CONVERSION SERVICES AND FACILITIES

facts book

In addition to knowing what products we make and how they perform, you should know something about HOW we make them. This is important for two reasons:

1. Upon occasion, a customer may wish to know some detail of how we propose to produce the material he wants (e.g., the fact that we intend to use a Sendzimir mill may be of interest to him), or he may wish to know what alternate technique is available (e.g., he might want to know what atmospheres are available for heat treating). Note: In some cases processing information may be proprietary so be careful to check with the plant before divulging information that could be confidential to our process.

2. We actively solicit conversion business . . . where we take starting material (arc melting electrodes) or a semi-finished form (ingots or billets) as furnished by the customer and convert it to the desired final form (forgings, sheet, strip, foil, bar, wire, etc.).

This Section of the Metals Course is devoted to the PRODUCTION FACILITIES used at the Metals Plant and the CONVERSION SERVICES available to our customers. We are engaged in four basic types of products.

1. alloy/mill products (also commonly called "wrought" products)
2. investment cast products
3. shell molded products
4. compacted and sintered products

Each type shall be discussed separately on the following pages.

ALLOY/MILL PRODUCTS

Our largest activity is in the primary production of alloy mill products using wrought practices. Here, we start with the raw material and end up with an alloy product in some final mill shape ready for the customer to use in his manufacturing activity. Let's start with a look at the over-all process and then discuss each step individually.

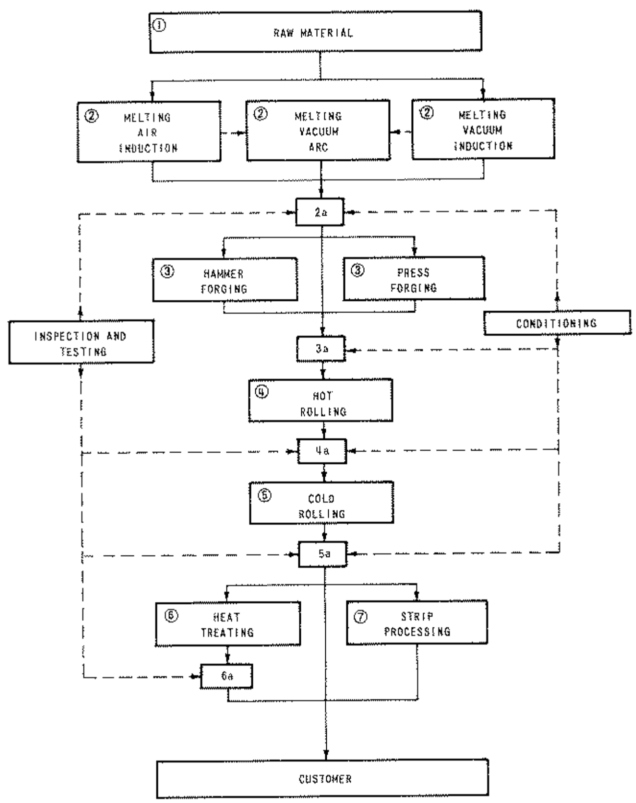

Figure H-1. Over-all Flow Diagram of Primary Wrought Production Processes Performed at the Metals Plant.

The flow diagram shown in Figure H-1 is only typical. There are many practical combinations of the various operations and thus it would be impossible to show them all. However, the flow pattern shown here is fairly typical and will suffice for the purpose of providing a general picture of the integration of the various operations.

A typical sequence of wrought manufacturing operations is as follows:

1. All the required raw materials are assembled and carefully weighed to make-up a furnace load (the CHARGE).

2. The CHARGE is placed in a furnace where it is melted into a specific composition (the MELT or the HEAT). The resultant molten metal is cast into and allowed to cool in one of a number of molds (INGOT MOLDS). The final mass of solid metal (INGOT) is then removed from the mold (STRIPPED) for further processing.

2a. At this point the composition of the final ingot may be tested (ANALYZED) and surface defects removed by various CONDITIONING techniques.

3. Because of its as-cast structure the ingot cannot be used as a structural material. In order to refine that structure it is reheated and worked to a smaller size (BILLET or SLAB) in a forging hammer or a forging press. (Special materials are sometimes extruded to final or intermediate shape). In some cases, this forging operation is used to form the material into a more complex shape that is shipped direct to the customer.

3a. Further conditioning can be performed here.

4. If the billet or slab is to be converted to strip, sheet, or bar, it is again heated and fed through a HOT (bar or strip) ROLLING MILL where it is reduced to a smaller diameter or thickness. In some cases, this is the product shipped to the customer. (Hot rolled bar or hot rolled strip).

5. The last forming operation in the manufacture of wrought product is done in a COLD ROLLING MILL where the material is reduced to its final thickness or shape.

6. HEAT TREATING, to make the material harder, stronger, more ductile, etc., may be performed several times during processing and after the processing is completed.

7. Final STRIP PROCESSING consists of such operations as leveling, slitting, deburring and cleaning where the surface of the material is prepared for the next operation or the customer.

Now, with this over-all flow pattern in mind, let's examine each step in greater detail. Keep in mind that the sequence of steps is not always the same . . . they are varied to suit the particular end product desired.

Raw Material

Most of the raw materials used by the Metals Plant are in the form of high purity elements or ferroalloys. Our basic raw material for most alloys is low carbon high purity Armco Iron.

Typical other raw materials that we purchase include:

Nickel (electrolytic grade -- 99.9% pure)

Cobalt (electrolytic grade -- 99.9% pure)

Ferrochrome (low carbon grade -- 70% chromium)

Manganese (electrolytic grade -- 99.9% pure)

One of the major raw materials we use is SCRAP. No, not junkyard scrap . . . rather, high-grade material that we have salvaged from our own operations, (edge trimmings, quantity overages, discards, etc.). This is an obvious economy that is practiced by all metals producers. However, to maintain the necessary high-quality standards, we practice a strict scrap control program . . . all scrap is carefully marked and segregated for reuse. When scrap is going to be used in a melt, the laboratory analysis of the melt from which the scrap originated is used in calculating its contribution to the new melt.

In most cases, the raw material for a melt is not all scrap. The balance of material required to meet the composition requirements of the new melt is made up of the selected elemental materials and/or ferroalloys mentioned above. In some cases, no scrap is used . . . the entire CHARGE (the composite of all materials used to make any given melt or heat composition) is made up of purchased elemental materials and ferroalloys.

Although most of the raw materials are placed in the furnace at the start, small quantities of minor alloying elements are held out and added during the progress of the melt. These additives can be adjusted in quantity up to the last minute to meet the particular composition that is desired.

Air Induction Melting

This is one of the primary melting techniques utilized by the Metals Plant and is based on the induction principal where an induction coil is used to convert electrical energy into heat energy.

The charge is held in a large ceramic CRUCIBLE (melting pot) which is located inside a helically-wound coil of hollow copper tubing. When a very high a-c current (in the range of 10,000-20,000 amperes) is fed to the coil, the resultant alternating magnetic field intersects the metal charge causing an electrical potential to be established in the charge which produces heat due to the I^2R losses. The heat thus produced is sufficiently high to melt the materials in the crucible.

Naturally, the copper coil heats up also. Therefore, to keep it from melting, water is continuously circulated through the hollow copper tubing. Electric power is provided by a motor-generator set which is connected to the coil by bus duct and pressure-type contacts.

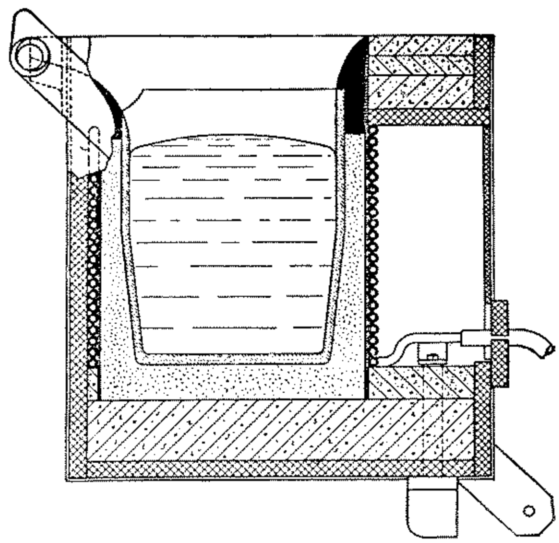

Figure H-2. Schematic Cross-sections of Typical Inducting Melting Furnace.

The sequence of steps for induction melting are:

1. Selected scrap and/or raw materials are charged into the crucible.
2. Power is applied causing the charge to melt.
3. Alloying materials are added to adjust the composition as needed.
4. The finished heat is poured.

Although it is a separate operation, the pouring and casting of the molten product is an integral part of the melting operation. To attain maximum cleanliness, the molten metal is first poured from the induction furnace into a refractory lined LADLE (transfer vessel). (See Fig. H-3)

The molten metal is held in the ladle for several minutes allowing any non-metallic impurities to rise to the top. It is then TEEMED (drained) through a small hole in the bottom of the ladle into ingot molds

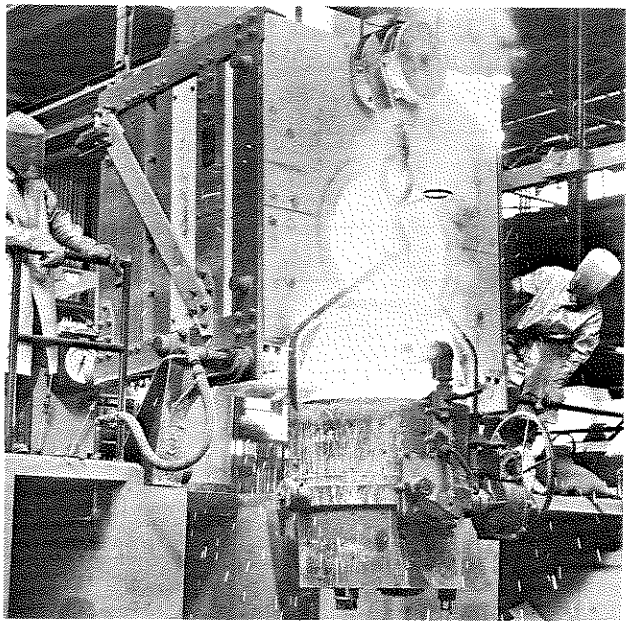

Figure H-3. An Induction Furnace Heat Being Poured into a Ladle.

