My subject is foundry productiveness, and by foundry productiveness I refer to all those factors which influence output from a foundry both quantitatively and qualitatively.

You, as engineers, are designers and users of castings, and your needs are for castings delivered to schedule:

In the quantities demanded;

Of the qualities specified;

And with the greatest dimensional accuracy possible.

In these directions, no doubt some of you are fortunate, but over the last five years industry has made such great and severe demands upon our foundry industry that foundry productiveness has lagged behind essential demands, and no doubt many of you have had to persevere with castings of quality far below your requirements, and castings delivered in insufficient numbers.

It is first necessary for us to consider the process by which a simple mould and the casting from it are formed, and from that stage I propose to deal generally with some of those steps by which the productiveness of overseas foundries has been stepped up, and which are now receiving some consideration from our more progressive foundries.

It is not my intention in the limited time available to endeavour to discuss in great detail any particular side of the question, but rather to outline the steps by which foundry productiveness can be increased.

I hope that I will be able to show you some of the problems which confront the foundry man, and ways in which you, as engineers, can assist him to give you better castings and service; and an appreciation of the speed with which some of our foundries are emerging from what I think may truly be styled the renaissance of the foundry industry—a troublesome period in foundry history from whatever view is taken.

The starting point in producing a simple casting is the submission to the foundry man of a slightly oversize replica of the article to be produced, and known as a pattern.

Pre-war the next step would often be for the foundry man to bid frantically for the privilege of producing the casting, and so castings were very often sold at prices which allowed no margin for quality, and most foundries remained right on the bread line; and progress, except in isolated cases, was slow.

Now many foundries, instead of bidding frantically, will dictate to you just how the pattern equipment must be made, and just what auxiliary equipment, such as boxes supplied, if they are to undertake the work, and this is exactly how things should be.

The manner in which a simple casting is made is as follows:

1. The pattern to be considered is a base plate. It is placed upon a flat board (illus. 1).
2. A moulding box or sand-retaining frame is placed over the pattern (illus. 2).

3. Carefully-prepared, finely-sifted sand covers the pattern (illus. 3).

4. Additional sand is added, and consolidated by peg ramming (illus. 4).
5. The box is then filled to overflowing, and the whole of the sand consolidated by flat-ramming the top (illus. 5).

This is done sometimes by a mallet or a flat rammer, as shown, the flat of a shovel, or by treading on the top of the sand.

The surplus sand is then strickled or shovelled off level with the top of the box. A flat board is then placed over the top of the mould, and the whole turned over, after which a second moulding box part possessing guide pins, which locate into lugs on the first box part, is placed in position, and sand rammed into it, as in the case of the first half-mould (illus. 6).

The top box part is lifted off, the pattern withdrawn, and a passage or runner cut to permit the entry of molten metal into the mould cavity (illus. 7).

This procedure of hand moulding applies to all types of foundries, both large and small, ferrous and non-ferrous, and does not differ in any way whatsoever from the procedure used over 1000 years ago.

When I used the term “foundry renaissance,” you will appreciate that some change of considerable import in the foundry is suggested, and from my description you will agree that a drastic change indeed is called for.

And this change to which I refer as the foundry renaissance is already under way, and, like every departure from the every-day way of life, is receiving a deal of opposition in some quarters.

This hand method of making a mould is at the best a haphazard method. If the moulder pushes his peg rammer too near the face of the pattern, the hard-rammed spot may cause a scab or blow. On the other hand, if the ramming is not sufficiently firm, some sand may be washed away from the face of the mould, or, due to the local softness, the hydrostatic pressure of the molten metal may cause swells on the face of the casting or penetration of metal between the sand grains.

The question then is how can we cut out the guesswork, and get uniformity of ramming; and the answer is to use a machine which will enable a predetermined amount of ramming to be given to each mould.

The simplest of these machines, of course, is a simple application of squeeze pressure, either by means of leverage applied by hand (illus. 8), or better still, squeeze pressure applied from a pneumatic cylinder (illus. 9).

Hydraulic squeeze machines have been developed, but have not obtained popularity in this country.

In England a machine has been developed applying a squeeze pressure electrically by means of a solenoid.

The disadvantage of the squeeze machine is that unless a somewhat complicated arrangement of tackle known as the “down sand frame method” is employed, the mould formed will be considerably harder at the back than at the face which comes in contact with the molten metal.

