The stopper rod is fastened to the "goose-neck," which in turn is inserted in its socket on the ladle slide. Small ladles may be heated up with stopper rod and goose neck removed, and the rod dried out separately. For large ladles, it is necessary to leave the stopper rod in place, and merely raise the stopper off its seat while heating the ladle.

In any case, the stopper should be carefully adjusted before the ladle is heated, so that it closes the hole in the nozzle exactly. To ascertain if the stopper leaks, it is seated firmly and a little fine sand thrown around it. This testing with sand should be repeated when the stopper is put in place or lowered into position, after heating the ladle, and a ladle should not be filled until the ladle man is sure that it does not leak.

Some ladle men prefer, especially for large ladles, to arrange the stopper so that it strikes the outside of its seat in the nozzle, and slides into position as it is pressed home. It is generally best, however, to have the stopper come vertically down upon its seat.

In pouring through a nozzle, the rod should be raised slowly the first time the nozzle is opened, and the pourer will do well, soon after he has got his stream going, to close off once or twice. By so doing he clears away from the nozzle any half-melted sand that may be sticking to it, and ensures a clean shut-off. The first few times the nozzle is seated after the first opening, it often will not shut off clean.

Should the stopper get stuck hard to the nozzle, it should be poked off with a pricker from below, rather than trying to pull it off with the ladle handle. Too much enthusiasm at the handle sometimes pulls a stopper head off the rod. A frozen nozzle in large ladles is pricked open in the same way. Wooden prickers are better for this purpose than steel ones, as they do not freeze to the metal in the nozzle. But a steel pricker often has to be used for a badly frozen nozzle. In pouring a small ladle, if the nozzle freezes up, the steel had better be poured over the lip.

CHAPTER VIII

MOULDING, POURING AND DIGGING OUT

The effect of the moulding and pouring methods used upon the soundness of the castings is so great that in order to be useful to a steel foundry, the metallurgist is obliged to be thoroughly familiar with the subject. Not that he need necessarily be a foundry expert, versed in the economies of moulding practice, the use of machines, etc., but as concerns the effects of different methods upon his steel he must be an expert. Many a foundry makes a practice of holding the steel maker responsible for blow holes, hot checks, shrinkage cavities, etc., in the castings, when the trouble is really the result of ignorant or careless foundry practice, and the melting shop men too often take the attitude that nothing is wrong about their metal, which would pour into the most beautiful castings ever seen, if only the foundry were in charge of men who knew their business. To prevent this cat and dog attitude of foundry and melting shop, often calls for a degree of tact on the part of the superintendent that too few men possess. Frequently an attempt is made to cut the Gordian knot by giving the foundry superintendent charge of both moulding and steel making, and indeed when a man can be found who is well versed in the practice of both departments, no better arrangement can be made. Too often, however, the man who is an expert in handling the moulding, possesses but a smattering of the principles of steel making, and under his rule the lives of the melting shop men are made a burden to them.

Mixing the Sand.—The moulding sands that are used in a steel foundry must be selected with care, and generally chemical analysis is needed at intervals to determine the suitability of a given sand for the work. The sand must be sufficiently high in silica to be quite refractory, in order that it may not be melted or softened by the heat of the steel. The average size and shape of the particles is also of importance, since they affect the porosity and bonding power of the sand. The practice in past years has been largely rule of thumb, and even to-day there is no way of making sure that a sand is suitable, without trying it. The mixture of several brands of sand with more or less fire clay to secure the desired results, is giving way to an increasing extent to the use of a single sand of high silica content, mixed with just enough fire clay to give the necessary plasticity and holding power.

A formula used successfully in some shops is as follows:

Green Sand Facing	Dry Sand Facing
8 shovels new sand.	12 shovels new sand.
4 shovels old sand.	1½ shovels clay.
1 shovel clay.	

The amount of moisture in both "facing" and floor sand, depends somewhat upon whether the moulds are to be poured "dry" or "green." As a general rule, however, no more water should be used than is absolutely necessary to keep the sand in place. Green sand facings should be mixed as dry as it is possible to make them, without having the sand too dry to hold together. A handful of the facing given a single good squeeze in the hand should just hold together and no more. Too much moisture in green sand moulds gives rise to an excess of steam, which cannot escape through the close rammed mould and causes blow holes in the steel. The floor sand, therefore, should not be made too wet.

Dry sand facing is frequently mixed with molasses water to make it hold together, and somewhat more clay can be used in it than in green-sand facings. The sand should not be too moist, however, as it is then prone to flake and spall in drying, rendering necessary a good deal of patching in setting up the mould. If the patches are not dried out, and especially if the silica wash be applied to them too freely, the resulting wet spot may cause blow holes in the casting.

