CASTING FERROALLOYS

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ABSTRACT

The importance of having a "good system" for the casting of ferroalloys is stressed, a comparison is made between ladle practice and the skimmer practice in tapping ferroalloys. Also the use of various tapping and casting methods are described namely, Stack Casting, Molds, Casting Machine, Casting Wheel, etc.

The advantages and disadvantages of each of the above methods and practices are given. In some cases, the economic aspects of a given method or practice are given based on the author's experience.

Figures are included describing the various casting methods and practices. The use of the conventional stack casting method is not recommended. The author makes clear that there is no "one best" casting method. Each plant has its own methods and experiences; hence it is difficult to make a general rule.

It is a fact that in the future, the customers for ferroalloys will be more demanding. Therefore, the ferroalloys producers must utilize the casting practice that provides a quality product, that still can be sold at a profit.

CASTING FERROALLOYS

When a plant is projected to produce Ferroalloys, generally, principal attention is given to furnace design, forgetting some very important aspects like the handling of raw materials and finished products. Within the handling aspects, there is a critical operation, namely, the tapping to casting of metal.

The way a ferroalloy is cast will have great impact on different aspects of production:

- The cleanliness of the final product.
- The amount of fines generated.
- The cleanliness of the Plant.
- The quality of the final product.
- The cost of product preparation.
- The cost of casting itself. etc...

Finally all these will affect the economic results of the operation.

A good design of the tapping system is very important; often the operation of a furnace is adversely affected when for some reason it is not tapped on time, due to some deficiency in the tapping method. A furnace must be independent of the casting system.

There are many methods of casting, some are applicable to any ferro alloy, others not. In the presentation, we refer mainly to manganese alloys.

In this presentation, only the tapping of "single tap hole" furnaces are considered; we will comment briefly on furnaces constructed with "double tap holes", with different levels for metal and slag.

The systems most frecuently used are the following:

1. - Tap from furnace to ladle with slag overflow. (Fig. 1)

1.1 - The metal is poured from the ladle to stack casting beds.

1.2 - The metal is poured from the ladle to molds (Fig. 1).

1.3 - The metal is poured from the ladle to a casting machine (circular or belt type) Fig. 2.

2. - Tap from furnace through a skimmer (Fig. 3).

2.1 - From skimmer to ladle once the metal is in the ladle it can be cast in any of the alternatives described in item # 1.

2.2 - From skimmer to stack-casting beds. (Fig. 3).

2.3 - From skimmer to molds (Fig. 4).

2.4 - From skimmer to casting machine (Fig. 5).

1 - TAPPING WITH LADLE

Tapping in this way has two great advantages:

a) Stream of liquid metal can be better controlled.
b) Casting temperature can be better controlled.

In comparison with other methods, ladle cast metal will be cleaner, more dense, more uniform in size, with fewer fines generated overall.

The main disadvantage in the use of ladles is that their handling require some type of heavy equipment such as overhead cranes, ladle cars, ladle dumpers, etc. This type of equipment is expensive and requires man power for the operation and maintenance.

The use of ladles in handling manganese alloys is not normally done, as many people prefer tapping directly into a skimmer. The use of ladles is common in handling silicon alloys especially when it is necessary to submit the metal to a refining step.

In the basic design of the ladle casting method, it is very important that the ladle capacity be compatible with the furnace production rate, the type of product manufactured, and the tapping frequency. Of equal importance is the selection of cranes, or other ladle handling equipment, of sufficient capacity to handle a full ladle. Further, it is important that the casting area be optimized, so that buildings costs are minimized and at the same time to have an adequate area available for molds.

As previously mentioned, the use of the ladle casting method represents a substantial investment because it is necessary to have a large crane, as well as a large casting area, within a building with heavy columns to support the crane and fully loaded ladle.

The present cost of a 50 tons. over head crane, and a building to house it and the casting area, is estimated to be $ 1,250,000.00 US. Dlls.

We have a very favorable arrangement at our plant in Mobile, Alabama (Fig. 6). Here the furnace, rate 40 MVA, produces Ferromanganese and Silico-Manganese; originally it was designed for pig iron. A ladle of 18 tons. capacity receives the metal with the slag over flowing and immediately granulated with water; the ladle sits in a hydraulically operated dumped fixed to the flat bed of a railroad car; the dumper is remotely controled from the cab of the locomotive used to move the railroad car; when the tapping operation is completed, the railroad car is moved to an outside casting area approximately 100 meters from the tapping area; here the slag is skimmed from the top of the ladle; the railroad car is moved to a platform scale when the gross weight is obtained; the railroad car is then moved to the metal casting area where the metal is poured to stack casting beds located very close to the railroad trucks. After the metal is poured into the casting beds, the railroad car is returned to the platform scale where a tare weights is obtained. Now we can determine the weight of the tap. With this method of casting:

- The area required for casting is quite small.
- There is no need for an overhead crane.
- There is no need for a building to enclose the casting area.
- It is rather easy to keep the casting area neat and clean.
- The entire skimming and metal casting process, which is rather dirty, takes place far from the furnace area and near close by the metalcrushing and screening plant. The casting beds are prepared using fines of the same metal being produced.

The entire operation, including tapping, ladle handling and preparation weighing, casting, as well as cast-bed preparation is done by a crew of five men per shift, which we consider our standard.

Generally, each plant has developed its own method in the lining of ladles. Various materials are used for ladle linings such as refractory brick, clay, cement, refractory paste, sand, granulated slag, carbon paste, etc.

Generally the life of a well-lined ladle is about 60 taps; after that, the ladle usually requires only spot patching. The total repair of a ladle is done infrequently; some ladles have been in service for several years, requiring only spot patching as previously mentioned.

Quick movement of the ladle filled with molten metal is very important in obtaining good results. The various movements must be made as fast as possible to prevent the slag covered metal from becoming cold with the formation of scrap that must later be reprocessed. It is possible to establish a relationship between the quantity of scrap (remelts) generated and the time required to empty the ladle at the metal casting area (Fig. 7). This curve is in accordance with our experience in the manufacture of Silico-Manganese. The richness of the remelts varies in accordance with the practice of each plant. In our case, the metallic content of the remelts produced is approximately 10%.

In an operation "with slag" such as Ferromanganese or Silico-Manganese, it is very important to skim the slag from the surface of the metal pouring the metal from the ladle into the casting beds. This maneuver has to be carried out very carefully so as to remove virtually all the slag while at the same time being carefull not to drag metal along with the slag as "skimmings".

Once the slag is eliminated, the operator of the equipment used to pour the metal from the ladle into stack a casting beds, into a molds, or into a casting machine plays an important part. His ability will reflect the final product uniformity, its density, its size, as well as the quantity of fines generated.