This is the reverse to the conditions we desire to obtain. For greatest hardness is needed at the face to resist the molten metal; while the sand most distant from the face should be more open and softer rammed to enable the steam and gases formed to escape readily.
With the hand squeeze machine it is customary to lower the lever until the squeeze platen rests on the mould, then the operator dangles himself from the bar, and the hardness to which the mould is rammed depends entirely upon the vigor of the operator.

This sudden application of force results in a bridging of the sand and a mould extremely hard at the back and often too soft at the face unless some hand ramming is resorted to. Further it will be appreciated that the sand will be rammed very much harder on top of a pattern, which is most undesirable.

A properly-designed pneumatic or hydraulic machine permits accurate control over pressure applied and thus permits reproduction of results found satisfactory. By controlling the squeeze speed, pressure may be applied slowly flowing the sand far more than the hand squeeze machine, and so giving more favorable mould conditions.

It has been mentioned that we desire a firm face to the mould and a softer back.

These conditions are best obtained by the use of jolt ramming.

The grocer packs sugar in a bag by bumping the bag several times upon his table, and in this way the Jolt machine (illus. 10) rams. It consists of a table fastened to the top of a piston operating in a cylinder.
Compressed air applied to the cylinder lifts the table, and when the air is exhausted suddenly, the table falls until its underside strikes an anvil forming the top of the cylinder. The moulding box filled with sand sits upon this table, and, as the table falls, it imparts a momentum to each grain of sand in the moulding box, and when the table strikes the anvil each grain expends its momentum, pressing down upon the grains beneath it.

So we get greatest pressure and hardest ramming at the face of the mould, which should be our aim.

Generally, this jolt function is combined with other mechanical functions such as jolt and strip, jolt and squeeze, jolt, squeeze and strip (illus. 11).
These machines are entirely satisfactory for any type of mould which can be lifted up off the pattern. Where the nature of the mould is such that it could not satisfactorily be lifted up off the pattern, the pattern and mould should be turned over before the draw is effected.

The Jolt Rollover draw machine (illus. 12 and 13) carries out this work. These rollover machines are particularly versatile units, and for large moulds are favoured because they can be economically be applied to every job within their capacity for which a split pattern, flat-sided pattern or plate pattern is provided. In addition to the units illustrated, other types of rollover machines are produced, and have found favour in other countries or for specialised work, but, because of their versatility, units such as these are most widely favoured both here and overseas.

Generally speaking, the core sands have less bond in the state in which the core is formed, but after baking at about 350-500°F, they harden, and the higher mechanical strength developed permits of a considerable amount of handling.
Due to the low green bond strength of most core sand mixtures, fast and uniform production can only be obtained by the use of machines which eliminate the human factor.

For bulky cores, a small jolt unit can be used advantageously.

Better still is a small machine which jolt rams the core, then turns the rammed core box over and withdraws the completed core downwards.

You can see quite a large and intricate core box mounted upon the table of this machine (illus. 14), and one which would require two men to handle by the old-fashioned methods.

Of recent years, core-blowing machines have been developed which blow the sand out of a storage chamber into the core box, which is clamped against an orifice in the bottom of the sand-storage chamber.

The core blower rams the core in less than a second, and its speed of operation is limited by the time taken to feed core boxes into and out of it. Where core blowers are used to advantage, it is customary to employ several operators to each machine.

The operating principle of the core blower is that when air pressure is applied to the top of the sand in the hopper, it permeates the sand and blows out the blowhole in the bottom of the sand chamber into the core box, carrying with it sand which fills the core box, while the air escapes out through the parting line in the core box or specially located vents. The principle is very simple and very efficient, but it is necessary to carefully control such factors as the bonding of the sand and moisture in the foundry air line if production is to be obtained.
A rather interesting machine, the sand slinger, has been developed, which takes sand handful by handful and pelts it down into the mould. The velocity with which the sand is thrown gives a well-rammed mould. The sand slinger can sling sand in any sized or shaped mould, and over practically any shaped pattern.

However, it only rams the mould, and auxiliary machines are required to strip or roll over and draw the pattern.

These sand slingers, however, can handle a vast amount of sand—up to 20 cubic feet per minute. Some of them are mounted in a stationary position, and sometimes they travel from one end of the shop to the other, ramming as they go.