The sand should not be too wet, even in a dry sand mould, as very damp sand packs so hard as to be impervious to the escape of gases, even when thoroughly vented; and a wet sand results in greatly increased drying time, or in a mould brought from the oven and poured with damp spots in it. A mould impervious to the escape of gases, especially if it is wet in spots, is sure to cause blow holes in the steel.

Venting.—Another prolific cause of blow holes is the insufficient "venting" of the mould. This is especially dangerous if the sand used is very wet and hence hard packed. It is impossible to overemphasize the importance of thorough "venting," or in other words loosening up the sand of the cope over the casting by driving a long needle or bodkin, used for the purpose, through the sand in numerous places. Especially in green sand pouring, where a great deal of steam is evolved which must be carried away quickly, thorough "venting" is a necessity.

Skin Drying.—Again, the skin drying of green sand moulds just before closing, by spraying them with gasoline and setting it afire, or better, by the use of oil or gas torches, is of great assistance in reducing the amount of steam and gas to be taken care of in pouring. This has become universal practice, and enables castings to be poured in green sand that would otherwise have to be poured in dry sand.

Frequently it will be found impossible to pour a shape in green sand without the loss of many castings from blow holes. With ordinary steel of .20 to .30 per cent. carbon, green sand pouring is possible on only a limited number of castings of medium section; the heavy work, and frequently the very light castings, have to be poured in dry moulds.

Cores.—"Blowing" cores are often responsible for abundant blow holes. To avoid this, long cores should be vented by making a hole in them, from end to end, which will carry off the gas from the core into the sand of the mould. Cores with one end exposed to metal, of course, cannot have a hole entirely through them, but if long, should have a vent going nearly to the exposed end. Insufficient drying, and the gases generated by the flour, oil, or other binder used in mixing the core sand are the sources of the gases evolved from cores.

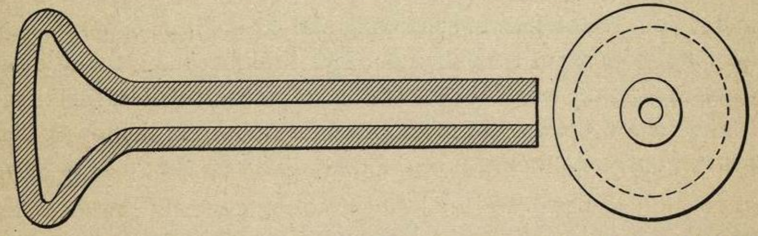

FIG. 15.—Gas engine valve. A casting that is apt to give trouble from blowing of the core.

The author recalls a gas engine valve, shown in Fig. 15, which gave great trouble in a foundry; the "blowing" of the core, even with the most thorough venting, produced harmful blow holes in the large section. Even well-vented dry-sand moulds, with the most carefully vented cores and careful pouring, could not be counted on to give a sound casting. With the welding methods now so common in steel foundries, it would very probably be possible to cast this shape with the core going through both ends, and weld up the hole in the big end afterward.

Hot Cracks.—Hot cracks in castings may be due to the high sulphur content of the steel, resulting in red-shortness, that is, brittleness when hot; to sharp corners, especially where a thin section joins a thick one, that are not protected by fillets (rounding off of the corner), or by brackets (extra metal in the shape of tie pieces across the corner); or to slow work in digging out the cores after the steel has frozen, in order to allow the casting to shrink unopposed. Many cracks that are blamed upon the steel, as the easiest explanation, can be traced to other causes. The test should be, did only one or two castings of a heat crack, or a great many? If the former, it is plainly not the fault of the steel—if the latter, it may not be, but the steel will bear investigating.

Sink Heads.—The location and shape of the "sink heads" or "risers" used has an important bearing on the soundness of a casting, not only on the porosity of the steel, but also, and more especially, on the formation of shrinkage cavities or "pipes." As steel contracts about $\frac{1}{4}$ in. to the foot in solidifying and cooling, the liquid metal occupies more space than the same metal solidified and cold. The metal around the outside of the casting, of course, solidifies first, and contraction of the interior metal produces cavities in the top of the casting, unless liquid metal be fed down to fill up the voids as they form. For this purpose sink heads are moulded in such places that the liquid metal from them will feed down into the heavy sections of the castings, and make them sound. The heavy sections, naturally, are the places where the opportunity for interior shrinkage occurs, since only in heavy sections does the interior lag much behind the outside in cooling. In the shaping and placing of sink heads several governing principles should be kept in mind. The first is, to make the sink head heavy enough to remain molten in its interior longer than the section of casting to be fed; hence it has to be of greater section than the casting at that point. The second is, that the thickness of the "neck" of the head must be such that this neck shall not freeze before the section of casting to be fed, or the sink head that is to do the feeding. If it does, the metal, of course, cannot feed. The third is the law of pressure in fluids, which teaches us that in a column of liquid, whether water or fluid steel, the *pressure* in any direction at any given depth below the surface of the fluid, is dependent only upon depth of metal. Interpreted literally, this law shows us that if the maximum area of cross-section of the neck of a sink head (imposed upon us by the size of the casting) is 2 by 2 in. as great pressure of fluid metal will be exerted upon that neck by a head 2 in. square as by one 2 ft. square, if both are of equal height. The neck being generally short, however (and the shorter the better), is kept hot by the mass of metal in the casting below and in the head above, so that a head considerably larger than the neck can be used. In fact, in order that the head may remain fluid and contain enough metal to feed properly, it generally has to be a good deal thicker than the neck. There is a limit, however, to the size of head that it is worth while to use when the diameter of the neck is fixed. Frequently heads 6 to 8 in. in diameter are seen on castings, with necks no more than 1 in. thick, where a 4 in. head would serve as well. Another error frequently committed is to increase the diameter rather than the height of a head, in order to secure better feeding, without increasing the size of the neck.