(see Figure H-4) where it is allowed to solidify and cool.

The ingot molds are made from cast steel with tapered sides so that the ingot can be stripped from the mold after it has solidified.

Figure H-4. Molten Metal Being Teemed from Ladle into an Ingot Mold.

Ingot molds are of many types, shapes and sizes . . . the particular size and shape used for any given heat is generally dependent upon the final application of the ingot:

slab-shaped ingots are used for the production of sheet and strip

square-shaped ingots are used for rods and bars

round-shaped ingots are used as electrodes in the vacuum-arc melting process

THE METALS PLANT HAS INTEGRATED AIR INDUCTION MELTING FACILITIES CAPABLE OF CASTING INGOTS RANGING IN SIZE FROM 1000 TO 10,000 POUNDS.

Vacuum Induction Melting

This technique utilizes the same equipment and methods just discussed for air induction melting with the added feature of performing the total operation under vacuum. To accomplish this, the entire furnace mechanism and ingot molds are located in a large vacuum-tight enclosure that is fitted with the pumps and other accessories necessary to develop and hold a high vacuum (see Figure H-5).

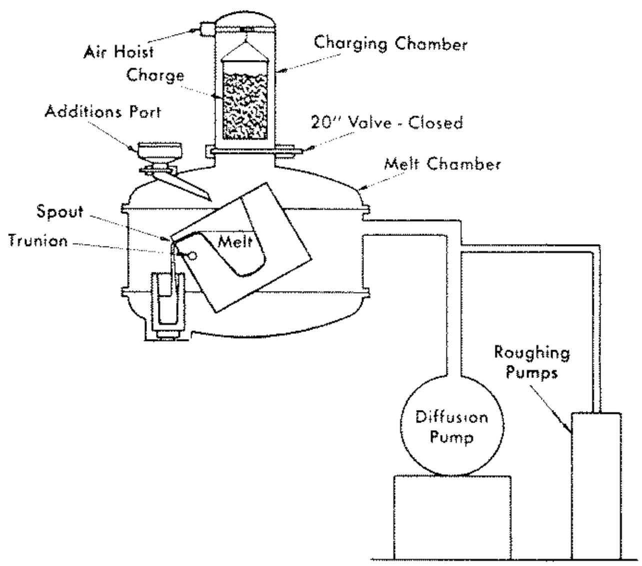

Figure H-5. Basic Components of a Vacuum Induction Melting Furnace.

The primary advantage of VACUUM INDUCTION MELTING over regular AIR INDUCTION MELTING is the purifying effect of the vacuum. Melting in a vacuum causes the non-metallic impurities to be volitalized and drawn off through the pumping system. The result is a cleaner melt and improved properties in the final product. Because of the extra equipment and longer melt times involved, vacuum induction melted material usually carries a price premium over that of air induction melted material.

THE METALS PLANT FACILITIES FOR VACUUM INDUCTION MELTING CONSISTS OF ONE UNIT WITH A PRACTICAL CAPACITY OF 300 POUNDS PER HEAT.

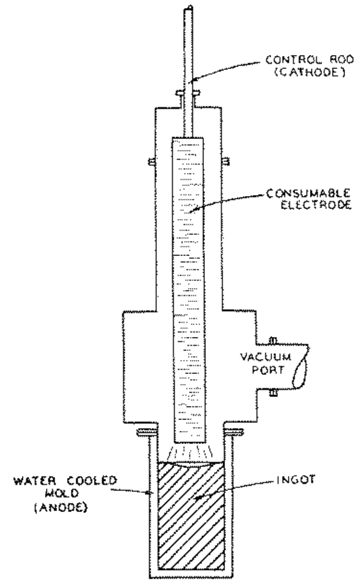

Figure H-6. Schematic Sketch of a Vacuum Arc Melting Furnace.

Vacuum Arc Melting

In general practice, this process requires some preliminary preparations of the raw material so that it is delivered to the furnace in a long, cylindrical form (referred to as an ELECTRODE). This electrode may be the product of another melting process, it may be produced via the pressed powder-sintering process, or it may be built-up by welding chunks of metal together into an electrode form.

The furnace itself consists of:

1. a large, water cooled copper mold
2. a means of supporting the raw material electrode and gradually feeding it into the copper mold
3. a vacuum tight enclosure to contain the above apparatus
4. the necessary equipment to develop a high vacuum within the enclosure
5. a source of high-ampere current

This melting process is somewhat similar to the conventional arc welding process in that an arc is struck and molten metal drips off the end of the electrode. In preparing for a melt, the electrode is attached to its lowering mechanism and hangs down inside the water-cooled copper mold. A starting pad of the same composition as the electrode material is placed in the bottom of the copper mold. The furnace enclosure is brought to a state of high vacuum and then a high ampere current is fed to the electrode. The electrode is lowered into the copper mold until it comes close enough to the pad to permit the striking of an arc between the two. The resultant arc melts the end of the electrode and the molten metal is deposited in the bottom of the copper mold. As the electrode is consumed, the automatic feeding equipment keeps the working end of the electrode the proper distance from the surface of the molten metal to sustain the arc continuously. After the melting has been completed, the molten metal is allowed to cool and solidify after which the ingot is stripped from the mold.

The basic function of the vacuum arc melting process is to remelt the base electrode under vacuum conditions that refine the material by gasifying impurities and cast it into a homogeneous ingot. One of its special advantages is that by careful control it can eliminate the loss caused by uncontrolled solidification shrinkage in air melted ingots. This increased yield of saleable material helps to offset the additional cost of vacuum melting.

THE METALS PLANT HAS FOUR VACUUM ARC FURNACES . . . MAXIMUM FINISHED INGOT SIZE IS 20-INCH DIAMETER -- 90 INCH LENGTH -- 8000 POUNDS. SMALLER INGOTS CAN BE MADE IN A RANGE OF SIZES STARTING AT 4" DIAMETER.

Forging

The as-cast ingots produced by the melting furnaces have a very coarse grain structure and thus in this form the metal has poor strength and ductility characteristics. It is necessary that the as-cast structure be hot worked to refine it (thus improving physical properties) and to get it into a shape for further processing. The structural refinement is achieved by a combination of hot forging and hot rolling operations.

In HAMMER FORGING, the hot ingot is subjected to a series of staccato-type blows that reduce its cross-section while refining the structure (see Figure H-7).

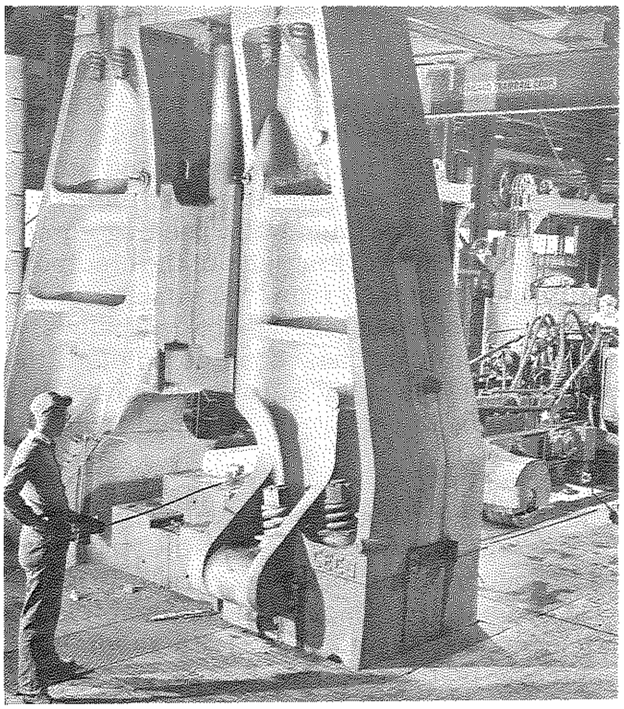

Figure H-7. A 16,000 Pound Forging Hammer at the Metals Plant.

A FORGING PRESS subjects the metal to a squeezing-type action where the force is applied slowly and held for a short time. Here, the force penetration is deep, providing a working of the grain structure all the way to the center of the piece. In general, a forging press is used to work the larger size ingots (see Figure H-8).

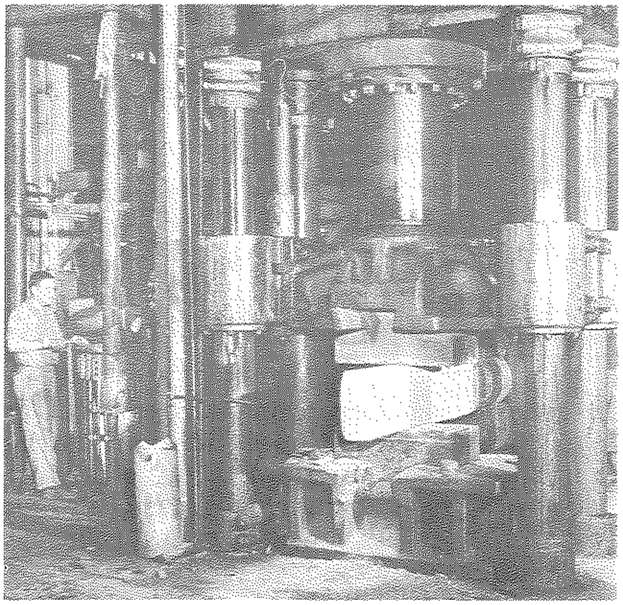

Figure H-8. A Typical Forging Press.

