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METALLURGICAL ASPECTS OF FOUNDRY EQUIPMENT MAINTENANCE

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PREVIEW

Metallurgical Aspects of Foundry Equipment Maintenance

There are a number of area's of the foundry which have had considerable emphasis placed upon them in recent years for improved productivity. These areas, of course, are not alone but all are metallurgically significant and each has its own critical maintenance problems. If we are going to look for reasonable success in upgrading productivity with satisfactory metallurgy then maintenance in each case must be carefully examined.

The significant areas for upgrading metallurgy and consequently maintenance upgrading are the laboratory and automatic controls with improved equipment and technology for:

Molding

a. Sand handling and conditioning materials

b. Material movement (handling) clays, coke, combustibles

c. Casting, cooling

d. Shakeout recovery and sand cooling

e. Pattern return and storage

Coreroom

a. Materials preparation, sand mixing

b. Core making

c. Core delivery to molding and core storage

Melting

a. Receiving, storage and raw materials technology

b. Charge makeup and metals charging

c. Metal melting, handling and metallurgical control

d. Pouring, ladles, inoculants

Cleaning

a. Casting movement and handling

b. Core knockout

c. Despruing and deffining

d. Grinding and trimming flash

e. Shot blasting and tumbling

Intimately and figuratively concerned with the foregoing, has been a significant demand for better maintenance, on much more sophisticated equipment.

AGGRESSIVE MANAGEMENT, TRAINING, RECORDS

The best possible practice for producing satisfactory iron, steel, and its alloy, aluminum and other metal products are demanded, for the maximum savings of material, time, cost and general improvement in the value and quality of products. This study will confine itself especially to the area of foundry metallurgy, maintenance of machinery and equipment, so necessary to improve the end product value and further reduce down time, particularly emergency breakdowns, in the normal production cycle. The particular areas with which this paper is concerned, are, Equipment, Lab Service, Producability, Metallurgy.

Other important areas of the foundry not included in this paper are,

a. electric power and light

b. water supply and drainage

c. buildings

d. production technology

Separate studies are suggested to cover these foundry areas.

It may be of interest to the reader to learn that the author's personal experience has shown, after visiting a number of foundries in under-developed countries, that hundreds of pieces of equipment are idle. The principle reason for idleness is lack of information or instruction concerning the proper care and maintenance of a machine or unit of equipment. It is unfortunate and depressing to see very good (costly) machires productively neglected, due often to a lack of confidence on the part of personnel, who have been trained (briefly at least) to handle a wrench and hammer fairly well. But they often avoid the record keeping art and very often find a good excuse to avoid taking time to clean their hands and update the record card, or even make one out originally. Unless the supervisor or engineer in charge of maintenance is aware of this undesirable situation and takes steps to correct the deficiency, it will seriously downgrade another good maintenance organization. This is an important part of managements training program for reliable maintenance practices. Another deficiency toward useful maintenance schedules is the timely ordering or the making of suitable replacement parts. Spare parts may require a lead time of, from four months to perhaps as much as eighteen months, from placement of order to receipt of delivery. The machine or piece of equipment should not remain idle for this long period. During progressive care, the decision will be made to replace on a pre-determined schedule. This is only a part of good maintenance responsibility to be prepared at the proper time with suitable parts, hardware and materials to do the repairs satisfactorily. There will be a number of spare parts which must be carefully considered and ordered well in advance (perhaps as much as two years ahead of time) to have available for a possible emergency.

Managements training of personnel, for maintenance and metallurgical needs are necessary to be conducted as early as operations begin, for most satisfactory results. Too often, maintenance, particularly in the underdeveloped countries, is handled in a very undesirable and unorganized manner. This often leads to very poor control of the production cycles, which in turn only results in a very unsatisfactory metallurgical product. The greater the emphasis that can be directed toward proper personnel instruction to provide them with the knowledgeable tools for the work that they are expected to accomplish can not be overemphasized. Briefly, the man in charge of maintenance must be one of keen analytical and with broad practical knowledge, of equipment and of the processes.

Truly much of his time must be devoted to the constant training and surveilance of his staff, who are charged with the maintenance function, to assure proper machinery and equipment operation at all times. It is quite easy for one charged with routine responsibilities to become careless with their day-to-day functions, of carrying out such details as adjustment, timing, lubrication and the analytical aspect which are an integrated part of their responsibility. A speck of dirt or a drop of water carelessly overlooked in the maintenance of equipment can very easily, and often does, result in the complete failure of critical bearings or precision equipment in a matter of a few months time, under otherwise normal operating conditions. The use of diagrams, charts, scales and visual instruction methods, are most important to the entire staff concerned with maintenance. Indeed the absence of knowledge on the part of the worker, or even carelessness on his part is extremely difficult to measure currently, in a monitary sense. The metallurgical quality of a product is never good enough for the replacement of an already failed unit. It may be assumed that the actual part failure was caused originally by. (one) unsatisfactory metallurgical knowledge of its required function, (two) by the lack of control during its production or, (three) maintenance during its productive life: therefore, when a part has failed, common sense tells us that the particular failure was caused by some very basic deficiency.