To consider this matter more in detail, let us assume that a casting has been poured with sink head and neck of a given size, and has proved unsound; that is, it contains a shrinkage cavity that has not been "fed" by the head. More effective feeding is desired, and the best means of securing it is being considered.

If the cavity is deep down in the casting and separated from the sink head and neck by a layer of sound metal, the trouble obviously is that the upper section of the casting did not remain fluid long enough to feed the lower section—the error is in the location of the head, or the position of the casting in the mould. The casting must be poured so that the last freezing portion is above, not below, the first freezing portion. In most cases such a cavity will not be detected unless the casting is cut open for inspection, or breaks in service.

If, however, the cavity is immediately under the neck, the head and neck were obviously to blame—they did not thoroughly feed the casting, but froze, or were drained completely, before the latter was solidified. The question now is, was the head too small to do the feeding? If the neck and head remained fluid long enough to allow the head to feed the casting as fully as possible, it is clear that the head will be hollow almost if not quite to its bottom—it did not contain enough metal to feed the casting. This occasionally happens with some alloy steels of low melting point and great fluidity. The remedy is more metal in the head, and therefore a larger head. A higher head will produce the most pressure at the neck, hence it is desirable to increase the height. But if we go too far in this direction it will take so long for the high head to empty itself that it will freeze to the center before feeding is complete. We may, therefore, be obliged to increase the diameter (generally of both head and neck), also. By so doing, we do not increase the pressure of metal on the neck, but we guard against the freezing of the head and neck before feeding is complete. We can judge of the necessity of increasing the diameter as well as height of the head, by the thickness of the walls of the head that has already proved too small. If they are very thick, it is plain that an increase of height only will be ineffective, since the head froze nearly to the center as it was. The diameter, therefore, must be increased as well.

Should the head be largely solid, and not drained of its interior metal, obviously either head or neck froze to the center before the part of the casting that was to be fed. We now ask ourselves, did the neck, or the head, freeze too soon? It is conceivable, but not probable, that the head was to blame. If it was, the neck obviously remained fluid and continued to feed after the head froze. We shall, therefore, find the neck hollow, with a hole running up into the head. In this case, the diameter of the head must be increased.

More probably, however, we shall find the neck, or at least its upper part, quite solid. This indicates that the neck closed up by freezing before the head had completed its work and was either too narrow, or too long, or both. The neck should if possible be widened and shortened—but the head may well be found to be amply large.

In case a narrow neck is unavoidable, it should be kept in mind that the narrowness of the opening decreases the flow of metal from the head, especially as the opening grows smaller, by the friction of the stream of metal on its walls. It may well be, therefore, that the opening in the casting grows too rapidly to be filled by the metal from the head during the last part of the time that the latter is still actually feeding. More pressure on the metal in the neck will increase the flow, and this pressure is obtained by increased height, not increased diameter, of head.

It is, of course, impossible to give hard and fast rules for such reasoning, especially in view of the fact that the shrinkage of the metal in the plastic state that succeeds solidification changes the shape and size of the interior cavities. Their location and shape may be such that exact deductions from them are impossible. It will, however, be advisable in a great many cases to consider the remedies to be applied, along the lines suggested above, rather than to jump blindly from the obvious fact that a shrinkage cavity has occurred, to the conclusion that a wider head is the remedy.

In placing sink heads the rule to be remembered is that a head will feed far more effectively downward from its base than sideways from its base. Efforts to cast a shape "on the flat" by the use of heavy heads, attached to the broad side of the section, frequently prove utterly futile—and then some fellow comes along and casts the thing "on end," and secures a solid casting with a sink head of half the size and weight used before. As sink heads are so much metal on which money is spent in melting, without return as salable casting, it is needless to say that the lighter the sink head the more money the shop will make.

The principle just stated, that a sink head acts best downward, is of course, simply another way of expressing the obvious fact that when a casting is poured "on end," each section of the casting, from below upward, feeds the section immediately under it and the head feeds the upper sections. A further precaution suggested by this line of thought, and one that has been mentioned already in discussing the size of sink heads, is so to locate the casting in the mould that as far as possible the upper portions will freeze last, and thus feed the lower portions and be fed in turn by the heads.

