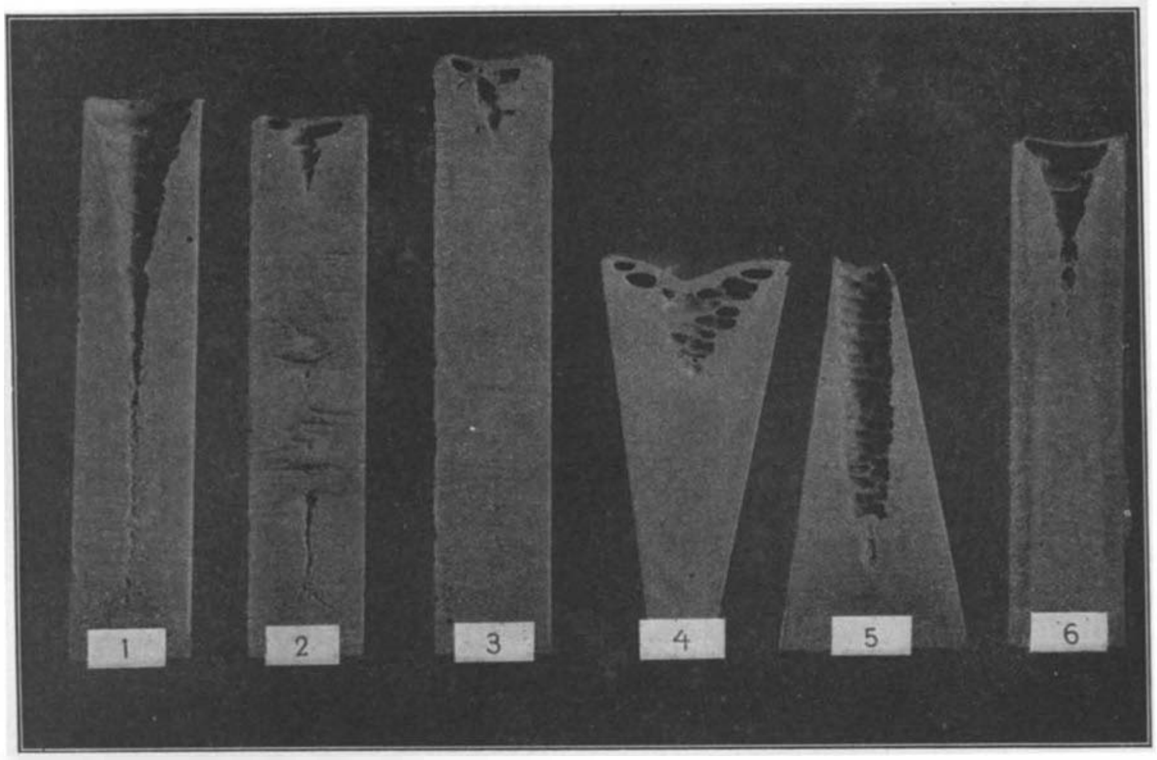
### EXPERIMENTS IN INGOT CASTING.

BY J. F. S. SPRINGER.

The tremendous expansion of rail transportation in the United States in recent years has imposed upon the steel-rail mills a correspondingly excessive pressure. The present plants are marvelous creations of inventive genius resulting in an almost incredible capacity of production. But it is more than hinted that their perfection of mechanical arrangement has been unaccompanied by any improvement in the quality of the rails. Indeed, Mr. R. W. Hunt, a railway expert, declared in effect at the April meeting of the American Institute of Mining Engineers (1907) that the rail process of to-day is inferior to that of twenty-five or thirty years ago. This he thought was conclusively shown by the fact that an abandoned mill of the earlier period was purchased some years ago and reinstated in the business of turning out rails. One of the railroads has about 100,000 tons of the rails made in accordance with the older methods and an equal amount of rails manufactured more nearly after the manner of the present procedure. In the matter of rail breakages, those occurring in the rails made by the older methods are but one-fourth those with the rails of the more recent procedure. If the chemical composition of the two classes of rails be taken into account, the advantage of the older methods of manufacture would be still more marked. Reheating and slowness of manufacture seem to be the main points of differentiation. But with the steel plants to-day, haste seems to be the cardinal virtue.