If high outputs of castings are to be expected, it is not sufficient to put a moulding machine into a foundry and expect results, for more time may easily be spent carrying moulds away from the machine to the pouring floor than actually to produce them.

I had one case of this some little time back. The approved production rate for a small casting of vital importance to our army was 72 castings per man per day, operating by hand methods. Another foundryman invested approximately £150 in a moulding machine, and employing, I believe, the local butcher's cart driver and an ex-furnaceman, got the production rate up to about 1400 units per day, and those two men were able to operate one machine between them because it took longer to carry the moulds away and return to the machine than to make the mould.

The usual American solution to this problem is a gravity roller conveyor, which feeds the moulds away from the moulder. The mould may be left on these roller conveyers while ladles of molten metal travel along monorail conveyers running parallel to pour them.

Sometimes these roller conveyor lines feed on to a travelling track, or the mould may be deposited directly on to the travelling track by the moulder.

Sand to form the mould should be brought up to the moulder and deposited into an overhead bin, from which it is fed directly into the mould either through bottom gates in the case of small moulds, or some sort of a belt feeder for large area moulds.

In a mechanised foundry all sand conditioning is generally carried out in one part of the foundry, and the prepared sand transported to the moulding stations, generally by belt conveyors, but sometimes by skips travelling along a monorail or even by skips carried by a crane.

While a belt conveyor certainly offers lowest transport cost for the sand, all machines must be placed in a straight line over which the belt passes. A monorail system with power travel and carrying bottom discharge forms a very versatile sand transport system in that sand can be economically and efficiently transported to machines placed in any part of the foundry. This is most important in modernising an existing foundry where it may not be possible or convenient to lay out for line production.

Sand used for forming a mould consists of a sand of suitable grain size and shape, plus a bonding agent, generally clay.

The process of sand preparation consists of coating each sand grain with a thin film of clay or bond so that where the grains touch, a point of bond is established, while the spaces between the grains should be open and clear.
so that the gasses and steam generated when the mould is poured can readily escape.

Sand conditioning consists essentially of some kind of treatment to thoroughly smear the bonding agents present over the surface of the grains.

Roller-type mills after the style of the Chilean mill sieving units, paddle-type machines, and units consisting of fast-revolving pegs or blades are used.

If uniformity of results are required, it is essential that sand be reconditioned and returned to the moulder in proper condition each day, and for this purpose a range of simple instruments have been developed which will quickly and accurately determine any physical tribute of a foundry sand.

These instruments are so simple and foolproof that an apprentice can operate them, and the results given can be used for comparison with results from day to day, and with foundries from any part of the world.

These instruments are now made in this country, and are being used by a number of our more modern foundries. The Council for Scientific and Industrial Research, realising the importance of foundry-sand control, has established a laboratory equipped with these instruments expressly as a service to the foundry industry.

Tests commonly employed include:
- Permeability or porosity.
- Moisture content,
- Fineness,
- Clay content,
- Sintering test;

Strength tests including:
- Compression,
- Tensile,
- Shear,
- Deformation and resilience,
- Behaviour under temperature and load.

Proper and efficient equipment to make a mould is useless unless proper pattern equipment is provided, and it is in this direction that great assistance can be given by the engineer to the foundry man.

I will take as an example pattern equipment to produce a simple bronze bush.

Firstly, we have a standard solid pattern which is usually used where production demands are just for an occasional bush.

Three or four such patterns are usually moulded in one box, and the first step is to produce an oddside. Often this is rammed from ordinary moulding sand, and lasts for but a few boxes.

Alternatively, the oddside may be made from a harder compound such as plaster of paris.
If these patterns are split into two half-round parts, the time and expense of making an oddside can be dispensed with, for the split pattern can be laid straight on a flat board, and the first half-mould produced. When this half is rolled over the second half pattern is placed on and located to the first half by means of dowel pins.

Split patterns offer a great saving in production time, and are particularly valuable with large or intricate moulds. The top half of a split pattern often stays in the top half of the mould when it is lifted off, and can be withdrawn more easily and cleanly after the top mould is turned over.

An advance upon the split pattern is the standard double-sided pattern plate, which is often made by affixing the two halves of the split pattern to either side of a piece of steel plate.

Cast aluminium plates are sometimes produced in place of these built-up plates, and while they are often cheaper and easier to produce, have two disadvantages, namely, uneven shrinkage, which may or may not be serious, and the fact that sand has a greater tendency to stick to aluminium than to iron or brass.

