

analysis of
**CASTING
DEFECTS**



an American Foundry Society publication

analysis of **CASTING DEFECTS**



American Foundry Society
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PREFACE

The original, **Analysis of Casting Defects**, was published in 1947 to help foundrymen eliminate or minimize inherent casting problems, improve casting quality and reduce cleaning and finishing costs. Guided by the dedicated efforts of the members of Committee 8-S, extensive data and photographs have been accumulated. This could not have been accomplished without many hours of involvement by members of this Committee or the support of their employers.

A second edition was published in 1966 under the guidance of original and new members of this Committee and a convenient pocket-size, ready-reference book published in 1972 for on-the-spot referral by operating personnel (as well as for in-plant training).

Many of the related casting quality problems and some of the recommended industry-proven corrective actions can apply to all metals — ferrous as well as nonferrous. It is hoped that the data contained will prompt the reader to be detailed in his investigative approach to properly identify casting problems. An error in identification will not only delay the actual solving of the problem but can result in the loss of many valuable manhours.

This, the third edition, with revision, again displays the results of combining the many years of experience and further development of casting production knowledge. In encouraging and supporting the respective Committee members' participation in this important contribution to metalcasting technology, the individual companies have performed a most valuable service to the Industry.

Committee 8-S of the Molding Methods and Materials Division became the Special Publications Committee (80 G-2). It is under the guidance of this Committee that this edition is prepared. Committee 80 G-2 —

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INTRODUCTION

Quality control implies both prevention and cure of casting defects. Preferably, wasted production which results in a rejected casting should be prevented before it occurs. In fact that is the ultimate objective of any quality control program. In the process, however, it is also necessary to correctly diagnose defects which have occurred so as to promote proper methods to prevent reoccurrence in the future. This text deals with the diagnosis and correction phases of quality control in the area of rejected castings or castings which require excessive salvage, costly grinding or cleaning, and other nonprofitable phases of casting production.

Every business would prefer a program of zero rejects (ZR)* and effort in that direction can be expected to yield excellent returns on the investment in time and energy needed to make every producing individual ZR conscious. However, in every manufacturing process, troubleshooting is necessary when the unforeseen does occur. At that point, it becomes necessary to rely on basic problem-solving techniques. This text is designed to be of maximum assistance to foundrymen in two of the most important phases of problem solving — diagnosis and recommended remedies. Particular emphasis is placed on the diagnostic aspects because they become the most important phase of the remedial quality control activity.

There are correct and incorrect methods of approaching any problem. The correct method is always the best and the most effective. The steps in corrective procedure are expressed in the following paragraphs.

(1) *State the problem.* A correct, concise, complete statement of the problem is synonymous with correcting the problem. If we can say, for example, "There is a blowhole in casting No. 1, which coincides with a wet sand condition every time the mold is rammed beyond a density of 92 unless the metal is poured at over 2625 F," we can believe the cure for the defect is obvious. The cure is obvious because the statement of the problem is complete. However, if we say, "There are a lot of holes in some of our castings," we haven't said anything which truly leads to solving the problem. In this case, our statement of the problem is ineffective because it is completely lacking in pertinent factors.

(2) *Get the facts.* In getting the facts this text becomes a valuable tool. It helps to identify the problem by illustration and description. It points out the many factors which may have an effect on the defect in question. It helps one decide the areas which should be looked into for pertinent data. Pictures illustrate the typical appearance of certain defects and should be used only as an aid in diagnosing defects. In some cases, two or more entirely different defects have a similar appearance. Just because a casting looks like the picture captioned, "Blowhole caused by wet sand," doesn't prove that the casting defect is caused by wet sand. The problem may be in one of the other 30 possible sources of the same defect.

In using the text to develop facts, it must be remembered that it can serve only as a guide. The facts or data must be developed from one's own records. These records then should be sufficiently complete to provide the data. As a first step, it may be well to review the records to see whether they would yield the data required if an occasion arose. The records should answer such pertinent questions as:

Where? When? How? How often? Why? Who?

It may develop that for a certain defect that pertinent facts appear to be missing. In this case, the next step will be to get the missing facts.

(3) *Research for missing facts.* Again, the text becomes a guide. It will help locate possible clues which can quickly lead to pertinent data. Perhaps there are data on "sand," for example, but none on "molding." In what areas of molding practice lies the answer to the problem?

It is to be hoped that at this point, the problem can be restated.

(4) *Restate the problem.* If Steps 2 and 3 have been completed, it should now be possible to state the problem in such a way as to proceed directly toward a proper solution.

(5) *Test a trial solution.* This is where many start. Too often one attempts to solve the problem without knowing the exact nature of the problem. Attempting a solution is Step 5 — not Step 1.

If the assumed solution indicates that this is the correct action, then one is ready for Step 6.

(6) *Take action.* Some people skip all five prelimi-

*ZR is the symbol commonly used in quality control to represent a goal to achieve.

nary steps and start at this final step. Such action may prove very expensive. Making a change in practice is the last step in the problem-solving process — not the first.

It should be emphasized that this text is not intended as an inspection handbook. Its function is to help foundrymen improve their product and reduce losses or rejects. Any phase of the casting which detracts from its appearance or increases the cost of cleaning or finishing is considered a defect. Whether the blem-

ish impairs the utility of the casting is not the criterion used in this text. The role of inspection is to make sure that the customer receives a quality product.

The purpose of control is to produce in such a way as to avoid the possibility of rejection. The function of control and inspection is to provide the customer with a casting at the lowest possible cost commensurate with the quality level demanded by the application.

BROKEN OR CRACKED CASTINGS

DESCRIPTION

This refers to castings which have been broken or cracked by mechanical action or rough handling. Figure 2.1 is an example of a typical broken casting.

CAUSES

Casting and Pattern Design

(1) *Irregular sections, such as isolated heavy sections, light sections or projections* require careful handling in the cleaning room and shakeout. (See Fig. 2.2.) The weakness is often compounded by a tendency toward internal heat stress in these sections prior to normalizing or annealing. These sections are also most apt to feed improperly. New jobs of this type should be checked by destructive testing, when possible, or x-ray to insure soundness.

(2) *Lack of fillets* is a modification of (1) since sharp corners are particularly prone to cooling stresses prior to heat treatment.

(3) If *reinforcing ribs or tie bars* are not used to strengthen areas of poor design that would otherwise contribute to breakage, castings may break or crack.

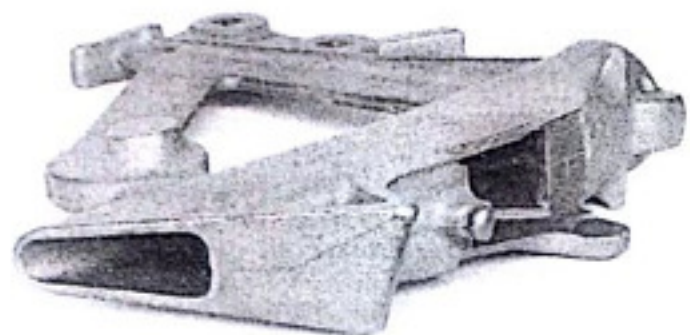


Fig. 2.2 — The protruding section of bar on the casting shown tended to break off during cleaning, milling or shakeout.



Fig. 2.1 — Typical broken casting in which the gate did not break off in the intended section.

Pattern Equipment

When proper break-off notches are not provided on gates and risers, undue stress is placed on the casting itself. Any design problems would thus be compounded.

Flask Equipment and Rigging

(1) *Flask bars that are too near to the riser or sprue* may create internal stresses by inhibiting the normal shrinkage of the casting. If this stress does not result in a hot tear, it may still be unrelieved. This then induces cold cracks or breakage during rough handling (including rapid cooling during shakeout).

(2) *Flask bars that extend into deep pockets*, not allowing normal collapse of the sand, will produce stresses in the casting of a nature similar to that described in the preceding paragraph.

Gating and Riser

(1) *Lack of adequate fillets* on the gating system permits the gate or riser to break into the casting during knock-off.

(2) *Incorrectly placed cracking strips and tie bars* can be either too large, so as to be hard to remove without cracking the casting; or too small, thereby failing to accomplish their purpose of preventing stress in the casting. (See Fig. 2.3.)

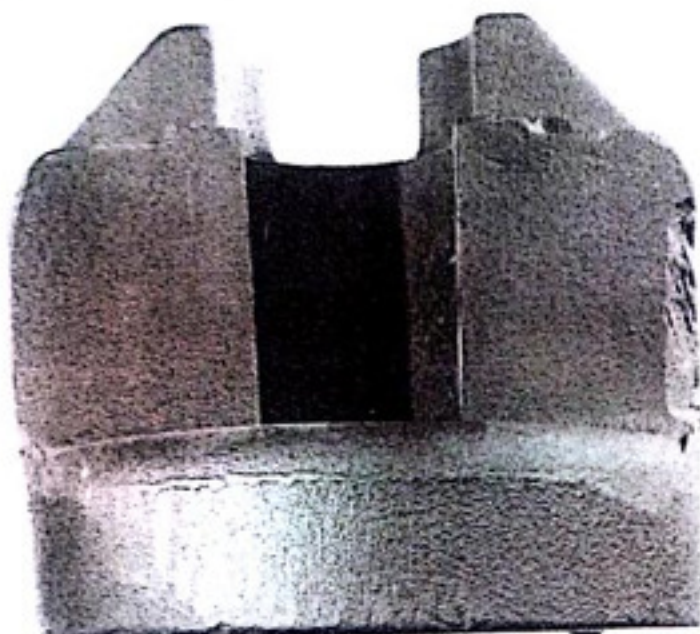


Fig. 2.3 — Poor design of the cracking strip increased the breakage of this malleable casting in the hard iron condition.

(3) Any gating system which promotes stresses can be a basic problem. The usual mistake is to ignore the normal rules of progressive solidification in such a way as to create strain or stress in light sections.

Molding Sand

Although the defect occurs from rough handling, there are many factors which commit the casting to unusual internal stress, thereby making the casting excessively delicate.

(1) Poor sand collapsibility due to excessive hot or dry strength which places a cooling strain on the casting may cause broken or cracked castings. Among the factors which promote excessive hot and dry strength are excesses of pitch, moisture, fines, clay or binder.

(2) Low sintering point materials (fluxes) can cause an abnormal rigidity in the mold and thereby prevent normal collapse.

(3) High hot strength coupled with low green sand deformation increases the cooling stresses within the casting. High hot strength can often be tolerated provided the hot deformation is adequate. For example, excessive density in the mold tends to increase hot strength more rapidly than it increases deformation. This factor reduces mold-wall movement but may pre-stress some of the more faulty casting designs.

Core Practice

(1) Poor collapsibility due to excessive hot or dry strength may be caused by excessive pitch, excessive moisture, excessive fines and excessive clays or binders.

(2) Low hot deformation when coupled with poor collapsibility of the core further compounds the problem. Types of binders used will change the cracking tendency.

(3) Rods, arbors, and the like that are too close to the surface of cores create a localized restriction in collapse and will cause localized stress during the cooling of the casting.

(4) Over-reinforced cores may interfere with the nor-

mal collapse of the core and create cooling stresses within the casting.

Molding Practice

(1) A mold rammed too hard prevents proper collapse or causes an undesirable increase in hot strength without a comparable increase in hot deformation.

(2) Rods, arbors, and gagers which are too close to the mold surface cause the same effect described under Cores (3).

(3) The effect of a riser or sprue too close to a flask bar has been described under Flask Equipment and Rigging (1).

(4) Excessive swabbing or sponging of the mold may create localized areas of high hot or dry strength as indicated in Molding Sand (1).

(5) Improper use of chills or excessive chilling may easily create internal stress in the metal because of unnaturally rapid cooling in local (chilled) areas.

Metal Composition

Metal composition is a factor in that the tendency of a metal to develop internal stresses is related to composition. Some metals are unusually sensitive to section size or cooling rate. These metals may be difficult to handle in critical designs. See (1) and (2) under Casting and Pattern Design.

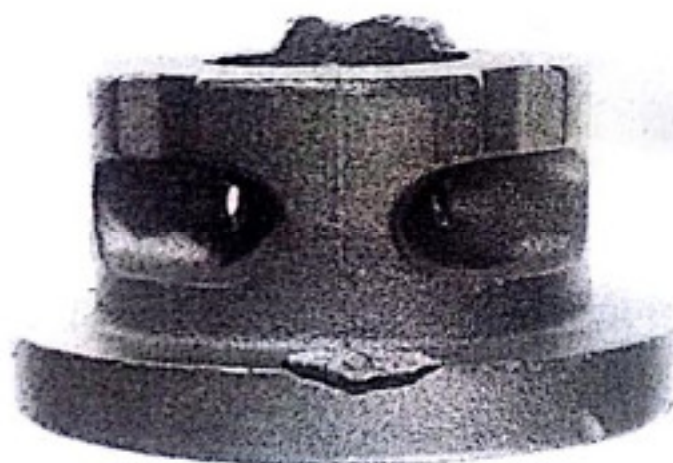


Fig. 2.4 — Early rough shakeout of the gray iron casting broke the gates into the casting while they were hot and weak.

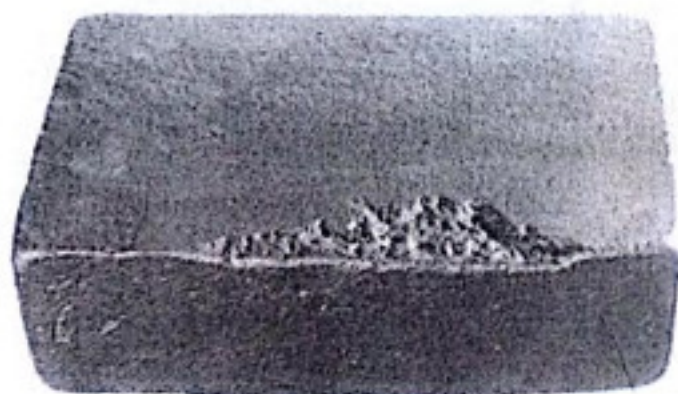


Fig. 2.5 — Careless de-finning caused the casting to break in the gate area.

CARBON FLOTATION (KISH) AND OTHER GROSS SEGREGATIONS

DESCRIPTION

Kish is free graphite which has separated from molten iron. Similar gross segregations occur in spheroidal graphite metal (ductile iron), in many nonferrous alloys and, in fact, in all metals in which the composition desired is close to, or exceeds, the maximum solubility of one or more elements. This defect is a function of metal composition and cooling rate. As a result, all factors which affect the cooling rate become important in determining the correct composition. Equilibrium diagrams indicate the limit of solubility and eutectic compositions under conditions of infinitely slow cooling. A more rapid cooling rate changes the compositions which may be cast without segregations. For example, 4.3 per cent is the theoretical eutectic point for gray cast iron at infinitely slow cooling (carbon equivalent). In practice, extremely fast cooling such as in piston ring castings, may permit as high as a 4.5 per cent carbon equivalent before showing hypereutectic structures. Heavier sections attempted in the same composition range could easily show kish formations (see Figs. 3.1 and 3.2). Slow cooling for any reason (such as near an ingate or runner) could likewise change the apparent eutectic effect.

CAUSES

Casting and Pattern Design

(1) *Too great a difference in metal sections causes segregation due to slow cooling in the larger sections if the composition is planned for the more rapid cooling sections. With some designs of this type, the foundry-*

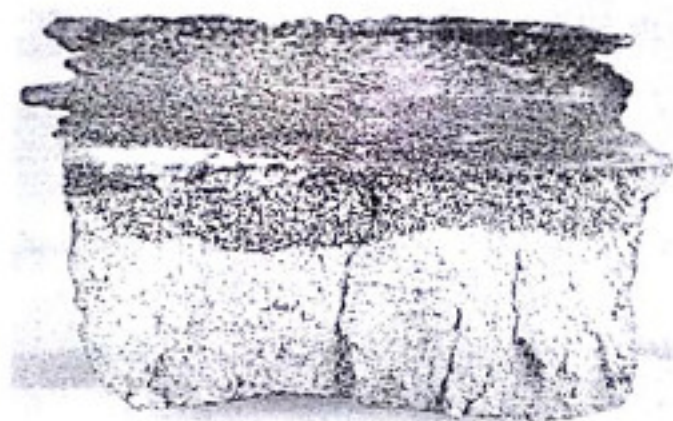


Fig. 3.1 — Typical carbon flotation in ductile iron.

man is forced to compromise between a correct composition for the sections involved. For example, in cast iron, he may have to choose between a chilled or unmachinable light section or a correct light section with danger of kish in the heavier sections.

(2) *A section of mold or core that promotes heat retention in the mold or core would promote localized segregation. An example of this problem is found in those designs which include a small core in a reasonably heavy section. The core may retain heat to the extent that the effective section is larger than indicated. The composition may have to be chosen on the basis of a heavier section than the design would seem to indicate. For example, a 6 in. section lightened with*

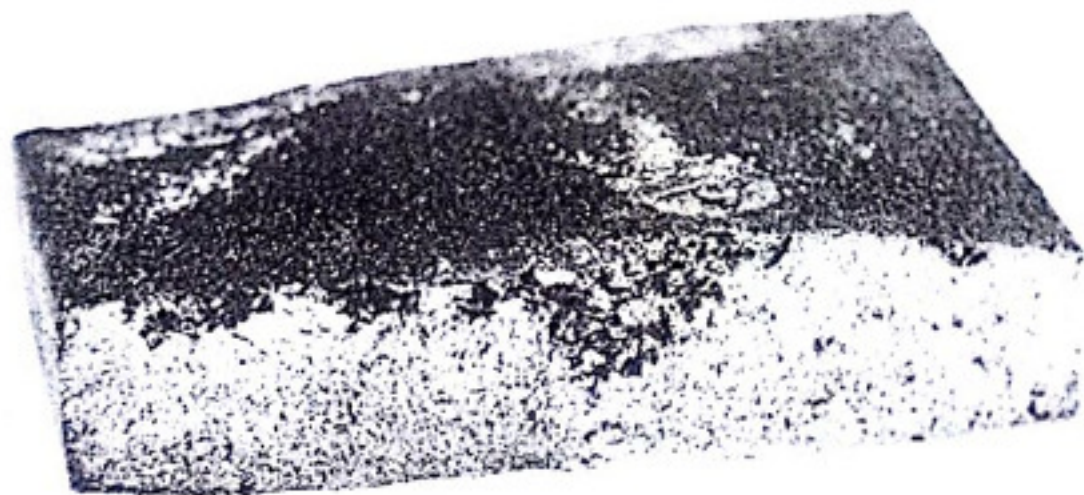


Fig. 3.2 — Dross in ductile iron.

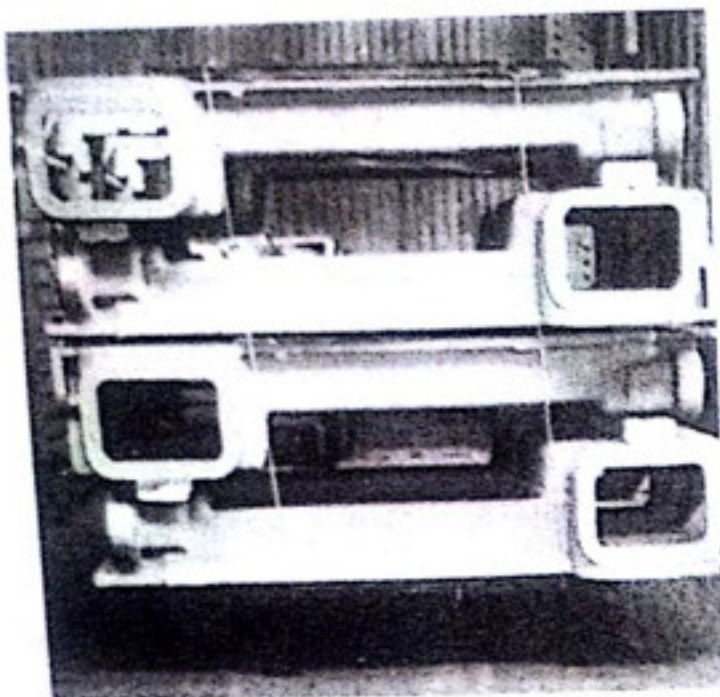
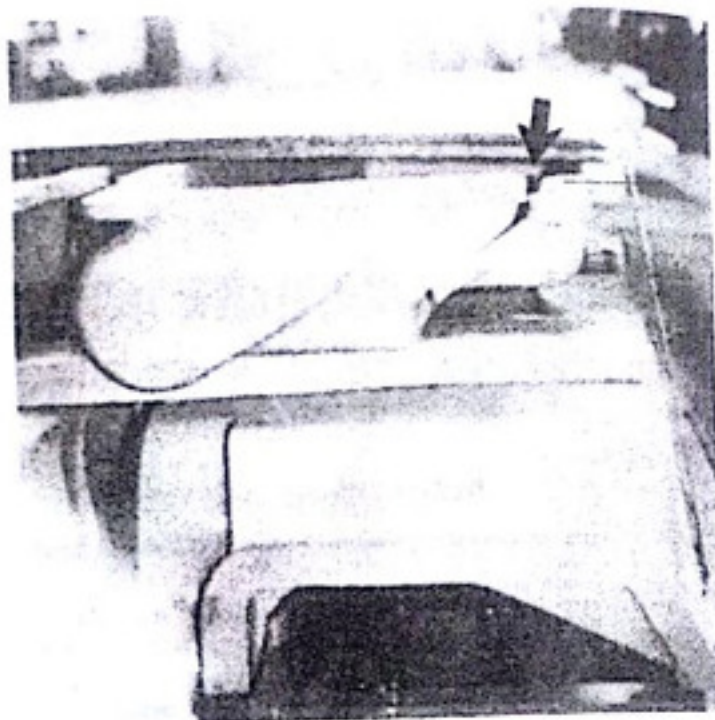


Fig. 2.6—Tight banding on pallets (shown left) broke the casting as shown in the end view (right).



- (1) *A wrong composition for the application may be a factor as described previously. However, an injudicious variation in composition further increases the tendency toward metal stresses. The wrong composition may have to do with a reduction in strength of the alloy so that even normal stresses cannot be tolerated.*
- (2) *A composition having too high shrinkage characteristics may be the result of incorrect melting technique such as faulty furnace atmosphere.*

Melting Practice

- (1) *Excessive carbide stabilizers which promote high shrinkage, particularly with gray iron, set up high internal stresses, especially with nonuniform sections. Highly stressed castings are easily broken.*
- (2) *Composition having too high shrinkage characteristics may cause defects.*

Pouring Practice

- (1) *Insufficient pouring temperature to promote proper collapsibility of the sand and cores may be due to melting practice, or it may be a matter of temperature loss during transportation of the metal or pouring. The result is that the casting fails to destroy the binder properly, and the mold or core fails to collapse as desired.*

Miscellaneous

Since the problem is defined as being related to mechanical abuse, or careless handling, it is principally

caused by miscellaneous accidents which can occur from poor housekeeping, carelessness or lack of personnel training.

- (1) *Shakeout may be too soon after pouring or too severe. This latter may be due to faulty equipment or long dwell-time in shakeout. (See Fig. 2.4.)*
- (2) *General carelessness in handling includes: dropping, throwing into containers, throwing heavy castings on top of light ones and careless trimming and finning. Figure 2.5 illustrates a case of careless finning.*
- (3) *Improper packing in tumbling barrels and in similar mechanical cleaning equipment permits the castings to tumble and break each other.*
- (4) *Heavy castings which are barrel-blasted or tumbled with light thin section castings may act as sledges on the light castings and either crack or break them.*
- (5) *Careless and rough handling in loading or unloading, especially prior to heat treatment, is an obvious cause of breakage.*
- (6) *Improper piling or stacking can impose undue stress on intricate or delicate castings.*
- (7) *Banding too tight on pallets has been known to crack light sections or complicated castings (see Fig. 2.6).*
- (8) *Any mechanical handling that drops casting any distance into containers may be the cause of breakage.*

a 1 in. core would seem, on paper, to be only $2\frac{1}{2}$ -in. thick (6 minus 1 divided by 2). The heat retention of the core would, however, provide the same cooling rate as a 6 in. section and, therefore, could show kish if the slow cooling was not allowed for in the choice of composition.

Pattern Equipment

Pattern equipment, as such, does not cause segregation unless the patternmaker is also responsible for the gating and risering size and location.

Flask Equipment and Rigging

Rough running flasks (out of balance) in centrifugal castings have been known to promote segregation of alloys which are on the borderline of composition. The interruption of normal centrifugal forces apparently acts the same as a modification of cooling rate, thus separating those components which have segregation tendencies. An example is found in spun cast iron pipe of high carbon equivalent. In this practice, both kish and manganese sulfide inclusions have been spun out.

Gating and Riser

(1) *Distribution of gates and risers promoting heat retention* in localized areas acts to provide a cooling rate in some sections which would normally be found only in a much heavier section. For example, a heavy riser mounted close to a relatively thin section could produce a cooling rate in the thin section of the casting which would be equal to a section many times as great. If the composition is based on an assumed fast cooling in the section involved, a gross segregation could result.

(2) *Localized hot spots at the gate or riser junction* may slow down cooling to the point that gross segregation is found in the gate junction or riser neck.

(3) *Turbulent flow* of metal interrupts the normal cooling rate to be expected in a given section. It may start precipitation or segregation of components which would otherwise remain in solution or suspension in a nonturbulent flow pattern.

(4) *Incorrect use of exothermic molding materials* causes localized overheating or a cooling rate other than that anticipated when specifying the composition to be employed.

Molding Sand

Abnormally slow heat transfer due to the use of insulating materials in the sand can change the anticipated cooling rate of a given section. Where very close composition tolerances are involved, an unusually soft mold or the presence of excess wood flour could be enough to start segregation. In most cases, compositions are chosen which have sufficient safety factors to overshadow these minor changes in cooling rate, but may not be enough for a drastic change in sand practice, as illustrated by major additions of perlite in nonferrous anti-scab practice.

Core Practice

(1) *Underbaked oil-bonded cores which create an exothermic reaction* causing excessive heating of the core

could materially change the cooling rate of an adjacent metal section.

(2) *Insulating gas films* such as in shell cores may act to change the rate of heat transfer from the metal section into the sand. The result is a retarding of cooling to the extent that the anticipated composition becomes dangerously close to segregation conditions. A major change in core practice could require a modification of metallurgy in those cases where the composition is critical so far as gross segregation is involved.

Molding Practice

(1) *Introduction of any insulating material* such as asbestos or perlite can produce localized slow cooling.

(2) *Incorrect use of exothermic molding materials* changes the cooling rate of the metal sections adjacent to the heat source (exothermic). As in the case of riser placement, it is necessary to recognize the effect of exothermic heat on the cooling rate of the casting section.

Metal Composition

(1) *Gray iron and malleable.* The carbon equivalent may be too high for the cooling rate involved. As described in the introductory paragraph, the exact eutectic point in these systems is seldom found at exactly 4.3 per cent carbon equivalent. The foundryman is forced to exceed this figure in thin sections in order to avoid excessive hardness. As a result, a heavier section may be adversely affected since the carbon equivalent could then be excessive for the heavier section.

Phosphorus too high for the application is a ramification of the above since, although phosphorus is not always shown in a carbon equivalent calculation, it has an influence on the eutectic formation. In some cases, the effect of phosphorus is equal to an equal amount of silicon.

Insufficient carbide stabilizers permit free carbon to segregate in high carbon equivalent irons.

Excessive use of graphitizers may have a direct effect on kish formation in addition to their obvious influence on carbon equivalent. Some graphitizers used as ladle additions have an apparent "seeding" effect when added to borderline compositions even in thin sections.

(2) *Spheroidal graphite iron* (ductile iron). In addition to the factors discussed in the preceding paragraphs, there is an added influence from the use of either excessive magnesium treatment or excessive secondary inoculation. Both of these have an effect on graphite formation and such practice may be easily overdone in spheroidal compositions close to eutectic.

High sulfur can contribute to segregation of manganese sulfide and other segregations which are thrown out of solution by the nodularizing treatment.

Aluminum plus titanium in excess of 0.10 per cent produces a segregation of ternary carbide eutectics.

(3) *Steel* does not usually exhibit gross segregations except in special alloys such as high sulfur or leaded (free machining) steels which can show segregations. Special purpose high copper steels may also show segregation if the copper is in excess of solubility limits (approx. 0.6 per cent).

(4) *Aluminum.* Copper or other alloy additions ex-

ceeding the solubility limit may show as gross segregation.

Melting Practice

(1) *Cupola-melted gray iron and ductile iron* may develop segregation as a result of faulty melting practice which produces an unintended change in composition. Improper balance of air to coke promoting carbon pickup will produce an undesirable level of carbon equivalent, in addition to a direct seeding effect if the base composition is already close to, or in excess of, eutectic.

Melting too hot causing excessive carbon pickup at the beginning of the heat produces an off-analysis in the direction of kish. Too long a tapping interval maintains contact between coke and metal to the extent that carbon pickup may be greater than anticipated. Intermittent operation (shutdowns, etc.) allowing excessive carbon pickup produces an unanticipated high level of carbon equivalent.

Nonuniform chemical composition, due to variation in size of materials charged, produces variations in carbon which then results in some metal with excessive carbon plus some with insufficient carbon. A uniform melting rate of all ingredients in the cupola charge can be accomplished only within a reasonable range of size and shape variation.

Careless charging of materials or careless weighing of ingredients of the charge result in nonuniform chemistry. Some of these nonuniform compositions may exhibit excessive carbon equivalent for the cooling rates under consideration.

(2) *Malleable*. Melting too hot, too fast, or with a carbonizing flame can result in excessive carbon equivalent, or may result in a direct seeding effect which then starts kish accumulations.

(3) *Steel*. None.

(4) *Aluminum*. Excessive superheat starts a grain growth phenomenon which may induce or show as a segregation. Careless makeup of the charge introduces

impurities above their solubility limit which thereby become segregations.

(5) *Magnesium*. Careless makeup of the charge introduces undesirable and segregating type impurities.

(6) *Brass and Bronze*. Leaded bronzes not adequately stirred will show segregation of the lead. This is a major problem since the lead is not in true solution and, therefore, can segregate easily. Dirty or skulled ladles causing contamination introduce segregations either because of a composition change or because the impurities are only partially reabsorbed by the melt.

Carelessness in segregating returned scrap permits the alloy to be melted with an incorrect analysis. Careful separation of returns is most important in those foundries producing more than one composition of brass or bronze. Wrong ingot or incorrect scrap charge would appear to be inexcusable carelessness, but it does occur on occasion since many nonferrous charge materials are similar in appearance and readily confused.

Pouring Practice

(1) *Pouring below the temperature of solubility* is most apt to occur when alloying elements differ widely in their solubility temperature. Cooling before pouring permits some components to come out of solution even though the original melt was adequately blended and alloyed.

(2) *Pouring too hot* in the case of leaded bronze permits the lead to segregate during the solidification process. These alloys must be poured as close to the solidification point as possible and be stirred immediately before pouring.

Miscellaneous

Rates of cooling too slow for the composition apply to many of the preceding points. In addition, there may be involved: molding material chosen whose rate of heat transfer is too slow for the alloy being produced; and the omission of needed chills.

CRUSHES, PUSH-UPS AND CLAMP-OFFS

DESCRIPTION

Crushes, push-ups and clamp-offs are indentations in the casting surface. These defects are caused by disruption of the mold surface due to external or internal force or weight.

Although certain sand or core weaknesses can cause or contribute to these defects, the major cause is some form of carelessness. Included as carelessness is the use of worn or warped equipment as well as the obvious misuse or rough handling of adequate equipment. Because of this, the more common causes are listed under **Flask Equipment and Rigging and Molding Practice**.

CAUSES

Casting and Pattern Design

These defects cannot be directly attributed to casting design. Some designs require unusually accurate equipment and, thereby, minimize the range of carelessness permissible.

Pattern Equipment

(1) *Worn patterns and core boxes.* These are the major sources of trouble. For example, a worn pattern can result in the core print being too small for the normal core. Conversely, a worn core box results in the core being too large for a normal print. The end result in each case is the same—a crush. These worn areas should be repaired as soon as they are observed—preferably before they result in a scrap casting. Figure 4.1 illustrates a typical crush defect due to worn pattern equipment.

(2) *Insufficient draft.* Insufficient draft can be due to an error in the original patternmaking or to worn equipment. If an error in manufacture, the error can be corrected. If the fault is the result of design calling for less draft than can be handled in the molding medium and equipment involved, the problem may have to be relieved by the use of a core.

(3) *Pattern not correctly mounted.* Such a pattern can crush either the sand or core print. This can be avoided by remounting the pattern correctly.

(4) *Misaligned cope, drag patterns and plates.* This is a modification of incorrect mounting where precision in matching the two separate patterns is necessary. It could result from worn matching equipment or from human error.

(5) *Worn pins and bushings.* Worn pins and bush-

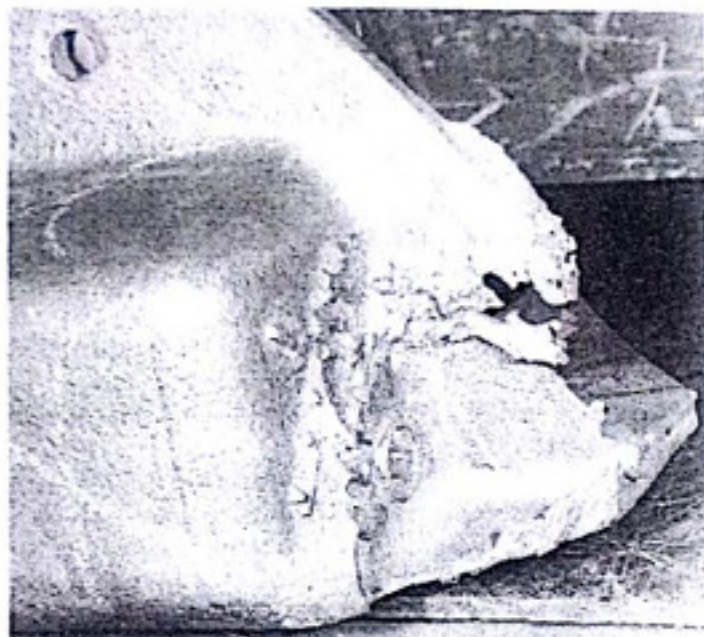


Fig. 4.1—Typical crush defect. In this case the original cause was worn pattern equipment which promoted uneven clamping.

ings, bent pins, wrong size pins, or the use of no pins are all the result of trying to extend the life of equipment too far. Pins and bushings can be reused and mounted, but only after adequate inspection.

(6) *Core prints not properly marked.* This leads to use of the wrong core in the foundry, especially if the job is new to the particular core setter who will handle the job. All prints should have adequate telltales, special shapes or nonreversible prints.

(7) *Lack of crushing strips.* Crushing strips may be required in the case of inadequate supporting sand between the flask and the pattern. The better approach would be to use a larger flask or relocate the pattern to suit the available equipment. Crushing strips can also be used to compensate for nonuniform plate thickness.

(8) *Core print too small to support core.* This creates difficulty in preventing a narrow neck of sand from breaking between main body of core and the print area. The print should be enlarged or, if this is impossible, a support core or ram-up core used at the green sand surface to develop adequate support.

(9) *Warped or untrue pattern plate (cope and*

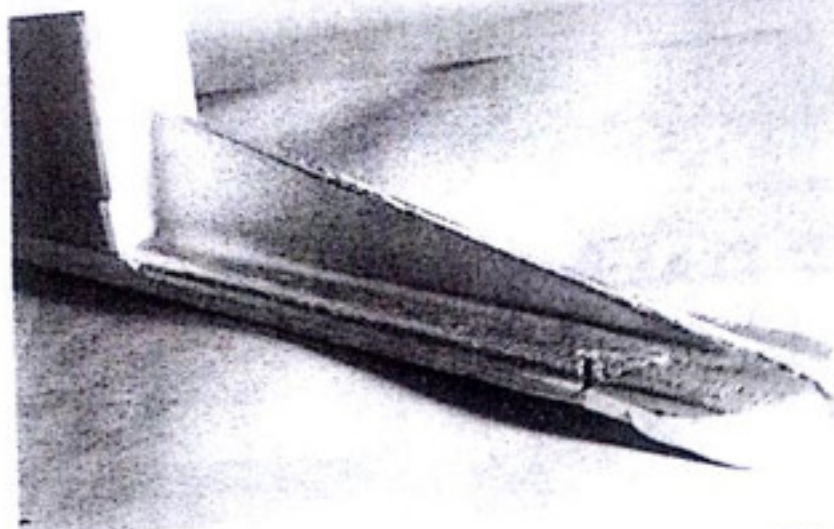


Fig. 4.2—Careless closing of the mold created the crush shown.

drag). This results from using a pattern plate which is too thin, too flexible or too weak for the application. It should be replaced with a heavier plate or reinforcing ribs may be added in some applications.

(10) *Excessive flexibility of matchplate*. This should be avoided or supports should be added under the matchplate frame when this is permissible. Reducing squeeze pressure may offset this problem but could lead to other defects common to soft ram (oversize castings, etc.).

(11) *Flask landing strips too high above parting line*. This creates a condition of excessive loading at the sand-to-sand contact. This problem usually results from an effort to reduce parting line runouts. It may also occur when changing molding practice from soft molding to high pressure squeeze. The increased mold hardness of high pressure molding may require some shims of pattern equipment in order to eliminate a crushing at the parting line. This may show as a crush defect or as loose sand in the drag after closing.

Flask Equipment and Rigging

(1) *Misalignment of flask equipment, pins, and bushings*. Misalignment is a normal result of wear or abuse. Bushings and pins should be replaced any time they fail to meet inspection using go and no-go gages. A common maximum tolerance on such equipment is 0.014 inch. Wear beyond this maximum cannot be tolerated in precision equipment.

(2) *Weights too heavy or uneven*. Such weights cause a direct crush unless the sand mold is unusually strong.

(3) *Insufficient bearing surface*. Insufficient bearing surface by excessive crowding of the pattern causes the mold weights to be supported by inadequate areas of sand. This results in compression failure.

(4) *Warped or uneven flask joints*. Flask joints warped from wear or misuse create a crush condition during the clamping or weighting process. This problem requires rework such as grinding or build up welding followed by surface grinding or machining. When beyond repair, the equipment should be replaced.

(5) *Worn stripping plate on molding machine*. The

worn plate causes an uneven push-off resulting in a scraping of the mold surface and distortion of the mold itself. Closing distorted molds is a common cause of crush.

(6) *Improperly fitting, dirty, or crooked jackets*. These place excessive loads on the sand mold. Unless the mold is unusually strong, a crush will result. If the mold is strong enough to carry the load, a parting line runout may result.

(7) *Worn pins and bushings*. Worn pins and bushings, bent pins, or wrong pins cause misalignment of the cope and drag resulting in the cores disrupting the cope surfaces of mold or prints.

(8) *Uneven, dirty, or burned bottom boards*. These cause an uneven pressure on the bottom of the mold and result in push-ups. Bottom boards should be inspected on a regular basis and either cleaned, repaired, or replaced as needed.

(9) *Weak bottom boards*. Weak bottom boards allow the mold to sag and distort to the point of crush—or even mold breakage and runouts.

(10) *Improperly barred cope*. An improperly barred cope permits cope sag and results in a crush during closing. In the same manner, an excessively shallow cope (or soft ram) may cause a crush.

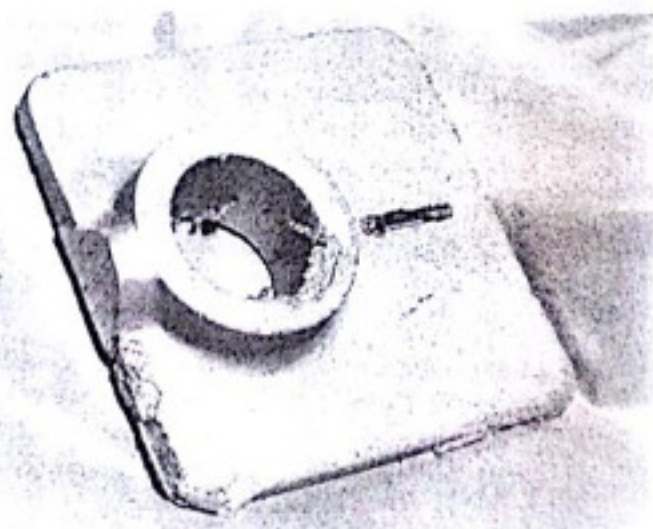


Fig. 4.3—Uneven clamping of the small mold crushed one side of the mold face.

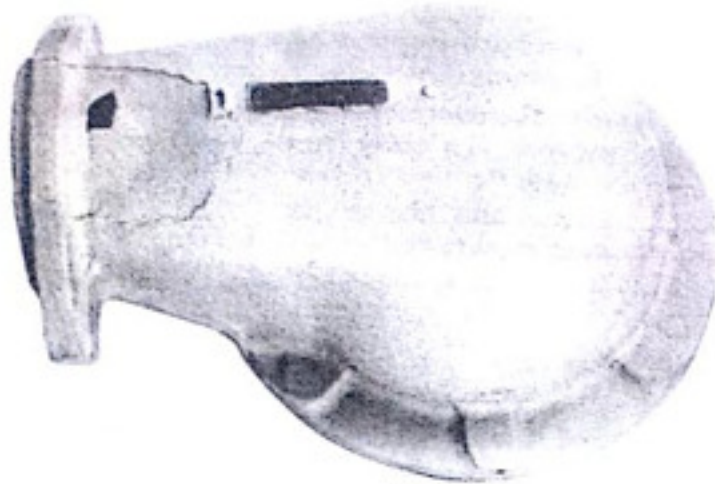


Fig. 4.4—A lump of sand in the bottom board created the illustrated push-up.

Gating and Riserling

Gating and risering do not, by themselves, create a crush although mounting gate runners too close to the pattern is a modification of inadequate bearing surface discussed under **Flask Equipment and Rigging** (3).

Molding Sand

The sand properties may contribute to all factors listed under **Pattern Equipment and Flask Equipment and Rigging**, since weak sand will crush more readily than strong sand. However, it is usually an error to attempt to compensate for poor equipment by increasing sand strength.

Even with adequate equipment, certain sand properties can contribute to crushes.

(1) *Low green (tensile) strength* may permit the cope to sag. This low tensile usually results from excess moisture. Such excess water is particularly important in large flat cope surfaces.

(2) *Low green deformation* causes the sand to crush rather than give during closing of cope. The low green deformation may be the result of unusually dense molding (high pressure) with inadequate cushion materials such as clay. Low impact values in the laboratory may be more indicative than the deformation test itself (shatter index).

(3) *Low dry strength* in a dry sand mold may fail to support the normal loads. For example, it is common practice to dry or skin dry the drag half of molds which have to support heavy cores. In this case, the dry strength developed must be adequate to meet the demands of the loads imposed.

Core Practice

Cores which do not conform to intended dimensions can lead to crushes, push-ups and clamp-offs during the closing of the cope.

(1) *A core too large for the core print* will fail to seat properly and cause a crush when the cope is lowered.

(2) *A misaligned core assembly* will cause incorrect contact when the cope is placed.

(3) *A core sagged out of shape* may be the result of such factors as: rough handling while green; soft ram; low green strength (sag resistance); excessive water in the core mix; warped driers (or lack of support); low warm strength such as from excessive solvent, e.g., kerosene (during early stages of baking, 125–200 F [52–93 C], cores go through a low strength phase prior to elimination of moisture or solvent); and inadequate reinforcement such as rods, wires, or arbors.

Such sagged cores create sand disturbance during setting or cope closing. Some shapes are particularly prone to this problem. For example, round or half-round cores may sag enough to create an out-of-round condition. Resin cores are more apt to do this than are oil-sand cores. Green strength is not always an adequate test of this tendency. The jolt-sag test is usually adequate to disclose a weakness in this important core property. A change in binder type should be accompanied by such test of sag tendency. An improvement in sag tendency can often be accomplished by small additions of southern bentonite without materially increasing the need for organic binder.

(4) *Warped cores (including shell)* can result from inherent weakness, rapid curing or inadequate support during curing. These cores should be caught by inspection before they are set.

(5) *Excessive core wash* results in an oversize core and, therefore, has the same effect as (1).

Molding Practice

Molding practice is a major area of concern because many of the defects result from human carelessness. In this sense, the problem is motivational rather

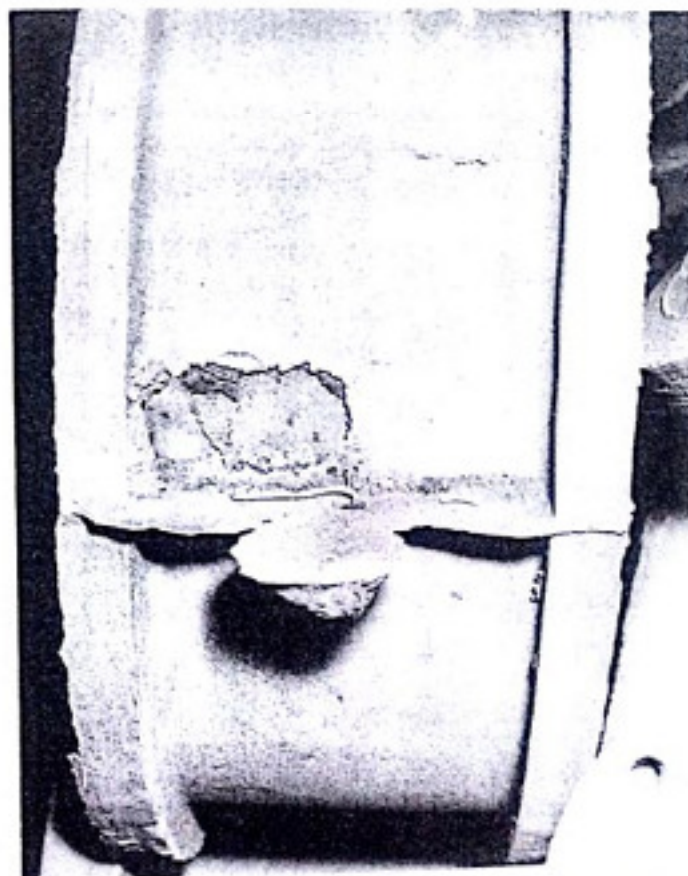


Fig. 4.5—Careless handling of the mold during assembly caused a crush condition on the cope section.

than technical. The cure is one of eliminating the following careless practices.

(1) *Careless closing of the molds* ranges all the way from reversing the cope to rough handling of the copes or trying to close molds on the bias. Figure 4.2 illustrates a crush caused by careless closing of the mold. Obviously, all the factors in **Flask Equipment and Rigging** can be a part of the problem. For example, good pins and bushings make the closing easier, faster, and more foolproof.

(2) *Uneven clamping of molds* is particularly bad on major sand-to-sand contacts which can be readily clamped off. The usual problem occurs when one side of the mold is clamped down before the other side is even set for clamping. (See Fig. 4.3.)

(3) *Faulty bedding of molds on bottom boards or plates* results from uneven sand layer, too much sand, or not enough sand. Improperly bedded molds cause either a push-up condition—too much—(see Fig. 4.4) or a sag—insufficient bed.

(4) *Improper setting of the jackets* may be a molder's error or a pouring crew error, depending upon how the job is allocated. See **Pouring Practice** (1) and (2).

(5) *Careless core setting* may be just sloppy practice or it may be a question of insufficient hand holds to handle the cores properly. The crush may result immediately, or the improperly set core may crush when the cope is set.

(6) *Use of wrong chaplets or failure to use chaplets*, permits the core to move or be misaligned in such a way as to break the sand surface during closing, clamping or weighting.

(7) *Setting dirty jackets* may be the fault of the molder or the metal pourer depending upon the allocation of responsibility. See **Pouring Practice** (2).

(8) *Stem chaplets not properly wedged* are as bad as using the wrong chaplets. The lack of core support permits core movement during closing or clamping of the mold.

(9) *Unshaved core prints and joints* is a modification of **Core Practice** (1) in those cases in which it is the molder's job to inspect and modify the print or core to suit the equipment being used.

(10) *Failure to wedge flask joints*. In the case of warped or wooden flasks, it may be necessary to use wedges to prevent crushing.

(11) *Careless handling of molds during carry-out* on the conveyor can easily crush a mold which could normally carry the load (Fig. 4.5). If molds are to be abused after closing, the bearing surface must be unusually large or the sand unusually strong.

(12) *Dropping the weights* may be an error of either molder or metal pourer (weight shifter). See **Pouring Practice** (3).

Metal Composition — Melting Practice

Metal composition and melting practices are not causes of crushes, push-ups and clamp-offs.

Pouring Practice

Pouring is a problem whenever the metal pourer is involved in the handling of jackets, weights, and clamps.

(1) *Improper setting of jackets*. Jackets are improperly set if they are placed on the mold crooked or are forced on too hard. This is usually a case of an individual forcing a jacket over the mold even though it has been started down incorrectly, i.e., crooked. The attempt to make it fit will cause a crush.

(2) *Setting dirty jackets* is a variation of forcing wrong fit. The dirt on the jacket may adhere enough to crush the mold. Obviously, such dirt includes lumps of sand or spilled metal welded into place.

(3) *Dropping weights on the mold* often results from moving too quickly, from lack of hand holds on the weight, or from handling weights which have become overheated.

(4) *Resting ladles or other objects on the mold* is more common than might be believed. It is unusual to detect unless someone actually observes the practice and relates it to a defective mold.

Miscellaneous

Rough handling during any part of the molding process can break or crush a mold.

Chapter 5

CUTS OR WASHES

DESCRIPTION

Cuts or washes are rough spots and areas of excess metal caused by erosion of the mold or core surface by metal flow. Figure 5.1 illustrates a typical wash or cut in the gate area. This definition differentiates between a cut and an erosion scab, in spite of the fact that the two defects are often similar or identical in general appearance. It is necessary to make such a distinction because the cure for the two defects may be diametrically opposed. For example, an erosion scab, being an expansion defect, may be related to a hard ram while a true cut would be caused by a soft ram. The exact difference between the two becomes clear by careful study of this and Chapter 8, EROSION SCABS, and by comparing the various causes in each of the standard categories. Quick or cursory decisions, based upon appearance alone, should be avoided until adequate data are developed to clearly pinpoint the essential cause and cure.

CAUSES

Casting and Pattern Design

(1) *A design that promotes excessive metal flow over any given area of the mold surface. Such design causes*

eventual heating of the sand or core to the point where such core or mold weakens and cuts or washes away. It is often necessary to widen the gates, or add additional gates from a runner, in order to spread the metal in such a way as to prevent excessive localized heating of the mold or core surface. If the design of the casting does not permit such handling of the problem, the design can be considered faulty for normal foundry practice.

(2) *A design which includes unavoidable nozzle effects. The word "unavoidable" puts the problem in the hands of the designer. The foundryman is forced to find a molding material which will stand the gushing effect of the molten metal stream. Special facings may avoid the defect but at an increased expense in production.*

Pattern Equipment

Pattern layouts which prevent correct gating. These usually involve parting-line design which prohibits proper dispersion of gate areas to equalize metal flow over a wider sand area. Equalized flow is essential if excessive localized heating of sand in mold or core is to be avoided. In making a pattern layout it must be recognized that passing an excessive amount

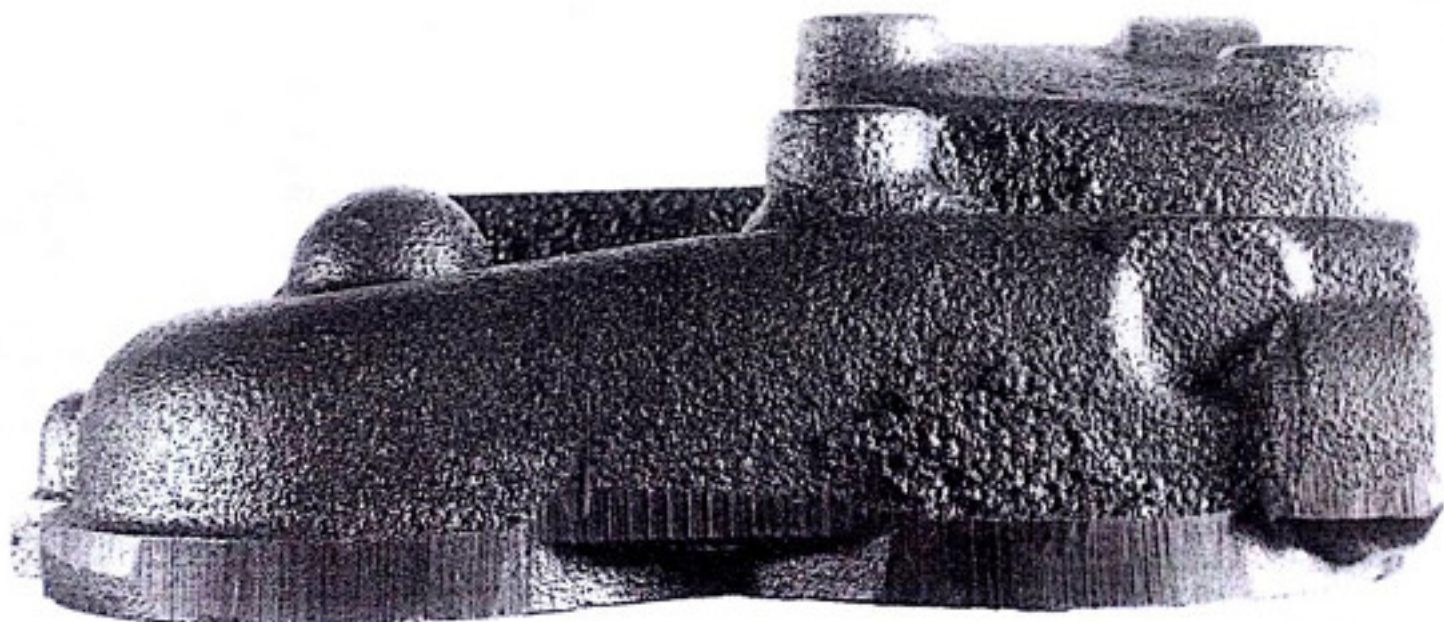


Fig. 5.1 — Typical wash or cut in the gate area.



Fig. 5.2—Cut caused by low strength sand.

of metal over a small sand or core area will weaken the sand by overheating.

Flask Equipment and Rigging

(1) *Flask too small to permit proper gating.* If a single gate carries so much metal as to overheat the sand and cause a cut, the cure is to use multiple gates.

A small flask can make this normal cure impractical or impossible. It may even prevent gating in the proper location, thereby forcing metal into an obviously weak core or mold section.

(2) *Flask bars too close to pattern.* This can cause problems in two ways: the flask bar location may create or augment a tendency toward a soft ram; or the bars (when hot) can cause a localized drying out of the sand surface.

In the first case, the soft ram causes a low hot strength (regardless of the laboratory results) and thereby a wash by reducing resistance to metal flow. In the second case, the dried area can wash mechanically before adequate hot strength can be developed in the sand.

Gating and Riser

Improper gating is a major cause of a cut or wash since it governs the flow of metal over the sand or core surface. Such undesirable practices are described in the following paragraphs.

(1) *The gate forces metal to impinge on a mold or core surface* as in the case of gating into a thin wall of a casting. This permits the full velocity pressure of the metal to strike a local spot before it can spread out over a wide surface.

(2) *The gate is made in such a way as to eliminate the pool of metal to cushion the flow.* If metal impinges on a wall and moves away into another area, the local spot of sand is constantly exposed to new hot metal with no opportunity to provide a chilled or solid skin to eliminate sand erosion.

(3) *Too much metal across any mold surface* will eventually redissolve the metal skin which formed during early stages of pouring. When this occurs, metal is free to wash away sand which has now reached a temperature of low strength and endurance.

(4) *Excessive metal velocity across a mold surface* may prevent the initial skin from forming to protect the sand surface. Early skin formations are needed to protect the sand surface as it heats up to temperatures of low strength.

(5) *Unequal distribution of metal through the gates* eliminates the desirable features assumed for the multiple gates since some gates are still carrying too much metal or moving too rapidly for proper skin solidification.

Molding Sand

If the gating system permits proper distribution of metal and eliminates excessive sand temperatures, then adequate hot strength must be provided at the temperatures which will be developed in the areas of metal flow (potential cuts). Figure 5.2 illustrates a cut caused by low strength sand.

A lack of adequate strength at the temperature involved usually stems from insufficient clay to develop the hot strength required, which results in low dry and hot strength.

Insufficient clay is only one basic cause of low properties at elevated temperatures. These properties are also initially affected by: insufficient water to properly activate the clay available; insufficient mixing to activate the clay water system; wrong type (low hot strength) of clay for the application; and excessive anti-bonds such as additives which reduce hot strength (cellulose, etc.).

Hot molding sand appears to have a direct and measurable effect on the problem. This may be a result of preliminary drying of the mold, or the direct effect of hot sand on the development of the properties inherent in the blend of sand, clay and water being used. Hot sand leads to dried brittle edges and corners which then become zones of weakness during pouring.

Core Practice

(1) *Soft core surfaces.* Soft core surfaces from any cause permit erosion or cutting to take place as either simple mechanical cutting of the relatively cold surface or by a drastic reduction in hot strength. As in the case of **Molding Sand**, it is important to realize that a soft mold or core does not have the same hot strength as might be indicated by a properly made (hard) laboratory specimen. References in this text to low hot strength apply to the core or mold proper and may or may not be reflected by a change in laboratory properties.

The possibilities of soft cores include: overcured or undercured (excessive air drying prior to baking); insufficient binder or water when needed; insufficient mixing; and in the case of chemically cured binders, overmilled sand.

Other factors involve the mechanics of making, patching or handling the core such as: not enough reinforcement of the surface (such as nailing); and

damaged or abraded core surfaces during jiggling, rubbing, gaging or delivery.

(2) *Improper core coating.* This is a factor whenever the core requires dipping, washing, or coating prior to use. In some cases, an improper job of coating the core produces a condition worse than if no coating had been used. One typical case in point is lack of penetration or bonding. This is often the result of wrong Baumé (thickness) of the wash. In some cases, the problem is wrong type of coating. The Baumé should be balanced to the type of use, namely, washing, dipping, spraying or brushing, since a coating good for one method of application is not necessarily ideal for another. In this connection wrong type may refer to essential makeup of the coating. For example, water base washes may be a problem with furan or chemically-setting core binders. With exothermic binders such as furan, it is essential that the wash be not applied before complete curing is achieved. If the wash is applied too soon, it will stop the chemical reaction and complete cure will never be achieved. When some coatings are dried with a torch, there is a danger of burning.

Burning the core surface with a torch will cause a weakening of the surface. A weak surface is easily washed or cut by the metal stream.

(3) *Vents or reinforcements too close to the surface.* This will create zones of weakness during the baking of the core. This area can readily wash when contacted by metal or may spall from heat shock before the metal makes contact.

(4) *Poorly patched cores or filled hook holes.* This often permits a cutting action. These causes are hard to detect upon inspecting the defective casting because such improper patching can easily be an occasional fault rather than routine.

(5) *Soft or nonuniformly made cores.* Such cores often fail. The core mix, as prepared, may be adequate when tested, but if poorly rammed or blown under conditions of incorrect blow holes and core box vents, the inherent strength of the mix will not be available in the actual core.

Molding Practice

(1) *Soft or nonuniformly rammed molds.* These become a major source of trouble. A true wash or cut is most commonly a lack of hot strength. This property is directly related to mold hardness. For example, a sand which shows 160 psi hot strength in the labora-

tory specimen rammed to 85 mold hardness, will have approximately 10 to 40 psi when rammed to only 60 to 70 mold hardness. Too often an obvious lack of hot strength is blamed on the sand mix instead of the method of molding.

(2) *Mold edges burned by torch drying.* Burned mold edges become friable and readily washed away by metal flow. This is also true of untorched molds which air dry excessively before closure.

(3) *Gaggers, bars or soldiers set too close to mold surface.* These contribute to a weakness in the immediate area. Sand may actually spall from thermal shock or may be washed loose mechanically.

Metal Composition — Melting Practice

Metal composition and melting practice are not a cause of cuts and washes.

Pouring Practice

(1) *Excessive pouring temperature for molding materials used.* Excessive temperature will heat the sand beyond its permissible operating range. For example, a sand with adequate hot properties for the metal temperature could fail if exposed to metal with 100-200 F (55-111 C) excessive superheat.

(2) *Hard pouring.* Hard pouring can lead to cuts and washes. However either the gating, sand or molding practice would be questionable if normal variations in pouring head caused trouble.

Miscellaneous

Excessive parting. Excessive parting is one of the most common and possibly least considered causes of cuts and washes. For example, excessive solvent, such as kerosene (common in liquid partings) can materially change the hot and dry strength when the mold surface is saturated with pools of excess parting spray. This change in properties can be readily demonstrated by adding 0.5 per cent parting to the laboratory sand mix when checking the sand practice.

In actual practice, the concentration of the solvent inadvertently added as parting can be many times this amount. Parting should not accumulate in depressions of the pattern before the sand is placed on the pattern. A specialized case of this is often seen with slinger operations. The operator can drive the parting ahead of the sand stream into corners and end up with localized concentrations not noticeable before molding.

DIRT, SLAG AND OTHER INCLUSIONS

DESCRIPTION

Inclusions are particles of foreign material embedded in the metal. If these inclusions are at the surface, they may be removed during cleaning, leaving only the holes. In this case, they may be referred to as dirt holes. The use of the word dirt is unfortunate because it is not descriptive, it does not truly identify the problem, and therefore, makes trouble-shooting laborious.

Since this defect involves an unintended object or foreign body, determining the exact cause may involve clever detection. For example, under **Miscellaneous**, the defect may be due to "any foreign materials getting into the mold, sprues, or open risers, through carelessness." Just looking for careless molding may not be adequate. The carelessness may be a matter of equipment, design, placement, or maintenance. For example, the sand distribution belt may be spilling sand into open molds below, or the roll-over or cope-setting equipment may accumulate loose sand and drop it periodically into an open drag, sprue, or riser. The possibilities involved in poor housekeeping are endless and often hard to locate. Figure 6.1 shows typical surface imperfections which are defined as inclusions.

It is obvious that the presence of a scab, erosion, or cut in the casting will produce sand or slag inclusions somewhere in the casting. It may not be equally obvious that such defects on any part of the gating system can create an identical problem. Since the gating system is usually detached before the casting is inspected and rejected, the source of trouble becomes mysterious. Epidemics of inclusions involving a given pattern should be studied by inspection after cleaning, but with the gating system attached. The presence of any expansion, erosion, or cut defect on the gate, runner or sprue, may easily be the cause even though at some distance from the inclusions in the casting itself.

Since defects which disrupt the mold surface lead to inclusions, it is often desirable to review the chapters on EXPANSION DEFECTS, EROSION SCABS, CUTS OR WASHES, DROPS, STICKERS, CRUSHES-PUSH-UPS-CLAMP-OFFS and, on occasion GAS DEFECTS.

CAUSES

Casting and Pattern Design

Those design factors which contribute to scabs,

cuts, washes and erosion will intensify the tendency toward inclusions which result from such defects in casting. Such designs involve abrupt changes of section, irregular contours, deep pockets, and sections which detract from uniform mold hardness or excessive metal flow over confined surfaces. Designs requiring inadequate fillets leading to torn up molds will provide loose sand.

Pattern Equipment

(1) *Improper coating for materials involved.* Some types of pattern coatings produce a tendency toward sticking of the sand. For example, on wooden patterns, care must be taken to avoid old, thick, or dirty shellac, varnish or lacquer which is gummy, goes on thick and doesn't properly dry. These coatings should be avoided on metal equipment because bonding to metal is most difficult unless the surface is porous or roughened. When coatings are used, care must be exercised to avoid improper mixing as well as exposure to excess heat or moisture.

(2) *Insufficient clearance for setting cores and closing.* Insufficient clearance for setting cores and closing the mold may result in sand being dislocated into the mold cavity. Most oil-bonded cores tend to grow during baking. The amount of growth will vary with the type, amount of binder and baking temperatures. As a result, what was adequate clearance at one time may not be adequate if there has been a change in core-room procedure. Except in height the usual clearance provided is .030 in. larger than the actual core dimension (1/8-in. clearance is common in large work). Closer tolerances are possible for furan and similar cores which are wholly or partially cured in the core box. These cores will tend to be smaller and more uniform than cores cured outside the core box.

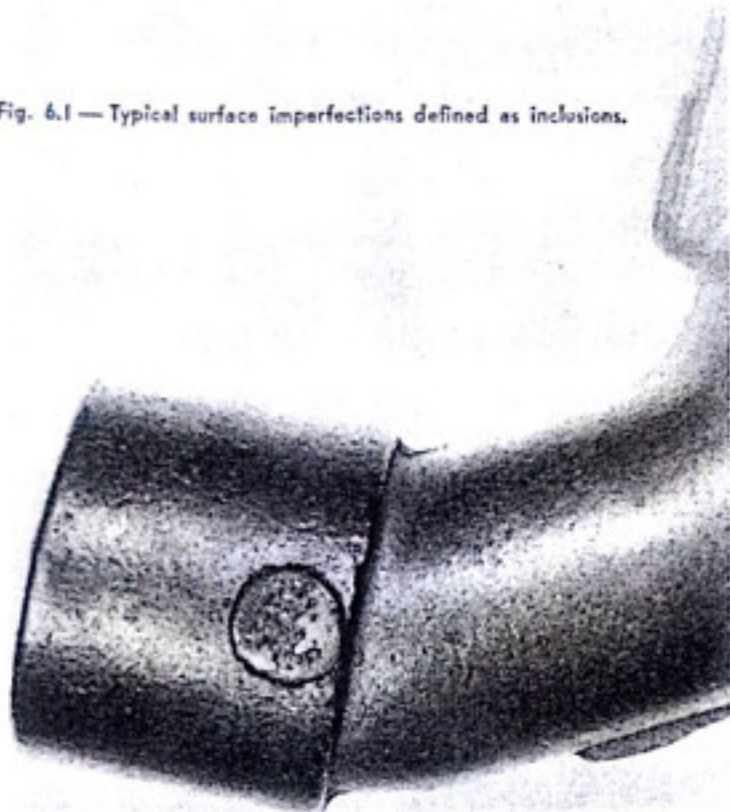
(3) *Lack of fillets.* Lack of fillets and radii can result in a torn up mold with its related loose sand deposited in the mold cavity.

(4) *Insufficient draft.* Insufficient draft causes a tear-up or shove during removal of the pattern or during the closing of the cope. This can be a case of incorrect transposition from a machine shop drawing to a pattern dimension. Sometimes specified tolerance enforces extremely small drafts and, therefore, unusually accurate molding and closing equipment.

(5) *Loosely mounted pattern or gating system.* A loosely mounted pattern or gating system, particularly



Fig. 6.1 — Typical surface imperfections defined as inclusions.



with flowable sand, permits sand to work under the pattern and create a tear-up. It is not unusual to find that a drastic improvement in sand flowability or an increase in molding energy will disclose a minor back-draft at the pattern plate which was not previously suspected. Loosely mounted patterns are sometimes not suspected because it is known that the mounting was tight originally. A looseness can appear because the patternmaker could not, or did not, lock the mounting screws or bolts to withstand the shock of molding and vibrating.

(6) *Worn flask landing areas.* Worn flask landing areas can create a crush or disrupt enough sand grains to show up as an inclusion somewhere in the casting. Such worn landings should be caught by visual inspection and returned to the pattern shop for repair.

In high production cope and drag work, the worn area may not be obvious because the two plates are examined separately. It is necessary to recognize that the crush will be the summation of the total wear on the cope and drag pattern plates; it may then be twice as great as visual inspection of one plate might indicate.

(7) *Inaccurate partings.* Inaccurate partings cause crushes and loose sand. Improper matching of male to female steps and pockets which cause such inclusions are usually a question of careless or inaccurate patternmaking (human error).

Flask Equipment and Rigging

Any factor in the rigging, which creates a rubbing or gouging effect during the closing of the cope or setting of cores, can create loose sand in the mold cavity. This then would include warped flasks, worn or

crooked pins and bushings, inaccurate core setting, assembly or inspection jibs, dirty (spattered metal) pins and bushings, and inadequate locators. A common problem is found on closing copes on molds having very deep pockets. It is necessary to have guide pins which are sufficiently long to guide the cope before the pockets can touch, rather than depending upon the molder's skill for the early stages of closing.

Warped or crooked flasks may occur if the walls are too light; if flanges are narrow; if the barring is inadequate; if welding is poor; or if there has been inadequate stress relief of the flask after welding.

Gating and Riserling

(1) *Factors causing scabs, cuts and washes.* As in the case of **Molding Sand, Core Practice, Molding Practice**, etc., any factor which creates a scab, cut, or erosion scab can produce sand inclusions which may look like slag if the sand fuses. This factor is exaggerated in the case of gating, however, because the creation of the inclusion (the scab) may occur on the sprue, gate, or runner, and not on the casting. Unless the gating system is cleaned and inspected, this common source of sand inclusions may not be readily detected. Any area of gate or mold which is covered and then exposed intermittently can scab.

(2) *Improper gating.* Gates should be located so the first metal will cushion the remainder of the metal and keep the sand covered until the mold cavity has been filled. This applies equally to the area at the base of the sprue where cuts are common.

Gating systems that create slow pouring can cause scabs, particularly on cope surfaces. Slow pouring ex-



Fig. 6.2 — Ineffective slag trap permitted ladle slag to locate at top of the boss.



Fig. 6.3 — Poorly designed pouring basin prevented proper choke and permitted slag to enter the mold.

poses the cope surface to radiant heat without a protective metal covering. This applies equally to the cope surface of runners. Gating formulas which create an unfilled runner should be avoided since the cope of such runners will eventually scab and drop sand into the gating system.

An inadequate number of gates creates cuts and washes in the casting. An inadequate runner or excessive choke can likewise cause a cut or wash of the gating system. Weak skim cores may break down and wash into the casting especially if the amount of metal through the core is excessive. Inadequate support for the skim core will permit it to break or erode and allow sand to flow toward the mold cavity.

A gating system may be designed in such a way as to create, permit, or increase the formation of inclusions. For example, the choke may be inadequate to stop the flow of slag or dross coming into the down sprue. The slag traps may be located incorrectly so as to permit further slag formations after the trap or they may be too small to retain the slag entering the system (see Fig. 6.2). In a rapidly moving stream of metal, slag probably does not float; it moves with the metal until it contacts and sticks to a sand surface. The pouring basin designs should avoid a vortex and must permit retention of slag in the cup (see Fig. 6.3).

The ratio of skim core area may be incorrect for the runner system. Skim cores do not really skim anything. They are a means of providing a choke, but only if the entire system is designed to fit. Weak or broken skim cores can be a direct cause of sand being washed into the mold.

