CHAPTER II
DESCRIPTION OF THE PRECAST CONCRETE PRODUCTS INDUSTRY

In this chapter the precast concrete products industry is described, its structure is examined, the number of plants and the size of the work force are defined, and the labor and trade organizations associated with the industry are identified. An operations approach that follows the production flow is used to give a description of specific manufacturing techniques or processes, the tasks performed by workers within each operation, and the tools and equipment associated with such operations.

Concrete is a building material made by thoroughly mixing cement; sand; aggregate, such as gravel or crushed stone; and water in desired proportions. The cementitious material usually is a hydraulic cement that sets and hardens in water. Initially, the concrete mix is a plastic material that assumes the shape of the mold into which it is cast. The mixture is poured into a cavity, an excavation in the ground, or a form designed for a specific purpose. After hardening, concrete has the appearance and structure of stone. In fact, it may be thought of as "moldable stone." When the mixture is deposited in its final position, it is known as cast-in-place concrete. When a concrete product or element is cast elsewhere (whether in a plant or on a field site) and then brought to its final position, it is termed precast concrete.

Precasting is a manufacturing procedure, whereas casting-in-place is a construction procedure. Being a manufacturing operation, precasting can have certain advantages:

- Work can be performed at a fixed site with accelerated curing facilities.
- A single location for batching and mixing concrete can be provided.
- A convenient source of water and other raw materials can be used.
- A location convenient to transportation facilities can be selected.
- Mass production techniques can be employed.
- Opportunities for storing product and working under shelter reduce the impacts of cyclical demand and weather conditions.

A. Plant Census and Worker Population

The precast concrete products industry is entrepreneurial, highly diversified, and geographically dispersed, with nearly 4,000 disparate plants manufacturing more than 600 different products. The NIOSH Industrial Profile data for 1980 (Table II-1) show that 3,930 precast concrete manufacturing plants employ about 82,049 workers [1]. These figures compare well with information derived from the 1979 Pennsylvania Industrial Directory [2], and the U.S. Department of Commerce 1977 Census of Manufacturers [3](Table II-2).

TABLE II-1
NUMBER OF PLANTS AND EMPLOYEES PRODUCING
PRECAST CONCRETE PRODUCTS, 1980
(SIC 3272)

	Range by Number of Employees							
	1-7	8-19	20-49	50-99	100-249	250-499	500+	Total
Number of Plants	2,004	951	610	236	106	17	6	3,930*
% of Plants	51.0	24.2	15.5	6.0	2.7	0.4	0.2	100.0
Number of Employees	7,548	11,113	17,924	14,910	14,341	5,088	11,125	82,049
% of Employees	9.2	13.5	21.8	18.2	17.5	6.2	13.6	100.0

*Thirty-three additional plants did not report the number of their employees; the actual total number of plants, therefore, is 3,963.
Compiled from Summary of Dun & Bradstreet Data in NIOSH Industrial Profile, 1980 [1].

TABLE II-2
SUMMARY OF PLANT CENSUSES (SIC 3272)

	Dept. of Commerce Census of Mfg., 1977	NIOSH Industrial Profile, 1980	Pa. Industrial Directory, 1979
Total Number of Plants	3,916	3,963	--
Number of Plants with 20 or More Employees	862	975	--
Number of Plants in State of Pa.	--	163	165
Number of Employees in State of Pa.	--	2,400	2,553

Compiled from the Summary of Dun & Bradstreet Data in NIOSH Industrial Profile, 1980 [1], 1979 Pennsylvania Industrial Directory [2], and 1977 Census of Manufacturers [3].

Information supplied by trade associations also verifies the plant census figures in the NIOSH profile. The American Concrete Pipe Association (ACPA) [4], the Prestressed Concrete Institute (PCI) [5] and the National Precast Concrete Association (NPCA) [6] estimations of worker population corroborate the NIOSH profile figures. Further, the trade associations estimate that the precast concrete industry is comprised of approximately 62,500 production workers. This equates well with the aforementioned NIOSH profile total population of 82,049 workers, and the Department of Commerce Census estimation that approximately 77% (or 63,178) of the total worker population in the industry are production workers. Table II-3 presents these trade association estimates.

For the purposes of this study, the NIOSH Industrial Profile data was used since it was the latest compilation of data on the industry.

TABLE II-3
TRADE ASSOCIATION ESTIMATES OF NUMBER OF PLANTS AND PRODUCTION EMPLOYEES, 1980
(SIC 3272)

Industry Product Sector	Number of Plants	Production Employees
Precast Concrete Pipe*	425	18,000
Architectural and Structural Products**	400	18,500
Miscellaneous Precast Concrete Products***	3,100	26,000
Total	3,925	62,500

*From Duffy J. J. American Concrete Pipe Association [4].
**From Freedman S. Prestressed Concrete Institute [5].
***From Tilford J. E. National Precast Concrete Association [6].

B. Process and Task Descriptions

This section describes the operations, tasks, and equipment required to manufacture precast concrete products. These descriptions are presented in organizational groupings that follow the primary production steps necessary in the precasting process. In many instances, the operations, tasks, and equipment described under a particular process heading are not unique only to that specific process; however, it is convenient to present the task descriptions in the sequence of the production flow. An additional section on materials handling is presented following the production task descriptions.

1. Forming

Forms or molds used for the casting of precast concrete products usually are made of steel or wood. However, they may be constructed of any material that remains stable during casting and is able to withstand the abuse of preparation, installation of steel reinforcement, oiling, curing, stripping, and reuse. Wood is commonly used for the construction of forms expected to have a limited use; that is, forms built for the casting of fairly unique concrete products. Concrete is sometimes used as a form because it can be cast into intricate shapes. With a dense, smooth surface finish and the application of form release agents, concrete is an excellent form material for products requiring smooth or curvilinear surfaces. Styrofoam, fiber glass, rubber matting, and various paperboards are also occasionally used to make forms or form liners for special surface effects. Because many of the products manufactured in the industry are produced repetitively, steel forms are common. Such forms are usually made to design specification by other departments or are purchased as standard equipment from other form manufacturers. Occasionally, it is necessary to modify or customize steel forms; that is, holes, notches, and sections may be burned out or fillets, boxouts, and seats may be welded in place as needed. Large forms may be equipped with access ladders, stairways, work platforms, conveyor connections for receiving concrete, and external vibrators for consolidation.

Steel forms are hammered, vibrated, modified, and moved, creating dents, holes, and misalignments that require periodic repair and maintenance. In addition to welding shops, many plants have portable welding equipment for repair and modification of forms too large and unwieldy to move. Welds and patches are occasionally required to fill in depressed spots; chipping and grinding operations are used to smooth rough areas.

The form surface against which the concrete will be cast must be clean and smooth (unless specifically designed otherwise). Forms are cleaned for reuse by chipping, wire brushing, scraping, scrubbing with water, sanding, and/or air blowing.

Form assembly follows repair and cleaning. Large forms are moved to the casting station by overhead hoists or cranes, or by lift truck. Many products have interior and exterior forms. Often, the interior form is placed and fixed to a cleaned steel plate, or pallet ring that forms the bottom of the product. Exterior forms are then locked into place with various fittings (makeup bolts, tack welding) that both fix its position and maintain the required dimension between the interior and exterior form.