As a general rule, the use of a ladle reduces the generation of fines. This is true because the metal flows from a ladle and the metal temperature can both be controlled. These can not be controlled when a furnace is tapped directly to its final receiver (mold, casting machine, etc.). These advantages have been offset when a method such as that practiced by Mizushima Ferroalloys is used; here, the metal is tapped directly from the furnace through a double skimmer into molds of a casting machine.

2 - SKIMMER

The use of a skimmer in the tapping operation has one great advantage in that heavy equipment, such as a large crane, is not required for its handling.

There are two main desadvantages:

a) On occasion, metal can be contaminated with slag if the skimmer is not working properly.

b) The generation of remelts can be excessive if the lengths of the runners are too long.

As mentioned previously, this method does not require a crane of large capacity or other heavy machinery to handle the tapping equipment used. It does require additional space for a skimmer and for rather lengthy runners. It is advisable to have 8 to 10 mts. of runner between the furnace taphole and the carbon gate of the skimmer (Fig. 3); after this, the length of the runners will depend on where the metal and slag are to be cast. It is recommended that an attempt be made to minimize the lengths of the runners, so as to reduce the quantity of remelts generated as well as reduce the usage of runner lining material and the labor to line the runners.

The skimmer can be in a fixed position like the ones that we use in our small furnaces or portable like the ones that Elkem Metal use in Marietta or Temco in Tasmania.

A well managed skimmer practice can produce a clean alloy of good quality; however, it does require experienced rather skilled workers.

Traditionally the skimmer practice has been used only where the metal was cast into molds or into stack casting beds; now the metal from the skimmer is being cast directly to cast machines; in this case it is advisable to cast through two skimmers in series to make certain that the metal is slag-free.

Furnaces with two tap holes at different levels, one for metal and one for slag, similar to the ones that we have in our Tamos Plant were meant to have only metal tap through one taphole and slag tap through the other taphole; but in practice there are many times when slag flows from the metal, perhaps five percent of the time. This would not present a problem when the ladle practice is used; however, it does present a problem when tapping directly to molds, stack casting beds or casting machines; therefore it is necessary to install a skimmer so it is readily available, should slag flow through the metal taphole. In either event, the furnace must be completely tapped and not plugged should slag appear in the metal taphole, as early plugging of taphole will have an adverse effect on furnace operation.

The recovery of "remelts from the runners as well as from the skimmer should be done every shift or in any event every 24 hours, so that the material can be remelted in a systematic manner. If this is done, the smelting process will not be seriously affected.

Any delay in the use of remelts is hard to overcome, as the smelting furnace normally does not accept high amounts of remelts. When a furnace is producing Silico-Manganese, it is easier to remelt this type of material.

There is not general consensus in favor of the skimmer practice or the ladle practice, each plant has developed its own practice, and the one that suits it purposes, where as, it might not at all acceptable or adaptable to another plant. In all cases, the objective is to "Obtain a final product of the highest quality at the lowest possible cost".

STACK-CASTING, MOLDS, CASTING-MACHINE

Whether the ladle practice or the skimmer practice is used, the metal is usually cast in one of the following ways:

STACK CASTING

Is the easier way to receive the metal.

In their simpliest form fabricated bins constructed of steel plates up to 2-1/2" in thickness. Steel plate is used for floors as well as for walls of the bin. Some plants use only alloy fines as a bin floor; in this case the concrete must be reinforced to resist the heat as well as the wear from the bucket of the front end loaders used to reclaim the metal. In Temco,Tasmania, stack casting is used with good results; here the bin walls are very strong being constructed of corrugated steel (Fig. 3).

As the stack casting method is well known it is not necessary to describe it further.

Problems.-

The stack casting method does present some problems:

1.- Using the skimmer practice, it is difficult to determine exact production weights. Usually the correct weight is not known until the metal is shipped. However, with the ladle practice, gross and tare weights can be obtained; then,the exact weight of metal poured into the stack casting beds can be obtained by difference.

2.- A lot of fines are handled, first to form the beds and later in handling the product. Several problems result in handling these fines:

- Excessive front end loader time is required.
- Large quantities of dust are generated which lead to product loss, contamination, electrical equipment problems, poor house keeping, and unsanitary working conditions.

3.- Wear and damage to the front end loaders used in reclaiming the metal is high; even though the loaders are well constructed and very rugged since working conditions are severe; damages to loaders include burned or cut tires, broker transmissions, worn and broken buckets. In brief, the maintenance of front end loaders is expensive. Our experience with front end loaders used in stack casting is that the maintenance cost approximately 20% per year of the total cost of the machine.

4.- When metal tapped directly from the furnace, it is difficult to control the thickness of the cast metal. In the area where the metal stream first enters the casting beds, the metal is usually very thick.

As the metal spreads out, the layers become very thin at the edges. Some operators are trying bins of different forms to avoid the above but have not been completely successful in their efforts.

5.- When for any reason, slag becomes trapped between the layers of metal, it is very difficult to remove.

The installation of stack casting beds for a Ferromanganese producing 50,000 metric tons. of alloy per year is approximately $ 600,000.00 U.S. Dlls.

Advantages.

The stack casting method has certain advantages which are attractive to some companies.

1) Relatively low operating expenses

2) Low Manpower requirements

3) Method does not require the use of a large overhead crane and associated building costs.

The experience at our Mobile Alabama Plant where we have our furnace has been favorable. Here there is plenty of space for stack casting which is done outside some distance from the furnace and we produce only one kind of ferroalloy at the time. On the other hand our experience at our Tamos Plant has not been fully satisfactory, as we have seemed to realized all of the disadvantages and not realized fully all of the advantages.

However, it is costly to radically change from our present method to another; nonetheless, studies with this in mind are underway.

M O L D S .

Usually molds are used in casting alloys of Silicon either using a ladle or tapping down a runner directly into molds. In Casting alloys of FeMn, SiMn cast-iron molds are not absolutely necessary.

There are various types of molds, all generally of cast-iron, some with side bars of cast-iron with bottoms made of refractory material: In Fig. 8, three types of molds are shown. The alloy cast into molds is normally very clean.

Advantages.

1) Clean metal
2) Lower generation of fines
3) Less dust in the atmosphere
4) Better control of quality
5) Better control of production weights
6) Cleaner plant.

There is a variation of this system in which FeMn fines (or SiMn) are placed on the floor and formed into the shape of molds.

This of course provides a "mold" less expensive than a cast-iron mold. This method works well when used with ladles, or when the level of the furnace taphole is no more than two feet above the level of the molds made of fines. This method is not as clean as the cast-iron mold method but appears to offer more advantages and fewer disadvantages than the stack casting method. The advantages and disadvantages of the method using molds made of fines are similar to those for molds made of cast iron.

Disadvantages.

1) Investment.

At the present time, cast iron in molds cost approximately $ 0.55 per Kg. of mold. The ratio of mold weight to cast Ferromanganese weight is 2.7 therefore, the cost of molds is approximately - - - $ 200,000.00 US. Dlls. plus instalation cost.