Exothermic materials used in the gating and rising system can cause slag inclusions if used in such a way as to permit the by-product of the reaction to enter the mold or casting. Any pouring cup design which is difficult to hit or keep filled can create a problem.

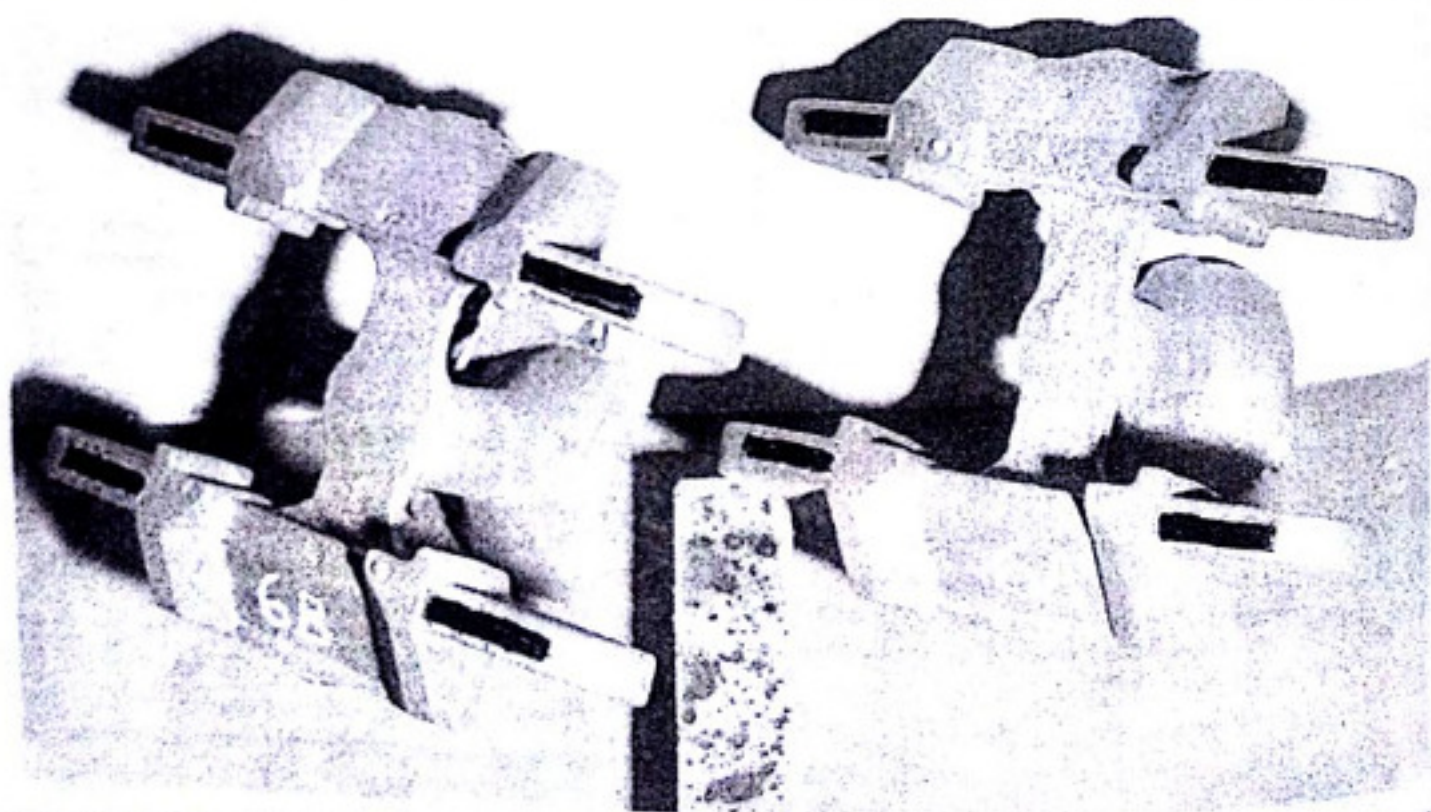


Fig. 6.4 — Illustration of the difference between adequate (6B) and inadequate (6A) hot strength in the sand. The obvious cutting action in the gate area caused sand inclusions in the casting.

Molding Sand

(1) *Those factors causing cuts, washes and scabs in both the mold and gating system.* Sand factors which are related to scabs, erosion scabs, or cuts and washes, in either the casting or gating system, will influence the number of sand inclusions to be expected. Since sand is one of the major causes of expansion problems, those chapters should be reviewed carefully after the source of sand inclusion has been located and identified.

(2) *Low fusion point materials.* Sand can also be a source of slag inclusions if the sand fuses or contains low fusion materials which are converted into slag and carried into the casting (ceroxides). Such low fusion products are especially dangerous in the gating system because it carries all of the metal entering the mold cavity and at maximum temperature. The metal is hotter in the gate and runner than in the casting. Sand used in the gating system should be adequate to withstand the metal flow. Illustrated are inclusions as a result of inadequate hot strength (Fig. 6.4) and low green strength (Fig. 6.5) of sand.

Core Practice

(1) *Factors causing cuts, washes and scabs.* Those factors which cause or permit cuts, washes, erosion, and scabs on cored surfaces can displace sand and create inclusions. The inclusion may be at a location other than at the core which originally created the problem so detection may be difficult.

(2) *Improperly cleaned cores.* If cores are not properly cleaned, they may be set with loose or partially loose sand or coatings which wash away easily.

(3) *Premature collapse of cores in molds and gating system.* Premature collapse of a core (including a skim core) creates loose sand. Such sand can appear as a sand inclusion or, because of low fusion binders, fuse and appear as a slag inclusion. Such collapse may occur as loose grains or even as small chunks which fuse to a rather sizeable slag inclusion. Gassy cores may literally blow sand grains into the metal.

Molding Practice

(1) *Factors causing cuts, scabs and washes.* Any molding practice which causes scabs, erosion, drops, crushes, and displaced sand in the mold cavity or gating systems can start a sand inclusion. Nonuniform ram on gating systems should be avoided. Many gate and runner systems are not designed for good ramming. Those having sharp corners, lack of fillets, minor back drafts and the like are examples.

(2) *Sloppy or careless molding.* Sloppy or careless molding is often considered the primary cause of inclusions (molder's scrap). It is so obvious as to need little comment except to point out that inspection of molds before closing should include inspection of gates and runners, as well as the mold cavity. Figure 6.6 shows an inclusion as a result of loose sand left in the mold cavity.

(3) *Excessive use of liquid parting.* Excessive liquid parting can lower the fusion of the molding sand to the point of creating slag (see Fig. 6.7). Even more

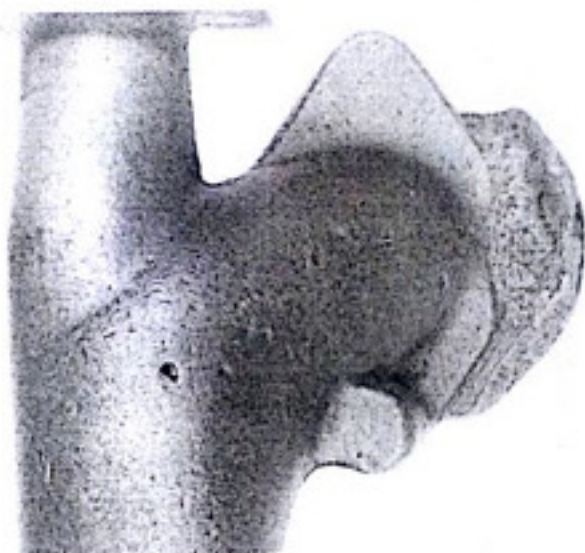


Fig. 6.5 — A broken edge on the mold caused by low green strength sand permitted sand grains to wash into other sections of the casting.



Fig. 6.6 — Loose sand left in the mold cavity by the molder causing sand inclusion on the drag face.

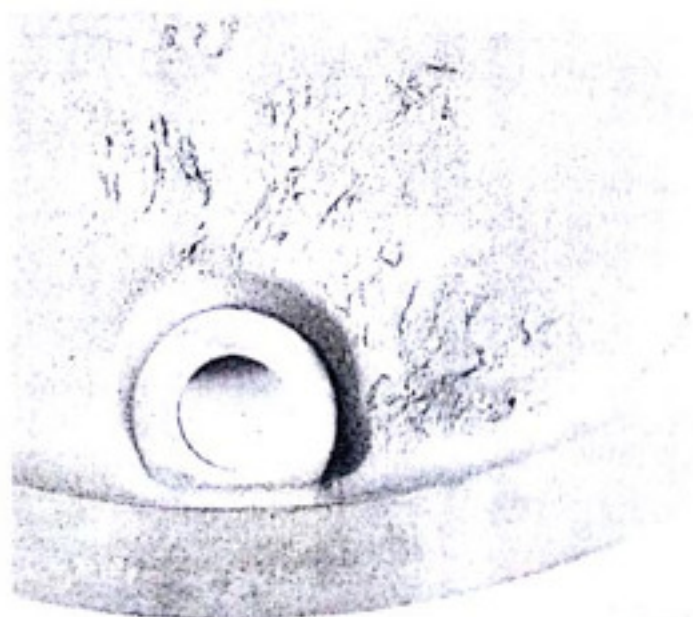


Fig. 6.7 — Use of excessive liquid parting material on the pattern, left "kiss" tracks which are classified as inclusions.

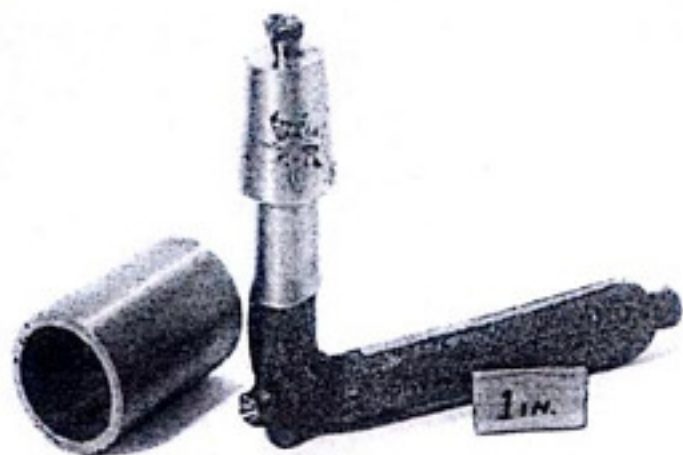


Fig. 6.8—Inclusions of aluminum in a copper-base alloy caused by contamination during melting.

common, the accumulation of liquid parting in pockets or gate runners in sufficient quantity may reduce the dry and hot strength to the point of erosion and scabbing. This is a common source of inclusions in high production automatic parting equipment foundries.

(4) *Loose sand from cores or molds.* Whether cores are set by hand or by jig, any rubbing or shaving of pockets of the sand will result in loose sand particles. Uncored molds can likewise cause the same problem if the closing of the cope is careless, especially when using deep pockets and short pins.

Metal Composition

In many metals, it is possible for an off-analysis to create a separation of slag or slaglike materials in such a way as to produce an inclusion. For example, in gray iron, a high sulfur may lead to manganese-sulfide slags separating during cooling. Leaded bronzes similarly may show separation under conditions of imperfect balance, e.g., yellow brass.

Metals vary in the degree to which they will erode sand molds and refractories and, therefore, vary in their tendency toward sand holes or slag inclusions. Surface tension and emissivity contribute to these differences and may modify both mold and ladle requirements. For example, a ladle refractory which might be adequate for stove plate iron would not be considered adequate for high alloy steel.

Melting Practice

(1) *Undissolved alloy addition or inoculant.* If the alloy additions or inoculants added to the ladle remain undissolved, they may be carried, as solids, into the mold and appear as inclusions. The melting point and heat of fusion of the alloy added must be considered and related to size of ladle and metal temperature plus efficiency of agitation. It is common for improperly added alloys to develop an oxide film before they are dissolved and, thereby, resist proper solution or melting. The fault then may be in the composition of alloy or in the method by which it was introduced.

(2) *Alloy addition producing dross.* Some alloys, par-

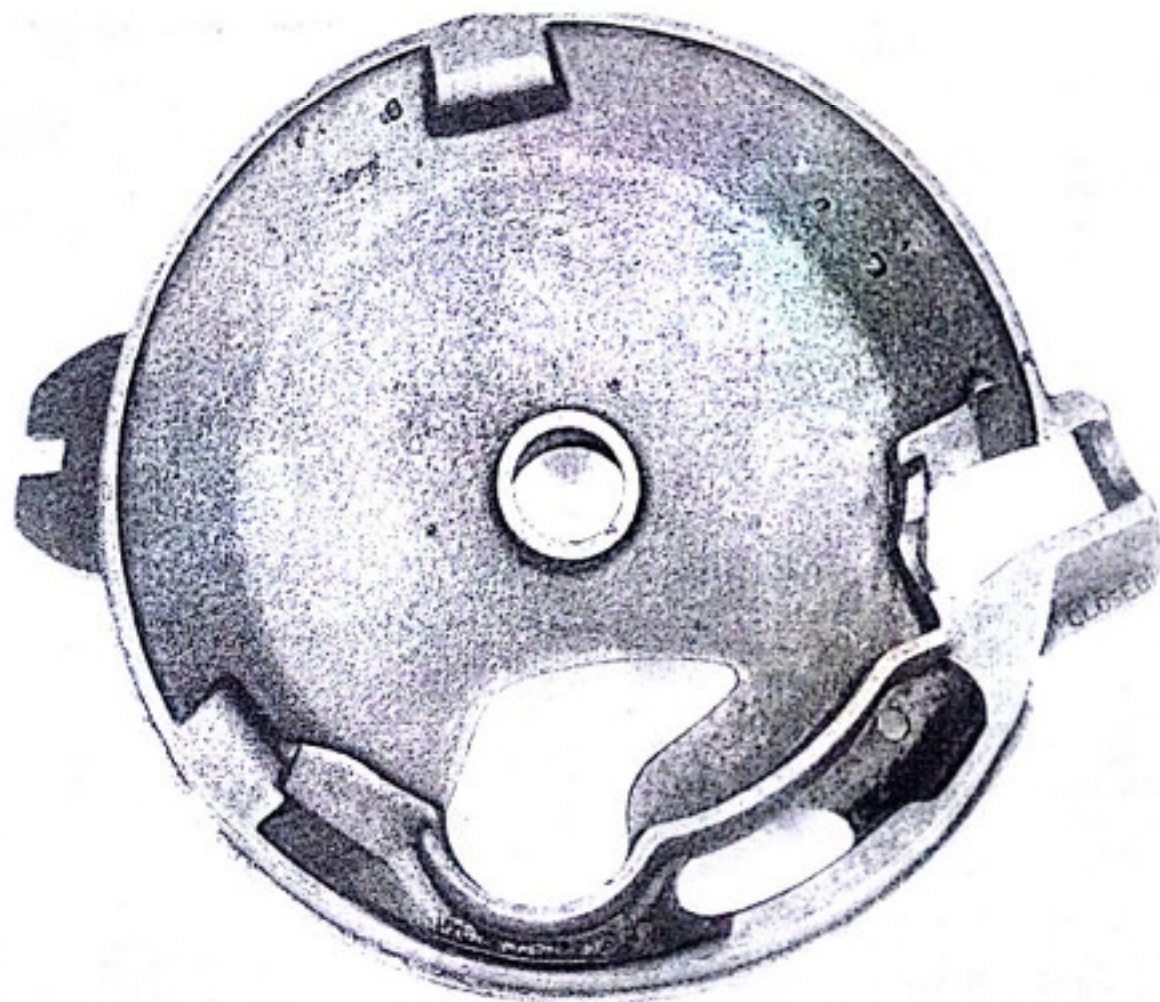


Fig. 6.9—Poorly skimmed ladle permitted slag to enter mold cavity.

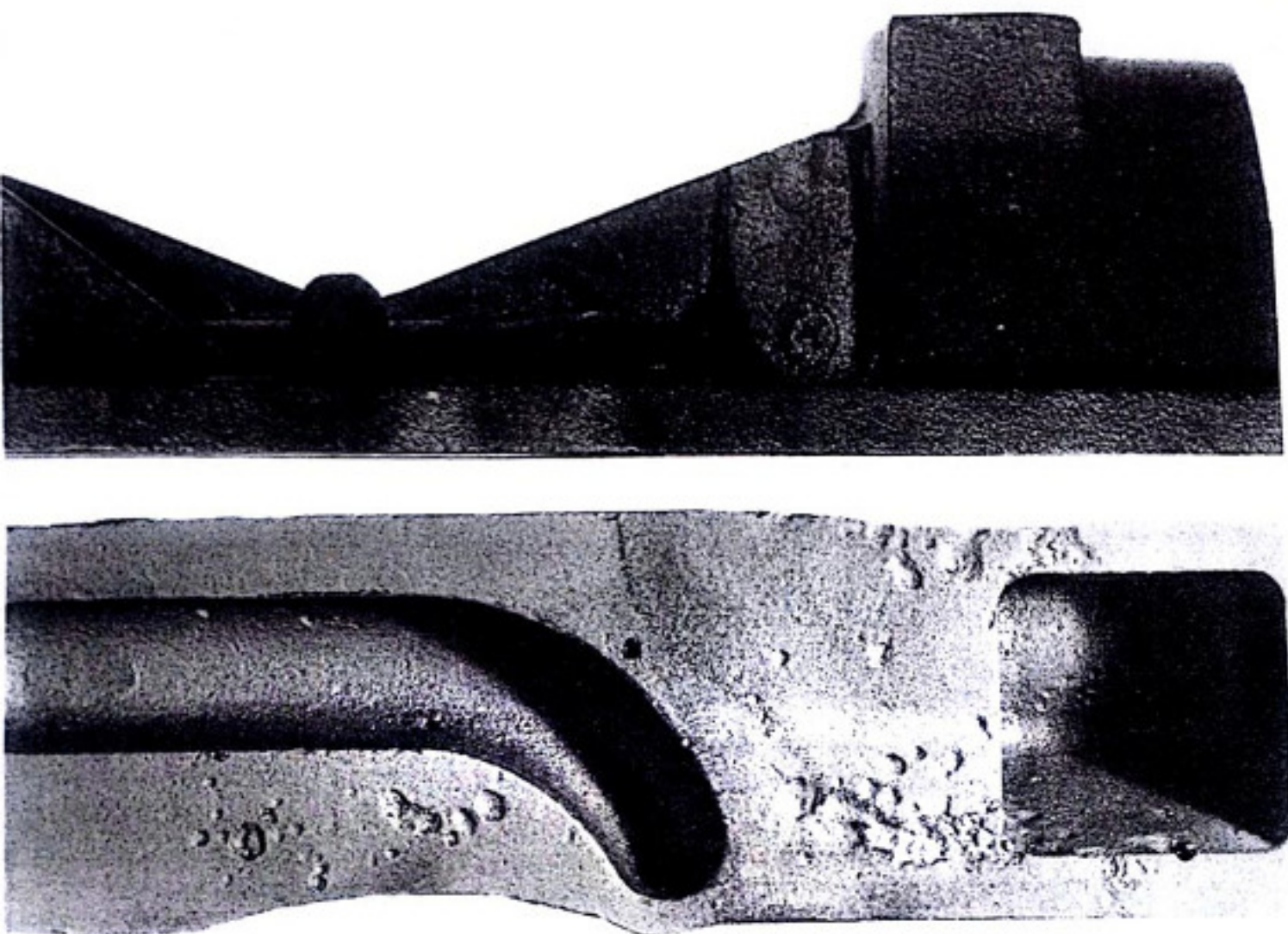


Fig. 6.10—Intermittent pouring trapped slag in the metal stream and permitted it to enter the mold.

ticularly in nonferrous practice, create dross readily. Exothermic alloys result in slag or dross which must be separated from the metal stream before pouring or be caught in the gating system. Figure 6.8 shows aluminum inclusions caused by contamination during melting.

(3) *Dross inclusions.* A reduced melting temperature may result in dross inclusions because of the inability of the slag to separate at the lower temperature.

(4) *Slag volume.* An insufficient slag volume during melting may prevent complete separation of metal and slag. Slag particles tend to attach themselves to a slag blanket. The absence of such a blanket permits individual particles of slag to stay with the metal.

(5) *Thin slag.* If the slag is too thin, it may tend to pour with the metal rather than separate. For example, in ferrous metals, a high FeO slag may have approximately the same density and fluidity as the metal and be almost impossible to separate from the bath under conditions of pouring. This factor is also related to cerioxide in steel and pinholes in malleable.

(6) *Refractory material.* An inadequate refractory material can easily release slag inclusions into the metal. Such refractories may spall if they are too wet or if expansion characteristics are too great. They may actually melt out if the fusion pyrometric cone equivalent

(P.C.E.) is too low. The loss may be largely chemical such as a penetration of FeO into a lining which results in a drastic fluxing of the refractory.

(7) *Desulfurizers.* The use of excessive fluxes or reaction additions (such as soda ash to remove sulfur from iron) may introduce slag directly, or result in a marked attack of the lining and related slag inclusion.

Pouring Practice

Many of the comments on melting practice apply equally to pouring if the pouring ladle (rather than the melting furnace) is the source of foreign matter in the metal stream.

(1) *Boiling ladle.* A wet or boiling lip on a ladle may chill the metal sufficiently to interfere with proper separation of slag. In addition, such wet lips tend to create slag by spalling.

(2) *Skimmed metal.* Careless skimming of the ladle results in excess slag being carried to the mold (Fig. 6.9). It is wrong to assume that the gate choke will do all the work. In fact, dependence on the gate choke may restrict metal flow to the point of causing cold shuts and misruns.

(3) *Pouring temperature.* Low pouring temperature is a common source of trouble. A gating system with adequate choke for relatively hot, clean metal may



Fig. 6.11 — Metallic oxides from the ladle entered the mold until the defect was corrected by proper gating.

fail to separate slag from a colder, dirtier ladle of iron.

(4) *Intermittent or slow pouring.* Failure to keep the sprue full destroys the effectiveness of the slag trap in the gating system and permits slag to drop down the sprue instead of remaining in the pouring cups where it belongs (Fig. 6.10).

(5) *Slag accumulation.* Use of dirty ladles can create more slag than the gating system can handle. This is particularly troublesome if the heel or slag skull on the ladle tends to oxidize toward a more fluid composition. For example, it is common practice to develop ceroxide (or pinhole in malleable) defects after a ladle has been used for any length of time. Many foundries regularly take ladles out of service to avoid these phenomena. Figure 6.11 illustrates the result of metallic oxides entering the mold.

(6) *Ladle linings.* Low fusion, high expansion, or green (wet) materials in ladle linings which may spall or fuse into slag inclusions should be avoided. Rammed ladle refractory material can be subject to erosion or spalling by nonuniform ramming.

(7) *Strength of ladle linings.* Both the hot and dry strength of the ladle refractory material must be adequate to avoid mechanical loss (erosion) during pouring.

Miscellaneous

As described previously the possibilities of careless design, maintenance, handling, and general house-keeping are extensive. Inclusions represent any foreign body from cigar butts in the riser to having the molder drop his dentures before closing the mold. Figure 6.12 shows an inclusion caused by a rag left in the mold.



Fig. 6.12 — Two views of an inclusion caused by a rag left in the mold.

DROPS

DESCRIPTION

A drop is a casting defect due to the dropping of a portion of sand from the cope or other overhanging section. In appearance, the defect resembles a sticker. Even though the mold has been released properly during molding, the drop occurs when the mold breaks during or after setting the cope. A drop is usually related to carelessness such as rough handling. Figure 7.1 illustrates a typical drop of one part of a green sand pocket.

However, many factors relating to the flask, sand, pattern and molding may contribute to inherent weaknesses so that even normal handling is then too rough, or extreme care is required to prevent the drop from occurring. An occasional defect is probably due to carelessness; an epidemic of defects is probably related to poor equipment or bad practice.

CAUSES

Casting and Pattern Design

Design is a contributing factor where deep pockets with inadequate draft are involved. In this case, the mold may be cracked during drawing and then the weakened mold lets go during subsequent handling. These designs may require dry- or core-sand molding. Inadequate draft contributed to drop shown in Fig. 7.2.

Design may be involved to the extent that it demands protruding and overhanging sections of sand. Such designs require definite compensation in either equipment or sand practice in order to avoid undue tendency to drop. It may be necessary to core extensively.

Pattern Equipment

(1) *Insufficient draft or back draft on a pattern creates friction during drawing of the mold (see Fig. 7.3). This action can crack or weaken the mold permitting a later drop. Since this condition is the result of poor pattern construction or worn pattern equipment, it should be caught by routine inspection and corrected.*

There are occasions in which such back draft is not noticed with normal or soft molding, but will show up with more precise molding techniques. For example, high pressure squeeze often betrays minor back drafts not noticed with softer molds or less flowable sand.

(2) *Improperly designed parting creating narrow pockets. This may be forced by the use of undersized flasks or by attempts to eliminate a core and reduce costs. These narrow pockets can easily crack during molding and drawing unless the equipment (molding machine) is in perfect condition or the sand unusually high in tensile strength or deformation strength.*

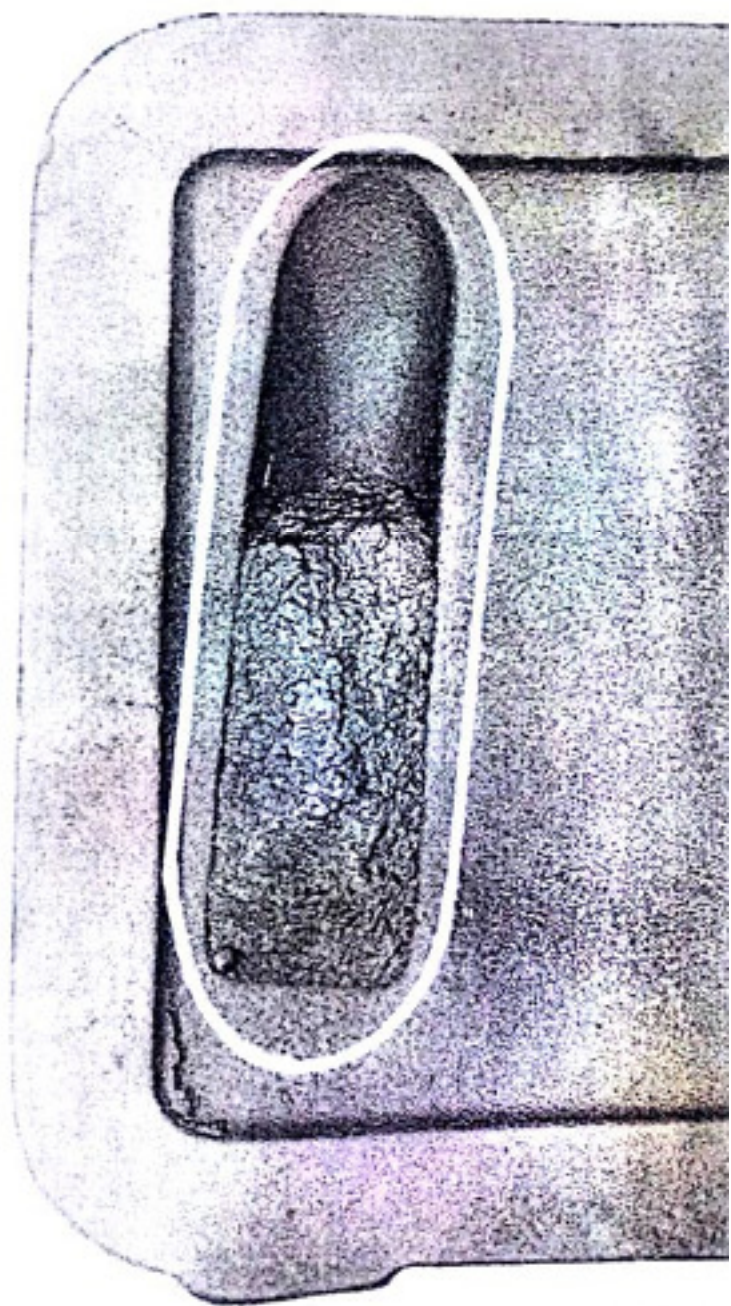


Fig. 7.1 — Typical drop of one part of a green sand pocket.

Flask Equipment and Rigging

(1) *Too many patterns for the flask size* result in a thin sand strip between impressions. These pockets are hard to ram to proper strength and are inherently weak even when properly rammed. The apparent economy of multiple mounting can be easily offset by high losses if the crowding is excessive.

(2) *Insufficient cope height* aggravates conditions in (1) above. The actual pocket strength is related to width and depth. Problems in this case are offset by changing to adequate flasks, incorporating upsets (extensions) and by the addition of gagers and soldiers.

(3) *Weak, loose, or springy flasks and bars* cause mold distortion and cracking during molding. This condition may be a case of inadequate equipment, wear or abuse. It may also show up when a process is changed in the direction of heavier loading of flasks, such as is found in high density molding, or when in-

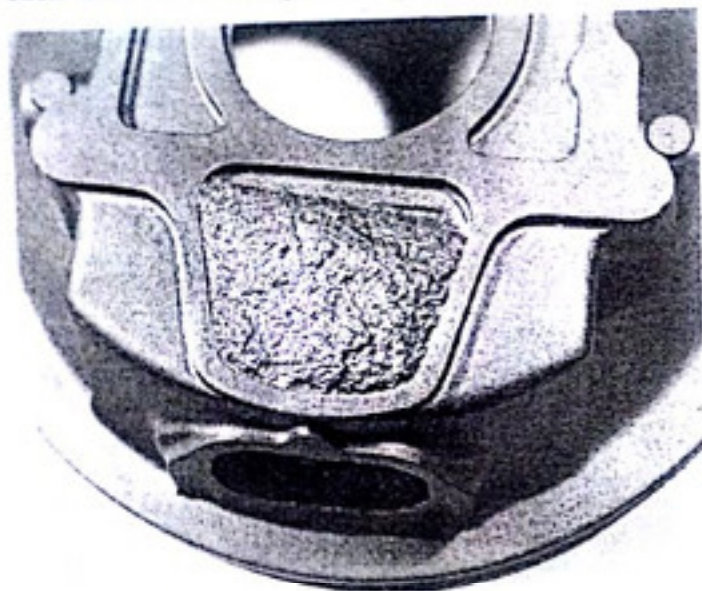


Fig. 7.2 — Inadequate draft in the pocket contributed to a drop.

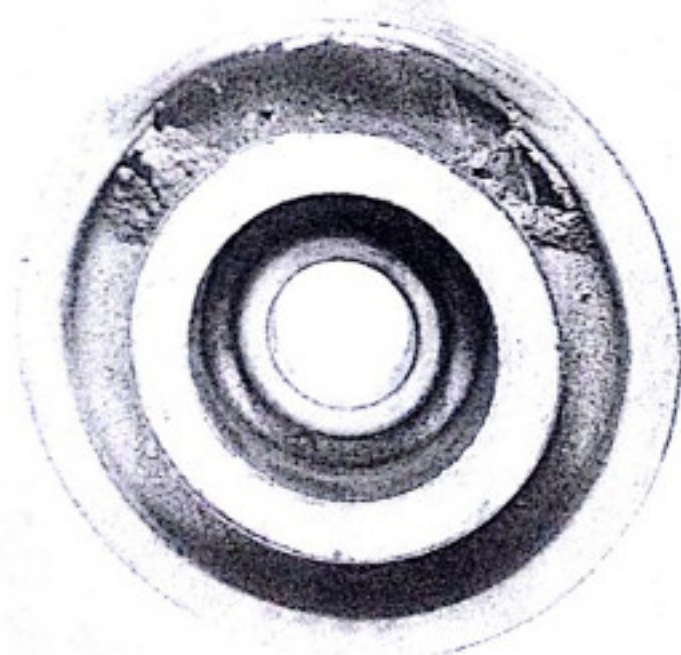


Fig. 7.3 — Back draft on the cracking strip weakened the sand.

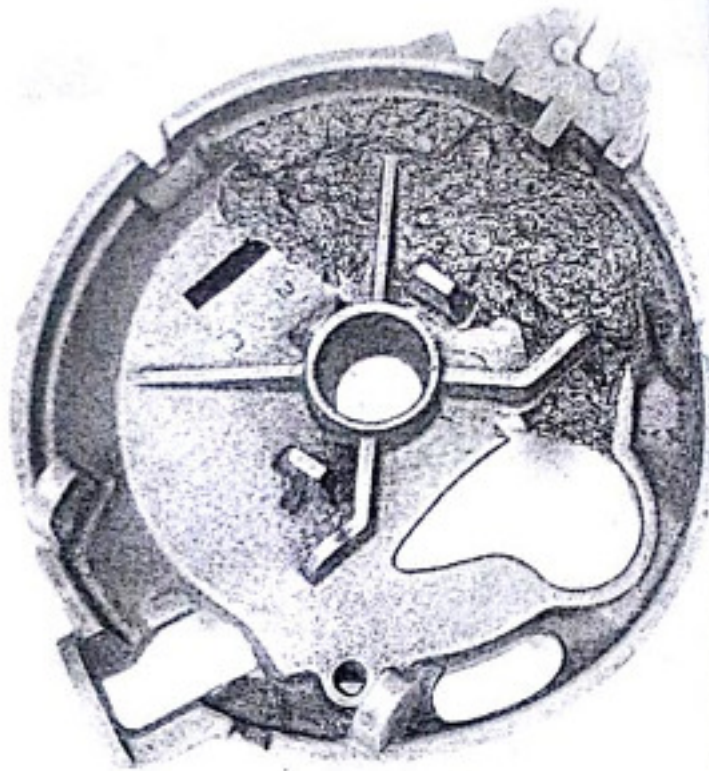


Fig. 7.4 — Inadequate green strength in the molding sand.

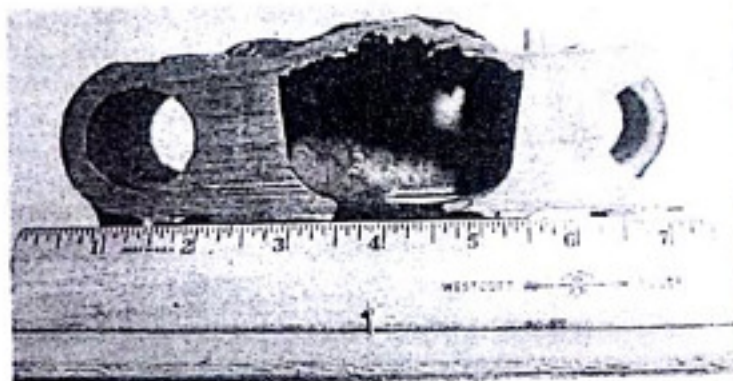


Fig. 7.5 — A low shear strength permitting the pocket to shear under the drop and float.

creasing the number or size of the patterns allocated to a given flask.

(4) *Misaligned, bent, or sprung bands* become a problem when rigidity depends upon bands rather than flasks. Such worn, weak, or bent bands should be eliminated in routine inspection.

(5) *Not enough bars, or bars misplaced* in a flask tend to let the sand sag and crack during pattern draw. Bars may be needed also for the purpose of anchoring gagers at frequent intervals. Not enough bars then translates into insufficient gagers.

(6) *Rough handling due to faulty equipment.* Flasks may be bumped on the conveyor or roll over. The mold may be dropped or jolted because the equipment used is inadequate for the job, or because the equipment is rough from wear or poor maintenance. Such rough handling may also result from an attempt to work without proper equipment such as rolling copes on the floor. Only the strongest of molds can withstand such abuse.

(7) *Improperly fitted, dirty, or crooked jackets* cause a cracking or weakening of the side walls and pockets thereby contributing to a subsequent sand drop.

(8) *Weights too heavy or uneven* cause uneven cope pressure and result in cracked sand across pockets and overhanging portions of the mold. A heavy weight may also be the direct cause of a drop of those sand portions already weak or cracked.

(9) *Flask bars too close to risers* may cause cracking from bar springback after hard ramming between the riser and the bar. The opposite can also occur, namely, a soft ram and a weak section because it is difficult to ram the tight pocket. There also may be a drop only because the sand section is too weak to remain in place under conditions of normal handling. In any case, the problem is usually relieved by moving the riser or bar, or by simply notching the bar to change the size of the pocket. If necessary, this section may be reinforced from the bar, gagger or grid.

Gating and Riser

Gating and risering do not influence this defect except in the placement of runners and risers in such a way as to permit a weak pocket. Unusually deep runners may create a weak pocket when placed close to the casting (as they should be for best feeding). Proper draft on runners will relieve this problem.

Molding Sand

Because of the nature of a drop, sand properties must be considered. However, the laboratory results may not show variation because the strength of sand is related directly to the mold hardness. In considering sand properties the type of molding should always be included since even a strong sand will be weak if soft rammed.

(1) *Inadequate green properties* may be inherent to the sand mix. The properties of interest are: impact strength; tensile strength; shear strength; and deformation. Figure 7.4 illustrates a drop created by inadequate green strength in the molding sand, Fig. 7.5 shows a drop as a result of low shear strength.

It is in these properties that sand may fail — not in compression as usually tested. Since most sand testing includes only green compression, the important properties may be out of proper range without the laboratory spotting the problem through routine testing.

(2) *Inadequate mold properties related to sand moldability.* This results in insufficient mold hardness or insufficient mold strength. Mold strength is related to molding and the ability of the sand to mold (ram or squeeze). The reduction in frequency of drops is often a direct benefit of improving moldability (flowability) either through modifications of clay or addition of moldability additives.

(3) *Inadequate dry strength* is a factor in dry sand molding practice just as is low green strength in green sand practice.

(4) *Poorly prepared sand* is a common cause for the above. As such, it is a common contributor to drops. A nonuniform sand may create zones of weakness in a mold by permitting dry or wet zones, low clay zones, or unbonded sand grains. Adequate mixing is needed to develop a uniform strength; especially important to tensile properties.

Core Practice

(1) *A weak or inadequately secured core or core as-*

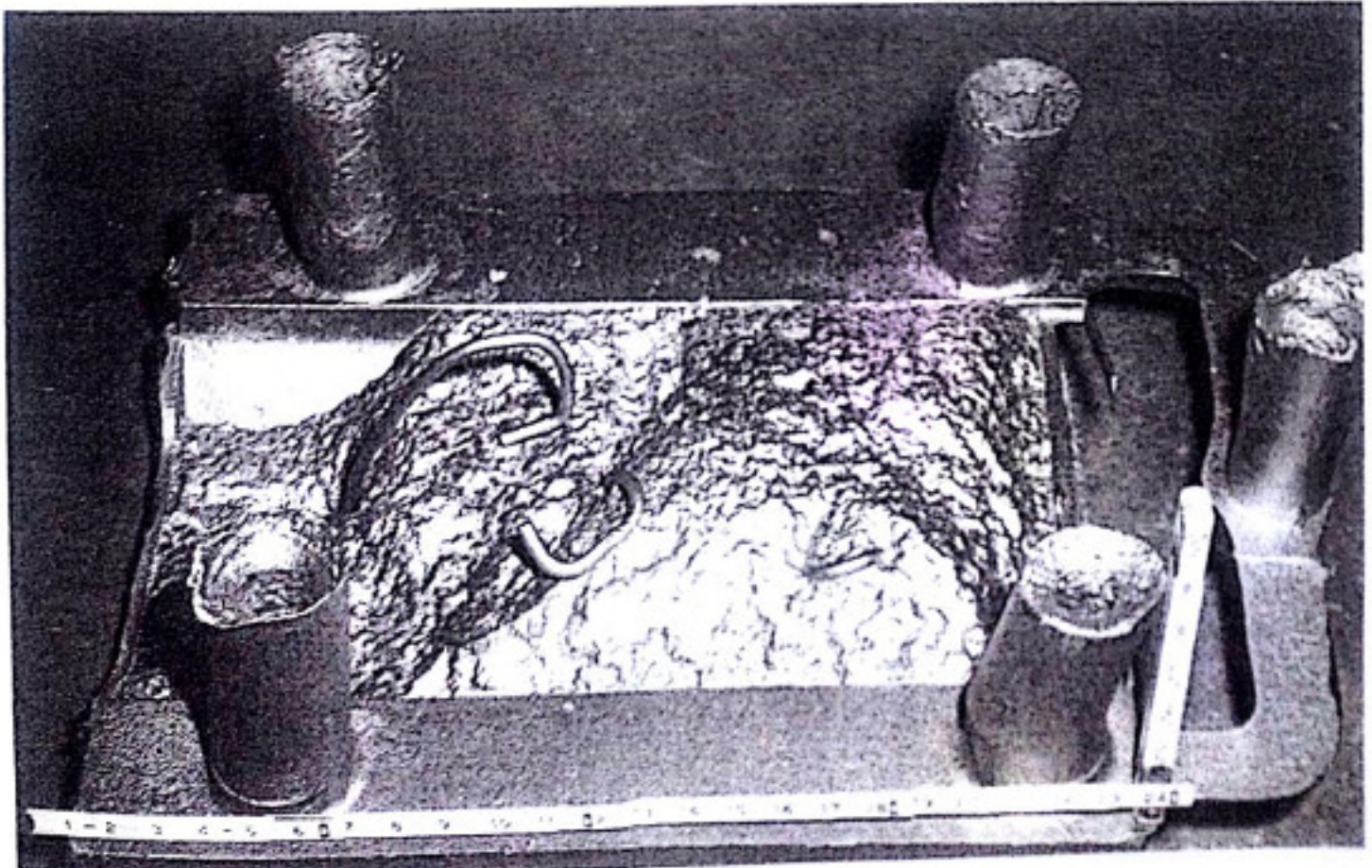


Fig. 7.6 — A nonuniform ram is the major cause of a drop in large mold sections.

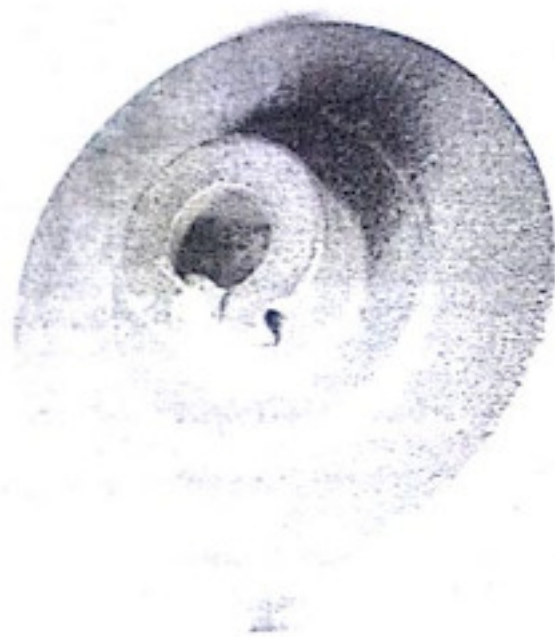


Fig. 7.7 — Sand broke off the core during setting and dropped into the drag. During pouring the sand section floated to the cope.

sembly is apt to be found more frequently in paste-in cores or ram-up cores. Weak or inadequately secured cores are liable to drop, or they may loosen part of the cope and cause it to drop.

(2) *Core failure in centrifugal casting* shows as a drop. The drop is caused by centrifugal force rather than simple gravity. Such broken cores penetrate the metal wall toward the outside surface.

Molding Practice

(1) *Nonuniformly rammed or soft rammed molds* create weakness which is not related to the sand properties found in the laboratory (Fig. 7.6). Too often attempts to strengthen the sand by clay additions merely aggravate the soft ram and make the condition worse instead of better. The cure is to ram (mold) better and more uniformly or, if this is impossible, to increase the sand moldability.

(2) *Gaggers, nails, soldiers, bars, etc. too close to the mold cavity* are a basic cause of mold weakness leading to drops. The small sand area can easily drop away from the reinforcement. This is further aggravated by inadequate wash on gaggers, soldiers, bars and the like.

(3) *Insufficient mold reinforcement* permits large sand areas to drop under conditions of too many patterns for flask size or insufficient cope height. In many designs, adequate reinforcing is essential in uncured (green sand) molds.

(4) *Careless core setting may break or mar a mold surface* to the extent that the mold is weakened enough to drop during or after closing. (See Fig. 7.7).



Fig. 7.8 — Weight dropped on mold

(5) *Setting the cope crooked* (on the bias) places a side strain on pockets and walls. This unusual side strain may set up a shear action for which the sand shear strength is not adequate. Such crooked setting may also bump a surface causing an immediate drop or loose sand in the drag.

(6) *Rough handling* includes jarring the mold, dropping weights on the mold (Fig. 7.8), and bumping molds on the conveyor. Only the strongest molds can withstand this type of abuse. Obviously, the tendency toward rapid automatic roll over and handling involves a need to keep these fast motions smooth and gentle, if excessive mold breakage is to be avoided.

(7) *Separation of molded layers of sand* is a special form of drop. It can occur as a separation of facing from backing. This is related to a lack of balance in sand properties such as weak facing and strong backing, or vice versa. A more common separation occurs as a specialized condensation problem caused by using cold facing sand and hot backing sand. Technically, a combination of hot facing and cold backing is equally bad but it is not expected in any normal foundry activity. A wide discrepancy in temperature results in condensation at the interface. Such high moisture reduces the tensile strength to the point where a drop occurs. It is also possible that such cold facing is literally blown away by rapid evolution of steam sand during slow pouring.

Metal Composition — Melting Practice

Metal composition and melting practice are not a cause of drops.

Pouring Practice

Pouring practice is a factor in this type of defect to the extent that the metal-pouring crew is involved in the handling of weights and jackets and to the extent that the metal pourers may abuse the mold by knocking against it. Typical of these effects are: resting the ladle on an unpoured mold; rough handling of weights; forcing jackets on molds; rough handling of molds on the conveyor.

Miscellaneous

(1) *Foreign material in sand acts*, as described in **Molding Practice** (2), by creating zones of weakness in the sand near the mold cavity to permit a drop.

(2) *Mold explosions* which occur when the gas between mold and bottom boards ignites is often sufficient to cause drops in adjacent molds.

(3) *Vibration* caused by heavy jolt machines, heavy machining and the like in the immediate vicinity of a mold is often enough to cause a drop.

(4) *Rough handling*. Any form of rough handling or mold abuse is dangerous.

EROSION SCAB

DESCRIPTION

An erosion scab is an expansion defect in which the loosened sand has been eroded away by the motion of metal, such as boiling, and has left a solid junction between the casting and the defect. As such, the defect can be removed by cold chisel, usually leaving a solid surface. However, it should be noted that the erosion scab may result in sand holes or sand inclusions in some other part of the casting. Figure 8.1 shows a typical erosion scab.

The erosion scab is similar in appearance to a cut or wash. It sometimes looks like a rat-tail or drop. The cure, however, may be entirely different because an erosion scab is essentially an expansion problem rather than a low strength (hot or dry) problem. It is best understood by visualizing an expansion taking place in or on the mold surface before the metal touches the surface at that point. Such expansion loosens or weakens the mold surface to a predetermined depth.

When molten metal flows over such an expanded surface, it can readily cut or wash the sand grains away, leaving a growth on the casting. As implied by the word "erosion," it is a cut, but the word "scab" implies that the cut or wash would not occur if the sand

had not tended to scab or buckle ahead of the metal flow. Obviously, this defect is caused by the tendency of the sand to scab and of the metal to erode or cut. Therefore, both metal flow and sand (or core) properties must be evaluated.

CAUSES

Casting and Pattern Design

A design which necessitates gating through thin sections. Such design will concentrate the metal flow in such a way that erosion may take place in any area which has been weakened by expansion. From a design standpoint, this problem can be alleviated by keeping combinations of light and heavy sections to a minimum.

Pattern Equipment

(1) *Insufficient fillets on gates and section changes. This is a fault of the pattern layout. Failure to properly fillet causes changes of section which increase the tendency to scab and buckle. These can erode especially at the gate area. Sharp corners always tend to vein or scab more than properly filleted changes of direction or section.*

(2) *Parting the pattern to necessitate gating through thin sections. This has the effect of encouraging jet-type metal flow and erosion of weakened areas. This same influence applies equally to cuts and washes and to erosion scabs.*

Flask Equipment and Rigging

(1) *Bars improperly placed, preventing uniform ramming. This may lead to hard and soft spots in the mold. Lack of uniform hardness is a prime cause of expansion problems. In addition, the hard spots may scab and the soft spots may cut under conditions of rapid metal flow.*

(2) *Bars, soldiers, and gagers, coated with wet clay and too close to the mold surface. These create a weak water wall close to the mold surface. This is a basic cause of scabbing. If such scab occurs in an area of metal flow, erosion is likely to result.*

(3) *Rigging in too small flask so that the vertical pattern wall is too close to flask or bar. This creates a condition of nonuniform heat loss through the sand and promotes scabbing. If the bar or flask is in the line of metal flow, an erosion scab will result.*

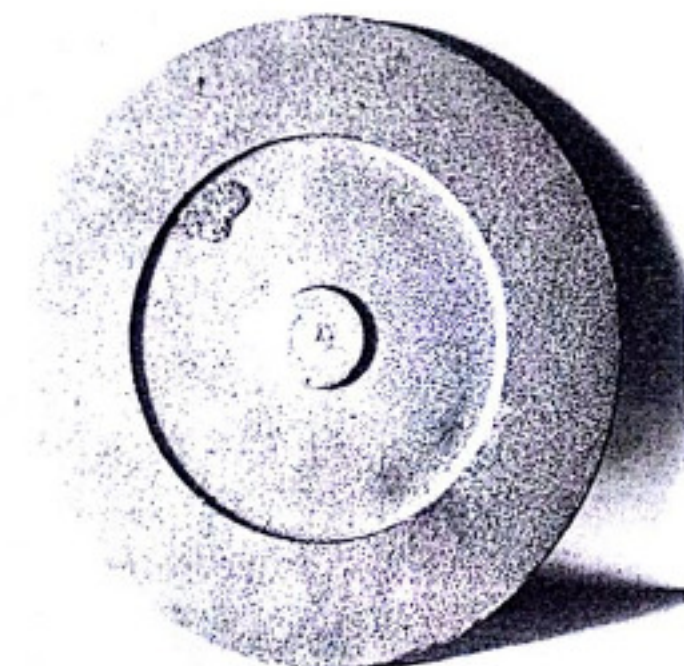


Fig. 8.1 — Typical erosion scab on the core surface. In this particular case the defect was caused by excessive slicking.

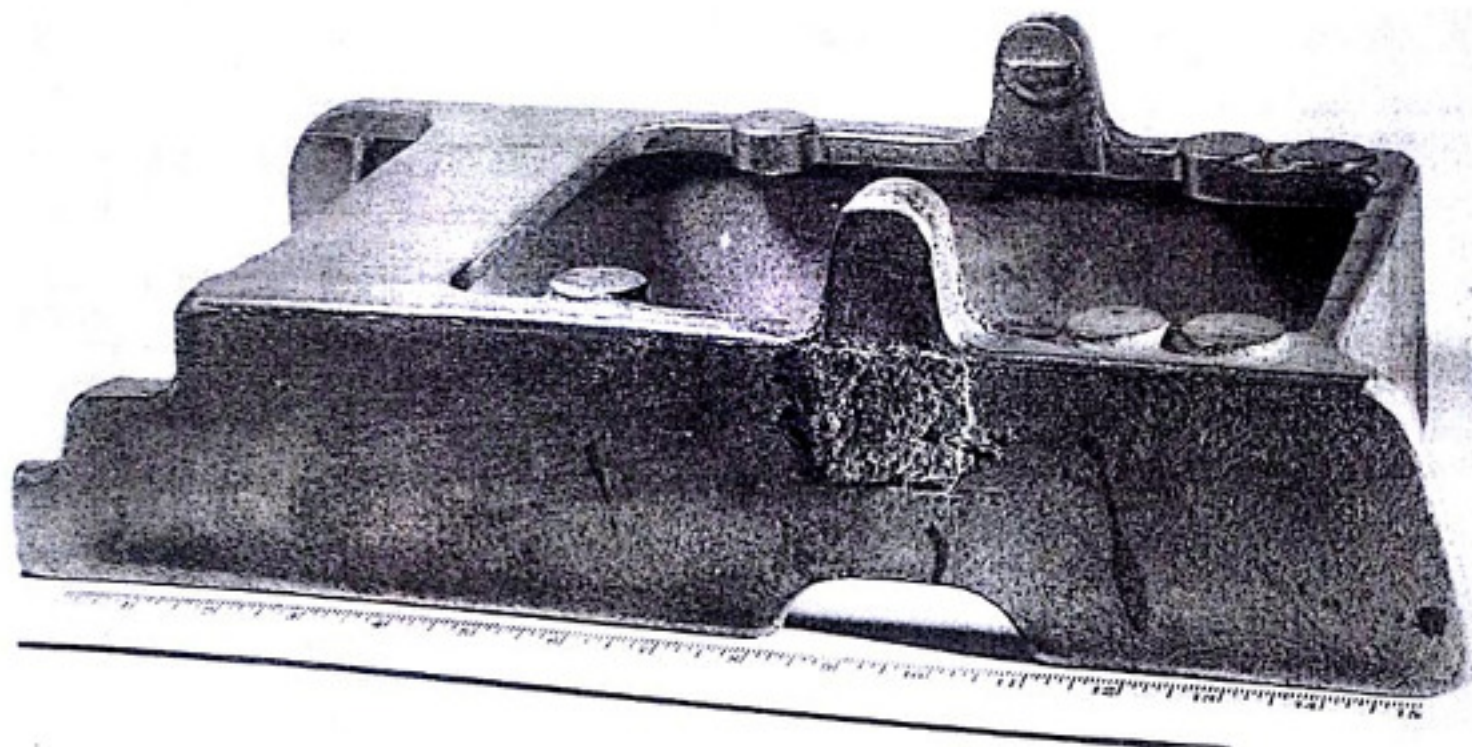


Fig. 8.2 — Erosion scab caused by metal impinging on the sand surface. The gates are on the inside of the two ears or bosses.

Gating and Riser

(1) *Gating which creates interrupted metal flow.* Such gating contributes directly to expansion-type defects. As the metal stops, heat continues to radiate ahead of it, thus heating the sand to the point of expansion. This interrupted flow often results in a rat-tail defect.

The same expansion phenomenon, however, may weaken the sand and permit erosion during subsequent later flow. Interrupted flow from careless iron pouring has a similar effect for the same reason.

(2) *Metal impinging on and disrupting sand surface* (Fig. 8.2). This affects the eroding ability of the metal stream. The implication of erosion scab is that the impingement would not be enough to actually cut, in the absence of expansion, but is enough when expansion weakening has taken place. This illustrates the point that there is a fine line of distinction between an erosion scab and a cut. As far as the metal flow alone is concerned, the two defects have the same cause. In the case of sand or core, the causes of the two defects may be quite different.

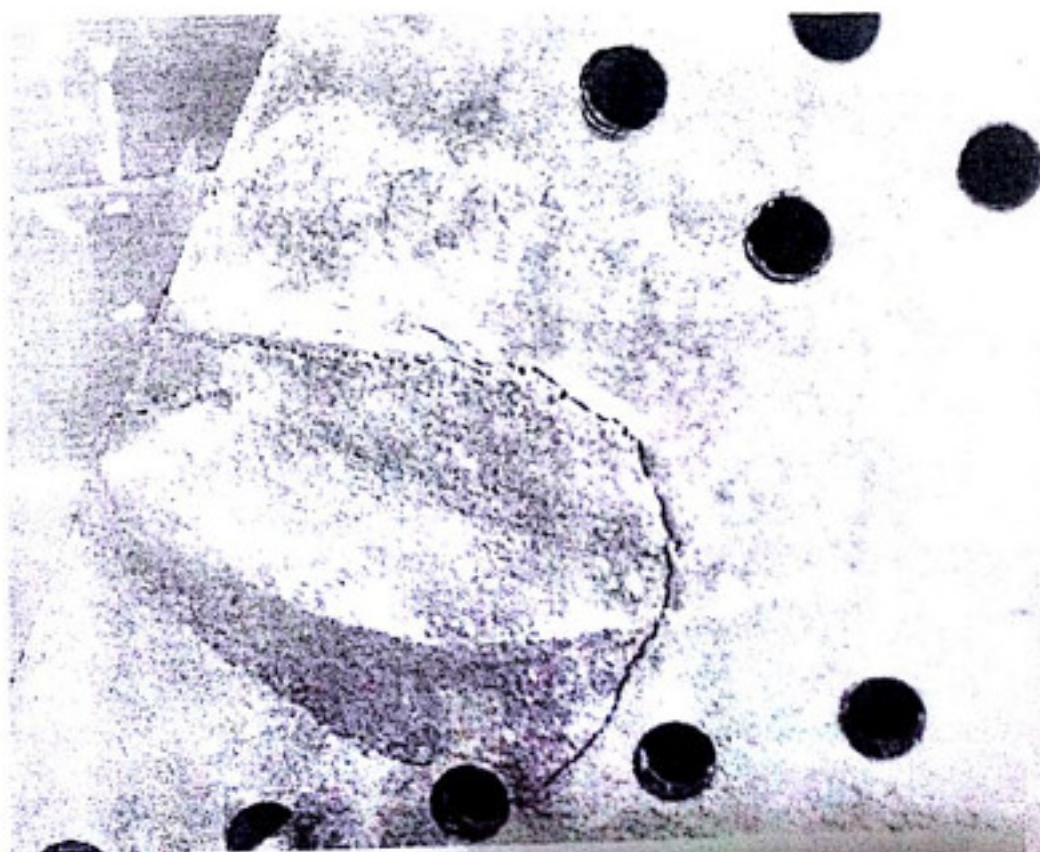


Fig. 8.3 — Erosion scab near the riser from localized overheating of the sand.

(3) *Gating which creates localized overheating of the sand (Fig. 8.3).* This increases the expansion tendency of the mold at such localized spots. The word "localized" implies that such sand will expand faster than adjacent colder sand and create an area of weakness or scabbing prior to the cutting action of the metal stream.

(4) *Gating which remelts initial metal skin (fast skinning metals such as bronze and steel).* Remelting of the initial metal skin is a modification of the previously described relationship between expansion and metal erosion. Normally, the expansion would have to precede the metal contact if erosion is to take place because the metal skin formed would prevent further erosion after the metal covers the sand.

However, if metal continues to flow over the same spot for a length of time, the skin can be redissolved (melted) and erosion of the then highly expanded sand proceeds rapidly. It must be remembered that the original metal-skin formation occurs because the sand is cold (extracts heat). As pouring proceeds, the sand can heat up to the point where remelting of the skin is inevitable.

Molding Sand

(1) *High moisture content.* High moisture is a prime cause of this and other forms of scab or expansion defects. The actual moisture is not as important as the free water, i.e., water over temper. Such high moisture can be general or highly localized from poor mulling or mixing. Such excess water is particularly dangerous when combined with low permeability, excessive fines or low clay content. Figure 8.4 shows an erosion scab caused by wet sand, aggravated by hard ramming.

(2) *Too broad or too narrow (one screen) grain distribution.* This promotes nonuniform expansion rates and creates areas of weakness during heating. Some

breadth of distribution is desirable to promote self-cushioning such as usually found in the 4-screen sand.

(3) *Excessive carbonaceous material causing boiling.* Boiling creates a localized agitation capable of eroding a weakened sand. In addition, such boiling action (also from excess water) directly disrupts the sand surface by weakening the bonding film between sand grains.

(4) *Insufficient carbonaceous (or cellulose) material for expansion control.* This is related to the need for expansion control. Narrow screen distribution, low clay, high moisture sands require definite amounts of expansion-type additive for adequate anticabbing control. High clay, low moisture and 4-screen distribution reduce these requirements for cushion material.

(5) *Insufficient hot deformation.* This is a major cause of erosion scabs because it permits the mold wall to break as expansion takes place. The broken surface erodes easily. An equal amount of expansion with a high hot deformation sand might create mold distortion, but the absence of a break in the sand surface would prevent actual erosion under conditions of normal metal flow.

(6) *Improper conditioning of the sand, such as clay or moisture not uniformly dispersed.* Failure to condition sand properly creates nonuniform expansion and broken mold surfaces (scabs and buckles). There is a distinct difference between undermulled sand and poorly mixed sand. Undermulled implies excessive clay adequately distributed, but poorly mixed sand contains localized wet or dry sand and the consequent variation in sand properties such as strength and deformation.

Core Practice

(1) *Excessive moisture in or on the core.* This may be from undercuring or be the result of moisture pickup

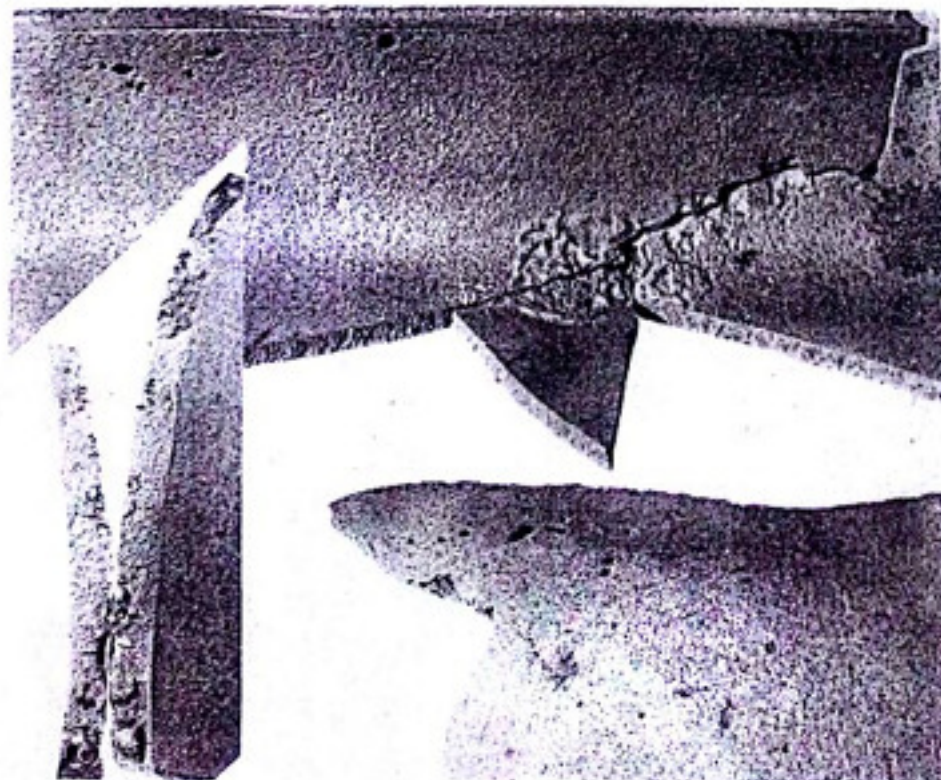


Fig. 8.4—Erosion scab caused by wet sand aggravated by hard ramming.

during storage or handling. The excess free water promotes rapid expansion to the point of loosening the surface sufficiently to permit metal erosion.

(2) *A core blow may cause an erosion scab on the adjacent mold surface.* In this case, the defect shows on the mold surface but the original agitation or boil comes from the core. A boil (flutter) of this type during the time of sand expansion prevents proper skin formation and permits erosion to occur.

(3) *Insufficient hot deformation.* Insufficient hot deformation due to type or amount of binder, permits the core surface to break during expansion, and erosion occurs if metal flow is present at that time. Core binders vary in brittleness at temperature depending upon their chemical characteristics.

(4) *Inadequate penetration of wash.* Inadequate penetration of a wash into a core surface may produce a blackening scab, which is easily eroded or washed away if molten metal flows over that surface. Such lack of penetration depends upon the Baumé (thickness) of the wash and the permeability of the core. If the wash is too thick or viscous (Baumé) for the sand fineness, the penetration will be shallow. The differential of expansion rates of the wash and the core can cause peeling of the wash because of heating during pouring.

(5) *Inadequate depth of facing sand.* When inadequate facing is used, an effect similar to inadequate penetration of wash results. The facing can peel or spall away from the base during heating, making erosion by metal flow possible.

Molding Practice

(1) *Nonuniform ramming.* This is a major cause of all expansion-type defects. Such nonuniformity is the result of hard and soft rammed spots. The problem usually occurs at the junction of the hard and soft areas where one section of sand is expanding more or faster than the adjacent section. If the growth results in a broken surface prior to or during metal flow, erosion is inevitable.

(2) *Gaggers too close to the pattern.* This causes an erratic expansion because the expansion of the metallic gagger is entirely different from that of the sand.

(3) *Clay wash on gaggers.* This further aggravates the problem because of steam formation and low tensile strength of the water layer.

(4) *Excessive slicking.* Excessive slicking of the surface is well known as a source of scabbing. It has the same effect as hard and soft ramming in that two different rates of expansion are encountered. The slicked area can readily be broken loose during heating, thus providing easy access to the molten metal. This acts like a blackening scab.

(5) *Mold or wash not properly dried.* This creates an excessive moisture condition. Properly dried molds tend to reduce erosion scabs but blackened or skin-dried molds which are not properly dried can be actually worse than good green sand molds. Variations in drying technique is an area of trouble frequently overlooked in studying this problem.

(6) *Insufficient penetration of the wash.* This is relat-

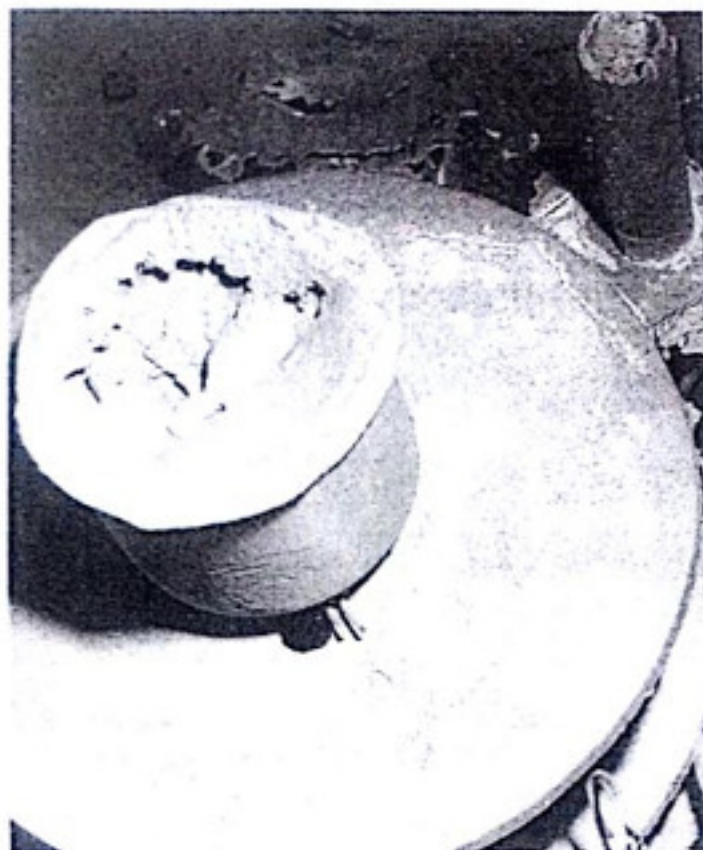


Fig. 8.5 — Excessive pouring temperature caused erosion scab on the cope surface.

ed to insufficient drying in that a skin weakness is permitted. Differential rates of expansion between the mold and the skin occur either from insufficient penetration or insufficient drying.

(7) *Expansion of wash not matched to that of sand.* This is a variation of (5) and (6) preceding. The composition of the wash should be suitable for the job. For example, a high clay content wash on a low clay sand will tend to peel away. Either the wash or the sand could be changed to provide a better compatibility of expansion rates.

Metal Composition — Melting Practice

Metal composition and melting practice are not a cause of erosion scabs.

Pouring Practice

(1) *Excessive pouring temperatures.* Excess temperature for the molding materials involved increases the cutting or washing tendency by heating the sand more rapidly. It thereby increases the rate of sand expansion, and in addition, may be more erosive in acting on the expanded sand. (See Fig. 8.5.)

(2) *Interrupted pouring.* Interrupted pouring causes nonuniform expansion of the sand surface. If one part of the mold expands more rapidly than an adjacent part, it can break away to permit easy erosion.

Miscellaneous

Any foreign body close to the mold surface can lead to a localized expansion or pushing of the mold surface into the path of the incoming metal.

EXPANSION DEFECTS

DESCRIPTION

Expansion scabs are rough layers of metal connected to the main body of the casting by a vein.

A **buckle** is a V-shaped indentation which may occur by itself or under an expansion scab.

A **rat-tail** is an irregular line caused by low temperature expansion of the mold surface showing as a change of plane.

A **blackening scab** is a specialized form of scab in which the defect is related to the coating rather than to the sand.

A **pull down** or **cope spall** is an indentation in the cope surface of the casting. Depending on the time of formation, it may have the appearance of a buckle, rat-tail, shrink, or blow. Figure 9.1 shows a typical defect on cope surface.

Since sand-mold surfaces go through the process of expansion and contraction during the pouring of a casting, it is common practice to assume that the sand is the principal cause. This is a mistake, as these defects are also closely related to all practices which control the rate of pouring. Since the sand-mold surface always shows expansion, the determining factor in preventing these defects is the time of covering the sand surface with metal and creating a protective skin of solidified metal. If the expansion occurs after the skin is solid, there is no defect. If the expansion disrupts the sand before the metal skin is formed, a defect will result. Therefore, the pouring time must be related to the rate of covering the sand surface — not necessarily to the casting weight. Using gating formulas based only on casting weight, while ignoring surface area, may lead to expansion problems in thin sections and similar ones of large surface area but low weight.

A common mistake is to base pouring time on total weight in the mold instead of the weight or size of the individual castings. Where multiple castings occur in a single mold, the expansion defects are related to the time of covering the sand surface of the individual casting, regardless of how many such castings are made in the same mold. For example, if the only correct pouring time for a single casting is 16 sec, then the pouring time should still be 16 sec even if ten such castings were mounted to be poured from a single sprue.