Forms for long or flat products require minimum assembly, except to position the edges, bulkheads, and boxouts at the desired locations. Edges and bulkheads usually require appropriate spacers, spreaders, braces, and stiffeners. These pieces are usually cut from wood to the proper length, hammered into place, and held by nails. Hammers are used for driving nails and tacking chamfer strips in wood forms. Sledge hammers, crowbars, and prybars are used in the alignment of forms as well as during the placement and removal of bulkheads.

The tasks and equipment used during the construction of the forms are typical to wood, Styrofoam, or fiber glass assembly/manufacturing processes. Most companies have carpenters' shops or areas equipped with hand and power tools for form construction. Larger companies usually have full-time personnel to use this equipment while smaller companies usually assign workers the task of making the form as part of their other routine responsibilities (casting, oiling, mixing, etc.).

2. Oiling

The form surface is coated with a release agent to keep the fresh concrete from bonding to the form. Form release agents usually have a kerosene or paraffin base and are applied to the form by swabbing or spraying before the reinforcing steel is placed.

Swabbing is the hand application and spreading of the agent on the interior surface of the form with the use of brooms, mops, rags, or brushes. Swabbing operations require a worker to fill a container (bucket) with form oil from a drum, transfer it to the form, and physically apply it to the form walls. Usually the worker will swab while standing and walking in the form. Some forms (vertical walls) may require the worker to stand on the form structure and mop the walls.

Most spray application of form oil is by hand-pumped, hand-carried sprayers similar to garden insecticide sprayers. The pump is filled from a central drum and carried by the worker to the form. Typically, the worker will walk along the edge of the form and spray the required surfaces. Some precast plants use a central pressurized air venturi system instead of hand pumps to spread the form oil.

3. Reinforcing

The reinforcing operation includes the fabrication and placement of steel reinforcement into the product forms. The tasks associated with this operation are cutting, bending, tying and welding of rebar, wire and wire mesh; and stringing and stressing of steel strand. The reinforcement, once sized and shaped, may be assembled in the form or fabricated outside of the form in a separate area or shop. The movement or placement of the steel may be done mechanically or by manual means.

There are four basic types of steel reinforcement:

- Plant fabricated cages and mats
- Prefabricated wire, loops, bars, rods, and welded wire mats
- Steel plates and rolled sections
- Prestressing steel strand.

a. Plant Fabricated Steel

Manual fabrication of reinforcing assemblies is common. Sometimes reinforcing bars or welded wire fabric are placed and tied in the form. For more complex assemblies, a jig is built to position bars. Transverse and shear steel is manually tied to the longitudinal steel with wire and pliers or with looped-end wire ties and a special "pigtail" tool that twists the two ends of the wire tie together when pulled. To produce reinforcing bars with the bends, loops, angles, and hooks specified by the design, a rebar bender is used. A cage or mat can be made to any desired size or shape. The completed plant fabricated reinforcing steel assembly is then lifted and placed in the form by manual or mechanical means. With prestressed concrete products, individual stirrups or welded wire fabric used for shear reinforcement are hand placed and may be tied to the prestressing steel.

Circular or elliptical reinforcing cages for concrete pipe are usually made of welded wire fabric (2- to 4-inch mesh made from 1/8- to 3/8-inch wire) or cold-drawn steel wire. A wire roller forms rolls or flat mats of welded wire fabric into the desired circular shape, which is then cut and spot welded to make the cage. Both cage machines or mandrels can be used to form steel wire into cages. In a cage machine, the operation is continuous and the endless cage produced is cut to the required length; in a mandrel operation, each cage is made individually to the desired diameter and length. Both techniques require that the wire mesh be shaped into a cylinder (by rolling or bending), the ends joined (by welding or using tie wires), and the finished reinforcing cage placed into the annular space of the pipe form.

b. Prefabricated Steel

Many small precast concrete products are reinforced by prefabricated steel manufactured to specification by others. This prefabricated steel is placed, tied, or secured into the form or pressed into the freshly cast concrete at the desired locations.

c. Steel Plates and Rolled Sections

For connecting some structural and architectural precast concrete products, small, rolled, sectioned steel plates with reinforcing bars or studs welded to them are tied to the cages inserted in the freshly placed concrete. Wire loops of prestressing strand or reinforcing bars are tied in place or inserted manually for lifting and handling the finished product. Connection and handling steel is called "hardware," and should be designed by the plant engineering staff or the project engineer. The tasks necessary when using steel plates are similar to those described in the preceding sections.

d. Prestressing Steel Strand

Prestressing steel is usually seven-wire strand that is manually or mechanically strung in the form before concrete is cast. Manual strand stringing is performed by a worker physically pulling the length of strand down the bed from a reel stationed at one end of the bed. The strand is then cut by torch or strand saw, and the process is repeated. Mechanical stringers pull multiple lengths of strand from separate reels at the same time. Single or multiple strands may be threaded through cages of reinforcing steel and through bulkheads used to separate adjacent members.

The steel wire strands are laid in the stressing bed (a long form up to several hundred feet in length with the cross section of the desired shape) and fixed at the ends (abutments). The stressing bed is the mold for several precast units along its length. For example, if 50-foot-long "double tees" are desired and a 610-foot-long stressing bed is used, 12 such units can be produced in one bed, each separated by a bulkhead. Some beds are designed as selfstressing forms, eliminating the need for end abutments.

Once the strands are in place they are then stressed. This operation is the tensioning (stretching) of wire strands previously positioned in the form. Stressing includes strand vise placement, jacking, tensioning, harping, and detensioning. The stressing operation can be done by single strand jacking or multiple strand jacking where all the strands are tensioned at the same time. The strands to be stressed (usually 1/2-inch, seven-wire strand [7], tensioned to approximately 200,000 pounds per square inch (psi) or a 30,000 pound load) are anchored at one end of the bed with a strand vise.

The strand vise barrel has a truncated conical hole along its longitudinal axis that holds the three jaws of a chuck. The chuck is serrated on the inside surface and conical in shape outside. The jaws permit free movement of the strand in one direction. In the other direction, they grip the strand and wedge themselves into the conical hole in the barrel of the strand vise. A strand vise is placed over each length of strand at the anchor end abutment, which fixes it in place. At the jacking abutment, two strand vises are placed on the strand in opposing directions. One is seated against the end abutment and allows the strand to be pulled through as the jack tensions the strand. This strand vise also holds and anchors the tensioned steel to the abutment. The other strand vise provides a grip for the jack. Figure II-1 shows a rectangular prestressed beam form with strands stressed and reinforcement in place.