Ingot forging operations are generally performed while the piece is at a high temperature. In most cases, the total forging cannot be completed before the piece cools to a point below its working temperature range. Thus, a series of heating and forging cycles are often required.

The handling of large, heavy ingots in and out of the furnace and during the actual forging operation is no small task. The answer is a large four-wheeled vehicle called a MANIPULATOR. This machine is about the size of a small army tank and is fitted with a mammoth pair of tongs that extend out the front in a general horizontal position. An operator sits on top of the manipulator at a control console that is equipped with a maze of hydraulic operating levers. As its name indicates, this machine is capable of "manipulating" the ingot through all the various forging operations (see Figure H-9).

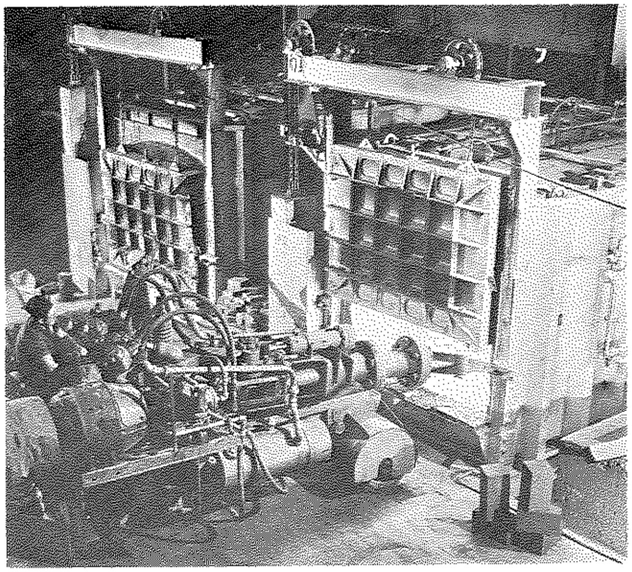

Figure H-9. Ingot Being Removed from Heating Furnace by a Manipulator. (This Machine has a Capacity of 6000 Lbs.)

It is generally desirable to remove any surface defects (scale, cracks, holes, imbedded foreign particles) from the piece following the forging operation. If so, this surface CONDITIONING is performed after the piece has been worked and before it is re-heated for the next operation. We shall discuss the details of conditioning a little later.

In many cases, the forging operation is used to produce contoured parts (e.g., turbine blades, rotor discs, etc.). Here, the forge is fitted with a set of dies whose work area is the shape of the desired part. A piece of heated metal is placed in or held between the dies which repeatedly hammer it until the piece is formed to the desired shape by the repeated blows. In some cases, only one set of dies are required . . . in other cases, a series of progressive dies are needed to gradually shape the part through a sequence of steps.

THE METALS PLANT HAS FOUR FORGE HAMMERS RATED AT 800 TO 18000 POUNDS AND ONE FORGE PRESS RATED AT 1000 TONS. IN COMBINATION WITH THE AVAILABLE MANIPULATORS THESE UNITS CAN HANDLE SINGLE INGOTS UP TO ABOUT 6000 POUNDS.

TURN TO WORKBOOK AND COMPLETE CHECK-POINT ONE

Hot Rolling

When further processing steps are required, the output of the forge is either a SLAB or a BILLET. A SLAB is always oblong in cross-section while a BILLET has a generally square cross-section.

Further working and shaping of the piece is performed by HOT ROLLING. Here, the slab or billet is again heated and then fed back and forth between a pair of large steel rolls that squeeze the piece to a smaller cross section dimension on each pass through them. As the thickness or diameter is decreased, the length increases. Sheet, strip and plate are processed on a STRIP MILL . . . bar and rod are processed on a BAR MILL.

The HOT STRIP MILL at the Metals Plant is of the single stand REVERSING type. In other words, the direction of rotation of the work rolls can be reversed so that the material can be reduced while traveling in either direction. For example, starting with a slab, the gap between the rolls is adjusted to give the desired reduction and the bottom roll rotated in a clockwise direction . . . the slab passes between the rolls from left to right. At the end of the pass, the roll setting is changed to the next setting in the pass schedule and the direction of rotation is reversed so that the bottom roll is turning counterclockwise . . . now the slab passes from right to left. The sequence is then repeated. Naturally, the actual roll settings vary with the job at hand.

As with forging, this particular type of rolling operation is performed while the material is hot. Periodic re-heating in a furnace is required for some materials while others can be finished in one heat.

The Metals Plant's hot reversing strip mill has a special feature in the form of a furnace mounted coiling mandrel located on each side of the main mill stand. As soon as

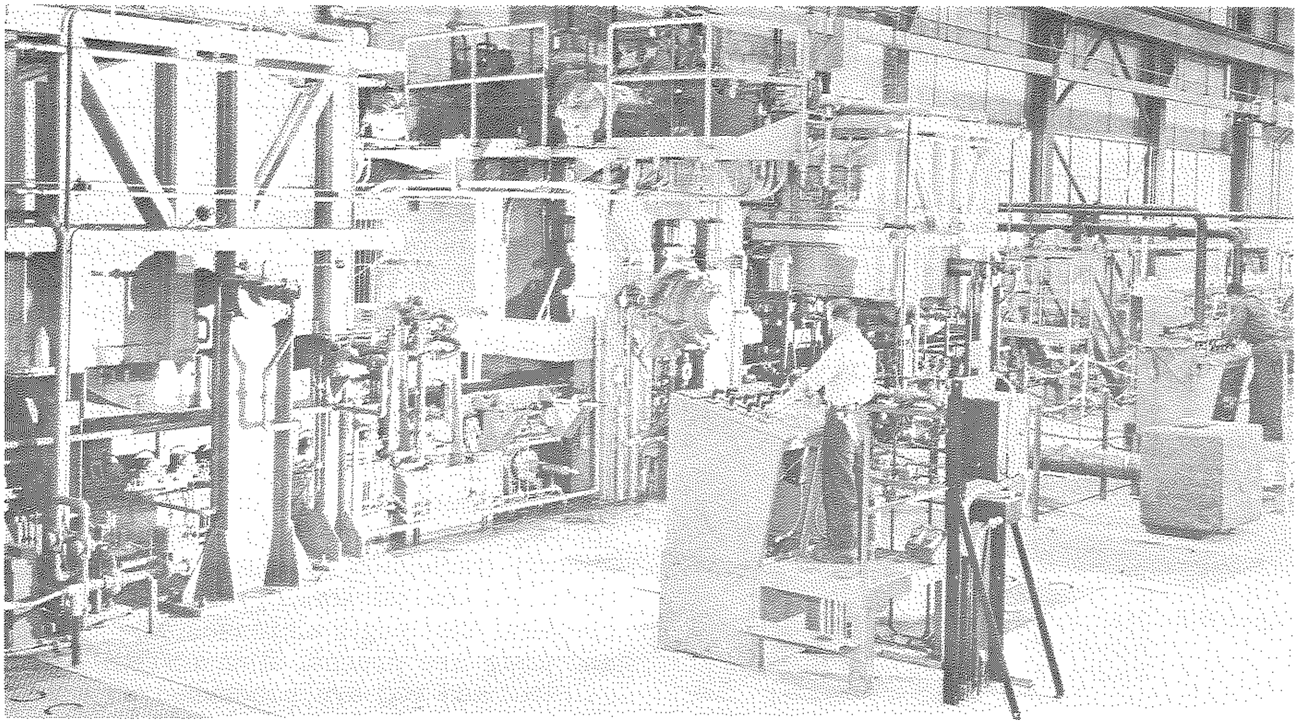

Figure H-10. Hot Reversing Strip Mill Showing Operator's Console in Foreground.

the piece gets long enough, it is coiled on one of these mandrels after each pass . . . the furnace around the coiler helps to maintain the material at a working temperature thus minimizing edge cracking and allowing more work to be done without re-heating.

THE METALS PLANT'S HOT ROLLING MILL HAS A MAXIMUM STARTING THICKNESS OF 8 INCHES AND CAN ROLL DOWN TO .090 INCHES . . . MAXIMUM FINAL WIDTH OF MATERIAL IS 20 INCHES. (NOTE THAT FINISH WIDTH VARIES WITH THE EDGE CRACKING TENDENCY OF THE MATERIAL.)

A BAR MILL is also a type of hot rolling mill. However, here the rolls are made with a series of grooves and each set of grooves is somewhat smaller than the set just preceding it. The distance between center lines of two adjacent rolls remains fixed, (see Figure H-11).

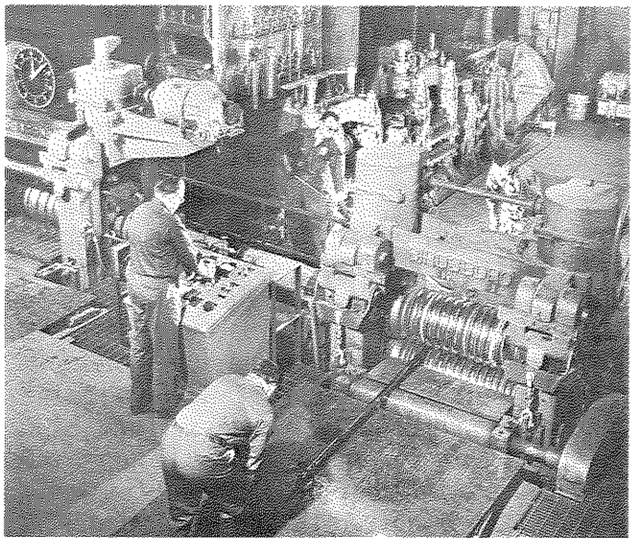

Figure H-11. A 16" Two High Bar Mill in Operation.