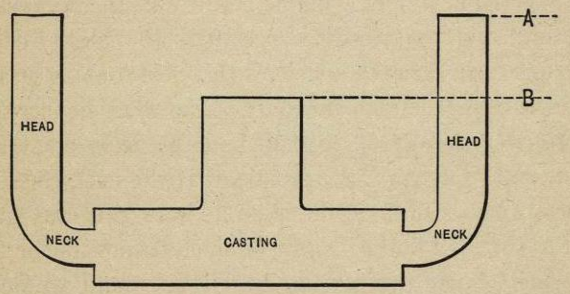

FIG. 16.—Ineffective manner of attaching sink-heads.

One of the least effective ways of placing sink heads, and yet one that is frequently attempted, is to attach them to the bottom of the casting by means of thick necks, in the manner shown in Fig. 16.

A few moments reflection should show the moulder who uses this method of attachment that the casting has as much tendency to feed the head, up to the level *B*, as the head has to feed the casting, and that only the portion *A–B* of the head is effective in producing pressure on the metal in the neck. A head equal in height to *A–B* placed on top of the casting will be as effective in feeding, as far as pressure exerted goes, and will be far more effective in fact, as it will feed the whole casting. The side attached head cannot by any stretch of the imagination be expected to lift the semi-solid metal within the casting and fill the cavity forming in the top. This is an extreme example, yet men have tried for a week to get a sound casting in a case almost as simple as this.

When a casting has to be poured in a horizontal position, so that a great horizontal area is presented that must be provided with heads to feed shrinkage, the rule that a sink head feeds most effectively downward, not sidewise, shows us that we shall secure the most effective feeding, by the use not of a few large heads, but of a number of small ones, placed closer together. The extent to which even a large head will feed sidewise from its base is so slight that the only way to secure a thoroughly sound casting under these circumstances is to see to it that the heads are close enough together to allow their effects to overlap.

Chills.—"Chills," so-called, are commonly used on steel castings to promote soundness. Their function is not, as in iron castings, to produce a change in the structure of the metal next to them by which it is made harder, but simply to cause the metal that comes in contact with them to cool rapidly. The usefulness of this is not at once apparent. It consists, first, in evening up the cooling of a casting with light and heavy sections, and thereby lessening the tendency to pull apart when the light section solidifies and contracts, and tears away from the soft and weak heavier section; and second, in assisting the sink heads to feed heavy sections. This is the more important of the two functions, and frequently makes it possible to reduce the size of the heads, or in extreme cases to dispense with them almost altogether. That a chill should have the same function as a sink head is not at once evident. On reflection, however, it is plain that the formation of shrinkage cavities in the steel is due to the fact that commonly a mould is poured full and the supply of metal through the gate cut off by freezing, before the setting of a heavy section has had time to proceed far. The contraction that then begins can be fed only from a head. Could the freezing of the steel be instantaneous from outside to center, no shrinkage cavity would form, since contraction would then take place throughout. As Prof. Howe has shown in his classic article on "Piping and Segregation in Steel Ingots,"[1] it is the lagging of the

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[1] Transactions American Institute of Mining Engineers, 1907, page. 3. See also Howe and Stoughton, same volume, page 109.

cooling of the interior after the outside has frozen that accounts for shrinkage cavities.

Now, if the metal, as fast as it runs into a mould, can be instantaneously chilled and frozen in successive concentric layers, each inside its predecessor, obviously each layer will assume its proper dimensions as fast as it freezes, and when the mould is filled the metal will all be solid. The same will be true if the metal freezes in successive layers from below upward. Though this condition cannot be attained, yet by the judicious use of chills the steel can be made to solidify so rapidly that much of the shrinkage occurs while the metal is still being poured into the mould, and hence much of the feeding of the shrinkage cavity is done by the stream of metal running in through the gate, and the action of the sink heads is made to occur earlier, and therefore more efficiently and thoroughly.

This is the same principle as that utilized to pour solid ingots—freezing the bottom of the ingot rapidly by casting in a heavy-walled iron mould, with the small end down, and causing the top to cool slowly by making it heavier than the bottom, by the use of a mould whose walls are thin at this point, or by means of sand sink heads. The casting corresponds to the bottom of the ingot, the chills to the heavy mould walls, and the sink head to the top of the ingot whose freezing we retard.

Obviously, to retard the freezing of the sink heads by scattering charcoal or sand on them, or even by the use of artificial means of heating, will assist us in the steel foundry. There is a distinct limit, however, to the extent to which it will pay to go in this direction. Charcoal and sand are often put on top of the heads of important castings to keep them hot, but artificial heating of sink heads generally does not pay.