2) High Maintenance.

When ladles are not used, mold wear damage is rather severe especially to the one nearest to the furnace. Mold life in the manufacture of FeMn is approx. 1500 - 2000 tons. of FeMn per mold if ladle is not used.

3) High Operating Expense.

To remove the solidified casts from the molds and to prepare the molds for the next tap require extra labor; further, a spray of carbon base material is applied to each chill; this is also an added expense. A furnace producing 160 M.T. of FeMn per day will require the preparation of 50 molds per day.

4) Tap thickness is hard to control when the furnace is tapped directly into molds; the molds nearest the furnace will fill more so than those farther away. This can be overcome when the ladle practice is used.

CASTING MACHINE

There are three well known types of casting machines.

a) THE CIRCULAR TYPE (CASTING WHEEL)(Fig. 2) in which square or rectangular molds are mounted over a horizontal wheel that can be moved in two directions, that is, forward or backward. There is a fixed position at which the solidified metal is dumped from a mold (temporarily raised) as the wheel rotates past this fixed spot.

This type of equipment is manufactured by Demag, Elkem and Tanabe. At the present time there are several installations in operation for casting FeMn and SiMn.

Since the wheel can move backward and forward, the operator can control the mold thickness with good precision. To my knowledge there is no place where metal is tapped directly from the furnace into a wheel such as in the manufacture of calcium carbide. The technology would be advanced considerably if it were possible to tap directly into a casting wheel thereby providing an advantage over the "inclined belt" casting conveyer which is a more complex piece of equipment when compared to the casting wheel.

The investment cost of a casting wheel with capacity of 45 tons. per tap of FeMn is approximately $ 900,000.00 U.S. Dlls.

Advantages.

1) Clean metal of good quality
2) Metal of uniform thickness
3) Low generation of fines
4) Dense metal
5) Possible elimination of crushing operation
6) Less generation of dust
7) Cleaner plant.

Disadvantages.

1) More space is required for a tapping area
2) No experience of tapping directly from the furnace, needs ladle
3) High operating and maintenance costs
4) High capital investment cost.

b) MOLDS MOUNTED ON TOP OF CARS.

Another system of casting into molds consists of molds mounted on top of cars that move lineally at the same time that they are being filled (Fig. 9). After the metal is solidified, the metal is dumped from the molds by tilting them at a fixed dumping point.

This system is similar to the one described in Item a) but simpler in its mechanism, although not as flexible. Usually the cars are moved at a slow speed by means of a winch. Normally the metal is cast from a ladle clamped in a tilting or dumping device. First one mold is stationed below the ladle spout, filled and so as to provide room for the second mold, etc. until the ladle is empty. Although this system is usually used with a ladle, I believe that it can be adapted to tapping directly from the furnace as is done with Calcium Carbide.

Advantages.

1) The tapping space requires a limited area
2) Clean metal is produced
3) Dense metal is produced
4) Metal of good quality
5) May be possible to produce lump sizes without crushing

6) Clean plant.

Disadvantages.

1) Limited flexibility
2) High operating and maintenance costs
3) Crushing required for smaller sizes, there by increasing the generation of fines.
4) Relatively high capital investment costs.

c) CASTING MACHINE - INCLINED BELT TYPE.

A casting method utilizing a casting machine designed with an inclined travelling belt or chain conveyor is frequently used in Japan.

Japan Metals and Chemicals and Mizushima Ferroalloys for example both use this type of a casting machine (Fig. 5). Generally the metal is cast from a ladle to the casting machine; however, Mizushima has developed a method whereby the metal is tapped directly from the furnace to the casting machine. This of course offers many advantages over the one utilizing a ladle.

This type of a casting machine must be equipped with a variable speed drive to allow for rate of flow of metal from the furnace. A well designed casting mold eliminates the need for a crushing operation; the metal needs only be screened, hence, the generation of fines is minimized. Usually a casting machine of the type used in Japan is designed for the production of specific sizes for specific customers.

It has been stated that this type of casting machine is costly to operate and maintain; however, the present design of the Japanese (Tanabe - Mizushima) is in the advanced stage, and according to the users, the operating and maintenance costs are economical (we have no actual data).

Advantages.

1) The final product is clean and uniform in size
2) Low generation of fines
3) Control of quality is good
4) Control of production weights is good
5) Small inside space for casting is required.
6) Partial elimination of crushing step is possible.
7) Clean plant.

Disadvantages.

1) High investment cost, at the present time, the cost of a casting machine to handle the production of a 18 MW furnace is estimated to be in the order of 1.4 million U.S. Dlls.
2) The operating and maintenance costs are in doubt.

In the table # 1 we have prepared a conventional comparison among the stack casting, mold, casting wheel and casting machine practices.

C O N C L U S I O N S

LADLE OR SKIMMER.

A ladle is indispensable when a refining operation is necessary, or when the metal must be removed some distance for casting as we do in our Mobile Plant. Also, when the practice calls for tapping into molds and at the same time, one does not want to tap directly into them, the only resource is the use of ladles of course, some plants use ladles for reasons of their own, not giving consideration to any of the above.

The use of a skimmer has the advantage in that metal passing through a skimmer can be tapped directly into molds of a casting machine as is done at Mizushima.

STACK-CASTING, MOLDS, CASTING MACHINE.

I definitely do not recommend stack casting unless it can be done at a distance from the furnace area as is done in our Mobile Plant.

With respect to the other casting methods, it is defficult the best option, as each one has certain advantages and disadvantages.

In my judgment the practice of using stationary molds in casting alloys of manganese will eventually disappear, but their use in the casting alloys of silicon will continue at this time, the casting machine in the form of a belt conveyor appears to offer the most advantages; it can accept metal directly from a skimmer, it can receive metal flowing at different velocities, as it is equipped with a variable speed drive, better control of metal size is obtained, the need for crushing the alloy is virtually eliminated which, in turn, brings about a reduction in the quantity of fines generated.

Again, in my judgment, the future will see an absolute need for the use of casting machines if one is to deliver a quality product which is essential in order to compete in all markets.

ACKNOWLEDGEMENT.

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REFERENCE.