The Record of Machine or Equipment

Complete individual records of all equipment and chronological history cards, are most essential for the proper care and in planning a useful progressively scheduled maintenance program. Details such as the following are necessary.

a. manufacturers data with name and address
b. serial number
c. type and model number
d. names of accessory or major components with manufacturer (if other names) including electrical data
e. date when equipment was made
f. date equipment was installed
g. by whom installed
h. lubrication schedule (record)
i. maintenance schedule (record)
j. rebuild or replacement schedule

Without this record of accurate information, the maintenance staff will soon fail in routine application of good technology. Maintenance people generally are lax with most record-keeping activities. Records may be started, but more often never finished. Another serious deficiency is often the lack of the manufacturer's instruction book. These books are usually handed to a responsible official when equipment is first installed; however, it is the writer's experience that at least 90% of the time, these valuable reference books are rarely made available to the responsible maintenance personnel. It is the duty of good managers, to see that such items as maintenance information and instruction manuals are securely contained and made easily available to their maintenance staff. With the instruction manuals and information at hand, the maintenance staff should proceed to complete their record cards. Unfortunately, these cards are often neglected with the thought in mind that personnel will refer later to the maintenance book for any need that may arise. But this is insufficient, impractical and usually inefficient for the routine needs as they arise. The writer has often visited a foundry in a remote location, only to be informed that the manual for a piece of equipment, or a particular machine, was assumed to be kept by their main office staff, often hundreds of kilometers (miles) distant. This situation is altogether too common; measures must be initiated early by management to assure improved order with maintenance practices. It may be of some consolation for the underdeveloped countries to learn that even in the developed countries, maintenance instructions at times, are slow or late to reach the responsible personnel. In the developed countries, however, it is the exception; whereas, in the underdeveloped areas it is a rule of accepted practice. Such poor practice necessitates critical analysis and upgrading.

Training Maintenance Management Personnel

There can be no substitute for effective training of personnel who are charged with the detailed care and upkeep of valuable machinery. In the foundry this can be far more critical than some other areas of industry. The abrasion of sands and the iron chippings, sprues, runners, hot or cold tailings, are severe and constantly break down the endurance of machinery and equipment in the foundry. Perhaps the one most essential factor which may govern foundry output more than any other is proper maintenance of equipment. This can only be fully realized when a reliable crew has been trained to handle such details as follows:

a. periodic predetermined lubrication
b. minor electrical adjustments
c. minor mechanical adjustments
d. functional inspection by personnel responsible for quality and production
e. a routine training and technical upgrading program, to guide personnel charged with a, b, c, d, above
f. major repair, preparation scheduling, and realization, with minimum loss of time and production
g. choice of alternatives, should there be a failure of equipment at any particular time

All of these factors should be phased into the training schedule, to prepare maintenance personnel for all emergencies that may arise.

The maintenance workshop should have available a minimum of equipment necessary for making tests for analysis of wear and calculated life usefulness.

a. diameters (taper) (out of round) (over or under size)

b. lengths (thrust) (limits of lateral motion)

c. thrust measurement and determination of acceptable tolerance

d. bearings (out of round) (wear reduction) (tolerance limits)

e. journal or shaft (out of round) (taper) (wear)

f. gears (tooth measurement) (wear) (pitch diameter)

g. revolutions counter (tachometer)

h. contact pyrometer (temperature) (calculation of endurance)

i. contact, voltage use analyzer (overload) (voltage fluctuation)

The proper management of foundry maintenance is one of the most important keys in a successful foundry operation. If maintenance is weak, the entire production process will suffer. A capable engineer with well-trained supervision will do much in organizing a satisfactory program of machinery and equipment care. Their maintenance manuals will be kept clean and available. Their subordinates will be regularly upgraded in their duties and gradually trained to be competent in additional classes of work.

Sessions of class training should be held at least once each week and more often if the need arises. Include the service manuals, drawings, charts, graphs, etc., also current review of machinery record cards to keep properly updated. The maintenance engineer should begin with and carry out training for the entire staff concerned with maintenance. If he is not competent to do so, then he should receive special training, or a competent engineer should be employed. There may be some aspects of training which could be turned over to a subordinate supervisor; however, a good start with a useful training program, will pay dividends in an active smooth operation and emergency free production with quality metallurgy.

CARE, PREVENTION, PROGRESSIVE MAINTENANCE AND REPLACEMENT

Every well organized maintenance program must include its short and long range plan. All equipment when used shall wear and its rehabilitation time schedule will one day arrive. The maintenance organization must be prepared with its plan of implementation when the time arrives. Progressive maintenance is that detailed work, preplanned for an opportune shutdown, when repair can be carried out without serious cost of production time and with the least cost for maintenance. The maintenance record cards are designed to assist with not only this work, but all other required on any particular piece of equipment. Long before the progressive schedule comes up, there must be plans. These plans must provide for all parts, hardware and necessary time to accomplish the needed work on the prearranged schedule. While the progressive schedule is being realized, a careful inspection must be made of other parts and/or units of the machine or equipment. Down time and idle time is expensive. Most machines and equipment used in the foundry are expensive by any standards. It is, therefore, essential that each piece of equipment be kept operable, or if this is no longer economical, then steps must be taken to replace the unit or units concerned. A little very simple arithmetic will illustrate the value of machinery to calculated hours and continuous operation on schedule. Let's assume the machine will operate one third of the actual time and no major repairs are needed for three years.

cost U.S. $ machine (equipment)	U.S. $ per hour (24 hour day)	U.S. $ per hour (8 hour day)
4,380.	0.50	1.50
8,760.	1.	3.
87,600.	10.	30.
876,000.	100.	300.
8,760,000.	1000.	3000.
87,600,000.	10000.	30000.