The original square cross-section billet is fed into the first set of grooves which squeezes the billet to a smaller cross-section. Once this pass is completed, the modified billet is moved over and passed through the second groove. This procedure is repeated until the piece has been passed through all the grooves. As many as ten different grooves can be used for this process. The actual number and shape of these grooves vary with the end product desired.

THE METALS PLANT HAS TWO BAR MILLS CAPABLE OF PRODUCING HOT MILL ROUND BARS FROM 9/16 INCH TO 3-1/2 INCHES IN DIAMETER.

All hot working operations cause an oxide scale to form on the surface of the metal being processed. This scale is undesirable and must be removed. The process used is referred to as PICKLING. In its simplest form, pickling consists of immersing the scaled product in a bath of dilute acid which is maintained at a predetermined temperature. The resultant chemical action removes the scale, leaving a clean, bright surface suitable for further processing.

Cold Rolling

Cold rolling is somewhat similar to the hot rolling process just discussed except the material is worked at or near room temperature. The cold rolling mill closely resembles the hot rolling mill except that it is much cleaner and has smaller work rolls.

The primary purposes of cold rolling are:

1. to reduce thickness
2. to produce a smooth surface
3. to develop controlled properties

The starting point is a coil of the material produced on a hot strip mill. Descaling and any other necessary conditioning operations have been performed. The coil is placed on an uncoiling device at one end of the mill, the lead end is fed through the main rolls and onto a coiling device at the other end of the mill. Both single-direction and reversing mills are used for this process.

Due to the fact that the material is worked in the cold state, it becomes considerably harder and less ductile than when going through the hot rolling mill. Thus roll pressures must be much greater. However, it has been found that the smaller the roll diameter the less the pressure required to produce a given reduction in thickness of the material. This combination of small diameter and very high pressure can raise the problem of the roll bending in the middle if pressure is applied only at the roll ends. To compensate for this, some cold rolling mills use an extra set of rolls to back up the contact rolls. This type of mill is referred to as a 4-HIGH MILL . . . (see Figure H-12).

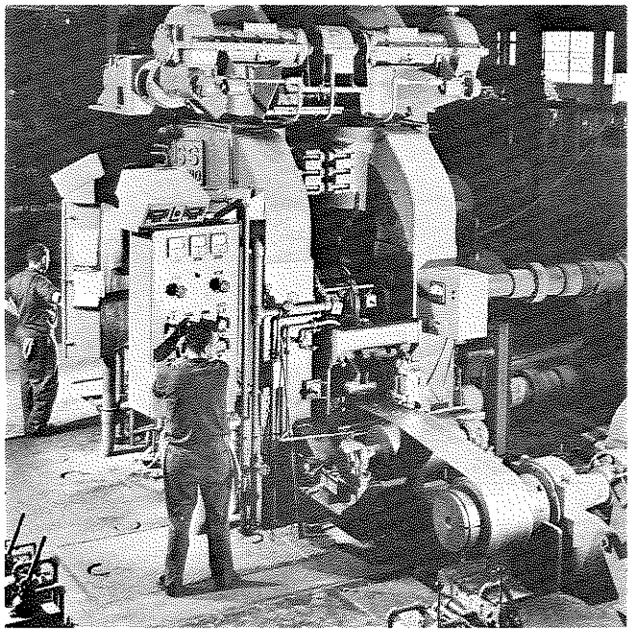

Figure H-12. A 4-High Cold Rolling Mill in Operation.

Conventional cold rolling mills can handle finished gages down to about .010 inch. Beyond that point they are not very practical. The Metals Plant has a SENDZIMIR MILL (Fig. H-13), that is specially designed to handle very thin gages . . . .001 to .050 inch. The operating principle of this mill is much the same as the conventional cold rolling mill, the main difference being in the details of construction. In addition to being capable of rolling very thin strip and sheet, the Sendzimir mill can hold much closer tolerances and provide a superior surface finish.

THE METALS PLANT COLD ROLLING FACILITIES INCLUDE A FOUR HIGH COLD ROLLING MILL WITH CAPABILITIES OF ROLLING STRIP AND SHEET UP TO 20 INCHES WIDE AND THICKNESS DOWN TO ABOUT .010 INCH. THE SENDZIMIR MILL CAN HANDLE WIDTHS UP TO 16-3/4 INCHES AND THICKNESSES DOWN TO .001.

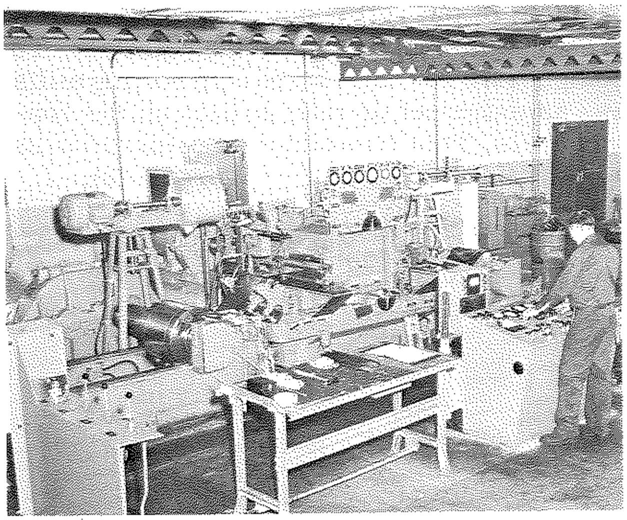

Figure H-13. The Sendzimir Mill Rolling a Strip of Alloy Metal...the Uncoiler is Shown in the Left Foreground.

Heat Treating

The general subject of heating treating was covered in Section A starting on page 12. A quick review of this material may be helpful to you at this time. There are over 30 heat treating furnaces at the Metals Plant . . . of all sizes, shapes and kinds. Let's take a brief look at a few of them.

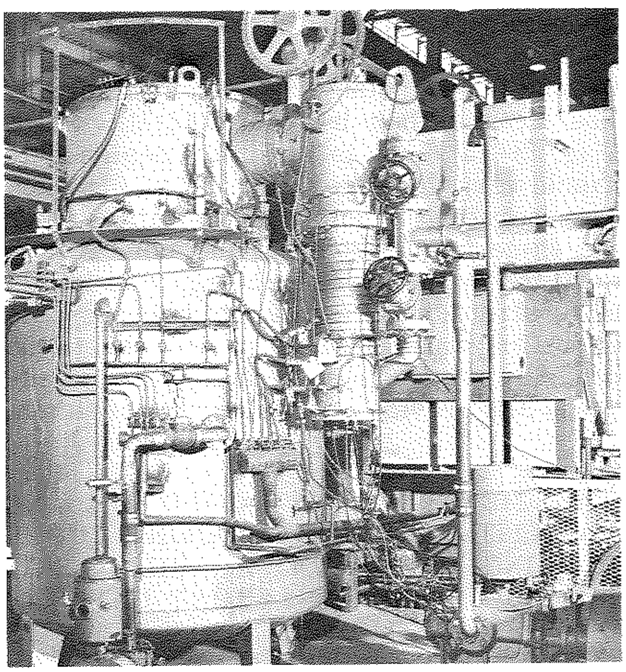

Figure H-14. Vacuum Annealing Furnace.

Some of our heat treatment is performed under vacuum because of the nature of the material. The 33-inch diameter vacuum annealing furnace shown in Figure H-14 is used for large coil annealing up to 2250°F.

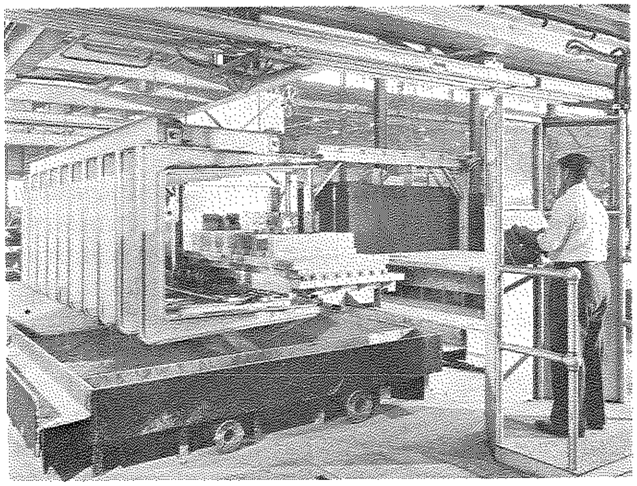

Figure H-15. Solution Treating Furnace.