CAUSES

Casting and Pattern Design

- (1) *Large uninterrupted flat surfaces.* These require

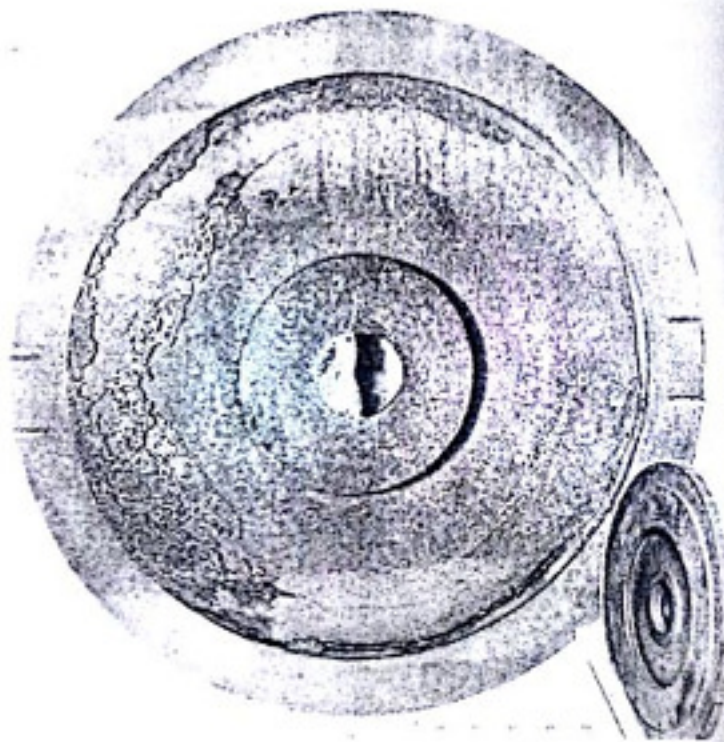


Fig. 9.1 — Typical expansion defect on cope surface.

fast pouring to cover the sand surfaces before expansion of the sand progresses to the point of rupture. Such surfaces are subjected to intense radiant heat during pouring. In addition, such flat surfaces are likely to promote nonuniform metal flow (interrupted flow) with its tendency to locally overheat some area of the mold before adequate metal coverage is available for protection.

If the design cannot be changed, care must be exercised to pour rapidly and smoothly. The mold and gates may be tilted so the metal will flow uphill. Proper gating will often solve the problem. If not, sand additives such as wood flour may be needed over and beyond normal good sand practice.

- (2) *Inadequate radii.* Inadequate radii tend to promote expansion defects because sharp corners permit free expansion of the surface during the pouring cycle. The expanded surface in such sharp corners is readily disrupted, or broken, since there is no restrictive force holding the sand surface in place until metal solidifies.

Sharp corners also are apt to reach expansion temperature more rapidly because they are exposed to heat concentrations from two sides. In some cases, the

foundryman can use contour chills at the point of inadequate radii. This will move the heat away from the surface. At best, this is a questionable means of correction. The only proven method is to increase the radii or it will be necessary to provide a special sand high in antibonds, e.g., wood flour.

(3) *Large, smooth uninterrupted concave or convex surfaces.* These may be even worse than similar flat surfaces because the shape of the mold promotes rupture of the expanded surface and because of the increased tendency toward slow or interrupted pouring. A dome shape is particularly prone to expansion defects unless care is taken to cover the sand of the entire surface rapidly before excessive expansion from the radiant heat can take place.

Pattern Equipment

Inadequate fillets or radii, see *Casting and Pattern Design* (2).

Flask Equipment and Rigging

(1) *Bars or flask too close to pattern surface.* This promotes nonuniform ram, leading to the combination of hard and soft areas which is a common cause of nonuniform expansion rates. When sand conditions are such that one area expands more rapidly than the adjoining area, sand movement or slippage is apt to occur. Part of the mold surface expands into the adjacent surface causing a break in the sand surface. Metal can move in to show as a vein, buckle, or scab. The

proper cure is to avoid crowding excessively large patterns into an inadequate flask and to provide adequate bar clearance for easier molding.

Some foundrymen change to a harder to ram sand which may eliminate the nonuniformity. This obviously tends toward a soft mold with its subsequent mold-wall movement, swell or strain. Others compensate for the poor equipment by careful hand peening or tucking to produce a uniform hardness, in spite of the handicap of inadequate clearance for normal molding.

(2) *Rigging which prevents proper pouring speed.* This causes slow covering of the sand surface thus permitting expansion to occur before the metal skin is formed.

(3) *Flask too shallow.* A shallow flask is a rare but possible reason for scabs and other expansion defects, but is more common in the case of cope spall or pull downs. In this case, the lack of adequate backing sand permits rapid heating of the cope. It also results in a mechanical weakness which cannot withstand the stresses of the rapidly expanding sand.

Gating and Riserig

Since sand grains expand when heated, it becomes important to cover all mold surfaces with metal as rapidly as possible — and to keep them covered. The three principal factors involved are as follows:

(1) *Gating system which prevents adequate pouring speed* (see Fig. 9.2),

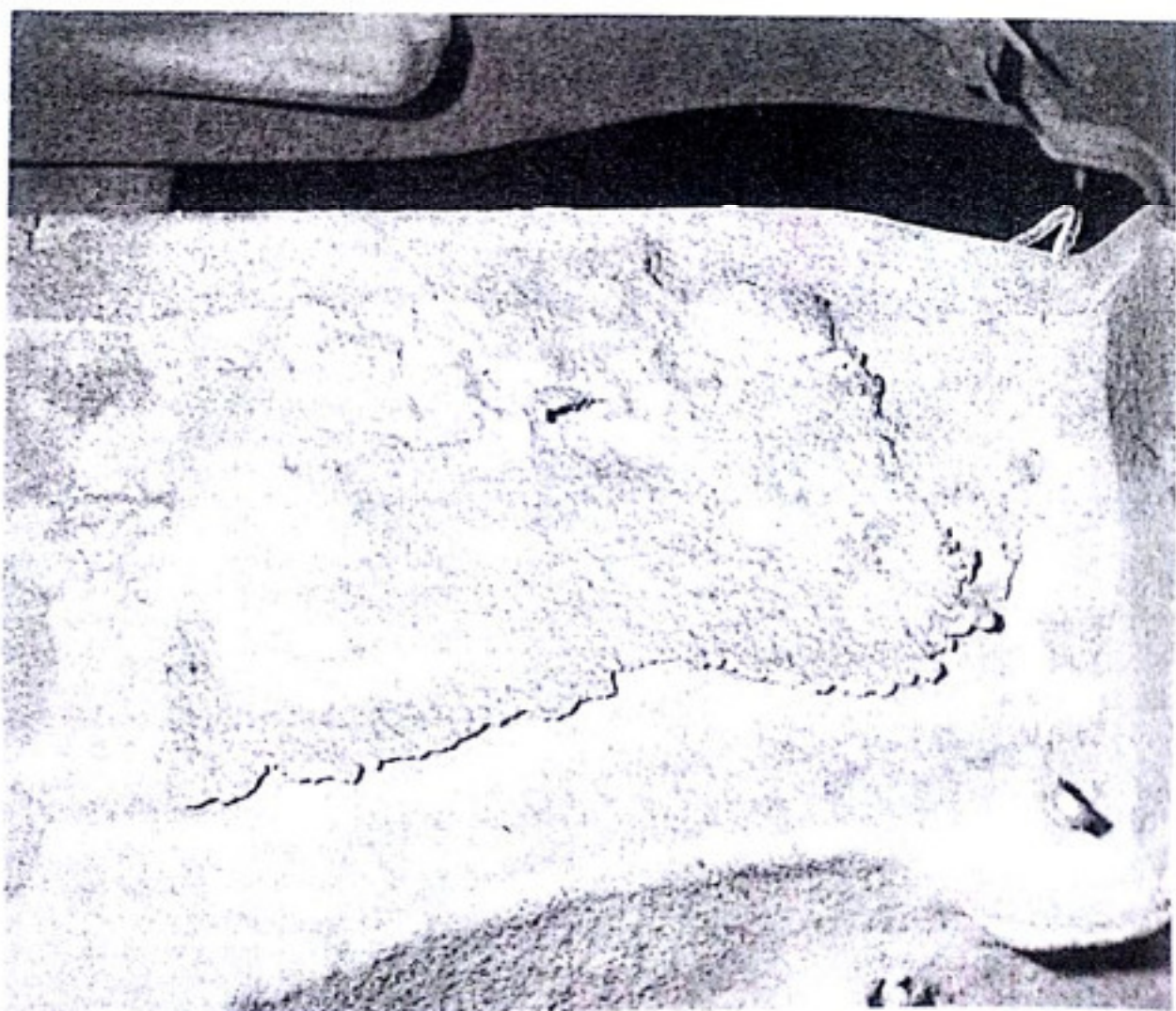


Fig. 9.2 — Expansion scab caused by slow pouring which permitted excessive heating of the cope surface before metal contact.

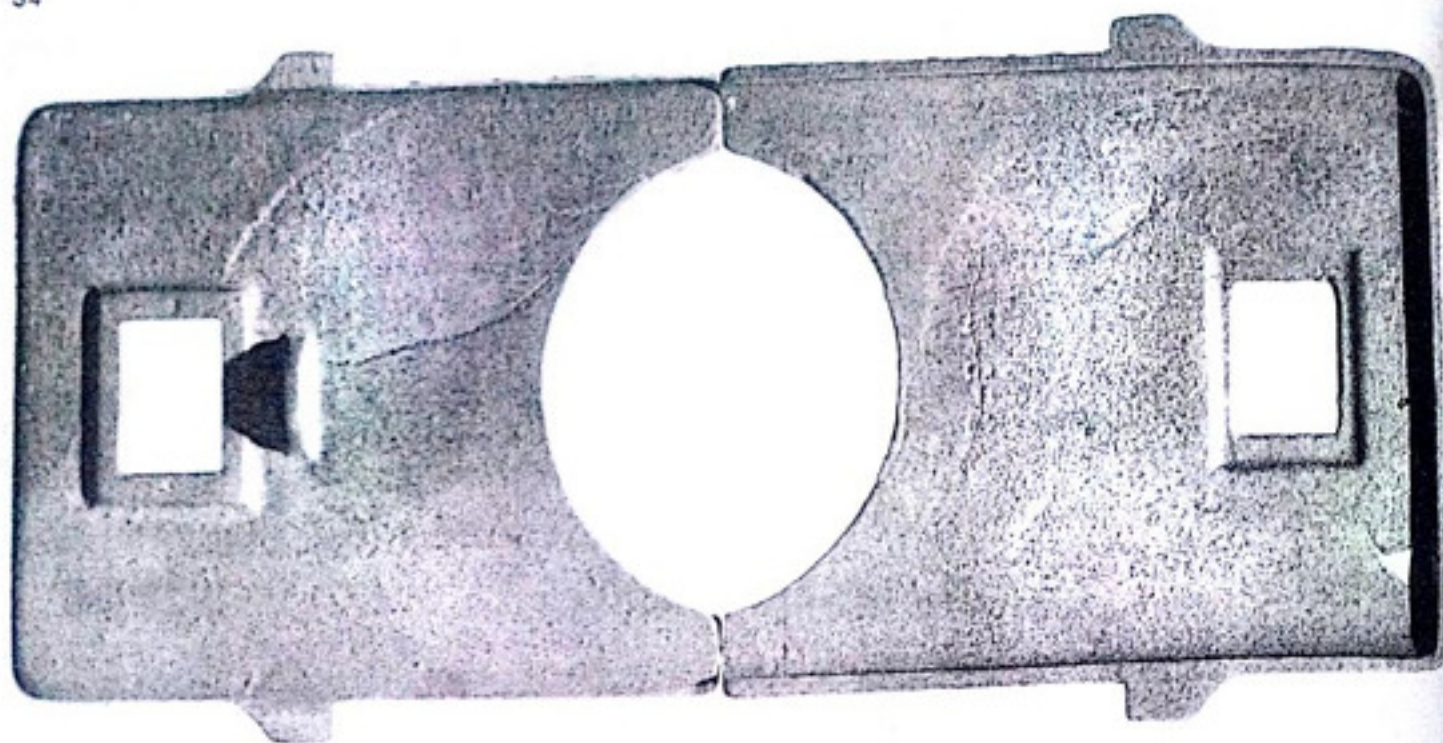


Fig. 9.3 — Typical rat-tail from interrupted metal flow. The flow marks are clearly visible.



Fig. 9.4 — Scab near the ingate caused by nonuniform heating of the mold surface.



Fig. 9.5 — Cope scab related to excessive moisture in the sand aggravated by hard ram.

(2) Gating system which causes interrupted metal flow (see Fig. 9.3),

(3) Gating arrangement which causes nonuniform heating of the mold surface (see Fig. 9.4).

It is important to recognize that getting all mold surfaces covered will not prevent the sand grains from expanding. It does mean, however, that getting all mold surfaces covered with a film of metal will offer protection and prevent the sand-mold walls from buckling into what would otherwise be a cavity in the mold when the expansion does occur. Many cope spalls or pull downs have been avoided by filling a mold faster and getting the metal up to the cope surface faster.

The heat radiated against the cope surface from molten metal on the drag face causes the cope sand to expand, buckle and sag. If this occurs before the molten metal reaches this surface, an actual spall may occur. If it occurs as a sag just before the metal touches, the molten metal may lift the sand surface back into place, but with a break occurring in such a way as to permit metal entry — a scab. These effects have been observed with high speed photography and are, therefore, well documented.

The same reasoning applies to any type of interrupted metal flow. If the mold surface is covered, uncovered and recovered intermittently by molten metal, spalling may occur on any mold face (see Chapter 8, EROSION SCABS).

Molding Sand

Although it is a mistake to assume the sand to be the best corrective measure for these defects (ignoring pouring rate), nevertheless the amount of expansion which the sand can withstand without rupture is a sand property requiring accurate control. Assuming that design and pouring rate are proper, corrective

measures are available through modifications in sand properties. In addition, it must be recognized that certain sand properties, when out of control, can create weaknesses that even proper gating cannot offset.

The following are sand properties which can account for inadequate control of expansion.

(1) *Excessive moisture content for the materials involved.* This is a matter of free or excess water rather than total water. A high clay or natural sand needs and permits higher moisture than a low clay sand, for example. Figure 9.5 shows a cope scab related to excessive moisture aggravated by hard ram.

(2) *Clay content too low for the moisture involved or the mold hardness involved (see Fig. 9.6).* High moisture sands require adequate clay. Sands which are subjected to dense (pressure) molding require higher clay to offset the high mold density (high mold hardness).

(3) *Carbonaceous material too low (see Fig. 9.7).* This applies where carbonaceous materials are part of the normal expansion control. In this case, carbonaceous materials act much as do wood flour and cereal in the noncarbonaceous sands.

(4) *Too low hot deformation (see Fig. 9.8).* This is a prime cause of failure and is often the result of the other factors listed above. In effect, the sand is brittle at elevated temperatures and, therefore, a rupture of the sand mold surface occurs under conditions of expansion. Excessive hot deformation, leads to mold-wall movement and shrinks.

(5) *Incorrect sand grain distribution.* Incorrect distribution can create more total expansion than necessary. A clean sand (low clay and silt) of a narrow distribution, or a sand with two maximum screens separated by a minimum screen, are high expansion problem sands. These are referred to as "one-screen" and "camel-back" distributions. A smooth distribution over three or four screens is usually most desirable.

(6) *Incorrect grain size and shape of sand.* This is a modification of (5) preceding. In addition to having a variety of sizes (four screen), it is also desirable to have a distribution of shapes, e.g., angular, subangular, and round. All one type grain is similar in character to having all one size grain (excessive total expansion).

(7) *Segregation of materials by improper mixing.* Segregation may fall in the category of (1)-(3), (5)-

(6) preceding. In other words, the deficiencies or excesses referred to may be strictly on a localized basis because of poor mixing. For example, a wet spot is excessive moisture (1). Even though it only occurs in one spot, that one spot can scab. In the same way, certain parts of the mold may have low clay, low carbonaceous material, improper grain size, and the like.

(8) *Insufficient cushioning material.* This may happen if one assumes that all other factors are correct but the sand needs added control to offset poor design, slow pouring, incorrect gating and similar non-sand causes. Likewise the sand practice may involve such combinations of water, clay and sizing that some other control over hot deformation is required. In this case, a drop in the accepted level would create a defect. These cushion materials are helpful tools but should not be considered as cure-alls if some basic practice is incorrect.

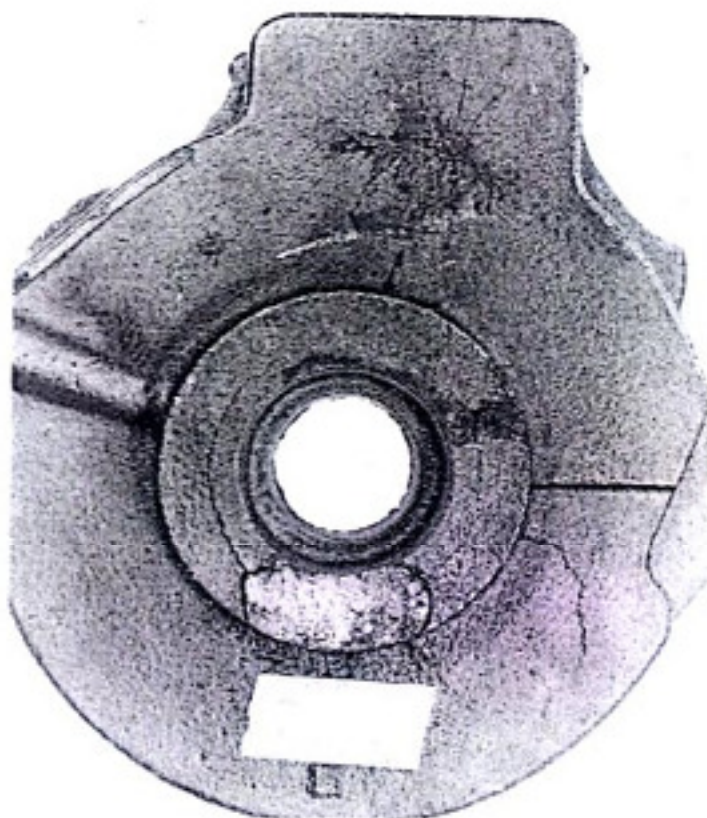


Fig. 9.6—Rat-tail caused by low clay content aggravated by high moisture in the sand.



Fig. 9.7—Buckle (which had a scab before cleaning) was caused by inadequate carbonaceous or cushioning material.

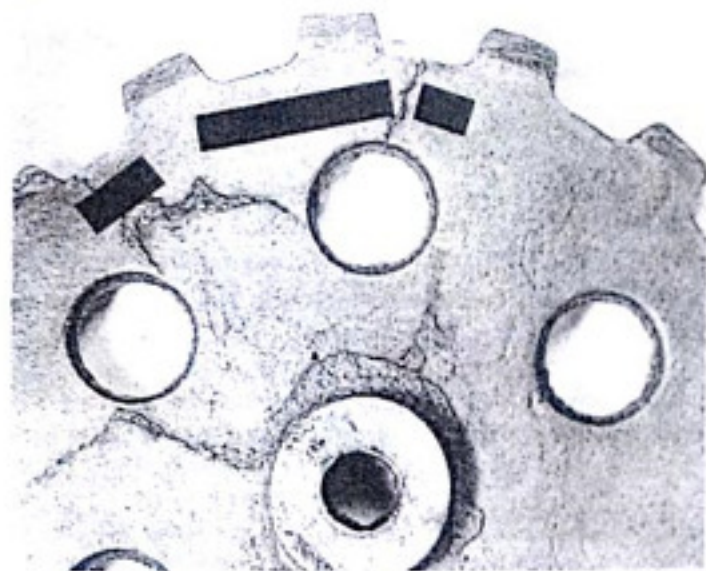


Fig. 9.8 — Scab (with buckle underneath) related to inadequate hot deformation in the sand.

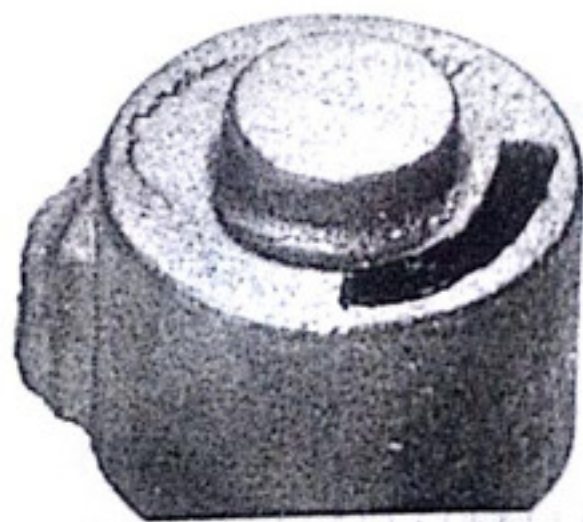


Fig. 9.9 — Uneven ramming of the drag mold permitted the pattern plate to bend in such a way as to prestress the mold surface. The defect was corrected by hard ramming the drag.



Fig. 9.10 — Blackening scabs caused by inadequate hot deformation in the sand.

Core Practice

- (1) *Low hot deformation.* This is a basic factor as in the case of **Molding Sand** (4) and for the same reason.
- (2) *Green sand or green top cores.* These are affected by all the factors described under **Molding Sand**.
- (3) *Nonuniform shell thickness.* In the case of hollow cores, this leads to a nonuniform expansion similar to that described in **Flask Equipment and Rigging** (1).
- (4) *Rods or arbors too close to the core surface.* This creates a nonuniform expansion rate since sand and metal (rod) have different expansion coefficients. The result is that the sand may readily break from the arbor, or the high expansion differential will cause the core to crack and permit metal to enter.
- (5) *A nonuniform ram.* Nonuniform ramming applies equally to molds and cores — and for the same reason to **Flask Equipment and Rigging** (1).
- (6) *Insufficient penetration of wash.* This creates a zone of weakness, resulting in a coating scab.

Molding Practice

- (1) *Uneven ramming.* Uneven ramming (including patching) is the major cause in this category (see Fig. 9.9). The mechanism of failures is described in **Flask Equipment and Rigging** (1).
- (2) *Insufficient penetration of wash* (see Fig. 9.10). This applies to a mold in the same way as to a core.
- (3) *Excessive wash* (see Fig. 9.11). Excessive wash can create the same effect as excessive moisture or have a direct effect by setting up unequal expansion rates if the expansion coefficient of the wash material is distinctly different.
- (4) *Insufficient drying of wash or mold.* This is a specific case of excessive moisture created because the additional water from the wash was not correctly removed. Such drying may be a case of sweat back which occurs when moisture from the interior of the mold comes back to the surface after the heat is removed (inadequate skin depth on skin-dried mold).
- (5) *Gaggers, soldiers, and bars too close to mold face.* This has the same effect as in **Core Practice** (4).
- (6) *Excessive trowelling and slicking.* This may draw the moisture to the surface or may result in hard spots similar to a nonuniform ram.

Metal Composition

Because expansion defects are believed to occur when sand expands upon heating, metal is not considered a cause, as such. Actually, the various metals vary in their tendency toward scabbing as they vary in temperature and pouring rate. For example, steel heats the sand more rapidly and to higher temperatures than aluminum, and therefore, in the case of steel,



Fig. 9.11 — Expansion scab in dry sand mold after removal from the casting. This defect was caused by excessive clay wash in a gagger which was close to the casting surface.

there is a much greater tendency to scab. However, normal sand practice within the industry conceals these differences. For example, a typical steel sand contains measurable amounts of clay and cereal or dextrin. These normal additions reduce scabbing tendencies. Since steel is never poured in an aluminum sand, the differences are not apparent. Minor differences in metal composition within a given family of alloys (such as steel, gray iron, malleable, etc.) do not seem to be a factor.

Melting Practice

Factors which control fluidity may also affect the pouring time. As such, melting practices which promote a sluggish metal (such as oxidized heats) may, by virtue of slow pour, cause expansion defects when the sand system is designed for adequate pouring speeds. This factor may be concealed since such conditions would usually create a misrun or cold shut defect in addition to or instead of the scab.

Pouring Practice

(1) *Pouring too slowly.* This major source of trouble has been described previously but, in those cases the slow pour was assumed to be due to the job rather than to the man. Unfortunately, the metal pourer can create a slow pour regardless of the design or the gate. Such a slow pour is particularly difficult to detect unless there is an actual record of the pouring time of the mold in question. A typical pouring time may conceal times of slow pour.

(2) *Pouring too hot.* This can create unusually rapid heating of the sand, which, when combined with slow pouring rates (small gates) can lead to expansion problems (see **Gating and Riser**ing).

FUSION

DESCRIPTION

Fusion is a surface defect having a rough glossy appearance related to the penetration of the metal oxides acting as a flux on the sand. Figure 10.1 illustrates the effect of atmosphere, sand and temperature on sand fusion. As such, it is an extension of metal penetration.

Many metal oxides, including iron oxide, have an affinity for sand (silica) and react with it at relatively low temperatures. When the oxide is absorbed by the sand, the resulting fusion may merely create a hard cake or fused layer which peels away from the casting leaving a smooth finish. This is typical of many steel castings that depend upon the fused shell for rapid cleaning.

If, however, the oxides remain in contact with and are part of the metal casting surface, the fusion of oxide and silica results in the rough glassy finish which requires additional cleaning. It should be noted that if the fused oxide-silica system continues and penetrates into the sand surface, trapping sand grains in a highly metallic matrix, it is termed penetration. (See Chapter 16, METAL PENETRATION.)

CAUSES

Casting and Pattern Design

Design is a contributing factor where sharp corners, or overhanging or protruding sections are necessary, or where a thin core or sand section is necessary and is surrounded by a heavy metal section. Since fusion is a high temperature chemical reaction, the speed of reaction increases as the temperature increases. A design which creates an unusually high temperature in any part of the core or mold will produce maximum fusion tendencies.

Pattern Equipment

1. *Pattern equipment, so constructed as to promote uneven or soft ramming*, modifies the metal-sand relationship. This tends toward either higher oxide formation or greater oxide penetration. These constructions consist of those listed below.

(a) Improper location of parting line so as to induce soft ramming.

(b) Improper location of the pattern on the plate causing pockets of sand between patterns or between the pattern and the flask. This makes it difficult to ram to proper density.

(c) Improper location of sprues, risers and runners. These may create small pockets of sand which are difficult to ram to proper density.

(d) Inadequate draft. This makes some patterns difficult to ram to proper hardness. Such patterns are difficult to get at and the lack of draft forces the mold to soft ram in order to avoid tearing up the sand when drawing the pattern.

(2) *Pattern equipment constructed to promote excessive metalostatic pressure such as in vertical rather than horizontal mounting*. The deep vertical sections create high pressures on the drag face.

Flask Equipment and Rigging

(1) *Design and construction of flask equipment which promotes uneven or soft ramming* should be avoided. Bars that interfere with the ramming of pockets can lead to a softly rammed section of sand under or near the bar. Flasks that are too small crowd the pattern in such a way as to permit a soft ram between the pattern and the flask. Bars that interfere with proper placement of down sprues and risers create difficult ramming conditions which, in turn, tend toward soft spots in the molds.

(2) *Excessive cope height* has a direct effect on metalostatic pressure and, therefore, upon the tendency toward fusion or fusion-penetration. Sufficient cope height is needed to avoid shrinkage defects and certain types of gas defects, but all height above that needed for feeding can be detrimental to finish appearance.

This cause of penetration has increased in recent years as the tendency to a universal flask size has increased. The use of a flask of sufficient depth for deep work has an adverse effect on castings which could all be made in shallower flask equipment.

Gating and Riser

(1) *The location of gates and risers which promote localized overheating of the sand* has a direct effect upon the rate of the chemical reaction which is fusion.

A sprue or riser too close to the vertical surface not only creates soft spots but unusually high sand temperatures in these areas. The high temperature increases the rate of reaction between metal oxide and refractory (sand mold).

Flowing too much metal over a given mold surface has the direct effect of heating the sand in this area.

Fusion of Silica on Steel and Ductile Iron

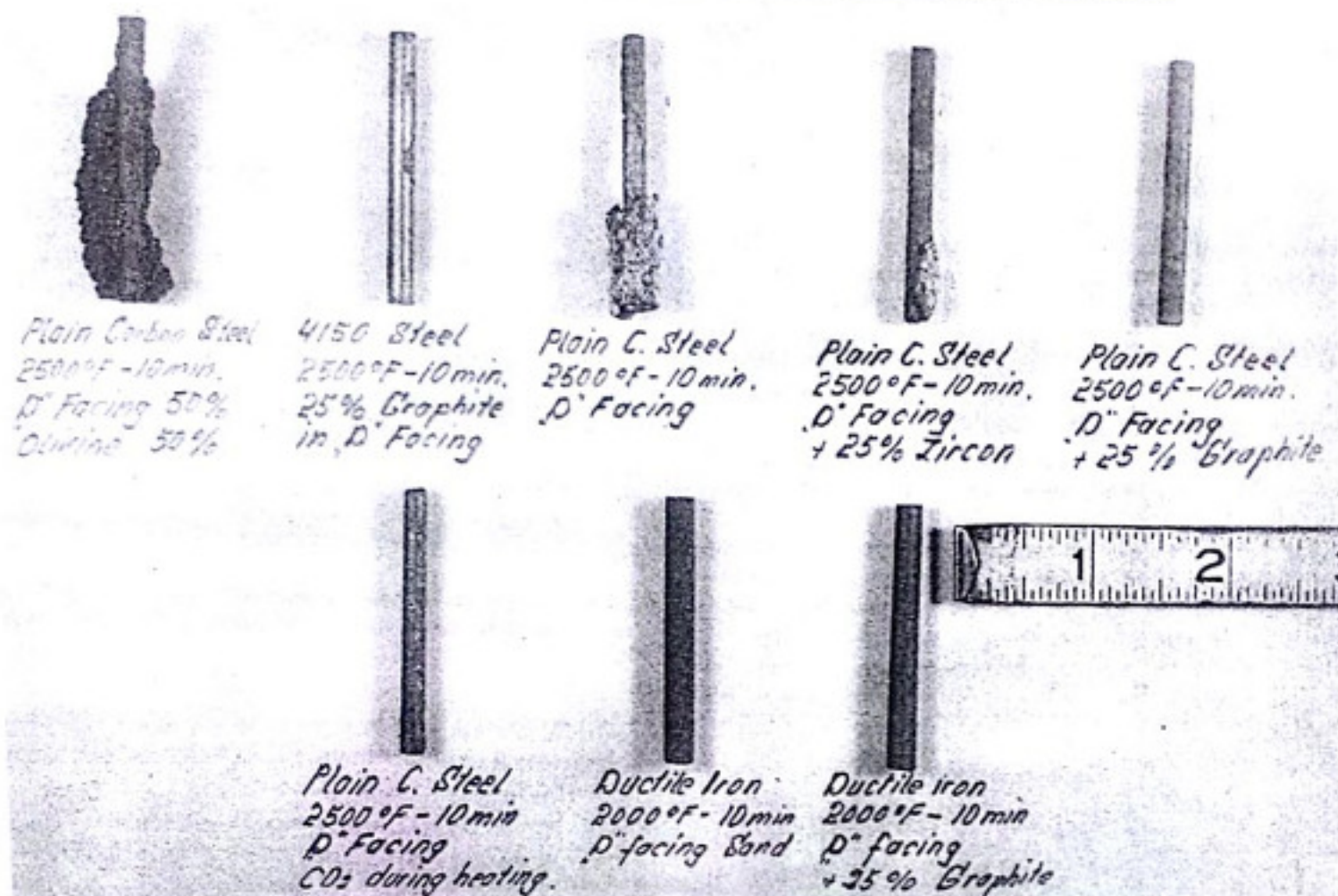


Fig. 10.1 — The photograph illustrates the effect of atmosphere, sand and temperature on sand fusion.

Since such practice also leads to cuts and washes, fusion near a cut or wash area may be expected when both have the same cause.

Anything that causes excessive pressure increases the degree of contact between metal and sand, and thereby converts a normal peel to a fused surface. Cope height and pouring height (distance from ladle to mold) are obvious examples. Not so obvious are cases of wave or surge metal flow within a gate system causing temporary high pressure on each cycle of the surge.

Slow pouring-type gates prolong the time of heating the mold, thereby increasing the degree to which the sand is heated. This promotes fusion.

(2) *Incorrect ratio of sprue, runner, and gate, permitting metal oxidation during pouring*, increases the amount of oxide on the surface. As such, it increases the amount of fusion product to be found on the casting surface. A full choke-ratio of the 10:9:8 type minimizes this problem. A misuse of the minimum-pressure 1:4:4 ratio, by putting the runner in the cope (wrong), tends to increase both this effect and the surge referred to in (1) above.

(3) *An oversize riser neck which overheats the sand* (especially true of a live riser) will increase the rate of fusion. This, combined with the heat of the riser

itself, often explains the fusion found near the base of a live riser.

(4) *A pouring cup or sprue, designed so as to cause aspiration of air (whirlpool effect) creating oxidized metal*, has the same effect as (2) since more metal oxide promotes a greater fusion product.

Molding Sand

(1) *A low sintering or low fusion point of the sand grains* indicates that they are already fluxed. As a result, further fluxing with metal oxide during pouring is easier and quicker. In some cases, the sintering point is so low that fusion in the absence of metal oxide occurs. In this case, it is doubtful whether or not such fused sand would adhere to the casting. The presence of metal oxide on the casting surface is probably necessary to develop the adherence defined as a fusion defect.

(2) *Any sand condition that promotes excessive porosity of the mold surface* can cause fusion. Low density sands caused by improper distribution of the grains increase the ease with which the metal oxide can adhere to the sand surface. Such low density sands are also characterized by high permeability since density and permeability are related.

Low flowability and/or low moldability will result in a mold porosity which, in turn, promotes ready access to the metal oxides during pouring and solidification. The general causes of low flowability or low moldability are: moisture segregation; excessive cereal; excessive moisture (see Fig. 10.2); excessive green deformation; poorly aerated sand; and prepacked sand. (See Chapter 17, METAL PENETRATION.)

Excessive permeability is an indication of low density. See **Molding Sand (2)**.

Insufficient carbonaceous or deoxidizing materials permit rapid metal oxide formation to take place. There must be enough of these materials to hold a reducing atmosphere down to the temperature below which fusion cannot occur. Unfortunately, too much carbonaceous material may increase the demand for water and the excessive water will more than offset the advantage of the higher carbon.

(3) *Any fluxing reaction materials including fluxing-type bonds must be considered.* The bentonites have lower fusion than a pure fireclay bond. On the other hand, some fireclays contain large amounts of organic impurities which promote fusion. Many chemical additives increase the rate of fusion. For example, a soluble silicate (such as sodium silicate) may completely change the rate of quartz formation to that of cristobalite, causing expansion penetration or expansion fusion.

Core Practice

(1) *Too low sintering or fusion point of sand grains.* See **Molding Sand (1)**.

(2) *Grain size too large or improper distribution in uncoated cores.* See **Molding Sand (2)**.

(3) *Soft rammed cores.* See **Molding Practice (2)**. Insufficient or improperly placed or plugged core box vents create soft rammed cores. Improperly tucked sand under loose pieces may cause fusion. Low air pressure for blown cores is a cause of a soft ram or low density.

High cereal or low oil for a particular mix (including moisture) has a direct effect on the ability to ram or blow. It can be particularly difficult in blown cores especially if the moisture is somewhat excessive.

(4) *A rough or porous core surface permits ready access to the metal oxide.* The surface of a core is usually the most dense. If the surface is bruised, rough, abraded, or loose, an abnormal fusion or penetration can result.

Improper or insufficient release agent will permit sand grains to adhere to the box, leaving a rough open surface on the core. Insufficient or incorrect coating on those cores designed for dipping or washing permits penetration into the more open core body. Underbaked cores may have a weak skin or they may be such as to provide a high gas pressure during pouring.

A partially disintegrated core surface due to overbaking is prone to a penetration-type fusion since the weak surface permits easy entrance for the metal oxide. Filing, jiggling, grinding, or otherwise abrading the surface of a coated or uncoated core destroys normal dense skin and permits entry of the metal oxides.

(5) *Any condition promoting veining or finning such*



Fig. 10.2 — Excessive moisture in the sand caused penetration followed by complete fusion of the mold surface to the casting surface.

as a core crack not only permits metal oxide entry but acts also as a chimney for the core gases in such a way as to increase the gas pressure.

(6) *A broken or disturbed core wash due to rough handling or handling while the core wash is still wet exposes an open grain for fusion.*

(7) *Insufficient penetration of the core wash can be due to a grain size that is too fine or incorrect Baumé of wash and the type of wetting agent used.* See Chapter 17, METAL PENETRATION.

(8) *Low hot strength of the core permits a breakdown of the core surface which is conducive to metal oxide formation and fusion.* The low strength may be because the binder is too low in hot strength or the binder content is too low.

(9) *Poorly mixed core sand permits concentration of gas as well as nonuniform, and therefore localized, low hot strength.*

(10) *Poorly cleaned and finished cores expose the open grain to fusion.*

(11) *Dipped or sprayed cores that are not redried cause high moisture.* The high humidity atmosphere in the mold during pouring increases the rate of oxidation and metal oxide formation.

(12) *A dirty core box will result in a rough core and open grain.*

(13) *Any fluxing reaction materials including fluxing-type bonds lower the ultimate temperature of fusion.*

(14) *Cores that have picked up moisture during storage promote a high humidity atmosphere during pouring, resulting in high rates of oxide formation.* Steam is unusually corrosive at elevated temperatures when in contact with many metals.

Molding Practice

- (1) *Soft or uneven ramming* may be the cause of fusion for the following reasons. There may be improperly tucked pockets and overhanging surfaces; soft spots on bedded-in areas; low air pressure; inadequate size of molding equipment; lack of, or poorly designed, pin blocks; and insufficient jolting.
- (2) *Poorly patched areas* can be rough and porous.
- (3) *Improperly fitted stop-offs* are open areas which can penetrate and cause fusion.
- (4) *Uneven or insufficient coating or spraying of cores* may lead to fusion.
- (5) *Uneven or insufficiently dried coatings on skin-dried molds* can also be responsible for fusion.
- (6) *Excessive use of parting compounds and washes* may cause trouble in one of two ways. Liquid parting in excessive quantities weakens the mold surface and promotes boiling action and erosion. Low fusion, dry partings or fluxes permit a fusion of sand grains.
- (7) *Too low Baumé for type of coating used* may cause fusion trouble.
- (8) *Not enough facing to cover the pattern* is a common type of carelessness.

- (9) *Any combination of hot and cold materials causing condensation* can cause fusion.

Metal Composition

Metals which oxidize readily will fuse readily provided the temperature of the sand reaches that needed for the particular metal-oxide-silica reaction involved.

Melting Practice

- (1) *Oxidized metal* may be a direct result of the melting procedures or furnace practice. This includes possible oxide pickup from refractories and the obvious effects of excessive oxygen and/or excessive humidity at elevated temperatures.
- (2) *Any fluxing-type of material, such as limestone, soda ash, and fluorspar,* causes fusion.

Pouring Practice

- (1) *Excessively high pouring temperatures* will overheat the sand, especially when aggravated by any of the design or gating practices described. The higher sand temperatures in turn aid in reaching the required reaction temperature for fusion at the interface of mold and metal.
- (2) *The effect of excessive pouring height* is described in **Gating and Riser**ing (1).

GAS DEFECTS

DESCRIPTION

Blows or gas holes in castings are cavities, either spherical, flattened or elongated. Fundamentally, they are caused by localized gas pressure that exceeds the metal pressure in any locality during solidification of the metal. Gas follows the path of least resistance and hence moves usually toward the cope portions of the casting. Blows or gas holes may appear as depressed areas in the surface of the casting or as a subsurface cavity.

Pinholes, blisters and body scars as well as certain types of porosity are variations of gas holes or of a blow. Fig. 11.1 shows a typical gas evolution cavity on a cope surface.

A gas defect is easier to identify than describe. Even so, a great deal of confusion can occur because of the frequent similarity in appearance to the shrinkage defect. It is often believed that gas defects are smooth and shrinkage is dendritic. While helpful most of the time this simple distinction can be misleading and, therefore, lead to a costly error in diagnosis. There are two areas of possible confusion which must be analyzed carefully. In the first place, gas defects may occur in combination with a shrinkage area. In the second place, shrinks and blows tend to occur

in the same general location. Both are apt to be located in the section of the casting which is last to freeze, i.e., the heavy section or the change of section.

It is an oversimplification to define a blowhole as a cope defect and it is false to conclude that a similar defect in the drag must be a shrink. It is true that gas tends to rise and, therefore, flows to the cope. On the other hand, if the gas is created in the drag, it may not have time to travel upwards. In this case, the blow is a drag defect.

There are many variations of the blowhole, but they can all be covered by the same check list. The specialized forms of blows may vary in the degree to which one cause is the predominant cause, but they can be associated with all phenomena listed—at least on occasion. For example, a body scar is a specialized form of blow which is found in centrifugally cast pipe. Therefore, the predominant characteristics are related to the centrifugal casting process. The spinning may be too slow. This produces the same effect as a short cope of inadequate head pressure in a static casting.

In order to speed up production, a metal composition may be chosen which solidifies faster than the gas can be cleared from the molten metal. This would



Fig. 11.1 — Typical gas evolution cavity on a cope surface.

be equivalent to design that prevents adequate metal pressure. In a similar way, each specialized form of gas defect can be related to the fundamentals covered by the outline.

CAUSES

Casting and Pattern Design and Pattern Equipment

In all gas-defect problems, there are two possible solutions. Something can be changed to reduce the amount of gas or the gas pressure. The volume of gas is kept unchanged but offset by providing easier escape or by providing more pressure to drive it through the existing vents before it can create a defect.

Sometimes the problem is so acute that both steps must be taken together. If the pattern or casting design prevents the foundryman from using these controls, the defect can be said to be the fault of the pattern or design.

(1) *Insufficient print or outlet provided for venting.* A design with insufficient print for adequately venting the core could create a problem; the patternmaker might fail to provide proper crush grooves (a sand seal around the core to prevent metal flow past the core print). The result may be a sealed off vent and a gas defect. Fig. 11.2 shows gas holes at the core vents.

(2) *Design that prevents adequate metal pressure.* Obviously, heavy and light sectioned castings compound these problems because there is the danger of inadequate feeding of the heavier sections.

Different metals differ somewhat in their relationship to design problems. For example, steel, with its rapid solidification, is more apt to show shrinkage at changes of section. By gating and risering to avoid the shrinkage, the foundryman automatically provides more metal pressure and, therefore, minimizes the tendency to blow. At the other end of the scale, the metals with long solidification ranges, such as copper, can be quite prone to gas defects from design or pattern equipment.

(3) *Parting line blow. Gas accumulation at parting line.* A specialized and fairly rare form of design or pattern blow occurs at the parting line. It is the result of an accumulation of gas between the cope and drag, thus preventing fast enough escape from the parting line. Scratches on the mold face to provide vents to the outside is an old remedy for this problem.

It is particularly troublesome when the design or pattern provides a heavy section (late solidification) at the parting line, or when too many patterns are mounted in the flask, so that the individual castings have no place to vent except into the neighboring casting.

Flask Equipment and Rigging

(1) *Bars too close to the mold surface.* If flask bars are too close to the mold surface, the ability of the mold to vent at this point may be reduced to the problem level. If these bars are wet or pasted, the problem is magnified because the bar is creating more gas and at the same time reducing the ability of the gas to escape. Metals of short solidification range, such as steel,

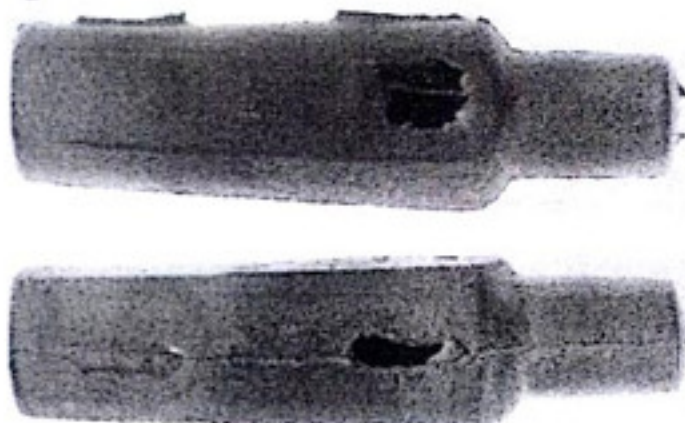


Fig. 11.2—Two illustrations of gas holes at core vent; cured by increasing length of core print and adding vent to outside edge of mold.

give less trouble in this regard than wide solidification range metals.

(2) *Flask wall too close to mold surface.* As in the case of flask bars previously mentioned, the flask wall being too close to the casting creates a similar problem. This is quite common because of the normal desire to put as many castings as possible in each flask. Such crowding can be troublesome by obstructing the movement of gas. Either hard or soft ramming will create this defect. In the first instance, it allows excessive gas to collect in the area. In the second instance, it will permit the gas to pass through the area. Thirdly, a combination of cold flask and hot sand exists causing excessive moisture from condensation. It forces the foundryman to depend upon his ability to reduce the amount of gas in the molding material or to vent the mold.

(3) *Cope too shallow.* (See Fig. 11.3.) One of the common causes of blows is insufficient cope height. This then is the problem of rigging and flask equipment. The metal pressure during solidification is a direct function of the height of the column of liquid metal feeding it, e.g., the sprue or riser height. If the pressure of molten metal is less than the gas pressure against it, a blowhole may result. This is one reason blowholes and shrinks can be confused. In this case, the cure for both is exactly the same.

(4) *Sprues and risers too close to bars or flask walls.* Insufficient venting in flasks for centrifugal castings. A specialized variation of the concept of metal pressure versus gas pressure is found in body scars. Here the metal pressure is related to the spinning speed (centrifugal force). Insufficient vents in the flasks used in spinning will cause blows or create the need for even higher spinning speeds to force the gas out.

Sprues and risers create the same problems as discussed in (1) and (2).

Gating and Risering

(1) *Head pressure too low.* Assuming that the rigger did provide sufficient cope height to permit adequate height of riser or sprue, the same relation between pressures can exist. For example, if the gates are of such design and dimension that they freeze off before the casting is sufficiently solidified, static pressure can-

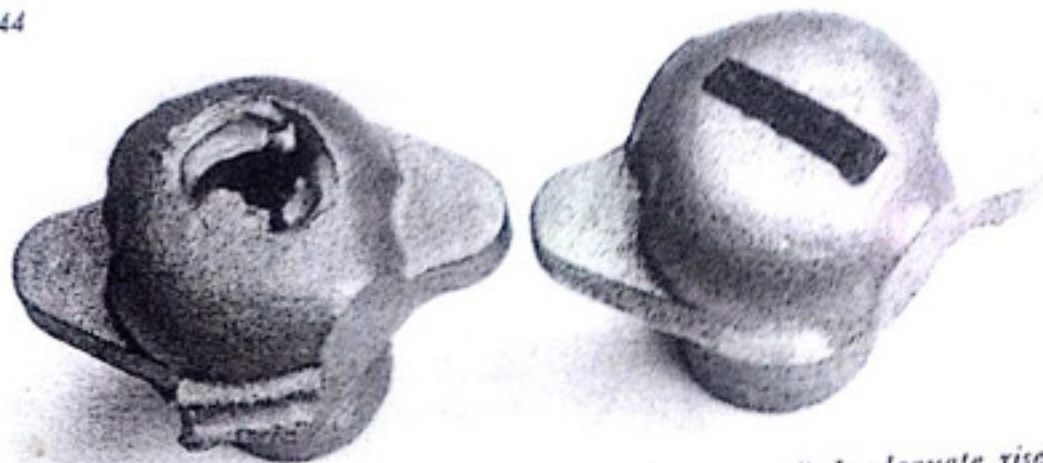


Fig. 11.3—Gas defect (left) corrected (right) by increasing cope height to develop additional ferrostatic pressure.

not be maintained regardless of proper sprue height. It is important that they be engineered to maintain adequate metal pressure until the metal skin is sufficiently strong to withstand gas pressure without rupture—or until the gas pressures have been reduced through the normal escape channels.

(2) *Gating causing turbulence.* The use of nontapered sprues, lack of basin at the bottom of a sprue and sharp bends in the runner and gate systems should be avoided. It has been proven that by pouring water into transparent plastic molds the above conditions will cause turbulence and aspirate air into the metal stream. This trapped air is then carried into the mold cavity and could cause gas cavities in the casting. (See Fig. 11.4.)

(3) *Gating design that causes interrupted flow of metal.* This could occur when the area of the sprue and/or runner would not be great enough to keep the flow of metal constant through all the ingates of the system until the mold cavity has been filled.



Fig. 11.4—Pinholes in a spheroidal graphite casting caused by turbulent flow in the gating system.

(4) *Inadequate riser height or size.* Inadequate riser height or size can cause gas defects where the riser system does not ensure adequate static head pressure. In those cases where metal is poured through or into the riser, this part of the system controls static head pressure. In addition, static head pressure is maintained only so long as there is available liquid flow.

Therefore, if the sprue entrance freezes off quickly (e.g., kiss gates), then the riser is the only source of liquid metal under static pressure. As such it controls the metal resistance to gas evolving from the mold materials.

(5) *Improper sprue or gate design allowing air or mold gas to enter metal stream.* Round design sprue cups, pouring basins or heads, should be avoided as this will create a vortex. Straight sprues on lengths over 5 in. should not be used. The sprue cup or pouring basin opening must be at least equivalent in diameter to the diameter at the top of the sprue. A basin at the bottom of the sprue should be provided and sharp bends in the runner system avoided. All of these factors cause aspiration of air.

Molding Sand

(1) *High moisture content in green sand.* Excess moisture in green molding sand is probably the greatest cause of gas defects in cast metals. Excess moisture is that amount of surplus water not required for a specific sand composition. Moisture is necessary in green molding sand but it must be closely controlled if large quantities of gas in the form of steam are to be avoided (see Fig. 11.5). The gas pressure must not be allowed to become greater than the pressure of the molten metal.

(2) *Inadequate permeability for the molding materials involved.* (a) Excessive fines and/or poor grain distribution. (b) Excessive carbonaceous or gas-producing materials.

Inadequate mold permeability is generally caused by excessive fines in the sand or poor grain distribution. What constitutes inadequate permeability must be determined for each set of conditions. If the grain distribution of the sand includes a wider range of screen sizes than usual, the permeability will be lower than usual. The presence of excess fines will cause a drop in permeability. If the removal of fines does not give the desired increase in permeability, then a more uniform grain distribution should be obtained by large additions (10 to 30 per cent) of a uniform grain sand.

The presence of large quantities of seacoal, pitch

or other gas-producing materials may necessitate a high permeability to vent the increased volume of gases. Periodic tests for loss on ignition of the molding sand is a simple control method of determining the amount of gas-forming materials. The volume of gases evolved or the gas pressure may be determined if necessary.

An increase in pitch, seacoal, cereal, oil, resins, water or any material that may form a gas at molten metal temperatures may be expected to give a higher gas pressure at the mold surface. The pressure of molten metal should be higher than the maximum gas pressure at the sand face. The percentage of these materials should be kept as low as possible.

(3) *Foreign material in sand*—shot, nails, coke, cinders, etc. Foreign material in sand can cause localized gas holes in a casting if the material is of a type that can produce gas when contacted by molten metal. (See Fig. 11.6.) All sand should be checked for foreign material such as roots, leaves, coke, cinders, rusty nails, shot and the like. Sand heaps should not be used for trash heaps.

(4) *Clay balls*. Clay balls contain high moisture, thus, they give off large quantities of gas when metal is poured on them. Randomly disbursed gas holes caused by wet clay balls are illustrated in Fig. 11.7.

(5) *Poorly mixed sand*. Poorly mixed sand also causes areas of high gas concentration. The optimum mixing time should be known for whatever type mixer is used. Liquid additions should not be made directly onto dry finely powdered additions.

Insufficient mixing can be caused by too short a mixing cycle where an operator will estimate the time instead of using a timer or clock. Worn out blades or wheels in a mixer will induce insufficient mixing. A short cycle does not allow the clays to be properly plasticized and worn equipment will contribute to poorly mixed sand.

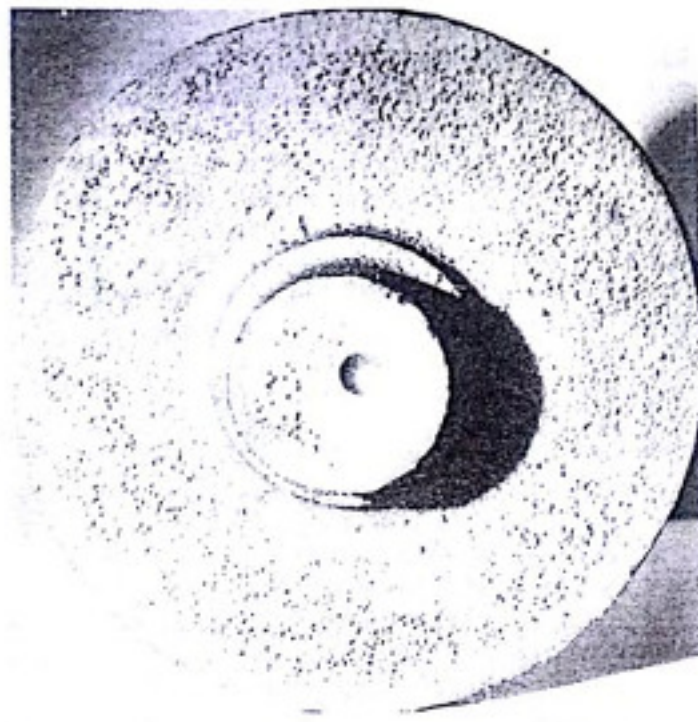


Fig. 11.5—Pinholes caused by excessive moisture in molding sand combined with low permeability and poor grain distribution (6 screen sand).



Fig. 11.6—Gas defect caused by grease from a machine fitting falling into the facing sand (foreign material).

(6) *Too coarse particles of gas-producing materials*. Coarse particles of gas-producing materials cause areas of high gas concentration.

(7) *Coatings containing excessive gas-producing materials*. Excessive gas producing inorganic materials can cause gas defects in castings whether the gas is produced by materials in the sand or in the coating. Excessive amounts of organic materials such as oils, sugars, or resins may be determined readily but clays may retain chemically combined water which may not be given off at normal drying temperatures. Uncured shell sand will contaminate sand systems and cause gas pinholes.

(8) *Excessive permeability in skin-dried molds, allowing sweat back*. High permeability in skin-dried

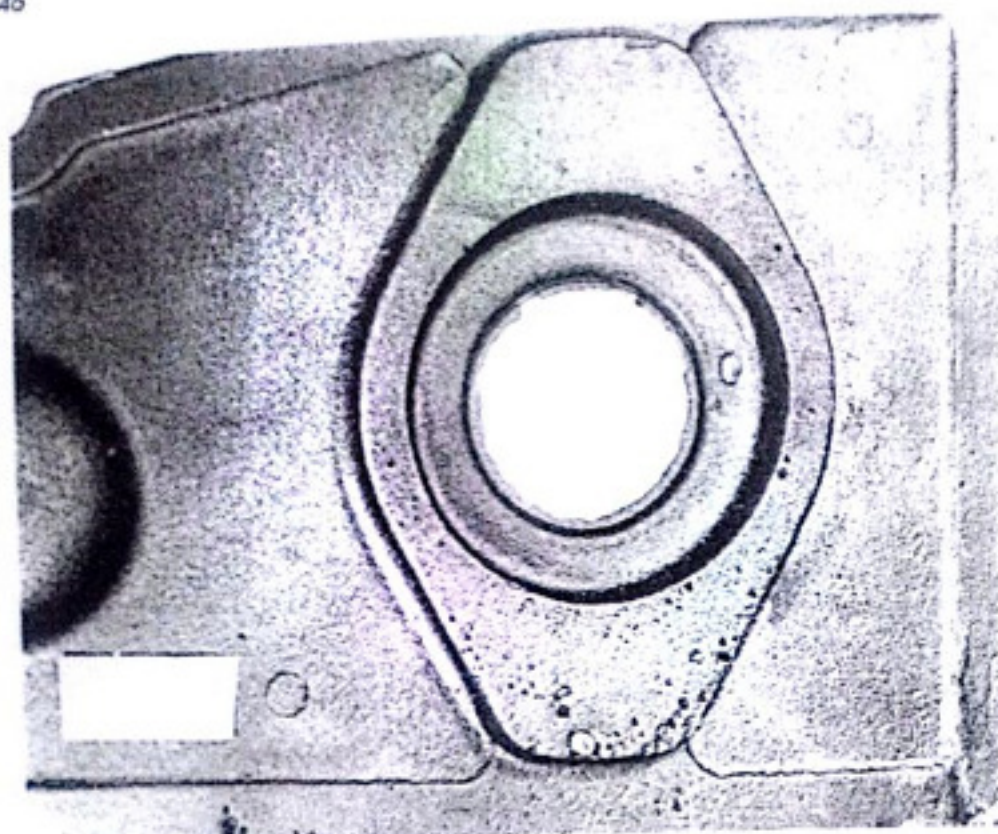


Fig. 11.7 — Wet clay balls in molding sand caused randomly dispersed gas holes.

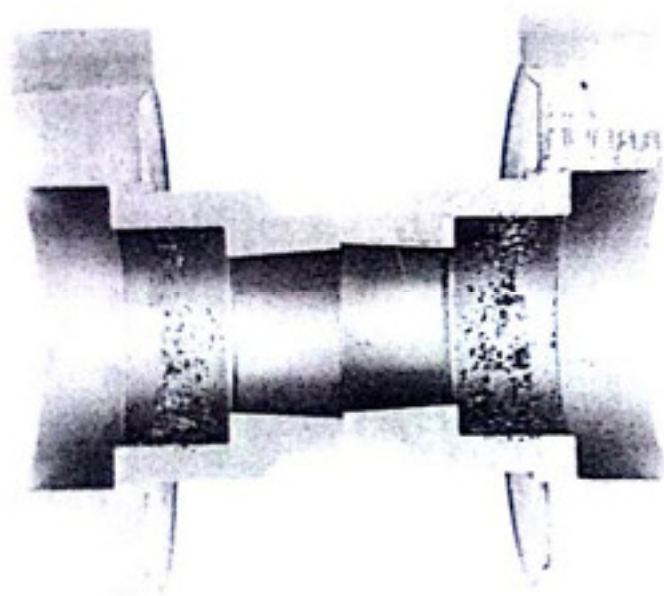


Fig. 11.8 — Undercured furfural alcohol type core caused gas defects on the internal surface.



Fig. 11.9 — Insufficient core vent created blowhole in the molding sand surface of a small steel casting.

molds can lead to sweat back before casting, thus, a high concentration of moisture is created. Whether or not the permeability is excessive will depend, in a large part, upon the drying temperature and time and the time between drying and pouring.

The time-temperature factor should not be overlooked in any case where gas evolution is a problem. The total gas evolved is important but even more important is the rate of gas evolution in relation to the pouring time and temperature, and to the solidification time and temperature.

Core Practice

The greatest problem with core blows is the ease with which they may be confused with sand blows. Since gas travels upwards in the mold, it is quite possible for a gas bubble to form from a cored surface and then travel to the cope surface and appear on or near the green sand face. Sometimes when this happens, the defect will leave a track or go back to its origin so that the proper cause becomes more evident. This clue is not present in all cases.

One aspect of a core blow which has no companion cause in sand molding is the partially coated core. In this case, the core has been dipped or blackened, and as a result, the entire skin or surface is impermeable to gas flow. If this coating was broken by handling when green or during the time it was being dried, the entire volume of gas created in the core must escape through the spot where the coating is broken or thin. This concentration of gas at one point may be too much for the mold above it to handle. The resultant blow may show all the way through the metal section at that point.

(1) *Underbaked or uncured cores.* Underbaked cores in all processes, including oil, resin and hot box

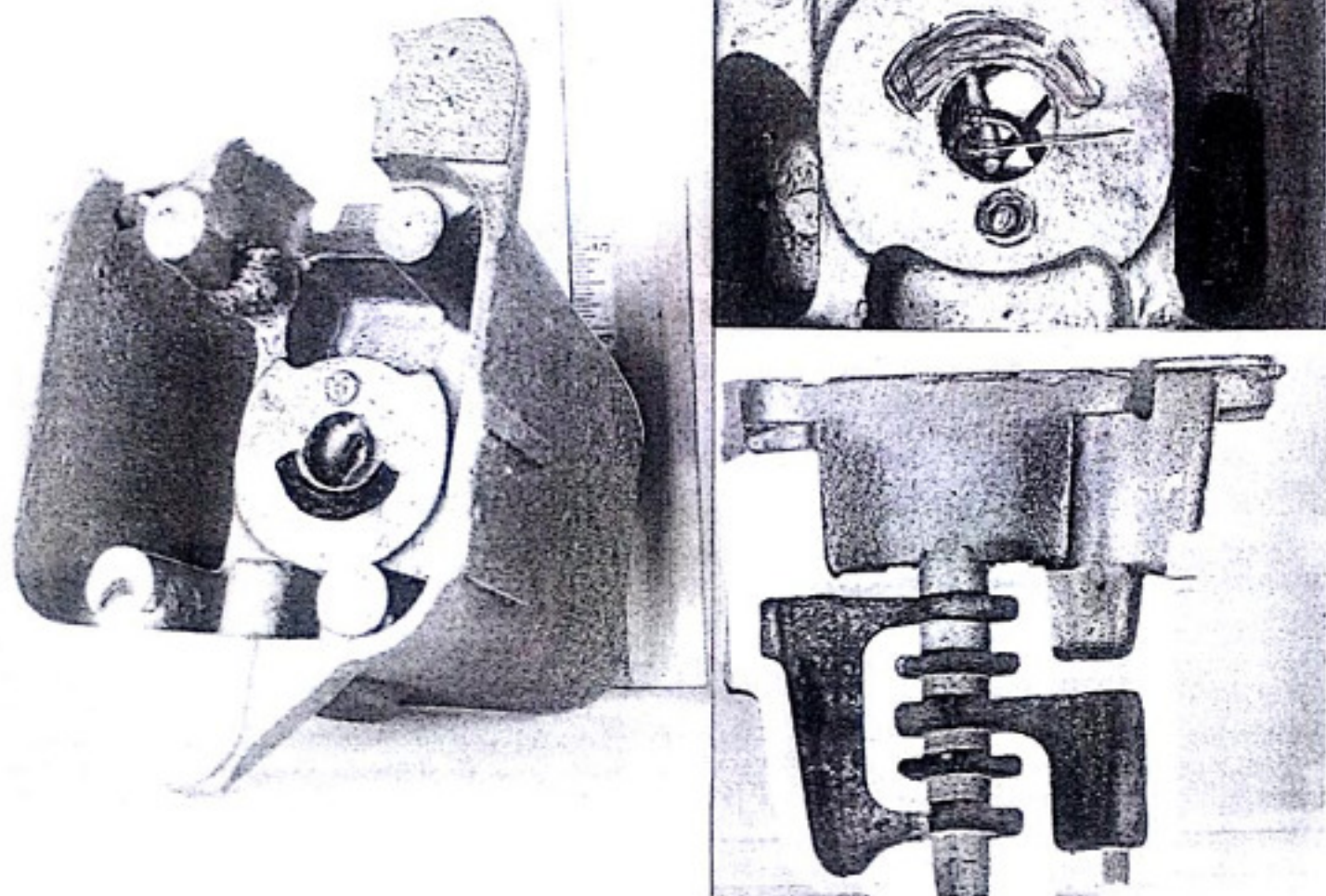


Fig. 11.10—Vents plugged with iron during pouring caused major blow defect on cope surface. Arrow points to the plugged vents which look like wires.

cores, provide an excess of gas which would normally be removed during the baking. In this respect, shell or hollow cores which have not been properly drained or mandrelled will have underbaked centers.

Shell and furan-type cores are not necessarily baked when they leave the box even though apparently rigid. Fig. 11.8 illustrates gas defects caused by undercured furfural alcohol core. Core sections over $\frac{1}{2}$ -in. require additional baking beyond that gotten in a hot box. Cores made with shell must be either mandrelled or cured out in another oven.

In the furan, CO_2 and oxygen-setting processes, moisture reaction may be enough to cause gas defects. In such cases, moisture must be removed by drying in an oven (250 F, 121 C).

The curing in the air set process involves a relationship between time, temperature and chemical catalyst. Incorrect proportioning of these three creates a condition of uncuring even though the core is apparently usable.

(2) *Excessive binder.* In all core processes, the presence of clay and organic impurities increases the need for binder and the resultant high level of binder creates large amounts of gas. (See **Molding Sand (2).**)

(3) *Inadequate permeability for conditions involved.* (See **Molding Sand (2).**)

(4) *Inadequate venting.* This may be caused by vents too near the surface; an insufficient number or too small vents; vents too small in proportion to permeability of sand; vents closed off in pasting; vents plugged with core wash; and vents not connected. Figure 11.9 shows a blowhole as a result of an insufficient number of vents, Fig. 11.10 shows a defect as a result of vents plugged with iron.

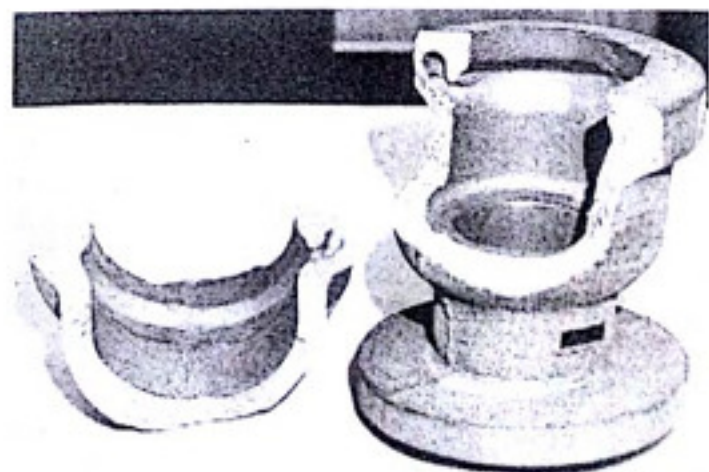


Fig. 11.11—Broken surfaces of core wash permitted gas to back up into heavy metal sections.

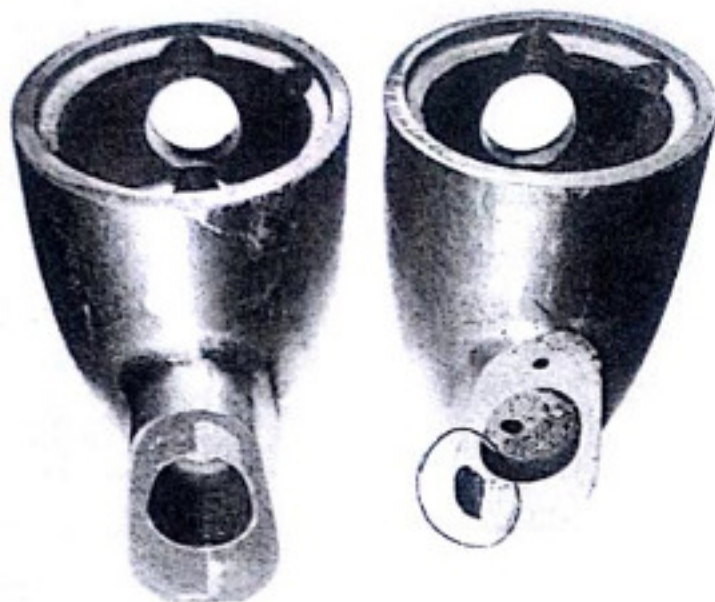


Fig. 11.12 — CO₂ process cores absorbed moisture during storage which caused blow on flange surface of aluminum casting (defect outlined).

(5) *Metal getting into the vents.* (See **Casting and Pattern Design and Pattern Equipment** (1).)

(6) *Excessive or wet paste.*

(7) *Core wash too heavy, broken or not dried.* Fig. 11.11 illustrates a gas backup into heavy sections as a result of broken core wash surfaces.

(8) *Too much gas-producing material either in the core sand or wash.* (See **Molding Sand** (6), (7) and (8).)

(9) *Cores absorb moisture either in storage or in the mold.* Some types of core materials have a tendency to absorb moisture (hygroscopic). This is particularly true if the curing binder (oil or resin) is low. Cores without curing resin as in the CO₂ process are hygroscopic unless they contain forms of carbon such as pitch. Moisture pickup can occur during storage, prior to use, or in the mold itself prior to pouring (see Fig. 11.12). Most core pastes and core muds are hygroscopic and may cause more problems than the core itself.

(10) *Exposed hooks, wires or hangers.*

(11) *Chill or sealing materials not dried.*

(12) *Hooks or hanger holes filled and not dried.*

(13) *Foreign materials, such as roots, leaves, coke, coal, etc.*

(14) *Poorly mixed core sand.*

Molding Practice

(1) *Combinations of hot and cold materials.* Any combination of hot and cold materials such as sand, cores, flasks, chills, gaggers, chaplets, metal riser covers and arbors, may cause blows due to condensation. (See Fig. 11.13.) Cores and chills are the chief offenders but any materials used that are hotter or colder than the sand mold will cause sweating, especially if not poured at once.

(2) *Improper venting in green or dry sand mold.* Under certain conditions the permeability of the sand, especially in larger molds, may not be adequate to carry off the gases at a fast enough rate. To compensate for this, sufficient venting must be done. Vent

rods or wires rigged with stop-off shields to keep vents from going completely into mold cavity may be more efficient at times than vents that connect to the casting, as the metal seals the latter off as soon as it flows into vents.

(a) Mold vent which permits back-pressure in core or mold. Gases released by the core must be given free passage to the outside of the mold; otherwise, the back pressure formed will push the gas through the metal causing a blow.

(b) Vents too close to skin dried molding surface causing sweat back.

(3) *Insufficiently dried molds.* Especially in large molds, sprays and washes are used for casting finish, sand peel and general protection of the mold surface. The materials used for this protection are usually suspended in water or other liquids that cause gas. Unless these molds are thoroughly dried, blows may be produced. Skin or torch drying of molds with deep pockets can result in nonuniform drying.

(4) *Hard spots caused by improper ramming for conditions involved.* Excessive ramming or squeezing on a high spot of a pattern will produce a hard spot, resulting in localized low permeability. This causes a blow. (See Fig. 11.14.)

(5) *Gagger, soldiers, arbors or bars too close to pattern.* Gaggers, soldiers, arbors or bars located too close to the pattern may produce blows by causing steam to condense around them. When the gagger is close to the pattern, sand may not tuck under it and the metal comes in contact with the gagger causing a kick or blow.