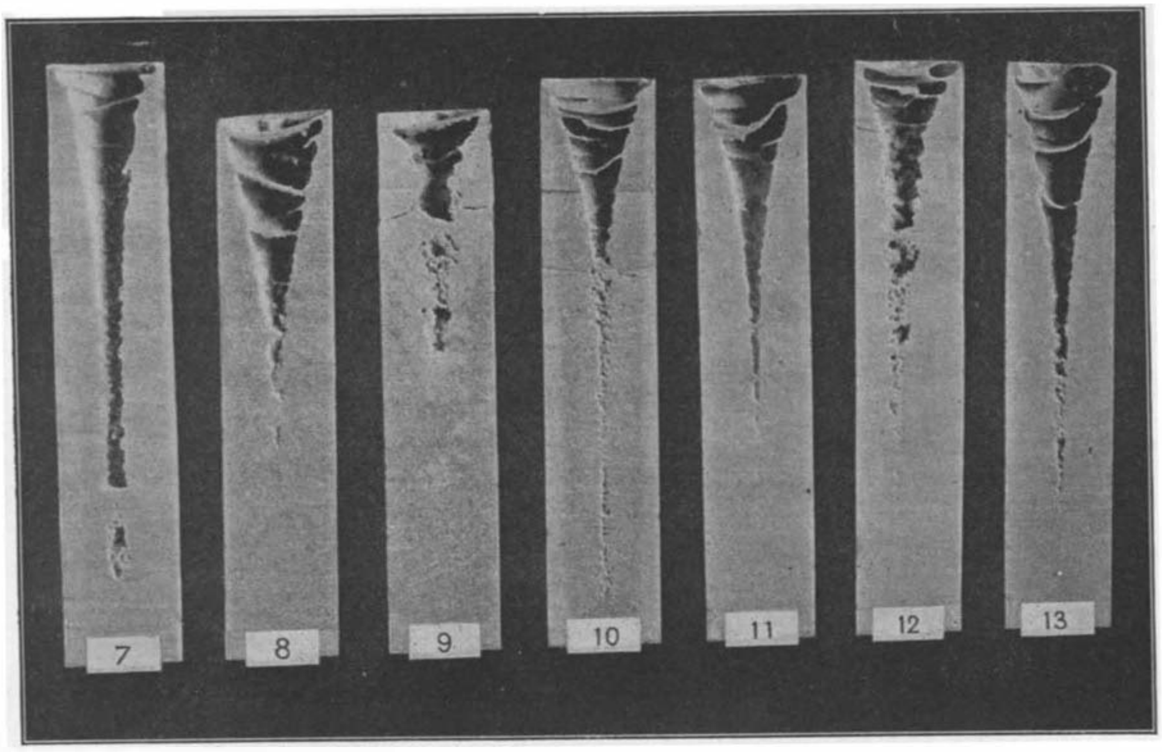


1. Ingot poured rapidly (half a minute); 2, ingot poured fast at first, but slowly afterward; 3, ingot poured very slowly; 4, ingot poured with large end up; 5, ingot poured with small end up; 6, ingot which was kept hot at top and progressively cooled at bottom.

A study of "pipes" in wax ingots.

Profs. Howe and Stoughton have been performing some experiments in ingot casting which indicate that increased deliberation in the preparation of the steel for the rolling mills is required. Their experiments have been made not with steel, but with wax, and their object has been the investigation of the laws governing the formation of "pipes" and segregates in ingots.

Not all substances form pipes. But wax and rail-steel agree in doing so. That is, each substance, when the attempt is made to cast it in the form of solid ingots, tends instead to solidify with a more or less open core along the upper part of the axis of the ingot. If this core or pipe is still in the ingot when it reaches the rolling mills, it has been pretty well ascertained that it will not be eliminated in any of the rolling processes. Consequently, it is important to learn the fundamental cause underlying its formation, as this knowledge may lead directly to such management of the casting operation as to secure either its complete effacement or a reduction to a minimum.



7. Ingot forced to "freeze" from top down; 8, 9, ingots cooled slowly; 10, ingot cooled rapidly; 11, ingot cooled less rapidly; 12, cooling on one side accelerated by cold water; 13, segregation in last cooling part.

A study of "pipes" in wax ingots.

EXPERIMENTS IN INGOT CASTING.

These two investigators have busied themselves in casting little bars or ingots of wax. Of course it would be preferable to experiment with large steel ingots of the sizes used in rail manufacture. But such experiments are rather unmanageable and very expensive. The wax-ingot experiments are, consequently, of distinct use in pointing the way that experimentation with large steel-rail ingots should take.

Further, a second large factor contributing to the imperfection of the rail-steel ingot is the presence of segregation. That is to say, the composition of the steel in large ingots is found not to be uniform throughout the mass. There is usually one locality where the carbon, phosphorus, and sulphur contained in the steel occur, not in the average degree, but concentrated. This concentration is the segregate. Metallurgists do not seem to entertain very strong hopes of its total prevention. At the same time, solid information as to its character and the laws of its formation can scarcely fail to lead to methods of casting favorable to a reduction of the evil.

The wax used in the experiments was commercially pure stearic acid mixed with a small quantity of copper oleate. The oleate was of a bright green color. As its specific gravity was greater than that of the wax proper, it might be expected to go to the bottom of the ingot, if gravitation were the only influence at work. This oleate represents the carbon, sulphur, and phosphorus of the ordinary steel. Its behavior under the conditions of casting might be expected to throw light upon the segregation in steel ingots. In order to make any concentration of this green oleate markedly visible, a small quantity of red ceresine was added to the wax. This substance has, it seems, little tendency, if any, to segregation, and consequently acts as mere coloring matter, giving the stearic acid a color contrast to the oleate. It should be noticed, before referring to the details of the photographs, shown in Figs. 1 to 13, that while the longitudinally split ingots of wax disclosed the color contrast, it was found necessary, in order to represent this in engravings, to retouch the photographs and then rephotograph them.