A small one ton cupola, for example, will cost approximately $8760, which cost represents $3.00 per each hour, of an eight hour day. Should it become necessary to shut down the foundry production, because of failure of this one key unit, the cost of the cupola alone immediately becomes a multiplier and the $3.00 hourly cupola loss, becomes a staggering figure, of inestimable hourly loss consideration. These figures apply only to the idle equipment. To this, must be added idle labor cost, plus any materials or other costs that may be involved. A well planned progressive and preventative maintenance program, with a reasonably rigid schedule, will avoid such unforeseen shutdowns. At the least, let me say the problem becomes minimized. Regular and routine inspection of all machines and equipment will produce very usable knowledge on its condition. The data which is most pertinent should be reported and recorded for benefit of all follow-up inspections.

In this way the proper timing for replacement of parts, or for complete machine replacements can be properly scheduled. Normally good maintenance calls for inspection of critical machine areas, each 620 hours of operation (about three months of eight hour days);

on sensitive areas of the machinery, a shorter period may very well be advantageous. The object, of course, is to learn the actual conditions under which reasonably accurate predictions and plans can develop, to provide the needed machinery and equipment care while avoiding any emergency shutdowns.

CONTROLS, METALLURGY, LABORATORY

The maintenance of a foundry laboratory, usually is handled under conditions of great care. Personnel, for example, who are assigned to maintenance of very heavy equipment will not be assigned to adjust, calibrate or repair laboratory equipment. Such items as a balance (scale) and other delicate instruments must be maintained, usually by the manufacturers service representative. In an underdeveloped country this is not possible. But it may be necessary to train personnel especially for this type of delicate maintenance work. A very capable automotive mechanic might be trained, at least for a part of the laboratory equipment. It is perhaps more practical to send the laboratory engineer on a combined training mission which will include the technical training to maintain his laboratory equipment. It would then be his responsibility to provide the instruction to a capable maintenance specialist. The engineer or technician in charge of maintenance is, of course, another logical specialist to receive specialized laboratory instruction. The author highly recommends that the specialized training be provided. I am aware of numerous metallurgical laboratories in several underdeveloped countries, that remain unused, despite the fact that most equipment is good. A bad experience has resulted in complete lack of confidence in equipment and also personnel concerned with the laboratory. When foundry personnel can bypass the normal lab analysis, they become careless at once with their product metallurgical quality. It is therefore imperative, that complete confidence be generated and retained for reliability of all foundry laboratory actions and reports. Modern metals and metallurgy are today, far more complex, than during the 1935 to 1950 period. The importance of the foundry laboratory has now taken its rightful place, beside the melting unit. The melt must be known correctly; the lab, if properly used and properly operated and maintained, will provide the correct answers to those responsible. A hit or miss technique, cannot be accepted under any realistic circumstances. Satisfactory, reliable progressive laboratory maintenance is most essential to any foundry. A program of periodic inspection belongs in the laboratory as well as the foundry. A constant watch must be kept of calibrations, on all instrumentation in the foundry, as well as in the laboratory. This action must be the responsibility of the laboratory maintenance and coordinated with all maintenance.

Emphasis On Hand Tools

It has been said many times, that a workman can be easily judged by his tools. It may also be stated that a supervisor can be judged by the kind of tools he permits his subordinates to use. A workman using an improper tool can indeed destroy a machine or piece of equipment, faster than normal wear. The author would like to suggest that hand tools are most basic to any useful maintenance organization. But unless personnel are thoroughly oriented in the proper use of such hand tools, as well as the common power assist hand tools, maintenance costs may easily be esculated rather than reduced.