The steel strand may run straight through the bed and may be stressed in this position. Alternatively, the strands may be depressed within the form for each member along the bed to create

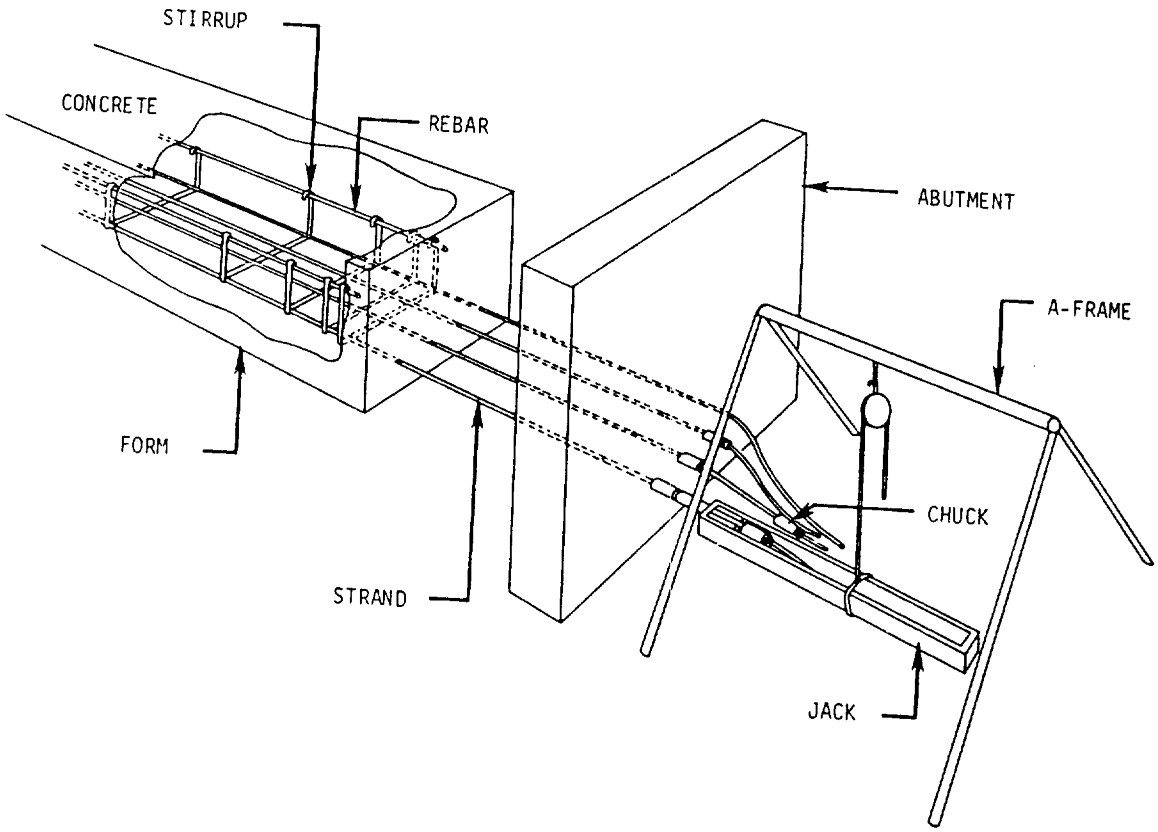

FIGURE II-1. PRESTRESSED AND REINFORCED BEAM FORM

an upward force that improves structural efficiency [7]. This technique is called draping or harping.

The term "draping" describes the profile of the steel strand, which is "draped" from its high point near the ends of each precast member to the low point at the midspan of each member. Strands can either be depressed or pulled up. The strands are passed through and over pin and roller fixtures that minimize friction at the points of change in the steel strand profile. Figure II-2 shows the strands depressed at the midpoint of a member, thus creating the appearance of strings on a harp. Some designs may require other holddown locations for each member.

After the concrete is cast and has gained the specified strength (usually 3,500 psi or more [7]), the strand tension is released, or detensioned. In some cases, strands are individually cut by torch; however, with hydraulic jacks, the tension is gradually released from the header.

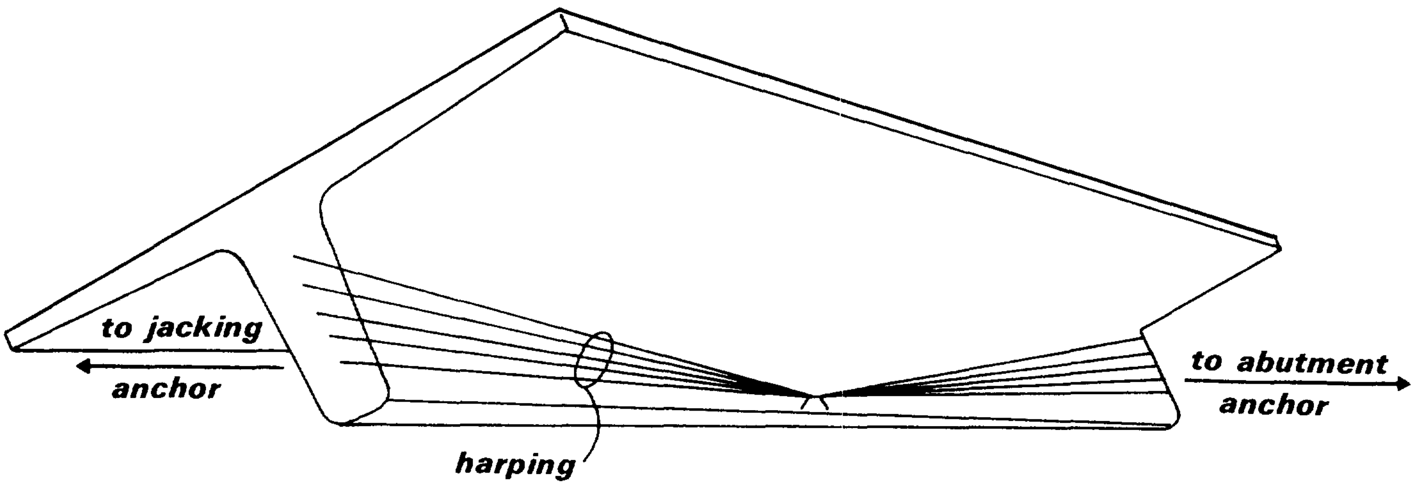

FIGURE II-2. A "SINGLE TEE" SLAB WITH THE STRANDS HELD DOWN AT THE MIDPOINT TO "HARP" THE PRETENSIONED STEEL

Adapted from Bennett W. B. Jr. [7].

Detensioning transfers the stress from the steel to the concrete to which it has bonded, precompressing the concrete.

4. Concrete Mixing

Concrete may be batched and mixed at the products plant or purchased from a ready-mix concrete producer. The correctly weighed proportions of cement, aggregates, and water are charged into a drum mixer, pan mixer, or a transit mix truck. Small mixers that are used in many miscellaneous products plants are gas, diesel, or electrically powered.

Cement may be delivered to the plant in bulk cement trucks or railroad cars and unloaded by a totally enclosed, screw auger pneumatic system that carries the cement to an elevated hopper or silo. Aggregates for larger plants are unloaded in much the same way as cement, except that open conveyors may be used. The material stored at a higher elevation is weighed and chuted by gravity (charged) into the mixer. The proper weight of water is added, and the mixer blends the components into a homogeneous mixture by rotating paddles inside an enclosed vessel at speeds of 2-15 revolutions per minute (rpm), or approximately 2 linear feet per second.

The two most common types of mixers used in the industry are drum mixers and pan mixers. A drum mixer is a rotating cylinder in which stationary paddles, mounted along the cylinder, mix the concrete (truck mixers are of the drum type, inclined from the horizontal). The pan mixer consists of a shorter cylinder than the drum mixer and is vertically oriented; paddles are mounted vertically and rotate to mix the concrete in the stationary cylinder. The mixer is usually positioned 10-15 feet above the adjacent working surface to allow gravity discharge of the mixed concrete into buckets, trucks, or other means of conveyance to the casting area. Access for cleaning, maintenance, or concrete quality control is provided by ladder or steps to a working platform that will partially or totally encircle the mixer. Figure II-3 depicts a concrete batching, mixing, discharge, and transport system.

