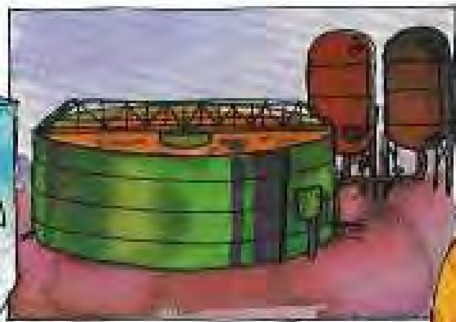
Atomic absorption analysis is a method used to analyze very small quantities of various elements in steel. The dissolved sample is put in a high temperature flame and subjected to excited atoms of the element to be measured. The percentage of this element is then calculated from the drop in intensity of the excited atoms.

Magnetic particle testing works by means of the properties of magnetism. Finely divided magnetic particles concentrate at surface cracks when a magnetic field is induced in steel products. The cracks which, in effect, form new magnetic poles, would otherwise be invisible to the unaided eye.









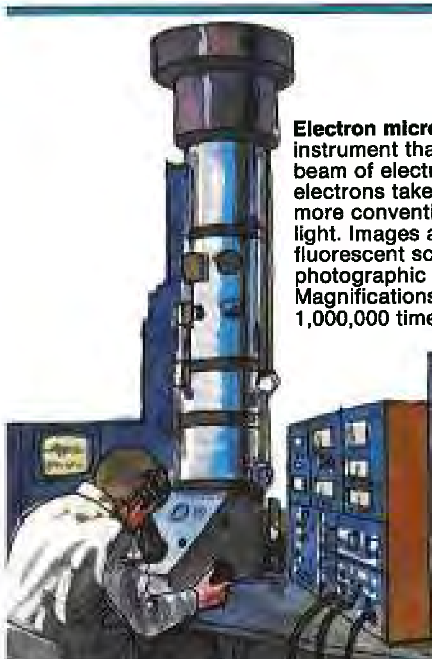
Acid neutralizers are used in the chemical treatment of water to eliminate acidity and remove iron compounds from solution.

Electrostatic precipitators are air cleaning devices in which dust-laden exhausts are passed through chambers equipped with high-voltage wires strung equidistant between parallel plates. The electrical discharge from the wires produces an electrical field that puts a charge on the dust particles and causes them to be attracted to grounded plates where they adhere. The plates are struck with rappers and the dust falls into bins for disposal.

Fume removal involves systems of ducts, hoods and fans to capture fumes generated in various operations.

Cooling towers are huge facilities which reduce the temperature of water by contacting it with the air.

Deep bed filters remove particulate material and oil from water by passing it through a bed of sand or similar finely divided material.

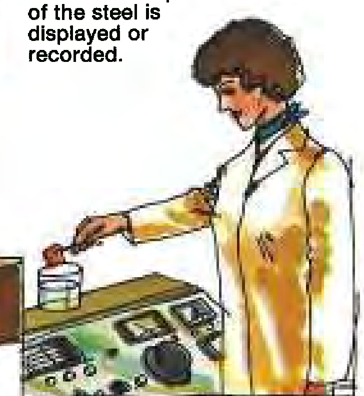


Electron microscope is an instrument that focuses a beam of electrons. These electrons take the place of the more conventional beam of light. Images are formed on a fluorescent screen or on a photographic plate. Magnifications of up to 1,000,000 times are possible.

X-ray gage testing is used for measuring thickness of steel products as well as the thickness of different types of metallic coatings applied to the steel. Basically x-ray or beta-rays of a calibrated intensity are directed at the steel. The intensity of the rays passing through the steel is measured. The amount of rays absorbed by the steel is proportional to the thickness of the steel.

Ultrasonic testing searches for internal imperfections by sending high-frequency sound waves through the steel. Imperfections reflect the sound waves and this is measured by an oscilloscope.

Spectographic analysis is commonly used by the steel industry for rapid chemical analysis of numerous elements. It is based on the fact that each element, when burned in an arc, emits radiation of characteristic wave lengths. The intensity of this radiation is measured electronically and the chemical composition of the steel is displayed or recorded.



steel processing glossary

Acid neutralization — Chemical treatment of water to eliminate acidity.

Annealing — The process of heating steel and then cooling it slowly to induce softness.

Baghouse — An air pollution control device used to trap particles by filtering gas streams through large cloth or fiberglass bags.

Basic oxygen furnace (BOF) — The chief method of producing steel. The furnace is charged with molten iron from a blast furnace and steel scrap. Oxygen is blown into the furnace at high velocity to speed combustion and refine the iron and scrap.

Billet — Semi-finished product that has been rolled or forged from an ingot or strand cast. Usually has a square cross section less than 36 square inches.

Black plate — Steel plate of 12 to 32 inches wide produced in a tin mill by cold reduction, prior to any cleaning operation.

Blast furnace — The furnace used to produce iron. A blast of hot air is blown through the charge of iron ore, coke and limestone. The coke burns, emitting gases that reduce the ore to metallic iron. The limestone combines with impurities and forms slag.

Bloom — Semi-finished product that has been rolled or forged from an ingot or strand cast. Usually has a square cross section exceeding 36 square inches.

Clarifier — A settling tank where solids are mechanically removed from waste water.

Cold drawing — Process of reducing the cross-sectional diameter of tubes or wire by drawing them through dies without previously heating the material.

Cupping — Process of forming tubular or closed cylindrical products from a flat plate. The plate is heated prior to forming.

Electric arc furnace — A method of producing steel to exacting specifications. The furnace is charged with selected steel scrap, limestone and other additives. Heat supplied by an electric arc melts and refines the charge.

Hot extrusion — The forming of material of continuous cross section by forcing it through a die in a press.

Ingot — Metal cast into a mold. It has to be rolled or forged to be usable. Can weigh as much as 30 tons.

Mandrel — Shaft on which work already bored is mounted for turning, milling, etc. Also a rod used to retain the cavity in hollow metal products during their processing.

O-ing press — A press that takes a plate that has been shaped by the U-ing press, and, using much greater force, completes the bending to cylindrical form.

Pickling — Process of chemically removing scale or oxide from metal objects to obtain a clean surface.

Planishing — Production of a superior finish on a previously rolled or forged product, accomplished by passing the bar or other product through chill cast or hardened steel rolls or by hammering with a smooth-faced hammer.

Reversing mill — Rolling mill designed so the direction the rolls are turning can be reversed following each pass of material. This rotation can be repeated until the desired reduction is attained.

Roughing stand — Mill used for preliminary rolling.

Sendzimir mill — Named after its inventor, Thaddous Sendzimir. It is a cold reduction mill.

Skelp — Steel sheet or plate from which welded tubing or pipe is made.

Slab — A rectangular semi-finished product hot-rolled down from an ingot or strand cast.

Tube reducer — Machine that uses a pair of rolls for cold rolling tubing and rod.

U-ing press — Press where a U-shaped die forces the steel down between rocker rolls.

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