Briefly stated, good maintenance requires good hand tools; but without suitably trained personnel to make the best use of such tools, you should expect to accomplish very little. With suitably trained personnel using proper hand tools, we can begin to organize a very useful maintenance program. Such a program will benefit metallurgy substantially. With exception to the power assist tools, regular hand tools are usually under the personal care of the user. A maintenance specialist needs a good supply of hand tools, but he should be expected to take good care of every one of them in his possession. Such care should not, however, consume more than one per cent of his total weekly work time. The power assist tools are usually provided by a foundry central tool supply organization. They are in substance loaned to the workman, to accomplish a specified task. All such tools must be inspected as soon as returned to central supply. Damage must be reported by the borrowing workman and repair or replacement action must be initiated at once. Here as in the foundry laboratory, specialized training is required for service on the power assist hand tools, also for large or complicated precision measuring instruments and equipment. These items are all under the central tools organization. A record card must be made and kept for each item. All preventative and/or progressive maintenance must be recorded and updated at each inspection interval. In the maintenance of many kinds of equipment and in working with almost unlimited materials, the foundry maintenance organization must be fully equipped. By doing so, a serious breakdown will be far less disruptive and much less costly. A carbide tipped masonry drill, for example, will open a hole through a cupola wall, a furnace refractory wall, or perhaps concrete flooring in a few minutes time. To do so by hand chipping methods would take hours or perhaps days. A carbide tipped saw, as another example, will cut concrete flooring or brickwork, with the use of hand power tools in minutes of time. The author of this paper has seen strong men struggle for days, with heavy hand hammers, to do a job that the carbide tipped drill and carbide tipped saw could do in minutes, even if operated by small men or women. Therefore proper training of supervisory personnel in such updated methods, to make their work much less burdensome, while expediting the rehabilitation effort of valuable machinery or equipment, to get it back on the production line. By the simple periodic voltage inspection of an electric motor consumed voltage on a piece of equipment, serious overloads will be uncovered, which will alert good maintenance personnel that analysis is needed of the equipment function. This procedure properly implemented can prevent motor burnouts, which often cause very costly and serious shutdowns while production is on line. Simple hand operated ramming air tools such as the common (so called) air guns, for packing refractory (fire) clay or similar materials into the compact areas of furnaces or cupolas are most useful and essential tools. They should be available to all well operated foundry maintenance organizations. It may be of interest to the reader to learn that after visiting many foundries, in several underdeveloped countries, the author could not find a single rammer tool available to any of the maintenance crews, assigned to cupola repairs. Nevertheless, repair costs were excessive and emergency shut-downs during production were constantly anticipated and burdensome delays endured. The electrical and/or air operated ramming gun is another item often neglected by supervisors of foundry maintenance personnel. Hand labor may be favored for reasons of extending employment, however, for reasons of quality repairs, the rammer gun should receive high priority. Even to the extent of making work elsewhere, if it is desired to generate employment. The even pressure consistency provided by the tool, cannot be duplicated by simple hand operations. The foregoing are but three examples of many that can be cited. My objective in presenting these examples, is simply to point up the need for training maintenance supervision thoroughly, in the fundamentals concerned with their responsibility, thus providing them with the ability to improve metallurgy while they resolve problems with more efficient use of labor tools, materials, and savings of productive time.

FINISH PATTERNS PRECISELY

Basic to all casting work required in any foundry, are reliable pattern equipment. The maintenance record cards are used in all areas of the foundry. The pattern shop is no exception. It can well be that somewhat less maintenance will be necessary for the pattern making shop. Woodworking machinery and the woodworking materials used for patterns, generally are far less severe upon machinery to shape or fabricate. Of course, wood is not the only material used for patterns, but it is the most commonly adopted. Aluminum, aluminum alloys and Epoxy Resins are also used, but usually only when large quantities of the same casting design are made. When the normal 620 hour inspection is carried out regularly, the pattern shop maintenance should not present any serious problems. Maintenance work can be much more easily scheduled in the pattern shop than in most other areas of the foundry.

Patterns

A pattern is made to provide a suitable cavity in a sand mold, so that melted metal can be poured to the desired shape for solidification, to be thereafter known as a casting. Well made accurate patterns are basic to the most satisfactory castings.

Much processing can be avoided by providing a quality refined pattern. Such detail as fillets and/or radius edges, can assist both metallurgy and processing. Sharp corners should be avoided at all times. If sharp corners are needed, they should be machined, not cast. A sharp fillet (concave radius) can be a sources of a crack by chilling, it can also increase the causes for a casting break, or weakness which may easily result in a casting failure after being placed in use.

A good clean finished surface on all areas of the pattern will be most helpful, first and foremost to produce a clean casting, free from rough edges as far as possible, secondly, to improve the strength of the casting and its metallurgical appearance, particularly following sand or shot blast. A third, equally important reason for a clean casting, are the benefits to ease further processing, machining, assembly, finish, painting, etc.

A wood pattern will usually be considered for a small quantity of castings, as a general rule it would suffice for most maintenance requirements. Should larger quantities be required, then good practice would dictate that another pattern material be considered.

As a guide to those interested, the following are an indication of average quantities of castings that may be expected from one pattern, before replacement is needed.

Pattern Material	Casting Quantities
Wood	25 to 40
Plastic	18,000 to 25,000
Aluminum	30,000 to 65,000
Iron, steel, Copper alloy or Magnesium	70,000 upwards

Wherever the jolt squeeze molding machine, or pressure squeeze molding is employed, the harder pattern materials need to be considered. It matters not which pattern material may be selected, the need remains to carefully finish, shellac, paint, wax or plastic coat, any and all pattern surfaces, providing the largest practical concave or convex radius. Large castings sometimes dictate that very light pattern materials be considered. If this should be the case, then perhaps the lay-up method, of glass fibre with Epoxy resin material, would provide the greatest benefits for accuracy, with corresponding lightness of weight.