(6) *Clay wash too heavy on gaggers.* The water from excessive clay wash on gaggers will tend to migrate

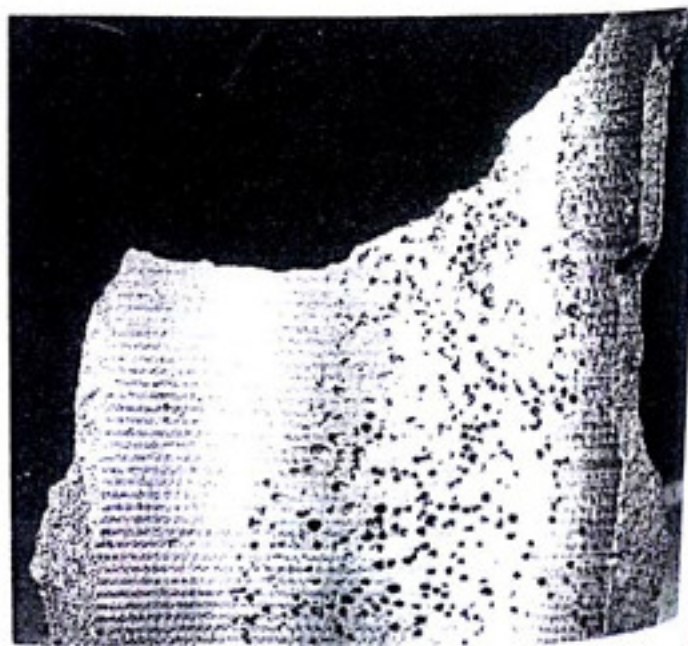


Fig. 11.13 — Blow caused by moisture from hot molding sand condensing on cold core surface. Room temperature was 65 F (18 C). The molding sand had a temperature of 136 F (58 C), permeability of 120, green compression strength of 11 psi and moisture content of 3.5 per cent. The mold stood 80 min before pouring. After cooling, the casting was cleaned and machined, the holes on the cope surface appearing during machining. The cylinder sleeve, 4 in. ID, cast on its side, was gated at both ends.



Fig. 11.14—Blister on sanitary casting caused by hard ramming and wet sand.

from the wash to the sand and cause the sand to be over-tempered at the point, thereby, causing a blow. Clay wash should be between 30 to 40 Baumé.

(7) *Excessive slicking and patching green sand.* Excessive slicking tends to harden, bring the moisture to the surface and lessen the permeability at this spot, thereby causing a blow. Patching by using over-tempered sand or the use of a sponge or swab is also a source of blows.

(8) *Dough roll too wet or too close to mold cavity.* Dough rolls, wet paste or wet clay used at the parting line, especially in excessive amounts, have the same effects as excessive clay wash on gagers. Also, the material may be squeezed into the casting cavity when the cope and drag are clamped together.

(9) *Wet pouring basins and gating systems.* If too hard or wet, a pouring basin may cause the metal to boil and carry entrapped gases into the mold causing pinholes.

(10) *Insufficient sand in flask.* It is possible to have proper sand and proper flasks but improper molding conditions such as insufficient sand in the flask may cause blows. By raising the sand height in the flask more static pressure will be built up causing the metal pressure to overcome any gas pressure.

(11) *Excessive liquid parting.* Liquid parting is a source of gas and used in excessive amounts may cause blows. Excess parting can be removed from the pattern by the use of a rag or air hose.

(12) *Mold wash or coating too heavy or not dried.* Excess mold wash or too heavy a coating will cause a blow because of excess moisture and/or volatile material left on the mold surface.

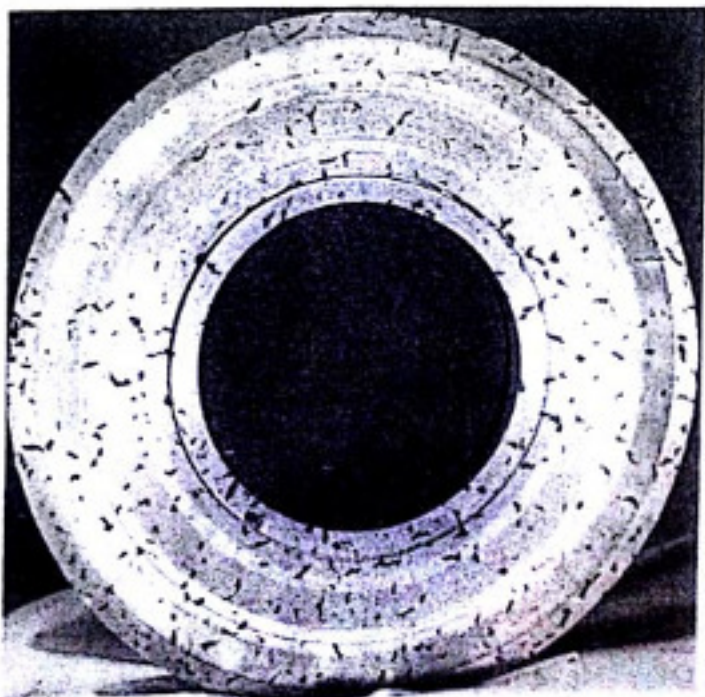


Fig. 11.15—Gas defects in a gray iron casting containing excessive aluminum (0.035 per cent).



Fig. 11.16 — Subsurface gas defects caused by cold pouring in high moisture sand.

Metal Composition

The major problems as far as gas defects are concerned are related to those factors which change the amount of gas dissolved in the molten metal. Molten metal will hold many more times the volume of gas than will remain dissolved in solid metal. At the time of solidification this gas may escape or may remain as a supersaturated solution. Normally its escape does not create a problem, but if outside gas pressures created by the mold are high, the gas from the metal may be confined. In this case it may remain in the casting as a bubble causing a pinhole. The factors which influence the amount of gas dissolved in the molten metal (and the amount which must escape) are related to the presence of metallic impurities, unclean scrap used in charge, and improper silicon and aluminum balance (steel). (See Fig. 11.15.)

Melting Practice

Melting practices which force even greater volumes of gas into the molten metal multiply the tendency toward gas defects.

(1) *Steel.* A vigorous, lengthy boil in the furnace will remove gases in the metal. Gases are removed during the boil by diffusion of those dissolved gases into the stream of CO and CO₂ bubbles rising to the surface. Because of its rapid diffusion rate, hydrogen is the first gas to be expelled with other gases following in order of their diffusion rates. Deoxidation must be completed in the ladle. Pinhole porosity may result from improperly degassed steel.

(2) *Iron.* The majority of scrap due to blows is caused by cold iron poured in the molds. (See Fig. 11.16.) This practice causes one of the major problems in iron foundries. Unfortunately, most of these blows are subsurface and are not discovered until the casting has been machined. The defect is usually due to low pouring temperature. Cold iron and low fluidity may indicate oxidized iron or oxide pickup from the refractories.

(3) *Nonferrous.* Most of the nonferrous metals are extremely active insofar as gas absorption is concerned. Most foundries melt nonferrous metals in furnaces where the flame impinges on the metal, thus causing further gas absorption.

A proper metal cover plus degassing additions must be carefully controlled to prevent porosity in the metal and castings. Special degassifiers are also added and sometimes an inert gas, such as nitrogen, is bubbled through the metal to remove occluded gases by diffusion.

Pouring Practice

- (1) *Cold, damp, or green crucibles or ladles (lip lining).*
- (2) *Pouring cold metal.* (See Fig. 11.16.)
- (3) *Interrupted pouring.*
- (4) *Ladle or crucible too high above mold.*
- (5) *Slow pouring.*

The relationship between pouring and gas defects is much the same as for melting practice. The effects in this case are created in or by the ladle instead of in or by the melting furnace. (See **Melting Practice** (1).)

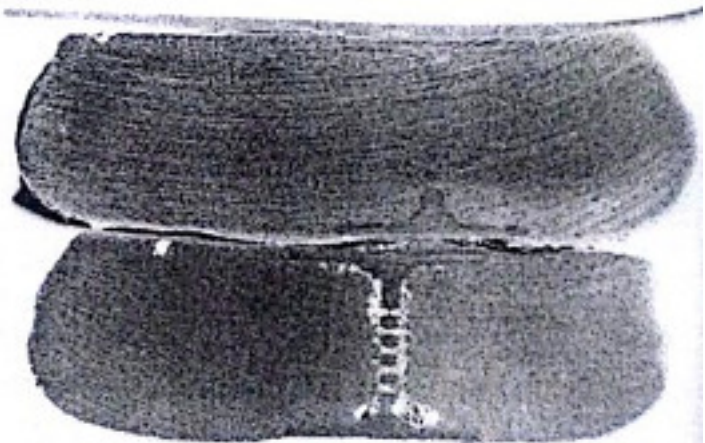


Fig. 11.17 — Chaplet blow caused by rusty chaplet being used as the core setting station.

Interrupted pouring and pouring too high above the mold introduce dissolved gases into the mold. In addition, interrupted pouring has the same effect as pouring too cold or too slow. Slow pouring permits the metal to cool in the mold and reacts the same as cold metal.

Miscellaneous

(1) *Chills, chaplets, wires* which are rusty, improperly coated, oxidized and damp may cause blows. (See Fig. 11.17.)

(2) *Insufficient centrifugal force — slow spinning.*

Most of the miscellaneous causes for gas defects involve some foreign body in contact with, or too close to, the mold face. These localized objects are sometimes hard to find on examination because they are released at the shakeout and not observed. Sometimes, of course, they weld themselves onto the casting face and their presence is obvious.

The slow spinning is described in detail in the sections on design, rigging and gating.

Chapter 12

HARD SPOTS, HARD AREAS AND CHILLED SPOTS

DESCRIPTION

Hard spots, hard areas and chilled spots in a casting are localized zones of excessive hardness and are more common defects than mass hardness. They occur in section changes because cast metals have different hardnesses in different sections of the same casting. All the causes listed in Chapter 15, **MASS HARDNESS**, apply here, plus those due to an unusual section or cooling rate.

Some metals are more section sensitive than others, so the following factors are particularly dangerous in section sensitive metals. Gray, malleable and ductile iron relate hardness to both the matrix and the graphite. Therefore, they are section sensitive. The response to heat treatment is also related to section size, for the same reason.

Incorrect chemistry, gassy metal, high heat transfer, and unusually thin sections are principal causes of hard spots, hard areas and chilled spots. Figure 12.1 shows a typical hard spot which was discovered upon machining.

CAUSES

Casting and Pattern Design

Unbalanced section thicknesses. Many design engineers do not allow for the section sensitivity of most

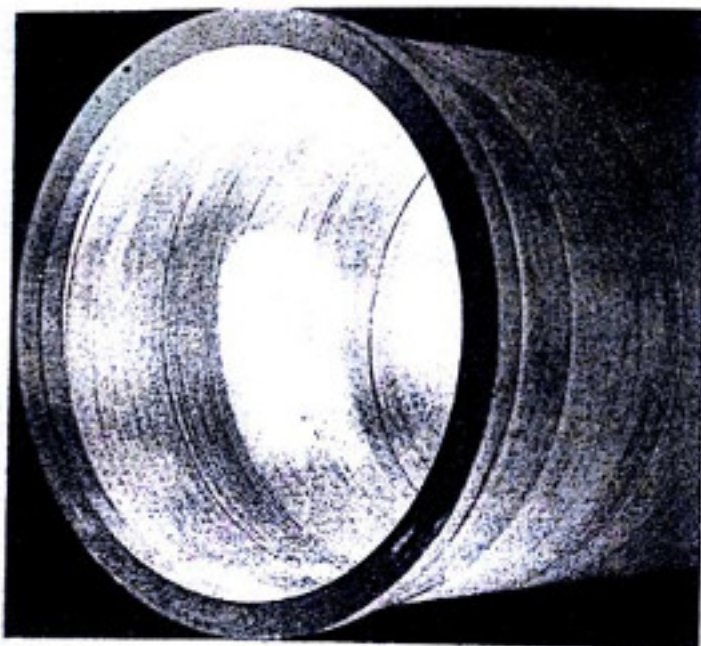


Fig. 12.1 — Typical hard spot which showed up on machining of the casting.

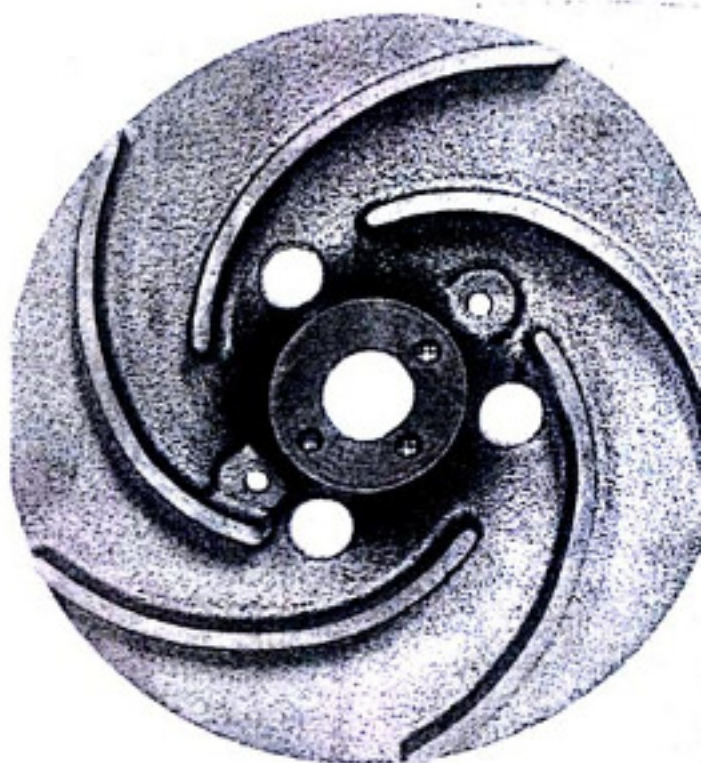


Fig. 12.2 — Nonuniform section, which required dense hub, noted chilled edges on the outer sections of the vanes.

cast metals, because it is difficult to specify the chemistry, hardness, and section cooling rate. This problem is greatest where many sections are involved in the same casting (see Fig. 12.2). When hardness is specified, it is important to know to which section of the casting this specification properly applies. The foundryman should try to negotiate the chemical specification so he can adjust to meet the important factors of strength and hardness. Close cooperation in this regard can save the customer many hardness problems.

Pattern Equipment

(1) *Worn sections or core boxes causing thin sections.* Any unusual or unexpected thin section can cause localized hardness. For this reason, worn patterns and core boxes can create a problem. Jobs which carry hardness specifications in thin sections should carry an allowance for preventive maintenance of patterns to avoid thinning below allowable standards.

(2) *Thin sections in the cope.* Any factor such as warped, bent or bowed patterns can create a thin cope and excessive chilling of the thin section.

(3) *Mismatched pattern equipment.* One common type of problem is the mismatch of cope and drag resulting in one or more thin sections. An incorrect match between core (core box) and core print (pattern) can cause these off specification thin sections.

Flask Equipment and Rigging

(1) *Flask bars too close to mold cavity causing chilled sections.* The flasks can have a direct chilling effect on the metal if either the flask or bars are so close to the mold cavity as to conduct heat during casting solidification (see Fig. 12.3). This sometimes happens when short run jobs are made in flasks which were never designed for them. Another, and more careless cause, is using the wrong flask when the correct flask is actually available. Occasionally one finds the penny-wise practice of saving on sand by crowding the job into undersized equipment but this is false economy.

(2) *Worn flask pins and bushings* can create a shift causing a thin section which results in a hard area. The only cure for this is supervision and preventive maintenance.

(3) *Weak or warped flasks* can permit mold sag with subsequent thin sections and rapid cooling.

(4) *Weak or crooked bottom boards or flimsy, dirty jackets* can cause a change in casting dimension sufficient to produce hard or chilled areas.

Gating and Riser

In many cases, the problem of thin sections is solved by proper gating. For example, gating into or near

thin sections helps to slow down cooling, and avoids excessive hardness. In some areas, merely keeping a runner near a thin section is enough to improve the uniformity of hardness. Running metal into a dead-end thin section, or gating in such a way that only cold metal enters the section of rapid cooling, should be avoided.

A good example of dangerous practice is to place a thin vertical wall in the cope so the metal has to flow up into the thin section. Such a combination of cold metal, thin section, and remoteness from the gate can create an incurable hard spot. In unusual cases, where the design or rigging forces this thin section in the cope practice, the problem can be relieved by flowing off a small amount of metal through the thin section to heat the sand.

Molding Sand

(1) *A wet spot in the sand* (clay ball or cereal ball) can produce a localized chilling effect and hence a hard spot. Adding liquids directly to dry binders such as clay and cereal before they are distributed through the sand should always be avoided.

Mulling practice can be important in moisture control. The worst practice is trying to use a muller beyond its capacity or letting the plows, wheels, and bed plates become worn and poorly adjusted. Constant preventive maintenance on mullers is important to all sand properties, but particularly important for proper moisture distribution.

(2) *Tramp materials in the sand* can act as chills and create hard spots. A major epidemic of such defects

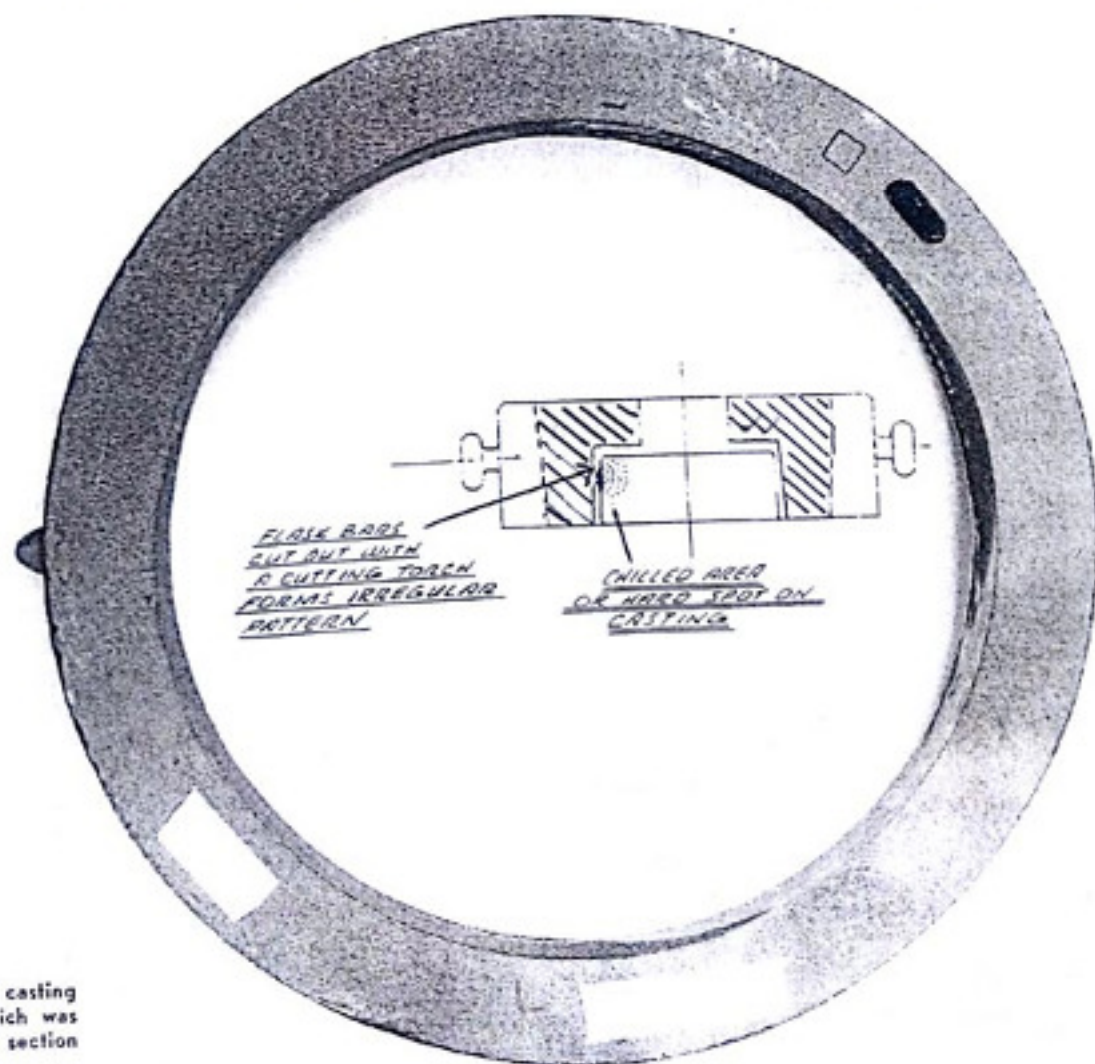


Fig. 12.3 — Flask bar close to casting surface caused hard spot which was corrected by cutting out one section of the bar (see diagram).

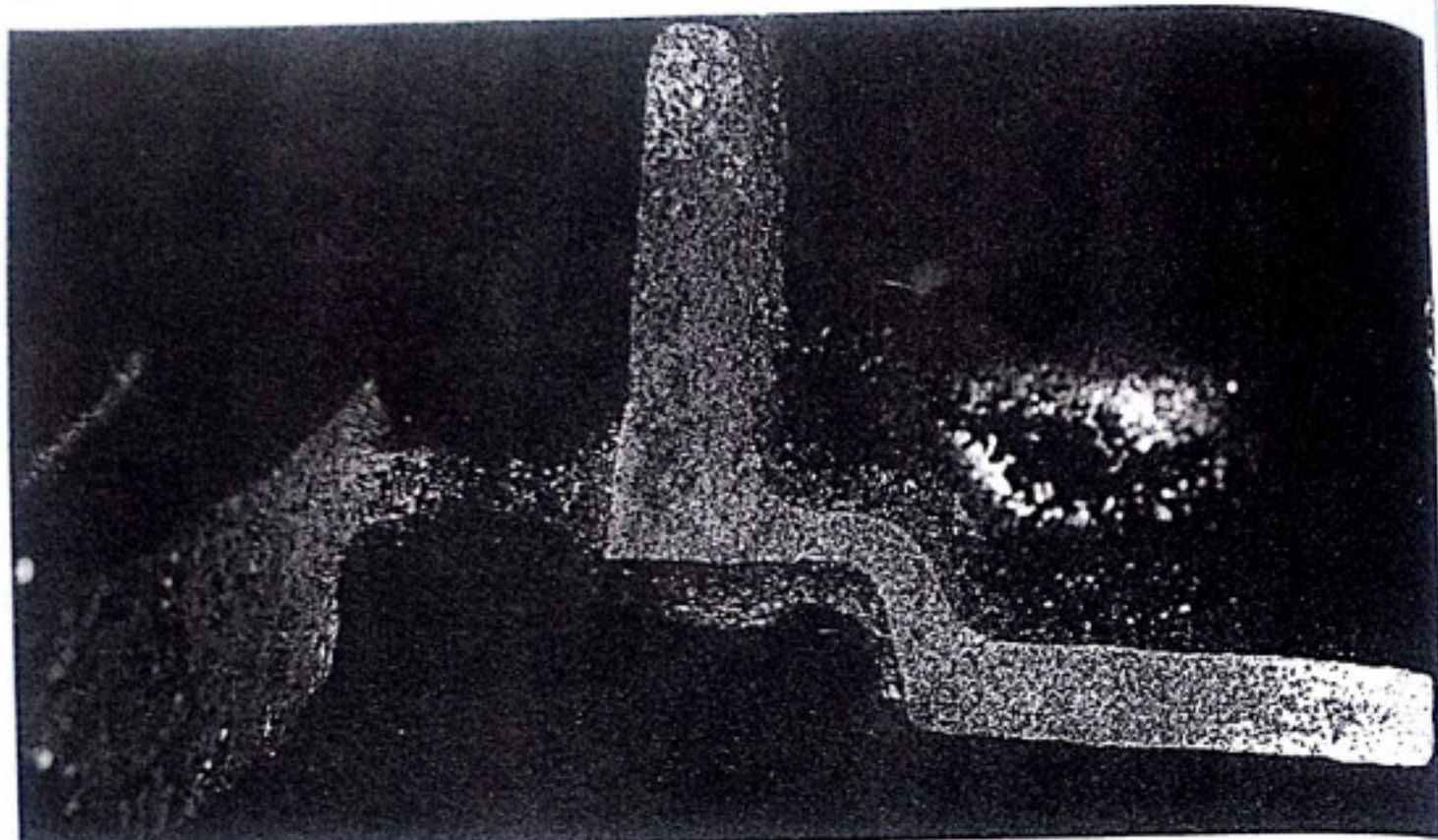


Fig. 12.4 — Chilled edges caused by low carbon equivalent in gray iron casting.

frequently is traced to a sand loaded with such miscellaneous and incidental debris.

Core Practice

Because cores commonly carry extraneous materials such as wires, rods, coatings, and the like, they cause more hard spots than the sand molds. They, of course, have all the possibilities shown by sand such as wet spots, cereal bulk, concentrations of binders, poorly mixed gaseous compounds (e.g., patch), and hard and soft rammed areas. In addition, they may create problems from wet or excessive wash, wet or excessive paste, or excessive heat transfer. Heat transfer by conduction increases as the density of the core increases, whether the density is due to the specific gravity of the material (zircon cores) or to the compaction of the core particles. Glazed cores are more highly conductive than unglazed cores.

Localized excess of chill coat or wash would be similar in effect to exposed or partially exposed pieces of arbor, rod, or core wire. Tramp material of any type can give a localized chill resulting in a hard spot.

In addition to the direct effect of inclusions, the core may cause a chill by creating a thin section of metal. An example here is the excessively rubbed print or warped core.

Molding Practice

Since molding practice also includes core setting, thin sections caused by careless core settings can fall into this category. The molder can also introduce local chilling by setting arbors, rods, soldiers, gagers and bars too near the mold cavity. Excessive nailing, or nailing a thin section, has the same effect. Applying wash too thickly or failure to dry such wash can either chill or create a thin section.

Setting chills where they do not belong or setting the wrong type and size chill (assuming that any are needed) is a careless practice.

Metal Composition

Because most metals are section sensitive, any tendency toward excess hardness will be aggravated in thin sections. In addition, many alloys make cast metals even more section sensitive than normal. For example, for a given carbon equivalent, a low carbon iron is more sensitive to section size than is a high carbon metal. Figure 12.4 is an example of chilled edges in gray iron caused by low carbon equivalent.

Elements such as sulfur are very apt to spot chill in thin sections without materially changing the heavy sections. Chromium, particularly in combination with high phosphorus may create hard spots in thin sections.

All metals have similar characteristics in which off-analysis becomes particularly dangerous. For example, aluminum alloys are sensitive to aluminum oxide, iron, and silicon. Magnesium is sensitive to nonmetallic materials such as ammonia, urea and the like.

Careless charging may also be responsible for hard spots and chilled sections.

Melting Practice

Any careless melting practice may lead to incorrect analysis and — far worse — even to segregated off-analysis metal.

- (1) *Cold melting* can lead to poor distribution of alloys.
- (2) *Excessive superheat and rapid melting* can lead to oxide formation.
- (3) *Absorption of gas from wet furnace* (including

cupola) linings, wet spouts, ladles, and the like can cause hard spots from gassy metal. It should be noted that the gas in metal is part of the composition even though not listed in the usual routine chemical analysis.

(4) *Wet sand bottoms, dirty crucibles, and tools*, and similar evidences of bad housekeeping around the melting department are all elements leading to defective castings.

(5) *Metal melted too cold*. Where ladle practice is part of the hardness control, such as the graphitizing inoculation of gray and nodular iron, carelessness or cold metal can create a problem.

(6) *Inoculation*. A basic error is a poor (incorrect) choice of inoculant: inoculation used when not needed; inoculation not used when required; and use of a wrong inoculant.

Pouring Practice

The effect of cold metal and gas from poor ladle practice is the same as described for **Melting Practice**.

Miscellaneous

Much of the problem of hard spots is due to miscellaneous causes because the hard spot involves: (1) any unusual reduction in section size, (2) a drastic change in cooling rate, or (3) cooling after casting (e.g., heat treating and welding).

There are many ways to quench excessively in addition to the obvious one of shaking out too hot. The hot casting could fall into water or rest on a cold mold weight or other objects normally found in a foundry.

The quench could be the result of localized overheating from rapid grinding or snagging, or careless use of the cut-off torch or wheel.

The specified heat treatment may be incorrect, or correct, not followed with adequate care (inadequate soaking time).

Special cases are involved in leaving a permanent mold casting or die casting in the mold too long. Similarly, welded castings may be spot hardened by failure to redraw, from excessive quench or by incorrect composition of weld metal (rod). Careless handling after welding would have the same effect as unintentional cooling after normal shakeout (falling in snow, etc).

Chapter 13

HOT TEARS

DESCRIPTION

As is also pointed out in Chapter 28, SHRINKAGE CAVITIES AND DEPRESSIONS, there is often confusion as to whether a hot tear or a shrink is actually involved. A discoloration is an important clue since the tear takes place in the solid or semisolid metal but only in the presence of sufficient heat to provide a typical oxidized color. Unfortunately, a shrinkage can also show such discoloration.

In many cases, these defects are so similar that the diagnosis is not substantiated until the cure used proves effective. Where doubt exists, it is well to consider both possibilities so as to avoid repeating incorrect cures. In many cases, such as those illustrated, the difference between a tear and a shrink is obvious.

CAUSES

Casting and Pattern Design

(1) *Lack of adequate fillets.* A most common cause of hot tearing or cracking is a lack of adequate fillets at sharp corners which set up high stresses during cooling. A tear can occur even if feeding is adequate to prevent a shrink in this same area. Increasing the size of the fillets is the usual cure provided the larger fillet does not create a shrink. The use of external chills can have the same effect. Cracking strips are common corrective measures for the same problem.

(2) *Abrupt variation in section thickness resulting in variation of cooling rate.* An abrupt change in section, even when properly fed, can create stresses which permit cracking or tearing after solidification. A variation of this is a gate too large for the section or not enough gates, thus creating a hot spot. In these cases, the hot spot acts as a change of section. It is then necessary to gate in more areas with smaller gates.

(3) *A U- or channel-shaped section or an I-beam section with Tee junction in which the mold resists normal solidification of the metal.* Any design involving channel or I-beam sections with Tee junctions can lead to a situation in which the mold wall resists normal contraction causing high stresses during cooling. This design is common and usually leads to the use of chills at the fillets or special molding such as hollowing or lightening the mold or core between the legs of the U or channel.

Pattern Equipment

(1) *Lack of adequate fillets.* The pattern shop rather

than the design engineer may be responsible for the lack of fillets. If the inside corner of a box section has a radius and the outside corner is left sharp, hot tearing can be aggravated. This can be handled by tapering the casting wall or by rounding the corners.

(2) *Incorrectly placed cracking strips and tie bars.* The pattern shop can be responsible for hot tears if the cracking strips and tie bars are either too small, too large, or incorrectly located. Too large a strip can act as a chill, setting up internal stresses. Too small a strip will usually tear the sand in the pocket. As a result, the strips do not have adequate strength to resist the strain. Tie bars should be approximately equal to the casting section size and filleted to prevent tearing.

Flask Equipment and Rigging

(1) *Flask bars too near the riser or sprue.* The hot tear is directly related to high internal stresses, either tension or compression, which result from a section of the casting being unable to expand or contract in its normal or natural fashion. Therefore, a major problem exists if the flask bars or other obstruction interferes with the normal movement of risers or sprues during cooling. The sprue or riser acts as a lever. If not allowed to move as the casting contracts, it puts a leverage strain on various casting sections.

(2) *Flask bars extending into deep pockets not allowing collapsibility.* A typical problem ensues when bars are extended into deep pockets to lift the sand. These bars interfere with casting sections immediately adjacent to the bar. In these cases, a gagger or soldier can be used to lift the pocket without interfering with normal contraction.

Gating and Riser

(1) *Down sprue or riser too close to flask bars.* Under **Flask Equipment and Rigging** it is pointed out that placing the bars too close to the sprue or riser will interfere with the normal expansion or contraction of the casting during cooling. If it is impractical to move the bar, it may be possible to move the sprue or riser in such a way as to eliminate this common problem.

(2) *Gates, risers and runners not permitting normal contraction.* There are many cases in which the gating system can retard normal contraction and cause stresses within casting sections. Obviously, these will show up at corners and changes of section already highly stressed. The casting with the gating system

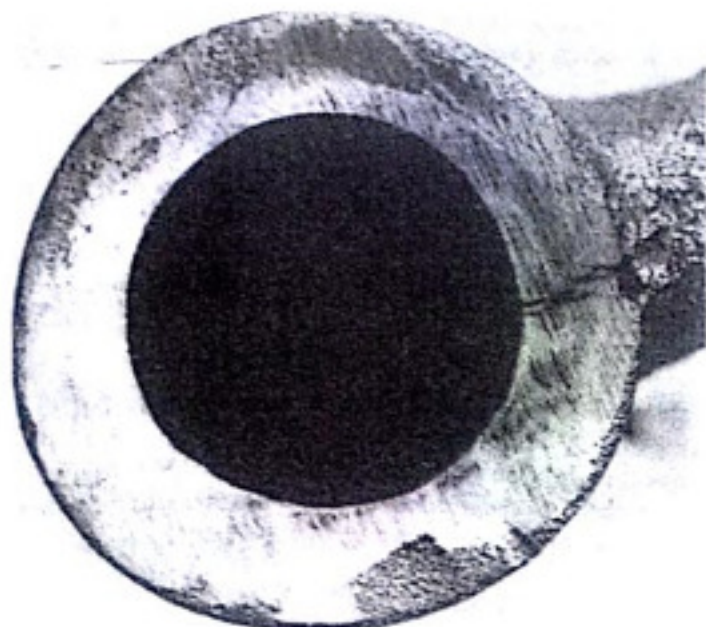


Fig. 13.1 — Hot tear in steel casting created by inadequate core collapse.

tached should be examined in order to judge whether these external parts are exerting a lever action on some casting section during cooling.

Molding Sand

(1) *Poor collapsibility due to excessive hot or dry strength.* Any sand which resists deformation as the casting contracts can aggravate hot tears in those designs or metals which already are prone to high internal stress. However, a radical change in sand should be approached cautiously in order to avoid shrinkage problems or oversized castings. It is here that the cure for a shrink and a hot tear differ radically. Soft ramming may relieve a hot tear but will probably aggravate a shrink. Hence in curing a hot tear, it is important to know how to avoid creating a shrink.

Excessive hot strength, low hot deformation and dry strength are the properties of greatest interest. These are related to the sand mixture and the mold hardness (see **Molding Practice**). The common controls over these properties are type and amount of binder, and the moisture. Excess water always imparts high (excess) hot and dry strength. The use of pitch can, through build up, lead to reduced sand collapsibility. Excessive fines, silica flour or even excessive clay can cause excessive hot and dry strength. The choice of the binder may be a ready cure; e.g., substitution of southern for western bentonite at controlled moisture level.

(2) *Low sintering-point materials.* Low sintering-point materials which become ceramic can promote hot tears without being of any benefit in controlling mold-wall movement shrinkage. Sodium silicate (water glass) and fluxing materials are apt to set up this type of fusion which could be harmful in ferrous castings. Nonferrous metals are usually not cast at sufficient temperature to find this unless such fluxes are present in unusually large quantities.

(3) *High hot strength coupled with low green sand deformation.* The sand must deform to some extent as the casting cools if the design or metal are prone to hot tears. Rather than soft ram, it is better to decrease moisture, bond and fines or increase cellulose materi-

al. In a specialized application, such as in centrifugal molding of steel, it would be desirable to increase hot strength and expansion.

Core Practice

(1) *Poor collapsibility due to excessive hot or dry strength.* The effect in cores is similar to that in sand plus a few special considerations. The materials most apt to retard adequate collapse are pitch, moisture (in the green state), fines, and excess binder (oil, resin, etc.). Figure 13.1 shows a hot tear in steel caused by inadequate core collapse. The type of binder is also a factor. For example, urea resins collapse more readily than the phenolics.

(2) *Low hot deformation when coupled with poor collapsibility.* The binder may lack hot deformation. Some oils are worse than others in this respect but the baking cycle could be the control.

An overbaked core may have higher retained hot strength than an underbaked core. This is contrary to many beliefs. It is based on the fact that hot strength increases with baking time and temperature, up to the point of burned. An underbaked core can also give trouble if the baking continues in the mold after pouring and leads to excessive hot strength and rigidity.

(3) *Rods, arbors, etc. too close to surface of cores.*

(4) *Over reinforced cores.* A mechanical problem is frequently found in cores through the use of wires, rods, and arbors which prevent normal collapse. Too much or improperly placed reinforcing can interfere with normal movement. A well-known cure for these problems in larger work is the coke center core. Shell cores provide a similar easy collapse when hollow but can be a problem if made incorrectly (solid in some sections).

In permanent mold work, the core becomes particularly important because the mold is rigid and the core is expected to provide for all the contraction. In these cases, failure to remove the core in time can cause the tear.

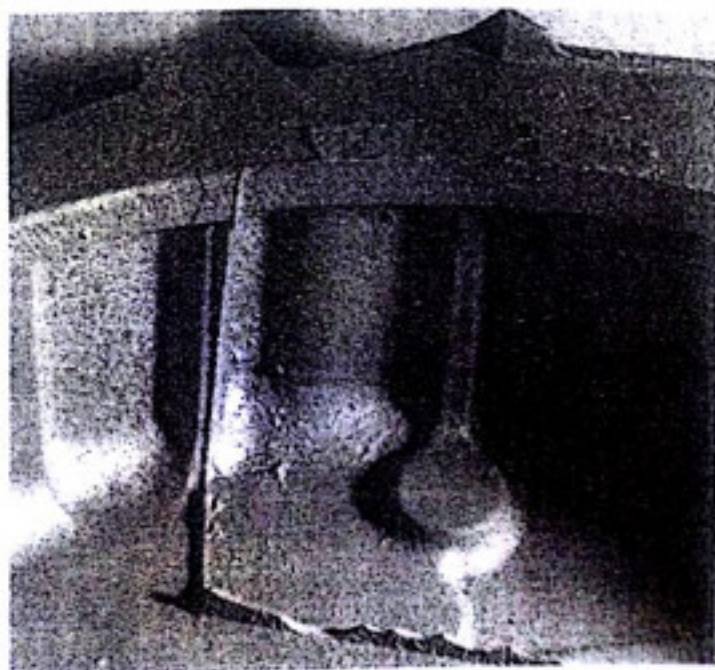


Fig. 13.2 — Hot tear caused by failure to set proper chills at the hot section near feeder area.

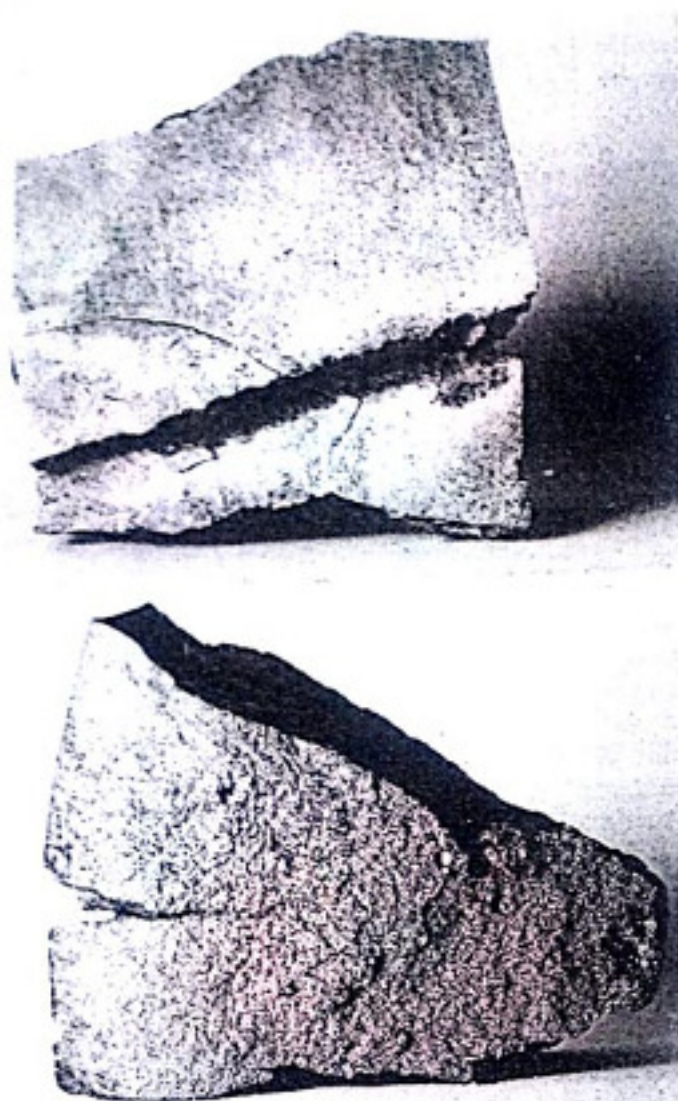


Fig. 13.3—Two views of crack in chilled casting. Chemical analysis: Si 0.52 per cent; total carbon 3.65 per cent; Mn 0.46 per cent; P 0.25 per cent; S 0.12 per cent. Increase of phosphorus to 0.40 per cent minimum eliminated cracks in chilled section.

Molding Practice

(1) *Rammed too hard.* Since the sand properties of interest are hot and dry strength, the mold hardness is a vital consideration. Dry strength increases with mold hardness and, in addition, the increase is most rapid at higher moisture. A wet sand, overrammed, is particularly dangerous. In many cases, the molding can be eased back enough to stop the tear without producing a shrink. For example, a mold hardness of 85 to 90 often will provide adequate protection against mold-wall movement while 90 to 98 hardness could create a danger of hot tears.

(2) *Rods, arbors, gagers, etc. too close to mold surface.* The use of rods, gagers, and soldiers is often necessary for good molds but they must be placed in such a way as to permit normal contraction. Molders may be careless of such placement unless they recognize the danger.

(3) *Riser or sprue too close to flask bar.* The placement of the riser and sprue has been mentioned under **Gating and Riser**, but it applies to molding if it is the molder's job.

(4) *Excessive swabbing or sponging.* Since high mois-

ture is a major factor in sand involving hot tears, the use of sprays (water base) and swabs can cause problems.

(5) *Failure to place chill when used to prevent hot tearing.* Occasionally, the molder simply fails to follow prescribed procedure. For example, he may forget the chills needed at certain sections (see **Casting and Pattern Design**) to prevent the hot tear. Figure 13.3 is an example of a hot tear caused by the failure to set proper chills.

Metal Composition

Certain metals are much more prone to hot tear than others. A wrong composition for application or a composition having too high shrinkage characteristics in these metals can have a greater influence than either the mold or the design (see Fig. 13.3).

Melting Practice

(1) *Excessive carbide stabilizers promoting high shrinkage.*

(2) *Wrong compositions due to careless charging.* Since metal composition is so important in some metals, the melting practice must be such as to produce the correct composition. Careless charging, weighing or lack of atmosphere control can be a major factor. In the ferrous metals using ladle inoculation or alloying there is some danger from excess carbide stabilization. Careless alloying or excessive super-heat and lack of grain refinement control are standard melting problems in this area.

Pouring Practice

Insufficient pouring temperature to promote proper collapsibility. In pouring, there is a definite need of avoiding temperature extremes especially with those metals prone to hot tear. Pouring too cold can fail to burn out the mold or core binders and prevent proper collapse. On the other hand, pouring too hot can create temperature gradients in castings of nonuniform section.

Therefore, it is desirable to pour as cold as possible while still providing adequate heat to destroy or collapse the mold and core binders. The possible spread of correct pouring temperature is improved if the mold and core binders burn out more readily or if the design is more foolproof. Some situations call for a very narrow critical range of correct pouring temperature.

Miscellaneous

Internal stresses set up by thermal gradients. The handling of the casting after pouring can have a major influence on cooling stresses and thermal gradients. The obvious problem is early shakeout or rapid cooling of critical sections such as found in small fillets, adjoining sections, and the like. In some cases, it is necessary to expose some sections of the casting while keeping others insulated in the sand. This is common practice in making pulleys and sheaves, for example. In some cases, soaking pits are provided to permit stress relief after shakeout.

Moving a soft rammed mold (such as on a conveyor) in a rough fashion or too soon can cause a hot tear effect.

INVERSE CHILLS

DESCRIPTION

Inverse chill, also known as reverse chill, reverse mottle (malleable), internal chill, and inverted chill is the condition in a gray iron, ductile iron or malleable casting section where the interior is chilled or white while the outer sections are mottled or gray (see Figs. 14.1, 14.2). This condition generally occurs in lighter sectioned castings. It is a relatively rare problem and, as such, can be rather confusing to one who has had no previous experience with it. Its cause is better known than understood.

CAUSES

Casting and Pattern Design

Thin sections adjacent to heavy sections in malleable iron are most prone to the problem but, of course, the design itself does not cause the defect.

There are no inverse chills resulting from **Pattern Equipment, Flask Equipment and Rigging, or Gating and Riser**ing.

Molding Sand

Excess gas from agitated metal, as caused by wet sand, can be absorbed by the metal to create this unusual metallurgy. However, this amount of gas from sand would usually scrap the casting from a blowhole or other gas defect.

Core Practice

Excess gas from a core causing agitation of cold metal can upset the chemistry toward inverse chill.

Molding Practice

Any practice involving abnormal, excess or free water could produce a hydrogen pickup which might result in an inverse chill, possibly at some distance from the point of actual agitation. Illustrations of localized excess water include sponge bulb, swab, and dough rolls.

Metal Composition

Metal composition is more of a factor in irons with high carbon equivalent than in the lower equivalent metals. In both cases there is the danger from the following factors.

- (1) *The presence of nonferrous metals in the iron such as tellurium, chromium, and other severe carbide stabilizers.*
- (2) *The sulfur content not balanced by manganese.* This is a severe carbide stabilizer and can aid in the transformation to the nonstable system involved in inverse chill.

Melting Practice

Melting practice (and to some extent, **Pouring Practice**) is the basic area of inverse chill control. The defect is known to occur under conditions which would lend themselves to solution of hydrogen gas by the metal. In other words, the presence of free moisture during melting or pouring is the usual problem. The common factors are as follows.

- (1) *Hydrogen atmosphere from a low coke bed in the cupola or wet linings in the cupola, electric, or air furnace.*

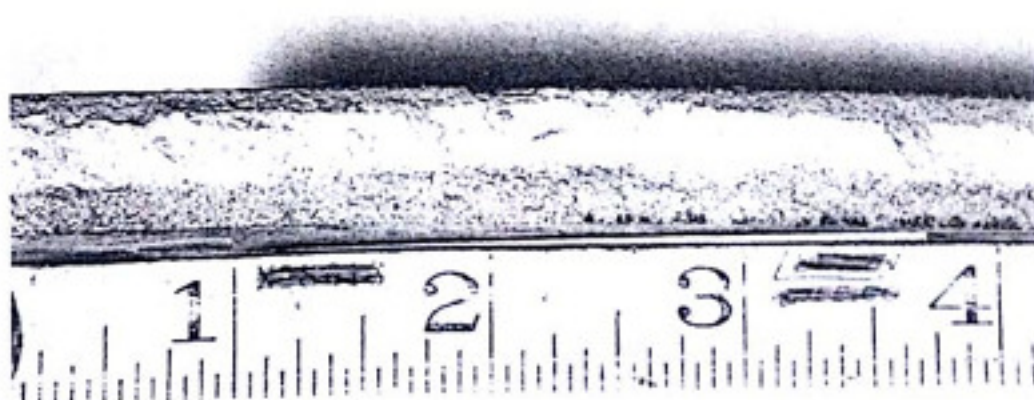


Fig. 14.1 — Typical inverse chill in a gray iron section.

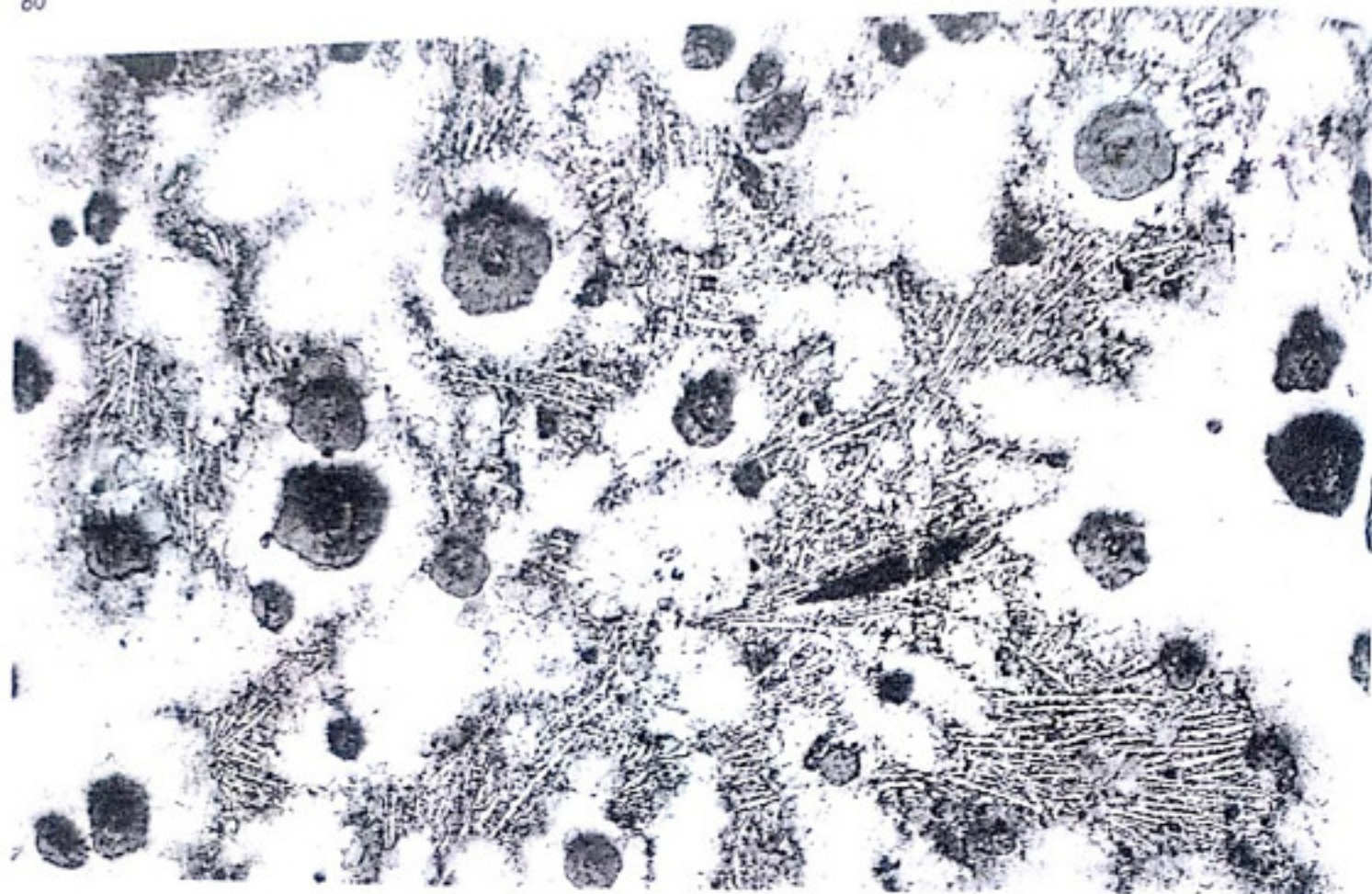


Fig. 14.2 — Photomicrograph of inverse chill section of a spheroidal graphite casting. $\times 50$.

(2) *Use of contaminated materials in the charge*, such as die cast non-ferrous metals.

(3) *Boiling metal* is commonly the result of wet runners and spouts, or a wet sand bottom in the cupola.

(4) *Moisture in the blast*, particularly in hypereutectic iron, such as used in piston rings, may have to be removed.

(5) *Inadequate inoculation* for the conditions of melting described previously.

Pouring Practice

(1) *Wet ladles or ladle lips* act as explained in **Melting Practice** (1) (3). Figure 14.3 is an example.

(2) *Holding too long after inoculation* lets the inoculant wear off. If there is still a moisture problem, hydrogen may be reintroduced as from the ladle lip, pouring cup, or skim core.



Fig. 14.3 — The casting shown was poured using a wet ladle.

MASS HARDNESS

DESCRIPTION

Mass hardness is a condition in which the entire casting is too hard for the application. The illustration shows the chill test history of a mass hardness epidemic.

This defect is related to heat transfer-metal composition and the relationship between the two. The composition is wrong for the rate of cooling or the rate of cooling is too fast for the composition. This depends upon which of the two, if either, is within prescribed specification. Occasionally, this situation is one of incorrect specification. For example, the engineer may specify the chemistry, the hardness and the section size in such a way as to create an impossible combination of requirements. Care should be taken that the various elements (chemistry, cooling rate and hardness) specified are actually compatible with prescribed or available foundry techniques and that allowance is made for subsequent heat treatment.

CAUSES

Casting and Pattern Design, Pattern Equipment, Flask Equipment and Rigging and Gating and Riser- ing have no effect on mass hardness.

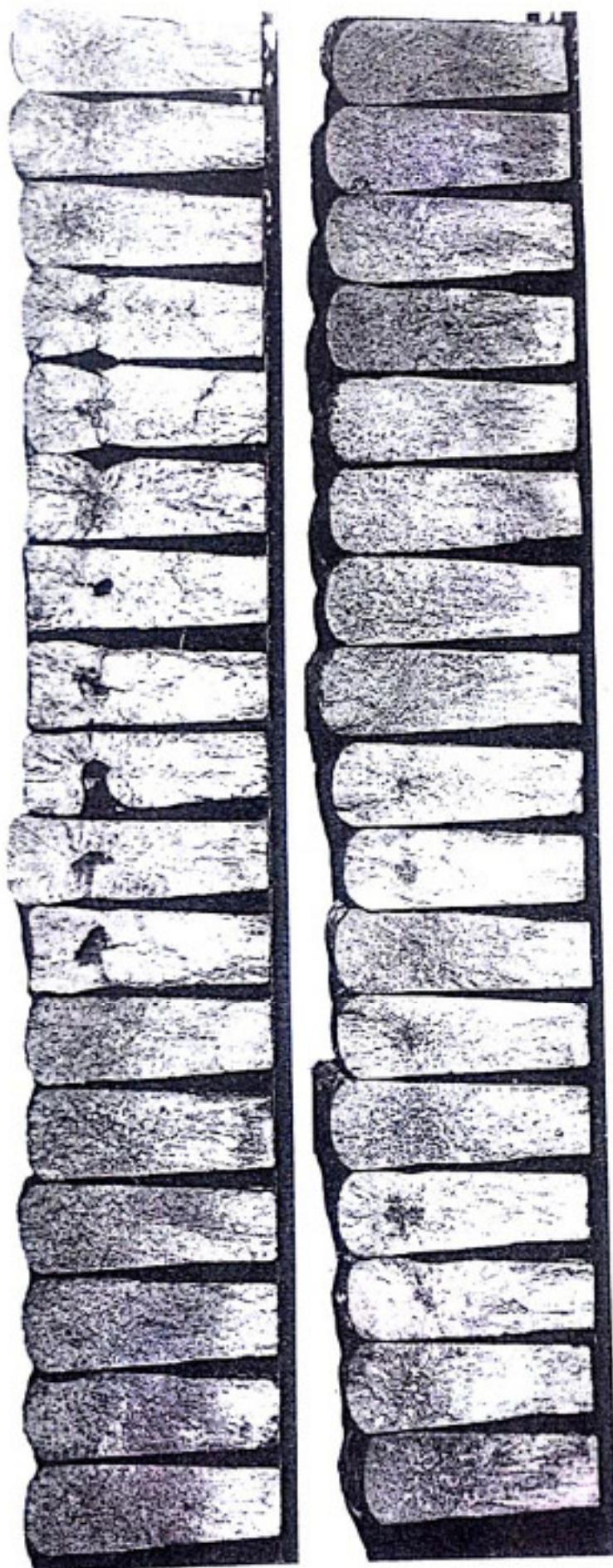
Molding Sand

It is unusual for the sand to produce mass hardness but it can contribute to it if unusually wet. The effects which seem to be caused by sand are usually due to a foreign material or to careless use of chill (e.g., tellurium) wash or tramp iron in sufficient quantity to make a major change in cooling rate.

In general, a dense mold has faster cooling than an open, permeable or soft mold, but the differences are minor. A mass hardness could result if the composition and other factors were such as to bring the casting to the point of mass hardness, then the sand could be the final factor producing mass hardness.

Core Practice

Heat transfer in cores can be excessive if the metal is close to being out of specification on hardness. The use of chill coat common on cores can be overdone. Another possibility of excessive heat transfer arises when heavy rodding or arbors are used (such as in pipe). If the sand layer over the arbor is too thin, the cooling rate of the arbor could predominate and create a chilling mass hardness effect.



Chill test history of mass hardness epidemic when stainless steel scrap was inadvertently substituted for regular steel scrap during the charging of a cupola.

Molding Practice

Carelessness with various chill techniques can be such as to create mass hardness. The use of too much chill wash, and misapplied chill wash are examples.

In permanent molds or die casting, the temperature of the molds can be an important factor especially at the beginning of the heat before the molds have reached operating temperature.

Some insulation is normal in permanent mold work. This basic practice should not be neglected.

Metal Composition

The defect is often due to incorrect metallurgy or to an incorrect specification. The metallurgy of each cast metal is different. Usually the problem is to have the correct chemistry for the section or cooling rate involved. Some metals, such as gray iron, are particularly sensitive to cooling rate and section size because of the influence of graphitization on hardness.

(1) *Steel*. Excessive carbide stabilizing alloys and (high silicon) ferrite hardening alloys are the more common problems.

(2) *Gray and Ductile Iron*. Incorrect carbon equivalent is the most common followed closely by incorrect alloying composition. Lack of inoculation in thin sections may produce less graphite than anticipated in the specification.

(3) *Malleable*. Incorrect alloying is one of the problems. In malleable (and in heat-treated ductile iron) there is a danger of elements that prevent malleablizing. The best known of these elements is chromium.

(4) *Aluminum*. Most alloys increase the mass hardness. The outstanding elements in this area are iron and magnesium.

(5) *Magnesium*. The usual troublemakers are excess silicon and aluminum but most alloying elements can raise mass hardness beyond specification.

(6) *Brass and Bronze*. Incorrect composition is possible through either wrong combination or contamination from stock intended for other compositions produced by the foundry.

Melting Practice

Since incorrect composition is so much a part of this problem, any poor melting practice which produces

an off-analysis can produce undesirable mass hardness. An obvious source of error is in weighing the charge ingredients or permitting unusual losses of certain elements. Sometimes contamination from a previous heat is a major problem.

Assuming the charging technique is correct and there is no contamination of the lining, the usual source of trouble is from an oxidized melt. This may be from rate of melt, slag protection or loss of atmosphere control. In gray iron, for example, a low coke bed can create a high chill iron without apparent change in basic composition, because of oxidation (hydrogen pickup).

The degree of super heat can be a problem in most metals either directly or by virtue of its effect on dissolved gases.

In the realm of pure carelessness is the unintended substitution of alloys such as confusing ferrochromium with ferrosilicon. Good housekeeping around the furnace often prevents these mistakes.

Pouring Practice

Oxidized metal (high gas) can cause mass hardness rather drastically. Therefore, wet, dirty, and contaminated ladles, spouts, and runners must be avoided. Some metals reach mass hardness because of pouring too cold especially in thinner sections where the cooling rate of the casting can be a factor.

Miscellaneous

The cooling rate after pouring can be very critical in some metals. The air quench of early shakeout will modify grain size in ferrous or nonferrous metals or change the pearlite stability in ferrous metals.

In many cases, heat treatment is specified. An error in the heat treatment will have a direct effect on mass hardness. A little confusion as to which oven to open first can cause trouble.

In water-cooled permanent molds, a common error is to leave the casting in the mold too long. In sand cast, the reverse is true.

In the area of pure carelessness is the unintentional quench in water. In this regard, some castings can be shaken out hot in front of an open window in the summer but not in the winter.

METAL PENETRATION

DESCRIPTION

Metal penetration is a condition in which the metal or metallic oxides have filled the voids between the sand grains without displacing them. Figure 16.1 shows overall penetration resulting from a soft mold.

In general terms, true penetration implies an openness of the mold surface. There are also occasions when an apparent penetration occurs even with dense surfaces such as from high pressure squeeze, CO_2 molding, shell cores and molds, and well-rammed chemically curing cores and molds. This type of penetration is described later in Chapter 17, METAL PENETRATION IN DENSE MOLDS.

The present chapter deals only with those factors which cause or encourage an open grain or mold porosity. This aspect is more truly an actual penetration than are the other defects which may appear completely similar.

It should be noted that the definition also includes the penetration of metal oxides. There has been adequate demonstration of the fact that some penetration takes place as a movement of metal oxide rather than

of molten metal. It is important to recognize that metals at elevated temperatures (including the molten condition) do have a measurable rate of oxidation when exposed to oxidizing atmospheres (including air). Some penetration defects can be shown to occur after the metal has solidified but while still at an elevated temperature. For example, it is not unusual to find that a penetration problem is much worse if the casting is held in the mold rather than shaken out while hot.

The role of oxide penetration is one of the explanations for those cases in which metal appears to penetrate the minor porosity of the mold under conditions which obviously are beyond the capability of metal fluidity. Metal penetration can exist even in combination with a cold shut defect if oxidation conditions during pouring and solidification are conducive to metal oxide formation and penetration.

There is apt to be considerable confusion between metal penetration, hard mold penetration, and fusion. It may be necessary to study all of these before making a firm diagnosis of the problem.

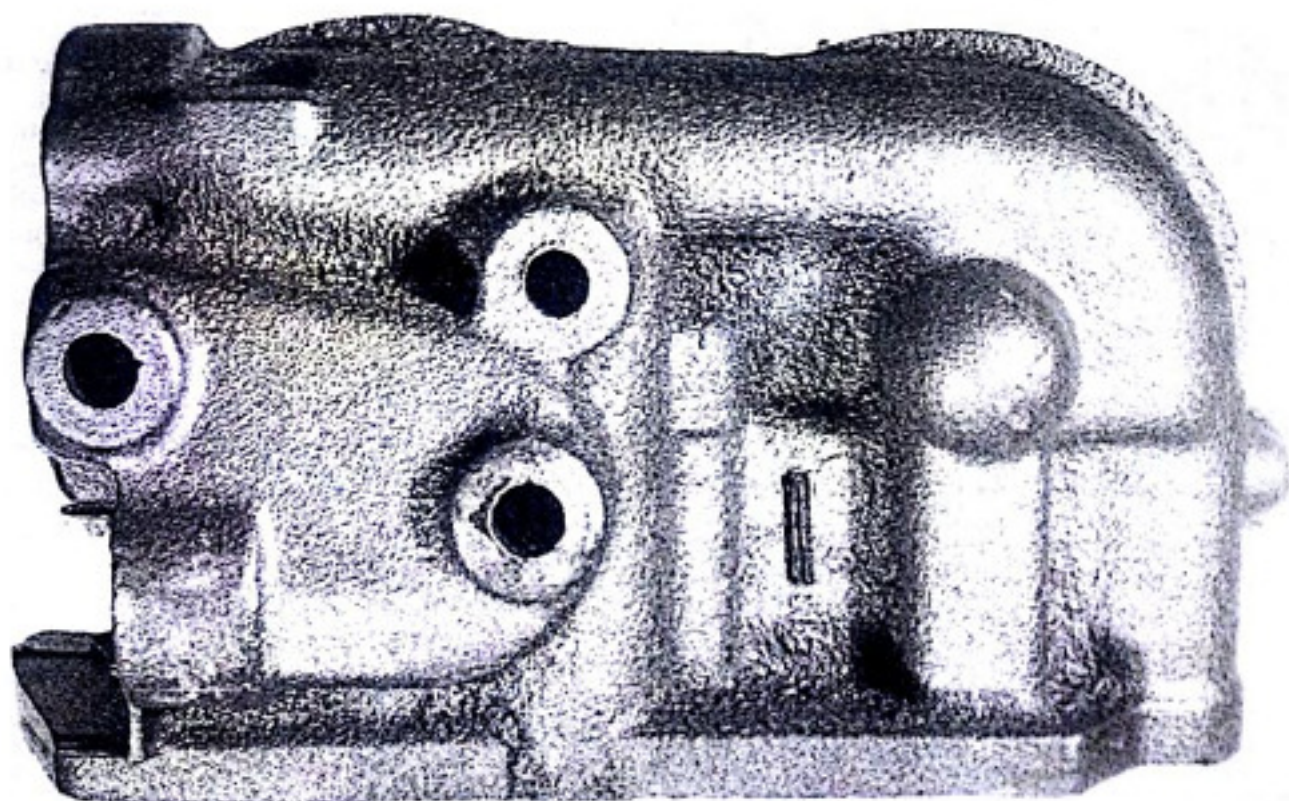


Fig. 16.1 — Overall penetration resulting from a soft mold.



Fig. 16.2 — Sharp corners and hot spots are most apt to penetrate when either molding or pouring creates penetration problems.

CAUSES

Casting and Pattern Design

Design is a contributing factor where sharp corners or overhanging or protruding sections are necessary, or where a thin core or sand section is necessary and surrounded by a heavy metal section (see Fig. 16.2). These designs permit a concentration of heat which ultimately destroys the normal properties of the mold or core. Preliminary collapse of the surface permits ready access to the metal or metal oxides. Some designs may require the use of special sands such as zircon, carbon or olivine in order to develop resistance to prolonged heating or excessive temperature.

Pattern Equipment

(1) *Pattern equipment constructed so as to promote uneven or soft ramming has a direct effect upon the penetration problem by promoting an openness or mold porosity. The most common errors in this respect are as follows.*

(a) *Improper location of the parting line may be a matter of excessive cope height or may result in deep pockets or vertical draws with less than 1½-degree draft. It is usually the result of an attempt to minimize the use of set or ram up cores.*

(b) *Improper location of the pattern on the plate results in sand pockets which are difficult to ram. This may be a case of mounting the pattern too close to the flask wall or mounting too many patterns on a single plate.*

In exaggerated cases, this technique will result in a major or minor swell but even in the absence of a noticeable swell, penetration can occur. It is common to have penetration and swell on the same casting since the cause is the same.

(c) *Improper location of sprues, risers, and runners is a modification of (b) in which the sand pocket being soft rammed is related to the placement of the pouring or feeding system.*

(d) *Inadequate draft of less than 1½-degree can result in a torn surface which permits ready penetration of metal or metal oxides even in a mold of adequate overall density. The broken surface is never as dense as the mold itself.*

(2) *Pattern equipment constructed to permit excessive metallostatic pressure is illustrated by the effect of vertical mounting versus horizontal mounting of a pattern. This results in greater static pressure at the lower extremities of the cast shape. The static pressure is related to both blows and shrinks and is often needed to insure proper solidification of some sections. The increased pressure imposes greater loads in the sand and may require special sand or more dense molding to offset the penetration pressures.*

Flask Equipment and Rigging

(1) *Design and construction of flask equipment which promote uneven or soft ramming may be a cause of flask distortion during molding or may prevent proper ramming of critical areas of the mold. The problem may be due to the flask design or to badly distorted, bent, dented or loose equipment. The common problem sources are listed below.*

(a) *Bars that interfere with the ramming of the pockets resulting in a soft ram section which can swell and/or penetrate.*

(b) *Flasks that are too small for the pattern creating a soft ram as in Pattern Equipment (1b).*

(c) *Bars that interfere with proper placement of the sprue and risers create a soft ram between the riser (or sprue) and the pattern. The problem is aggravated by the necessary concentration of heat in the same area. It may be necessary to cut or remove the bar if the sprue or riser location cannot be changed.*

(2) *Excessive cope height is also described in Pattern Equipment (2). Penetration is always related to both resistance and pressure. A mold which is adequate for low metal pressures may easily penetrate if the pressure is increased. The pressure is related to metal density and cope height (a heavy metal, such as steel, produces greater metal pressure than a light metal such as aluminum for the same sprue height). The sand requirement may have to be modified if the cope height is really needed for feeding. In other cases, the cope height may be greater than necessary in which case it should be reduced.*

Gating and Riserig

(1) *Location of gates and risers which promote localized overheating of the sand leads to premature destruction of the mold surface. This permits ready access to the metal, or to metal oxides formed at elevated temperatures. The following are typical of this.*

(a) *A sprue or riser too close to the mold surface creates a definite hot spot which is aggravated by a tendency to soft ram in the same spot.*

(b) *Flowing too much metal over a given mold*

surface will heat the sand to the point of destruction. This is particularly so if the later stages of metal flow redissolve any metal skin formed in the earlier stages of solidification.

(c) Anything which causes excessive pressure of metal during pouring will act to promote penetration especially if the pressure is accompanied by high temperature.

(d) Slow pouring retards solidification and, therefore, acts to prolong the time during which the sand is exposed to high temperatures.

(2) *Incorrect ratio of sprue, runner, and gate, permitting metal oxidation during pouring increases the amount of metal oxides and introduces fluxing action. Any part of the gating system can be the cause unless all sections are full of metal at all times.*

The so-called pressure-ratio gating system minimizes problems because all sections are full and oxygen has a minimum opportunity to contact the metal. Any form of turbulence will increase the rate of oxidation. A nonturbulent flow is therefore desirable especially with metals showing a rapid rate of oxide formation (e.g., steel).

(3) *An oversize riser neck which overheats the sand is a common problem. It is often the result of using a long connecting neck which freezes unless it is made oversize. When lack of feeding results from faulty neck design, it is better to shorten the neck to prevent freezing rather than making it oversize. The smaller neck has the advantage of reduced heating of the sand plus the reduced cost of chipping and grinding.*



Fig. 16.3 — The photomicrograph shows the type of metal structure which is often found between the sand grains under conditions of mold porosity. $\times 400$.

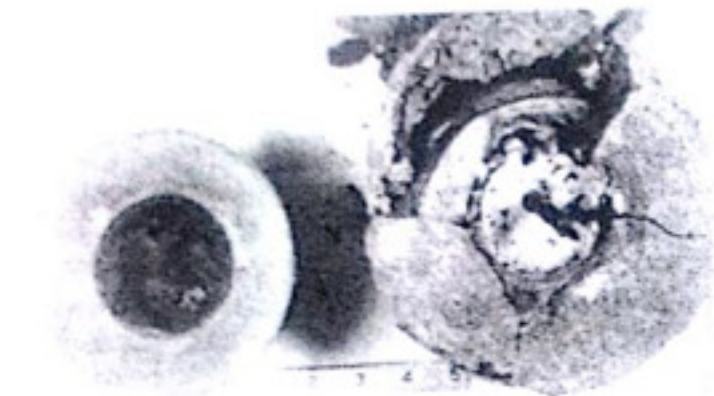


Fig. 16.4—A test casting showing the effect of a reducing atmosphere on metal penetration.

(4) A pouring cup or sprue designed so as to permit aspiration of air (whirlpool effect) creating oxidized metal, is a common cause of turbulence which promotes penetration by building up the metal oxide film on the molten metal.