At the end of each shift or after mixing is completed for the day, the mixers are cleaned. In addition to daily cleaning and flushing of concrete mixers, it may be necessary to hammer or chip away built-up encrustations of concrete on a periodic basis. Mixers also require maintenance, paddle replacement, and repair. All of these tasks may require workers to enter the mixers.

5. Concrete Delivery and Casting

Casting of small products can be a manual operation; a quantity of mix is made available to the operator, who trowels or shovels it into a prepared mold around the reinforcement. The material may be hand tamped or vibrated to consolidate the mix. Many small products are made with high production, automated equipment.

For casting larger pieces, the concrete is delivered from a truck, a concrete bucket, or a concrete buggy moved to the location where the concrete is to be used. For very large pieces or for long-line prestressing beds, the concrete may be delivered by a monorail bucket system, overhead bridge crane, or other mechanical means and deposited directly in the form, where it is vibrated and consolidated by machinery or by manually inserted spud vibrators. Usually two to five employees will be directly involved in these tasks. In addition, concrete may be extruded through a die to form products such as hollow-core slabs.

Systems used to deliver the mixed concrete to the placement location vary from simple manual handling to totally automated, enclosed conveyances. Concrete mixed in small power mixers is delivered by direct deposit (when the mixer or form is portable), by front-end loader (which carries concrete from mixer to form), or by wheelbarrow. Ready-mix trucks frequently are used to deliver concrete because they can carry, and continuously mix, large volumes (up to 12 cubic yards) directly to or near the forms for placement. A chute, attached to a lip below the discharge opening of the truck's drum mixer, is directed by a worker to deposit the concrete. The chute is moved around during the casting process to spread the concrete and reduce shoveling or raking.

As parts of the form are filled with concrete, the truck moves along the form, placing concrete to the desired level. The process continues,

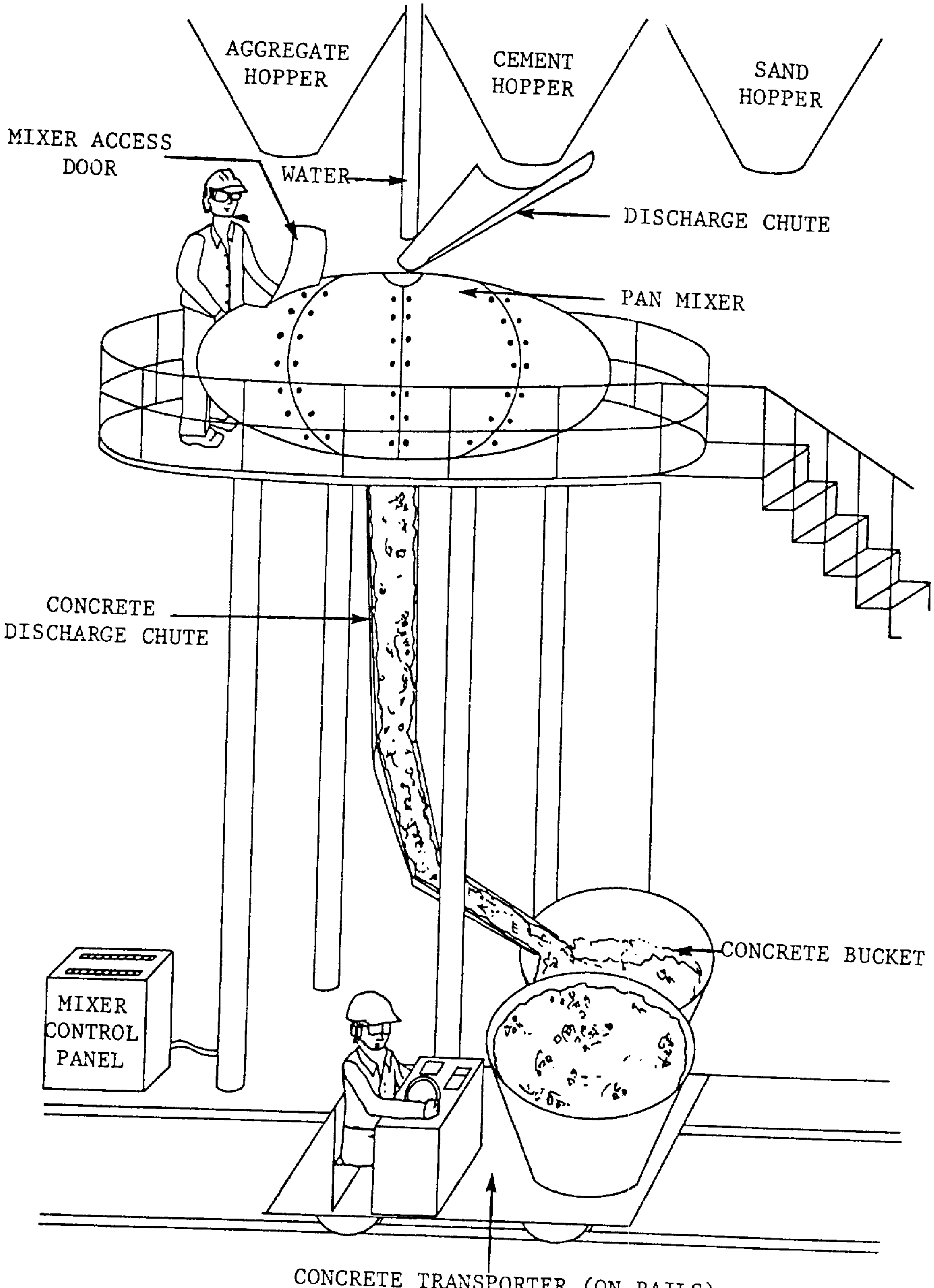

FIGURE II-3. CONCRETE BATCHING, MIXING, DISCHARGE, AND TRANSPORT SYSTEM using additional ready-mix trucks with loads of concrete, to completely cast the products being made. During casting, workers will be engaged in a series of continuous tasks directed at filling the form with concrete. When a ready-mix truck is used, workers will be working adjacent to and along with the movement of the delivery truck. Access (steps or ramps) to low forms (1-3 feet high) is usually limited or nonexistent. Employees will frequently be working and moving among multiple form tiedowns, spacers, and spreaders as well as walking on the reinforcing mats while filling and vibrating the forms. When it is not possible for a truck to deposit concrete directly into the form, wheelbarrows, hoisted concrete buckets, or concrete delivery vehicles are used. Workers may push wheelbarrows along walkways, planks, or ramps to fill the form with concrete.