HANDLING SAND, PREPARATION, MIX MULLERS, CLAYS AND MOLDING EQUIPMENT

This group of equipment with its machinery generally has the most sever service of any concerned with the foundry operation. It will be the screening sieves and separating units, which come into contact most with the sharp sand grains, that will require the greatest maintenance. Much attention should be directed toward the screen materials and too, the record cards need close observation. There are wide variations in sand hardness; therefore, a considerable variation in the life cycle of screen equipment can be expected. The inspection sequence (620 hour) should be increased with sand equipment, to provide a second cursory inspection, midway at least, between the 620 hour normal inspection period. The clay mixing and moulding machines (jolt, or pressure squeeze) do not endure quite the severe abrasion conditions found in the sand handling and mixing equipment. It must, nevertheless, be carefully observed for indications of wear. The mix muller is designed to withstand severe use; it does so extremely well. As a result, these units are often neglected in the underdeveloped countries especially. When they finally do fail to operate, the units can be idle for many months before replacement parts are obtained. The mix muller is a key machine for the sand mixing and molding process; it must be carefully maintained. Use of the record card information as developed by the periodic 620 hour inspection, will assist immeasurably with reliability for this and other foundry units. Repair parts such as bearings and the bearing seals are very precise; they must be kept perfectly clean and free from dirt or sand, both before and after installation. There is no room for careless assembly, since a single days operation could mean the end, of an otherwise three or more year life, of a delicate bearing for foundry sand mix mullers, shakeout, clay blenders and screening equipment. If bucket elevators or conveyors are used, they also will require equal care and caution during repair. All dirt must be kept out of bearings.

MELTING UNITS, CUPOLAS, CRUCIBLES, LADLES

Twenty five years ago in the more developed countries a 15 ton per hour, cupola iron melting capacity, was considered large. It took 8 men using wheelbarrows, to charge materials of about 18 tons into the cupola. Each man would maintain his own wheelbarrow and also worked on the cupola repairs during shutdowns. In the 1970's, a man sits in a traveling crane and does all the lift charging with the use of a magnet or charge bucket.

Other materials needed, are conveyed into the charge semi-automatically by a second man operating the cupola. The two men will melt 50 or more tons per hour, compared with 8 men to produce 15 tons per hour in the old days.

The foundry metallurgy and maintenance picture has also changed, even more drastically. The wheelbarrow mechanic now requires extensive training to maintain equipment, that now does the job of his 8 wheelbarrows. He must make repairs on the new equipment on schedule, while idle equipment production time is available.

A piece of wire or a rivet is not now suitable for the repairs on present day charging units. These new units demand the best of care, but the savings with better care will compensate extremely well, when repairs are properly organized and carried out.

Today's metallurgy requires precise control. Air volume, humidity and fuel consumption are now automatically controlled, regularly. This was not possible twenty five years ago, except in perhaps some limited instances.

The quality of iron and/or other metals, are known throughout the process. Preheaters and hot blast has been added to reduce coke consumption, high refractory usage has been greatly reduced, or eliminated, by the use of water cooled shells in the cupola and melting furnaces.

Actual labor per ton of production has been reduced, but the quality of labor has been continually pressed to upgrade. Foundry maintenance with metallurgy, consequently has been subjected to extensive upgrading of quality, skills and schedules. The underdeveloped countries are aware of these changes and are trying to meet the demands for improvements with advanced metallurgical practices. Wherever high maintenance does exist, a thorough analysis must be undertaken to learn reasons for its existence.

Mechanical handling equipment can if properly maintained, turn a losing foundry into a highly productive one. Often an answer is real simple, but analysis is needed, that means perhaps a meeting of the best minds available to determine which course of action should be followed.

In a pouring room operation familiar to the author, the maintenance costs for screens, hammers, chisels and remelting was excessive.

Ten men worked a 16 hour day at keeping spilled metal collected. Another fifteen men worked constantly for their 16 hours, handling, sieving, separating and drying sand. Small basket sieves were used, each time a man dropped his basket, the screen would be bent slightly. It would occasionally be bumped back into the desired position. As a result, after two days use a new screen had to be installed by maintenance. This took another 3 men, the 28 total manpower required 2 supervisors, all required additional accounting labor cost.

With their social benefits and extra time for remelting of metal, this package loss amounted to a total yearly cost of over $150,000. (U.S. dollars). The cost for additional coke and the further maintenance cost on the cupola were not calculated.

It was decided to install semi-automatic pouring and screening equipment, since the screen maintenance cost alone was over $100 (U.S. dollars) per 16 hour day, with actual manpower costs extremel low.

A total savings realized after the second year of operation was well over $110,000 (U.S. dollars) with this example there are many others similar. However, a point is made, to analyze and evaluate constantly to reduce maintenance costs, while improving metallurgy usually. To do so intelligently, one must have complete production data and thorough knowledge of the particular process concerned.