Molding Sand

Any sand condition that promotes excessive porosity of the mold surface tends toward penetration. In this regard, it must be recognized that porosity is a mold condition and those inherent features of the sand which make it difficult to mold on the equipment available are pertinent factors.

(1) Improper distribution of the sand grains may cause low density molds. Grain distribution has a direct effect on potential mold density (see Fig. 16.3). For example, a sand composed essentially of two sizes, such as 40 and 200, is considered a double peak sand. It may have maximum theoretical density but should be avoided since it leads to expansion defects. (See Chapter 9, EXPANSION DEFECTS.)

At the opposite end of the scale is the one screen or two screen peaked sand of maximum permeability and minimum density. A proper compromise is usually found with a three or four screen distribution.

(2) Low flowability and/or moldability is related to many factors. It must be remembered that the type of molding must be considered. For example, small amounts of cereal increase the ability of sand to be squeezed but reduce its ability to be jolted.

Likewise a high clay may reduce the ability to blow a sand but increase the overall hardness from a blow-squeeze. This is because of its ability to utilize pure squeeze forces.

It is not possible to refer to a single property of flowability since each molding method applies energy differently. What is best flowability for one type may be less desirable for an entirely different piece of equipment. The aspects of interest are as follows.

(a) Moisture segregation will lead to poor moldability and penetration in all types of molding. It is to be avoided because it is the cause of many other defects such as blowholes, scabs and inclusions, and is the result of poor mixing.

(b) Excessive cereal reduces moldability although some cereal improves flowability under conditions of squeeze.

in hard molds. It reduces moldability in most cases although it may provide a greater density under conditions of squeeze. Unfortunately, the excessive moisture usually cannot be tolerated in dense molds because of its relationship to gas defects and others.

(d) Excessive green deformation can reduce mold density especially under conditions of jolt and ram. It is also undesirable in slinger operations.

(e) Poorly aerated sand is often a variation of moisture segregation. The sand grains leaving the muller may be already premolded which reduces the ability to be molded under normal conditions. Such prearrangement of the sand grains can be broken by some form of riddling or aeration.

(f) Prepacked sand is an intensification of (e). It may occur in the hopper, on the belt, or as the sand falls into the flask. Additional energy is then required to reorient the grains into the desired pattern of mold density. This factor is particularly noticeable in jolt or very low pressure squeeze equipment.

(3) Insufficient coating of shell sand permits penetration of shell molds by the simple mechanism of localized low strength and localized open grain.

(4) Excessive mold permeability is another way of saying open grain. Permeability and density are functions of each other. Low density is the same as high permeability and vice versa.

(5) Insufficient carbonaceous or deoxidizing material permits excessive metal-oxide formation. It also allows the oxide to wet the sand grain and penetrate easily. Oxidization of a casting surface is exothermic promoting localized heating. Figure 16.4 illustrates the effect of a reducing atmosphere on metal penetration.

Core Practice

(1) A grain size which is too large or improperly distributed in uncoated cores is related to Molding Sand (1). It applies only to uncoated cores because it is assumed that a wash, dip, or coating will conceal any openness in the core proper.



(2) *Soft rammed cores* are of the same undesirable nature as soft rammed molds. They are often the most vital factor in this type of penetration (see Fig. 16.5). The actual openness of the core or mold must be related to the potential density (**Molding Sand** (1)) and the molding or coremaking process. In cores, such openness would be expected for the following reasons.

(a) Insufficient vents or improperly placed (or plugged) vents. If the air cannot escape quickly from the box, the core will not blow up and fill the box to maximum density. In most cases, the air carries the sand rather than pushing it so the air must escape before the sand can take its place and fill the box completely.

(b) Improperly tucked sand under loose pieces. This is a matter of carelessness on the part of the coremaker. This factor is most common on handmade cores which involve tucking or peening of some sections not reacting to simple jolt or ram.

(c) Low air pressure. This is a common cause of failure in blown cores. It often occurs as a temporary and perhaps unnoticed variation from standard when the drain on the compressor is excessive. If a box is rigged and vented for a given pressure, any deviation from that pressure, even temporarily, will produce a non-uniform core density.

(d) High cereal or low oil for a particular mix. This is related to **Molding Sand** (2b) and makes the sand harder to blow or ram than it should be. The high cereal or low oil may also be a relative matter and actually involve a change in the moisture. Some mixes require rather accurate moisture control for maximum blowability.

(3) *A rough or porous core surface* creates the problem by its very nature. When the metal or metal oxide wets such a surface, it can penetrate. This is especially true where pressure is involved, such as in heavy metal sections, deep drags, and expansion metals (gray iron) cast in permanent molds. The rough or open surface is commonly related to one of the following factors.

(a) Insufficient or improper release agent permits the core surface to tear up upon stripping or removal from the box.

(b) Insufficient or incorrect coating permits the penetration to occur because such a coating is unable to protect the relatively open core underneath. Obviously, the more open the core, the greater must be the care to protect it with adequate and proper core washes, dip or coating.

(c) Underbaked cores can cause penetration from the gases and steam generated during pouring (see Fig. 16.6).

(d) A partially disintegrated core due to overbaking likewise produces a weak surface. This may be a simple miscalculation of the proper baking time or temperature. It may be related to an improper mix in the oven (large and small cores on the same cycle) or poor heat distribution in the oven. Oven temperature indicators may be faulty. Another common cause is a solid large core which overbakes on the surface while the center is coming up to temperature. In large cores this can be avoided by use of coke centers



Fig. 16.6—Complete fusion of iron into the core because core was underbaked.

or other lightening techniques so the core can be removed before the surface is destroyed or weakened to a low scratch hardness reading.

(e) Filing, jiggling, grinding, or otherwise abrading the surface of a coated or uncoated core is an obvious mechanical method of creating a rough or porous surface. The problem is usually more acute than might appear from a cursory glance at the abraded surface. It seems to be even more troublesome in the coated core than in the uncoated core, possibly because the abraded surface exposes a relatively open core underneath.

(4) *Cores that have picked up moisture during storage* act like those described in **Molding Sand** (2c) (excessive moisture). It is particularly troublesome in cores because the excessive moisture is not readily apparent. The core may look dry and still carry a high moisture on the surface. It can usually be noticed by a scratch hardness test on the suspected core.

(5) *Any condition promoting veining or finning* such as a core crack will provide the opening wedge for penetration. Such a crack exposes the open grain of the core and permits both penetration and erosion.

(6) *Broken or disturbed core wash due to rough handling or handling while the core wash is still wet* is a variation of (3b) preceding. It results in insufficient coating to stop the penetration of the metal or metal oxide. It is aggravated by the fact that the broken coating acts as an unintentional vent for the core at that point. The resultant boil becomes evident as a penetration defect.

(7) *Insufficient absorption of the core wash* will allow direct penetration or will permit the coating to peel or flake away exposing the open grain core underneath. Such a peel, as in (6), also acts to promote boiling and penetration from that cause. Such insufficient penetration is usually the result of: very fine grain size; incorrect Baumé of wash; or incorrect type of wetting agent used.

(8) *Low hot strength* due to insufficient clay in the wash or to a low binder content from the use of too much solvent leads to penetration.

(9) *Poorly mixed core sand* (like poorly mixed molding sand) provides areas of low strength which disintegrate during pouring and permit penetration.

(10) *Poorly cleaned and finished cores* provide pene-

tration in a direct manner. Inspection of such cores would prevent this from occurring.

(11) *Dipped or sprayed cores which are not redried* can easily spall or flake as in the case of sweatback in a mold. Penetration occurs after the spall or as a result of the boil from the wet surface as in (4).

(12) *A dirty core box* has a direct effect upon sand sticking to the box leaving an open surface on the core. A good core has a smooth dense surface. Such a good surface is important but is impossible with a dirty box.

Molding Practice

Molding practice is often the prime cause of soft mold penetration. It may be a question of carelessness or improper correlation of the machine and the mold. For example, using an undersized machine for a large mold can easily create a built-in soft ram unless the molder substitutes laborious tucking, peening, and ramming to compensate.

(1) *Soft and uneven ramming* are equally important in most cases. In some cases, however, uneven density is a greater problem than overall softness. Improperly tucked pockets and overhanging sections, when necessary in the design, must be handled by either careful, skilled molding or by using unusually moldable sand and specific aids such as a peen, follow-boards, and the like.

Soft spots on bedded-in areas result from carelessness on the part of the molder. They may be difficult to ascertain from examination of the casting since the exact source of the soft ram which took place is not obvious.

Low air pressure as in **Core Practice** (2c) may be unnoticed by the molder. It may, of course, be an overall error in practice. In either case, the resultant soft mold may penetrate.

Inadequate size of the equipment can be considered as part of the rigging of the job, but it certainly controls the overall mold density unless the molder is expected to compensate by ramming.

Lack of, or poorly designed, peen blocks fail to develop density where it is needed. In some cases, this is poor rigging and in other cases, it may be a matter of having well designed peen blocks lost or broken during production or in storage of pattern squeeze equipment.

Insufficient jolting can be as bad as too much. Too much might start a ramoff; too little may create a soft rammed area in the mold.

(2) *Poorly patched areas of sand* can be rough and porous causing direct penetration, or it may be due to overslicking or excessive moisture causing a boil-type penetration.

(3) *Improperly fitted stop-offs* are open areas which can penetrate. This may also act to start a boil-type penetration.

(4) *Uneven or insufficient coating or spraying of cores* as described in **Core Practice** (3b) applies to molds also.

(5) *Uneven or insufficiently dried coatings on skin dried molds* act in the same way as described in

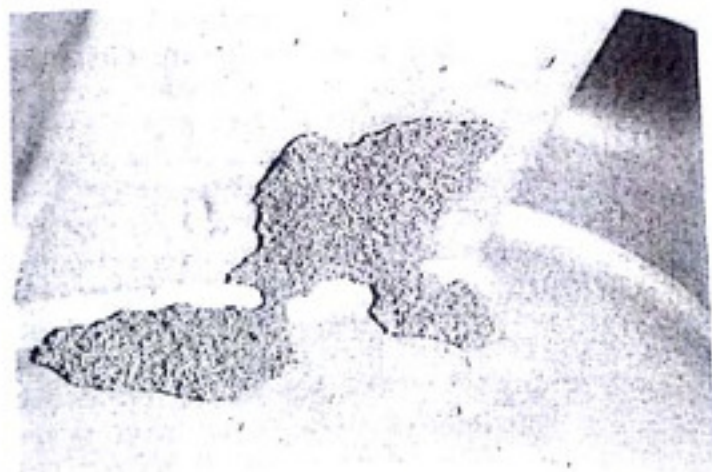


Fig. 16.7—Insufficient drying of mold wash created a penetrated area.

Core Practice (6, 7, 11). Figure 16.7 illustrates a penetrated area as a result of insufficient drying of mold wash.

(6) *Excessive use of parting compounds and washes* may cause trouble in one of two ways. Liquid parting in excessive quantities weakens the mold surface and promotes boiling action and erosion. (See also Chapter 9, EXPANSION DEFECTS.) Low fusion, dry partings or fluxes permit a fusion of sand grains (see Chapter 10, Fusion) which is often confused with true penetration.

(7) *When the Baumé for the type of coating used* is too low, absorption of the wash occurs. As a result, the wash may peel, chip or spall permitting both direct penetration and boil penetration.

(8) *Not enough facing to cover the pattern* is a common type of carelessness which may lead to rather mysterious penetration (mysterious because it is assumed that the pattern was covered). Variations of this fault include: wrong kind of facing which is not of a type which can stop the penetration; or excessive venting to the pattern surface leading to easy access for metal or metal oxide penetration.

(9) *Any combination of hot and cold materials (cores, molds, chaplets, chills, etc.)* can set up condensation deposits of water. These can cause a boil-type penetration and can vastly increase the rate of oxide formation and subsequent metal oxide penetration. This is a common cause of this type of penetration and a predominate cause of hard mold penetration.

Metal Composition

(1) *Metals which are prone to fluid oxides* will penetrate readily if given an opportunity to do so by soft molding or some other previously described practice. In the same way, unusually fluid metals will penetrate more easily than those with high surface tension or viscous flow.

(2) *Low melting constituents such as lead in leaded bronze* will penetrate since they are fluid at lower

(3) *Composition requiring high pouring temperature* may penetrate because of high fluidity. In addition, the required high temperature increases the rate of oxide formation and, therefore, the tendency to oxide penetration.

Melting Practice

Oxidized metal will tend to be low in fluidity and, therefore, might not be expected to penetrate. However, the large amount of oxide film does have a pronounced tendency toward wetting the sand and penetrating into a porosity that even a fluid clean metal might not.

Pouring Practice

(1) *Excessively high pouring temperatures* have a double effect. In the first place, they tend to be fluid. In the second place, they oxidize rapidly and increase oxide penetration. There is also a secondary effect in which the unusually high temperature rapidly destroys the core or mold surface.

(2) *Excessive pouring height, like excessive cope height*, creates unusually high metal pressure and forces the metal or oxide into the mold pores. It, therefore, aggravates all conditions previously described in **Molding Sand, Core Practice and Molding Practice.**

METAL PENETRATION IN DENSE MOLDS

DESCRIPTION

Metal penetration is a condition in which the metal or metal oxides have filled the voids between the sand grains without displacing them. This can occur in dense sand molds even with the minute size of the voids in the sand. The illustration shows a typical hard mold penetration.

Although the exact mechanism of hard mold penetration is somewhat mysterious, it is known to be directly related to moisture conditions within the mold. Most of the factors involved have to do with moisture, temperature, rate of oxidation of the metal, and degree of contact between sand and metal. The reactions involve high temperature chemistry and are, therefore, difficult to study. It is obvious that more than simple metal flow is involved because the porosity which exists is too minor to permit normal metal flow into the voids. The action may involve metal vapors or metal compound vapors. The movement of metal may be largely a matter of capillary attraction which in turn depends upon metal to sand contact, plus surface tension characteristics of the metal or metal compound.

Some metal oxides are known to be fluid at many hundred degrees lower than the melting temperature of the pure metal. Metal oxide silica formations (i.e., fayalite) have very low melting points and high attraction for capillary flow into sand molds. Since sand to metal contact is frequently a major factor, there is some reason to believe that dense mold penetration may be a specialized case of sand expansion defects in which individual sand grains are forced into intimate contact with oxidized metal surfaces to start capillary flow.

Regardless of the theory used to explain this phenomenon, it is obvious that basic factors to avoid include the following:

- (1) Any excessive moisture.
- (2) Any increase in metal oxidation.
- (3) Any increase in expansion of sand or increased metal static pressure.
- (4) Any excessive mold temperature.

CAUSES

Casting and Pattern Design

Design is a contributing factor where sharp corners or overhanging or protruding sections are necessary,

or where a thin core or sand section is necessary and is surrounded by a heavy metal section. These hot spots in the mold and core bring the metal or metal oxides up to sufficient temperature to flow as either liquid or vapor into the mold or core pores.

Pattern Equipment

(1) Pattern equipment so constructed as to promote uneven ramming will produce hard and soft spots in the same mold. In many cases, the hard mold penetration in reality is the penetration in the soft areas of an otherwise hard mold. Apparently, the combination of high permeability and low permeability (hard and soft ram) in the same mold forces penetration into the softer sections. Possibly this is the result of high moisture being developed in the open sections (soft ram) during the heating of the harder sections of the mold while pouring. Such uneven ramming is often the result of improper location of the parting line, the pattern on the plate, of sprues, risers, and runners, and inadequate draft.

(2) Multiple patterns mounted too close together are apt to produce a soft ram in the space between patterns. Combining heavy and light sectioned castings in the same mold often causes hard mold penetration. Surprisingly, the small castings seem to be most prone to the defect when this occurs. Possibly, the larger castings drive the sand moisture toward the lighter work or lighter sections and thereby increase the rate of surface oxidation of the smaller castings. This effect in combining castings of various sizes is one of the peculiar characteristics of hard mold penetration as differentiated from soft mold penetration.

(3) Inadequate provision for mold and core venting is a major cause of hard mold penetration. The normal permeability of a dense mold is such as to require extra care in provisions to relieve gas and steam pressure, as well as to prevent entrapment of the air and moisture present in the mold before pouring. Vented flasks, parting line vents, core print vents, and pouring runner relief vents are some of the ways to minimize back pressure and resulting penetration effects. In many cases, excessive areas of green sand will require false runners near the mold and leading to the flask line in order to avoid excessive buildup of water wall steam concentrations at critical areas.

(4) *Pattern equipment constructed to permit excessive metal static pressure tends to increase the degree of penetration in both hard and soft molds. For example, some work can be made either vertically or horizontally in the mold. Preference given to horizontal mounting minimizes the depth of the casting and, therefore, reduces the static head pressure.*

Flask Equipment and Rigging

(1) *Design and construction of flask equipment promoting uneven ramming has the same effect as that described in Pattern Equipment. The factors of flask design which promote this problem include the following.*

- (a) Bars that interfere with ramming of pockets.
 - (b) Flasks too small for the pattern equipment so that it is difficult to ram between the pattern and the flask.
 - (c) Bars that interfere with proper placement of down sprues and risers so that these, in turn, provide a difficult ram or soft pocket.
 - (d) Incorrect contouring of the squeeze board or head so as to oversqueeze some areas and soft mold in others.
- (2) *Excessive cope height increases static head pressure thereby increasing the contact between metal and sand which in turn accelerates capillary flow of liquid or gas metal phases.*

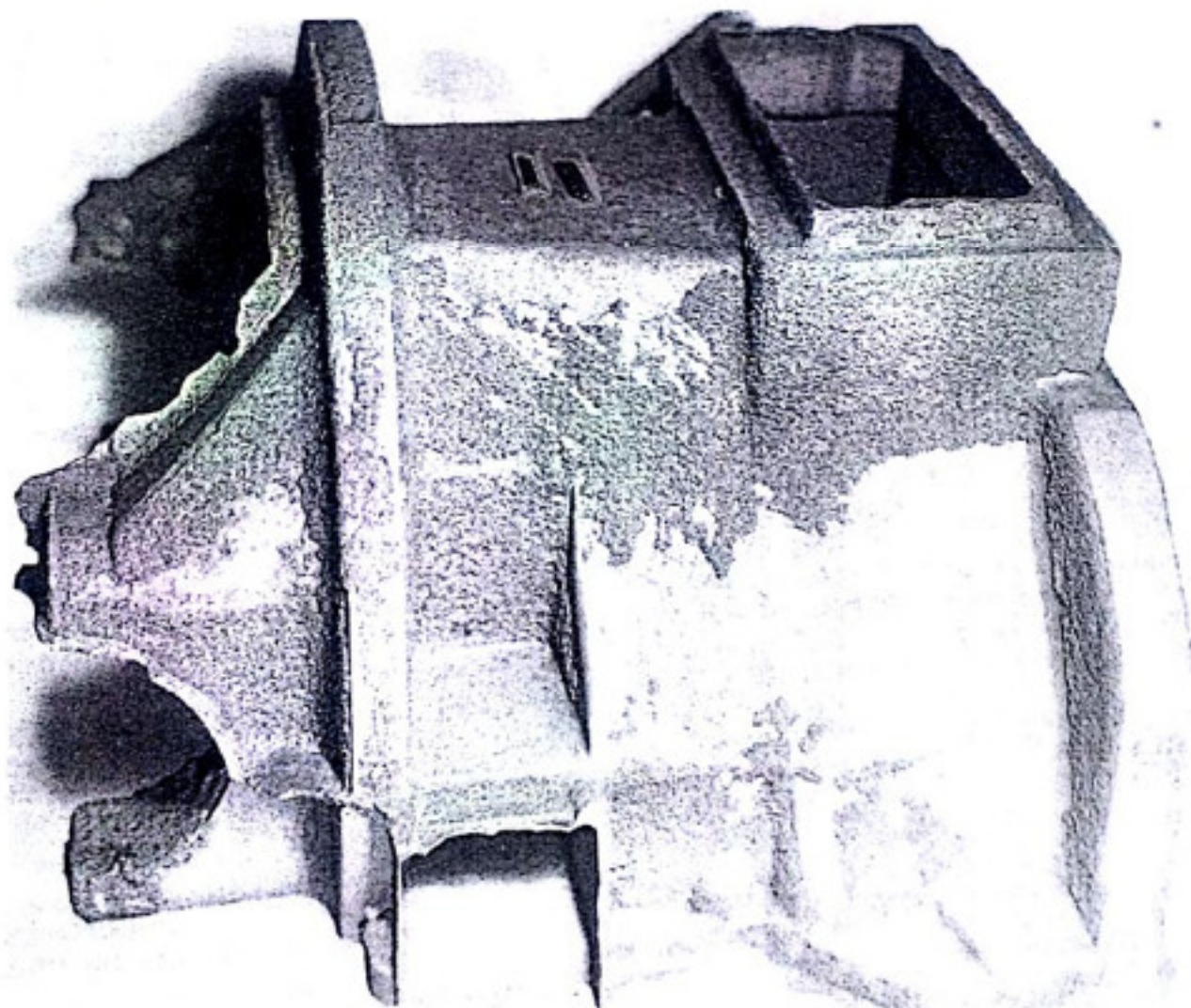
(3) *Lack of venting of flask and bottom boards is particularly harmful when a pattern is close to the flask wall. As the moisture is driven from the mold face, it may build an unusually wet water wall if the steam is not permitted to escape in a normal fashion. See also Pattern Equipment (3).*

(4) *Metal inserts or chills, especially in the cope, act as condensers for moisture moving before or during the pouring of the casting. The condensation effect is sometimes called explosion penetration because it appears to develop a sudden high back pressure and penetration occurs instantly.*

When the chills are in the drag, they may accumulate moisture before pouring, and cause blowholes and similar gas defects. When in the cope, the condensation may take place as the molten metal rises in the mold cavity driving the hot moist air ahead of it.

Gating and Riser

(1) *Location of gates and risers which promote localized overheating of the sand increases the likelihood of penetration. The chilling effect of cold green sand tends to seal the surface and skin the metal so that no penetration takes place. However, as the sand heats up, the metal skin may oxidize and liquefy enough to penetrate. At this stage, no chilling or congealing action is available because the sand is hot. The following characteristics produce such localized overheating.*



A typical hard mold penetration caused from using a green sand mold rammed to 85-90 hardness.

- (a) Sprues or risers set too close to the vertical mold surface.
- (b) Flowing too much metal over a given mold surface.
- (c) Anything which causes excessive pressure of metal during pouring, such as excessive cope height or excessive pouring height.
- (d) Slow pouring which prolongs the time of contact between the sand mold and liquid metal.

(2) *Incorrect ratio of sprue runner and gates* can lead to penetration and other defects related to oxidation or reoxidation of the metal surface. Any part of the sprue, runner, ingate system which is partly empty during pouring permits surface oxidation to take place. Oxidized surfaces are more prone to penetration in both soft or dense molds.

(3) *An oversize riser neck* which overheats the sand in the immediate vicinity of the neck may cause penetration on those sections of the casting close to the neck. This tends to be particularly noticeable on live risers since the metal is hotter in that type.

(4) *Pouring cup or sprue designed so as to permit aspiration of air* during pouring tends to increase the rate of oxidation of the metal surface. Oxidized metals show a pronounced tendency toward penetration when other conditions also favor the defect.

Molding Sand

(1) *Any sand condition that promotes nonuniform density* exaggerates any tendency toward penetration. This effect is obvious in soft mold penetration but is sometimes confusing in dense molds. Close examination frequently reveals that many instances of hard mold penetration actually occur in soft ram sections of an otherwise dense mold. Many times such penetration is greater than that found in an overall soft mold. The factors which contribute to a nonuniform mold density include the following factors.

- (a) Improper distribution of the sand grains which induce poor ramming.
- (b) Low flowability and/or low moldability caused by: moisture segregation (poorly mixed sand); excessive cereal content; excessive moisture; excessive green deformation; poorly aerated sand; and prepacked sand in the muller or hoppers.
- (c) Insufficient coating of shell sand causes poor molding characteristics. This coating may result from roughening of the coating from excess mulling.
- (d) Carbonaceous or deoxidizing material reacts with the water vapor to prevent penetration because water vapor oxidizes the metal. Oxidized metal is more fluid and hence more apt to penetrate the sand.
- (e) Insufficient red iron oxide in steel facing sands or core sands does not provide enough resistance to prevent metal penetration.

(2) *Any sand condition that promotes excess or free moisture in the sand* increases the tendency toward penetration. This could be the number one factor as far as sand is concerned. All theories used to explain metal penetration recognize the outstanding role of moisture and other oxidizing gases.

The excess moisture may or may not be obvious to the feel or apparent temper. Some sands can appear dry or at temper in spite of the fact that they actually contain excess water. Excess water is defined as that moisture in excess of what the clay can absorb under conditions of perfect dispersion. The factors which lead to free or excess water include the following.

- (a) Insufficient or inadequate mulling which permits moisture segregation.
- (b) Insufficient new sand dilution which permits buildup of dead materials, metallic coatings and similar surfaces which take water but do not truly temper.
- (c) Incorrect mulling sequence leads to inadequate slaking of the clay. With new sand blends, the best sequence is water before clay. This is less important in reused mixes because these already contain both clay and moisture.
- (d) Careless measuring of water added to the muller often accounts for excess water.

(3) *Hot sand* is defined as being more than 15-20 F (8-11 C) above room temperature. Such sands do not have proper distribution of clay and water and do not develop the inherent properties of the intended blend. Hot sand may show up as penetration caused by excess water, or as the direct effect of large percentages of uncoated sand grains, rapid drying of the surface, and low hot properties.

Core Practice

The defect involved is a mold defect, not a core defect. However, one characteristic commonly seen in dense mold penetration is that the core surface often penetrates to the same extent. In the case of graphitizing metals a low mold-wall movement resulting from a dense mold will tend to increase the penetration of a cored surface. This is similar to the effect commonly seen in permanent molding.

Molding Practice

(1) *Uneven ramming* is a major source of trouble in supposedly dense molds. This combination of high permeability (soft ram) and low permeability (hard ram) seems to provide high concentrations of moisture in the soft areas. It appears to be unusually important to develop uniformity of ram in dense molds to avoid wide ranges of permeability. Many foundrymen fail to recognize that with high density molding (and lack of uniformity), it is possible to have 40 permeability and 400 permeability in the same mold. Such uneven ramming may result from the following factors.

- (a) Improperly tucked pockets.
- (b) Excessive squeeze pressure in some areas.
- (c) Lack of, or poorly designed, peen blocks which result in soft ram, especially near bars or in hard to ram locations.
- (d) Insufficient jolting to develop density in pockets or at the pattern face.

(2) *Combining high permeability facing with low permeability backing sand* concentrates moisture as cumulations close to the mold surface. A similar effect is found when the molding mechanism permits spring back which in effect produces a high permeability face on the mold.

(3) *Uneven or insufficient coating or spraying of molds* may permit open or porous areas even in a dense mold which can then permit penetration.

(4) *Uneven or insufficiently dried coatings* introduce a prime source of penetration — water.

(5) *Excessive use of parting compounds* is a common source of penetration problems. Many partings reduce surface hot strength and permit rapid disintegration of the sand surface at the time when penetration influences are at a maximum. The excessive partings may be of two types, liquid partings and low fusion dry partings.

(6) *When the Baumé is too low for the type of coating*, the coating may be hard to dry and thereby retain a high moisture surface.

(7) *Not enough facing to cover the surface of the mold* becomes a factor when only the facing sand is of such a character as to avoid penetration. The unfaced portions of the mold may then penetrate as a result of incorrect fineness, excessive moisture or other effects listed under **Molding Sand**. The wrong type of facing has the same effect as insufficient facing.

(8) *Any combination of hot and cold materials* (cores, molds, chaplets, chills) produces condensation of moisture before or during pouring. The free moisture of condensation produces penetration. (See also Chapter 11, **GAS DEFECTS**.)

Metal Composition

(1) *Metals whose oxides have low surface tension* are most apt to develop capillary flow into the voids of the sand mold, assuming that these liquid oxides also have a molecular affinity for sand. In ferrous metals, for example, increases in the FeO content of fayalite films increase their ability to wet and penetrate sand surfaces. In contrast, aluminum oxide films have high surface tension and are less prone to penetration of dense molds.

(2) *Metals with high vapor pressure at the required pouring temperatures*, for example, gray iron, have measurable vapor pressure at 2600 F (1427 C), but the vapor pressure of iron at the pouring temperature of steel is approximately ten times as great. Aluminum in contrast, does not develop measurable vapor pressures below 2000 F (1093 C). Vapor pressures of brass and bronze vary with composition. Lead has pronounced vapor pressure at the pouring temperature of bronze.

(3) *Metals whose oxides react chemically with sand* develop fluid complex silicates which have outstanding penetration ability. A typical highly reactive oxide

is FeO which combines to produce a low melting point compound — fayalite.

Melting Practice

Melting practice which leads to oxidation increases the tendency toward metal penetration. Such practices include the following.

(1) *Excessive use of deoxidizers promoting fluidity*. This results from erratic oxidation practices.

(2) *Melting too hot* increases the tendency toward oxidation buildup.

Pouring Practice

(1) *Excessively high pouring temperatures* lead to penetration by heating the sand, increasing fluidity of metal and metal oxide films, and tending toward oxidation in the ladle and in the gating system of the mold.

(2) *Excessive pouring height* develops high metal pressure during pouring which increases the pressure of contact between the sand and metal (same as excessive cope height).

Miscellaneous

(1) *Any factor involving free moisture in the mold cavity* accelerates penetration, since moisture is a powerful oxidizing agent when in contact with molten metal, and because steam pressures in the mold act to develop intimate contact between the sand and metal.

(2) *Shaking out too cold or too late* will cause penetration in castings which would be free of such defects if removed from the sand contact while still hot. This penetration in the solid state (after solidification) is typical of many instances of hard mold penetration. In some production units, a temporary shut down of the line, such as over the lunch hour or breakdown, is enough to cause penetration of otherwise good castings.

(3) *Metallic-coated sand* (lack of new sand dilution) tends to increase the percentage of free or excess water. Metallic-coated sands also develop low fusion characteristics which accelerate the fusion aspects of penetration. In ferrous practice, these metallic-coated sand grains can be identified because they are magnetic. In nonferrous practice, identification must be by microscope, or by circumstantial evidence such as increased demands of the sand for water and clay coupled with a simultaneous increase in permeability.

(4) *Sand or binder reacting chemically with metal oxides* may increase penetration such as in the case of sodium silicate and certain furfural alcohol core binders.

Chapter 18

MISRUNS AND COLD SHUTS

DESCRIPTION

A **misrun** casting is one which lacks completeness due to failure of the metal to fill the mold cavity. There may be a smooth round-edged hole through the casting wall or one or more extremities may be only partially filled out. Figure 18.1 shows a typical misrun.

A **cold shut** casting is one in which a definite discontinuity exists due to imperfect fusion where two streams of metal have converged. This defect may have the appearance of a crack or seam with smooth, rounded edges (see Fig. 18.2).

Both of these defects may be duplicated in appearance by a gas defect. In some cases, a runout may also be confused with a misrun. There are times when a rat-tail may be confused with a cold shut. (Breaking the casting through the defect will identify this one.) The misrun or cold shut may actually be a gas defect. Therefore, it is well to check Chapter 11, GAS DEFECTS, before assuming that cold metal is the only cause.

Both misruns and cold shuts are quite common in the foundry. In many cases, these represent the number one or number two source of unsalable cast-

ings. These defects are usually found by inspection and, therefore, most of the scrap is discovered at the foundry and not in the machine shop or customer's plant. These defects are also unique in that they have many causes found in almost every process in the foundry, except in the cleaning operation.

CAUSES

Casting and Pattern Design

- (1) *Nonuniform casting sections resulting in interrupted metal flow.* Some designs are almost impossible to gate properly because of thin sections in inaccessible locations. When possible, such designs should be modified. Whenever design change is not possible, it becomes necessary to introduce rather complex gating practices. See also Chapter 25, SCARS, SEAMS, PLATES.
- (2) *Metal section too thin for area involved.* This design fails to take into account the laws of metal flow and solidification. If the designer cannot thicken the section, the only recourse is to increase melting and pouring temperatures or modify the chemistry to develop better fluidity. Changing to a nonchilling mold (core) is sometimes the better method of compensating for the poor design. All of these practices raise the cost, so design should be changed when possible.

Pattern Equipment

- (1) *Worn patterns or core boxes causing thin metal sections.* Sand is rather abrasive material so equipment will wear. Sometimes the problem stems from abuse causing nicks or dents which must then be polished out. The only cure is to set up a regular inspection technique to catch this worn equipment before the sections are reduced to a point of causing a misrun or cold shut.
- (2) *Patterns not made according to blueprint.* This problem may stem from inaccurate or illegible drawings, poor interpretation of symbols and marks, careless blueprint reading or lack of supervision and quality control in the pattern shop. Inspection of patterns should be standard. Particular care must be exercised to check the allowed tolerances.
- (3) *Pattern equipment not properly reinforced.* Without adequate reinforcing, patterns and core boxes cause distorted molds and cores when the equipment yields under the pressure of molding or core-making. This in turn creates thin sections of metal

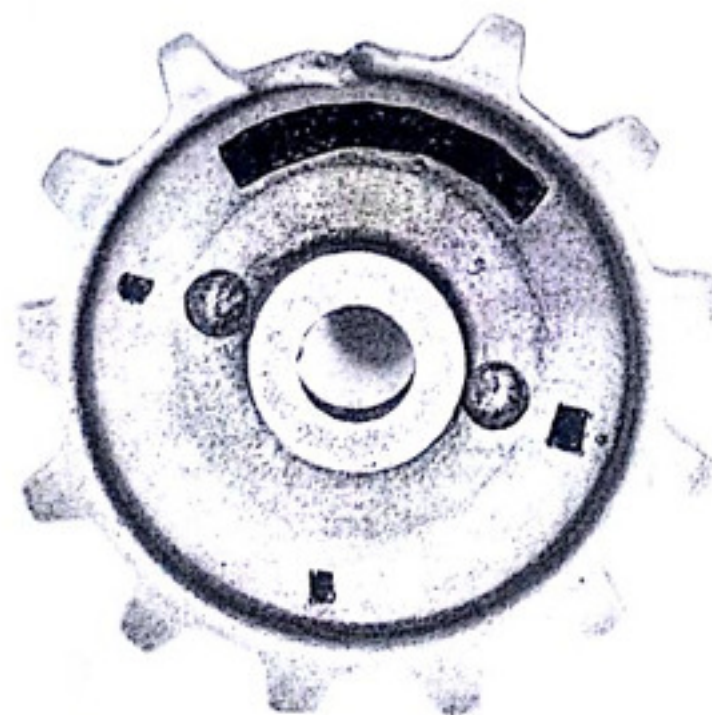


Fig. 18.1 — Typical misrun; one tooth is missing completely.

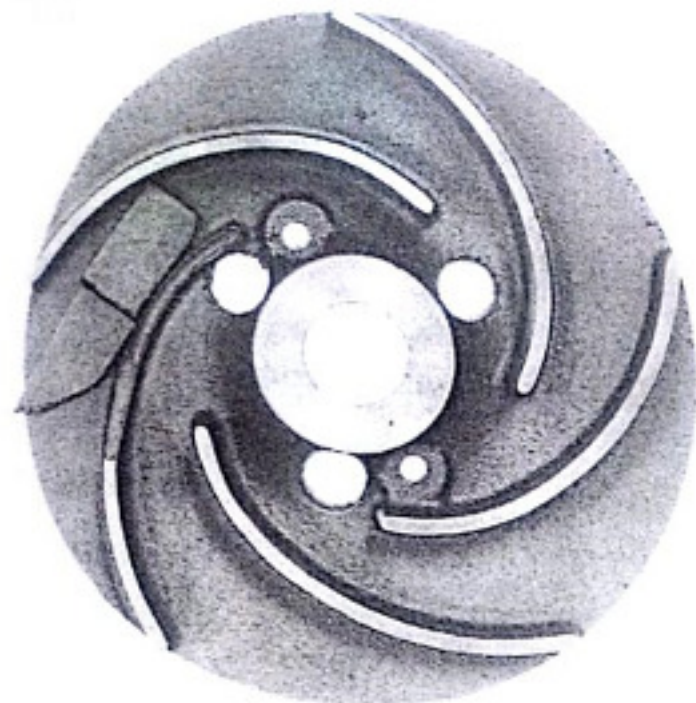


Fig. 18.2—Typical cold shut on impeller casting. The defective vein was broken away from the casting to demonstrate the cold shut section.

which do not run as anticipated. The correct procedure is to reinforce.

(4) *Misalignment of pattern or core equipment.* A common contributor to this defect is worn pins and bushings. The original cause may be a small pin or bushing which results in rapid wear, or it may be the number of pins used. Too few pins carrying the load may show unusually rapid wear. One should keep in mind that inadequate or small pins will wear with unnecessary rapidity.

A misalignment may also occur when mounting split patterns by centerlines on cope and drag plates. This match cannot be proven without a sample casting. Inspection becomes the primary cure for this problem.

Flask Equipment and Rigging

(1) *Cope and drag shift causing thin metal sections.* This is usually a routine maintenance problem involving worn pins (or using the wrong pin), bent pins, worn bushings, or foreign matter in the seat of the flask ear. It may be careless molding such as reversing the cope. Maintenance on such equipment should be regular since shift is a major source of trouble.

(2) *Patterns not properly mounted.* This is usually negligence on the part of the personnel doing the mounting. The matching centerlines on pattern and boards must be sufficiently prominent to provide for easy checking by layout.

(3) *Lack of tilting for thin flat castings.* Some thin work will develop gas locks and cause interrupted flow of metal unless tilting is incorporated in the rigging. This may be left up to the molder or may be built into the pallet board or conveyor car. When tilting is done to smooth the metal flow, it is important to do it in such a way as to provide sufficient cope height over the highest point of the casting (after tilting).

(4) *Flask insufficiently barred allowing cope to sag.* The amount and type of bar depends upon the sand and the molding energy. In high pressure molding, it is common to remove bars and depend on hard molding and unusually rigid flasks. In softer molds, however, adequate support is needed. In addition, the bars must be properly designed to support the sand by incorporating holes, flanges, and the like as needed, and by keeping the flasks and bars in proportion to the pattern.

It is common, but false economy, to use a flask not designed for the job. In such a case, temporary bars may be bolted in to provide the support needed. A defect occurs if the cope sags enough to produce a thin section on the casting.

(5) *Distorted or dirty jackets.* These are usually the result of rough handling by the personnel that strip the jackets and handle the shakeout. Oftentimes a run-out causes a distortion or a welded roughness which is not caught before molding. When these jackets are used, they can create thin sections that then misrun or cold shut. In a more severe case, they can cause a crush; thus, the misrun is a form of crush.

Frequent checking of equipment by use of a dummy block will prevent the defect. Rough handling should be discouraged and personnel trained not to set faulty jackets.

(6) *Weak or improperly reinforced flasks.* These can permit mold distortion to the point of misrun or cold



Fig. 18.3—Misrun caused by too small gates which froze before casting filled.

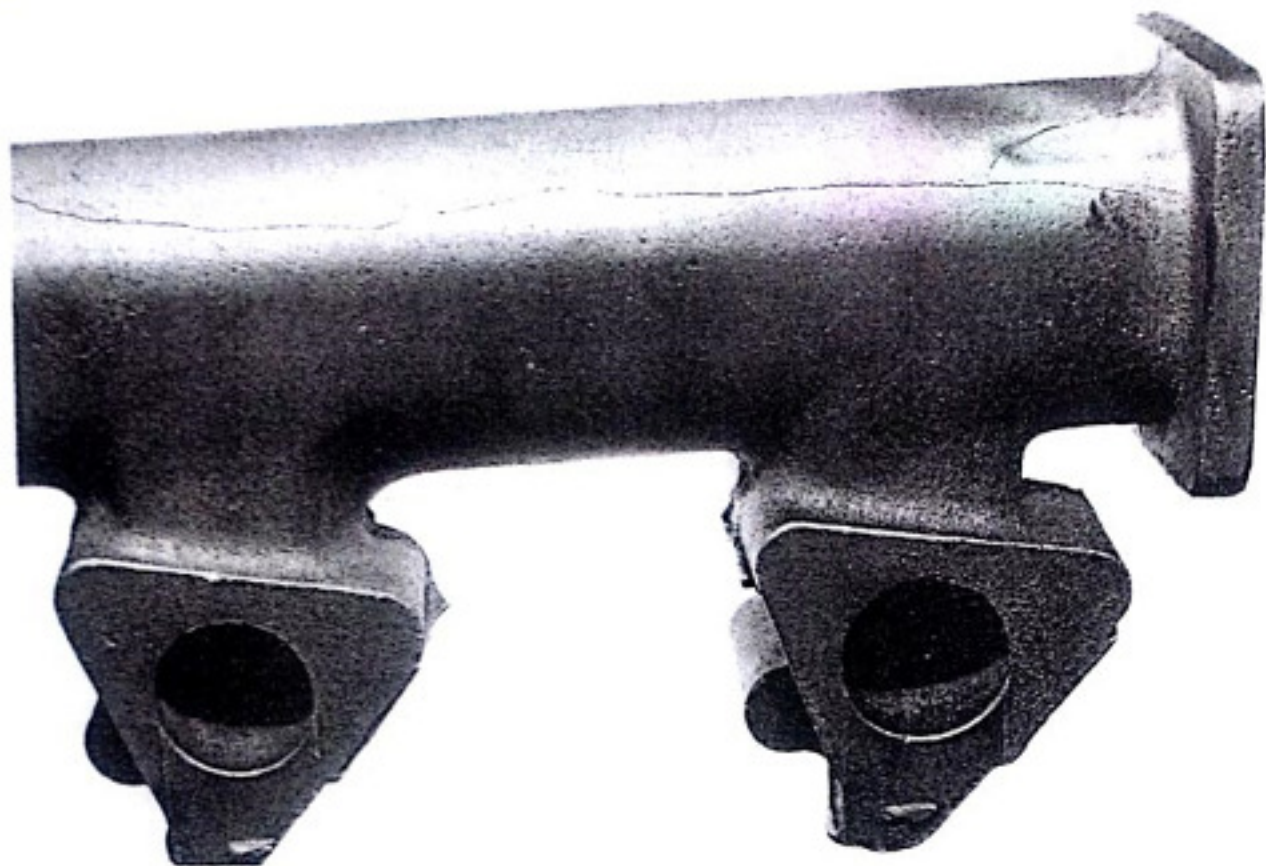


Fig. 18.4 — Cold shut caused by small ingates.

shut. The use of such flasks often stems from a false economy in buying equipment, or may be the result of changing to a heavier operation and continuing use of worn or inadequate flasks. Increasing squeeze pressure requires flasks which are designed for rigidity. Older flasks can often be reinforced.

(7) *Distorted bands.* Such bands also permit mold distortion, thin sections, and cold shuts. The bands may be too light for the job or may be impaired by abuse and old age.

(8) *Cope flask too shallow.* A shallow cope flask may permit a cope sag which pinches off the metal section to the point of a misrun. In heavier work, this shallow cope would probably lead to shrinks and blows because of inadequate metal pressure, but in lighter castings the result will be a crush or a tendency toward misrun defects.

Gating and Riser

(1) *Improper sizing of gates, runner and sprue.* The gating system must be designed so that the sprue and runners are of adequate size to supply metal to all gates evenly, and to keep the gates full in order to avoid interrupted metal flow. See Figs. 18.3 and 18.4.

The nonpressure system depends upon a large basin under the sprue. With this system, it is imperative that the runner be in the drag and the gates in the cope in order to avoid prefill and spatter. The ratio of sprue, runner and ingate (total area) with this system is $1/4/4$.

The pressure approach depends upon decreasing the area in order to keep the metal flowing with a completely filled system. It is especially desirable in metals prone to pinholes and inclusions, and in cases where a positive pressure is required to minimize blows and shrinks. With this system, the ratio of sprue to runner (total area) to ingates (total area) is

$1/0.9/0.8$. It is most desirable with this system to keep the runner and casting close coupled (short ingates) in order to develop maximum feed ability. Other ratios are used with success by the industry. The basic principle of smooth flow and a full gate system to prevent interrupted flow must be kept in mind.

(2) *Gates not properly located.* The proper location depends entirely upon casting design. How the mold cavity will fill and the probable flow pattern must be visualized and the gates located accordingly.

(3) *Improper distribution or balance of gates.* This results from not correctly anticipating the actual metal flow. Since metal friction, cooling phenomena and metal fluidity are factors in addition to the usual considerations of liquid flow, it is often impossible to anticipate the exact sequence of filling the mold. In this case, it is helpful to check the flow pattern by a deliberate short pour. For example, if a casting normally requires 20 sec to pour, one mold may be poured for 5 sec, one for 10 sec and one for 15 sec. These three partially filled castings, when cleaned up with gates attached, disclose the metal flow pattern which actually does exist. From these data, an excellent job of gating should be possible.

(4) *Too low head pressure* may also be a cause of misruns.

Molding Sand

(1) *High moisture*, causing metal to boil and lose fluidity can result in misruns and cold shuts.

(2) *Sand too high in volatile matter.* Excessive volatiles fill the mold cavity before the metal has an opportunity to fill out the desired shape properly. The result may be a gas lock or gas seam which prevents knitting of the metal when the metal does reach its normal position. This can show as either a cold shut

or misrun depending upon the amount of gas and the permeability of the mold.

(3) *Weak backing sand causing cope to sag.* A sagging cope, be it from inadequate bars or weak sand, pinches off the thinner sections and creates thin walls which won't fill with the metal fluidity available.

(4) *Permeability too low.* This factor is related to both (1) and (2). If the permeability is too low for the amount of gas present, a gas seam or gas lock can result. In addition, but less common, the high density (low permeability) sand extracts heat from the metal more rapidly and may set the casting before the mold is filled.

(5) *Too high heat transfer molding material.* Aside from the density factor (4) mold materials differ in the rate at which they extract heat and set the metal. An outstanding example of this would be the difference between a permanent mold and a sand mold, but even in green sand there are definite differences between silica, olivine, and zircon.

Core Practice

(1) *Cores too hard for sections of metal involved.* It is often difficult for metal to lie to a hard core. The resulting boiling action creates preliminary freezing.

(2) *Insufficiently vented.* Any gas which becomes trapped can cause a gas seam, especially if the gating system permits any amount of interrupted flow.

(3) *Cores not properly sized or fitted allowing decreased metal sections.* Movement of cores pinches off the metal sections to the point where the available fluidity of metal is not adequate to prevent misrun or cold shut.

(4) *Excess wash, mudding compound or paste on core.* In close tolerance work, or thin sections, the additional dimension from coatings may be enough to change the cavity beyond permissible tolerances.

(5) *Raised or sagged cores.* These have exactly the same effect as a raised drag or a sagged cope — metal sections become too thin.

(6) *Core shift causing thin metal section.* This is a modification of a raised or sagged core.

(7) *Distortion.* Distortion due to thermoplasticity of binder (shell or underbaked oil-bonded cores) is a cause. Such warpage during pouring acts as a core shift to pinch off thin sections.

(8) *Reinforcing rods too close to core surface.* Such rods provide a chilling effect on the metal, thereby retarding normal flow and reducing metal fluidity.

(9) *Heat transfer.* Core material with too high a heat transfer has the same effect as described in **Molding Sand (5)**.

Molding Practice

(1) *Hard ramming causing low permeability.* Permeability is a function of ramming up to about 85 mold hardness. Above that no measurable change takes place. Sands designed for soft ramming may create problems when rammed up to full density.

(2) *Uneven ramming.* Uneven ramming tends to

modify metal flow because of the variations in sand density developed. This changes the flow patterns or creates localized chilled sections which can then cold shut. It is a localized low permeability.

(3) *Soft ramming allowing cope to sag causes thin metal sections.* Sand does not have laboratory properties except when rammed to the same density as the three-ram laboratory specimen.

(4) *Mold insufficiently gagged or barred allowing cope to sag.* This is the same effect as described in **Flask Equipment and Rigging (4)** whether it be the responsibility of the molder or the rigger.

(5) *Improperly bedded or clamped bottom boards.* Such bottom boards permit the drag face to be pushed up. This results in a thin metal section as in the case of a cope sag. The common mistake in this area is to clamp a dirty or distorted board, or to inadequately strike off the drag before clamping.

(6) *Excessive slicking or patching.* Assuming that this did not cause a scab or buckle, the effect would be the same as a boil or a change in heat conductivity.

(7) *Thin flat surface molds set level instead of tilted.* The effect is the same whether the responsibility rests with the rigger or the molder.

(8) *Wrong dimension chaplet used allowing the core to raise.* A core raise causes a thin section which will not fill with the metal fluidity available.

(9) *Too small a stem chaplet or too few chaplets allowing the core to raise.*

(10) *Too heavy coat of wash.* A heavy coat of wash on either core or mold can change the dimension enough to pinch off thin sections of the casting.

(11) *Careless cutting of the sprue (missing the button).* This is a man-made problem giving the same effect as an inadequate down sprue.

Metal Composition

Fluidity may be too low for section involved. Fluidity control is a function of metallurgy, including melting practice. The following paragraphs discuss the fluidity of various metals which may lead to misruns or cold shuts.

(1) *Gray, malleable and ductile iron.* The carbon equivalent may be too low or too high for the section involved. In general, the harder, stronger (low carbon equivalent) irons are most apt to cold shut or misrun because of low fluidity. An unusually high carbon equivalent can also produce trouble especially if primary graphite is thrown out of solution. This is often referred to as a kish lock. Excessive carbide stabilizers have an effect similar to a low carbon equivalent. Excessive graphitizers may create a kish lock. Phosphorus may be too low (gray iron). Phosphorus creates a low melting point eutectic to improve fluidity.

(2) *Steel.* Composition change from low carbon to high carbon plus various alloys modify the essential metal fluidity. Steel has a high emissivity (rate of heat loss) which tends to reduce fluidity rapidly when in contact with a cold or wet mold.

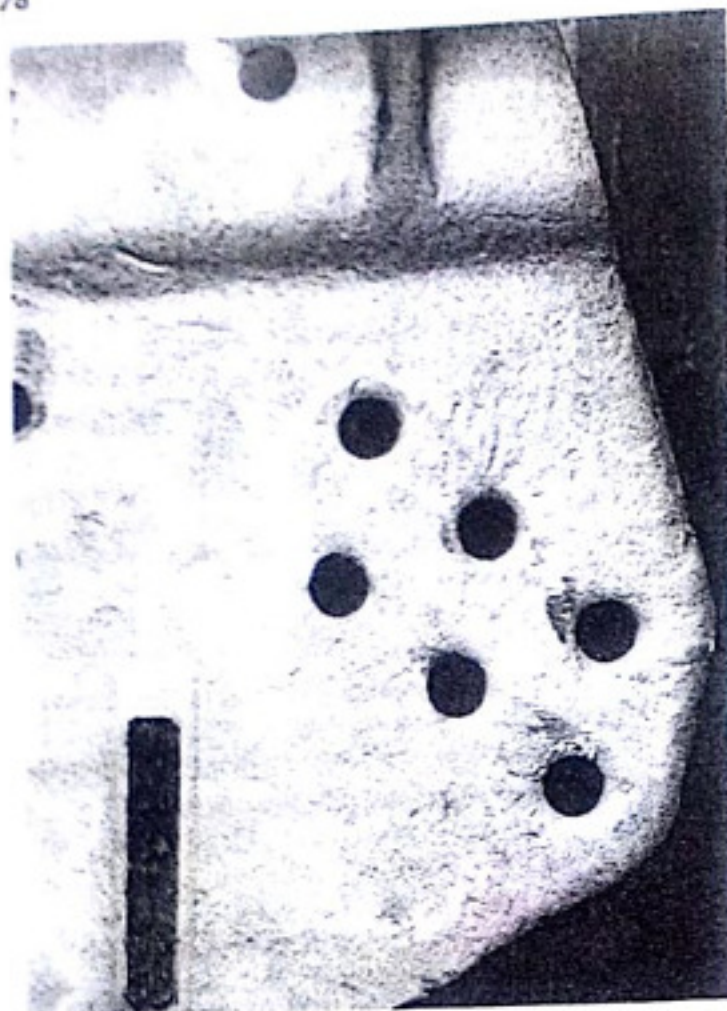


Fig. 18.5 — Cold metal poured during first part of heat caused poor definition of both the edges and cored holes.



Fig. 18.6 — Same kind of casting as shown in Fig. 18.5 after correction of fault.

(3) *Brass and Bronze.* The wide range of alloys in this classification vary widely in their fluidity. The method of improving fluidity depends upon the alloy type involved.

(4) *Aluminum Alloys.* Low fluidity compositions can often be improved by increasing silicon or iron and by decreasing the sodium content. Gassy or dirty metal is particularly prone to cold shuts.

(5) *Magnesium* fluidity can be improved by changing to a composition closer to eutectic.

Melting Practice

(1) *Wrong composition due to careless weighing or charging.* When composition is a factor, it is important that scale maintenance and other such factors provide assurance that the composition is correct. This applies to all metals.

(2) *Cold melted or sluggish metal.* It is obvious that a basic cause of misrun is cold metal, regardless of the kind. See Figs. 18.5 and 18.6.

(3) *Oxidized or gassy metal.* Whether it be caused by wet refractories, turbulence or lack of atmospheric control, oxidized or gassy metal regardless of kind will reduce the fluidity. For example, a fast, hard furnace practice in malleable usually yields a low fluidity metal which can result in both cold shuts and pinholes. Nonferrous metals are particularly prone to pick up undesirable gas from poor furnace practice. A low coke bed in cupola melted gray iron has a similar effect.

(4) *Over reduced metal.* This can create a problem from hydrogen absorption. It is particularly common in aluminum but is a factor in all metals.

(5) *Excessive ladle additions.* Such additions have the direct effect of reducing temperature and thereby reducing fluidity. In most cases, this chilling effect is not just the presence of a few pounds of cold alloy; the heat of fusion required to melt and dissolve the metal is a major temperature loss with many alloys.

(6) *Damp ladle additions.* Damp ladle additions provide an additional temperature loss and produce cold metal.

Pouring Practice

Pouring is probably blamed for the major percentage of misruns. It is an important factor but it is also important to regard all the other possibilities. The fact that the pouring practice is the most obvious doesn't necessarily mean that it is the actual cause. When it is the cause, however, it may be ascribed to one of the following reasons.

(1) *Pouring temperature is too low.*

(2) *Interrupted pouring* produces an uneven fill and permits oxide films or gas to prevent knitting of the metal after pouring is resumed (see Fig. 18.7). Letting the sprue drop (not keeping sprue filled) also acts as an interrupted pour.

(3) *Reducing the rate of pour too soon* may reduce the pressure needed to finish filling the mold cavity. This is especially pronounced with castings that have bosses in the cope or when the cope is shallow.

(4) *Boiling metal* from any cause such as wet spout, wet lining, wet lips, or refuse in the ladle reduces both metal temperature and fluidity.

(5) *Thin flat castings poured on the level* may cold shut whether the tilting is the responsibility of the rigger, molder or metal pourer.

(6) *Pouring pressure reduced by runout* may cause an interrupted pour or act the same as reducing pouring pressure too soon.

(7) *Slag, dirt, or ladle refractory which stops off the gate* acts as an interrupted pour or a reduced pouring rate.

(8) *Pouring short* for any reason reduces the feed pressure just as does a short cope. If the cope is shallow, even a slightly short pour may bring the pressure level lower than the top of the casting. If a misrun does not result, a blow or shrink is apt to develop. In fact, blowholes in cope bosses are commonly related to misruns and may be confused with them when short pour is the fault.

(9) *Pouring too slowly* prevents an adequate gate from filling the mold fast enough to prevent a cold shut. Slow pouring also is a primary cause of expansion defects. A tendency toward a cope expansion further aggravates the tendency to cold shut.

(10) *Not keeping sprue, runner, and gates full* acts as an interrupted pour or inadequate pressure. In addition, this practice permits air entrapment which reduces fluidity of metals (especially nonferrous), or allows rapid oxide film formation in pure metals such as steel.

Miscellaneous

(1) *Chills and chaplets too large for section.* These act as a chill to reduce fluidity to the point of cold shut. The cold shut may appear at the chaplet or at a slight distance.

(2) *Reduced metal section from any cause, e.g., ex-*



Fig. 18.7 — Cold shuts (laps) due to interrupted pouring.

cess mold weights. If this is carried to extreme, a crush results but a minor change in the dimension of a thin section can lead to misrun.

(3) *Condensation in mold cavity on thin-sectioned work.* Condensation acts to reduce metal fluidity and also to create a gas lock. The various forms of condensation phenomena are covered in greater detail in Chapter 11, GAS DEFECTS.

OFF DIMENSION RELATED TO CORES

DESCRIPTION

An off dimension defect is an incorrect dimension occurring as a result of the wrong core being used, correct cores improperly set, cores omitted, or cores incorrectly assembled. Many other aspects of molding may create an off dimension (shifts, swells, etc.) but the specialized situation of assembling or setting core assemblies does not logically fall into any of the other categories. Hence, it is handled as a separate defect to make sure that these problems are not ignored. On many occasions, the faulty core assembly leaves a mark or dimension change which is rather mysterious until one considers the possibility of omitting core paste, or too much core paste, and similar careless core practices. Figure 19.1 illustrates the result of not cleaning core assembly before setting mold.

CAUSES

Casting and Pattern Design

Design does not contribute to this problem. It is strictly a foundry or pattern shop error.

Pattern Equipment

(1) *Unidentified locators and prints* permit the core setter to make a mistake, even to the point of omitting the core. Figure 19.2 shows a casting with the core left out because print was not identified.

(2) *Improper or broken telltales* or lack of them encourage error in assembly. In some cases, the original pattern may have been properly marked but the telltale is later broken. Pattern inspection before production can prevent this loss.

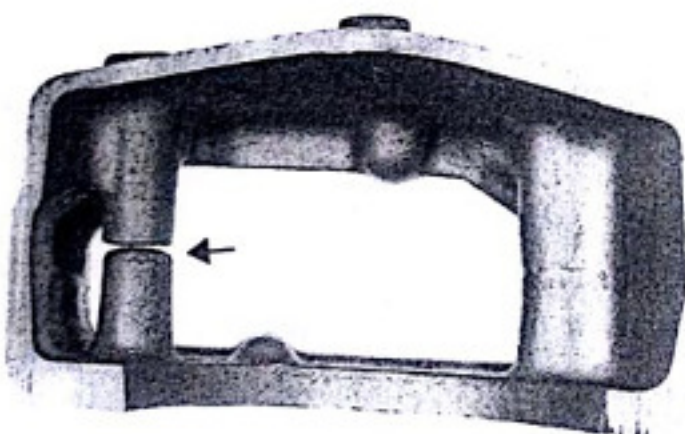


Fig. 19.1 — Result of not cleaning core assembly before setting core in mold. Boss was intended to be solid.

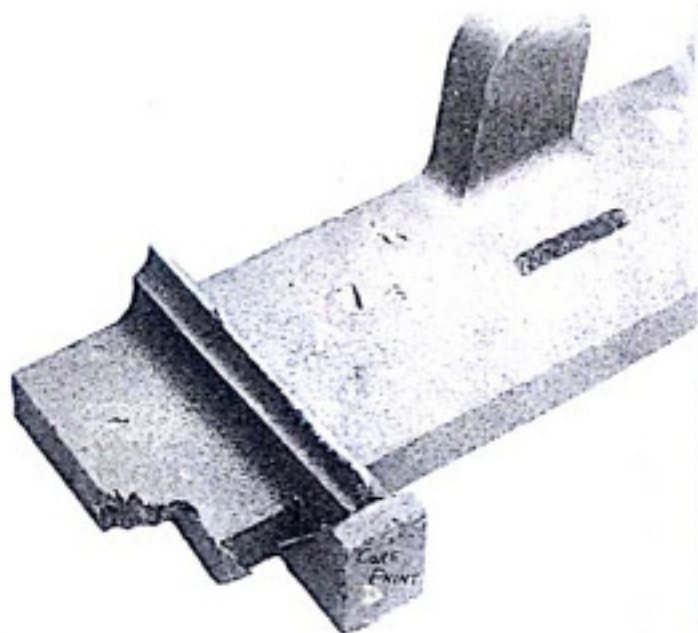


Fig. 19.2 — Core left out of casting because print was not identified.

(3) *Improperly marked core boxes and patterns* have resulted in cores being omitted — or set in the wrong mold (see Fig. 19.3).

(4) *Faulty core box construction* causing distortion results in an off dimension core not obvious to the core setter. The result could be a thin or thick section of metal or inadequate contact with the core print.

(5) *Core prints* that are too large or too small will result in a core shift and an incorrect dimension and may also be a source of crush (see Fig. 19.4).

(6) *Chaplets whose locations are not identified or size marked* will result in a form of core shift. On occasion, the location may be marked but if the correct size chaplet is not specified, the core setter can err. With no locators marked, he may set too many or too few chaplets. Too many chaplets could result in leakers or cold shuts; too few could result in a sag or floating core.

Flask Equipment and Rigging

(1) *Arbor or chaplet locators in flask* that are not properly identified or located are the same problem as **Pattern Equipment** (6) except this applies to flask equipment rather than pattern equipment.

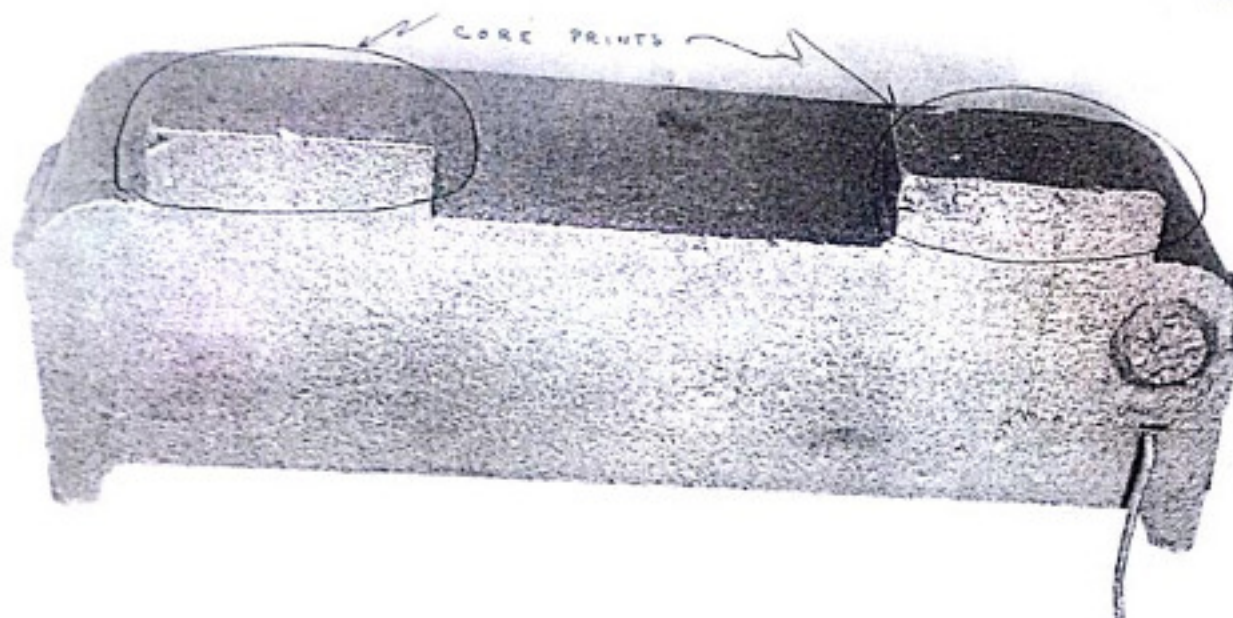


Fig. 19.3 — Improper marking of the pattern caused the mold-er to leave required cores out of a casting.

(2) *Loose pins and bushings* may result in a shift of the core assembly or in two sections being misaligned. In automatic blow equipment, a loss of accuracy in the pin or bushing segments may produce an improperly filled box.

Gating and Riserling

Excessive pressure of metal against cores can cause a core motion during pouring (see Fig. 19.5). This can occur because of the design of the gate causing metal pressure on one side of the core.

Molding Sand

Since this is a core defect, molding sand is involved only in the case of a green sand core or top core.

Core Practice

(1) *A wrong core used in the assembly* may result from **Pattern Equipment** (1), (2), or (3). There may also be a confusion between two similar core boxes resulting in the wrong core being produced, or sent to the molding station.

(2) *Setting cores end for end, upside down, or in the wrong sequence* are examples of improper setting in the core assembly. On occasion, it may involve failure to set one or more cores in a complicated assembly.

(3) *Improperly marked cores for the application* may be due to confusion in the box number, broken or unreadable identification marks, or simple confusion of two similar boxes.

(4) *Sagged or distorted cores*, from an incorrect mix, rough handling, or some other factor will result in an incorrect dimension in the casting.

(5) *Too much or lack of paste* changes the dimension of pasted cores or pasted core assemblies. Sometimes the defect shows as a vein or even a mark which is easily confused with a buckle. Figure 19.6 shows marks left on cored surface because paste was not removed.

(6) *Wash coating which is too thick or too thin*

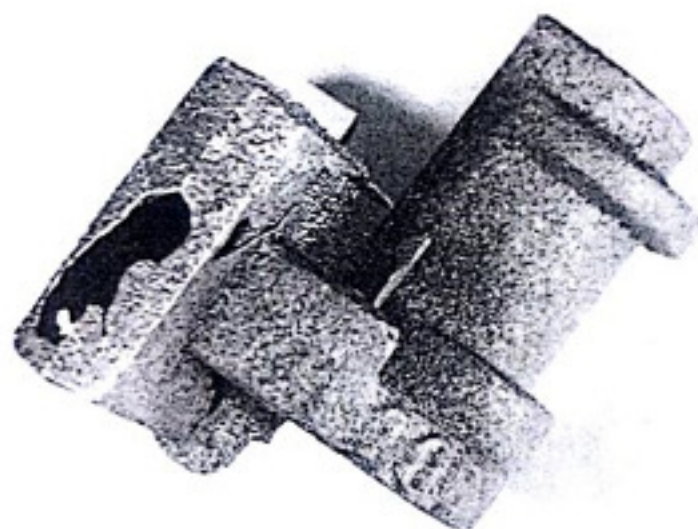


Fig. 19.4 — The large core print permitted metal flow around the entire core.

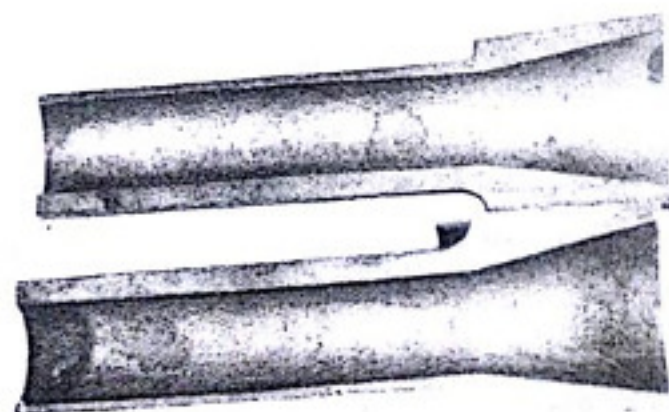


Fig. 19.5 — Excessive metal pressure caused the core to warp during pouring.

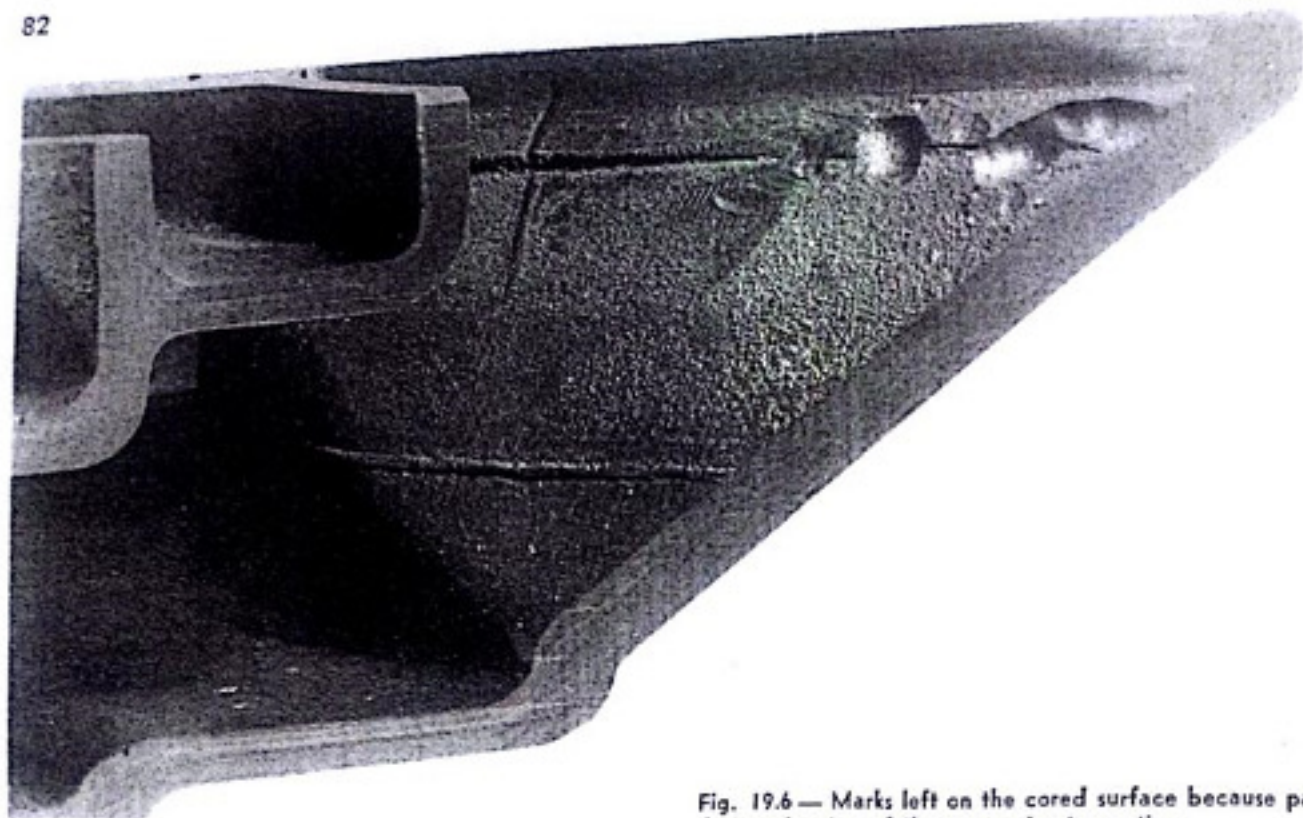


Fig. 19.6 — Marks left on the cored surface because paste was not removed during cleaning of the core prior to casting.

can cause a change of dimension which may be serious in accurate practice. In some cases, the core box is designed with no allowance for a coating, but a coating is used. In other cases, the situation may be reversed. Often this is because of lack of accurate records or a breakdown in interdepartment communication.