Gates.—The manner of gating a casting and the size, number and location of gates and runners, have a very considerable effect upon its soundness and general appearance. Theoretically, to take the reasoning that has been so well worked out for the pouring of ingots, the best way to pour would be straight down into the casting, so that the bottom would be filled first, and chill first, and each succeeding layer would be poured of hot steel, the sink head last. The shrinkage of the lower parts of the casting would then take place first, the upper parts would "feed" the lower, and the sink head would feed the top thoroughly. It is from the nature of the case inexpedient to pour castings in this manner because the falling stream of metal would destroy the mould, and as a rule separate runners or vertical pouring channels are used, with horizontal passages or gates leading to the mould near the bottom. The bottom of the runner is "dished out" slightly to form a pool from which the steel shall flow quietly into the casting; and this cavity is protected from the cutting action of the falling stream of metal by a paving of nails. In this manner the metal is taken into the mould with the least possible commotion and bubbling, which is essential to prevent the surface imperfections which result from having the steel come swirling and splashing into contact with the walls of the mould and freezing while still in commotion.

In consequence of this necessity for filling the mould quietly, the gate or gates are commonly put at or near the bottom of the casting, and, in consequence, the metal fills the mould from below upward. In pouring castings of considerable height, this results in the worst possible condition of the metal for filling shrinkage cavities, since the cooling proceeds from above downward. To overcome this difficulty it is most useful to place a second and often a third gate part way up the casting. By this arrangement, the mould is filled in successive layers, the metal flowing through gate 2 as soon as the metal reaches its level, and running in on top of that introduced through gate 1 and so on. As each layer feeds the one below it, the heads will act more efficiently. To carry this procedure to its logical conclusion, obviously the sink heads should be poured from above, and poured slowly, in order to keep them molten as long as possible and add fresh hot metal to feed shrinkage. In pouring very small work it is not always possible to take these precautionary measures, but it is very common when large and important work is being cast to take the ladle over the heads when the metal reaches them, and pour them from above. Sometimes the sink heads are fed again with hot metal from the ladle, a few minutes after they are first filled. Since these extra gates and this method of pouring sink heads from above tend to reduce the size of heads necessary, a little forethought in this direction is often of great value.

When horizontal moulds are tipped up at the pouring end to assist the metal in flowing freely into the casting, as is often done with long thin pieces, top pouring is to a certain extent substituted for bottom pouring. Care has to be taken, under these circumstances, that the metal does not flow so fast as to scour the mould, and in general any part of the mould where metal flows rapidly or falls a few inches has to be protected with nails.

In the case of a long casting having one end much heavier than the other, two methods of pouring can be followed, depending upon the relative cross-sections of the ends and the kind of steel of which the casting is made. With some alloy steels of low melting point and great fluidity, heavy chills placed upon the large end will serve to make that end freeze before the metal has filled the casting, so that by gating at the light end and tipping that end up, the casting can be made solid by the use of chills alone. In that case the bottom (large end), freezes first and is fed by the metal flowing from the small end, which in turn is fed and made sound by the metal in the gate and runner.

When, however, the large end is so much heavier than the light end that chills will not cause the heavy part to freeze in time to be fed by the metal running from the gate, sink heads on the heavy part are needed to take care of the shrinkage that occurs after pouring ceases. In that case, if the casting is gated and tipped up at the small end, the sink heads are not well placed to feed the whole casting. For instance, in the casting shown in figure 17, if chills will not cause the heavy end to freeze early enough to be fed by the metal from the gate, there will be fluid metal in the upper portion of the casting practically from end to end, when pouring ceases. Let us assume that the runner will suffice to feed the casting as far along as the point where the horizontal line XY intersects the casting at D. The rest of the fluid metal from D to C will tend to run downward to feed the shrinkage of the big end, and will exert a fluid pressure equal to the vertical height of D over C, or DE. This will be balanced by the portion of the sink head from C to B, equal in height to DE, and only the portion of the head AB will exert effective pressure downward. The cavity will by definition tend to form somewhere between C and D, because the fluid metal will run down to feed the shrinkage near C, and leave a void above, and it is not at all probable that the portion of the head AB will exert suffi-

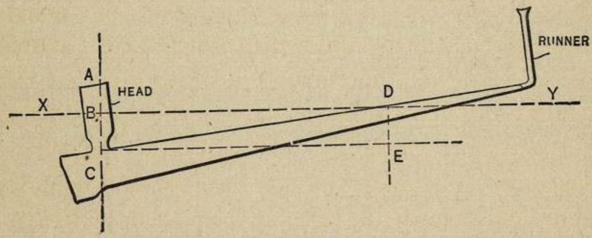

FIG. 17.—Illustrating action of sink-heads and chills.

cient pressure to force the solidifying metal back along the length of the casting and close this distant opening effectively. Though a second head between *C* and *D* will help matters to a certain extent, yet the same reasoning applies to a second and a third head as to the first. True, a second head located exactly where the cavity tends to form would no doubt prevent its formation. But it will be a difficult matter to determine in advance just where this head should be located, because many factors, such as temperature of metal, speed of pouring, etc., will affect the rate of cooling of the castings to such an extent that the cavity will not be located in the same position in every case.