Another method of delivering concrete is by transporter, which takes mixed concrete from a central mixer and carries it directly to the forms. Enclosed transporters have a smaller capacity (up to 6 cubic yards) and are usually lighter, smaller, and more maneuverable than ready-mix trucks. This method of depositing concrete is similar to that for ready-mix trucks except that the chute is tubular in shape, with an enclosed auger or conveyor belt, allowing concrete to be pushed to higher elevations instead of depending on gravity. Some transporters consist of wheeled or tracked carriers that take large buckets or hoppers of mixed concrete (up to 4 cubic yards) to placing or casting machines. Transporters may travel on aisleways, rails, or roadways at speeds of up to 500 feet per minute. Transfer, turnaround, or backing areas may be provided at the end of the travelways for moving the transporters laterally relative to the casting areas or for access to the concrete mixers. Visibility may be limited because of walls, corners, other equipment, storage, or layout. Once the concrete buckets have been delivered to the casting area, an overhead hoist, which may be an integral part of a casting machine, will be used to hoist and position the bucket over the form or casting hopper.

Conveyors are frequently used to deliver concrete to the point of placement, especially in the miscellaneous and pipe sectors of the industry. The forms can be set up under the discharge end of the conveyor, or a portable conveyor can be set up with its discharge over the forms (depending on form mobility). Concrete is deposited onto the conveyor and moved along the conveyor system (which can be arranged to move the concrete around corners, to different elevations, or to remote plant locations) to the point of discharge.

Access to elevated forms during casting is usually provided by platforms, stairs, movable scaffolds, or ramps. Large pipe forms and miscellaneous products forms will sometimes have walkway platforms built around the forms or attached for the casting operations. Ramps are a convenient means of access to forms at elevations different from the surrounding working surface; otherwise, stairs are used. Access to lower beds up to 3 feet above the plant or yard surface usually is by stepping up and jumping down; it is uncommon for steps or ramps to be provided.

In mechanized plants, placement of concrete into longbed forms is accomplished by placing or casting machines, similar to pavers or extruders. The concrete is spread, vibrated, compacted, screeded, and finished as the machine passes over the form, or is extruded as it moves along the bed. Drive controls are located in a cab on the machine or on a panel reached by workers from the side of the machine.

One method of casting utilized in the manufacture of pipe and many miscellaneous circular products requires a concrete mix that is wet compared to the mixes used in dry mix processes. Using both inner and outer forms, a cone is placed on the inner form to direct concrete down into the annular space between the forms. The concrete is then consolidated by stick vibrators or external vibrators, and the exposed top surface shaped and finished as required by hand, using edgers, trowels, and brushes.

Figure II-4 depicts an automated vertical pipe casting operation. Employees work from scaffolds that are rolled into place around the perim eter of the external pipe form. As the concrete discharge chute rotates around the form, workers using shovels, boards, tampers, and/or vibrators ensure the proper placement and consolidation of the concrete.

Most concrete pipe is cast with a relatively dry, low-slump mix that is mechanically placed and consolidated in the form. Two of the four mechanical methods use both inner and outer forms, which vibrate with either tampers or vibrators while the dry-mixed concrete is cast into the annular space between them. In the tamping method, compaction is performed directly by vertically operated tampers. In the dry cast method, consolidation is done by external vibration of the inner or outer form. The other two mechanical methods use only the outer form and either spin the pipe horizontally while centrifugal forces distribute the concrete delivered by conveyor, or spin a mandrel-like packerhead that is drawn up inside the pipe as concrete is cast from above, compacting as it goes. These four mechanical, dry-type mix methods of casting pipe are shown in Figure II-5.

Figure II-6 shows one type of vertical packerhead operation used in the manufacture of pipe. Metal pipe forms are placed by forklift or manual or automated cranes onto openings in a circular casting floor. The floor rotates (at slow speeds) to position the form in the operational packerhead area. An employee on an elevated platform controls the packerhead spinning speeds, the up-and-down motion of the packerhead, and the flow of concrete into the form. When the casting is complete, the floor rotates an empty form into place and the forklift removes the cast pipe and mold to a curing area.

Pipes manufactured by spin-casting methods have an inside diameter of 12-60 inches or larger. The form is spun at speeds of 2-4 revolutions