(7) *Improper rodding* permits core sag or distortion as described in (4).

(8) *Nonsagging core mixes* used in boxes with sag allowance may occur as a result of a basic change in core practice such as from an oil to an air set or self-curing binder.

(9) *Uncured cores* can cause casting dimension changes.

Molding Practice

(1) *A common mistake is to set cores improperly*, especially with a strange or new job, and to inadequately mark cores. Better practice provides for core print design that makes it impossible to reverse or otherwise set incorrectly.

(2) *If cores are left out* it is due to inexcusable carelessness, but it does happen, especially if core prints are not properly indicated and someone fails to produce or deliver cores to the molder.

(3) *Setting defective cores* can be eliminated by adequate core inspection before the core leaves the core room.

(4) *Improper filing or rubbing of cores* is usually a situation in which a print or section is slightly oversize. In the process of making it fit, the molder may overrub the core with file or stone. Improper fit of the core in the print also can occur because of failure to ram sufficiently or failure to remove loose sand from the print.

Metal Composition

Metal composition is not a factor in off dimension cores.

Melting Practice

Melting practice has no effect on core assembly.

Pouring Practice

(1) *Pouring too hard* can move a weak or poorly printed core.

(2) *Pouring too hot* causing core distortion may occur especially with thin long cores.

Miscellaneous

Carelessness in any phase of the coremaking or core assembly process is the most common source of this defect.

Chapter 20

OPEN GRAIN STRUCTURE

DESCRIPTION

Open grain structure is a condition wherein a casting, when machined or fractured, appears too coarse grained for the application. This structure may be general or it may be localized. Figure 20.1 shows open grain iron.

It is often difficult to differentiate between open grain, porosity, microshrinkage and gas. As a result, it may be desirable to check each of these sections before making a final diagnosis. The defect referred to as open grain is essentially a metallurgical-type defect, so the important areas of control are design, gating, composition and melting practice.

CAUSES

Casting and Pattern Design

(1) *Metal section difference.* Too great a difference in metal sections, causing the heavy sections to be open grained due to slow cooling should be avoided. This design type is especially prevalent in metals, such as gray iron, which are section sensitive. When differences in section are great, a composition is required which yields sufficient machinability in the thinner sections. As a result, the metal is incorrect for the heavier sections with their slower cooling rate.

The obvious cure is to request a redesign in order to eliminate the excessive discrepancy in section size. Since this avenue of escape is generally not available to the foundryman, he may minimize his problems by the use of chills, controlling pouring temperature, or by selective gating. The use of chills increases the cooling rate of the heavy sections. Excessive pouring temperatures aggravate the problem and should be eliminated. The gating practice may be modified to put the colder metal in the heavy section. Risers on the heavy section should be designed for maximum efficiency so as to be as small as possible.

(2) *Lack of provision for coring heavy sections that are later drilled out or machined.* Many of the modern machining techniques permit just as fast machining of solid sections as those with cored holes. The designer may rely on this fact and eliminate the use of cores which would serve to reduce the effective section size. The result is an excessive section for the metal compositions involved.

It is frequently possible to have a core introduced in the heavier sections unless the design also prevents adequate core prints. Spring chills may be used to

tighten the grain if the subsequent machining operation permits this.

(3) *Sections promoting heat retention.* In some cases, the metal section is not excessive but a confined pocket or core creates a hot spot which gives the same effect. For example, stud bosses in the deeper portions of the casting may require a core design which promotes slow cooling. In cases where no design modification is possible, the best approach is to use chills in the core or mold section unless it can be modified by a reduction in metal temperature or a relocation of gates.

(4) *A design requiring the removal of excessive metal during machining.* It is not unusual to see designs which not only involve high machining costs, but



Fig. 20.1 — Open grain.

which also require removal of the denser sections and exposure of the slower cooling center sections of metal. This type of design helps no one.

The only correction if a design change is not permitted is the usual use of chills, temperature control and gating. In this case, however, the foundryman can frequently get a design change if a proper appeal is made, because it is easier to demonstrate the poor economics of both the casting and the machining aspects of the design.

(5) *Liaison*. Lack of liaison between designer, patternmaker, foundry and machine shop is a factor. This may come about by a management decision which does not take into account the need for cooperation. It may be largely a lack of understanding of the other man's problem or an honest divergence of opinion. In either event, the best cure is to develop a common meeting ground based on facts and costs. For example, an accurate record of rejected castings, salvage cost and unnecessary machining costs will go a long way toward a meeting of the minds. Costs and profits make a common language between men of different technical interest.

Pattern Equipment

(1) *Improperly cored heavy sections*. These effects are the same as those described in **Casting and Pattern Design** (2-5). The only difference is whether the problem is inherent in the design, or whether provision for proper coring is the responsibility of the pattern shop. For example, the pattern may be mounted in such a way as to prevent the use of lightener cores as by inadequate provision for core prints.

(2) *Incorrect core supports*. Pattern equipment is also involved if a metal section is changed through the use of incorrect core supports or other techniques which involve a core shift. Pockets of sand which create hot spots and slow cooling may be a question of pattern design and mounting rather than incorrect design of the part.

Flask Equipment and Rigging

There are no open grain defects attributable to flask equipment and rigging.

Gating and Riser

(1) *Directional solidification*. Gating which does not permit proper directional solidification is often a cause of open grain structure. It is necessary to pay close attention to number and location of gates when drastic metal section changes exist in a single casting. Putting hot metal in the riser area for feeding purposes may reduce the cooling rate of the heavy section to the point where open metal is experienced. Riser design which is inefficient such as long necks, inadequate basin, or oversized risers contribute to an unnecessary amount of heat at the heavier sections.

(2) *Distribution of gates and risers promoting heat retention*. Again, attempting to feed the heavy sections may lead to excessive heat retention at local spots. For example, there are cases where side risers are impractical because they overheat heavy sections and promote slow cooling. It requires good riser design to permit the smallest possible risers, but such

practice is needed in those castings which must be poured from metal not well-suited to the section size.

(3) *Localized hot spots due to gate or riser junction*. Short necks are needed for proper feeding but they do bring the runner or riser close to the casting and promote slow cooling. Extending the neck is apt to create feeding problems so the best control is to use an efficient design for minimum size. Also, it is often possible to locate the runner or riser so it does its feeding job without being close to a critical section of metal subject to open grain.

(4) *Insufficient number of gates*. The use of too few gates is not only apt to cause cuts and washes but it may also create a localized hot spot, and open grain. This is common in all metals, even in aluminum with its relatively low temperature. In some cases, the use of too few gates will lead to shrinkage defects which overshadow the open grain structure from the same cause. In fact, open grain, when sufficiently aggravated, becomes a shrinkage or porosity defect so the cure for both is often the same.

Molding Sand

Sand is a factor only if it permits mold-wall movement sufficient to increase the section size of critical sections. Since mold-wall movement tends to be greatest in heavy sections, this effect is possible. The open grain in this case is related to the swell.

Core Practice

Underbaked cores. Oil-bonded underbaked cores or oil-bonded air setting cores which may produce an exothermic reaction and excessive heating of the cored section should be avoided.

This effect is seen occasionally in large castings or heavy cores using binders with some exothermic properties. In a sense, the core then acts as an unusually effective insulator and slows cooling of the metal to a dangerous degree.

Molding Practice

(1) *Lack of vents which are capable of promoting faster cooling*. In heavy sections, the cooling rate of the casting will involve the rate at which heat can flow through the sand. Adequate venting helps to permit moisture to escape rapidly thereby providing a refrigerating effect.

(2) *Omission of chill nails or chill promoting materials*. This omission is usually a matter of carelessness.

Metal Composition

Since open grain is essentially a function of matching the metal composition to the cooling rate, such matching is critical. If it is assumed that the cooling rate cannot be modified (see **Casting and Pattern Design and Gating and Riser**) then open metal must be attributed to incorrect metal composition — either through incorrect specification or an unintentional off-composition. Because of its importance, each metal is considered briefly as follows. Greater detail is available in textbooks on metallurgy.

(1) *Gray iron and malleable*. Carbon equivalent too high (see Fig. 20-2). This mathematical lumping of

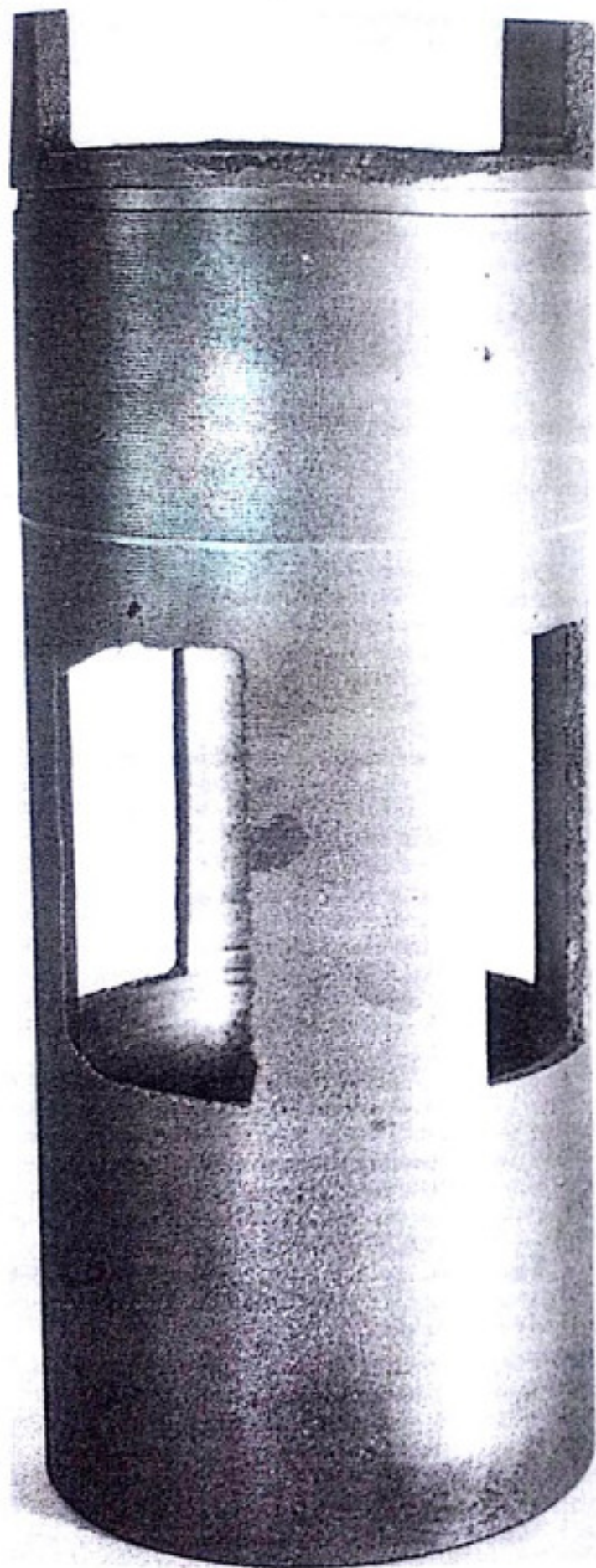


Fig. 20.2 — Diesel sleeve with three defects — open grain, dirt inclusions and shrink (on the inside).

the carbon and silicon effects is usually expressed as $C.E. = C + \frac{1}{3} Si$. As such, it indicates that open grain can come from excess carbon or excess silicon or both. Carbon is three times as effective as silicon, so

a minor change in carbon can be more dangerous than an equal change in silicon. This function of carbon and silicon affects malleable as well as gray iron. In malleable, the open grain does not appear black (as in the case of internal shrink) nor mottled indicating primary graphite. It is a general openness which is sometimes present in high carbon or high silicon, or both.

Phosphorus may be too high for application. Carbon equivalent is sometimes written $C.E. = C + \frac{1}{3} (Si + P)$ indicating that phosphorus does influence the openness of grain. In addition, phosphorus has a tendency to increase shrinkage when present in excess of 0.10 per cent. This aggravates any open grain in slower cooling sections.

There may be insufficient carbon stabilizers. Higher carbon equivalent is often offset by alloying elements which refine the grain. This is particularly true when it is desired to increase density and strength, and yet maintain adequate dampening and machining characteristics.

Graphitizers may be used in excess. Although open grain is related to the carbon equivalent, certain alloys known as graphitizers act to produce more graphite from the same amount of carbon. They are particularly valuable in thin gray iron casting sections to maintain machinability. In heavier sections of the same casting, however, the effect is to open the grain.

(2) *Steel*. Cast steel is not as susceptible to grain growth as are wrought steel products because the melting and deoxidation practices include elements that tend to retard grain growth. Any coarse grain inherent to the composition can be refined by annealing or normalizing.

(3) *Aluminum alloys*. Impurities such as iron give a coarse, brittle or open structure. Most of these result from faulty melting practice.

There may be lack of grain refiners such as boron and titanium. In many aluminum alloys, especially those requiring superheat temperatures, adequate grain-refining alloys are required.

(4) *Magnesium alloys*. Incorrect composition covers a wide range of contaminating alloys. As in the case of aluminum, grain-refining procedures must be followed for most alloys.

(5) *Brass and bronze*. Open metal in these alloys is usually concealed by a porosity, gas or dross pattern. Composition changes which would be expected to cause openness will usually show first as micro- or macrosrinkage, or finely divided porosity.

Melting Practice

Any melting practice which produces an incorrect composition (including gas composition) will affect open grain in direct proportion to the composition-change provided. Therefore, the various cast metals must be treated separately. For more information on these practices, it is necessary to refer to the standard metallurgy and melting practice handbooks.

(1) *Cupola melted gray iron*. Improper balance of air and coke create an excessive pickup of carbon. For example, an unusually high coke bed has the

same effect as reduced blast rate. This tends to be aggravated as the cupola burns out because the larger diameter cupola requires an increased blast rate to maintain the same carbon.

Melting may be too hot causing excessive carbon pickup at beginning of heat. Melting at unusually high temperatures will tend to raise the carbon. An example of this is found in hot blast operation. A good rule of thumb is that an increase of 100 F (55 C) of blast temperature will increase carbon by 0.10 per cent. Raising temperatures by use of oxygen does not necessarily produce the same problem.

There may be too long a tapping interval. Long intervals between tapping lead to carbon increases while metal is being held in the well. Foundries desiring low carbons generally use a shallower well, and more frequent (or continuous) tapping.

Intermittent operation (shutdowns, etc.) allowing excessive carbon pickup may cause open grain. Intermittent operation as a result of shutdowns almost invariably leads to wide fluctuation in carbon and silicon. It usually requires 15 min after a shutdown to reestablish the intended analysis. Variations in the size of the charge materials will lead to variations in chemistry especially variations in percentage of carbon pickup.

A careless charging of materials or weighing can result in nonuniform chemical composition. Careless charging is inexcusable and a common cause for variations in chemistry. Sometimes this is carelessness on the part of the charging crew or inadequate maintenance of scales and other measuring equipment.

(2) *Malleable.* An excellent method of reducing porosity pinholes and open grain is the use of the green pole to cause turbulence and avoid stratification in the furnace. Any errors in the weighing or makeup of the charge will change the composition. Unwarranted pushing of the air furnace tends to reduce control over the final chemistry. Melting hot and with a smoky flame tends to increase carbon.

(3) *Brass and bronze.* Use of a dirty crucible where skulls or metal films from the previous heat are left on the bottom or on the side walls will cause contamination of the next melt. Carelessness in segregating the return scrap may result in alloy contamination. Use of a color code or marker system to provide positive identification of each piece of scrap is accepted practice.

Adding the wrong ingot to the charge or using scrap of an unknown origin may cause the defect. A color or marking code on the ingot should be used and unidentifiable scrap avoided. Allowing turnings to become mixed in the machine shop and then charging them back in the furnace is bad practice. Better housekeeping is the only cure for this problem. Introducing into the metal gas-forming materials such as wet, oily, or dirty materials, and careless additions to the molten metal should be avoided.

(4) *Aluminum.* One of the common causes of open grain metal is improper melting temperature control

which allows aluminum to become very hot. However, if the overheated aluminum is allowed to cool slowly to a low pouring temperature, the castings will often be sound.

In oil- or gas-fired furnaces, the character of the combustion gases is important. If the flame is reducing (insufficient air), the presence of unburned hydrocarbons is a source of hydrogen which is soluble in aluminum. The combustion gas should be neutral or slightly oxidizing.

Any carelessness in charge makeup or contamination can be a problem.

Pouring Practice

The common cause in all metals is pouring too hot. This may really be a reflection of the basic problem created by melting too hot, but a correct pouring temperature may be a possible remedy.

Miscellaneous

(1) *Rate of cooling too slow for composition.* This has been covered from the standpoint of design, gating, and composition. If all these factors are correct, there are still a few miscellaneous techniques which affect the cooling rate.

The molding material may be acting as an insulator. This could be the case with a lower than normal sand density. Sometimes a change from a high density bond such as fireclay to a low density bond such as southern bentonite will make a measurable change in the cooling rate of the casting.

When chills are needed, a failure to set them will cause scrap from open grain. Occasionally, the time between pouring and shakeout is critical. Some jobs require fast shakeout and air quench to maintain the proper structure. In some castings involving drastic section changes, only the heavier sections are exposed. (This same technique is used to control cracking in large sheaves and pulleys.)

A special form of slow shakeout occurs when sand is retained in pockets or corners producing a slow cooling in that area. This is particularly hard to detect when troubleshooting because the cleaned casting may not show the areas of sand adherence. However, it can sometimes be located by looking for spots or areas of local penetration and roughness.

Piling of hot castings after shakeout can permit some castings to cool too slowly. The pile of castings acts as a soaking pit.

(2) *Improper heat treatment.* Improper heat treatment can cause grain growth in some metals. The absence of proper grain-refining heat treatment could be considered as the same problem.

(3) *Improper machining.* Improper machining will make a casting appear to have open grain even though it is actually dense. Under this heading are such things as improperly sharpened, or dull tools, wrong speed and feed, or improper rough cut. All of these create a torn porous appearance which may lead to the assumption that the metal was open as cast.

Chapter 21

POURED SHORT

A casting which lacks completeness due to the mold not being filled has been poured short (see illustration).

Insufficient metal is the only direct cause of this defect. However, there are many aspects of foundry practice which can contribute to the lack of metal or the apparent lack of metal. It must be recognized that it is often difficult to tell whether a casting was poured short or whether it ran out.

On many occasions, the short pour may be the result of a back pressure or resistance caused by inadequate mold permeability or lack of pop-offs and bleeders. In some cases the poured short may really be a case of poured cold or cold shut. However, a true poured short is just poured short.



Typical short pour.

RAMOFF OR RAMAWAY

DESCRIPTION

A ramoff or ramaway is an incorrect casting dimension resulting from the sand moving away from the pattern during molding. It is frequently confused with a swell or shift. This confusion exists because of a similarity in appearance under many circumstances. The confusion may usually be avoided by more careful inspection. For example, if an apparent shift occurs only in one area or on one side, or if the apparent shift is in two different directions, it is obviously a ramoff condition. It is surprising, however, how often this type of defect occurs on the scrap report as a shift. To distinguish between a swell and a ramoff may require more experience. In general, a swell is apt to occur in an area which is difficult to ram. A ramoff occurs in an area which may easily overram. Figure 22.1 illustrates a typical ramoff in the hub section of a casting.

CAUSES

Casting and Pattern Design

(1) *A curved or rounded vertical surface such as pipe lends itself to ramoff conditions by inducing the sand to bounce away after reaching density. Since this type*

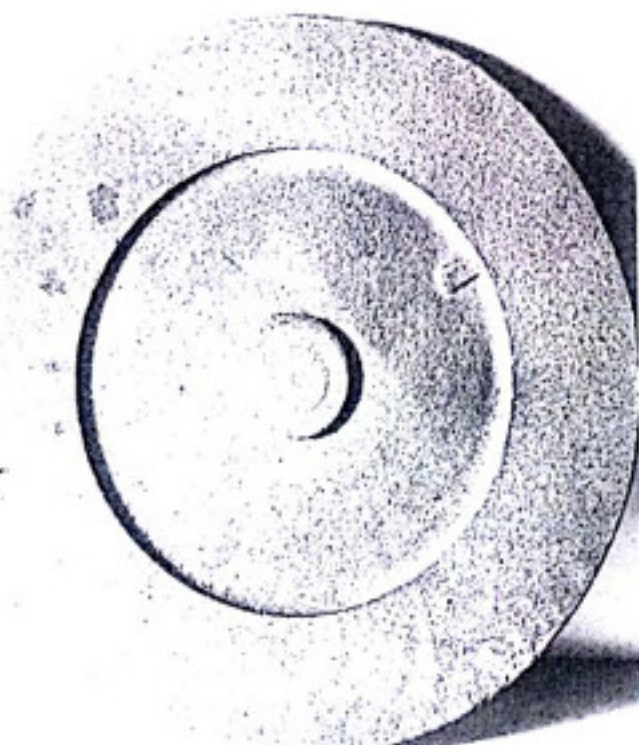


Fig. 22.1 — The hub section of a casting showing a typical ramoff.

casting is also prone to show up a true shift of the parting line, there is apt to be frequent confusion between the two problems. The bounce mechanism occurs by squeezing after jolting to full density or by bringing the slinger head back over a previously slung section of sand. The packed sand slides away from the pattern as a result of the second molding operation (e.g., jolt followed by squeeze).

(2) *Extended vertical sections lend themselves to the double molding effect which causes a ramoff or ramaway.*

Pattern Equipment

(1) *Loose pieces not properly secured to the pattern may move in the later stages of molding and force the sand away from the intended contour.*

(2) *Patterns not equipped with ramoff strips permit the molded sand to slide out of position during the later stages of molding.*

(3) *Patterns too close together, especially when using a sand slinger, contribute to uneven ramming, a prime cause of ramoff.*

(4) *Patterns too close to the edge of the flask have the same effect as patterns too close together. Since both this factor and (3) contribute to swells, it may be difficult to name the defect correctly.*

(5) *When patterns and plates are too smooth, the sand slides readily during the later stages of molding. As a pattern wears smooth and slick, it may be necessary to add ramoff strips.*

Flask Equipment and Rigging

(1) *A loose squeeze head on a machine may move during molding and thereby squeeze at a tangent. If this occurs after preliminary compaction, the tangential force will move the sand away from the pattern face.*

(2) *A loose pattern plate on a jolt machine will (as in 1) result in a tangential force being applied at some stage of the molding cycle (assuming the mold is jolted more than once). If the jolt is followed by squeeze, a ramoff can occur by squeezing a mold which has been jolted nonuniformly as a result of the loose pattern plate.*

(3) *Inadequate support under the pattern may permit either (1) or (2) to control the molding results.*

(4) *Incorrect design or placement of peen blocks on a squeeze head or weak bottom boards will readily force the partially compacted sand to move from its normal position.*

Gating and Riser

A gate or riser too close to the pattern usually creates a swell but it may result in a nonuniform ram which is more truly ramoff.

Molding Sand

Sand characteristics that contribute to nonuniform ramming will aggravate any of the design or mechanical conditions which create ramoff. These factors are essentially those that contribute to low moldability including excess moisture, poor mulling, excess cereal, clay or cereal balls, incorrect sand distribution, and lack of green strength.

Under these conditions, the casting would also tend to exhibit a rather rough surface and penetration of vertical surfaces. It would be difficult to imagine a smooth casting surface and a ramoff due to poor flowability of sand on the same casting. In fact, it is possible for ramoffs to occur when sand flowability is improved.

The more flowable sand may act in a manner similar to a smooth slick pattern or it may result in greater sand density from the preliminary molding (jolt) and thereby slide away during the second phase of molding (squeeze).

Core Practice

One would not expect a ramoff in cores although the cores themselves might be off dimension by a previously mentioned similar process during core-making.

Molding Practice

(1) *Ramming and peening in the wrong direction are human variations of those given under **Flask Equipment and Rigging** (1) (2) (4). Figure 22.2 illustrates the result of peening in only one direction.*

(2) *Improper tucking around loose pieces and bosses has the same effect as described in **Pattern Equipment** (1).*

(3) *Whipping of a pattern due to worn pads and guides on a jolt machine causes ramming and peening in the wrong direction.*

(4) *Preramming of sand while filling a flask usually occurs by letting the sand have free fall from an excessive height. This acts as a slinger (to a degree) and, therefore, sets the stage for a ramoff during the later stages of molding. An unusually flowable or*

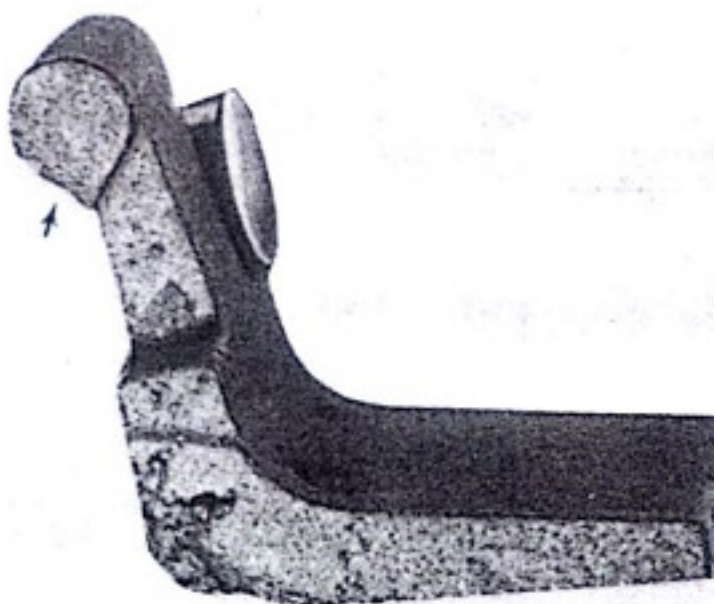


Fig. 22.2 — Result of peening in only one direction which caused round boss to become elliptical in shape.

moldable sand may contribute to this effect since will prepack most readily. Filling the flask with shovel and not dropping the sand perpendicular to the pattern will have the same effect.

(5) *Filling the flask too full before peening, ramming, or jolting creates a nonuniform ram especially on vertical surfaces which are prone to ramoff; so does jolting the cope before squeezing.*

Metal Composition — Melting Practice — Pouring Practice

A ramoff is a mold effect and is created before the metal is poured.

Miscellaneous

Rough handling of molds prior to drawing the pattern can readily move a section of sand away from the pattern, especially if the sand is weak, or if the mold is weak because it was compacted to a low density. Rollover machines when worn or out of adjustment sometimes go through some amazing gyrations before they finally set the mold down and draw the pattern. Such equipment should be adjusted to roll over smoothly and gently.

Pattern draw equipment when worn or out of adjustment may bounce the pattern from one side of the mold to the other during the draw process. A ramoff would be one of the defects such equipment can produce.

Chapter 23

ROUGH SURFACE

DESCRIPTION

A casting lacking the required degree of smoothness for specific application has a rough surface. Figure 23.1 illustrates a typical rough surface.

CAUSES

Casting and Pattern Design

Design is a contributing factor only where sharp corners, deep pockets and the like are involved. Sharp corners are prone to breakage and scuffing. Deep pockets are apt to promote soft ram, porous sidewalls, and torn up molds. Designers often forget that these sharp corners not only increase foundry costs but may also drastically reduce the potential strength from stress concentration effects. These sharp corners usually reflect a design background in fabricated shapes and a lack of understanding of cast shape design.

Pattern Equipment

(1) *Pattern equipment with inaccessible areas* such as hydraulic passages, jacketed areas, and loose pieces lead to soft ram and burn-in or rough finish. If the pattern cannot be modified, it becomes necessary to core or develop special sands which eliminate the need for cleaning. For example, in hydraulic passages, it is common to use very fine sand with minimum binder and a refractory wash. For unusual cases, it is possible to use an unusually open sand which is dipped or washed so that the coating penetrates to a maximum depth (even to 100 per cent penetration of wash).

(2) *Fillets that are too small* lead to minor tear up and rough or open mold surfaces. These areas tend toward moderate stickers (see Chapter 29, STICKERS) and rough finish.

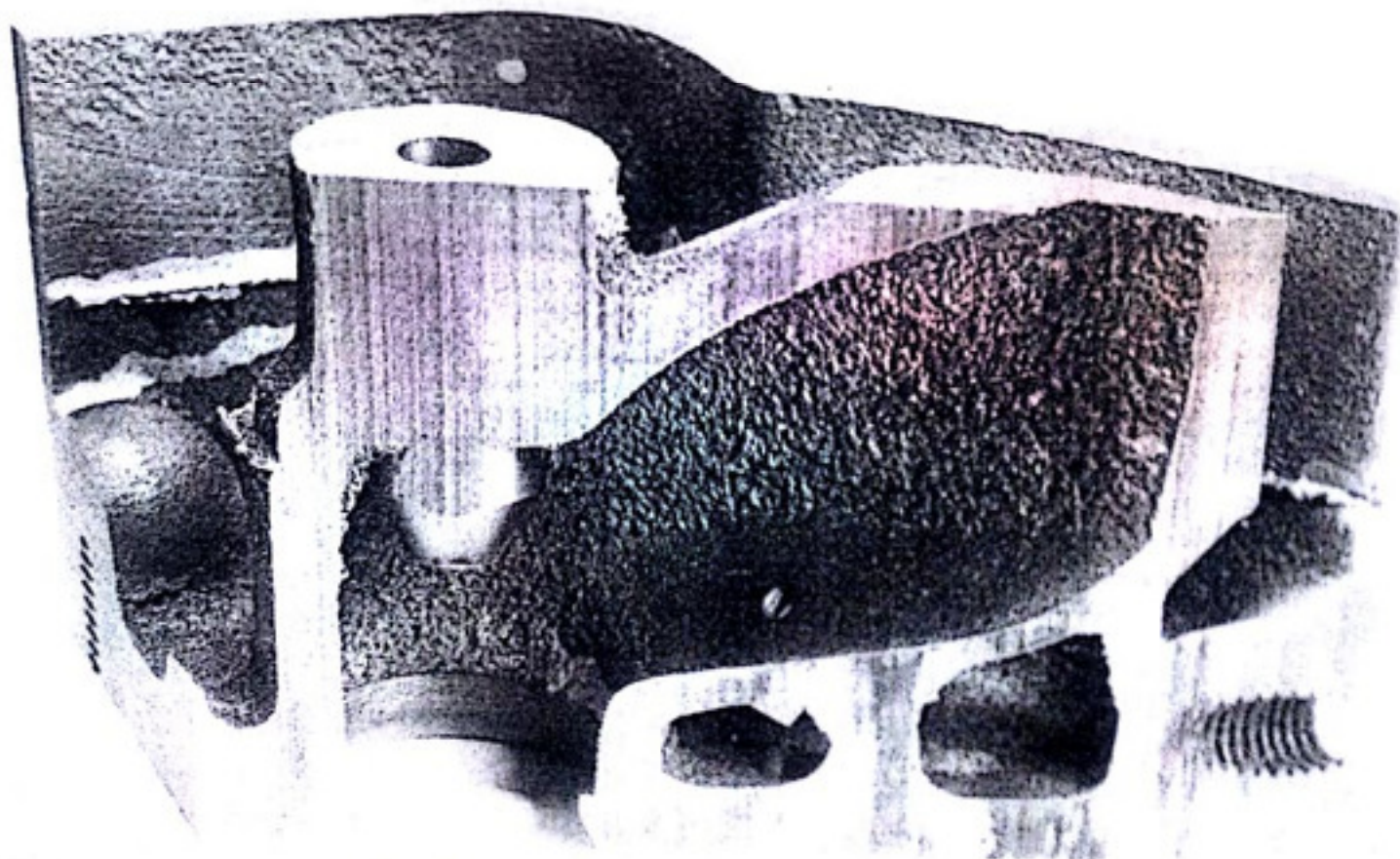


Fig. 23.1 — Typical rough surface caused in this case by uncoated open core.

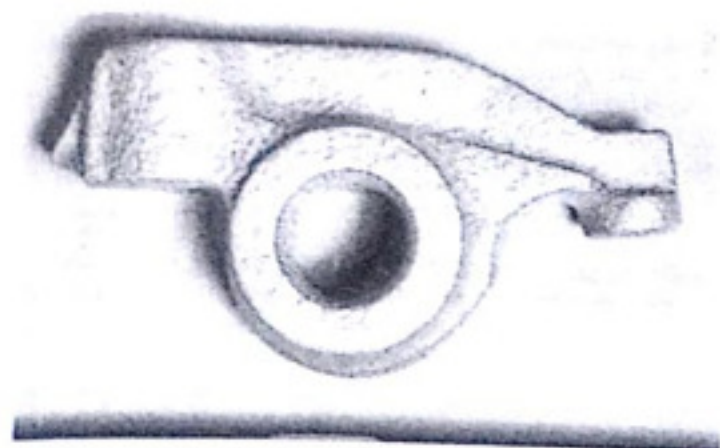


Fig. 23.2 — Excessive moisture in the molding sand created a low moldability and an open mold surface.

(3) A pattern surface that is too rough may be a case of misuse of sharp vent rod during molding, porous metal pattern, or flaked or chipped patterns. A tough, gummy sand may not reproduce these minor blemishes but a change to a flowable sand will show all pattern imperfections. These patterns can usually be smoothed with solder or plastic fillers. Sometimes, the roughness acts as a backdraft producing a torn up sidewall.

In the case of full mold styrene patterns, the roughness is usually due to excessive porosity of foam, lack of wax-type wash, or unfilled glue joints. These patterns are also subjected to nicks and cuts if mishandled. Small imperfections can be filled with wax but large nicks require a block insert and a recut surface.

(4) Weak patterns are involved when producing from single use patterns. Too often they may show back drafts because they yield under the pressure of molding. When such a pattern is drawn, the pattern will drag and tear up the mold.

(5) Pattern materials and coatings which induce sticking of sand will produce small stickers (see Chapter 29, STICKERS). In wooden equipment, the cause could be old, thick, or dirty shellac, varnish or lacquer which is gummy and does not dry. Metal patterns are not usually coated in this manner except to conceal porosity. The best metal coating is chrome plate from 0.004 to 0.006 in. thick. Some wooden patterns are metal coated with liquid metal.

(6) Thick and thin patterns which lead to nonuniform heating of patterns in shell or hot box can cause a sticker or rough finish. Green sand pattern plates may also cause sticking when used under conditions of condensation (hot sand and cold pattern).

Flask Equipment and Rigging

(1) Arrangement of flask bars preventing proper ramming leads to minor swells, open sand, and similar evidence of soft ram. In many cases, this openness results in roughness. In worse cases, it could be listed as a swell or strain. These conditions are more pronounced on automatic equipment and slingers since

there is no opportunity to compensate by peening and tucking.

(2) A flask which is too small for the pattern equipment is another factor involving ability to ram to adequate density. It can be compensated for to some extent by more flowable sand and/or special handling such as tucking or peening. Use of such flasks is false economy since the extras needed to compensate for inadequate molding clearances are usually expensive.

Gating and Riser

(1) An arrangement of gates and risers which creates hot spots will lead to localized mold-wall movement, minor swells, fusion, or penetration. All of these are considered as rough finish. In many cases, the placement of the riser must be such as to allow adequate feeding, and special care is needed to withstand the action of the hot spot (core insert, special facing, or hard ram). Often, a better riser design will do the feed job without the need to create the hot spot on the casting. Smaller risers with exothermics, smaller risers with adequate depth in the drag (below the neck) and "firecracker" risers are three possible redesigns which reduce this problem.

(2) Ingates creating high metal velocity cause cutting action at gate area of casting. In this case, roughness is the cut or wash plus the possible sand inclusions in other areas of the casting. Cuts in the gate may also show as sand inclusions which may be considered rough surface.

Molding Sand

(1) Sands with too high or too low moisture are equally bad but for opposite reasons. Excessive moisture (over temper) produces a direct tendency to stick and roughen the mold surface (see Fig. 23.2). A sand which is too dry (or dries out in use) will permit cuts and washes during pouring, or dislocated sand (crumbly edges) during the blowing out of the mold or during mold closing.

Hot sand is a variation of both these either through over compensation for heat (too wet) or inadequate compensation (rapid drying out during molding or standing).

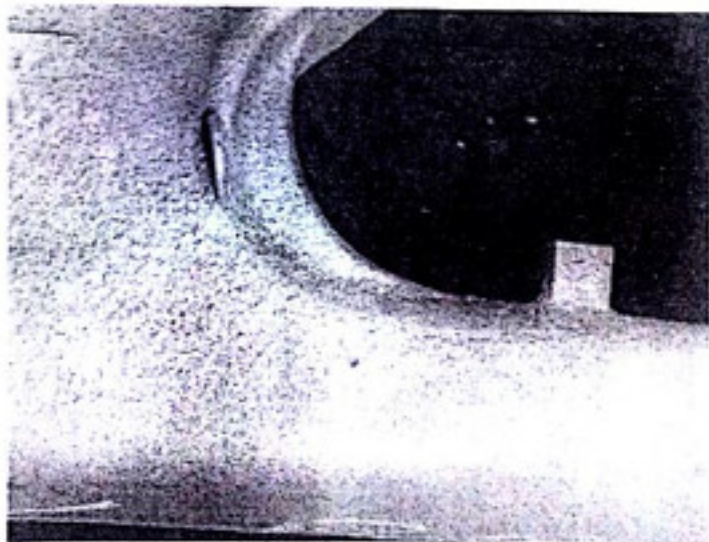


Fig. 23.3 — A poor choice of molding sand caused excessive permeability and rough surface.

(2) *Too high permeability* can be an indication of sand grains too coarse for the application. This has a direct effect on roughness since good metal flow will show up the large coarse grains (see Fig. 23.3). It is very difficult to make smooth castings with more than 5 per cent of the grains on the 40 screen unless the surface is disguised by washes or coatings.

Excessive permeability is also a factor by permitting more rapid drying out of the sand and subsequent friable brittle edges on the mold surface.

(3) *Improper sand preparation* is a major factor. A lack of uniformity of sand, water, and clay distribution (clay balls) will immediately result in rough areas in the mold at points of concentration of any of these. Improper sand preparation is particularly harmful if it results in poor distribution of moisture. In this regard, it has definitely been determined as the cause in many cases of hard mold penetration (above 90 mold hardness) — an obviously rough surface.

(4) *Foreign materials in the sand* will permit sand grains to drop away if the foreign body is near but not touching the mold cavity. (See Chapter 7, DROPS, Chapter 29, STICKERS.) If the foreign material is on the mold surface, the result is direct roughness either through burn out of the foreign material (e.g., cigar butt) or adherence of the foreign material (e.g., tobacco can).

(5) *A sand too high in easily fused materials* such as compounds of sodium and calcium (e.g., soda ash, limestone and non-silica partings) creates a special form of burn-in or roughness (see Fig. 23.4). Reuse of the sand without adequate dilution from new sand will eventually lead to a buildup of fusible materials such as metal oxides and dross. A good rule of thumb is to maintain a new sand dilution (including core sand pickup) of 300 pounds of sand per ton of metal poured.

(6) *A sand too low or too high in carbonaceous materials* such as coal, cereal, sugar and cellulose can cause trouble. These materials protect the metal finish

by creating a reducing atmosphere. Therefore, the level must be adequate for the metal cast (temperature) and the refractoriness of the sand. However, such materials, when carried to excess, will lead to localized rough spots and penetration from gas agitation (boiling), or to roughness due to modification of the sintering point of the sand.

(7) *When flowability (or moldability) is too low*, it leads to an open mold structure unless unusually effective ramming or molding is used to compensate. The moldability index must be adequate to match the conditions of molding. This property is controlled by clay, moisture, grain distribution and special additives.

(8) *Insufficient hot strength* permits deterioration of the mold surface before solidification is sufficiently advanced thereby creating a cut or wash. The amount of hot strength will be related to mold hardness and the metal poured plus the type of gating practice involved.

(9) *Carbonaceous material that is too coarse* involves both the original grind of the material and the subsequent buildup (e.g., pitch balls). These coarse particles create agitation of the metal and result in roughness (and possible blowholes, etc.)

(10) *Excessive partings (liquid or dust)* have a direct effect on sticking and on sand properties during molding. In addition to these effects, a buildup of these materials in the sand will so disrupt the normal sand properties as to permit cuts and washes and similar roughening effects.

Core Practice

(1) *Sand grains too coarse for the application (high permeability)*. See **Molding Sand** (2).

(2) *Dirty core boxes*. Dirty core boxes are those which have, among other things, a buildup of resin, oil, and similar partially oxidized binders which became sticky and, thereby, created rough core surfaces. Too often this problem is met by increasing the amount of release which merely increases the undesirable residue. The correct cure is to clean the box chemically, if necessary.

Sometimes a new core box will stick until it is broken in. This is usually a case of minor porosity in the original box which is later disguised by release agent absorption into the porous surface.

(3) *Soft rammed cores* include open surfaces in cores in the same sense as open molds result from soft rammed molds. In addition, the soft ramming of cores involves proper venting and blowing equipment, plus the factors of blowability or flowability.

Some core sands are difficult to ram but most problems seem to stem from proper core box design. Special attention is required to properly vent corners and pockets which are apt to blow open. Practice differs for various binders such as oil, resin, shell, and hot box. Air-set and self-curing cores also are subjected to soft ramming or air pockets even when of the type which requires minimum ramming energy. Flowable mixes must still be handled properly for maximum soundness. This is particularly true in the

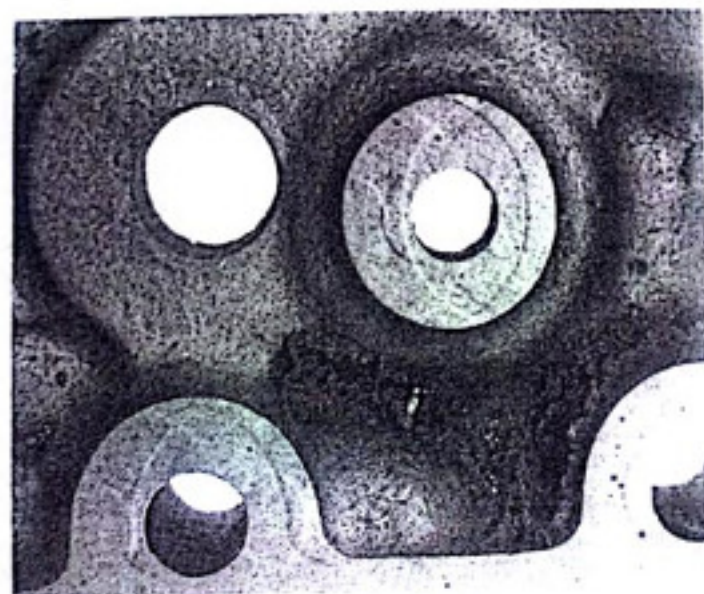


Fig. 23.4 — A sand high in lime created this rough effect (pockmarks) in the areas of maximum temperature.

latter stages of the short bench life when some setting may have built in an unexpected green strength.

(4) *Cores incorrectly sprayed, dipped, or coated (low Baumé wash)* will cause a rough surface. In many cases, the smoothness of the coating is the governing factor. In these cases, only close control of the fluidity of the wash and proper balance with respect to the core permeability (penetration ability) will insure a smooth surface. Comparison is made of the casting surface from a washed and unwashed mold in Fig. 23.5.

Improper coatings may expose the core surface or produce a flaked or chipped surface after drying and handling. Some coatings are particularly prone to pick up moisture after being placed in the mold, thus creating condensation problems such as agitation or penetration.

(5) *Overcured cores* are found in all practices including oil, hot box and shell. Such cores may abrade when handled or during setting in the mold. They are also subject to cutting action during pouring. In some cases, such as shell, there is an increased penetration from overcured cores.

(6) *Rough handling of cores* in the core room or foundry may result in abrasion and scuffing (or even broken edges). These abraded spots will usually appear in the casting as a rough finish unless they are properly repaired before setting in the mold.

(7) *Scuffed core surfaces* not properly reworked are a modification of the previously mentioned factors plus the fact that the repair job is faulty. This results in an agitation (metal boil) during pouring or a cut or wash from inadequate hot strength of the repaired area.

(8) *Low hot strength* may be due to the use of binders too low in hot strength, or to insufficient binder for the application. If hot strength is low, the core will fail too quickly and allow penetration, roughness, and cutting.

(9) *Incorrect core coating* will create a rough spot in any area in which the refractoriness of the coating is not adequate to withstand the metal being poured. A coating which is perfect for one application may be wholly unsuited for another.

(10) *Poorly mixed core sands* result in nonuniform conditions, and, thereby, cause defects to the extent that they create a localized situation as described in (1), (5), and (8).

(11) *Poorly cleaned and finished cores* are rough and hence cause a rough cast surface.

Molding Practice

(1) *Soft ramming* is a major cause of rough finish since it leads to open grain molds, minor swells, strains, penetration and washing. Even when the sand is inherently strong, a soft ram will leave an open or porous mold, particularly on the side walls and pockets, or where pattern to flask wall clearance is at a minimum.

(2) *Dirty patterns* involve a buildup of sand admixed with old parting, and the like. This type pattern leaves a rough broken surface on the mold.



Fig. 23.5—Illustration of the difference between a washed and unwashed section of mold.

Anything which interferes with the development of a smooth slick surface on the mold exposes a porous sand structure which is reproduced on the casting.

(3) *Sand that is not riddled* will create a rough finish if the sand is of the type which normally should be riddled to screen out lumps, foreign material and refuse, or merely for the purpose of aeration to improve flowability.

(4) *Uneven or insufficient coating or spraying of molds* may create a rougher surface than an uncoated mold. Such uneven coating may spall and chip. Incorrect torching of such washes further aggravates the problem. It should be recognized that a poor job of spraying and skin drying does more harm than good. Baumé of the coating must be closely controlled to provide the correct amount of penetration. Skill is required to avoid buildup in localized spots and care is required to ensure perfect drying.

(5) *Poor finishing* includes poorly applied patching, excessive slicking, and leaving abraded surfaces unretouched, etc. Such rough spots on the mold will produce an equally rough surface on the casting, especially if metal is poured hot and fluid.

(6) *An arrangement of gates and risers which create hot spots* is poor practice whether the molder sets or cuts gates or whether such arrangement is part of the rigging. (See *Gating and Riser*ing (1).)

(7) *Excessive use of parting compounds and washes* tends to reduce the hot and dry strength of the sand surface and also to make the patterns dirty. Most of these materials are, or include, solvents which can leach carbon from the sand or soften pattern coatings. They have a direct effect upon reducing sand strength and moldability when used to excess but are valuable tools when properly used.

(8) *Too low Baumé for the type of coating used* leads

to incorrect penetration of the coating and insufficient coating of the sand grains.

(9) *Cores that are rubbed and not refinished by the molder* have the same effect as that described in **Core Practice** (1) and (2). Mention of this is made here because in many cases the core surface is proper when it leaves the core room but is reworked by the molder to insure a proper fit.

Metal Composition

(1) *A composition which necessitates high pouring temperature* will lead directly to burn-in and will also aggravate any open grain or rough surface on the mold. For example, high strength alloy irons must be poured at elevated temperatures in order to develop adequate fluidity. This imposes greater loads on the sand mold. In a similar way high alloy steel requires maximum mold finish to avoid areas of roughness.

(2) *Any composition that tends to react with the mold surface* such as manganese steel or even aluminum-killed steel may create a direct roughness. For this reason, it is common to use olivine, zircon, or special coatings on manganese steel. With aluminum-killed steels, care is required to prevent mold reactions which form cermet or ceroxide defects and rough finish.

Melting Practice

Melting practice has no effect other than its contribution that metal which is melted too hot may be poured too hot.

Pouring Practice

(1) *Too high a pouring temperature for the materials used* causes a burn-in, penetration, or cutting action and, by higher fluidity, shows up mold imperfections which would be glossed over by cold pouring. It is necessary to make sure that the mold is able to handle pouring temperatures required. Excessive pouring temperature (more than required for proper casting) also leads to oxidation and dross inclusions which may react with mold surfaces to increase roughness.

(2) *Improperly skimmed ladles* permit oxides to enter the mold where they can react with the mold surface and appear as burn-in or penetration.

Miscellaneous

(1) *Foreign materials* of a miscellaneous nature are covered in **Molding Sand** (4) and **Molding Practice** (3).

(2) *Improper cleaning.* Too coarse shot or grit, and insufficient cleaning time to remove adhering sand will cause a rough surface.

Chapter 24

RUNOUTS AND BLEEDERS

DESCRIPTION

Runouts and bleeders are defects which result in an incomplete casting. Runouts occur during pouring; bleeders occur after pouring has stopped. If this seems like quibbling over semantics, it must be remembered that the cause of the two can be quite different in some cases. For example, bleeders can occur from rough handling on the cooling conveyor, from shifting weights, or from removing clamps too soon. In contrast, a runout implies a weakness in the mold and is most often due to either faulty equipment, improper clamping, or weak molds. Figure 24.1 is an illustration of a typical runout.

CAUSES

Casting and Pattern Design

Design is not a factor unless one wants to recognize that heavy sections are more apt to run out than thin sections.

Pattern Equipment

- (1) *A pattern mounted on too small a board produces a soft ram near the flask wall thus causing a weakness of the mold at its outer edges.*
- (2) *Worn bearing surfaces create a tendency toward a gap or weakness between the cope and drag at the parting line.*
- (3) *Dirty bearing surfaces will tend to hold the flask away from the pattern plate and thereby produce a nonuniform kiss when the cope and drag are closed.*
- (4) *Mismatched patterns create one of two conditions: cores holding the cope up prevent closing of the mold (Fig. 24.2); or nonuniform plate thickness produces a nonuniform kiss when closing the mold, thereby setting the stage for a runout.*
- (5) *A weak pattern plate, too thin for its size, permits flexing of the plate during molding. This creates an unnatural parting line with inadequate bearing surface. As in the case of (1), (2), (3) and (4), these faults may also show up as a crush rather than a runout. The difference is a question of the relative position of the weak or poorly matched areas of the bearing surface.*

Flask Equipment and Rigging

Flask problems usually fall in one or more of the six following categories.

- (1) *A flask too small for the casting size produces a weak mold because of lack of sand and the relative inability to develop an adequate ram around the pattern when the flask is crowded.*
- (2) *A warped or twisted joint line will create flask-to-flask contact in some areas and sand-to-sand in others. One or the other area is apt to allow a runout.*

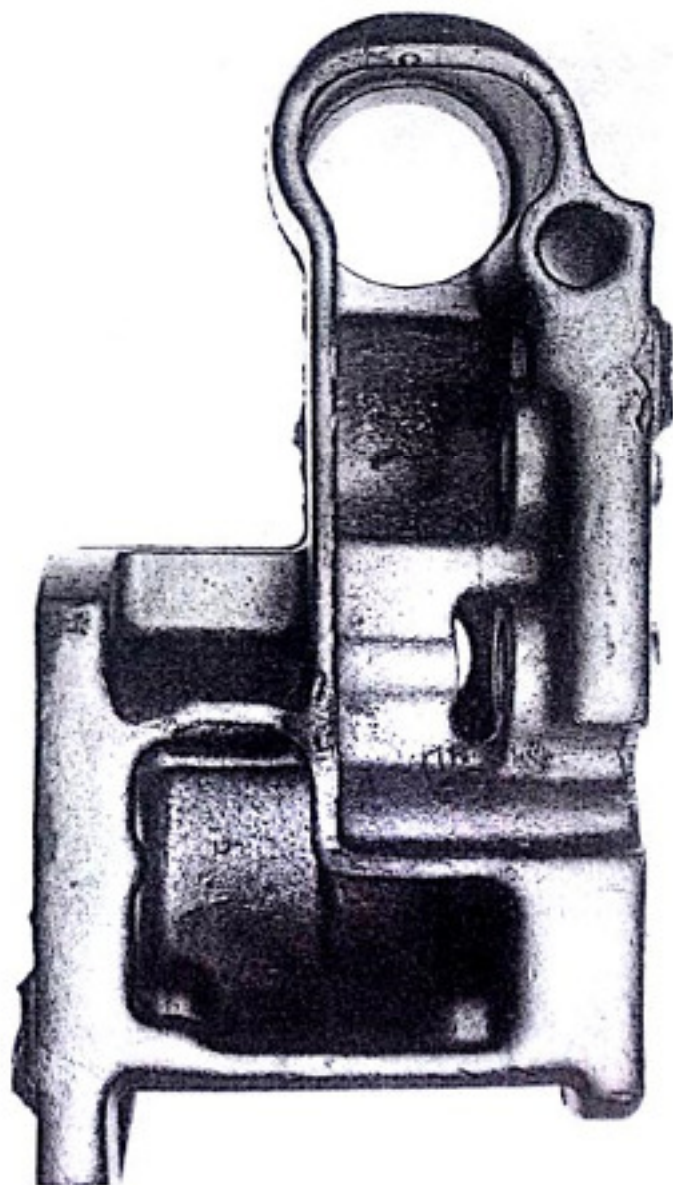


Fig. 24.1 — Typical incomplete casting caused by a runout.

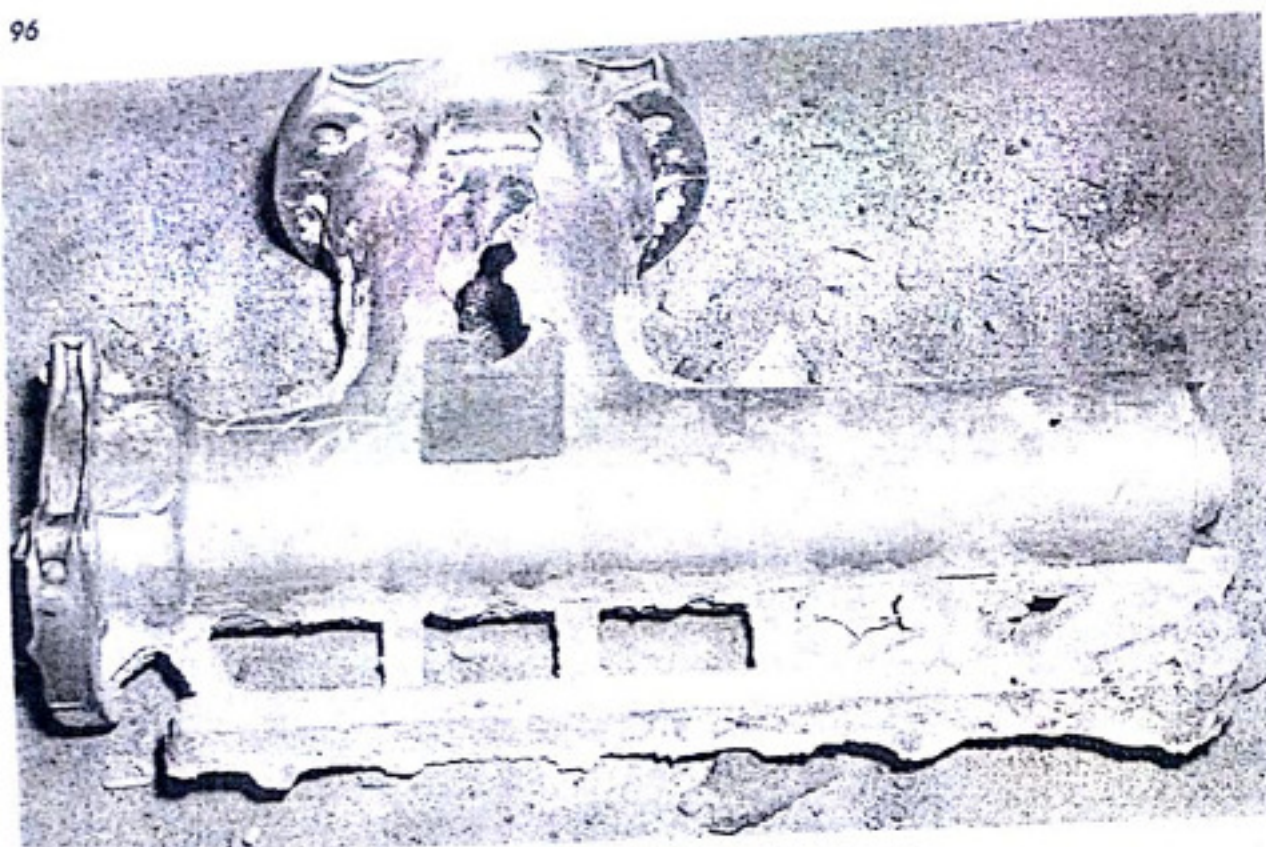


Fig. 24.2 — Typical parting line runout occurred as a result of the core holding the cope out.

(3) A poorly cleaned joint line creates local spots of poor contact and tends to create a crooked or nonkiss parting line.

(4) Faulty pins and bushings, which do not allow the cope and drag to seat properly, should be seen during mold closing, but unfortunately they are not always observed in time to prevent the runout which must occur.

(5) Worn hinges and locks on snap flasks result in an off-size mold in either cope or drag or both. The resulting mismatch leaves some sections unsupported even when good jackets are used.

(6) Warped and twisted bands produce an area of weakness at the parting line where most runouts occur.

Rigging problems are listed in the following seven groups.

(1) Weak or burned bottom boards or insufficient battens permit the drag to sag, especially with weak sand or soft ram molds. The runout is apt to occur through the drag, but may be at the parting line if the sag is near the edge of the mold.

(2) Improperly fitting jackets are a most common cause of runouts and bleeders. The sand can break out while pouring (runout) or after the water wall has moved sufficiently to weaken the mold (bleeder).

(3) Faulty bands act as faulty jackets.

(4) Weak, insufficient, or improperly placed clamps put an unnatural strain on some mold sections and not enough pressure on others. Unless the mold is unusually strong, a runout can occur. Even a strong mold may bleed as the water wall creates a zone of weakness and throws the burden on the clamp.

(5) Insufficient or improperly placed weights are probably the prime cause of runout defects. A casting creates a lifting force equal to the area of the horizon-

tal face multiplied by the pressure per square inch as represented by the sprue height. For example, a 10 in. x 10 in. plate (even though it may be a thin light casting) will exert a lifting force of 100 lb when poured in gray iron with a 4 in. cope.

$$10 \times 10 \times 4 \times \frac{1}{4} = 100.$$

(6) Bumping molds on a conveyor line is a common source of bleeders if the bumping occurs after pouring. If the bump occurs before pouring, it could result in a sagged drag and runout if there is any inherent weakness in the mold, flask or jacket.

(7) Insufficient sand between the bottom board and pattern (insufficient drag depth) can produce a runout unless the mold is unusually strong. Even a strong mold with a shallow drag may develop weakness after pouring and cause a bleeder.

Gating and Riser

(1) When the sprue, runner, or riser is too near the sides or bottom of a flask, a twofold cause of mold weakness can result. In the first place, insufficient sand results in a weak mold and this is aggravated by the difficulty of getting a good ram.

(2) If the head pressure is too high for the amount of sand in the flask, excessive static pressure or bursting force is created. However, it is well to remember that insufficient head pressure can develop shrink or blow defects, so caution must be used in reducing head pressure to cure the runout. It might be wiser to strengthen the sand or increase the density of the mold.

(3) When mold cavities are too close to the edge of the flask, they have the same effect as in (1).

Molding Sand

(1) If the sand is weak, the mold will be weak even with adequate molding density or molding energy.

Such weakness will show up particularly if there is any problem such as described in preceding sections.

(2) *Low deformation sand* is, by definition, on the brittle side. As such, the mold may crack rather than distort under static load (cope height). It should be noted, however, that excessive deformation can lead to a swell or strain instead of a runout. Care must be exercised when counteracting runouts by a change in this property of sand.

(3) *Excessive expansion and contraction characteristics causing cracked molds* will permit metal to run-out if there is any weakness in flasks, jackets, and the like.

Core Practice

(1) *Cores, improperly fitted or pasted (core assemblies)*, can easily produce a run-in which is merely an inside out runout (internal bleeding).

(2) *When vents or rods are too close to the surface*, metal can run into the core cavity or vent. When the vent is filled in this manner, a pronounced blowhole in the casting may occur.

(3) *If cores are too weak*, they have the same effect as weak molds except the bleeding becomes internal (see Fig. 24.3). This is especially true of shell cores.

(4) *The statement, "Inert core-filling material too close to the surface,"* refers to the coke filled-type core practice for larger cores. If the shell of the core cracks or breaks, an internal runout or bleeder may occur.

(5) *Shell cores that are improperly sealed* will permit metal to run into the center. This is a common source of trouble and is illustrated in Fig. 24.4.

(6) *Thin spots in shell cores which crack during or after pouring* are obviously a cause of bleeders (see Fig. 24.5).

(7) *Thermal breaking of shell cores* will permit bleeding or seepage of the metal during solidification. This is most pronounced with metals which have a long freezing range or which do not rapidly skin. It is usually the result of hot brittleness in the shell mixture.

Molding Practice

Molding practice is a major source of trouble since both runouts and bleeders result from a weakness in the mold. Failure to mold to the full potential of the sand is a most common fault. It must be remembered that a 15 psi sand, for example, may have only 2 to 4 psi strength when soft rammed.

(1) *Soft ramming* of the entire mold or of some areas of it is a prime cause of trouble.

(2) *Insufficiently or improperly weighted molds* allow metal to run out because the cope lifts. It is necessary that the weight be sufficient and that it bear properly on the sand. Figure 24.6 shows a runout caused by inadequate weights.

(3) *Unevenly clamped molds* permit easy runout at the parting line. This is illustrated in Fig. 24.7.

(4) *Improperly bedded bottom boards* create an uneven bearing surface thus allowing the mold to break out through the bottom (see Fig. 24.8).



Fig. 24.3—A weak core permitted metal to run into core cavity. The casting was rejected because it was impossible to remove the core section.

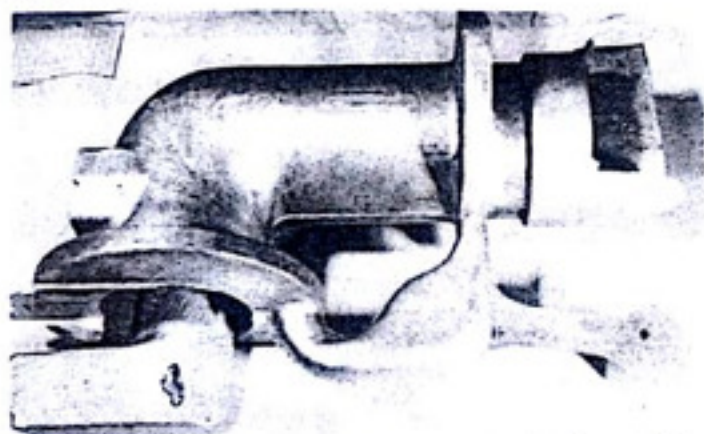


Fig. 24.4—Shell cores improperly sealed permitted the metal to run into the core cavity.

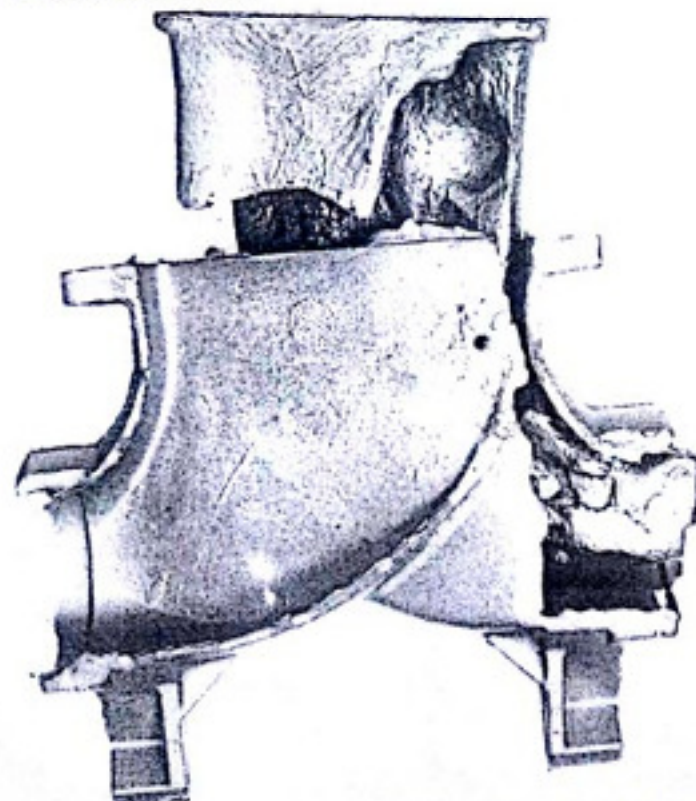


Fig. 24.5—Runout condition caused by break through of thin spot in shell core.



Fig. 24.6—Runout at the parting line in a casting caused by inadequate weights.

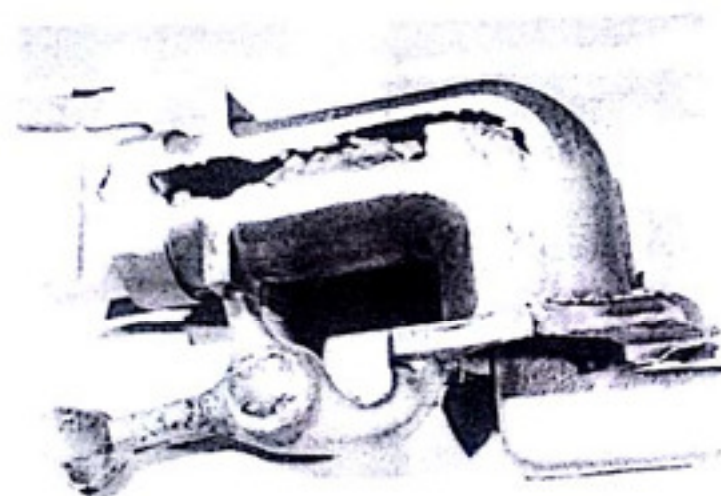


Fig. 24.7—Runout caused by improper clamping.

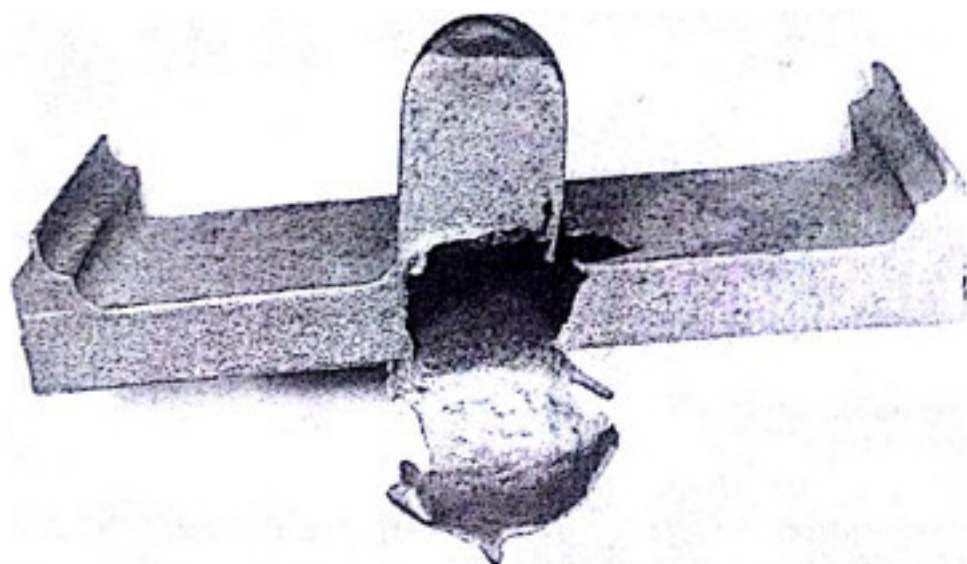


Fig. 24.8—A poorly bedded bottom board permitted this casting to bleed after pouring.

(5) *Nonuniform hardness of bedding sand* will provide a nonuniform support to the mold. Both (4) and (5) imply that the drag is not of sufficient strength to carry the load without firm support.

(6) *Careless closing of the mold* results in a cocked condition which lets metal run out at the parting line.

(7) *Venting too close to the pattern* destroys the normal sand density and weakens the mold. If the amount of sand is dangerously small, any such weakening produces a runout.

(8) *Lack of cope seal* in large molds permits a fin to form at the parting line. It must be remembered that the fin itself then produces an upward thrust in direct ratio to the metal surface, and further lifts the cope unless weights are adequate. The fin then becomes the cause of the subsequent runout.

(9) *Under or overbaked dry sand molds* may be weak enough to permit a runout.

(10) *Rapid heating of skin-dried molds* during the drying process is apt to crack the mold sufficiently to start a runout when the casting is poured.

(11) *Insufficient internal and external reinforcing of a dry sand mold* acts as described in **Core Practice** (3). The mold in this case is the same as a baked core and must have adequate strength to resist cracking.

Metal Composition

Metal composition is a factor to the extent that it controls metal fluidity and solidification range. Increased fluidity due to high carbon equivalent in graphitic metals, or long liquidus range as in copper or copper-base metals is a factor.

Melting Practice

There is no relationship between melting practice and runouts or bleeders.

Pouring Practice

(1) *Failure to use jackets, weights, or clamps* will usually result in a runout. This is pure carelessness.

(2) *Improperly placed or adjusted jackets* can also be a matter of simple carelessness. In some cases, local conditions may have made it difficult to set jackets straight, for example, when jackets have to be set from one side of a rather high conveyor.

(3) *A jacket that is too narrow fails to protect the mold.*

(4) *Pouring too hard for the gating arrangement will temporarily raise the cope. This is aggravated by failure to use enough pop-offs and bleeders to relieve the trapped air pressure during hard pouring. In the case of high pressure molding units, the problem persisted until adequate pop-offs were provided at the end of the runner system.*

(5) *Pouring too hot provides an unusual degree of fluidity. Very fluid metal seeks out any weakness such as a tendency to fin or runout.*

(6) *Bumping molds during pouring will start a wave effect within the mold which can have a surprisingly large breakout effect.*

(7) *Removing weights, clamps or jackets too soon after pouring is a common cause of bleeders. This has also been known to cause a shift. Lifting a weight too soon may result in a scrap casting. Shifting the jackets while the mold was on a moving conveyor created the runout shown in Fig. 24.9.*

Miscellaneous

(1) *Shaking out too hot will permit the casting to*



Fig. 24.9 — Shifting the jackets while the mold was on a moving conveyor and before solidification caused bleeding. Note evidence that mold was full.

bleed back through the gate or riser if it is knocked off in the process.