All our large-batch heat-and-quench treatments (solution treatment) are performed in the 5 foot by 3 foot by 18 foot gas-fired furnace shown in Figure H-15. The operator is

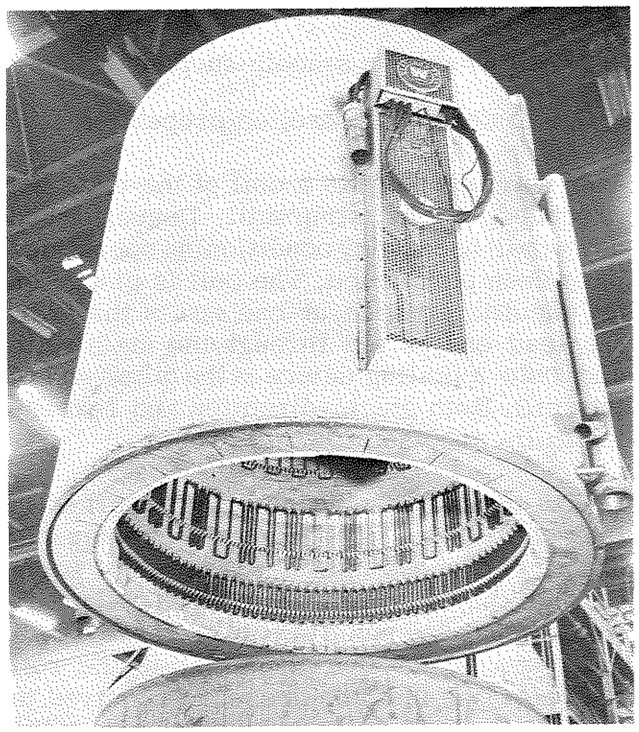

Figure H-16. One of Eleven Electrically-heated Bell Type Atmosphere Furnaces.

lowering a batch of parts into one of the quench tanks . . . both water and oil tanks are available. A number of billets are being moved into the furnace proper on the large charging car.

Figure H-16 shows one of our Bell-type furnaces with the furnace bell being lowered over the inner cover. A portion of the electrical heating element is visible on the inside of the enclosure. The pipe located on the right-hand side is used for the introduction of the circulating Amogas (dissociated ammonia), atmosphere under which the furnace operates. The use of an atmosphere in annealing allows us to heat the strip to high temperatures without oxidizing it. This is commonly known as BRIGHT ANNEALING.

The Metals Plant is currently planning the installation of a commercial continuous annealing furnace. This unit will reduce costs and improve the quality of our strip product.

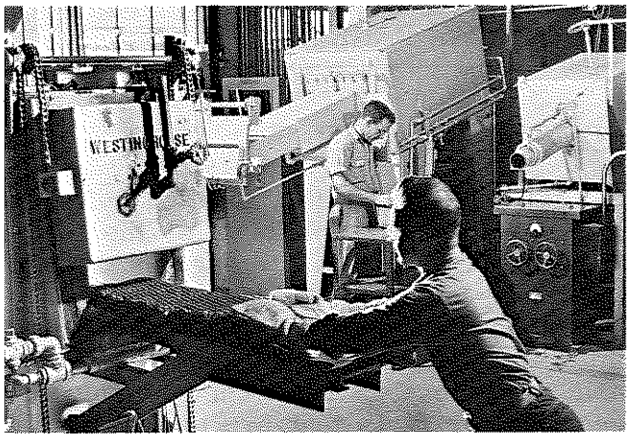

Figure H-17. Tube and Box-type Furnaces.

A few of our small, laboratory-type furnaces are shown in Figure H-17. In most cases, the use of these furnaces are confined to research and testing projects.

Strip Processing

This activity encompasses all the auxiliary operations needed to give the material the finishing touches before delivery to the customer. It includes: surface grinding, leveling, shearing, slitting, deburring, and cleaning. The following photographs will give you an idea of what is involved in some of these operations.

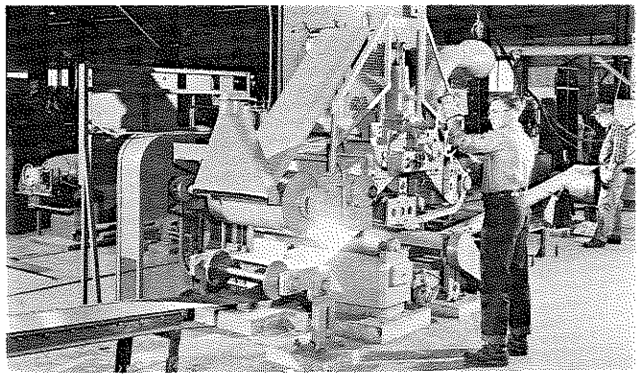

Figure H-18. Continuous Strip Grinder Used to Condition the Surface of Semi-finished Strip Before Final Cold Rolling.

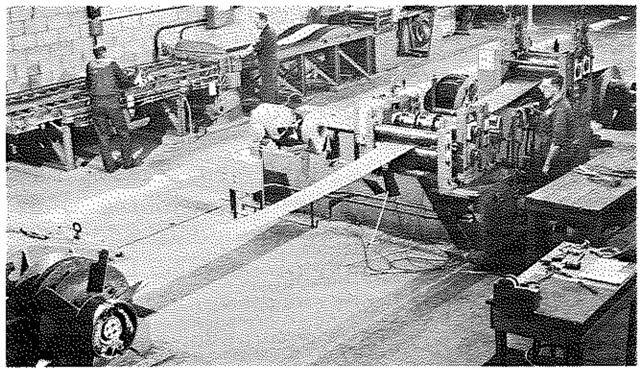

Figure H-19. Both Leveling and Edge Trimming are Performed in One Operation on this Machine. The Windup Coil is in the Foreground.

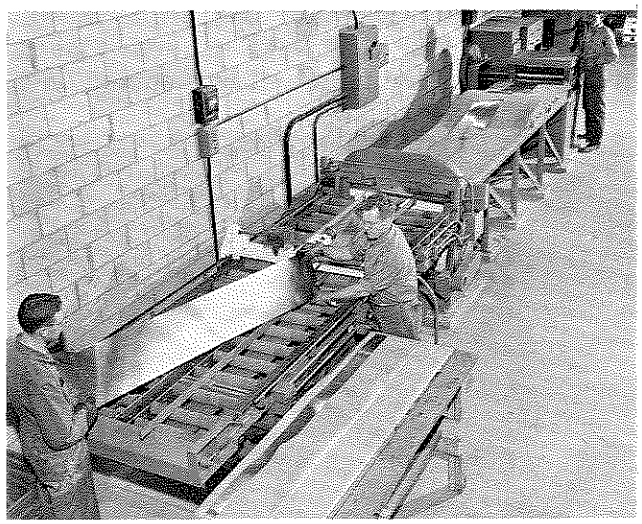

Figure H-20. Here a Coil of Cold Rolled Strip is Being Levelled and Cut to Specific Lengths. Each Piece is Carefully Separated by Paper to Prevent Damage to the Surface Finish.

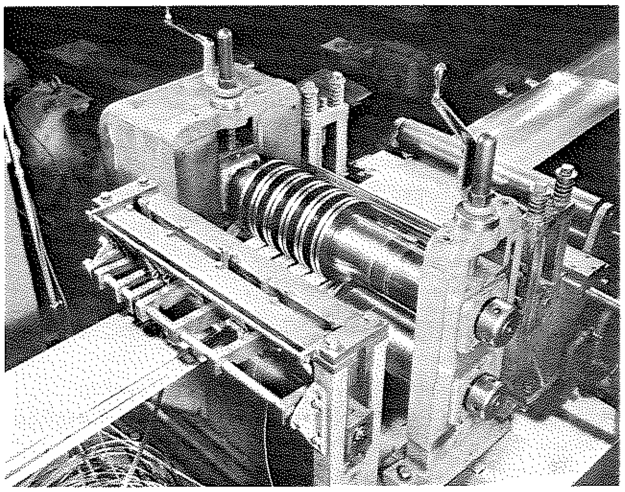

Figure H-21. A Typical Slitting Operation. Circular Cutting Blades Can Be Adjusted in Number and Spacing.

Note that the Metals Plant is currently planning an improved strip conditioning line. This equipment will reduce costs and provide a broader range of surface finishes.

Conditioning

Many times throughout the manufacturing process it is necessary to CONDITION the surface of the material to remove imperfections and imbedded particles. One of the primary tools for this operation is the SWING-FRAME GRINDER (see Figure H-22). The grinding wheel is mounted on a

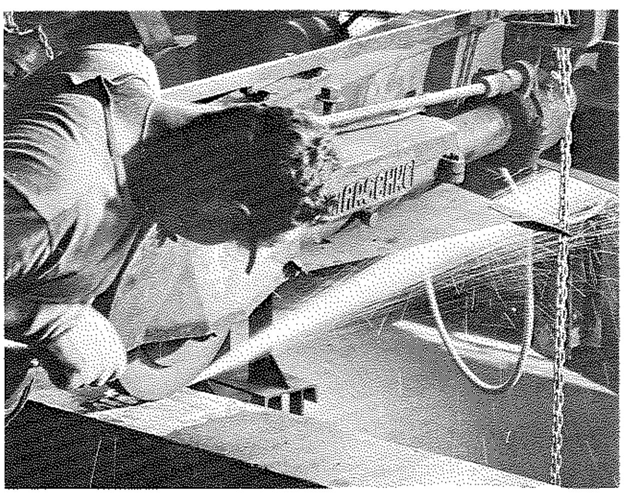

Figure H-22. Operator Conditioning a Surface with a Swing-frame Grinder.

counter-balanced frame that can be swung about by the operator to any position he desires. The actual operation merely consists of grinding away the undesirable portions of the surface.

Shotblasting is another important surface conditioning technique. Here, a continuous stream of metal shot is blown at high velocity against the surface of the material. The end result is a surface with millions of uniformly dispersed minute pits . . . the appearance is much similar to that of an etched surface. Shotblasting is often used between cold rolling operations.

Sawing is considered one of the conditioning operations because the ragged end of billets and other large pieces must be discarded. Both power hack saws and abrasive cutoff saws are used for this purpose.

COMPLETE CHECK-POINT TWO ON WORKBOOK PAGE II

INVESTMENT CASTING

INVESTMENT CASTING is often referred to as PRECISION CASTING or the LOST WAX PROCESS. All three terms refer to the same process which basically is a technique for the mass production of small intricate parts whose tolerances must be held very closely. The technique may also be used for parts that are to be made in an alloy that cannot be readily shaped mechanically and hence must be cast to shape.