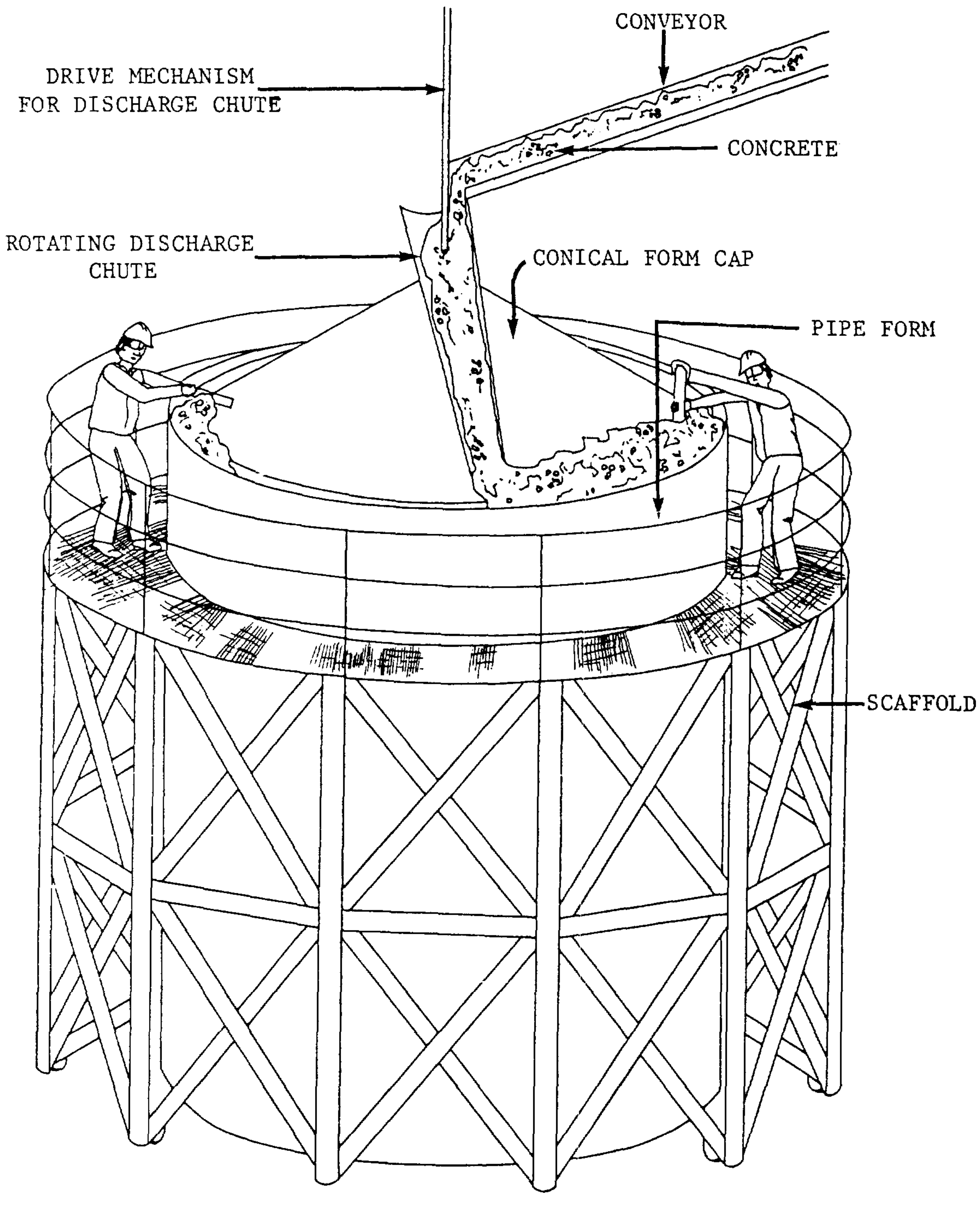

FIGURE II-4. VERTICAL PIPE CASTING

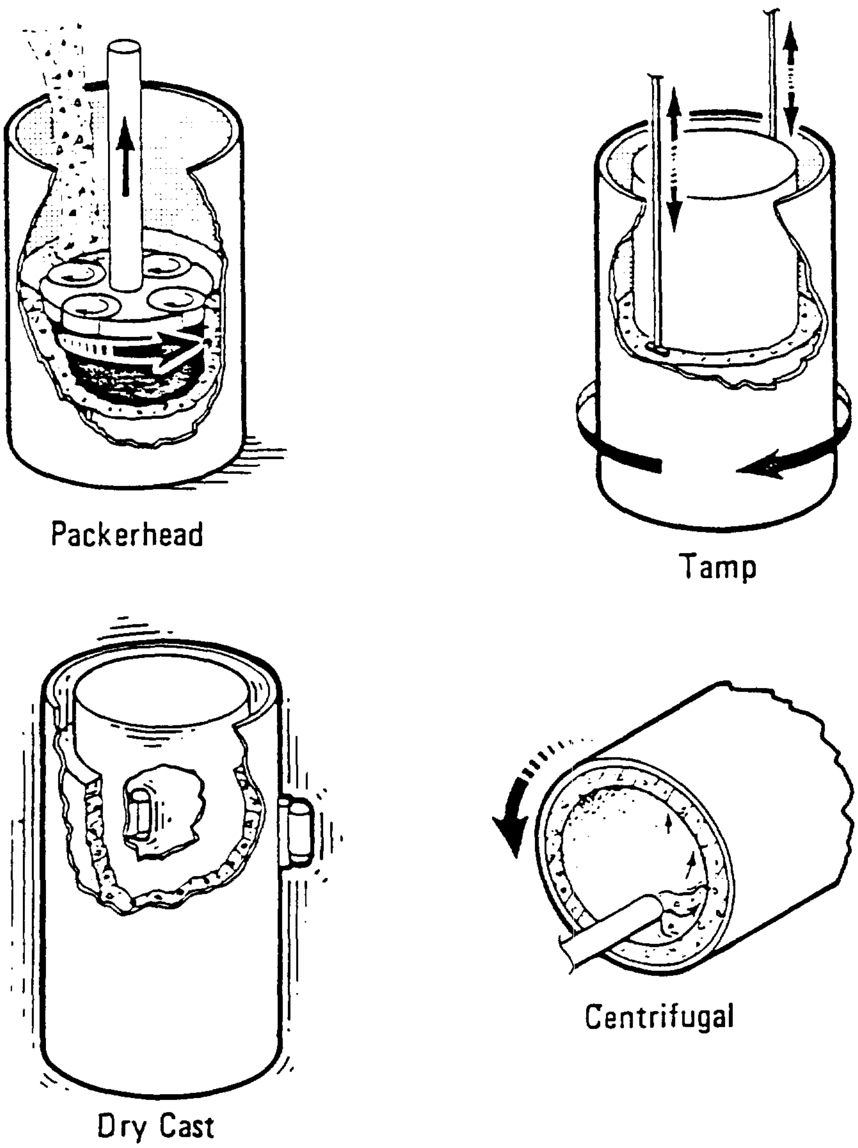

FIGURE II-5. FOUR MECHANICAL METHODS OF CASTING CONCRETE PIPE [8]
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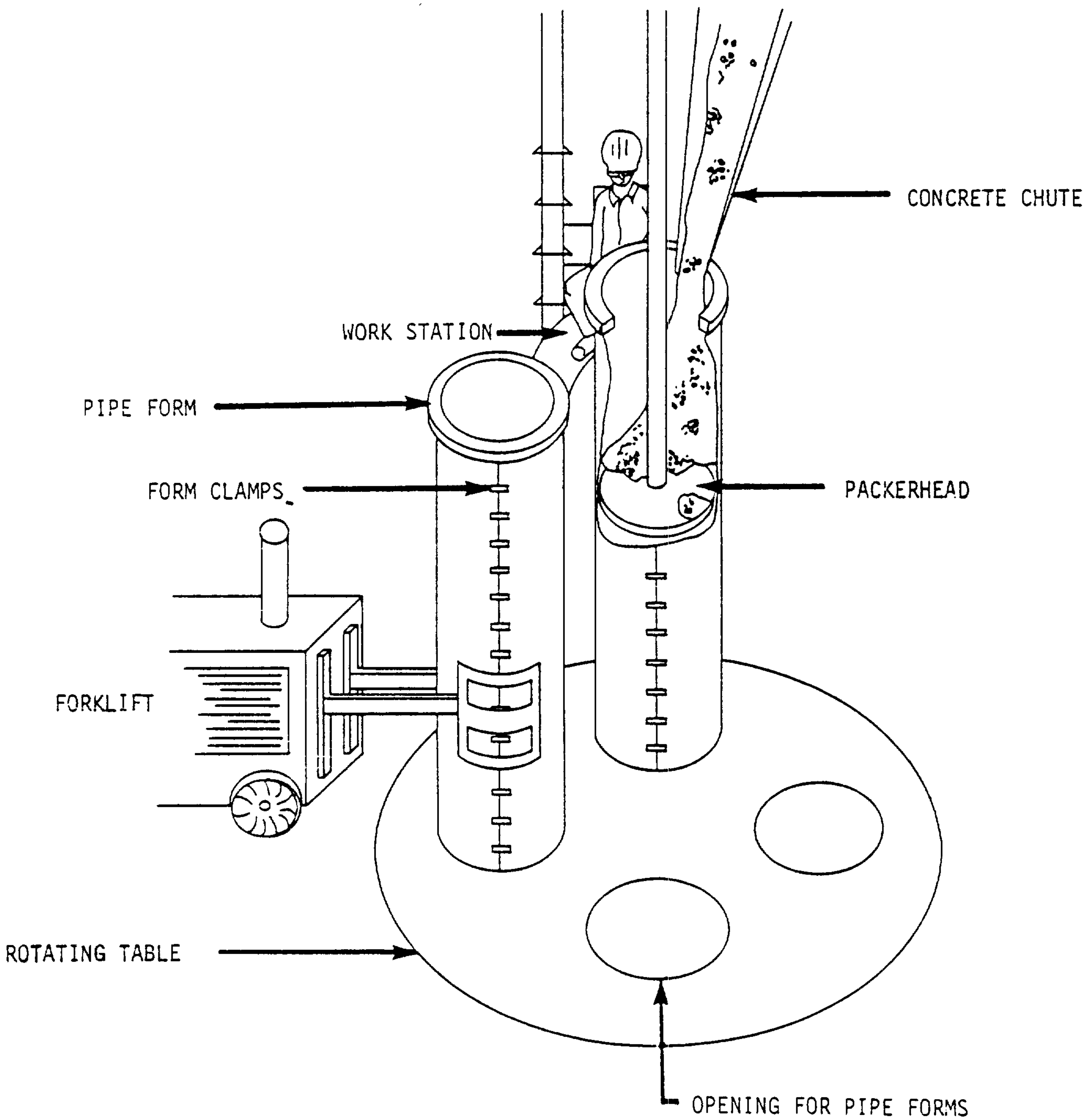

FIGURE II-6. SEMIAUTOMATIC VERTICAL PACKERHEAD PIPE CASTING SYSTEM per second (rps) while vibrating and depositing concrete, and at speeds up to 10-12 rps while "throwing" the concrete and compressing it against the rotating form. In the centrifugal process, excess water is removed, further lowering the water/cement ratio of the concrete.