(2) *Knocking off gates and risers too soon can occur during early shakeout or, in some practices, the gate or riser is broken before shakeout.*



SCARS-SEAMS-PLATES

DESCRIPTION

Scar — A scar is a minor or shallow shiny mark on a casting surface where the casting does not conform to the pattern by reason of mold-wall movement or gas entrapment.

Seam — A seam is a specific form of scale occurring as a depressed line.

Plate — A plate is a layer of metal partially separated from the main body of the casting section by a scale. Figure 25.1 shows a typical plate defect.

These defects usually occur on flat surfaces. Such flat surfaces nearly always involve "stop and go" type metal flow. As a result, cold metal or excessive back pressure and gas can prevent complete filling of the mold cavity. In a sense, these defects can be related to cold shuts except that they are strictly surface phenomena.

If the interrupted flow fills or partially fills the cavity but leaves an unwelded joint parallel to the casting surface, it is referred to as a plate.

A seam can easily be confused with a rat-tail or a minor buckle but close examination will usually indicate a difference in the mechanism of formation.

Sometimes these defects are referred to as specialized types of blows, and sometimes as specialized cold shuts. Probably the most common cure is to pour such flat sections on a slant or change gates in an attempt to obtain smooth, rapid, uninterrupted metal flow.

CAUSES

Casting and Pattern Design

(1) *Abrupt change in casting section resulting in interrupted metal flow.* Since the interrupted metal flow is a major cause of this defect, it is important to avoid any design which forces interrupted flow. For example, abrupt changes or nonuniform sections can start an ebb and flow of metal. Unusually thin sections may require special care, such as uphill pouring, in order to avoid these defects.

(2) *Sharp corners resulting in interrupted metal flow.* Sharp corners in the line of flow have a similar effect. These should be rounded wherever possible. If the corner cannot be rounded-off, it is possible occasionally to regate so metal flows into the corner instead of past the corner.

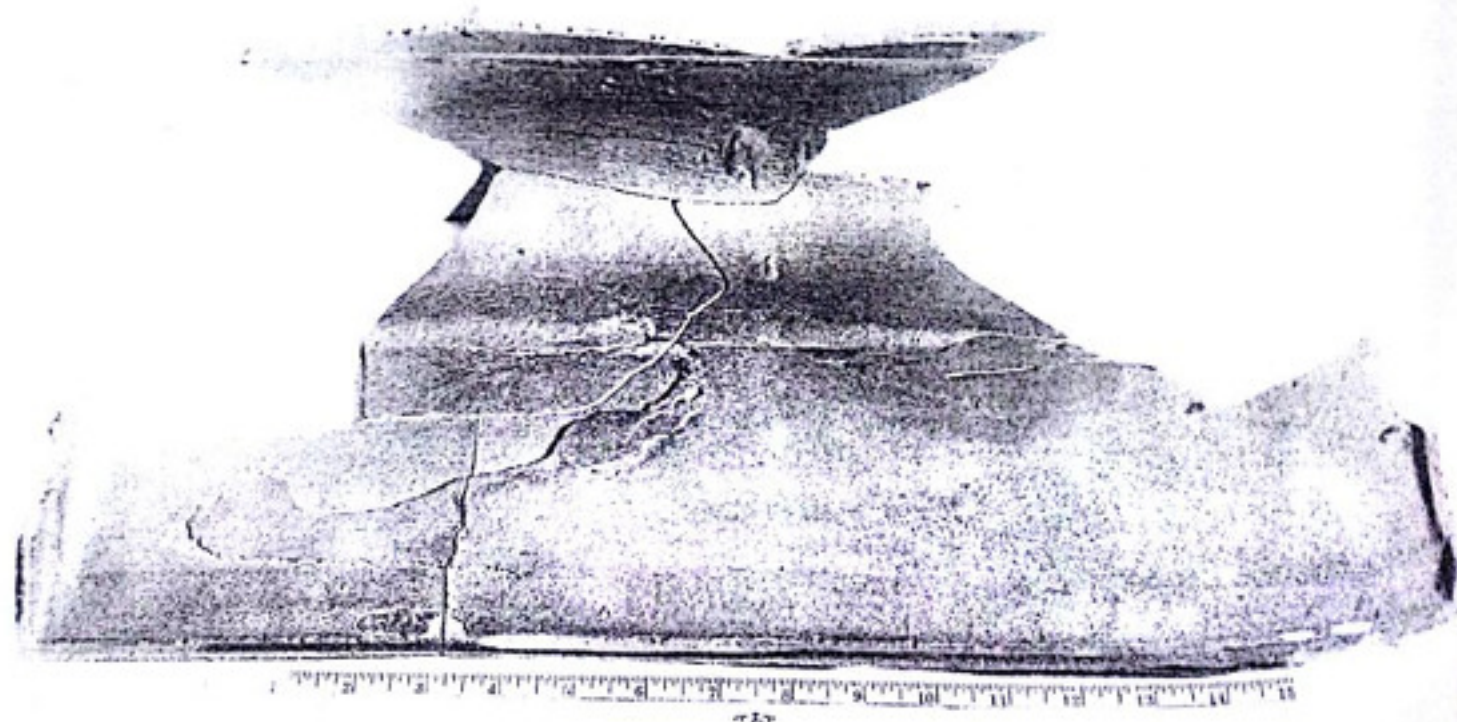


Fig. 25.1 — Typical plate defect in which the plate is semi-attached to the casting.

Pattern Equipment

(1) *Worn patterns or core boxes causing thin metal sections.* It is not unusual to find patterns which have worn to the extent that the metal section is even thinner than planned. This thin metal can create "stop and go" flow in the same way as would a faulty design. It is desirable to spot check such patterns periodically in addition to making a close check when the defect becomes noticeable.

(2) *Incorrect pattern dimensions resulting in casting sections too thin for the fluidity of the metal.* Thin sections may be caused by careless pattern shop practice. When thin sections do occur in the design, the patternmaker must provide all the section the design permits. If the patternmaker does not recognize the importance of this problem in horizontal flat sections, he may work on the minimum side and still meet the design specification of tolerance.

(3) *Patterns improperly reinforced causing excessively thin sections.* The same problem may occur only because the pattern is weak or without adequate reinforcement. A thin section, because of this factor, is frequently the result of cheap patterns; these may be expensive in the long run.

Flask Equipment and Rigging

This phase of foundry operations has an important relationship to the formation of plates, scars and seams because of the many ways metal sections may be thinned out from worn or faulty equipment.

(1) *Cope and drag shift causing thin metal sections.* Flask equipment and rigging should be carefully inspected for wear or fault. Casting dimensions should always be checked when these defects occur in order to locate the cause of the thin section. For example, bushings on flask pins should be inspected to make sure a cope and drag shift did not occur (causing thin section).

(2) *Patterns not properly mounted.* The pattern mounting, especially at center lines, is important since improper center lines cause shifts and result in thin metal between the mold and core.

(3) *Lack of tilting arrangement for thin flat sections.* Adequate tilting on large flat sections helps to avoid surge flow of metal. This is always good insurance and may be essential with some designs.

(4) *Flask insufficiently barred allowing cope to sag.* Flask bars and cope height should be checked to make sure there is no possibility of a cope sag creating a thin section in one or more spots.

(5) *Bottom board distortion caused by clamping the edges of the board without supporting the center.* Bottom board thickness, rigidity and warpage, especially when the boards are clamped to the flask, should be checked. Distortion in the board can readily create one or more thin spots. Only temporary restriction of metal flow will cause trouble in unusually thin, flat surfaces or large, flat surfaces poured flat.

Gating and Riserling

Since the defects are caused by stopped or interrupted flow patterns, the gating system is extremely

important. It is not generally known how very difficult it is to develop fast uniform flow across a large, thin, flat section. Tilting the mold does make the gating easier but even so care must be exercised in the following areas.

(1) *Gates which create turbulent flow.* Entire books are written on this subject. It is too lengthy to handle here except to point out that flat surfaces require a nonturbulent gate.

(2) *Gates which create interrupted pour.* Pouring basins improperly designed. AFS publications on the subject of proper design for the gating and runner system are available but the pouring basin or cup must not be ignored. These too must permit smooth flow. They must be easily hit by the metal pourer and be easy to keep filled.

(3) *Gates which foster slow pouring.* Slow pouring by virtue of excessive choke can easily produce defects. The gate design may be at fault or it may be a question of mismatching and similar molder's error. Cut sprues may have an unintended jog or the sprue cutter may not match the button or runner. Nicked or rough gate sticks may leave protusions which cause slow or turbulent flow. The various parts of the gating system must line up to avoid unintentional shoulders or bulges of sand.

(4) *Low head pressure.* Low head pressure will create a soft pour. Inadequate pressure will not force the air from the mold cavity in time to avoid premature freezing of thin sections.

(5) *Widely separated or too few gates.* If ingates are too far apart, the flow of metal will be too slow in some areas even when the pouring time may seem adequate. Too few gates can have the same effect because too long a pouring time will then be necessary for the metal section involved. This gating error is most commonly made when the casting is relatively heavy and the pouring rate is based on the needs of the heavier section.

Castings having thin flat sections require fast pouring even if the rest of the casting is chunky. Such designs require careful consideration of the controlling section as far as pouring time is concerned.

Molding Sand

(1) *Low permeability caused by excessive fines and poor grain distribution.* Low permeability can be a factor in causing scars, seams and plates in much the same manner as it contributes to gas defects. The low permeability allows the gas pressure to exceed the metal pressure.

(2) *Excessive free water — over-tempered — in the sand* can be a cause of these defects.

(3) *Too high in gas forming material.* High moisture and gas forming materials also keep the metal from flowing smoothly and continuously into the mold cavity. The gas pressure may be developed at such a rate as to interrupt the flow of metal into the mold, in the same manner as interrupted pouring does.

(4) *Differences in strength and differences in permeability of facing and backing sand.* These defects are frequently caused when facing sands are used. There

is a great tendency when using facing sands to make the facing mix considerably stronger than the backing sand. If the facing sand is too high in strength in relation to the backing sand, the two will tend to separate during the pouring. Differences in grain sizes and additives of the two sands result in differences in strength, expansion, and permeability. This tends to cause a separation of the sand layers.

(5) *High expansion.* High expansion of the sand permits greater mold-wall movement which may result in one of these defects. Increased clay or organic additives or a more uniform grain size would serve to reduce the expansion.

(6) *Low hot deformation.* Low hot deformation leads to scars because the sand will crack. The hot deformation must be high enough to compensate for the expansion.

Core Practice

(1) *Low permeability from excessive fines and poor grain distribution.* Low permeability in a core may have the same effect as low permeability in the mold if it permits back pressure to interrupt the metal flow. This would be especially true if part of the cavity were venting through the core and core print.

(2) *Cores may be too high in gas forming material.*

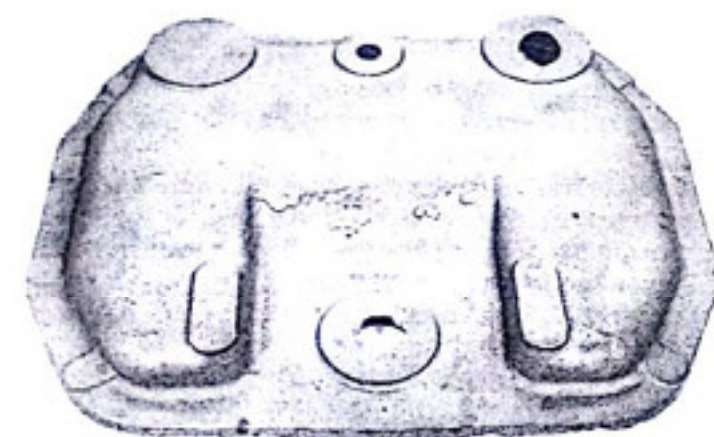


Fig. 25.2 — Plate defect caused by hard ramming of wet sand.



Fig. 25.3 — Enlarged section of plate defect illustrated in Fig. 25.2.

(3) *Insufficient or plugged vents.* Obviously, any consideration of low permeability should include plugged vents or core prints whenever such vent or print creates back pressure in the mold. It is surprising (as in the case of blows) how often the plugged core vent is found in shop practice. This cause may be hard to locate after shakeout and, therefore, may be missed as a defect cause.

(4) *Wet underbaked core.* Commonly, the core becomes a factor by causing a change in the solidification rate. A wet, underbaked core or core wash has a chilling effect which can create a cold shut which is the cause of plates, scars and seams. Many washes conduct heat very rapidly when wet or damp.

(5) *Cores not properly sized or fitted in thin metal section.* As mentioned previously, the section thickness is a prime consideration. Even with perfect patterns and rigging, such section change can be observed if any change is permitted in the core size by reason of rubbing, excessive blackening, pasting and mudding. Raised, sagged or shifted cores are also major factors in causing this defect. The actual metal section near the defect or between the defect and the gate must be checked if the cause of the defect is to be discovered.

(6) *Rubbed core surface broken or thin wash permits gas concentration in unvented area.*

Molding Practice

(1) *Combination of hot and cold materials.* Example of such materials: sand, cores, flask, chills, gagers, chaplets, metal riser covers, arbors. Because these defects are related to gas defects, they follow many of the same rules. A major cause, then, can be condensation caused by combinations of hot and cold materials. Such condensation is most common in large castings which also include one or more relatively thin, flat sections.

(2) *Nonuniform ramming may create hard and soft spots and localized low permeability.* Gas problems (including condensation) are particularly aggravated by nonuniform ramming (see Figs. 25.2 and 25.3).

(3) *Insufficient venting results in these defects.*

(4) *Too low head pressure.* Hard and soft spots in the mold area involved tend to create gas pockets and stop and go metal flow. Any tendency in this direction will be further aggravated by insufficient head pressure and soft pouring.

(5) *Thin metal section.* The molder can cause thin sections as well as misaligned gating systems (hand cut sprues, etc.). Thin metal sections may involve a soft rammed cope or insufficient gagers and supports. A poorly vented or plugged bottom board can cause a push-up, having the same effect as a cope sag.

(6) *Excessive slicking and patching.* Metal flow does involve friction. As such, soft and hard ram can slow down or speed up the flow. Slicking the surface can have this bad effect or it may change the solidification rate and freeze off the flow.

(7) *Turbulent metal flow or gas locks in thin or flat castings.* The tilting of the mold is usually the molder's job. He may also fail to provide sufficient

vents or pop-offs. If he hand cuts the gates, runners or pouring basin, he may be the major cause of these defects.

(8) *Wrong length chaplet, light chaplets, inadequate chaplet bearing.* Core-setting can easily be involved if the wrong size chaplet or insufficient chaplets are used to hold the metal section.

Metal Composition

Metal may not be fluid enough due to composition. This may be caused by the following factors.

- (1) *Too high or too low carbon equivalent for the mold conditions involved.*
- (2) *Excessive carbide stabilizers.*
- (3) *Excessive graphitizers.*

Melting Practice

The essential characteristic needed in the metal is adequate fluidity for the section size of the castings.

- (1) *Sluggish metal* is apt to be rather troublesome. This could be a matter of cold melting, gassy metal, improper flux treatment or incorrect composition. For example, in aluminum alloys, it is necessary to avoid excess sodium or insufficient iron and silicon. In magnesium, the metal may be too far from eutectic.
- (2) *Oxidized or gassy iron.* In ferrous metals, there can be a real problem from oxidized metal. For example, the tendency to melt malleable iron fast and hard in an air furnace can lead to low fluidity.
- (3) *Excessive ladle additions.* In iron, a common mistake is to over-inoculate or over-alloy in the ladle which both chills and gases the metal. Steel practice

can likewise readily involve low fluidity for any given temperature and composition.

Pouring Practice

The pouring method may change fluidity in many ways besides the obvious one of pouring too cold.

- (1) *Interrupted pouring.* These are cases of interrupted pouring through carelessness or, as in the case of multiple down-sprues, a lack of synchronization of pouring. A temporary runout may disturb the metal pourer causing him to make an interrupted pour. Holding the ladle lip too high leads to an inaccuracy in hitting the hole resulting in an interrupted pour.
- (2) *Reducing rate of pouring too soon.* Sometimes the metal pourer will slow up too quickly and then have to speed up again.
- (3) *Any gas introduced during pouring* will be directly harmful and will reduce metal fluidity. The most common gas sources are undried or underdried refractories, such as in ladles, ladle lips, spouts and crucibles.
- (4) *Thin flat sections poured level instead of tilted.* Since tilting is so important, it should be recognized during the pouring set-up.
- (5) *Crushed cope.* The pouring crew can cause thin sections in otherwise good molds by excessive mold weights, rough handling, bad jackets and careless handling of jackets.

Miscellaneous

All gas-producing materials, such as rusty, dirty, oxidized or damp chills, chaplets and nails must be carefully avoided. Obviously, foreign materials, such as cigarette butts, cigar butts and tobacco juice in the mold are likewise undesirable (and not too rare).

SHIFTS (ALSO CORE RAISE)

DESCRIPTION

A shift is a mismatch of the casting at the parting line, or a variation from specified dimensions of a cored section due to a change in position of the core or misalignment of cores in assembling. This defect is usually easy to identify by appearance (see Fig. 26.1). However, it is sometimes confused with a ramoff or ramaway to the extent that many ramoffs are called shifts. It is unlikely that the parting line can shift in opposite directions at the same time. When it seems to

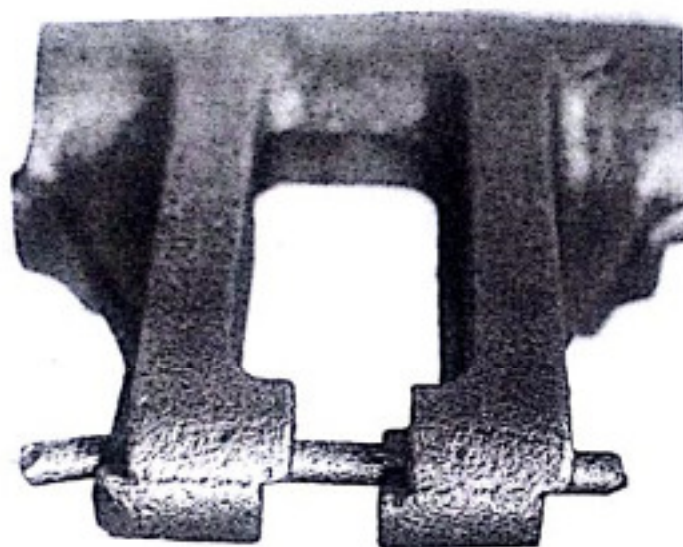


Fig. 26.1 — A typical mold shift is shown where a cope and drag did not match.

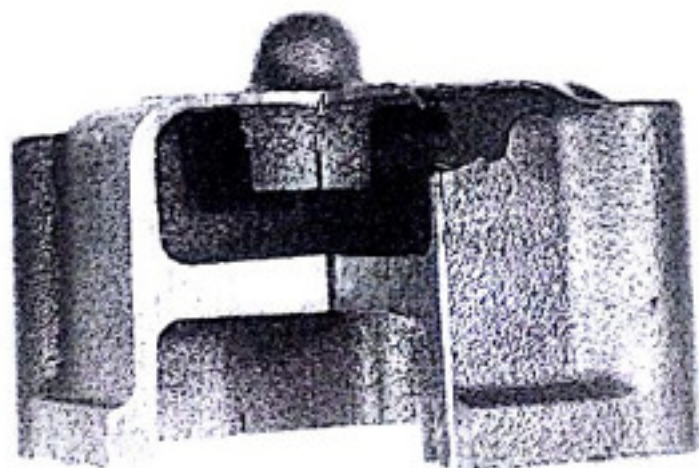


Fig. 26.2 — A typical core raise resulted in an apparent misrun over the core.

be questionable (such as shifting at one end more than at the other, etc.), it is well to check for ramoffs since the problem may not be a shift.

CAUSES

Casting and Pattern Design

Inadequate provision for core prints or core support will let the core rise during pouring. The core raise is classified as a shift. Figure 26.2 illustrates a typical core raise.

Pattern Equipment

- (1) *Patterns not properly aligned in the cope and drag are a most common cause of shifts. In fact, the majority of shifts is related to some part of molding, or to flask or pattern equipment. Some of the fault is carelessness; a more common fault is wear and lack of maintenance.*
- (3) *Misaligned locators on nonshift devices fail to stop the shift as was intended.*
- (3) *Loose or worn dowel pins in loose patterns permit the cope and drag sections to be misaligned during molding, rapping, or drawing the pattern from the sand.*
- (4) *Loose patterns on plates can move during molding, vibrating or stripping causing a misalignment.*
- (5) *Lack of locators permits shifts to occur more readily than would be expected from good commercial pattern equipment.*
- (6) *Inadequate or improper core prints lead to core movement since there is not enough support provided in such a pattern design. A comparison of the results of inadequate and proper core prints is shown in Fig. 26.3. (See also Chapter 24, RUNOUTS AND BLEEDERS (5).)*
- (7) *A soft ram caused by inadequate space between patterns or between patterns and flasks will permit the sand wall to move during rollover or pattern draw.*

Flask Equipment and Rigging

- (1) *Worn, bent, or missing pins or bushings are the most common causes of shift (see Fig. 26.4). The tolerance permissible depends upon the requirements of the casting but for any given tolerance, preventive maintenance and inspection are essential.*
- (2) *Tight, worn, bent, or broken bands or jackets*

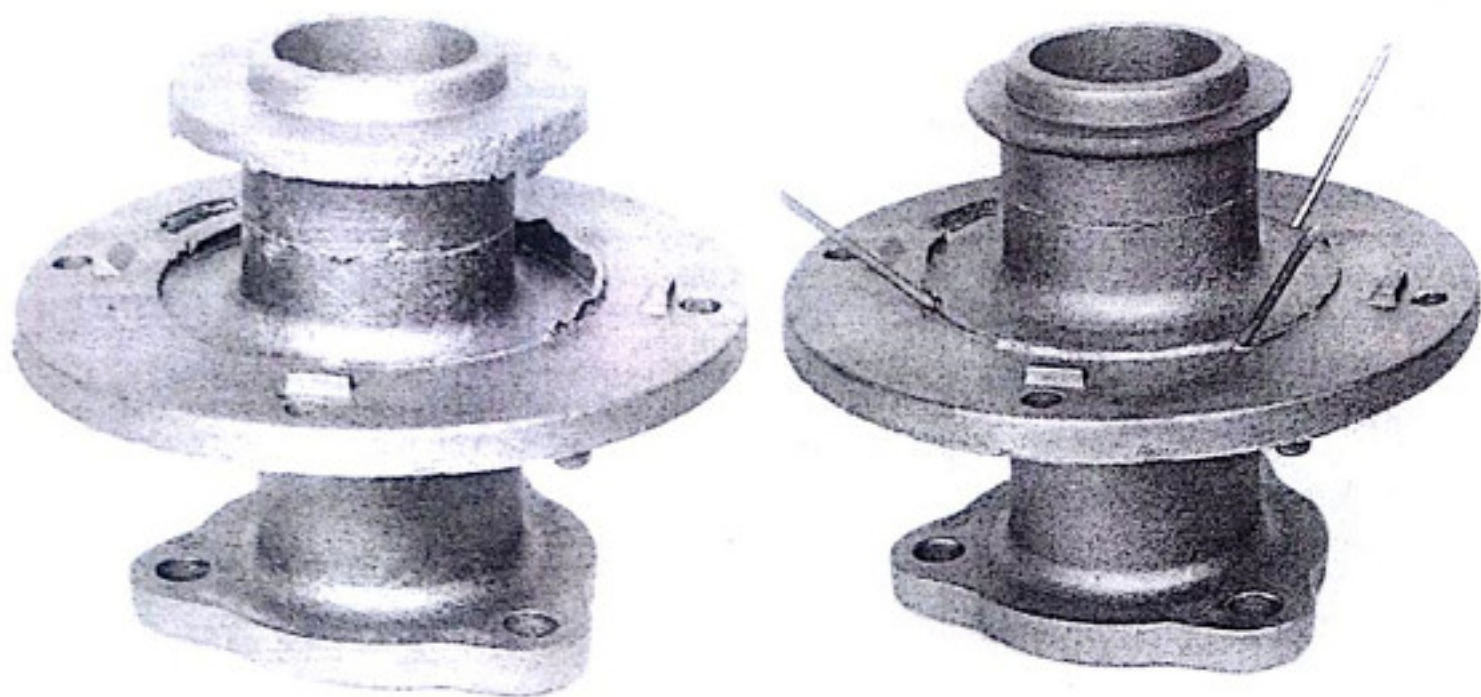


Fig. 26.3 — Comparison of the two castings illustrates one result of inadequate core prints which produce a vertical shift. Left: Casting with vertical shift. Right: Good casting.

are a factor when jobs depend upon bands or jackets (snap flask-type work) for location rather than pins and bushings described in (1).

(3) *Weak or warped flasks* create a tendency to shift during assembly and handling. Worn or new flasks may also be out of square.

(4) *Faulty or worn molding machines for impression work*, which is common in stack molding, determine a shift because in these cases the molding machine becomes part of the alignment procedure or practice.

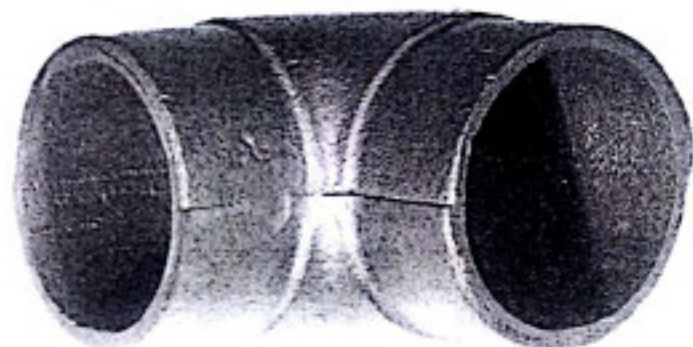


Fig. 26.4 — Illustration of how worn pins and bushings permit a mismatch in one or more dimensions.

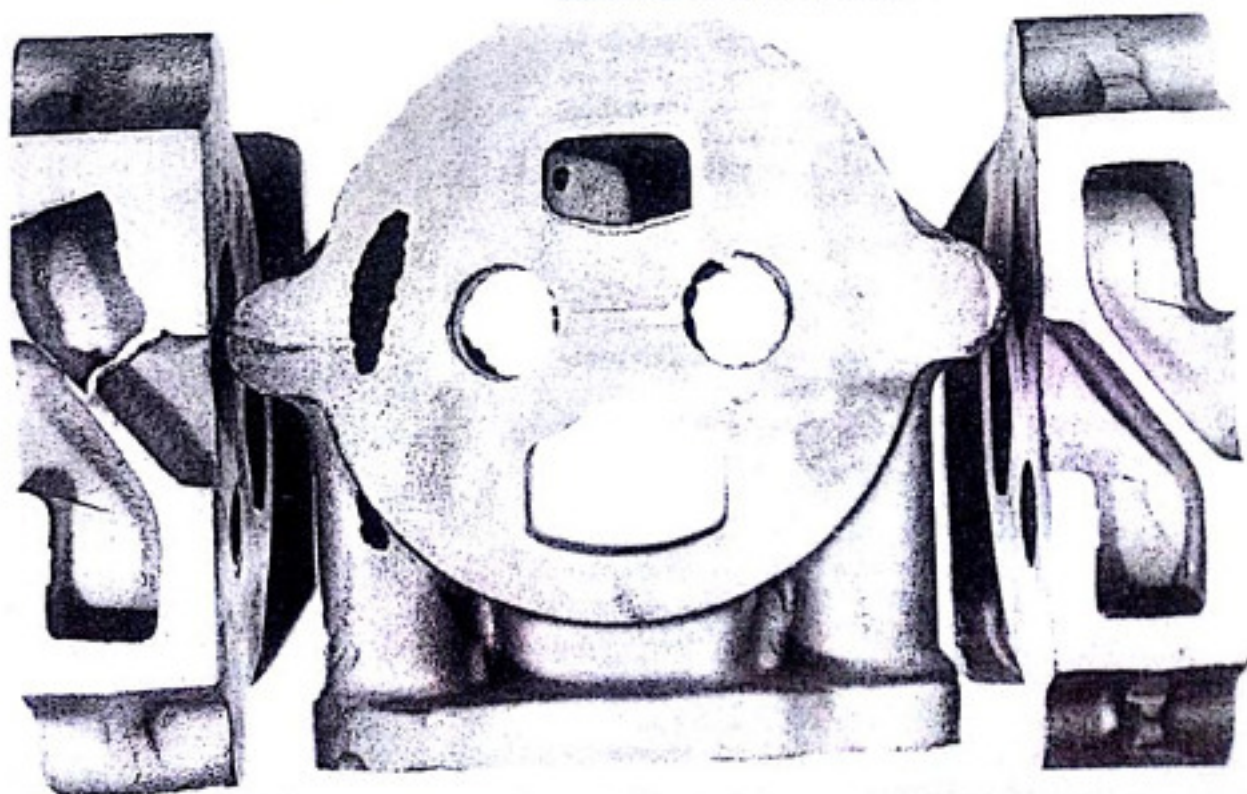


Fig. 26.5 — Left: Casting with defect as result of incorrect assembly of cores. Right: Casting after core assembly was corrected.

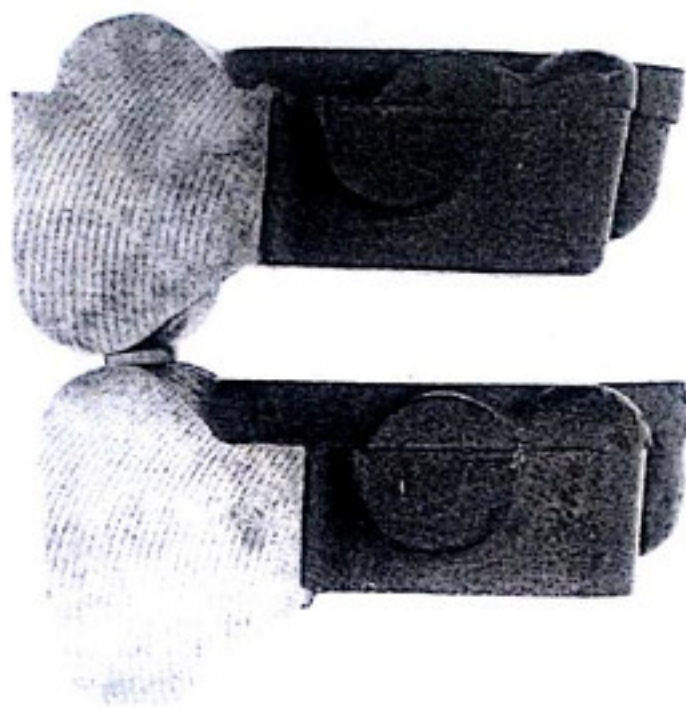


Fig. 26.6—Shifts as a result of cope motion while the molder was carrying the mold to the pouring floor.

(5) *Worn setting, assembling, rubbing or checking jigs* cause shifts by failing to disclose shift tendencies when they are used for inspection or setting operations.

Gating and Riser

The gate design, per se, does not induce shifts although placement of runners may modify a tendency toward a ramoff condition which might be mistaken for a shift.

Molding Sand

Any sand condition which promotes a weak mold can permit shifts during handling or rollover operations. The problem is created by the low strength in the mold and is, therefore, a function of inherent strength and mold density. A soft or weak ram is most apt to be the problem, so that the sand itself contributes to the extent to which it is either weak or difficult to ram (low moldability).

Core Practice

Since a core raise and core shift are both involved in the general classification of shift, any inaccuracy in assembling, pasting or joining can create the problem. (See Fig. 26.5.)

(1) *Misalignment of cores in assembly* is usually due to: excessive rubbing of the core or rubbing it out of square; and excessive core paste or failure to support the core until the paste is dry.

(2) *Green core distortions due to low green strength (inadequate chemical set) or improperly fitted driers* show as a shift on the final casting. These factors should be caught in core inspection.

Molding Practice

(1) *Excessive rapping of loose patterns* creates an oversized cavity which shows as a shift unless the rap-

ping of both cope and drag is identical. The problem is aggravated by soft molding or variations in mold density. Excessive rapping also makes oversize core prints.

(2) *Using dowel pin holes for rapping holes* soon distorts them and leads to misalignment.

(3) *Use of improper or unsecured chaplets* produces the mislocation of the core or permits movement of the core. This could be a case of the incorrect length of chaplet or weak chaplet which fails to support the load or pressure.

(4) *Setting the core incorrectly* includes end for end, upside down, etc. This is due to carelessness.

(5) *Reversing the cope on the drag* produces some of the most interesting but obvious shifts.

(6) *Improper clamping or weighting* of the mold produces a shift with normal tolerance of pin and bushing locators. Many who use clamps fail to realize the tremendous thrust imparted by a wedge when misapplied to one side of the mold before the other. With pins removed, the effect of clamping or weighting produces a shift most easily. Inadequate or worn pins permit movement under clamping pressure to the extent of the wear. Uneven clamping can be from side to side or end to end.

(7) *Rough and improper handling* of the mold may induce shifts in direct proportion to the accuracy of pins and in proportion to the strength or density of the mold. The cope may be shifted by the molder

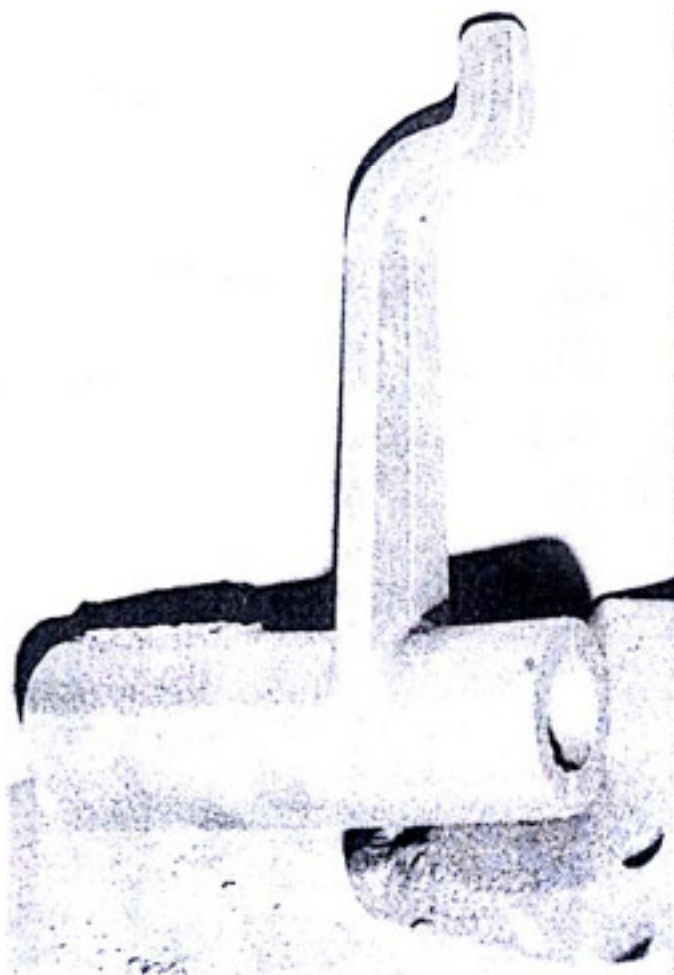


Fig. 26.7—Defect caused by mold shifting while being moved on a roller conveyor.

carrying the mold especially if he carries part of the weight on his body (see Fig. 26.6). Bumping molds on a pallet line is common in high production work and creates a shift. Bumping molds in automatic handling is the result of poorly designed or poorly maintained equipment which imparts a rough jolting action.

Rolling molds on a rough gravity conveyor can induce shifts if it doesn't cause crushes, core sags and a few other defects first. A defect caused by mold shifting on a moving conveyor is shown in Fig. 26.7. Tilting or upending molds causing slippage of the cope on the drag can happen with hand work or is common in work rolled over in slings. It is also found in weak molds being raised to pour on an incline.

Metal Composition and Melting Practice

A shift is a mechanical problem and does not involve the metal composition or the melting practice.

Pouring Practice

A shift occurs before or after the metal is poured and is due to a mechanical fault in the mold. However, the pouring crew is often responsible for the handling of weights and jackets which can induce a shift.

(1) *Slippage of the cope on the drag when shifting jackets* is common, especially if the man is located on one side of the mold and is forced to place the jacket in a side motion.

(2) *Bumping molds with the ladle* while pouring or while handling the bull ladles, may not be easily detected but is not uncommon.

Miscellaneous

Vibration from adjacent heavy equipment has been known to shift molds, especially if the pins are worn or the mold is weak. Vibrations of this type carry a surprising distance under certain circumstances.

SHOT METAL OR COLD SHOTS

DESCRIPTION

Shot metal or cold shots are small globules of metal embedded in, but not entirely fused with, the casting (See Fig. 27.1). The only problem in defining this defect is to avoid confusion with a cold shut, or possible confusion with small plates described in another chapter. A cold shot shows as an approximately round shot, while a cold shut is a form of misrun and appears as a crack or seam.

Actually, seams, shots, and shuts are closely related but some differences occur which may have importance in proper diagnoses. If doubt exists, it would be well to compare all three as described in this book.

CAUSES

Casting and Pattern Design

Casting and pattern design have no effect in creating shot metal or cold shots.

Pattern Equipment

If there is *excessive tolerance* between the core and the core print, the molder is apt to provide some type of seal to prevent metal flow around the print. If the metal flow is not prevented, the vents will be

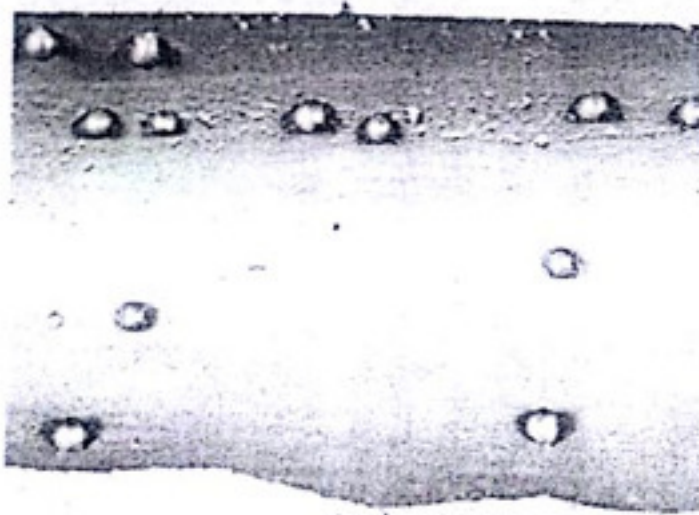


Fig. 27.1—Cold shot on inside surface of centrifugally cast iron pipe. This particular defect was cured by ladle additions of silicon.

plugged resulting in a blowhole. The sealing compound used to correct the excess clearance around the print is apt to be wet. When the metal hits the wet sealer compound, it sputters and splashes, throwing shot metal into the mold cavity. If this shot does not redissolve, a defect results.

With inadequate venting of the parting line between cope and drag, gas can kick back into the mold. This may create a blowhole (see Chapter 11, GAS DEFECTS) or the turbulence may result in a shot and sputtering action. Such turbulence may leave shot metal in the casting if resolution (redissolving) does not occur in time.

Besides eliminating these causes, it is desirable to make sure that the gates permit smooth, nonturbulent flow in order to reduce any tendency for sputtering and boiling action.

Flask Equipment and Rigging

(1) *Bars in flask too close to mold surface.*

(2) *Flask wall too close to mold surface.* If the bars, flask, gagers, and other metal surfaces are too close to the mold cavity, it is possible to produce shot from turbulence and gas. This is especially aggravated if the bars, etc., are so close as to permit the thin sand to drop or fall away, exposing the bare bar or flask. It is quite common to find gas holes (blows) in those castings having cold shot, because the turbulence, boiling or sputtering does cause both types of defects.

(3) *Sprues and risers too close to bars or flask walls.* Sometimes the shot is created in the sprue system and washed into the mold. This is particularly true of those metals which oxidize or dross readily. The oxidized shot does not redissolve even in a stream of metal. For this reason, having the sprue too close to a bar or flask can produce a shot defect.

Gating and Riser

Since the defect is primarily a result of sputter or spray, it is necessary to avoid turbulence and interrupted flow. Therefore, special care in the design of multiple gates is needed. If the runner and gates are not properly proportioned, small amounts of metal can shoot into the mold even before the gate starts to feed smoothly and fully.

Often, many or most of the gates of a multiple system will shoot such shot while most of the metal is moving through one or two of the gates. Later, all gates may feed, but too late to redissolve the shot

formed during those first critical seconds of pouring. One cure is to design gates to feed backwards (at an angle) from the runner in order to avoid preliminary feed. A second is to use a step-down runner in order to force all gates to feed uniformly.

Another related problem comes from pop or pencil gates which are too small. In these cases, the first metal hitting the drag may splatter until an adequate pool is developed below the pencil gate. The use of skim cores in the mold cavity is a specialized form of small pencil gating. It is sometimes assumed that one may gate directly down on the cavity (such as pouring through a riser) if a skim core to break the fall of metal is used. It is not unusual for this to cause exactly the same trouble (cold shots) as too small a pencil gate.

Molding Sand

Sand is a factor only to the extent it may create a severe blowing action causing metal to spatter. In other words, only rather drastic errors in sand practice could cause these defects. There have been cases, for example, where automatic moisture control equipment has gone out of adjustment so that the sand became much wetter than normal. Obviously, any condition of excess water would be exaggerated by low permeability resulting from excess fines, poor distribution or uneven ramming. There is a relationship between permeability and water to the degree that a tight sand has much less tolerance to errors in moisture control.

Foreign materials such as clay balls, cereal balls, miscellaneous metal and similar impurities will have the same effect in a localized area as excessive water. The condition is usually aggravated because such foreign materials are usually wet, rusty, or oily.

Core Practice

As in the case of sand, cores produce this defect only if they are so far from normal as to produce a violent blowing action causing the metal to spatter. Any unusual wetness in the core, core wash, core mud, or core paste can be responsible. Some core pastes are particularly apt to cause spatter if not properly dried. It is wise to avoid excess mud because a large amount of core mud will be hard to dry.

Exposed wires, arbors, and supports will also cause a kick if they are wet, dirty, oily or rusty. A good example may be found when lifting eyes (hooks) imbedded in core surfaces to facilitate core setting. If these are not properly patched they can cause spatter. If they are set too deep, they will require too much mud and the excess mud, being difficult to dry, may kick.

If a core vents into the cavity (poor core design) or if the core vents are allowed to plug with metal, a volcano of shot often occurs. In large molds, such shot has been found at a great distance from the vent. Any foreign material or even concentrations of high gas binder on the surface can start a spatter action. The usual expression is "the metal won't lay to the core."

Molding Practice

As in the case of sand and cores, one should look for something so unusual as to cause a violent boil. The most common mistakes are to seal off the vents by careless mudding-over; by failing to connect the



Fig. 27.2 — Cold shot from interrupted pouring.

vent to the outside; or by permitting metal to flow into the vent. The gas pressures during the temporary plugging of a core vent can build up to the point of explosion, thus producing a shower of shot.

Metal Composition

Some metals are more prone to form shot than others. It is important to remember that if the shot redissolves there will be no defect. If the shot becomes coated with an oxide film or dross, it will not redissolve. Therefore, conditions of rapid oxidation (e.g., low carbon steel) or rapid dross (e.g., aluminum) are more apt to form shot than high-carbon cast iron.

These effects are further aggravated if the metal composition is badly out of range of the anticipated composition. An excess rate of solidification makes such shot hard to redissolve. The gating, sand, core, and molding practices should be controlled in such a way as to avoid the shot formation in the first place.

Melting Practice

There is no evident relationship between melting practices and formation of cold shots.

Pouring Practice

The spatter effect can occur outside the mold by careless skimming or careless pouring. For example, the metal pourer may do his skimming over the sprue hole in such a way as to drop the dross down the sprue. The pourer may also miss the sprue just long enough to bounce a load of shot down the sprue or open risers. If such shot oxidizes, it will not redissolve during pouring.

An interrupted pour will create shot (see Fig. 27.2) along with a few other defects. Interrupted pour or "dropping the sprue" is always dangerous practice. Cold metal exaggerates all of the problems which may

be related to the other practices. If the shot is cold when formed or if subsequent metal is cold, there is little hope for resolution.

Miscellaneous

Any factor which causes a spatter can cause shot. The list of foreign materials which have been found in molds is a long one, but the more common include wet, rusty, and cold nails and tramp iron. Besides one often finds rust, oil, and dirt on the chaplets or chills which are placed in the mold intentionally.

A condensation between cold and hot objects such as a core and mold can produce enough water to throw shot iron. The use of cold chills and hot sand or vice versa will cause a late boil. The resulting blowholes will frequently be accompanied by shot.

In this regard it is important not to confuse the shot in the bottom of a large blowhole in gray iron or nodular iron with a true cold shot. The small shot in such graphitizing metals is usually the result of metal being exuded into the blowhole by the pressure of late graphitization.

Chapter 28

SHRINKAGE CAVITIES AND DEPRESSIONS

DESCRIPTION

A shrinkage cavity is a jagged hole or spongy area lined with fernlike crystals called dendrites. A shrinkage depression on the surface of the casting is a recession from the true plane or the mold surface. These true shrinkage defects must be differentiated from hot tears and cracks.

As mentioned in Chapter 11, GAS DEFECTS, there is apt to be confusion between a shrink and a blow. If a doubt exists, the chapter on GAS DEFECTS should be referred to. An incorrect diagnosis of the defect can be expensive. Many of the cures for both are the same but in some cases the cures are just opposite. As a result, the intended cure can make the problem worse. If the defect has all the physical appearance of a shrinkage cavity, such as dendritic crystals, it may be confused with a hot tear or hot crack.

Therefore, it is well to check Chapter 13, HOT TEARS particularly in the case of metals prone to hot tears (e.g., malleable and steel). It is characteristic of a shrink to appear in heavier sections, at changes of section, or at hot spots. These same locations are also prone to permit gas defects and hot tears. Thus diagnosis must be carefully made by obtaining the facts and all the facts.

CAUSES

Casting and Pattern Design

(1) *Change in section size too abrupt.* Some designs provide unnecessary abrupt changes in section. This problem has become more intense with the trend for reduced weight or modern appearance. Unfortunately, the designer may not recognize that a thin section solidifies more rapidly than the adjoining heavier metal section, and progressive solidification and feeding become difficult. Design should permit each section to blend with the adjacent section. If this cannot be done, it may be necessary to use chills to provide progressive solidification and feeding. (See Figs. 28.1 and 28.2.)

(2) *Isolated heavy sections which cannot be fed.* Isolated sections can easily become a problem if the design does not permit any method to feed metal to them. Again, the desire for weight reduction intensifies the problem especially if the design makes it impossible to feed a heavy section through a thin section (see Fig. 28.3).

(3) *Fillets too small.* Even when the design does

incorporate fillets, the fillets may be insufficient for the sections involved. The design engineer may be forced to compress mechanisms into confined areas and sacrifice a fillet area to do so. Sometimes this situation may be met by reducing the metal section more nearly proportionate to the small fillet. If the fillet size can be increased it should be until the defect disappears.



Fig. 28.1—Typical shrinkage defect occurring in a thick section which could not be fed.

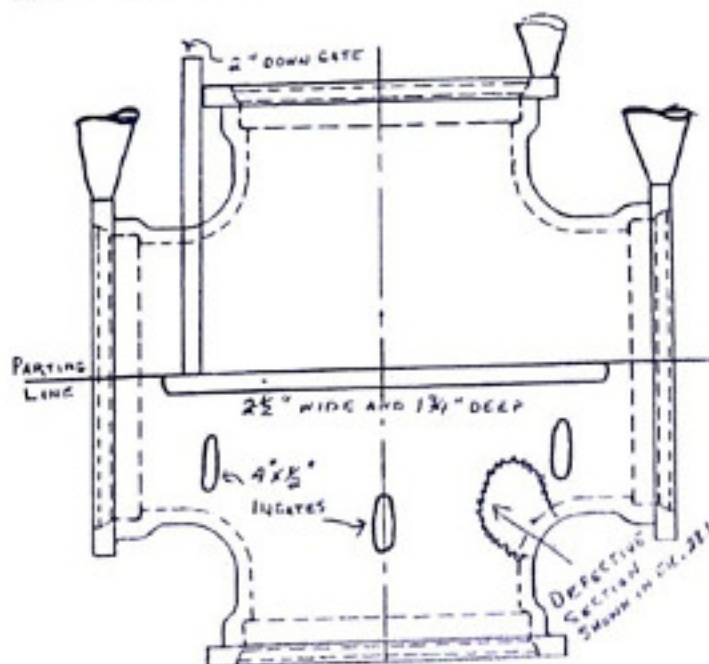


Fig. 28.2—Design of casting shown in Fig. 28.1 which prevented adequate feeding of heavier sections.

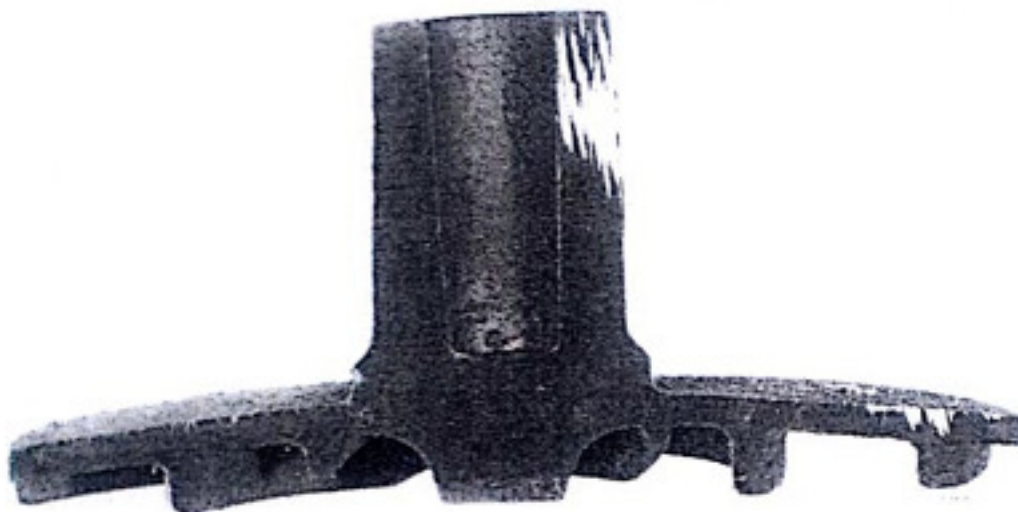


Fig. 28.3 — An isolated heavy section makes casting prone to shrinkage defects. As illustrated, the defect was cured by lightening the section through the use of a core.

(4) *Fillets too heavy.* Contrary to the previous statement, it is also possible to have a fillet that is too large. For example, this may be done to facilitate drawing the pattern from the sand or in an attempt to develop extra structural strength in the design. If overdone, the fillet becomes the heavy section which cannot be fed by the thinner adjoining sections. If it is not possible to reduce the fillet or make the adjoining sections heavier, it may be necessary to use chills on the fillet area.

(5) *Insufficient area for feeding or chilling isolated sections.* Occasionally, practical design is ignored and an isolated heavy section is placed in such a position that it cannot be reached by any feeding technique. In this case, it becomes necessary to redesign the adjoining sections so they can act as feeding areas.

Pattern Equipment

(1) *Worn patterns or core boxes causing thin metal sections.* Since shrinkage is vitally related to feeding ability, it is necessary to make sure that equipment is maintained in such a way as to permit such feeding. For example, worn patterns may reach the point where certain sections become undersize and prevent feeding. Difficult designs should have long-life pattern materials to guard against any problems from excessive wear in critical areas. Obviously, this same situation applies equally to core boxes which control section size.

(2) *Incorrect pattern dimensions resulting in castings sections too thin or too heavy.* A new pattern can have the same problem of thin sections in critical areas, and still be considered within the range of tolerable human error. The carelessness may be gross or merely a lack of recognition of the importance of maintaining maximum thickness in thin sections adjoining heavier sections. It is often desirable to

adjust these areas to dimensions other than the normal shrink rule allowance to make sure they cast to maximum thickness permissible within the specifications. A sample casting should be made and checked when practical.

(3) *Poor pattern construction resulting in too thin or too heavy casting sections.* A poor pattern can cause these problems by flexing under molding pressure and creating thin sections in areas already critical. This must be watched carefully if molding methods change, e.g., a change from normal to high-pressure molding. The quality of the pattern must be suitable for the requirements imposed by the molding equipment or process.

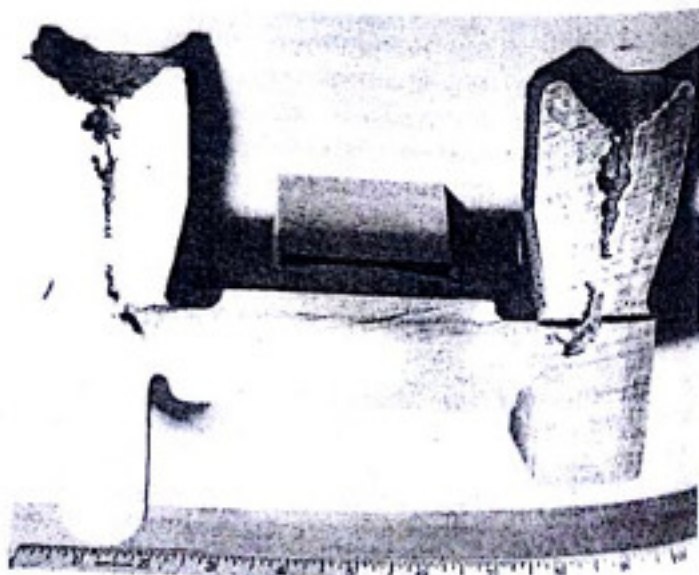


Fig. 28.4 — Insufficient cope height prevented adequate riser height to feed the sections involved. Sectioning through both the riser and the casting demonstrates the need for additional feed metal height.

Flask Equipment and Rigging

(1) *Cope flask too shallow.* A frequent cause of shrink is to rig with insufficient cope height, as illustrated by Fig. 28.4, in an attempt to save sand or reduce flask and molding costs. The short cope will reduce metal static pressure to the point where feeding becomes difficult. The lack of feed pressure can result in either a shrink, blow, or both in combination. When the foundry is forced to work shallow copes, some relief is possible by using sleeves on risers and pouring cups on the sprue. These methods artificially raise the cope height. It is also possible to use exothermic sleeves or topping to ensure getting the full height of what cope height does exist.

(2) *Flask too small.* Sometimes an undersize flask may be used to save sand and molding cost or because no other flask is available. The danger is that proper gating becomes impossible or the risers are so close to the flask wall that they cool and freeze before the feeding cycle is completed. It may be necessary to resort to exothermic sleeves to retain heat. If proper gating is impossible, a clever use of pop or pencil gates may be successful with certain designs and metals.

(3) *Improperly fitted jackets.* Improperly fitted jackets can be as bad as incorrect flask size. In this case, the problem is one of mold-wall movement. The lack of support permits the mold wall to move or distort, creating a heavier section than can be fed by the designed feeders. It may be necessary to go to tight flasks if jackets do not give adequate support.

Any job which is rigged in such a way as to prevent adequate ramming may permit mold-wall movement. The problem may be diagnosed as soft ram but the real cause may be the flask size, the number of patterns in a flask, the placement of bars, or the relative inefficiency of the molding methods.

Gating and Riser

Everything else being equal, the gate and riser system is the logical place to look for trouble because, by definition, shrinkage is a feeding problem. Other conditions may offset a good gating system, but a poor gating system will give repetitive problems and high percentage of rejected castings. A high percentage of scrap from a given pattern is cause to suspect the gate. A low percentage usually indicates another cause because a bad gate is usually bad all the time — not just 5 per cent or 10 per cent of the time.

(1) *Gates and risers not promoting progressive solidification.* Gates and risers must be designed to promote progressive solidification. Therefore, the placement and size must be considered in relation to the sections which naturally freeze first, and which freeze last. The last sections to freeze must be fed by either an active sprue or a riser containing liquid metal. Figure 28.5 shows a shrinkage caused by long connecting section between riser and casting.

(2) *Insufficient number of, or improperly attached, gates or risers.* A common mistake is to use an insufficient number of gates or risers. (See Fig. 28.6.) There is a limit to how far each feeder can feed. The distance will depend upon the metal section, tempera-

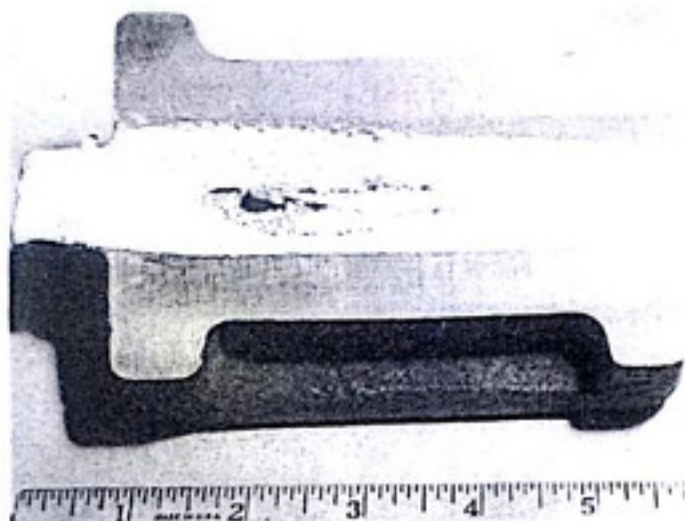


Fig. 28.5 — Shrinkage was caused by excessively long connecting section between riser and casting which prevented correct feeding even though riser was of adequate size.

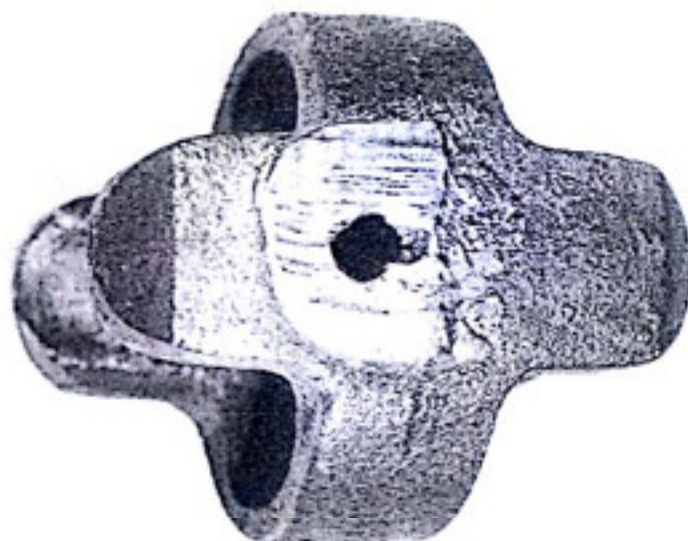


Fig. 28.6 — Feeding four of these castings from one small riser was not sufficient to prevent shrink in the riser neck.

ture and composition. Thin sections freeze most rapidly and shut off the potential feed. An incorrectly designed gate, such as one causing excessive choking, will freeze off, rendering the neck inadequate. There is not much point in having liquid metal in the riser if it can't get to the casting.

(3) *Risers too small.* A common error is to have the riser too small. The riser section should be greater than the metal section being fed unless the correct exothermic material is used to increase riser efficiency. A common human error is to fail to use exothermic material on risers specifically designed to work only by virtue of the extra heat it provides. It is also a mistake to assume that a small diameter riser can be made effective by increasing the height. The increased height has no effect if the riser solidifies because of the small diameter. The ideal riser is a sphere because it has the least cooling surface per pound of metal. In some instances, it is more practical to chill heavy sections than to try to overfeed them.

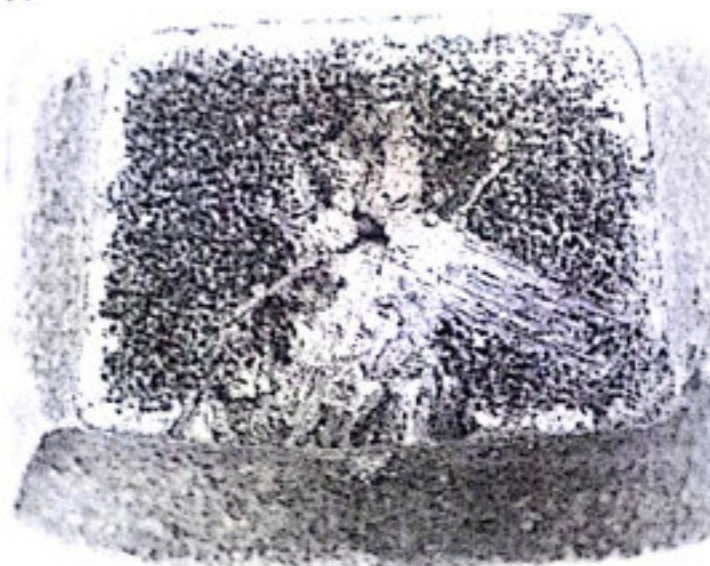


Fig. 28.7—Gate area being equal to the casting section created a shrink in the gate itself.

(4) *Improper ratio of riser neck to casting size.* The neck of the riser is often critical to riser efficiency. Too often there is a tendency to shortcut on the size of the riser below the neck. If this is too shallow the neck will freeze leaving liquid in the riser with no place for it to go. It should be borne in mind that spherical shape is ideal. The neck should lead to the center of a mass of metal, not to the bottom. Therefore, metal below the neck keeps the neck open. It is not wasted metal.

(5) *Excessively large ingate(s).* Occasionally, a shrink can develop in the neck or ingate itself (see Fig. 28.7). This is usually caused by the ingate being too large.

Because the neck is surrounded by hot sand, if it is too large it will be the last metal to freeze. If it stays open too long, the neck itself will contain the pipe since there is nothing to feed it. In a correctly designed system, the first part to solidify is the casting. After the casting, the neck or ingate should freeze. The last to freeze should be the riser. If this progressive order of freezing is destroyed, intentionally or by accident, a shrinkage can occur.

Molding Sand

Any condition in the sand that will permit mold-wall movement under pressure. Mold-wall movement can cause shrinkage defects particularly if it is a variable. An anticipated movement can be handled by changing the riser if the mold-wall movement is in a section that can be fed. However, a variable mold-wall movement creates a feeding problem for which there is no feeder provision. The greater the mold-wall movement, the greater the tendency to shrinkage defects. This is especially true if the motion creates a change of section problem. Such mold-wall movement shrinkage is rare in cement, CO₂ and good dry sand molds but is common in green sand molds.

It is aggravated by soft ramming. Mold creep is large and erratic in molds of 60 to 75 hardness. It is much less, and more uniform, in molds of 85 plus hardness. A careful measurement of every section will disclose the presence of objectionable mold-wall movement. It should be kept in mind that the shrinkage is related to volume and volume to the cube of the section change. Therefore, a small change in thickness creates a large change in volume—and shrinkage to be fed.

Mold creep or mold-wall movement can be reduced by high green strength and hard molds. Weak, soft

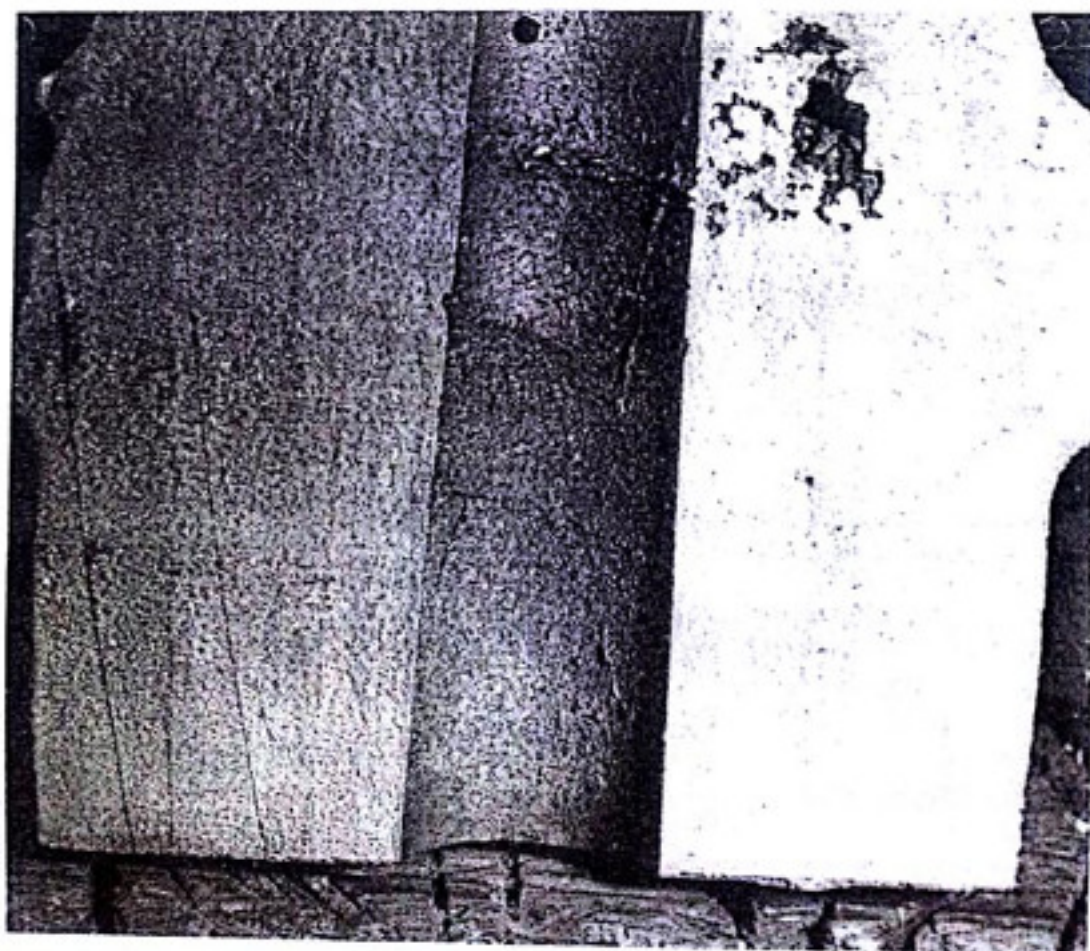


Fig. 28.8—Soft ram mold, permitting mold-wall movement created a feeding problem in the heavier section.

molds are major offenders. Excessive hot deformation is another major cause of mold-wall movement. Shrinkage defects frequently occur when the molder attempts to cure an expansion scab by soft ramming or by use of excessive hot deformation materials. The cure for expansion (when overdone) becomes the cause of shrink.

Core Practice

(1) *Core movement causing uneven metal sections.*
 (2) *Any condition in the core that will permit mold-wall movement under pressure.* A variation of mold-wall movement is found when cores move and permit an oversized section of metal. Such a motion of cores is related to lack of chaplets, soft or insufficient prints or weak warping cores. In fact, any core situation which permits a change in section or mold-wall movement can be a factor. When the core is all or part of the mold wall, it is the important factor. This motion has both a direct and an indirect effect. The enlarged section may need feeding beyond the designed feeding capacity of the system. The enlarged section may create a change of section or an isolated heavy section, or interfere with progressive solidification. A major danger in mold-wall movement is that it often creates a section which cannot be fed. Even if feeding is possible by the addition of a riser, it is undesirable because it creates an unnecessary loss of yield.

Molding Practice

Any molding practice that will permit mold-wall movement under pressure. Much of the information given under **Molding Sand** applies also and to a greater degree to molding. Sand strength, moldability and the hot deformation are sand properties. However, the degree to which the sand is molded changes all properties drastically. This is especially true in mold hardness over 85.

The sand properties in the laboratory are based on a sand molded to 85 to 90 hardness. If the actual mold is much softer, such as 70, the properties are completely different from those found in the laboratory. Therefore, the effect of sand on mold-wall movement is largely under the control of the molder. Soft molding can easily cause shrinkage (see Fig. 28.8).

Metal Composition

Chemical composition unsuited for section involved. Metal composition is involved in two major and distinct areas. First, there are the direct effects on metal shrinkage itself (see Fig. 28.9). For example, low carbon irons have more overall shrinkage than high carbon irons. In nonferrous work, it is possible to reduce shrink problems by widening the solidification range and aiding progressive solidification. In aluminum, grain refiners such as titanium and boron can reduce the shrink. If aluminum is low in fluidity, it can be aided by silicon. Occasionally, lowering the iron content will also help aluminum, but the reverse may be true. Most of these composition effects are direct and usually allowed for in the riser system.

Secondly, the indirect effect on mold-wall movement is more a problem because the shrinkage is not anticipated and allowed for in the gate and riser technique.



Fig. 28.9—In this small gear, a phosphorus content in excess of 0.14 per cent caused a shrinkage between the teeth.

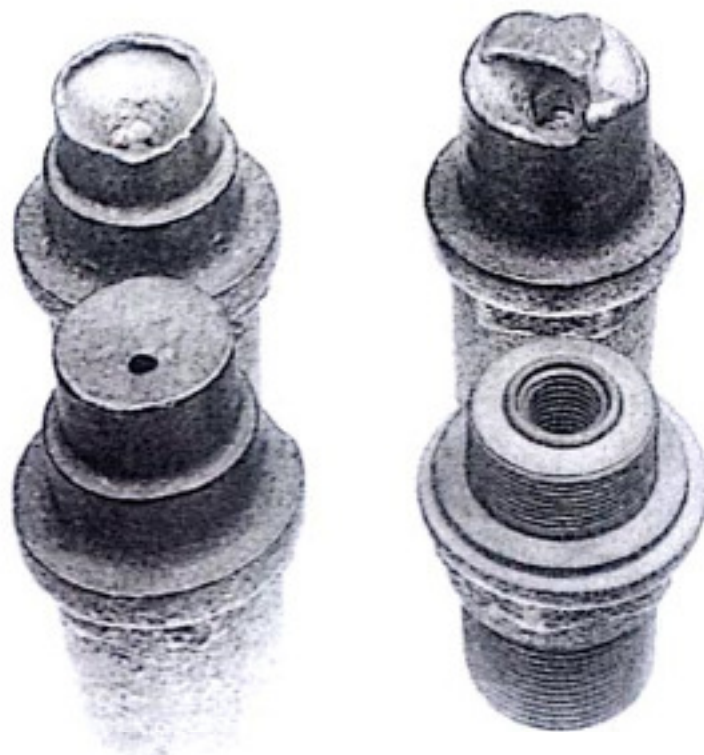


Fig. 28.10—Shrinks occurring as a result of incorrect composition and improper riser height caused by short pouring.

Mold-wall movement takes place because the metal pushes and the mold yields. The degree of push or mold-wall pressure is a variable related to metal composition. The outstanding examples are in the field of graphitizing metals because late graphitization exerts tremendous pressure on the mold wall. These metals vary in mold-wall pressure as follows: Gray iron—least; alloy iron, inoculated iron, inoculated alloyed iron, ductile iron—most.