Moreover, the metal that rises into the lower head will have run over the chills and become cold, reducing the effectiveness of the head, if the pouring is confined to the gate. In case cores that would be cut out by the running stream, or other considerations, render gating at the large end impossible, the head should be filled by a second ladle as soon as the metal from the gate reaches it, in order that it may be poured with hot metal and so tend to remain molten longer than the casting.

Should there be no objection to gating at the large end, this casting should be so gated, and tipped up at that end. Then the freezing of the upper end will occur after that of the lower, both because it is heavier, and because it is poured last. It will effectively feed the lower portions, and the head, especially if filled separately from above, will be in a position to feed the upper portion most thoroughly. The chills in this case should be omitted, since it is not desired to hasten the cooling of the upper portions, in fact quite the contrary; and moreover, they would possibly so cool the entering metal that it would not "run" the light end. If any chills are used, they should be placed at or near the lower portion of the casting, *i.e.*, the light end.

Though a fairly large head would be needed in this method of pouring, since it would have to take care of the entire shrinkage of the casting, while the head in the other method of pouring would take care of only the shrinkage occurring after the casting was filled (and therefore the excess over what the chills were able to accomplish); yet as the conditions would favor complete soundness, better work would be done, with perhaps no more metal in heads, than in the method of pouring with big end down, using chills and a head.

To use big end down pouring, with chills at the lower end and the head at the small end, is assumed to be impossible in this discussion, owing to the light end being too small to stay liquid long enough to carry metal from a head to the lower end.

The size and number of the gates and the size of the runners must be such that the metal flows freely into the mould. Steel, especially low carbon steel, has so high a melting point that it is comparatively sluggish at temperatures that make cast iron as fluid as milk. The gates for steel castings are therefore made much larger than those used in pouring iron.

In pouring a casting that is filled up from a gate in the bottom, the metal, of course, is always at a higher level in the runner than in the casting. Were it not, the flow would cease, as the pressure on the metal in the gate is due to this difference in level, and proportional to it. To make the runner large and heavy does not increase this pressure, nor, as long as the steel is fluid, does it tend to send any more metal through a given size of gate.

If the gate is as large as the runner it will, of course, carry the metal into the mould with the minimum loss of flow by the friction between the metal and the sides of the gate. With a gate much smaller than the runner, which cannot carry the metal into the mould as fast as it is poured down the runner, the latter will fill up and produce great pressure on the gate, so that the steel will enter the mould at high velocity. But though at first this high pressure will maintain the flow, yet as the casting fills, the pressure will fall, and the amount of metal running in will be less than if the runner and gate were of the same size. The result will be, first, that when pouring begins, the steel will flow too rapidly over the mould, resulting in great scouring and cutting of the sand; and second, that the mould will fill slowly, especially toward the last, and the gate may even freeze before the casting is filled. The gate area, therefore, should be equal to that of the runners.

In filling a high mould, the cross-section of runner and gate needed will be greater than for a low mould of the same approximate section, for the reason that as the metal rises in the mould it becomes chilled (and even semi-solid at the surface), and hence flows less freely. The runner will fill up to levels increasingly higher and higher than that of the metal in the mould, and partially overcome the increased resistance to the flow. But there is a limit to this, which is reached when the runner is full, and any further slowing down of the flow may well result in the freezing of both gate and runner. Hence to fill a tall mould with one gate, heavy runners and gates are needed, that the pouring may be done rapidly.

If, however, use is made of gates at several levels, in the manner already described, this difficulty is overcome, since as soon as the metal in mould and runner has reached the level of the second gate, the metal flows in on top of the sluggish steel already in the mould, and no longer has to lift it. Should the runner or gate freeze at the bottom before this level is reached, moreover, the runner will at once fill up to the second gate and fill the mould through it, whereas if but one gate is used, pouring would have to be finished down the sink head.

The use of several gates at different levels, therefore, decreases the size of runners and gates needed, since the runner between the bottom and the second gate need stay open only until the latter begins to work. After that, the runner down below can freeze without hurting anything. We can, therefore, fill for instance a 10-ft. mould, using two gates, with a runner of the same size that we would use for a 5-ft. mould. The saving in metal scrapped in runners and gates by this method is considerable.

In a high casting, it is plain that the use of gates of smaller cross-section than that of the runners will by decreasing the amount of metal entering the mould, increase the tendency to slow filling of the mould and consequent freezing of the gate or runner.