The cupola is probably one of the oldest units of metal melting equipment known to man, in his search for a means to produce products (parts) for, either original equipment, or for parts needed in periodic replacement. The cupola must withstand the most severe changes in temperature that can be expected of almost any other kind of equipment. Yet, it must perform continuously throughout the extremes of those temperatures, which may vary upwards, to perhaps as much as 1700° C (degrees Centigrade), 3092° F, (degrees Fahrenheit). The manufacturer, building equipment such as the cupola, has had a vast and varied experience with his equipment, under very broad operating conditions. His instructions should be very carefully considered, both before and during all maintenance functions that may become necessary. The melting equipment can be said to make the foundry. Without melting of metals, there would be no foundry. The word foundry tells us that this is the place where metals are cast. When metals melt, we have a general temperature range as shown by the following table,

Material	Melting Temperature F°	Melting Temperature C°
Steel	2850° 3200°	1565° 1760°
Gray Iron	2550° 2680°	1399° 1471°
Copper Alloy	1800° 2240°	982° 1227°
Alum. Alloy	1250° 1400°	677° 760°

While these figures do not apply to all material classes, they represent an approximation. As can be seen, the cupola or other melting unit must endure extreme high temperature ranges, wherever contact is made with molten metal. Consequently, maintenance in these hot areas is critical. Should there be any low grade materials, poor maintenance or a lack of close supervision during these critical repairs of a melting unit, it can result in failure. Certainly such ineffective low quality workmanship must be avoided. The best metallurgy requires close attendance to equipment record cards, regular inspection, good supervision, with constant training and periodic updating of all personnel concerned. The furnace and cupola firewalls are most critical, major repairs sometimes follow each melt period on non-water-cooled units. This should not be the usual requirement, but unfortunately, it is a fact in many foundries. While visiting foundries in a number of underdeveloped countries, the author has seen cupolas particularly, suffer the misfortune of having inferior refractory (firebrick and (fire) clays installed, to make the repairs. The results are usually disappointing and often a repair disaster, with one or more tons of melted iron a loss. With the very high temperatures required for iron, steel, copper and their alloys, there can be no compromise with quality materials, for the cupola and melting area repairs. As mentioned earlier such repairs are always expensive, but metal cannot be otherwise melted satisfactorily. Therefore, the time consuming lining repairs should not be considered, unless suitable refractory (fire) brick and clay materials have been obtained. If possible, the guidance of the manufacturer of the equipment should be secured. This can be in written, verbal, drawing, sketch or diagram form, or a combination of all, including pictures. In many of the underdeveloped countries known to the author, there is often a language problem and the manufacturer who provides only verbal or written instruction, assures only a very limited service, to users of his equipment in a foreign country. A picture, drawing or diagram carries with it unwritten pages of technical interpretation that writing cannot replace. Personnel concerned with major cupola repairs must be guided very carefully during this type work. They are unable to read pages of written instruction and thoroughly understand its meaning. As a result of numerous unsatisfactory repair experience in the multiple foundries known to the author, I strongly suggest experts should be employed as often as needed to provide satisfactory melting equipment repairs, if it is at all possible. The second choice would be a special training mission for one or more personnel who shall have responsibility for future maintenance and repairs. Obviously, if training is given, it should be on the specialized equipment concerned.

There are many factors which determine the original selection of melting units. The conventional or refractory lined cupola is by far the most widely used. In many of the underdeveloped countries known to the author, this type is the only one generally available. In recent years the water cooled type has been much more successfully employed, with a substantial savings in maintenance cost. The induction furnace and the arc furnace are now widely used in the more developed countries, with a great deal of metallurgical success and further savings in maintenance cost; also, the production cycle is extended many times by use of the water cooled type induction or cupola units. If the arc type furnace is used, volume production demands should be high, or maintenance can be expected to rise to prohibitive limits. The cupola is substantially less costly for small batch production, but unless water cooling is employed, a major repair job on the lining can be expected in a few days operating time. The heating and cooling action of the "hot" refractory lining, is extremely detrimental to its life and the endurance of the melting area. As a consequence, the maintenance staff is usually faced with a repair job very often. The coreless type induction melting furance is best suited to a job shop operation; however, its initial cost is high. Therefore, a long period of ammortization must be kept in mind. The melting is sometimes accomplished jointly, first in the cupola, as soon as melting takes place, the molten metal is tapped into the induction furnace crucible. Tapping must take place only after preheating of the induction crucible lining, unless a previous batch has just been melted and the refractory remains at a high temperature. The need for a reliable supply of electricity in large volume (about 600 KW input for 10 tons iron per hour) is one of the requirements for use of induction melting equipment. If this is available to those seeking to reduce costs of the cupola repairs, then a close examination should be made of an installation of the induction type equipment. Coreless induction melting is often combined with an induction holding furance and/or crucible, also a batch type preheater may be used. With this combination the initial cost will be considerably higher than the cupola, with or without water cooling. The operating and maintenance savings however will often outweigh the added initial cost for induction melting. Further savings may be available for a continuous casting line, even in job shops, providing however that weekly volume can be considered and reasonably regulated. Beyond the maintenance benefits, induction melting has a much more beneficial effect with good production control and quality of metallurgy. The important aspects of production and product quality control are not included in this writing, since it is an extremely valuable consideration and should be produced as a broad separate text.