There are five basic steps:

1. A permanent metal die is used to make an accurate wax pattern (replica) of the desired part.

2. The wax pattern is used (invested) as part of an expendable one-piece mold.

3. The wax is melted out of the mold.

4. Molten metal is poured into the mold and allowed to cool.

5. The mold is broken apart, leaving the finished part.

Let's examine each step in some detail.

The Wax Pattern

The master die is very similar to a conventional die used in other metal casting processes such as die casting. It usually is a two-piece unit with about one-half of the total cavity shape in each part of the die (see Figure H-23). The two halves of the die are clamped together in a special machine and hot liquid wax is injected into the cavity under 500-800 psi pressure. The wax solidifies almost instantly and when the die is opened, we have a perfect wax replica of the desired part (see Figure H-24).

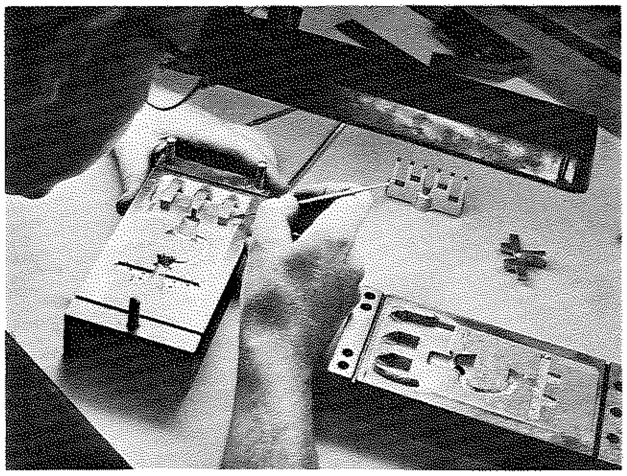

Figure H-23. Die maker putting the finishing touches on a master die.

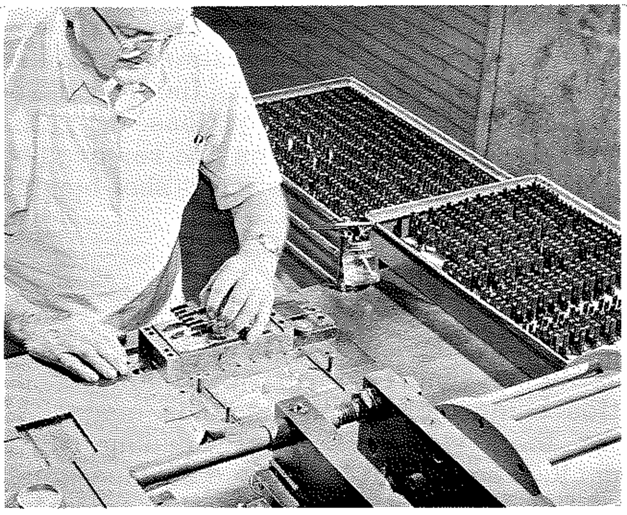

Figure H-24. Die being opened and wax pattern being removed.

The Mold

The first step in making an investment mold is the assembly of a group of wax patterns onto a common base or MOUNT which is made of the same wax. The necessary RISERS and GATES are also assembled on the mount at this time (see Figure H-25).

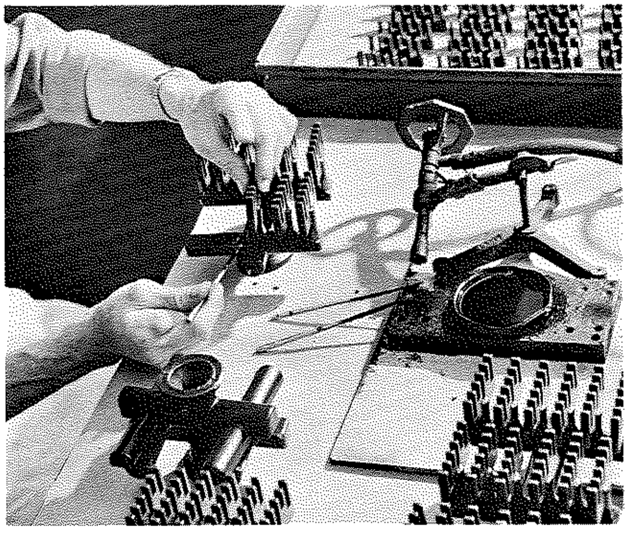

Figure H-25. Individual wax patterns being assembled on mount.

The complete assembly is dip coated with a refractory powder and placed in an aluminized steel FLASK. The flask is then filled with an investment mix called a SLURRY. . . a mixture of various sands and a chemical hardening sodium silicate binder (see Figure H-26). The filled flask is vibrated to settle the solids. After chemical hardening, the excess mold is cut off.

To give us the hollow mold we need, the encapsulated wax must now be removed. This is accomplished by placing the mold upside down on a mold conveyor which travels through a heat-lamp bank that gets progressively hotter causing the wax to melt and drain out of the mold. The mold then moves directly into a gas-fired preheated furnace and its temperature is brought up to about 1000°C. This cycle requires about 24 hours and serves to de-wax the mold and prepare it for the casting operation (see Figure H-27).

Figure H-26. Slurry being poured into flask containing wax patterns.

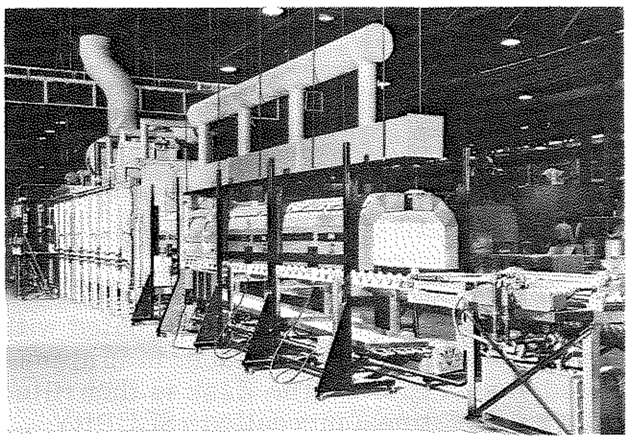

Figure H-27. Mold dewaxing and baking furnace.

Casting the Mold

The metal to be cast is prepared by melting prealloyed metal shot in small indirect arc furnaces whose capacity is designed to cast one mold at a time. As shown in Figure H-28, each furnace is mounted on a center trunnion to facilitate inverting. When the molten metal is ready to be cast, the pre-heated mold is clamped on top of the furnace with its opening over the furnace casting hole. When the total assembly is turned upside down, the molten metal flows into the mold under gravity and air pressure. The amount of metal shot charged into the furnace crucible is carefully weighed so that there will be just enough to fill the mold.

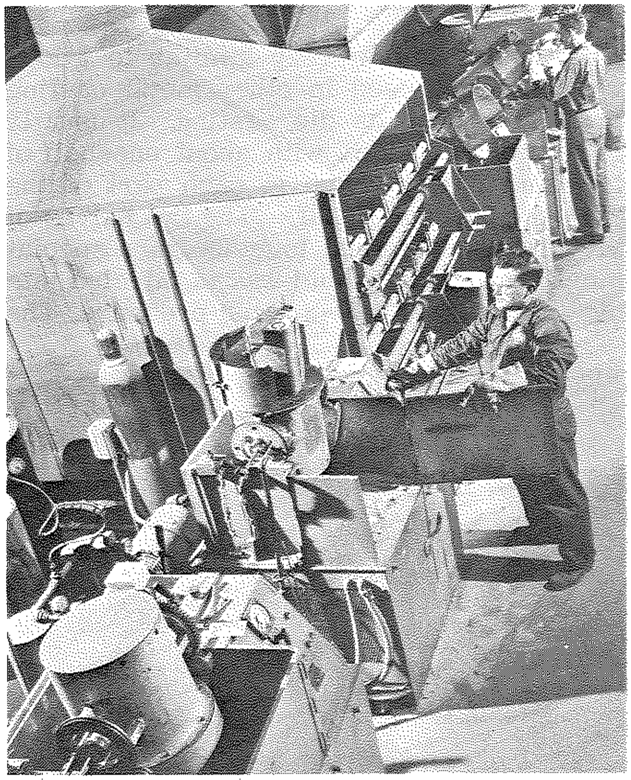

Figure H-28. Range of casting furnaces on each side of mold cooling hood.

After solidification, the mold is removed from the casting furnace and held on a rack until it cools to room temperature. The metal flask and investment mix are then broken away from the finished casting. During finishing operations, the gates are cut-off, imperfections are removed by belt grinding and the casting is shot blasted or sand blasted.

Shell Mold Casting

Shell molding is somewhat similar to conventional sand casting. . .the main exception being the way the mold is made. As for the end result, shell molding has a decided advantage in that the surface finish of the cast part is considerably smoother and in many cases better tolerances are possible.

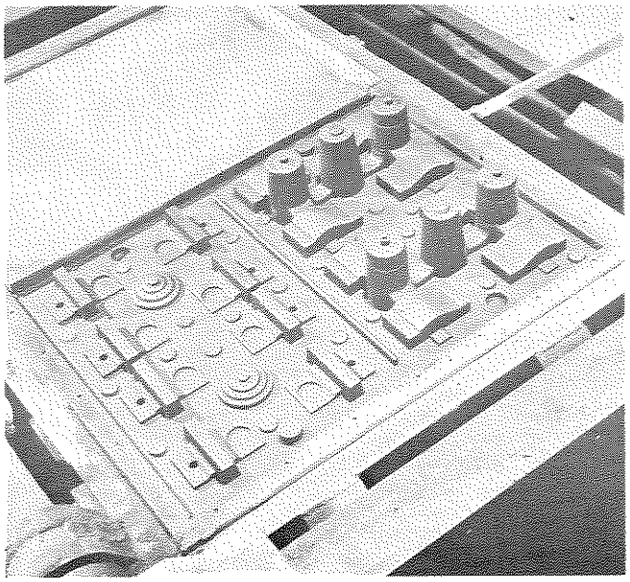

Figure H-29. A two section shell mold master pattern.