The mold-wall pressure of ductile iron is rated as high as five times that of common gray iron. Within each group, mold-wall pressure increases with increasing total carbon and to an extent, with increasing carbon equivalent.

Melting Practice

Careless charging or weighing giving wrong composition. In dealing with mold-wall movement shrinkage, melting becomes a factor. There are direct effects

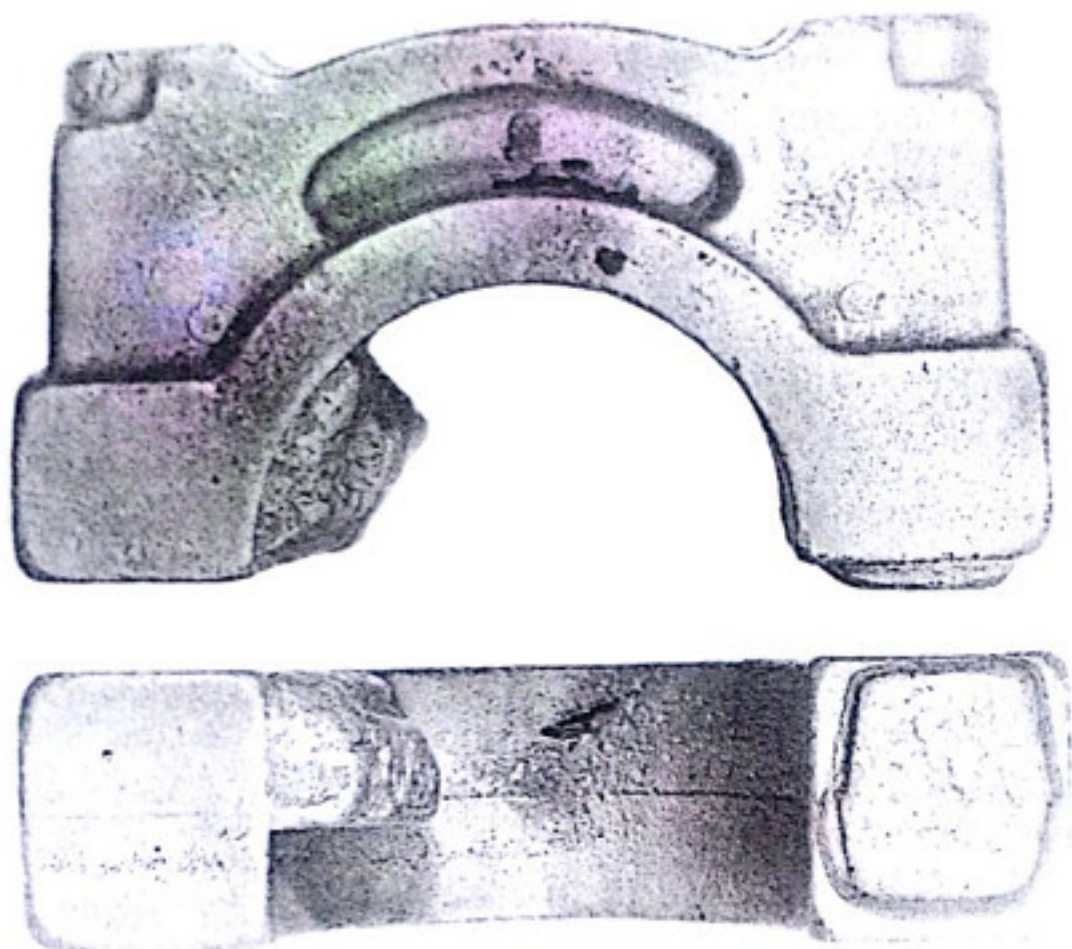


Fig. 28.11 — Shrinkage related to broken mold—an exaggerated case of mold-wall movement.

on primary shrinkage from dirty metal (nonferrous) and fast freezing oxidized metal. The mold-wall movement effect, however, is primarily a temperature and a gas absorption problem. Dissolved gases create mold-wall pressure when released during solidification.

Hot metal increases mold-wall movement by heating the sand to the point of plastic flow. This is especially true as the casting section increases because the latent heat is a function of mass.

Pouring Practice

(1) *Pouring too cold for riser design or location.* Pouring metal too cold will cause shrinkage because the riser system is usually designed for adequate fluidity and temperature. Cold metal makes the riser system ineffective.

(2) *Pouring too hot without adequate feeding provisions.* Another problem is created by pouring too hot. Excessive heat will increase mold-wall movement because the increased heat input to the sand brings the sand to the point of plastic flow (hot deformation).

(3) *Improper touch up of risers with hot metal.* A common problem in large work is the failure to touch up the riser with hot metal. This, of course, is true if the riser design is such as to require hot metal. Exothermic compounds or larger risers may be used instead of touch up if desired. Figure 28.10 is an illustration of a shrink caused by a combination of incorrect composition and improper riser height.

Miscellaneous

Metal loss through core or mold-wall fracture including fines, runouts, etc. A special case of mold-wall movement is an unexpected large fin, runout (or run into a core) or bottom sag. In these cases, the change of mold size or change in demand for metal is obvious. The effect is the same as for any other type of mold-wall movement since the problem is that the change takes place where feed metal is not available, inadequate, or cannot reach the affected section. Shrinkage related to a broken mold is illustrated in Fig. 28.11.

Chapter 29

STICKERS

DESCRIPTION

A sticker is excess metal on the surface of the casting caused by a portion of the mold face remaining on the pattern.

In most cases, a sticker may be hard to differentiate from a drop when the casting appears on the scrap pile. These cases involve one or more lumps which may have occurred during drawing the pattern. These are sometimes called "rats." In other cases, the defect shows as an overall or localized roughness from grains or small clusters of grains sticking to the pattern. Both these general types are illustrated in Figs. 29.1 and 29.2.

Unlike the drop, these defects are seldom caused by rough handling. They are usually due to stickiness of the pattern equipment or the sand, although they are aggravated by any misalignment which leads to a poor draw or sand disturbance during the draw. An apparent sticky effect may be due to low sand

strength, i.e., the forces causing the sand grains to stick to the pattern are greater than the forces causing them to stick together.

CAUSES

Casting and Pattern Design

(1) *Design is a contributing factor when it does not permit sufficient draft.* Insufficient draft creates a suction effect and promotes abrasion and loosening of the sand surface. Many designs can be handled only by using core surfaces with adequate draft on the print for a clean draw.

(2) *Design incorporating deep, narrow pockets leads to a tear up condition during drawing.* This may have to be offset by reinforcement (gaggers and soldiers), or special pattern devices such as vents or rubber-type inserts, on the bottom of such pockets to prevent vacuum-type stickdowns.

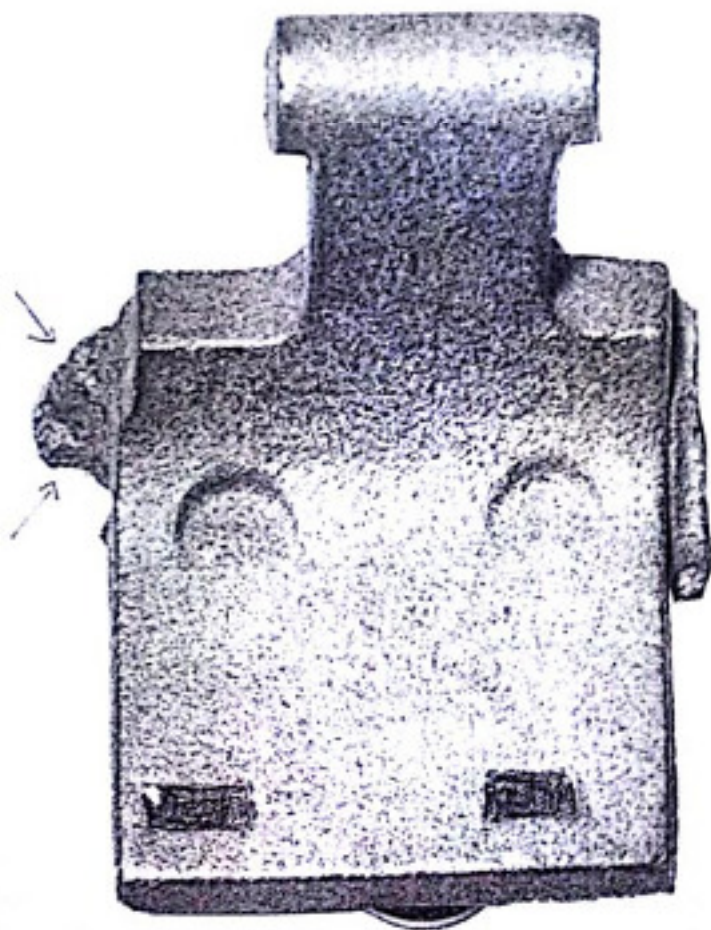


Fig. 29.1 — (Left) A lump on the casting surface caused by sand sticking to the pattern during molding.

Fig. 29.2 — (Above) Excessive moisture used in an attempt to compensate for hot sand caused general sticking of the sand grains to the pattern surface.

Pattern Equipment

(1) *Poorly polished or coated patterns* cause sand grains to adhere individually (minute back drafts) or in groups. This problem usually results from insufficient time in preparing the surface before coating or from inadequate drying of the coating. It is important to properly sand and polish patterns in order to remove any irregularities which may act as back drafts.

(2) *Worn or rough patterns* permit the sand to ram into the voids and be loosened or torn during drawing. Such patterns should be resanded and coated making sure no back drafts can occur.

(3) *Wax fillets and depressions filled with wax* are soft and either stick or wear rapidly. Any fillet more than $\frac{1}{8}$ in. should be replaced with leather, wood, metal or other suitable material.

(4) *A sticky pattern surface due to improper finishing* is an obvious and direct cause of stickers. The coating should be compatible with the sand to be used. For example, many coatings are permissible for oil-sand cores but not for self-curing binders. Some coatings can be used with dry partings but react and become sticky when exposed to solvent base liquid partings.

(5) *Insufficient draft or back draft* may cause a portion of the mold to break during the draw and leave the portion on or in the pattern. This should be seen by the molder and the mold should be scrapped or repaired before pouring. If this inspection is not made defects may result.

(6) *A pattern undercut or loose at parting line* acts as a back draft to hold the sand onto the pattern during draw. This problem sometimes appears when changing to a more flowable sand which molds more tightly into the faulty pattern. High pressure squeeze often reveals poor pattern equipment and creates problems in picking up deep pockets.

Flask Equipment and Rigging

(1) *A flask lacking rigidity* can cause breathing or distortion during squeeze molding. The flask spring-back when molding pressure is released will crack pockets and permit them to remain on the pattern during draw. They do not stick in the true sense of the word, but the defect is the same.

This problem has become increasingly apparent with higher density molding in light or under-reinforced equipment. In many cases, reinforcing of the interior or exterior surface of the flask will eliminate the problem. In other cases, a heavier flask or a reduction in squeeze pressure is needed. In some cases, the flask may be barred for increased rigidity.

Loose, poor fitting or binding pins and loose or worn bushings also affect flask rigidity. In this case, the mold breakage occurs because of side motion during drawing. This side motion creates a shear load which is greater than the shear strength of the mold.

(2) *Insufficient flask height* may permit sand to be overrammed in pockets creating a suction action during draw. Another factor is the overall strength of the pocket. A shallow cope (or drag involving lift

pockets) provides minimum strength of pockets and permits them to pull loose under conditions of suction (low permeability) or slightly crooked draw. To illustrate by exaggeration, a four in. pocket could not be lifted by a one in. layer of sand in the cope; it would pull by its own weight.

(3) *Placing too many patterns for the flask size* is a variation of the preceding. A large number of patterns will necessarily result in a large number of sand pockets between patterns. These act as deep pockets and require unusual strength to lift. Such a condition also tends toward nonuniform ram and mold brittleness (low strength plus low deformation).

(4) *A worn or misaligned pattern draw device* is a most common source of stickers. In fact, it is one of the first things to be checked. It requires only a temporary side pull to shear the pockets loose during draw.

(5) *Overjolting, or an out-of-level or worn molding machine* may separate the facing from the backing or shear the pockets after full mold density has been reached. A worn or crooked machine will set up shear stresses, but even a perfect machine can loosen and shear pockets if permitted to jolt after maximum density has been attained. Under these conditions, the jolt effect is the same as rough handling.

(6) *Excessive or insufficient vibration of the pattern* is equally bad but for opposite reasons. Excessive vibration can shear a pocket during the draw. Insufficient vibration fails to loosen the sand from the pattern and to break the vacuum created by drawing the mold.

(7) *An incorrectly adjusted automatic parting spray* leads to excessive parting in some areas and not enough in others.

Gating and Riser

Gating and riser are not factors except to the extent that the placement of runners, sprues, and gates may create pockets which are difficult to draw. The most common fault is lack of draft on deep runners located close to the pattern—they should be close for best feeding. Stickers in this location require extra work during the grinding and chipping operation.

Molding Sand

(1) *Hot sand* is a major problem in many production foundries. Such sand tends to be brittle leading to easy shear. In addition, there is a condensation phenomenon which causes the sand to stick to a cold pattern.

The correct cure is to reduce sand temperatures, but the most common method of alleviating this condition is to heat the patterns to the same temperature as that of the sand. Many operators heat the pattern only at the beginning of the shift; then rely on the sand to keep the pattern warm from then on.

(2) *Inadequate sand properties* include all properties which pertain to the ability to lift a pocket. These properties include: impact strength (shatter index); tensile strength; shear strength; deformation

(and toughness) and permeability (may be inadequate for fast draw).

Of these, the impact, shear, and toughness relate to the ability of the sand to withstand shock, rough handling, and crooked draw. The tensile strength (controlled by moisture and clay) is related to the actual lifting ability. Some additives have a direct influence on tensile strength. Deformation is a measure of toughness. Permeability is related to the degree of suction especially if the draw is rapid. Low permeability is sometimes offset by vents in the pockets or rubberlike inserts that start the draw. Some more difficult jobs use pusher pins to offset vacuum conditions in small deep pockets.

(3) *Inadequate mold properties related to sand moldability* are usually indicated by incorrect mold hardness. The sand properties recorded in the testing laboratory exist only at the same mold hardness as that recorded on the test (3 ram) specimen. Lower or higher hardness on the mold proper indicates that some other value exists. Therefore, the actual tensile, shear, etc., in the mold relates to the moldability of the sand. This property is derived from clay type, moisture and moldability additives.

(4) *Poorly mixed sand* results in nonuniform properties. Therefore, it is probable that some portions of the mold will contain sand with inadequate shear and tensile strength.

(5) *Wet sand* means that the sand contains excess water over and beyond that required to activate the clay. Moisture may be high in high clay sands but such sands are still not considered wet. On the other hand, any excess of water will directly reduce the green tensile and may also increase actual stickiness (adhesion). Since it reduces cohesion while increasing adhesion, excess water is a major cause of stickers.

Core Practice

Cores which have stuck in the core box should never be set but sometimes they are, either because of failure to inspect or through oversight.

(1) *An oversized ramup core* can be the cause of a sticker even if the core itself does not stick. Such an oversized core will break a portion of the molding sand during molding and appear as a sticker.

(2) *A sticker in the core box* results from those factors which are the same as in molding sand. In addition there are factors peculiar to the core process.

(a) A reaction between the core binder and core box finish. Alkalies and other impurities cause excess sticking to boxes.

(b) A dirty core box means an accumulation of residue which is sticky.

(c) Plugged vents are a major cause of apparent stickers and actual stickers when core is drawn.

(d) A worn area under and around the blowhole is a form of back draft.

(e) Various core binders differ in their inherent stickiness and therefore require different types and amounts of release agents. The amount and type of release agent is also related to the material of the core box.

(f) Moisture in the air line affects the release of sand directly below the blowhole or at the impact area.

(3) *Reaction between the binder and parting* sometimes occurs, especially when the type of binder is changed. For example, some resin cores require a different parting than oil sand. The supplier of the binder should be consulted for recommended releases.

(4) *Excessive moisture in sand* creates the same problem in making cores as it does in making molds—low shear and tensile strength.

Molding Practice

(1) *Rough handling of the mold* is a major or common cause of stickers, whether the molds be made by hand or on automatic equipment.

(2) *Excessive liquid parting* is a common cause because most partings contain solvents which (in excess) will reduce the tensile and shear properties of the molding sand. Puddles of such parting will weaken the sand to the point of failure. Parting is something which is good in moderation but very bad when used to excess. A clean pattern is essential in all cases.

(3) *Excessive or insufficient vibrating or rapping of the pattern.* See **Flask Equipment and Rigging** (6).

(4) *Too great a temperature difference between the pattern and sand* will produce condensation which directly causes a stick.

(5) *Leaving the pattern in mold too long* before drawing will often cause a stick by wetting the pattern or softening the pattern coating.

(6) *Ramming directly on the pattern with a slinger* creates a nonuniform mold hardness and a separation of sand layers. In a sense, this becomes a ramoff or ramaway condition slightly removed from the pattern and the lack of cohesion permits the sand layer to drop or stick.

(7) *Insufficient mold reinforcement* will prevent lifting of some pockets or sections unless gagers or arbors are used. If these are needed but omitted, a stick or drop can result.

(8) *Gagers, nails, soldiers, bars too close to the mold cavity* create a condition in which the sand layer is so thin as to lack strength. It falls away from the reinforcement by its own weight. Obviously, this condition is worsened by inadequate wash on gagers, soldiers, bars, and the like. A misplaced or unwashed gagger can be a source of weakness rather than a means of reinforcing as intended.

(9) *Careless or improper drawing of the pattern* is the same whether the draw is by hand or by machine.

Metal Composition — Melting Practice — Pouring Practice

These foundry operations are not a cause of stickers.

Miscellaneous

Foreign material in sand acts as a misplaced gagger.

SWELLS, STRAINS AND SAGS

DESCRIPTION

These defects are gross imperfections in casting dimension. In other words, they depart from the correct dimension by more than the allowed or expected tolerance.

A **swell** is an enlarged metal section related to mold-wall movement (Fig. 30.1). Mold-wall movement causes the casting to be somewhat larger than anticipated. This change in section may induce shrinkage defects or even aggravate a gas condition, or it may permit expansion defects without making a noticeable or visual swell. If the lump is noticeable and objectionable, it is called a swell.

A **strain** is a swell with a fin on it (Fig. 30.2). In this case, the mold distortion is sufficiently pro-

nounced to permit the mold to crack open while liquid metal is present. The metal runs into the crack causing a fin or vein on the swell.

A **sag** is an increase or decrease in a metal section due to sagging of the cope (decreased section) or core (increased section). This is illustrated in Fig. 30.3. When this occurs on the top surface, it may be confused with (or aggravated by) a pull-down shrink.

A **core fin** is a depression in the casting caused by a fin on the core which was not removed before the core was set (see Fig. 30.4). The core fin could also be due to paste which had oozed out from between the joints.

CAUSES

Casting and Pattern Design

(1) Designs requiring long or thin cores and not permitting the use of a support can be a basic cause of core sag. Internal reinforcing of the core may be needed to offset this design problem, or a redesign may permit proper chaplet and support locations. Special core mixes may help.



Fig. 30.1 — A typical swell.

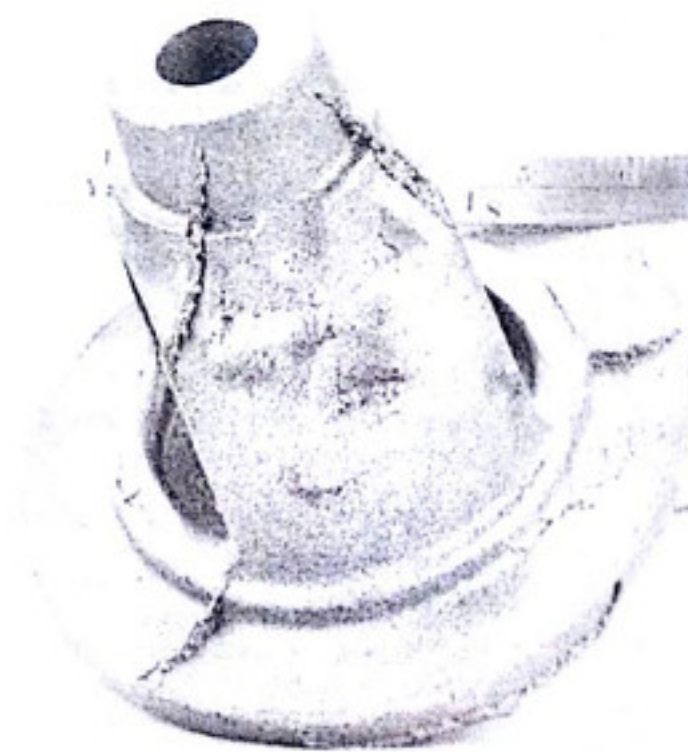
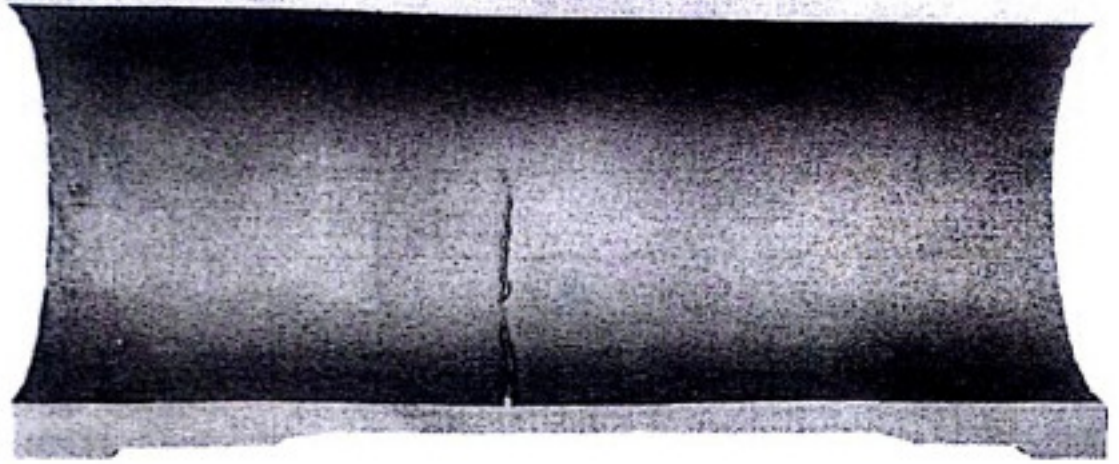


Fig. 30.2 — A strain is a swell with fins.

Fig. 30.3 — A sag in the shell core created a thin section with a corresponding thick section.



(2) Any design which necessitates closing over a core involving clearance fins obviously produces a fin which requires extra labor to remove. Thus, the design adds to the expense of production even though the casting is not scrapped.

(3) Any design which contributes to soft ramming can lead to swells or strains. For a description of such designs see Chapter 16, METAL PENETRATION. The cause of a swell will often increase the tendency to penetrate or fuse. The area of swell or strain usually shows penetration or rough surface since the causes of both are often identical.

(4) Large flat surfaces are prone to strains and sags. Such designs may be reinforced by arbors, etc., or they may be offset by the use of stronger molds and deeper flasks.

Pattern Equipment

Inaccuracies in pattern or core box dimensions reduce the support provided for in the design and thereby induce distortion during pouring. Such inaccuracies are illustrated in the following paragraphs.

(1) Parting lines may be so inaccurate that the drag cannot support the cope in certain areas. The lack of local contact induces sag.

(2) Core prints may be inaccurate thus depriving the core of its needed support. This permits the core to sag (or raise).

(3) Inaccurate dimensions of multiple kiss-throughs (particularly in high pressure molding) leave some prints unsupported unless the first contacts crush (causing sand inclusions). In softer molds the first contact may distort and crush without harm so as to permit overall contact. However, when molds are strong, the first contact may carry the load, leaving other areas unsupported. These areas may then sag at elevated temperature. The stronger the mold, the more accurate must be all pattern dimensions.

(4) Warped core boxes have a direct effect on casting dimension since they produce crooked cores.

(5) Worn pattern equipment alters the intended shape of the mold. This results in sags or swells depending upon which section is worn.

(6) Flask landings lower than the parting line, change the cope-to-drag contact in such a way as to overload the cope sand or deprive it of adequate support during pouring.

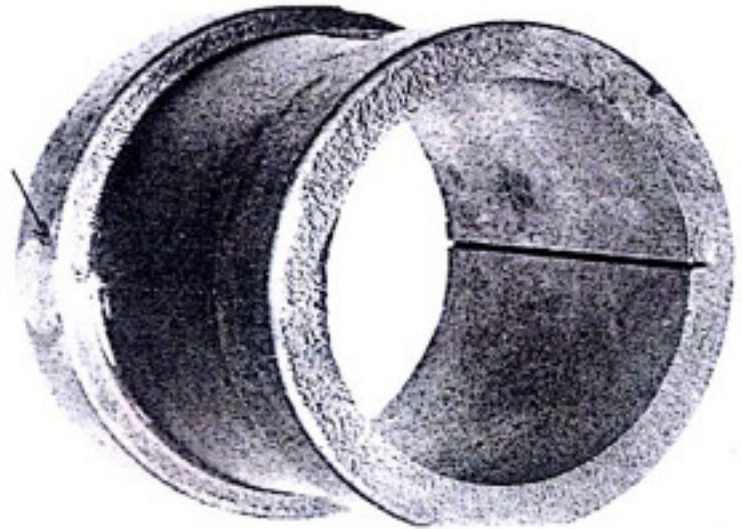


Fig. 30.4 — A typical defect resulting from a fin which should have been removed from the core before setting.

(7) Warped strained or off-dimension matchplates deprive the cope of its normal support.

(8) An inadequately reinforced pattern for the type of mold can produce a distorted cope or drag which permits a sag. An opposite direction of distortion would cause a crush.

(9) Excessive number of multiple patterns in an unbarred, clamped flask may cause a sag.

(10) Inadequate relief vents produce a temporary but high gas pressure which can distort the mold. This type of swell will usually show penetration and may show gas defects if the gas pressure occurs while the metal is solidifying. It can also cause a mold-wall movement and induce feeding difficulties and shrinks.

Flask Equipment and Rigging

(1) Warped, burned, broken, or weak bottom boards rob the mold of its needed support, allowing various surfaces to distort either before or during pouring.

(2) A curved or worn strike-off leaves sand on the mold surface which will then be forced down (or up) during subsequent squeeze operations.

(3) Weights that are too light permit the cope to raise in the flask, giving a swell or strain. This also causes parting line fins.

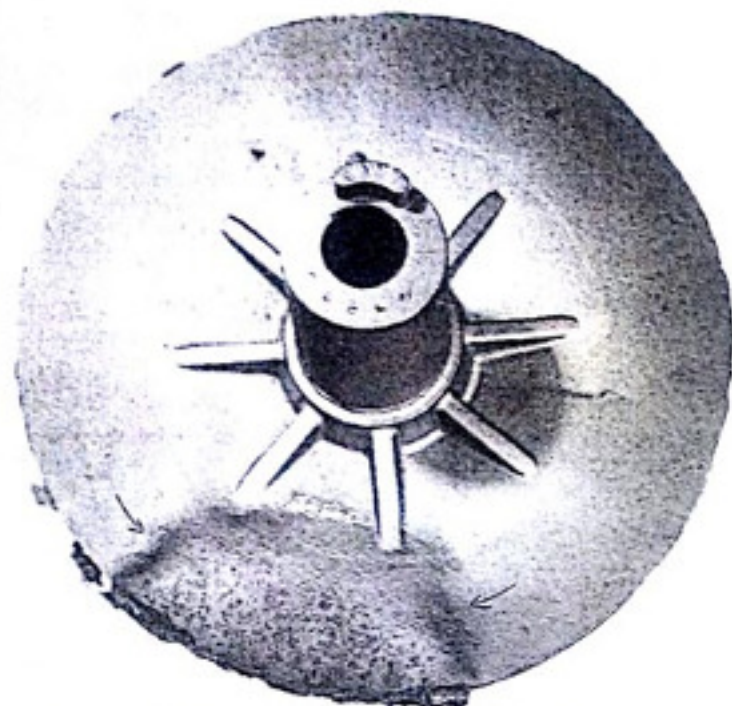


Fig. 30.5—Insufficient clearance between the bars caused the mold to soft ram the illustrated section.

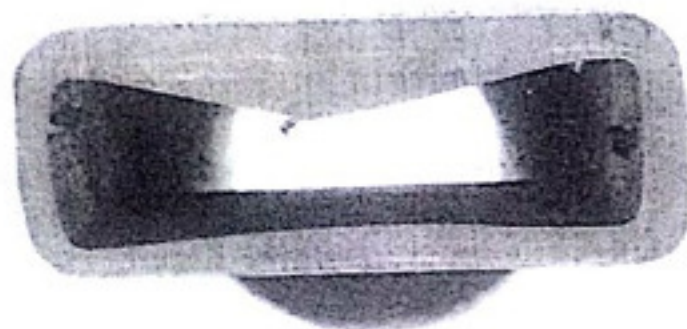


Fig. 30.6—Weak core distorted during pouring. In this case a shell core was involved.

(4) If the wrong flask is used for the molding condition, the needed support to the sand mold will not be provided. A flask that is not rigid enough permits flask-breathing or distortion. When this occurs, the mold will distort.

If there are too few bars in an unweighted flask, the effect will be similar to lack of weight since in this case, also, the mold is permitted to distort during pouring. Insufficient clearance between bars (bar supports) and pattern, or improper contour of bars creates a difficult molding problem often leading to a soft ram swell (see Fig. 30.5).

Warped or twisted flasks that do not close properly leave an unsupported sand mass which can fail during pouring. When the interior wall of a flask is too smooth or is improperly tapered (clamped flasks), the cope or drag may sag, thereby creating either a sag or parting line fin (or even a runout).

(5) Poorly fitting jackets distort the mold and also fail to support it. The result may range from a crush to a swell.

(6) Dirty jackets are variations of poorly fitting jackets.

Gating and Riser

(1) When there are not enough hot-offs or relief

vents for the pouring rate involved, a temporary high back pressure occurs which helps to distort the mold surface. Such lack of venting is usually a cause of penetration as well as a swell.

(2) Inadequate bearing surface because of runner design for multiple gating permits mold-wall movement even to the point of swells or cope sags. Low bearing surface calls for unusual strength of sand.

Molding Sand

(1) Any sand which promotes a weak or soft mold can cause these mold-wall movement defects. However, it must be recognized that there may be a difference between the laboratory properties and those developed by the molding process. A sand that is inherently weak, or difficult to mold to optimum density, has a direct bearing on the problem. These properties of sand may come from either wrong combination of clay and cereal causing either inherent weakness or inherent poor moldability; or excessive water content (particularly likely with hot sand) which increases mold-wall movement (and penetration often accompanying the swell).

(2) Any sand property contributing to exaggerated mold-wall movement includes the items mentioned plus any additives which induce unusually high hot or green sand deformation.

Core Practice

(1) When a core is too small for the print, it will sag or raise, thereby changing the intended dimension.

(2) Insufficiently reinforced cores may sag of their own weight either when green or at elevated temperatures, or may bow because of metal pressure.

(3) Setting the wrong core produces an off dimension section of the casting which can easily be diagnosed as a core sag or swell.

(4) Weak cores (improperly blown, rammed or wrong mix) are a common source of core sags, fins, or swells. The actual cause of the weakness may be in the inherent strength of the mix, but it can just as easily be a lack of blowability or inadequate air pressure



Fig. 30.7—A soft ram on the mold was aggravated by a hard pour to cause this swell at the parting line.

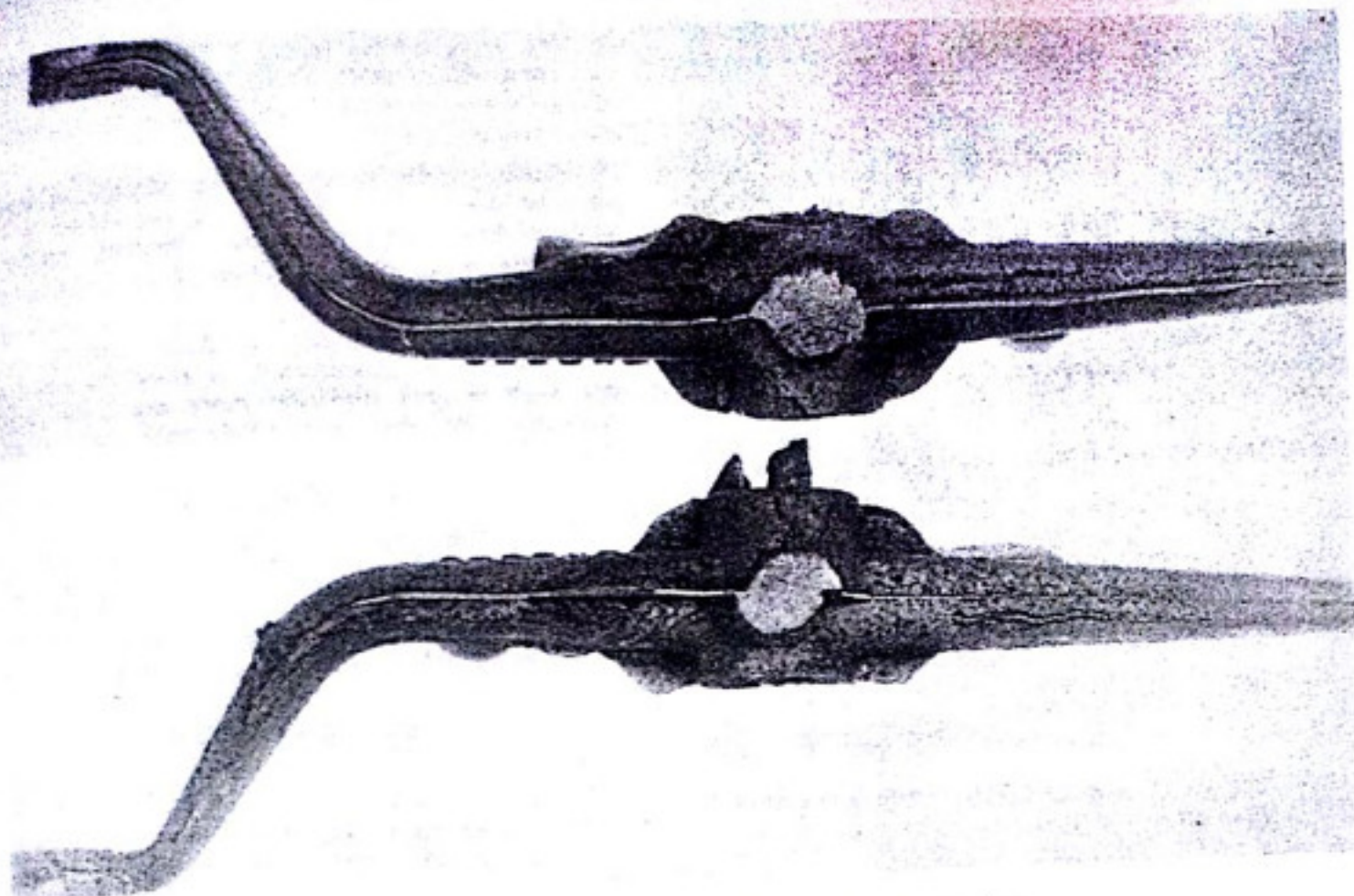


Fig. 30.8 — Uneven clamping permitted a strained mold during pouring.

to compact the core sand properly. Handmade cores can be softly rammed and have an effect similar to that of soft ram molds.

(5) *Cracked, broken or warped cores (twisted drier)* permit a core movement to take place which then appears as a swell, fin, or sag.

(6) *Excessive hot deformation* indicates excessive ability to move under pressure at elevated temperatures. If the mold-wall movement (core) is large, a large swell or strain is observed.

(7) *A thin section on shell core* may come from peel back or inadequate hold time. In either case, it constitutes a zone of weakness, and distortion can follow (see Fig. 30.6).

Molding Practice

(1) *A soft ram, not tucked or properly peened*, is the obvious and most frequent cause of mold-wall movement defects. Many of the aspects described in the preceding sections are related essentially to the ability to develop optimum density in the mold. However, the molding itself is the common denominator which determines to what extent the other factors can produce rejected or defective castings. A swell caused by a soft ram aggravated by a hard pour is illustrated in Fig. 30.7.

(2) *Excessive shaving of the joint* may occur in hand assembly or hand molding, especially of large work. The result of any lack of support is a mold-wall movement.

(3) *Poorly reinforced molds* tend to mold-wall move-

ment. Gagers, soldiers, arbors or bars are used to compensate for a design or flask problem, or to provide added support to molds which otherwise lack strength.

(4) *Uneven clamping of molds* creates distortion either toward a crush or a sag or swell as shown in Fig. 30.8.

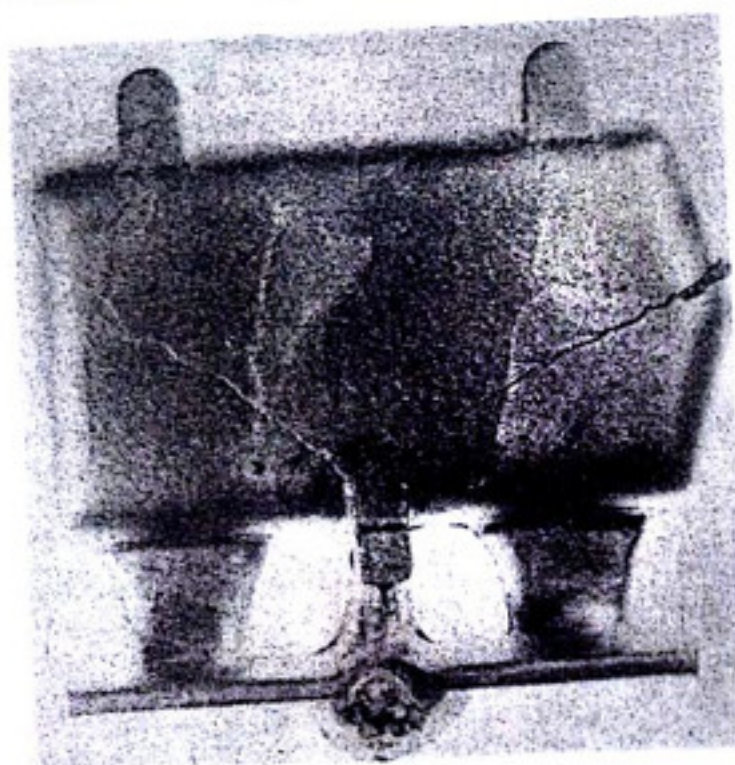


Fig. 30.9 — A poorly cleaned bottom board strained the mold and caused this distortion.

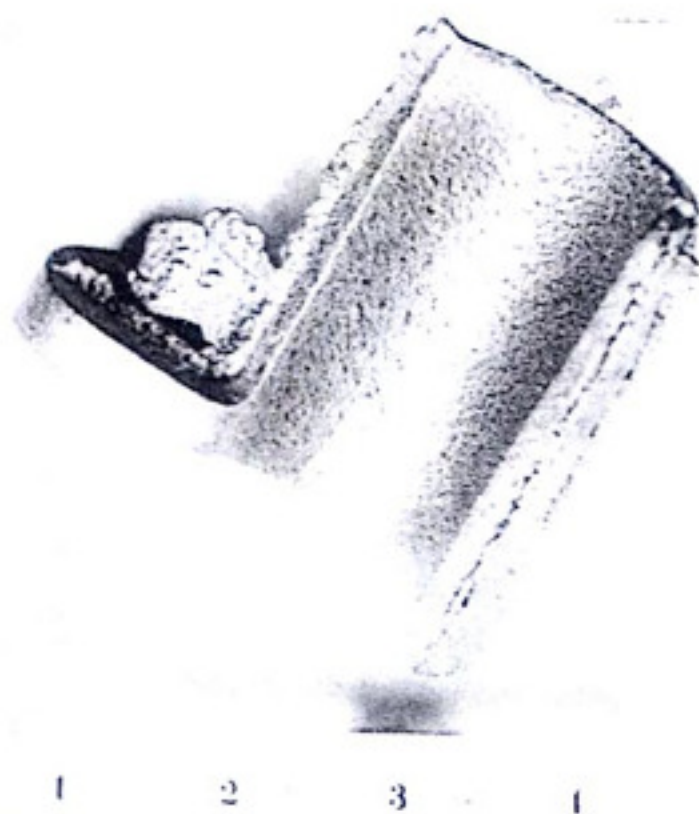


Fig. 30.10—High metal pressure during pouring caused the strain shown.

(5) *Ramoff or ramaway* produces a zone of weakness which will permit a swell.

(6) *Uneven bedding of the bottom boards* detracts from intended support and produces a swell in the drag, or reduces support of the cope, resulting in a cope sag. A poorly cleaned bottom board caused the distortion illustrated in Fig. 30.9.

See **Flask Equipment and Rigging** for additional factors which control the molding aspects of these defects.

Metal Composition

Mold-wall movement is related to many factors other than the original mold stability such as those factors which increase metal pressure. Movement is a result of pressure versus resistance and metal composition is a factor of pressure.

(1) *Metals vary in specific gravity.* For example, steel is heavier than aluminum and produces a greater tendency to swell or distort the mold.

(2) *The weight of the casting is related to both size and composition of the casting so that a large aluminum casting may have more pressure than a small steel casting.*

(3) *Pouring temperature* certainly affects the resistance of the sand mold since the deformability of sand increases with temperature. Pouring temperature differs with the composition of the metal (e.g., steel versus aluminum).

(4) *Expansion and contraction effects of metal* vary with composition. For example, a graphitic metal as cast, such as gray iron, has more expansion force than malleable which is graphitic only after annealing.

Melting Practice

Melting practices in graphitic metals (such as ductile iron) which affect cell count also affect mold-wall movement. For example, inoculation of gray iron increases the tendency toward mold-wall movement and therefore increases the tendency toward swells.

Pouring Practice

(1) *Metal pressure which is too high* for the mold density involved and available is a factor in causing a strain as shown in Fig. 30.10. Pouring too hard may easily distort mold surfaces already on the soft or weak side. It is the metal pourer's job to avoid this.

A ladle that is too high above the mold during pouring creates a kinetic head of pressure much greater than might be expected from the cope height needed for adequate pressure. Not cutting the pour soon enough is apt to promote a strain in molds which are somewhat weak because the high pressure of pouring is maintained too long.

(2) *Excessive metal temperature* causes the sand mold to become overheated and promotes excess deformation by increasing the plasticity of the mold surface.

Miscellaneous

(1) *Dirty pallets* have the same effect as dirty or uneven bottom boards in those cases in which the pallet serves as the bottom board.

(2) *Excessive spinning speeds* in centrifugal castings, such as pipe, act as excessive pressure to increase both distortion (swells) and penetration.

Chapter 31

VEINS AND FINES

DESCRIPTION

Veining appears on the casting as an irregular fin or fins of metal protruding from the surface of the casting. Two conditions must exist. The core or mold surface developed a crack either from expansion-contraction forces or mechanical handling and the metal must be fluid enough to enter the crack.

Note: (T) Signifies thermal cracking, (M) mechanical cracking.

CAUSES

Casting and Pattern Design

(1) *Sharp corners that develop hot spots. (T)* Design of casting or sometimes pattern equipment can promote veining tendencies. Thin casting sections, requiring high fluidity of metal, with adjoining heavier sections can create excessively hot spots. This is particularly true with sharp corners, thin sand sections or inadequate radii or fillets which tend to promote hot spots in the cores.

(2) *Thin cores surrounded by heavy metal sections. (T)* When thin cores adjacent to heavy metal sections are exposed to severe thermal punishment they are likely to fail either by expansion-contraction stresses or mechanically when their strength is rapidly diminishing.

(3) *Massive sections (M)* Refer to Chapter 30 — Swells, Strains and Sags.

Pattern Equipment

(1) *Sharp corners that develop hot spots. (T)* Patternmakers should place maximum fillets or radii on all corners that can be allowed by the casting design. This will help to minimize hot spots that promote core failure.

(2) *Thin cores surrounded by heavy metal sections. (T-M)* Thin-sectioned cores such as small pin cores should be placed in the mold in a vertical position if possible. The cores will be able to stand up to compressive stress more effectively than to transverse loading as they are buoyed upwards and organic binders are being destroyed.

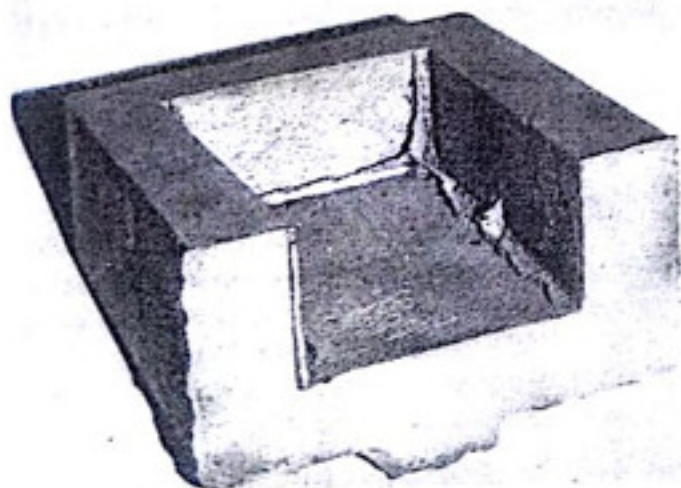


Fig. 31.1 — A casting exhibiting severe veining. This defect is also referred to as finning.

(3) *Uneven metal sections in core box equipment causing nonuniform heat distribution in shell or hot-box equipment. (T)* Care must be used in building core boxes for hot-box or shell applications to maintain thoroughly uniform sections and uniform temperature. If the core box is free from broad temperature gradients, a more uniform core of the binder in the sand is effected and it is easier to avoid veining as well as other problems.

(4) *Inadequate support from core driers causing cracked cores. (M)* Core driers must adequately support green cores during necessary handling until baked strength can develop. Driers must be relieved to allow for differences in expansion between the driers and the sand during baking so the cores will not be cracked.

(5) *Warped Core Driers (M)*

Flask Equipment and Rigging

(1) *Rough mechanical handling of uncured cores. (M)* Cores are particularly sensitive to rough handling in the green or uncured state. Green strength is low and any jolting or bumping can initiate a crack that can be virtually invisible but will produce a fin or vein on the casting. Such rough handling can include rough placement of drier, excessive rapping or vibrating, rough transfer to oven racks, in-

operative decelerating devices on coremaking equipment, rough spots on conveyor, rough floor, etc.

(2) *Misaligned shell or hot-box equipment causing cracking of cores. (M)* Misaligned hot-box or shell equipment can crack cores when the box opens or when cores are removed from the machine. Hot-box and shell cores are generally rather weak when removed from the core box. They continue to gain strength after removal from the core box so they should be handled carefully when removed from the machine in order to avoid cracking or breaking.

(3) *Flasks not rigid enough for molding process involved. (M)*

(4) *Loose flask bars. (M)* Molds can develop cracks that produce fins on the castings if flasks are defective in any of several ways. Flask bars or walls can bend when the mold is squeezed then spring back, cracking the mold. Hardware may be defective on snap- or pop-off flasks or jackets can be bent or dirty, cracking the mold.

(5) *Rough conveying of cores or molds. (M)* A combination of rough roller conveyors and weak bottom boards can crack molds and produce fins or veins on the castings. Any piece of equipment that subjects cores or molds to jolting, or fails to provide adequate support can cause cracking of the core or mold that results in a fin or mechanically induced vein on the casting.

Gating and Riser

(1) *Gate causing metal to impinge on core causing hot spot in critical area. (T)* Any gate so located as to cause metal to impinge on a localized area of a core or mold, causing a hot spot in the critical area should be avoided. This impingement of metal onto the sand at a corner or change of section will accentuate expansion-contraction forces resulting in thermal shock to a degree that may cause veining.

(2) *Riser too close to core print. (Hot spot) (T)*

(3) *Insufficient number of gates causing local hot spots. (T)* Insufficient number of gates causes excessive amounts of metal to flow over a given area causing hot spots. More and smaller gates are sometimes advisable. With more gates, it may be necessary to increase the size of the runner and down sprue in order to keep the metal moving through all of the gates for the time it takes to fill the mold cavity.

Molding Sand

(1) *Excessive organic material in sand (seacoal, etc.) (T)* Organic materials such as seacoal, cereal, cellulose are beneficial in preventing expansion defects. When added in excessive amounts, they provide more contraction in the mold surface than necessary and may even cause contraction effects that will form cracks in the mold surface resulting in veining.

(2) *Excess moisture in the sand for skin-dried or oven-dried molds. (T)* High clay levels are often used to control expansion in molds rammed to high density. In low density portions of the mold, the excess contraction of the clay as it dries can cause cracks resulting in veins, particularly if

flowability of the sand, which in turn, promotes uneven density in various locations. High moisture content will cause some clays to swell considerably and thus contract excessively when they are dried either by torch or oven or by the hot metal. Excess binder in washes can cause cracking of the surface of the mold and wash thus producing veins.

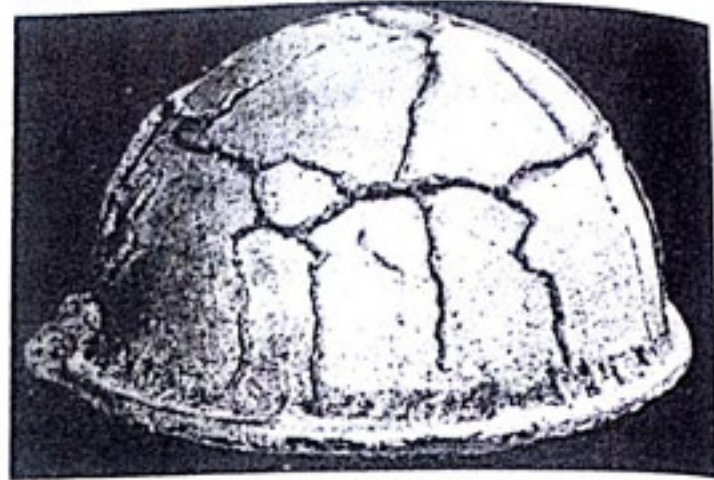


Fig. 31.2 — A gray iron casting exhibiting severe veining due to high percentage of fines in molding sand mixture.

(3) *Improper mulling. (T-M)* Inadequate mulling will not only produce nonuniform sand, but will increase moisture requirements with results as related above.

(4) *Excess amounts of fines (material on U.S.A. Sieve Nos. 200, 270 and Pan) in molding mixtures. (T)*

Core Practice

Most veining is found on cored surfaces. When this defect occurs it is necessary to determine if the crack producing the vein is of mechanical or thermal shock origin. The solution to the problem will depend on accurately determining the cause. It is obvious that if a core is cracked before the casting is poured, that this type of crack will probably result in a fin or vein on the casting.

(1) *Weak cores (green or cured). (M)* Cores can be cracked in the green state due to rough handling, inadequate drier support, rough conveyors or any other cause including inadequate green strength for the core configuration and necessary handling. The jolt over-hang test is far more significant than green compressive strength in indicating the ability of a core to resist green cracking. If cores in a production shop vein when made on one machine or in one core box but not one made with other equipment, the equipment should be carefully checked. Sometimes these green cracks are hardly visible if at all.

(2) *Cores too dense. (T)*

(3) *Excess binders. (T)* Oven-baked cores, particularly those containing cereal binders, will pick up moisture when stored under conditions of high humidity. This moisture will weaken the cores and make them more subject to cracking and veining. Blows may also occur. Excess amounts of organic binders aggravate veining tendencies. Ineffective sand mixing encourages excess binder usage in order to attain adequate strength. Lack of uniformity of

preparation should be encouraged so that minimum amounts of binders will be adequate.

(4) *Too rapid heating and cooling in core oven. (T)*

(5) *Baking temperature too high. (T)*

(6) *Oven-cured cores. (T)*

(7) *Brittle cores. (G-M)* Cracks sometimes develop during baking of cores. Oil-bonded cores tend to become brittle as oven temperature increases. Cores of substantial section or containing heavy and light sections when too rapidly brought to a high baking temperature develop brittle surfaces and thin sections. As the heat penetrates into the heavier sections a small amount of expansion takes place which can crack the hard, brittle surface. Too rapid cooling can also crack the surface as the surface sand contracts more rapidly than the interior in coming to room temperature. These cracks have been observed to open up ten or fifteen minutes after the cores are removed from the oven, then disappear later. When metal is poured around these cores, the cracks reappear causing veins on the casting. More gradual heating and cooling of the cores or a lower baking temperature will help. As larger and heavier cores are encountered, oven-cracking problems become more extensive. Use of one of the no-bake binder systems may be the easiest way to avoid this problem. Heat-curing binders tend to become more brittle and susceptible to veining when over-cured.

(8) *Improperly reinforced cores — rods, wires or bars. (M)*

(9) *Inadequate drier support-warped driers. (M)* Dirty or warped driers are a common cause of green cracks. Considerable support of green cores sometimes is obtained from well-placed wires, rods, or arbors. These must be correct when used. Occasionally, baked or cured cores are broken in rough handling, but wires may hold the broken pieces together. These cores should, of course, be scrapped.

(10) *Improper portions of hexa in phenolic (shell) cores for humidity conditions prevailing. (T)* In the case of shell cores bonded with phenolformaldehyde resin another factor is added. Hexamethylenetetramine is used to chemically alter the resin from thermoplastic to thermosetting type. Increased ratios of hexa tend to make the cores stronger when freshly cured and hot but will tend to make them more brittle and subject to cracking or veining. Reducing the amount of hexa used will help to prevent this cracking.

(11) *Cores stored under conditions of high humidity. (T)* Oven-baked cores, particularly those containing cereal binders, will pick up moisture when stored under conditions of high humidity. This moisture pick-up will weaken the cores and make them more subject to cracking and veining. Blows may also occur.

(12) *Poor sand mixing. (T-M)*

(13) *Inadequate hot plasticity of cores. (T)* A strong sound core may develop cracks at metal pouring temperatures and produce veining. This veining is most often found at casting hot-spots and in fillet areas. As the surface of the core is suddenly heated, it quickly rises in temperature past the alpha to beta transformation point of quartz where no

further expansion occurs. Simultaneously organic binders are destroyed tending to produce contraction of the sand core surface. The sand below the surface of the core heats more slowly and expands over a longer period of time. Organic binders are being destroyed more slowly. The net result is that the sub-surface expansion plus the surface contraction produces tension stresses on the surface portion of the core. This effect is intensified in fillet areas, re-entrant angles and other hot spots. The surface layer of sand must either stretch or it will crack open and invite the metal to form a vein. A sand that is brittle near metal casting temperatures will produce this type of failure. High purity silica sands and high percentages of organic binders aggravate this condition. Binder requirements are dictated by room temperature strength requirements. If the surface of the core can be made more plastic without actually fusing the veining from these conditions can be alleviated.

Sands containing iron oxides, feldspars or even small amounts of low refractory clays or other materials that tend to form viscous slag will provide the necessary plasticity or ductility of the core surface. The addition of small percentages of proprietary iron oxide compounds or similar slagging material to the sand is very effective in eliminating veining when the cause is a true high temperature failure.

Molding Practice

(1) *Excessive slicking of molds. (T)*

(2) *Inadequately reinforced or supported molds. (M)*

(3) *Non-uniform torching of skin-dried molds. (T)*

(4) *Uneven clamping of molds. (M)*

(5) *Excessive mold wash. (T)*

(6) *Soft ramming. (M)*

(7) *See "Flask equipment and Rigging" for additional factors which control the molding aspects of these defects.*



Fig. 31.3 — Test bar poured after soft ramming.

Metal Composition

(1) *Metals with a tendency towards veining such as high-leaded bronzes, high carbon-silicon-phosphorous gray irons. (T-M)* Metals with excess fluidity, whether due to composition or excess pouring temperature, are the most prone to veining. Examples of composition would be: too high a carbon equivalent, especially with high phosphorous content in gray iron, or leaded bronzes with high lead content, and red brass with high phosphorus content due to excessive additions of phosphorus-copper used for deoxidizing. Pouring temperatures should be lower in some cases to reduce veining tendencies.

Melting Practice

None.

Pouring Practice

- (1) *Pouring too hot for metal composition involved. (T)*
- (2) *Pouring too hard causing metal to forcibly impinge against a core (ladle too high). (T)*

Miscellaneous

- (1) *In centrifugal casting, any condition that causes a lack of adherence of the sand to metal mold.*

Chapter 32

WARPED CASTINGS

DESCRIPTION

Warpage is undesirable or unintentional deformation that occurs during or after solidification. The problem is greatest with gray or white cast iron (non-ductile cast metal). Figure 32.1 demonstrates a typical warp in a malleable casting. Other metals may pose the same problems but the use of straightening dies is so common as to disguise the frequency of occurrence. In strictly jobbing-type (short run) work, the use of a straightening fixture may be impractical. In these cases, the corrective measures used for gray iron may be resorted to.

The problems involved are exactly the same as those described in Chapter 13, HOT TEARS, namely, differential stresses set up during cooling. The difference between the defects (aside from appearance) is either in the degree of stress or the difference in the tearing tendency of various metals. For example, a stress situation which would hot tear a steel or malleable casting might warp a gray iron or ductile

casting. Therefore, everything in Chapter 13, HOT TEARS, applies to warping.

CAUSES

Casting and Pattern Design

Large flat sections are particularly prone to warpage. The judicious use of ribs can correct this tendency but an incorrect rib design can worsen or create a warp. It is important that the rib sections are equal to the adjoining sections and designed to promote uniform cooling and contraction. Flat sections tend to solidify and cool most rapidly at the edges (causing warpage) so any ribs involved should help to offset this effect. In other words, ribs which act as cooling fins in those areas already cooling most rapidly should not be used. Figure 31.2 is an example of a faulty design which caused warpage.

Pattern Equipment

It is sometimes possible to break up a large flat

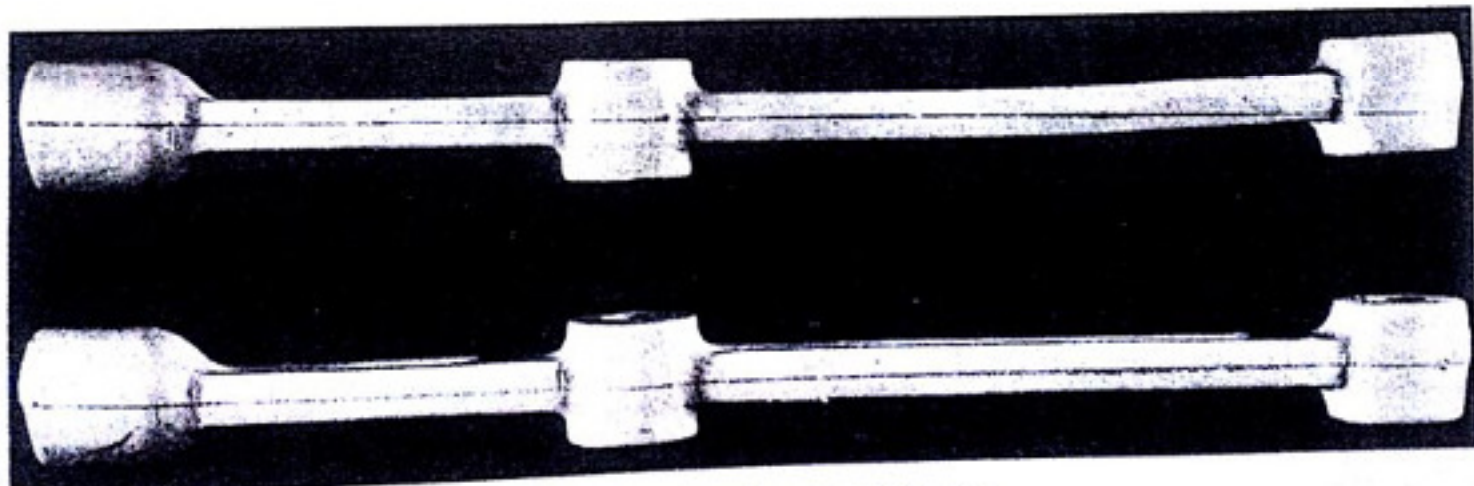


Fig. 32.1 — Typical warp in a malleable casting.

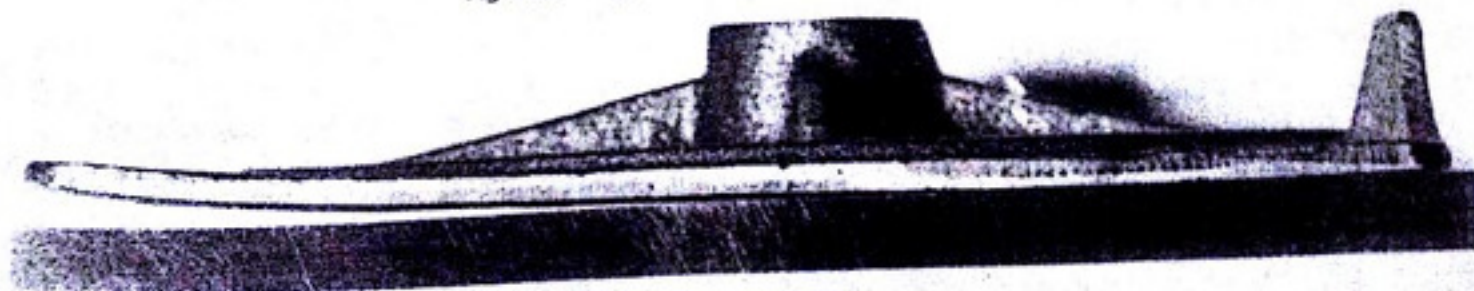


Fig. 32.2 — Faulty design increased the tendency of this casting to warp.



Fig. 32.3 — Uneven cooling after malleabilizing treatment caused this casting to warp.

surface with wavy or roughened sections, provided, of course, that this does not interfere with the use (including appearance) of the casting. The most common technique in designs prone to warpage is to fake or warp the pattern to compensate. It is up to the foundry to operate under conditions that create a uniform degree of warp in such designs. The patternmaker can then compensate for this known and uniform warpage.

Pattern equipment may also be responsible for warpage when there is a lack of, or too many, tie bars.

Flask Equipment and Rigging

- (1) Any condition which prevents desired contraction such as flask bars too close to the pattern; flask bars too close to risers and down sprues; or bad bottom boards may be responsible for warpage.
- (2) Flask may be too small inducing rapid cooling of edges or ends of casting.
- (3) Weak flasks which actually permit mold-wall movement cause a true warp.
- (4) A weak squeeze board may be responsible for warps.

Gating and Riserig

- (1) Gating system which prevents desired contraction because of continuous or multiple runner system tied to casting by gates could be responsible for warpage defects.
- (2) Gates inadequate for sufficiently rapid pouring may cause warping.
- (3) Gating location may cause undesirable cooling rates.

Molding Sand

Sand may be responsible for warp for the three following reasons.

- (1) Sand has too low green strength.
- (2) Sand has too low flowability or moldability.
- (3) Hot strength of the sand may be too low or too high.

Core Practice

- (1) Poor collapsibility of cores due to excessive retained or dry strength may cause warpage problems. There are several reasons for this including: excessive binder; excessive moisture for materials used; excessive hot strength additives (silica flour); any low fusion point core mix (CO_2); wide grain distribution with excessive fines content; and under- and over-baked cores.
- (2) High hot strengths caused by overtempered moisture, or the wrong amount or type of binder may be responsible for these defects.
- (3) Over-reinforced (rods and arbors) not permitting collapsibility can also cause problems.

Molding Practice

Molding practice can also be blamed for warping defects for the following reasons:

- (1) There is an improper relationship of mold hardness between cope and drag.
- (2) Special molding techniques such as ramming after casting is poured, nonuniform ramming, etc., are not used.

A standard method of controlling design prone to warpage is to control the relative hardness of cope and drag surface. If the casting warps up, the cope should be hardened. If the casting warps down, the drag should be hardened. Sometimes it is necessary only to harden part of the cope, such as by the use of a curved strike-off prior to squeeze. There are numerous tricks of the trade used in difficult designs. For example, the molds can be hand or pneumatically rammed after pouring.

Metal Composition

Warpage in gray iron is influenced by the following three factors.

- (1) High combined carbon.
- (2) Excessive use of carbide stabilizers.
- (3) Any factor that promotes the stabilization of combined carbon (chills, etc.).

Melting Practice

Melting practices may be blamed for warping defects if the following procedures are in use.

- (1) *Carelessness in charging or weighing* which can give the wrong metal composition.
- (2) *Melting may be too cold* in relation to pouring temperature (insufficient superheat).
- (3) *Any melting practice which stabilizes carbides or changes metal composition.*

Pouring Practice

Pouring may be blamed for warpage if it is too

hot or too cold depending on the design of the casting and method of gating.

Miscellaneous

In addition to those causes described, warpage can result from handling hot or warm castings. For example, failure to provide proper support during heat treatment can cause a warp (see Fig. 31.3). Even the peening action of cleaning techniques can cause (or cure) a warp. Warpage can occur during or after machining if the machining creates a *partial* stress relief. The cure in this case is to stress relieve (and straighten if necessary) before machining. In large castings, a warp can be caused (or cured) by the method of support during shipping.

CASTING DEFECTS

- Blackening Scab**
 - see entries under expansion defects
- Bleeders**
 - see entries under runouts and bleeders
- Blisters**
 - see entries under gas defects
- Blows**
 - see entries under gas defects
- Body Scars**
 - see entries under gas defects
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- Buckle**
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 - causes, 6-8
 - description, 6; Figs. 3.1, 3.2, 6
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 - see entries under hard spots
- Chills, Inverse**
 - see entries under inverse chills
- Cold Shots**
 - see entries under shot metal or cold shots
- Cold Shuts**
 - see entries under misruns and cold shuts
- Cracked Castings**
 - see entries under broken and cracked castings
- Clamp-offs**
 - see entries under crushes
- Cope Spall**
 - see entries under expansion defects
- Core Fins**
 - see entries under swells
- Core Raise**
 - see entries under shifts (also core raise)
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- Dirt**
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 - see entries under carbon flotation
- Hard Areas**
 - see entries under hard spots
- Hardness, Mass**
 - see entries under mass hardness
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 - description, 52; Fig. 12.1, 52
- Hot Tears**
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 - description, 56
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 - description, 16; Fig. 6.1, 17
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 - see entries under inverse chill
- Inverse Chill**
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 - description, 59; Fig. 14.1, 59; Fig. 14.2, 60
- Inverted Chill**
 - see entries under inverse chill
- Kish**
 - see entries under carbon flotation
- Mass Hardness**
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 - description, 61; Fig. 61
- Metal Penetration**
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 - description, 63; Fig. 16.1, 63
- Metal Penetration in Dense Molds**
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 - description, 70; Fig. 71
- Misruns and Cold Shuts**
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 - description, 74; Fig. 18.1, 74; Fig. 18.2, 75
- Mottle**
 - see entries under inverse chill
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CAUSES OF DEFECTS

(alphabetized by foundry operation)

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- Lack of fillets, 3
- Reinforcing ribs or tie bars not used, 3

Carbon Flotation

- Difference in metal sections, 6
- Heat retention, 6

Carbon Flotation

- Mold or core that promotes heat retention, 6
- Too great difference in sections, 6

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GATING AND RISERING

Broken or Cracked Castings

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- Lack of adequate fillets, 3
- System which promotes stresses, 4

Carbon Flotation

- Distribution of gates and risers promoting heat retention, 7
- Incorrect use of exothermic materials, 7
- Localized hot spots, 7
- Turbulent flow of metal, 7

Cuts or Washes

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Fins, see Veins

Fusion

- Incorrect ratio of sprue, runner and gate, 39
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Metal Penetration in Dense Molds

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Broken or Cracked Castings

- High hot strength coupled with low green sand deformation, 4
- Low sintering point materials, 4
- Poor sand collapsibility, 4

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- Abnormally slow heat transfer, 7

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- Low dry strength, 11
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- Low fusion point materials, 19; Figs. 6.4, 6.5

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MOLDING PRACTICE

Broken or Cracked Castings

- Excessive swabbing or sponging, 4
- Improper use of chills, 4
- Mold rammed too hard, 4
- Riser or sprue too close to flask, 4
- Rods, arbors and gagers too close to mold surface, 4

Carbon Flotation

- Change in cooling rate, 7
- Crushes, Push-Ups and Clamp-Offs
- Careless closing of molds, 12; Fig. 4.2, 10
- Careless core setting, 12
- Careless handling of molds, 12; Fig. 4.5, 11
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- Use of wrong or no chaplets, 12

Cuts or Washes

- Gagers, bars or soldiers set too close to mold surface, 15
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Erosion Scab

- Clay wash on gagers, 31
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Expansion Defects

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- Excessive wash, 37
- Gagers, etc. too close to mold face, 37
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Fusion

- Any combination of hot and cold materials causing condensation, 41
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- Failure to place chills, 58; Fig. 13.2, 57

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Riser or sprue too close to flask bar, 58

Rods, arbors, gagers too close to mold surface, 58

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- Gray iron, 7
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MISCELLANEOUS

Broken or Cracked Castings

- Banding too tight on pallets; Fig. 2.6, 5
- Carelessness in handling, 5; Fig. 2.5, 4
- Heavy castings tumbled with light castings, 5
- Improper packing in tumbling barrels, 5
- Improper piling or stacking, 5
- Shakeout too soon after pouring, 5; Fig. 2.4, 4

Carbon Flotation

- Rates of cooling too slow, 8

Crushes, Push-Ups and Clamp-Offs

- Rough handling, 12

Cuts or Washes

- Excessive parting, 15

Drops

- Foreign material in sand, 27
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- Vibration, 27

Erosion Scab

- Foreign body close to mold, 31

Fins, see Veins

Gas Defects

- Chills, chaplets, wires rusty, oxidized or damp, 51; Fig. 11.17, 50
- Insufficient centrifugal force, 51

Hard Spots, 55

Hot Tears, 58

Inclusions

- Rag left in mold, Fig. 6.12, 22

Mass Hardness, 62

Metal Penetration in Dense Molds

- Free moisture in the mold, 73
- Metallic-coated sand, 73
- Sand or binder reacting chemically with metal oxides, 73
- Shaking out too cold or too late, 73

Misruns and Cold Shuts

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Off Dimension Related to Cores, 82

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Improper machining, 86

- Rate of cooling too slow, 86

Ramoff or Ramaway, 89

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- Foreign materials, 94

Improper cleaning, 94

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Scars-Seams-Plates, 103

Shifts (also Core Raise), 107

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