Where a double-sided plate is used upon a machine, the functions of jolting and squeezing can be applied to one side of the mould only, and the second side can only be squeezed if the jolt is applied to the second side; then the sand on the under-half mould would be jolted down away from the pattern face.

Where maximum production is required, it is preferable to use pattern plates possessing a plain flat back, and to use two separate plates, one to form the bottom half-mould and another to form the top half-mould.

These plates are fastened to the table of the machine, and from them the respective moulds are produced by a combination of jolting, squeezing, and stripping.

Great strides have been made in the methods of production, and applications to which cores are being put.

Complete moulds are being formed by clamping two or more cores together. Such moulds are mechanically strong, can be readily handled and stored, and enable castings to be produced to extremely fine dimensions.

Mention should be made of the equipment used to melt the metal and handle it into the mould.

In the iron foundry the cupola is still the customary melting unit, but the old idea that wind pumped into any brick-lined vertical shaft would suffice for production of iron castings is slowly dying, as the importance of correct cupola design is being more widely realised.

It is generally stated that 30,000 cubic feet of air and about 2-3 cwts. of hard foundry or metallurgical coke are required to melt one ton of iron. Such statements are little more than guesses, for many factors enter into the calculation behind the design of an efficient cupola.

Actually we must supply sufficient oxygen for proper combustion of the coke charged, and as changes in atmospheric temperature and barometric pressure make considerable variations in air weight, efficient cupola operation necessitates either a blower which delivers a constant weight of
air instead of customary constant volume, or the less efficient alternative of instruments which register volume and pressure of air being delivered to the cupola, and room temperature, and barometric pressure, and a chart from which the furnace man may read the necessary variations from standard to be made for existing conditions, of temperature and barometric pressure.

Too little air may result in the absorption of some carbon by the iron from the coke, and slow melting. Too much air will result in oxidised metal and also is very wasteful, for nearly half the heat is lost through the endothermic reaction of the CO₂, with incandescent coke to reform CO, which may burn higher up the stack, where it is least wanted, or escape entirely.

Most of our foundries charge their cupola by hand-throwing the pig iron in, piece by piece, and the coke forkful by forkful.

Many of them still raise their charges from ground level to the charging platform by throwing it up piece by piece. Several of our foundries have installed charging devices, which consist of a skip travelling up an inclined track, and which tips up at the top of their run, allowing their contents to fall in a haphazard fashion into the cupola.

If the charge chances to fall level, good results may be obtained; or the iron may fall largely to one side, with the result that the coke falls beside it instead of on top, and so we get unsatisfactory and uneven melting.

The most efficient charging equipment consists of a cylindrical container, which is supported from a runway, and runs into the cupola stack, and drops its load straight down.

One such unit employs a conical bottom which, when lowered from the cylinder, permits the charge to drop. Such a unit, while very efficient, is limited to large-sized cupolas.

There is another really good unit, which has a hinged drop bottom, and this unit can be applied to much smaller cupolas than the cone-bottom charger.

The longer a cupola may be operated at each run, the more economical it becomes, hence most foundries like to cast as seldom as their run of work will permit. This means that if a foundry is going to cast every third day, that foundry must have floor space and moulding boxes and equipment to last each man for that time, that is, three times as much as would be required casting every day. Some iron foundries, on the other hand, cast every hour to hour and a half by using a batch type of furnace.

Such a practice often permits particularly close control of compositions, and, equally important, each man requires far less floor space, and the capital investment for equipment is materially reduced.

With batch casting, moulders can spend their entire day making moulds, while a separate team can be employed to tend the furnace, pour the moulds, knock them out, and reheap the sand for the moulders.

Of the batch furnaces, the Rotary, fired by either oil, tar or pulverised coal, is the most efficient and popular. It is claimed by their makers that their melting and operating costs compare favourably with those of a cupola, and, provided they are of correct design and under the control of a metallurgist or experienced operator, I consider they offer many advantages.
The electric furnace also is finding favour for melting iron, and non-ferrous metals, as well as steel.

It, too, permits close control of temperature and composition, but must be controlled by an experienced metallurgist or melter if consistent results are to be obtained.