Figure II-7 depicts one method of pipe spin-casting. In this method, the pipe form is assembled by bolting or clamping the halves together. The form is placed by hoist onto a rotating pipe machine. Horizontal pipe machines are usually constructed from groupings of auto/truck tires that serve to cradle and spin the form. In this figure, the rotating force is applied by overhead tires that spin the pipe form at the required speeds. Concrete is added by a movable extruder, operated by a worker who is positioned to visually inspect the centrifugal consolidation during the placement process. Internal finish work is usually performed by a hand-held, dowel-mounted trowel. A worker runs it in and out of the pipe orifice while the form is spinning.

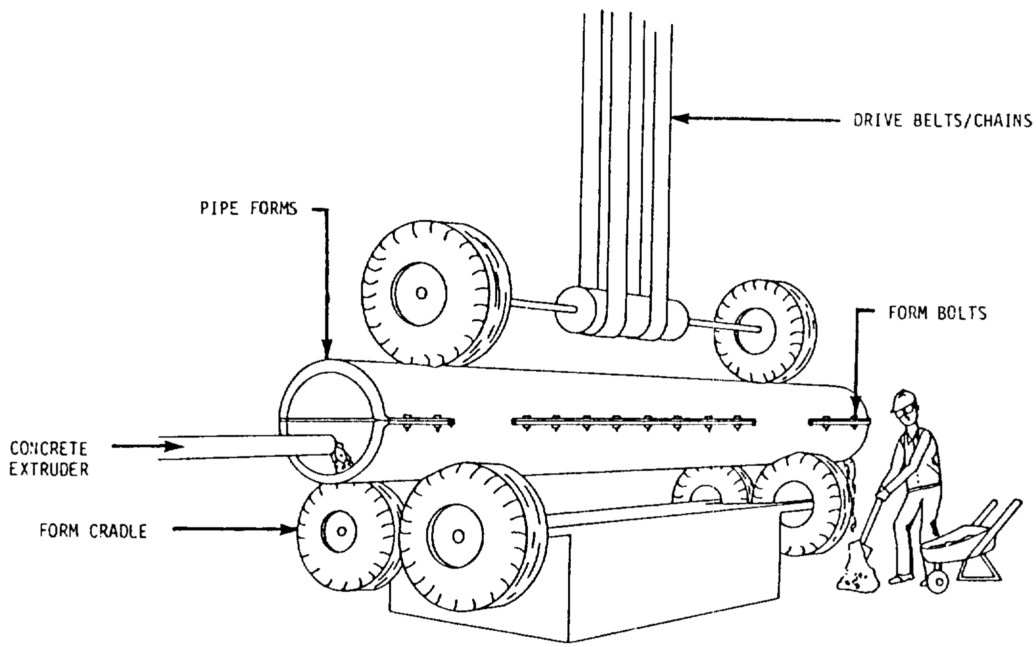

FIGURE II-7. HORIZONTAL PIPE SPIN CASTING

Casting large miscellaneous products is similar to the tamping, dry cast, or wet cast methods used for pipe manufacture; however, the form may be square or rectangular as for burial vaults or septic tanks.

6. Finishing

Wet finishing includes tasks such as screeding, floating, troweling, patching, rubbing, and cleaning surfaces not in contact with the form. Screeding is the back-and-forth motion of a strike off (a wood 2 by 4 or steel channel) resting on a screed guide to form the surface of the concrete to be finished. Workers may have to reach, bend over, and pull to perform this task. Floating, the smoothing of the surface with a wood, aluminum, or magnesium float, is manual work requiring bending, kneeling, and reaching. Troweling smooths and compacts the floated surface when the surface is hard enough to walk on without leaving indentations.

Additional treatment of the formed surface may take place after the form has been removed and the product has cured. This is particularly true for architectural panels, when the surface texture is important. Techniques such as grinding, bush hammering, sand blasting, water washing of retarded surfaces, or acid etching are used to produce a variety of desired architectural effects. Bush hammering is the roughening of the hardened concrete surface with a vibrating hammer, the head of which is serrated with a series of pointed teeth. Sand blasting is the high-pressure spraying of sand onto the exterior concrete surface to clean or smooth it. Water washing (up to 300 psi) is the flushing of cement paste that purposely has been retarded in setting to expose the surface of the aggregate. Acid etching serves a similar purpose, but does not expose as much of the aggregate. This procedure involves the mixing, dilution, and application of muriatic acid, an industrial grade of hydrochloric acid.

In some instances, precast concrete products are cut to length or have portions removed by sawing them with a concrete saw. This type of saw is similar to that of a carpenter's circular skill saw except that the blade size ranges from 1-3 feet (or more) in diameter. During repetitive operations, or when using larger blades, saws may be semiautomated and suspended overhead. The power source for the concrete saws may be electricity or pressurized air, although some of the smaller, portable models may be powered by gasoline engines. Most saws are not provided with a lower (exposed) blade guard.

7. Curing

Three fundamental factors in all methods of curing concrete are time, temperature, and moisture. Within limits, an increase in temperature shortens the curing period by accelerating strength gain. The time/-temperature relationship is not the same for all mixtures, materials, and conditions and is determined empirically.

The curing of many larger precast products is accelerated by radiant heat, steam, hot water, or hot oil. In some instances, the cast product is exposed to live, low-pressure steam within an insulated kiln or steam shed. Pipe or other products to be steam or heat cured will usually be transferred from the casting area to the heated shed by conveyor, fork-lift, hoist, or, in some instances, by rolling. The products remain in the steam shed for 2-8 hours (frequently overnight) before being removed and the form stripped. In some instances, the form is stripped before the product is steam cured. Large pipe is frequently enclosed (in the place where it was cast) by canvas, plastic, or other material into which steam or warm, moist air is introduced. Steam and hot water for accelerated curing procedures are usually generated at the plant by a low-pressure boiler and piped to designated locations prior to release into the curing shed. Occasionally, a chemical curing compound is sprayed on the finished surface of the concrete.

8. Form Stripping

Once a concrete product has cured sufficiently to be handled, it is necessary to remove it from the forms it was cast in or, conversely, to remove the forms from the product. The tasks and equipment used in form stripping operations vary considerably with the nature of the product. Reusable metal forms, such as those used during the manufacture of pipe, are usually handled by overhead hoist. The inner form is rigged to the crane and removed--a task made more difficult because the product frequently adheres to the form surface. In some instances, striking the form with a hard rubber mallet is sufficient to jar the concrete loose. In others, a hoist is used to shake the form and/or to pull the form free. Large pipe forms are frequently equipped with a means to collapse the internal form within the pipe bore. Workers enter the pipe bore to release retaining clamps. Rigging of the hoist to large form members requires that employees gain access to elevated areas. This may be done by ladder, rolling scaffolding, or climbing the form structure itself if it provides safe access. With low-slump, consolidated pipe, the mold is removed at the kiln prior to accelerated curing.