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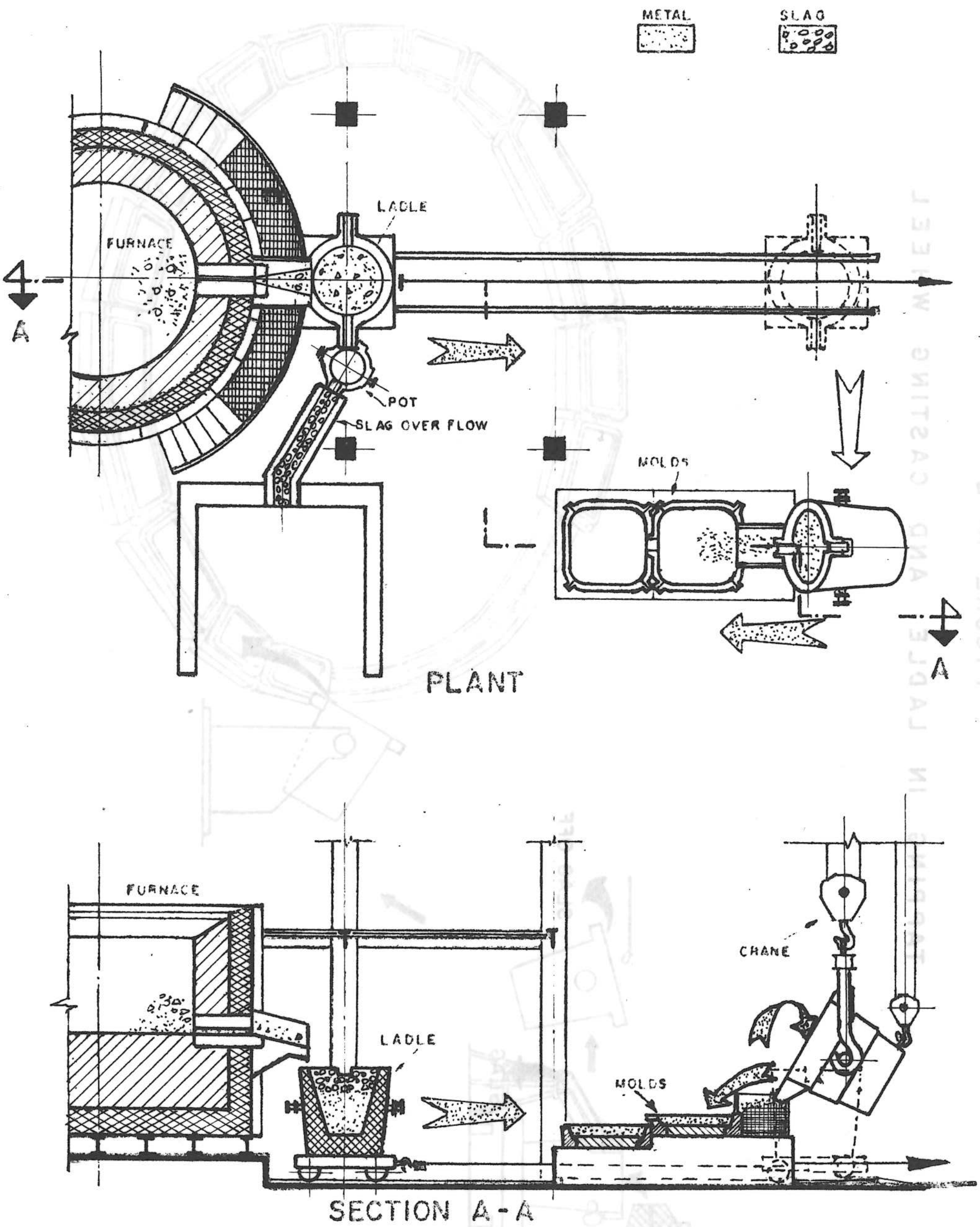
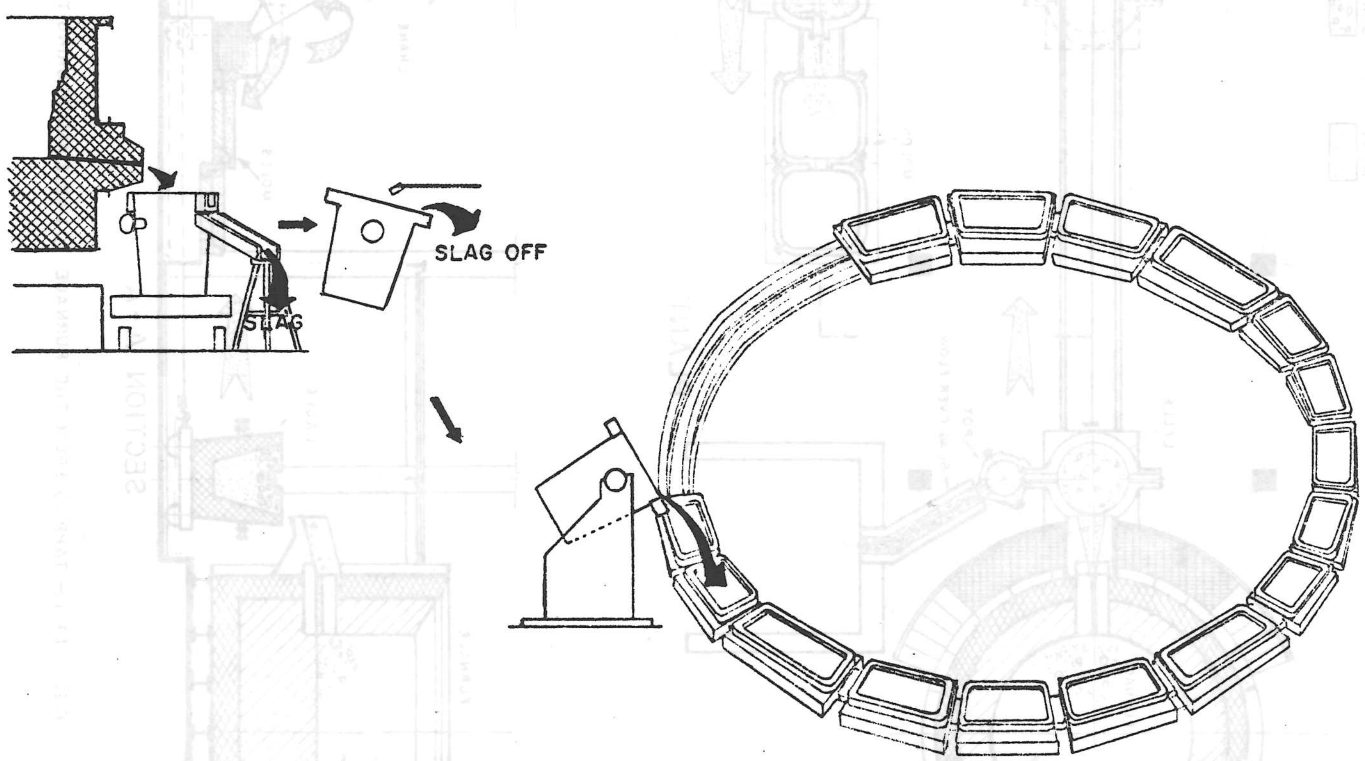


FIGURE Nº 1.- TAPPING FROM THE FURNACE TO LADLE AND POURING TO MOLDS.