Starting with a master pattern made up of the various parts that are to be cast in one mold, the first step is to prepare the SHELL. The sequence of steps are shown in the following photos.

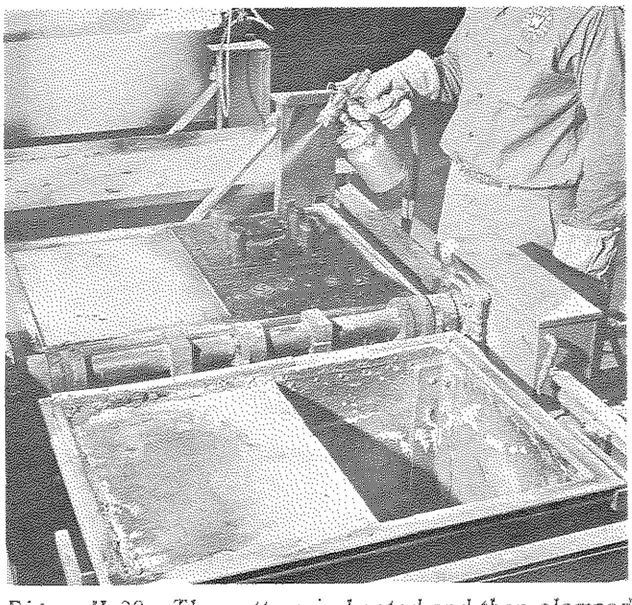

Figure H-30. The pattern is heated and then clamped in the right half of the shell making machine as shown. The dump box on the left side of the machine contains the zircon sand mixed with a resin binder from which the shell will be made. The operator is spraying the pattern with a silicone compound to prevent the mold material from sticking.

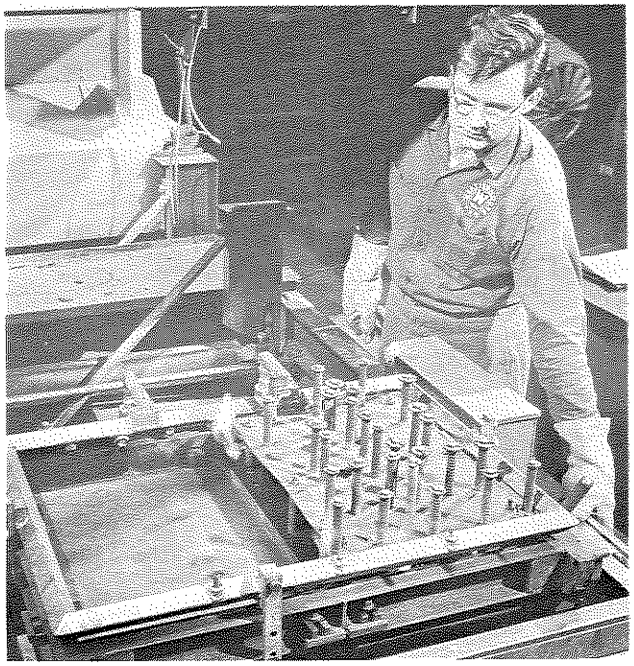

Figure H-31. The right half of the machine containing the master pattern is shown flopped over the dump box. The two units are clamped together. (The spring and rod assemblies shown are STRIPPING PINS that will be used later to remove the completed shell.)

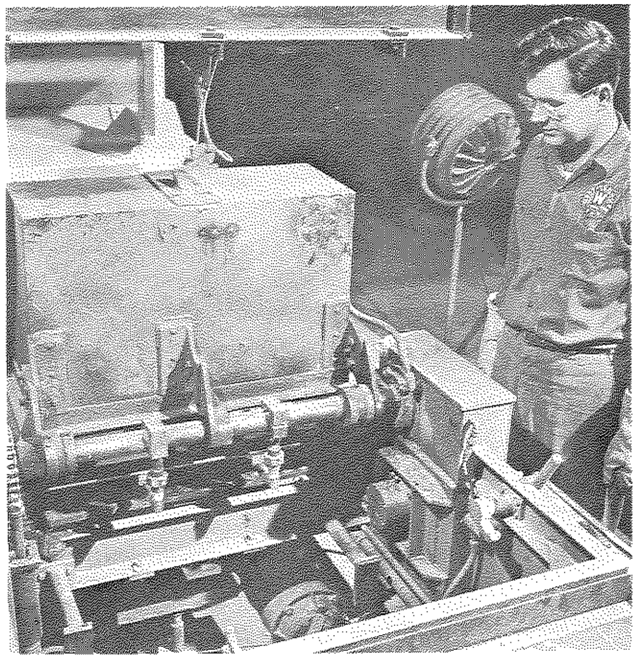

Figure H-32. The two halves of the machine are flopped 180° so that the supply of sand-resin mix will come in contact with the heated pattern.

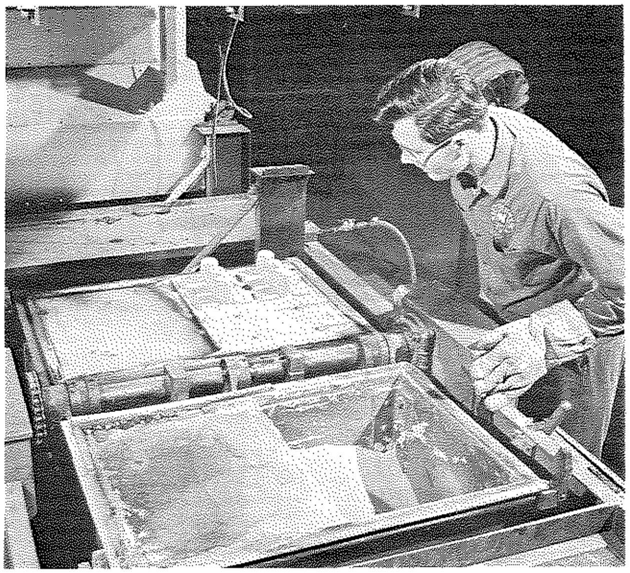

Figure H-33. The sand contains a binder that is heat responsive. Thus when the sand and pattern come in contact, the heat from the pattern is sufficient to bond a thin layer of sand to it as shown here. A flame torch is then used to provide the additional heat needed to harden the sand layer completely.

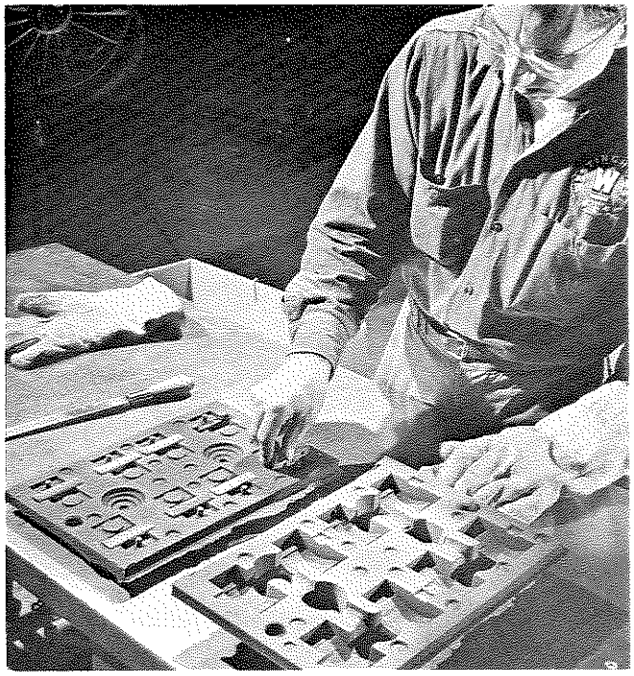

Figure H-35. Here are the two halves of the shell. The operator is placing the necessary CORES (mold inserts that will produce holes and similar cavities within the final part).

Figure H-34. As the right half of the shell machine is returned to its place, the stripper pins are depressed causing them to push up against the hardened shell and strip it away from the pattern. The shell is then removed from the machine and placed on an adjacent work table. Each machine cycle produces both halves of a shell which when glued together will make a complete mold.

Figure H-36. Here the operator clamps the mold halves in the glue press to permanently bond them into a complete shell mold.

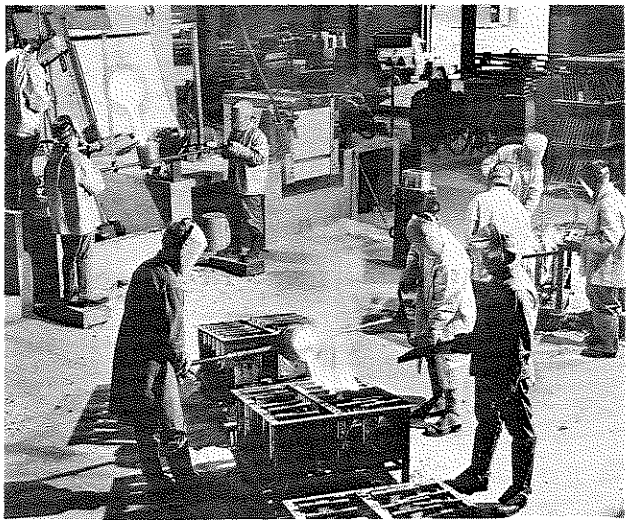

Figure H-37. This is the actual casting operation. The molten metal is poured from the furnace into a small ladle held by two men who then carry it to the various shell molds and pour each full of molten metal.