Flat products are removed from the mold by means of a vacuum lifter, or by lifting the product from the mold utilizing "lifting eyes" previously inserted in the product. Girders, beams, or other large, vertical products may have side forms to be removed before the product is freed from the forms. Bolts and other connectors are removed, and the side form panels pulled away or dropped to the ground.

Some concrete products may require dismantling of the forms for removal either because the form material will not be used again or because this is the only practical means of removing the completed product. Depending on the size and shape of the form, workers may perform the dismantling from the plant floor, from the elevated casting beds, from rolling ladder/scaffolds, or from the form itself. Workers will usually be performing their tasks on and among the equipment and material used during the form stripping process. Prybars, crowbars, sledge hammers, and wrenches will be used to pull nails and remove the spreaders, stiffeners, and bulkhead-retaining tie rods. Sledges and prybars will be used to force the separation of bulkheads from the product and/or other form structures. This frequently involves workers pushing or pulling on the bar until the adherence forces release, sometimes suddenly.

9. Material/Product Storage

Material storage in the precast concrete products industry follows a usage pattern typical to most manufacturing processes. Raw materials necessary to produce the product will be shipped and temporarily stored in a yard. Usually raw materials will consist of the basic ingredients of the concrete (cement, sand, aggregate), the reinforcing materials (reinforcing steel, strand, wire mesh, hardware), and a variety of ancillary materials (blasting sand, equipment maintenance materials, etching acids, etc.) necessary for the production of a finished concrete product.

The bulk ingredients for the production of concrete may be hauled in by truck and dumped in covered bays or, in smaller plants, a convenient place on the premises. Larger, more automated plants may yard considerable volumes of various sized aggregates and cement prior to transfer to mixers. Cement may be bagged, palletized, and stored in weatherproof areas or it may be delivered by bulk tankers and stored in silos. These 94-pound bags of cement may be stacked higher than a worker's head, requiring access to the upper levels. Reinforcing steel bars are usually received in banded lots of various lengths, ranging up to 40 feet or more. Prior to cutting to required lengths, the rebars will usually be stored on the ground on cribbing material. Spooled or reeled material (e.g., wire mesh) is frequently stored in stacked rows. The end spools are chocked to prevent rolling or shifting; second level spools are nestled in the spool interface. Since forklifts or mobile cranes will be used to move these heavy rolls, adequate access space between rows of stored materials should be considered.

Product storage methods vary considerably with the size and shape of the product. Small miscellaneous products are frequently produced in a variety of shapes at the same plant. Yard areas are usually limited, necessitating multilayered stacking of the pieces. Layers may be separated by cribbing and/or pallets to both protect the finished surface and to increase the load-bearing surface stability. Larger and heavier shapes, such as vaults and manholes, are frequently stacked with cribbing layers between them to provide access for forklifts or rigging material. Pipes and cylindrical products are stored in the manner described for rolls and reels. Pipes of the same size are stored in the same stack. Again, care must be taken to allow adequate access for materials handling equipment and to prevent stack shifting. Large pipes are usually stored vertically.

Discarded products, broken pieces, metal scrap from forms, reinforcement, tie-wire, wood scrap, nails, chamfer strip, rejected hardware, concrete, forms, and the remainder of unused raw materials can be found in plants in this industry. Many plants have a "bone yard" in which such discarded material is kept, pending burial or removal.

10. Materials Handling

Materials handling operations are performed throughout all phases of the production of precast concrete products. At the simplest (and frequently overlooked) level, employees lift, carry, push, or pull everything from concrete debris to wood form material to smaller, finished products. In fact, throughout the industry, manual handling is necessary to perform many of the tasks required in the production process, including:

- o Building and locating form and form material
- o Placing and tying reinforcing steel
- o Hand batching concrete
- o Casting (shoveling concrete)
- o Transporting moist concrete by wheelbarrow
- o Form stripping
- o Housekeeping and general cleanup
- o Handling and moving products.

Individual, small miscellaneous products may be loaded or unloaded by hand. When several small items of the same variety are to be handled, they usually are strapped and palletized. Larger products and concrete pipe require the use of lifting and unloading equipment. Architectural and structural products usually are large, bulky, and heavy, requiring the use of cranes and special loading and handling techniques such as "A" frame holders and wood and metal chocking for security, for bolting to the trailer bed, and for single-product loads.

Since precast concrete products and their components are heavy by their nature, the industry makes use of a variety of mechanical devices to assist in handling and movement operations.

a. Hoists and Cranes

For the most part, the types and varieties of hoists and cranes that are used in precasting operations do not differ significantly from those used in other industries. However, because of the weight of the material and products being moved, crane and hoist usage may be more prevalent.

Smaller plants may use rubber-tired cranes with hydraulic booms to move material and products around the yard, onto trucks for transport, and from the casting bed to the storage yard. These mobile cranes are prevalent throughout the industry for movement of yarded material and products. In most instances, the crane operator will work in tandem with other employees charged with the material rigging responsibilities. Products may be manufactured with integral picking eyes that facilitate proper rigging and load balance. In other instances, the rigging and hoisting will be performed on material necessitating new or single instance handling procedures. Load weights and balance points must be identified by the workers as part of the rigging operation.

Larger, more automated plants are likely to have semipermanent work stations and fairly repetitive product design. These plants are likely to use a number of overhead hoists. Overhead hoists may run on tracks and be located to service multiple operations in the manufacturing process. Larger overhead cranes are controlled by an operator located in the crane cab. Work stations may be serviced by smaller, 2- to 10-ton jib cranes. Although a jib crane may be mounted on an independent vertical column, the horizontal "jib" is most frequently affixed to a vertical column integral to the plant's structure. Employees at the work station operate the jib crane by using a wire-attached pendant control, which allows the worker to control the up/down and back/forth movements, or other functions of the crane, from the floor of the plant. In these instances, the hoist operator is usually the same worker that performs the rigging. He is also likely to accompany, with hands on, the load being transported to its destination.

Straddle carriers are large, four-wheeled, wide-spaced, high-legged movers that straddle large products (such as girders, planks, or other structural elements) pick them out of forms and move them. This open-framed machine, basically square in configuration, hoists and carries the load within a large open bay between the four wheels on which it travels. The operator's cab is located on the extreme left-hand side between the front and rear wheels. Loads suspended in the bay often obscure the driver's view of the right side wheels. The machine ordinarily moves at about 2 miles per hour (mph) and has a maximum speed of about 10 mph.

b. Forklifts

Many of the palletized raw materials and finished products used in precast plants are moved by forklifts. Fork extenders may be used to increase the bearing surface of the forklift. In some instances, a jib may be added to the forklift to convert it to a small, movable crane. Pipe and other circular products are moved by forklifts with specially designed long forks or fitted forks with curved surfaces to cradle the product. Some forklifts are equipped with clamping forks used for attaching to and moving forms or other compatible shapes. The power source on forklifts is most frequently propane or diesel fuel.