FIGURE Nº 2

TAPPING IN LADLE AND CASTING WHEEL



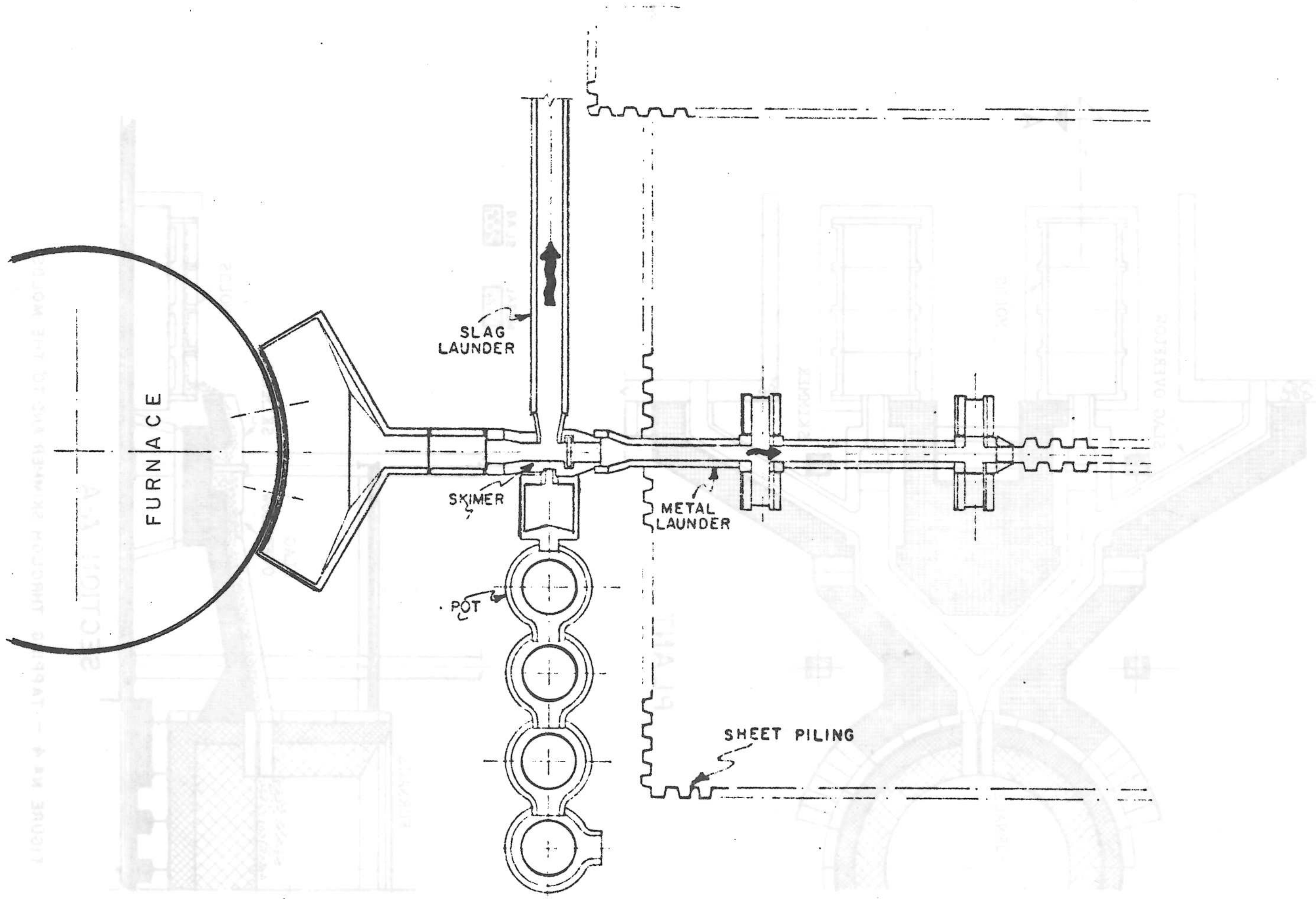
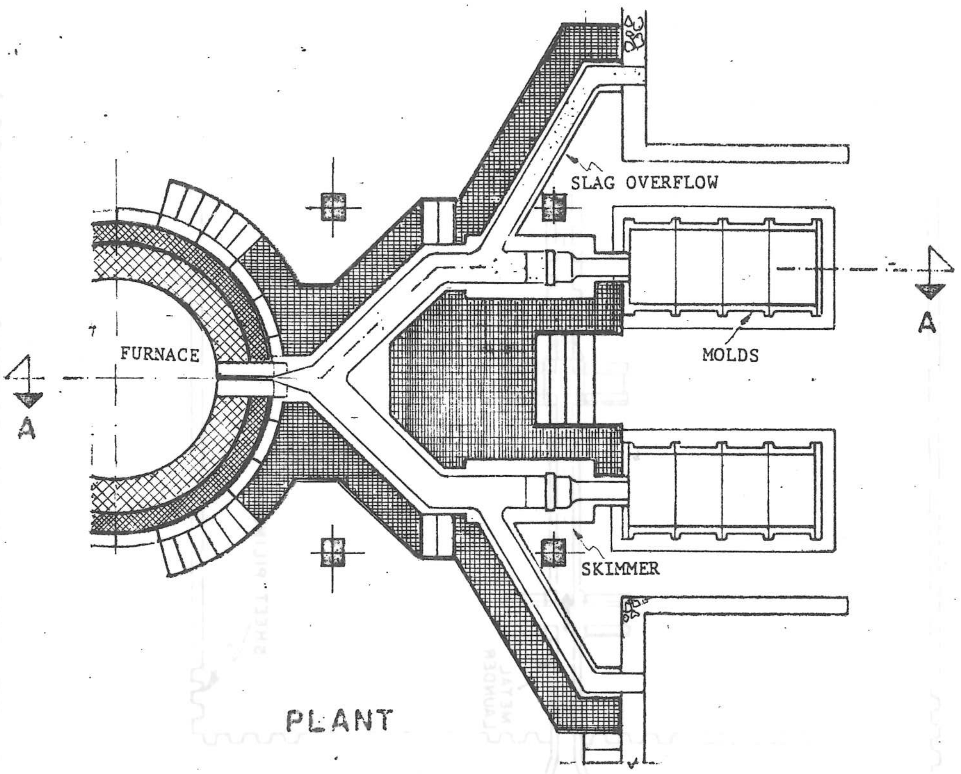


FIGURE Nº 3 TAPPING WITH SKIMER AND STACK CASTING (TEMCO)