High-strength irons are readily produced, and an English authority claims that, as cheap scrap such as turnings can satisfactorily be remelted, good iron castings can be produced at a lower cost from the electric furnace than from a cupola.

Three types of electric furnaces may be considered.

Firstly, the Direct Arc furnace, commonly used in the steel foundry in which three graphite or carbon electrodes protrude into the furnace through the roof, and the heat is generated by three arcs between the electrodes and the charge in the bottom or well of the furnace.

In addition to melting steel, these furnaces are also used to some extent to melt non-ferrous metals which are not readily vaporised, such as pure copper and nickel and nickel-chromium alloys. They are finding increasing favour with the iron founder either as a sole means of melting, or, alternatively, for what is referred to as duplexing. Duplexing consists of melting the iron in one furnace such as a cupola, and then transferring the molten metal to another furnace, where it can be superheated, adjusted for composition, and held until required.

The advantages of the electric furnace are very obvious where large alloy additions are required.

The indirect-arc type consists of a refractory lined drum with the arc between two carbon or graphite electrodes, one entering from each end. As an alternative to melting by the electric arc, induction melting furnaces are now being used, but they have so far found favour for specialised work only.

Pouring and handling molten metal is a hot and tiring job at the best of times, and every endeavour should be made to minimise the weight to be handled, and the exposure of the worker to heat.

Covered ladles, either of the conventional pattern or the drum type, are to be recommended. Not only are working conditions so much better but the metal retains its heat for longer periods.

Overhead handling gear, such as cranes and monorail, permit each man handling heavier loads, particularly if proper ladle hoists are used.

It is customary to use two men to steady a ladle of molten metal, and a third to operate a hoist for raising or lowering the ladle. With the ladle hoist and proper ladle, one man can do the job quicker and easier than a team using the old methods.

It is only of recent years that attention has been directed towards making the foundry a cleaner, clearer and healthier place to work, and the risk that the foundry worker faces of contracting silicosis, fibrosis tuberculosis is not generally realised.

The Department of Labour and National Service has compiled data on this subject which indicates that, in a survey of foundry workers in U.S.A., of 4066 persons examined, 2.7 per cent. were found to be affected by silicosis.
Further, of some 190 men examined by the workers' compensation (silicosis) committee in N.S.W., 27 have been certified as having some degree of silicosis.

So important is this subject considered by American authorities that the American Foundrymen's Association have drawn up a code of recommended practices for control and removal of dust and fumes in foundries.

In many States of America for many years the installation and operation of efficient dust and fume removal equipment has been required by law and legislation of this type has recently been introduced in this country.

Briefly, these regulations require that dust and fume concentrations shall not exceed certain defined maximums, and that efficient dust and fume removal equipment shall be operated with all dust-producing equipment. Old-type slatted rumblers or tumbling mills must be enclosed in chambers connected to a suction system removing specified volumes of air.

Internally-ventilated tumbling mills are recommended. These are of two types, duct or trunnion ventilated types, and large volumes of air are sucked through the mills carrying away the dust as it is liberated.

Grinding equipment must have proper hoods, and defined minimum volumes of air removed at specified velocities and through specified-sized pipes.

Dust can be removed from a swing-frame grinder either by means of a hood affixed to the frame or by the use of a chamber, in the mouth of which the grinding is done, while a current of air is sucked past the operator and into the chamber at a velocity of not less than 100 feet per minute at the face.

For general fettling operations a similar booth may be used, or, for some operations, a steel grill-topped box with air sucked down into the box is favoured.

In summing up, you will agree with me that the increased productivity that must be obtained from our foundries can only result from the introduction of more men into the industry, or the increased application of labor-saving equipment.

The Department of Labour and National Service, as the result of a survey of Australian foundries, states: "In many foundries the conditions were below the minimum that is essential for the safety and health of employees, and in some cases, indeed, existing legislation governing working conditions in foundries was not being observed."

Until the conditions under which men work in many of our foundries are improved, I am afraid that good labour will refuse to even consider working in a foundry, yet with labour saving and dust and fume removal equipment, even a foundry fettling shop can be made a reasonably congenial place to work.

Your castings must be produced more rapidly, of greater uniformity and to closer tolerances, and this necessitates the more extensive and efficient use of modern foundry machinery and equipment, and this is often only possible if your pattern and core box equipment have been designed with due regard to the problems of casting production, and preferably after consultation with your foundry man.
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