QUALITY REFRACTORIES, HEAT RESISTANT LININGS

The manufacturer of the cupola may or may not manufacture the accessory equipment, items such as the blower, thermostatic controls, the refractory (fire) brick and clay materials. The latter two must be carefully considered, relative to the actual conditions under which they are expected to operate. Should the operating conditions demand temperatures in the lower melting range, of perhaps 1200° C (2192° F), then the quality requirements of refractory (fire) brick and refractory (fire) clays, would be much less, than those in the higher temperature ranges of 1600° C to 1700° C or more (2912° F to 3092° F). Fire brick normally, are manufactured by a specialty refractory, or a ceramic manufacturer, who may make a wide variety and quality of other products, which can be adapted to many different applications, under many different operating conditions. It is appropriate to mention here that a particular refractory (fire) brick of highly reputable quality may not be the most suitable for a specific application. The cupola operating staff, especially the maintenance supervision, must often judge, on the basis of all known methods, including trial and error, which of a wide variety of manufacturers produces the most satisfactory brick, for his particular application needs. It has been the experience of the author of this study, to have learned through practice, that a cupola refractory costing substantially more can ultimately be the least expensive. Refractory bricks are made under extremely variable conditions by each manufacturer. Each manufacturer uses ingredients which in turn have extremely variable qualities made under similar conditions during manufacture, yet the extremes of temperature and abuse that can befall the refractory (fire) brick in its desired application, may result in a totally unsatisfactory application. Let me present an example, of a refractory product built to withstand very high temperatures, under constant operating conditions. When the refractory brick can be initially preheated slowly to its operating temperature, it can withstand the demanding high temperatures amazingly well and for long periods. Should the same refractory brick be placed in operation under conditions whereby, it is expected to withstand the same very high temperatures, but without the controlled preheating initially, this product can easily become a complete failure, even though it may have normally endured all other demands, under exactly the same conditions as the previous application mentioned. Indeed the careful consideration of products and their endurance to the temperature demands can not be over emphasized. The harder materials, usually are much more brittle when placed under impact or heat shock conditions. It is well known that a cupola in one foundry, may operate for days at a temperature of, for example, 1400° C (2552° F), while the cupola in a similar foundry operating under very similar conditions will require much greater rebuilding (maintenance) than the former. The reasons for satisfactory of unsatisfactory product performances are rarely known to anyone, other than the technical management staff who are responsible, or those concerned with cost control or cost reduction analysis, in either the maintenance of the production of the product. Therefore, a critical requirement exists for rigid and constant analysis, in order to achieve the maximum results for productivity. It has been the experience of the author to know of excessive maintenance of equipment, which were entirely reflected by the desire for higher employment of manpower, in order to make work for the staff. Under these conditions it is often difficult for non-technical management to evaluate the most economical refractory brick for the specific purpose, for which it must perform. The best quality of refractory product, used under abnormal or unspecified operating conditions, may result in its immediate failure when required to withstand any abnormal hazards to which it can be subjected. If the product is expected to withstand or endure abnormal conditions or abuses, then the best quality products should not be considered. A compromise, therefore, for a slightly inferior quality may easily result in a much more satisfactory and economical application.

STABILIZE METALLURGY, FURNACES, HEAT REDUCTION (COOLING)

One of the most restricting factors to the production line is the time lag which follows pouring of foundry castings. This equipment, generally found lacking, or as makeshift units, consisting of blowers, exhaust fans, or similar types of circulating equipment positioned in such a way as to remove the radiated heat as it leaves the casting shakeout area. When this type of equipment can be strategically built-in with the cupola air intake as preheated air, it can serve a most useful and economical purpose. Such combinations of equipment will do much to reduce the burden of foundry maintenance. Since it permits heat exchange or transfer to effectively reduce the severe hazards of heat shock with expansion and contraction.

Let me explain it in this way. It is generally well known that when boiling water comes in contact with glass, usually it is a disaster for the glass, unless certain precautions are first taken, to carefully preheat the glass. When this is done properly, the glass will withstand very high temperatures.

The refractory materials compare similarly to glass in this respect. By preconditioning the refractory materials properly the foundry maintenance manpower load can be substantially controlled while maintaining the production line equipment in a most satisfactory way.

As mentioned earlier in this text, one of the worst situations that may confront the refractory in the furnace or direct heat reduction units, is the uncontrolled heating and cooling action.

Much can be said for automation, much more should be considered, as we look toward the automatic processes to answer a serious foundry metallurgy control problem. The latitude given and the flexibility of manually operated equipment vs. automatic or semi-automatic processing should be very carefully analyzed, if maintenance costs shall be kept under control.

The melting furnace refractories, whether the arc, the induction type, or the cupola types, are all fragile when we think about heating and cooling alternately. When the heat goes up, it must be kept up without undue fluctuation. When cooling down, the heat must be gradually reduced under control.

The foundry maintenance staff is charged with the responsibility of keeping the equipment operable and in its best condition. They must constantly be alert to improved metallurgy methods, and a philosophy which will help reduce the demands for their vigilance, while helping to improve the end product and its entire process.

The cooling of castings must either be controlled at shakeout or the castings must be furnace annealed to avoid chills.

Some types of castings will require heat treatment anyway, in order to produce their desired metallurgical qualities. It is, however, much more economical to control the cooling process initially, than to reheat the castings after they are cold.

It is in the interests of an efficient maintenance organization, to make such recommendations that overall equipment upkeep is reduced and that the process is blended into any benefits that can be realized through a reduced maintenance requirement, also by extending the life of costly equipment.