Pouring.—To secure the best results in running castings, the rate of flow of the steel should be under control. That this is true will be at once apparent if we consider the extreme, and of course impossible, case of a mould filled instantaneously. The metal being then at an even temperature throughout, cooling will begin at all parts of the surface at once, thin sections will cool much before thick ones, setting up heavy stresses; and the entire work of feeding the shrinkage will fall upon the sink heads. In some cases very rapid pouring, approximating these conditions, does not reduce the effectiveness of the sink heads—but frequently, the result of rapid pouring is that the top of the casting cools as rapidly as the bottom, so that the feeding is very incomplete. Generally it is most desirable to get the first metal into the mould as rapidly as possible without cutting into the sand, and gradually decrease the rapidity of flow as the mould fills. Such pouring, especially when the gating has been so arranged that the metal enters the mould at successively higher levels, or from above, allows the maximum proportion of the shrinkage of the solidifying bottom portions of the casting to be taken care of by the hot metal being run in, and leaves the sink heads less to do when the pouring is stopped. The heads when possible should be filled from above with hot metal.

The desirability of being able to control so nicely the rate at which the mould is filled is the chief argument against the use of ladles that pour through the bottom with stopper and nozzle in the usual manner. The bottom pour ladle gives a stream that runs with great velocity; and the velocity is dependent upon the depth of metal in the ladle. To check the flow of steel, we can only lower the stopper head, which results in a fan-shaped stream that strikes the pouring cup instead of running cleanly down the runner, and the wear on stopper heads prevents us from indulging in this practice too freely, lest we cut the head off.

Large ladles, of course, cannot be poured with nicety over the lip, but can be handled only with a nozzle. Used for castings of such size that the full flow of the nozzle is required for some minutes (and in very large work it is often hard to get the steel in fast enough), the nozzle does excellent work. But for small castings it is generally best to use a ladle of not over 3 tons capacity and pour over the lip. It is even probable that many of the moulds that are commonly poured from a 10-ton ladle with nozzle, could be far better handled by the use of two or three light ladles filled from the large one—the big ladle meanwhile handling the heavy work. To follow this practice makes necessary some means of tipping the big ladle to pour into the small ones, which is not commonly provided.

Again, when we have to pour very light castings, the 2- or 3-ton ladle is too big, and its stream is too heavy and falls too far. It would take too long also to pour a great many small flasks from the big ladle. "Bull ladles" or "shanks" are needed for this work, and are used in sizes of from as light as 50 lb. capacity up to 1000 lb. or so, depending upon the size of the castings to be poured. For a given weight of castings, say an average of 5 lb. each, it is questionable whether the very small shanks sometimes used are desirable. Some foundries making 2-ton heats use 100-lb. shanks, pouring 20 castings from each, working five shanks at once; and thus are obliged to refill each shank eight times. The metal to be sure is held in the shanks a very short time, and hence has little time to cool off; but in such small masses it cools rapidly, and the time lost in running back to the big ladle to refill increases the time spent in pouring the heat, and hence the cooling off of the steel in the big ladle. To save the time spent in refilling ladles it is desirable to use the largest shanks that can be poured without allowing the steel to grow "cold" in them.

When heats of some 2 to 3 tons are made, as in the majority of the small Bessemer shops, many heats are poured partly from the large ladle, partly from the shank. In this case, the first of the heat is, of course, used for the light work, poured from shanks, and the pouring generally kept up until the metal becomes too "dull" to run the light castings, when what remains in the ladle is used for heavier work. The advantage of providing both light and heavy work for each day's pour is too plain to require extended exposition, as the heavier work uses the dull metal from the last of many a heat, which would have to be poured as scrap, if only light castings were made up for pouring.

In small Bessemer foundries (and to some extent in small electric furnace work), the relative advantages of "shanking from the vessel" and "shanking from a ladle," are in debate.

The advocates of the former method base their arguments upon the fact that the hot vessel keeps the steel up to temperature better than the ladle. On the other hand, the advocates of pouring the whole heat into a ladle point out that filling shanks from the vessel is slow and rather dangerous, so that the heat is poured more rapidly by shanking from a ladle—and further that by taking the steel at once from the vessel and starting another heat, the vessel is kept very hot, with the result that the steel of each heat is hotter when blown. The advantage probably lies with shanking from the vessel when rather large shanks are used, and access to the vessel for filling is made easy, and with shanking from the ladle when very light shanks are employed, and access to the vessel is difficult.

In the case of the small electric furnace the question of initial heat of the steel does not come up, since the furnace can be kept up to full temperature while the steel is being poured by means of shanks—hence shanking from the furnace undoubtedly will result in the steel being brought to the moulds hotter than if shanked from a ladle. Should the shanks used be very light, the time spent in filling them would seriously affect economy, by cutting down the day's output of the furnace. Shanking from the ladle should be practised when possible, in order to increase production, and decrease the consumption of current per heat. Should a great deal of very light work have to be poured, necessitating extremely hot steel, the metal can be shanked from the furnace—or the heat can be poured into several ladles, each serving four or five shanks.