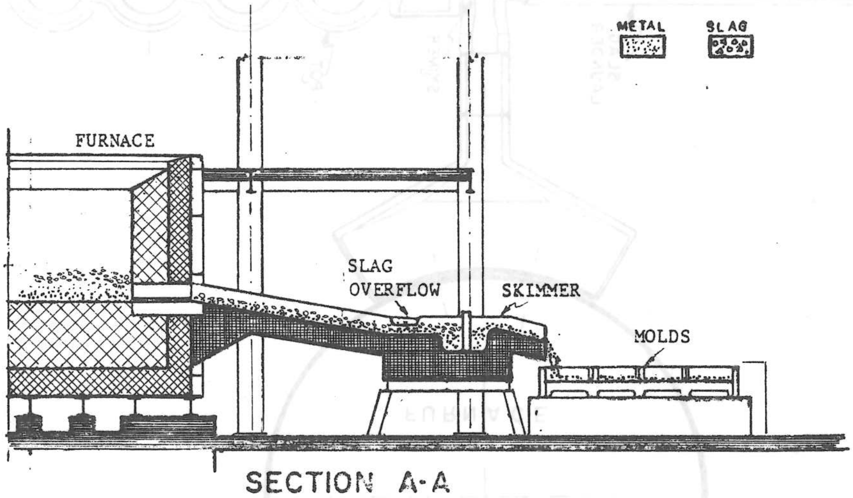


FIGURE Nº 4 .- TAPPING THROUGH SKIMMER AND TO THE MOLDS.

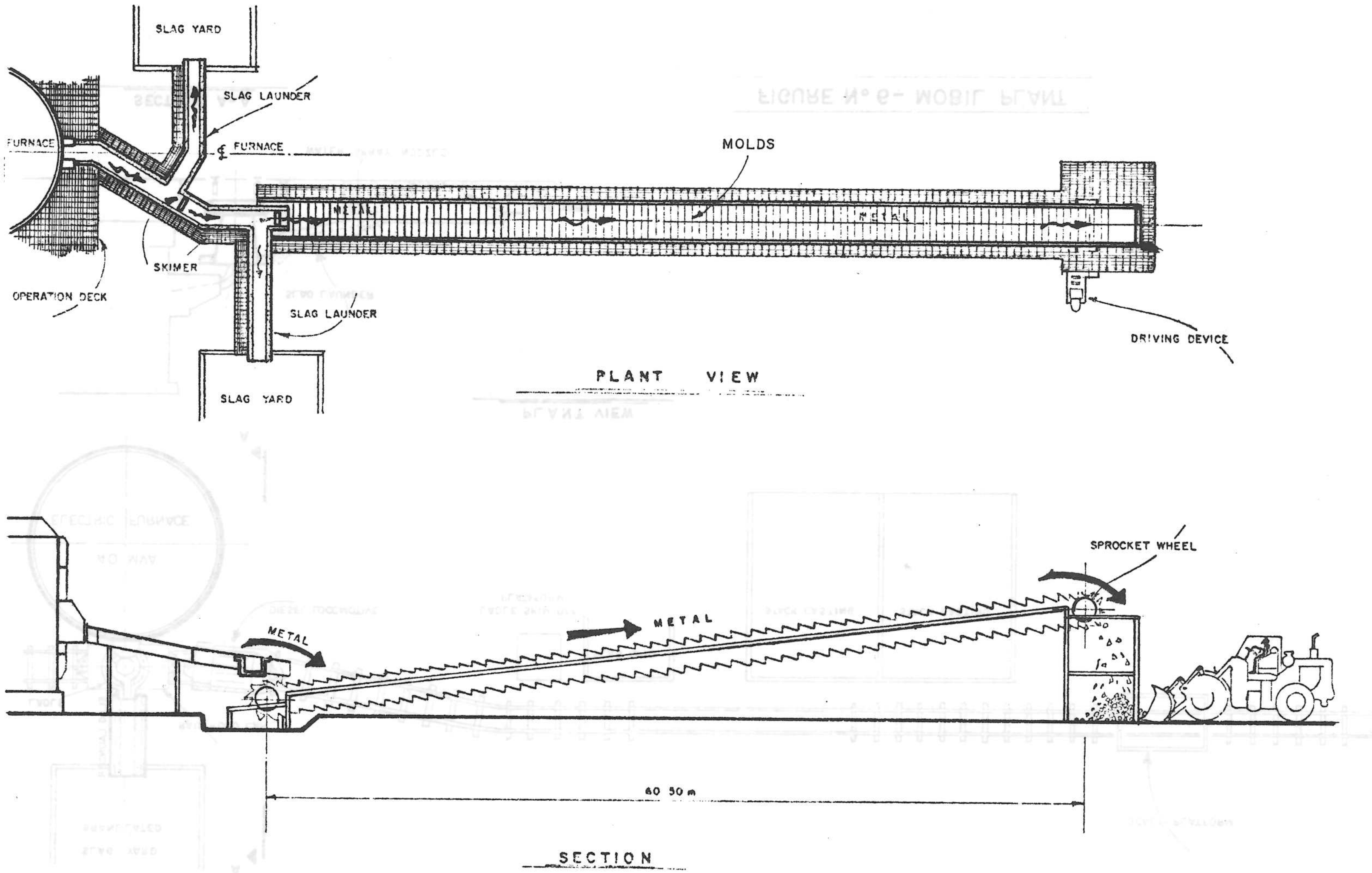


FIGURE No 5 – TAPPING WITH SKIMER AND CASTING MACHINE (MIZUSHIMA) .