As the metal solidifies and cools, its heat causes the resin binder to deteriorate and the mold practically falls apart. Thus, it is a simple matter to remove the cast parts from the mold. In the final cleanup stage, gates are removed, general touchups are made and then the parts are either shot blasted or tumbled to remove burrs.

THE METALS PLANT UTILIZES THE SHELL MOLDING TECHNIQUE PRIMARILY FOR THE PRODUCTION OF PERMANENT MAGNETS.

POWDER METALLURGY

Powder metallurgy is a manufacturing process that utilizes metal in a powder form for the production of end-use parts of a particular size and shape. It is a process that permits economical quantity production and offers many technological advantages such as the attainment of compositions and properties that are beyond the scope of the conventional methods of melting or casting.

The basic process was discussed under the subject of "Sintering" in the Refractory Section of this course (see Section G, page 12). This discussion covered the use of powder metallurgy as one means of producing mill forms of refractory metals.

The main difference between the process used for mill forms and that used for the production of parts having a peculiar configuration is in the PRESSING operation. In the case of end-use parts, the perforated metal cage must be the same shape as the desired product. Thus, its configuration is more complex than the cages used for mill forms. Although not included in the Metals Plant facilities, some powder metallurgy processes utilize metal dies to perform the pressing operation.

Following are a few typical parts produced at the Metals Plant by means of the powder metallurgy process:

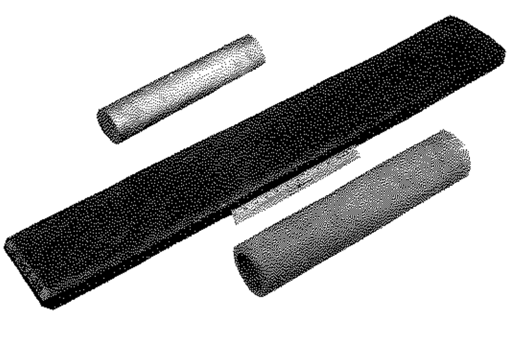

Fig. H-38 *Sintered molybdenum shapes formed by powder metallurgy techniques.*

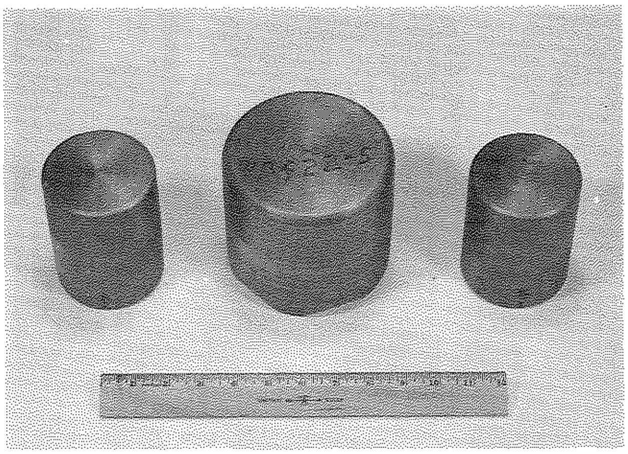

Fig. H-39 *Sintered tungsten forging billets formed by powder metallurgy techniques.*

Fig. H-40 *Large sintered tungsten forging billet for an aerospace application.*

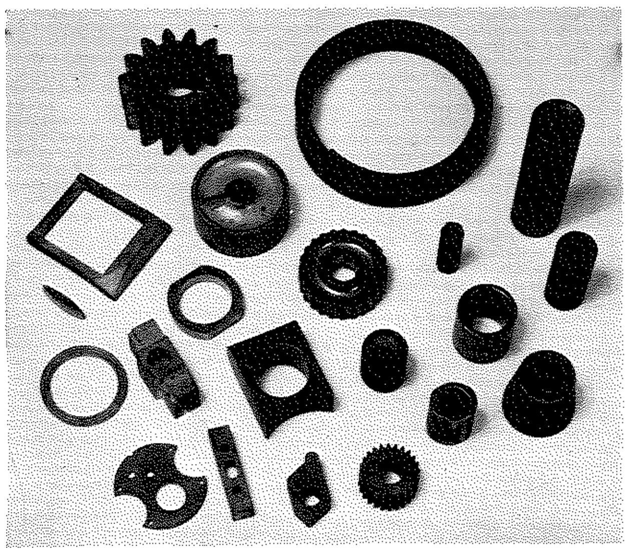

Fig. H-41 *A display of typical powder metallurgy parts that were made by mechanically pressing in cavity dies.*

Metals Plant capabilities range from 1" ø rods to massive rounds up to 8" in diameter x 500# weight in tungsten, and 8" in diameter x 900# weight for moly. Preforms (hollow structures) with holes ranging from 1/4" ø as a minimum to 5" ø as a minimum and outer diameters to 8" can be made in either metal. Various alloys of both metals are capable of being made by premixing the elements and forming into electrodes for melting.

Electrodes are used for arc melting and are ordinarily made in sizes 1-1/2" ø to 4" ø x 12" to 20" long for tungsten, and from 1-1/2" ø to 8" ø and one foot to four feet in length. The Metals Plant can produce most electrode size and alloy requirements.

Often slabs or squares for rolling or forging are needed and here, too, the Metals Plant can supply a wide range of thicknesses, widths, and lengths in sintered bar needed for further processing by rolling, forging, extruding, etc.

COMPLETE CHECK-POINT THREE IN THE WORKBOOK.

CHECK-POINT H-1

A. What is meant by the term "conversion business"?

(see check-point answer #11)

B. What is the difference between an "ingot mold" and an "ingot"?

(see check-point answer #6)

C. Why is scrap used whenever possible in the production of new melts?

(see check-point answer #19)

D. What is used other than scrap to make up the total furnace charge?

(see check-point answer #26)

E. What is the range of a-c current used for air induction melting?

(see check-point answer #5)

F. Why is a ladle teemed from the bottom?

(see check-point answer #24)

G. What shape ingots are used for the production of rods and bars?

(see check-point answer #21)

H. What size air induction melting heats can the Metals Plant produce?

(see check-point answer #12)

I. What is the basic difference between air induction melting and vacuum induction melting?

(see check-point answer #10)

J. What is the difference between vacuum induction melting and vacuum arc casting?

(see check-point answer #16)

K. What are the two basic functions performed by forging?

(see check-point answer #8)

L. What type of equipment is used to handle the ingots during the forging operation?

(see check-point answer #20)

M. What is the purpose of conditioning?

(see check-point answer #23)

CHECK-POINT H-2

A. What is the general shape of a billet?

___________________ ◯

(see check-point answer #15)

B. What is a reversing mill?

___________________ ◯

(see check-point answer #25)

C. To what thickness can materials be rolled on the Metals Plant hot-rolling mill?

___________________ ◯

(see check-point answer #17)

D. What size round bars can be produced at the Metals Plant?

___________________ ◯

(see check-point answer #9)

E. What is the purpose of the pickling operation?

___________________ ◯

(see check-point answer #30)

F. What are the three primary purposes of cold rolling?

___________________ ◯

(see check-point answer #7)

G. What is the purpose of back-up rolls on a cold-rolling mill?

___________________ ◯

(see check-point answer #13)

H. What equipment is utilized when the desired thickness of material is less than the normal 5 mil limitation of a standard cold roll mill?

___________________ ◯

(see check-point answer #1)

I. What is the maximum width of sheet or strip that can be cold rolled at the Metals Plant?

___________________ ◯

(see check-point answer #18)

J. Why do we perform annealing in an Amogas atmosphere?

___________________ ◯

(see check-point answer #27)

K. What is the term used to describe the removal of surface imperfections and imbedded particles?

___________________ ◯

(see check-point answer #2)

CHECK-POINT H-3

A. What are two other terms used for investment casting?

(see check-point answer #22)

B. What is a slurry?

(see check-point answer #29)

C. How is the wax pattern removed from the mold in investment casting?

(see check-point answer #14)

D. What are the advantages of shell molding over sand casting?

(see check-point answer #28)

E. How are the two halves of a shell mold held together?

(see check-point answer #31)

F. What type of products are made at the Metals Plant using the shell molding technique?

(see check-point answer #3)

G. What type of products are made at the Metals Plant using the powder metallurgy technique?

(see check-point answer #4)

CHECK-POINT ANSWERS

1. Sendzimir mill or cluster mill
2. Conditioning
3. Permanent magnets
4. Molybdenum and tungsten sintered shapes, some iron magnet parts, and silver-tungsten contacts
5. 10,000-29,000 amperes
6. An ingot mold is the vessel into which the molten material from a furnace is poured . . . an ingot is the mass of solidified metal formed in an ingot mold
7. To reduce thickness - produce a smooth surface - develop controlled mechanical properties
8. Reduce cross-section - refine structure
9. 1/2 to 4 inches in diameter
10. In vacuum induction melting, the entire melting operation is performed under vacuum
11. Jobs we get in which the customer furnishes the material in some semi-finished form and we convert it to the desired final form
12. 100 to 10,000 pounds
13. To prevent the contact rolls from bending
14. It is melted out
15. Its cross-section is generally square-shaped
16. In vacuum induction melting, heat is produced by an induction coil . . . in vacuum arc casting, heat is produced by an arc between the electrode and the molten metal
17. Down to .090 inches thick
18. 22 inches wide
19. To keep down cost of raw material
20. A manipulator
21. Square-shaped ingots
22. Precision casting - lost wax process
23. To remove surface defects
24. The non-metallic impurities and slag have risen to the top
25. A rolling mill in which the piece being processed can be fed through the rolls in either direction
26. Selected elemental materials and/or ferroalloys
27. To prevent oxidation of the surface of the material
28. Smoother surface - closer tolerances
29. A mixture of sand and sodium silicate
30. To remove the oxide scale formed during hot rolling
31. Glued