When sufficient volume of product is needed, a conveyor type cooling furnace may be most desirable. This type furnace would permit a variation of heat, spaced to control gradual cooling (or heating) of foundry materials. Hot sand from the mold shakeout is often used for control of casting cooling. It is however, usually inefficient and except for very small volume of casting, should not be considered. A small volume would be in the 15 to 30 ton range, smaller lots of castings made at any one time should be avoided. High operating and maintenance costs on small lot production will soon ruin the foundry, except perhaps for emergency casting, where costs are not an important factor.

When small quantities of castings must be made repeatedly, consideration should be given to combining two or more foundries into a joint operation.

It has been the authors experience in several underdeveloped countries, that each workshop or even a maintenance specialty shop, will attempt to cast his needs, no matter how small the casting volume may be. Such practice should be avoided except perhaps for an owner desiring his own research.

USE MOLD BOXES

In a number of the underdeveloped countries visited by the author, it was learned that their casting industry just grew, without aid of serious technical development. As a result, many of the foundries continue with very primitive methods.

Some foundries actually may be classed as reverting their technology. To further illustrate this point, a foundry which had been in existance for many years, serving small industry, received a sizable order for spare parts. Because their mold boxes had been poorly maintained and skills to make new ones were untrained, an immediate problem arose.

The responsible personnel thought, now what do we do. The idea came, it was, to bury a bottom mold into the ground. Now this provided an extra mold box to use for the top. It seemed like a good idea, it was done so by the early Romans, long ago. But as it was with the Romans, if there is any moisture contained in the ground and in most places except for the deserts, moisture is always found in the near surface areas.

The foundry in mind was no exception and moisture was in the ground. This fact was not considered, apparently at least. So the molds were made, hundreds of them, and buried into the ground surface. The cupola was charged, the iron (five tons) was melted and poured. The management were happy that the job could be finished so easily and so soon. The next day the molds were opened, the castings cleaned, despruced (sprues removed) to prepare for machining. Now a close examination of the castings showed some very rough surface areas, some much worse than others, many with holes in the surface, some of which were quite large.

The manager was called, then the customer was called, to learn if he would accept the defective castings. His answer was no, he had a new product and could not accept them, since there was no way of covering the unsightly appearance, on the finished product. So now what to do? The maintenance crew were called, a meeting was arranged, there a suggestion was made to repair the castings, weld them by filling the holes. Another suggestion was made, to melt a pot of lead and dip each casting into the molten lead bath, to fill the unsightly casting holes, then paint over the surface. Seemed like another good idea, except that some of the holes simply would not hold the lead, during the subsequent handling process. As one may guess, at this point no thought had been given to metallurgical quality. To the author's knowledged, about 30% of the castings were salvaged, by either welding up the holes or dipping the castings in lead or grinding out surface blemish. All this at extra cost of time and labor, to a hard pressed foundry structure. Beyond the extra cost, was a badly hurt reputation for the foundry.

In retrospect, the ground moisture found a highly attractive source in the drier sand and clay mold, burried in the ground. Moisture is further attracted by heat and heat will vaporize the moisture at once.

Unwanted vapor in a casting mold is a disaster for the casting, no matter what the metal may be. The heat and vapor combined generates steam and steam trapped in a small pocket of sand or clay is explosive. The explosions are numerous under conditions of ground or other undesirable moisture. A very common cause of blow-holes, surface roughness and porosity.

Mold boxes are extremely simple to make. They are most valuable to control metallurgical quality, to prevent undesired moisture from finding its way to an attractive (dry) mold source. The boxes can be used for months or perhaps years, with only very limited maintenance required.

The metallurgy as well as the product can be expected to suffer any and all the ill effects of the outside elements, when mold boxes are not maintained operable and available.

Mold boxes are not a cure-all, but they are part of good molding and casting practice. They are beneficial to metallurgical control. Their use aids maintenance by reducing the volume of sand and clay handled per ton of castings. With suitable mold boxes and proper copes and drags, with wood or metal plate (boards) to unitize the cope and drag. Metallurgy then has its chance of survival, assuming that metals and other elements are satisfactorily controlled.

The American Society For Metals, Metals Park, Ohio, 44073, has recently (January 1970) published an excellent volume over 470 p. p. and pictures, entitled: Metals Handbook, Volume 8, Number 5, Forging and Casting. The author suggests that this book should be in the hands of every foundry, interested in improving the practice of metallurgy and casting in general. The above source (ASM), also the American Foundryman's Association, have in fact much valuable data, books, slides, film, literature and information in general, on the broad metals field and metals processing.

ORGANIZATIONS PROVIDING VALUABLE METALLURGICAL INFORMATION

American Foundrymens Society
Pittsburgh, Penn.

American Society for Metals
Metals Park, Ohio, 44073

Society of Manufacturing Engineers
20501 Ford Road
Dearborn, Mich., 48128

Foundry
The Penton Publishing Co.
Penton Building
Cleveland, Ohio, 44113

Ductile Iron Society
Box 853
Cleveland, Ohio, 44122

American Smelting and Refining Society
P. O. Box 5795
Tucson, Arizona, 85703

Society of Automotive Engineers
Two Pennsylvania Plaza
New York, 10001

Iron and Steel Institute
Bedford Hills, New York, 10507

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