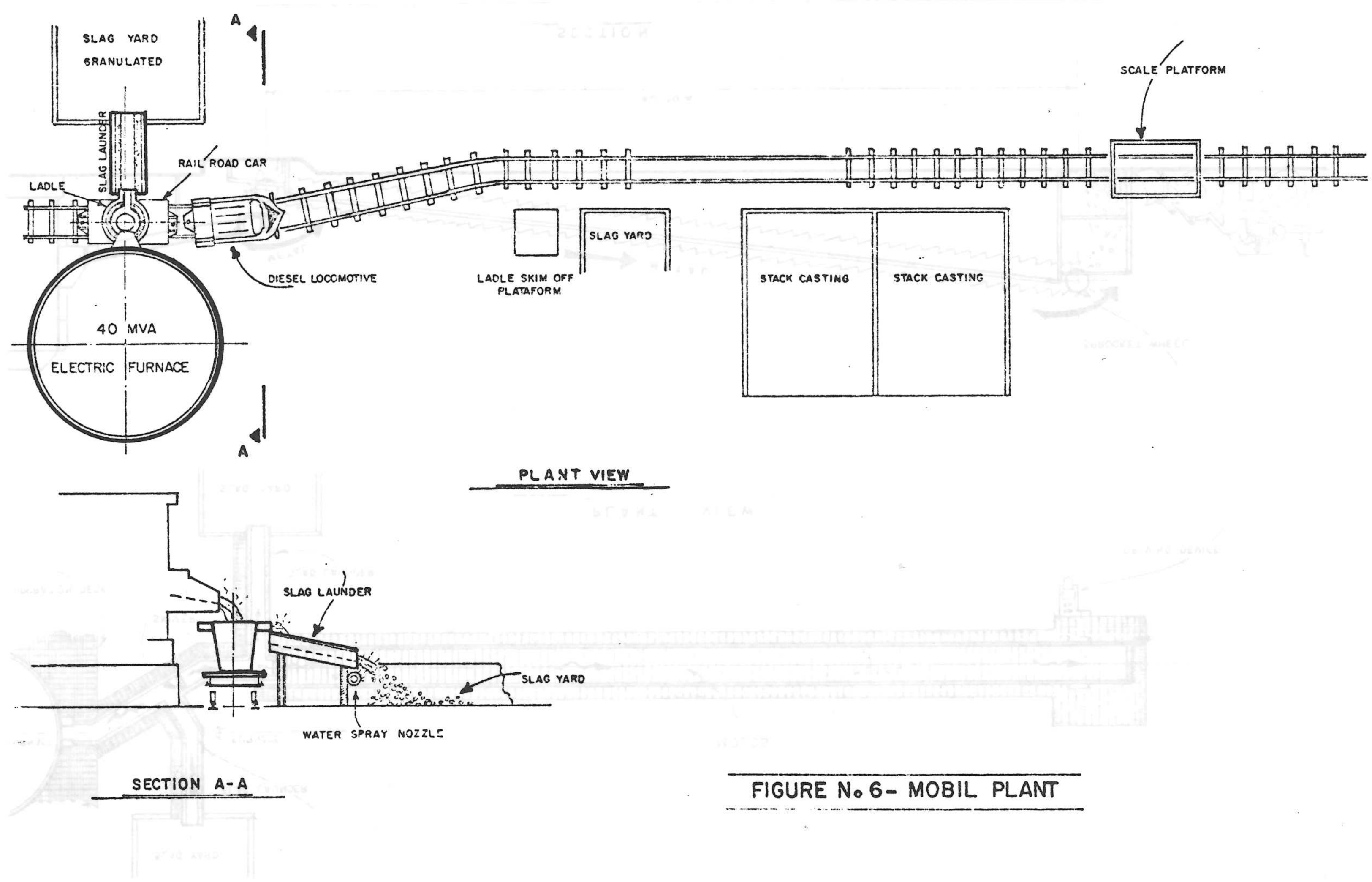
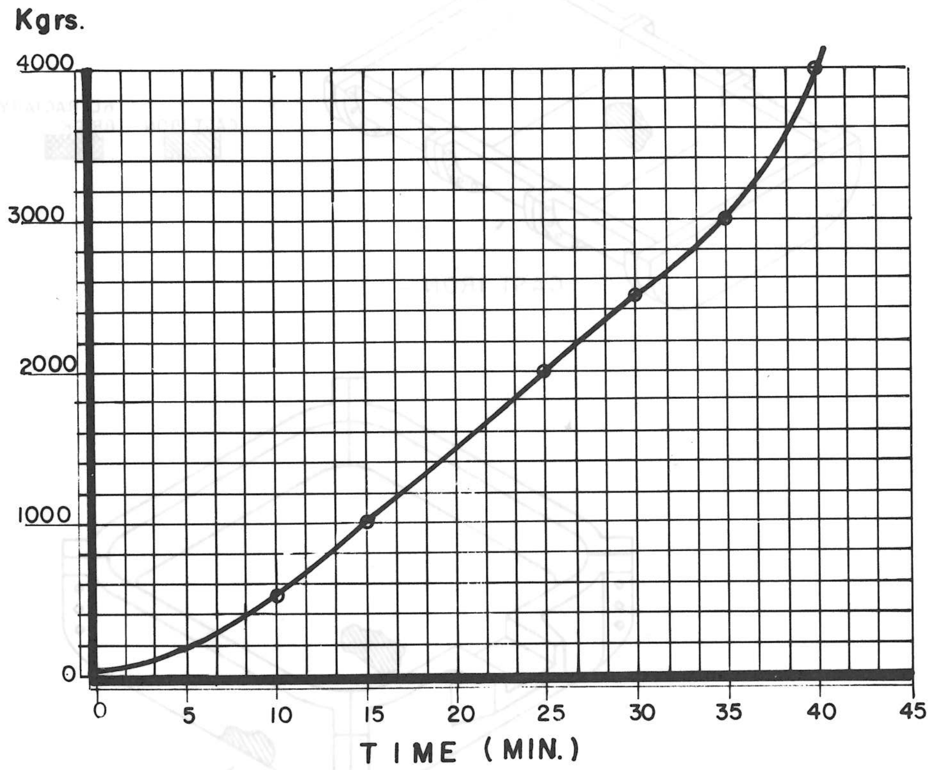


FIGURE No 6- MOBIL PLANT



RATIO BETWEEN THE AMOUNT OF "REMELTS" GENERATED AND THE TIME SINCE THE - FURNACE IS PLUGED UNTIL THE LADLE IS POURED.