The foundry lay-out governs to a very great extent the pouring methods that can be used. This will vary so widely from shop to shop that only general consideration of the subject is possible. The lay-out for the day's pouring should be so arranged that a definite routine can be followed with each heat. Care should be taken that the moulds are not so distributed as to necessitate carrying the ladle long distances in moving from casting to casting. Should several ladles be necessary, especially if each ladle is serving several shanks, the floor space must be ample, to avoid interference between crews. A little attention given to this subject in planning the shop when first built will save countless vexatious delays when the productive capacity of the shop is reached.

Digging Out and Cleaning.—Frequently, especially with steels whose shrinkage is high, a casting cannot be kept from cracking, unless cores or portions of the mould are broken up as soon as the steel has solidified. Large cores and portions of moulds are frequently made partly collapsible, for instance by making their interior portions of cinders or of some inflammable substance like sawdust, so that they will yield to the pressure put upon them when the casting begins to contract; but it is generally necessary also to break up the cores thoroughly. By making their interior of loose ashes, and the arbors of very brittle cast iron, the destruction of the cores with bars and sledges is greatly facilitated. Many castings, especially of some of the alloy steels, must be dug out of the mould and the cores thoroughly broken up, the moment the steel is strong enough to bear handling.

Castings of very uneven section, especially of steel of high shrinkage, even if thoroughly dug out when red hot, will crack if allowed to cool in the air. The author has seen a 6-ton casting of ordinary carbon steel break clean in two through perfectly sound metal, some 36 hours after it was cast and some hours after it was cold enough to lay the hand on, from the strains set up by the unequal cooling of the thick and thin sections. To avoid this difficulty, the castings may be deeply buried in sand and allowed to cool; or cleaned very roughly, charged into a furnace or heated pit, which is brought to about the temperature of the castings, and there allowed to grow cold. These precautions, in the majority of cases, will be sufficient to insure against cracking and breakage.

Many castings of steel that has a high shrinkage, however, must not be allowed to grow actually cold before charging into the heat treatment furnaces; unless kept quite hot, they will break in cleaning, or in the first stages of heating up in the furnaces. It is not pleasant work to clean the sand and nails from a casting hot enough to show a temper color on the fresh fractures when the heads are knocked off, but it has to be done. Castings of this class almost always have to be taken from the sand and cooled in a preheated furnace or pit, mere burying in sand not being a sufficient safeguard against cracking, and are removed from the cooling furnace while still hot enough to show temper colors on a fresh fracture, when the heads and runners are knocked off, the sand and nails cleaned off as rapidly as possible, and the cored holes cleaned out, and are got into the furnaces while still hot enough to boil water that falls upon them. Heads that cannot be knocked off without danger of cracking the casting are burned off with the blowpipe.

Fortunately, these steels often have a low melting point and are very fluid, hence a neck very small in proportion to the sink head can be counted upon to feed the casting so thoroughly as in many cases to completely empty the head, leaving it a mere shell. The small necks, especially if the steel is brittle, make it possible in the majority of cases to knock off the heads, either by hand or with a dolly or drop, without fear of cracking the casting. Very good judgment, however, is needed in proportioning the necks and heads, in placing the heads, and in knowing how far to go in hammering on a head that refuses to come off. Many a casting is destroyed by an overenthusiastic man who persists in pounding away at an obstinate head or runner.

Steel castings that can be allowed to grow completely cold before cleaning and annealing, either by merely shaking them out and leaving them to cool in the air, or by cooling them in a furnace, can be cleaned at leisure. In removing runners and heads, good judgment is necessary. They may be broken from the castings, when the necks and gates are small enough. It is a pretty safe rule, however, that if a head cannot be broken off by hand, or by a very light "dolly" or drop, it had better be burned or sawed. By cutting away the neck with an air hammer and chisel or the torch, many heads can be broken by hand; but to make the necks small enough to break, at the cost of bad feeding of the casting and holes under the head that require a lot of plugging, is poor economy.

The large heads, if accessible, can be cut off with a cold saw; and it is part of the business of the moulders so to place the heads that they shall be accessible, unless it is manifestly impossible to do so. In that case the oxyacetylene or other burning torch comes into

play and either cuts the head entirely off, or so cuts into the neck that it can be broken without jar.

The practice occasionally followed of setting a casting up and beating off the sink heads by means of a heavy falling weight, is especially to be avoided. The casting is commonly full of strains; if of very brittle steel, so much the more danger is there of the casting giving way under the interal strain plus the gratuitous strain imposed by the heavy blow; if of soft steel, and consequently less brittle, so much the heavier the blow needed to break off the head, and so much the greater the added strain produced by the blow. There is really no need for haste in removing the heads, as in the case of steel that has to be cleaned hot; and the money saved by the quick and cheap method of getting off heads will be lost in the castings that break and are scrapped, or that crack but do not fail until they are in service—a far worse matter than the loss of a casting in the shop.