FIGURE - 7

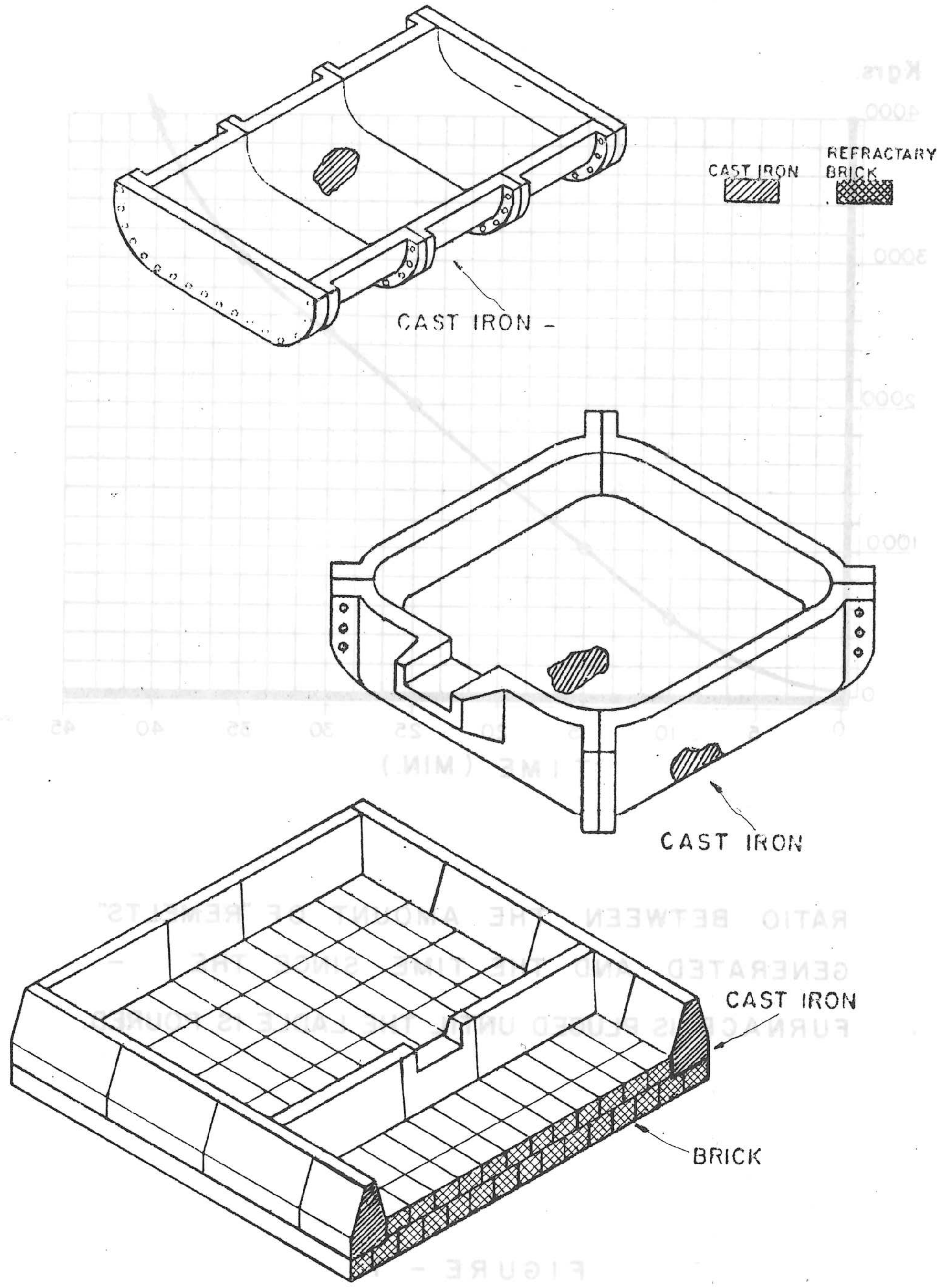


FIGURE Nº 8.— THREE DIFFERENT TYPES OF MOLDS.

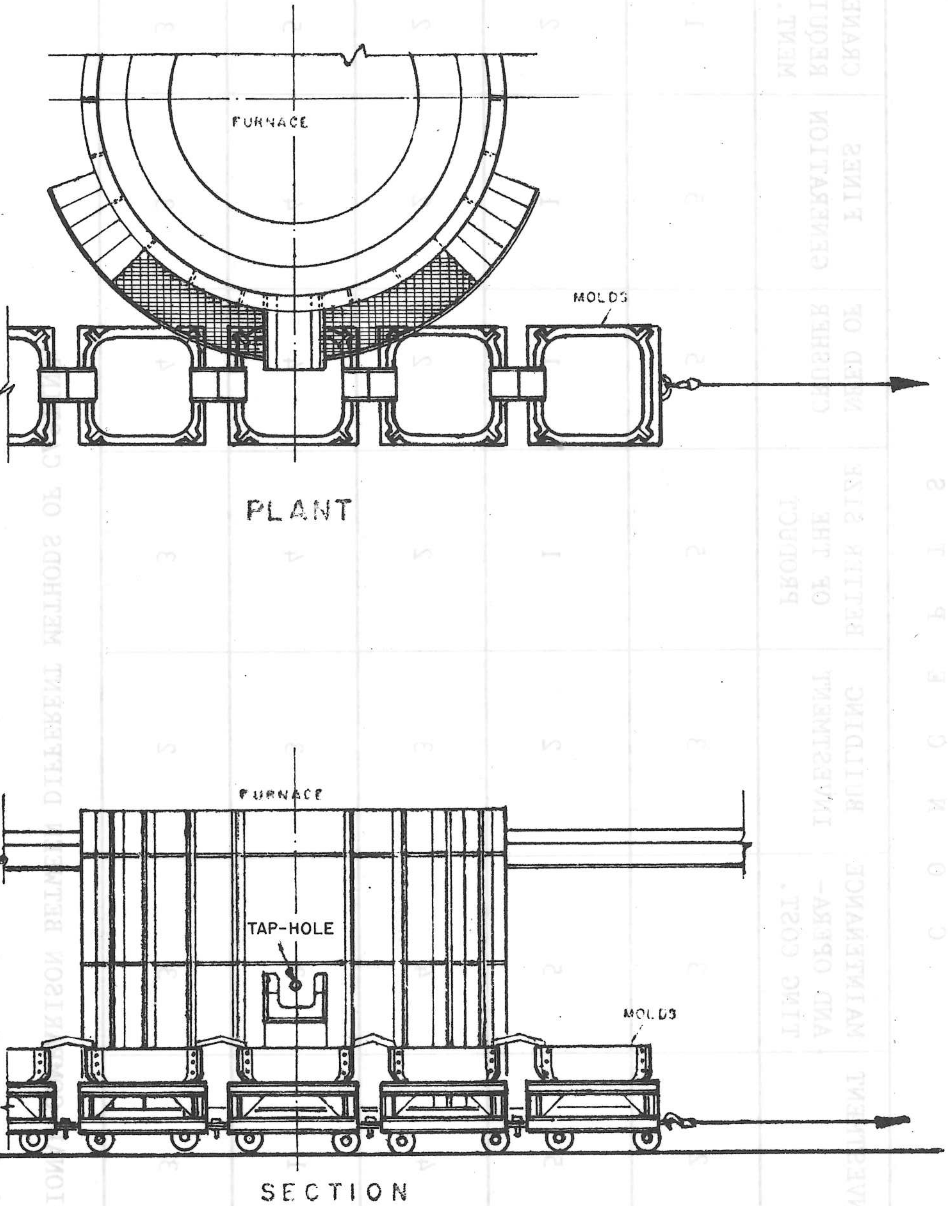


FIGURE Nº 9 – LINEAR CARROUSELL OF MOLDS.

METHOD OF CASTING	CONCEPTS							
	INVESTMENT	MAINTENANCE AND OPERATING COST.	BUILDING INVESTMENT	BETTER SIZE OF THE PRODUCT	NEED OF CRUSHER	FINES GENERATION	CRANE REQUIREMENT.	TOTAL POINTS
STACK CASTING	2	3	3	5	5	5	1	24
CASTING MACHINE (Conveyor Type)	5	5	2	1	1	1	2	17
CASTING WHEEL	4	4	3	2	2	2	2	19
STATIONARY MOLDS	1	3	3	4	4	4	5	24
MOLDS MOUNTED ON CARS	3	3	2	3	4	3	3	21

TABLE # 1 - CONVENTIONAL COMPARISON BETWEEN DIFFERENT METHODS OF CASTING.

In each space a relative value in points is given, less points are assigned to the best method and more points to the worst. In accordance with this table the best method is the casting machine. Each Plant will have its own qualification.