Fig. 1 is an ingot where the teeming, or pouring, was done rapidly, occupying but half a minute. Fig. 2 is an ingot poured fast at first, but with extreme deliberation afterward, the teeming occupying about an hour and a quarter. The pipe in the first ingot occupies about 90 per cent of the length. The pipe in No. 2 (if we except the small pipe at the bottom where the teeming was rapid) is about 14 per cent of the length of the ingot. If it be thought that this botttom pipe ascribed to fast pouring at the commencement of casting confuses the evidence, Fig. 3 makes the matter clear. This ingot was poured even more slowly than No. 2. The evidence afforded by these three ingots would seem, therefore, to show very clearly that slow pouring tends to efface the pipe.

The next two ingots, Figs. 4 and 5, disclose the marked advantage of casting ingots with the large end up. The pipe in Fig. 4 occupies but 30 per cent of the total length of the ingot in the one case, as contrasted with 82 per cent in the other. It is quite conceivable that if the wax had been teemed into the mold corresponding to Fig. 4 with the deliberation exercised in the case of ingot No. 3, the pipe would have been well nigh eliminated. Apparently, Profs. Howe and Stoughton did not experiment with this combination of conditions, perhaps deeming the result sufficiently obvious, apart from particular demonstration.

Now there is good evidence, aside from these wax ingot experiments, tending to prove that tapered ingots cast with the big end up disclose considerable reduction in piping. Mr. J. O. E. Trotz cast a number of gently tapering steel ingots, some with the big end up, some with it down. The result was found to be very distinctly in favor of the larger end up. The steel used was 0.50 per cent carbon. Mr. A. A. Stevenson likewise reports great diminution of piping in a steel ingot cast with the large end up as contrasted with others cast with the small ends up, all the ingots being strongly tapered.

In casting the ingot shown in Fig. 6, the top was kept in a molten condition for over an hour, while below, from the bottom upward, the ingot was progressively cooled by ice-water. Now the ingot shown in Fig. 7 was cast with these conditions of solidification pretty well reversed. That is to say, this ingot was forced to "freeze" from the top downward. By comparing the two, it will be seen that there is a great contrast in the length of the pipes. The pipe in ingot No. 6 was continuous for 26 per cent of the ingot's length, but extended in a modified form for 37 per cent. In ingot No. 7 the pipe was 85 per cent of the total length of the ingot. In the engraving, the pipe of No. 7 is apparently interrupted by a "bridge" near the lower end. The pipe extends, however, through this bridge. The difference in piping brought about by solidifying from below in one case and from above in the other is indicated by the two percentages—37 and 85.

The ingots shown in Figs. 8 and 9 do not exhibit any very marked difference in piping—the pipe of No. 8 being 61 per cent while that of No. 9 is 45 per cent. The conditions were largely the same, both being cooled very slowly. The 16 per cent difference is to be attributed mainly, no doubt, to the fact that although both ingots were retarded greatly in cooling, as wholes, No. 8 was cooled from the top and No. 9 from the bottom. This agrees with the results disclosed by Nos. 4, 5, 6, and 7. Now No. 10 was cooled very rapidly, and, in contrast to the slowly cooled ingots Nos. 8 and 9, exhibits a pipe extending almost to the bottom.

In Fig. 12 we have the case of an ingot in which the cooling on the one side was accelerated by means of cold water. On the opposite side, cooling was hindered by the use of flannel. The distinct displacement of the pipe in the direction of the flannel may be very distinctly seen in the engraving (Fig. 12). Now let us gather up some of the lessons to be learned from these experiments, in so far as piping is concerned: First, slow teeming reduces the pipe. (See Figs. 1, 2, and 3.) Second, casting with the large end of tapered ingots up tends to shorten the pipe. (See Figs. 4 and 5.) Third, a top kept molten diminishes the pipe. (See Figs. 6 and 9 as contrasted with Figs. 7 and 8, respectively.)

But what of the segregate? In Fig. 1, it lies at *A* near the bottom. The slowness with which Nos. 2 and 3 were cast tended to prevent the concentration of the green oleate into a single segregate. There were a number of local concentrations along the axis of No. 2. In No. 3, which was cast with still more deliberation, the absence of segregation is stated to be very marked. In ingot No. 4, the segregate lies above the center, while in No. 5 it is near the bottom.

The segregate seems to display a tendency to lie in the part which freezes last. By referring to Fig. 12, where the cooling was retarded on the left but hastened on the right, the bridges *E*, *F*, and *G* because of the strong green coloration seem to Profs. Howe and Stoughton to mark the position of the segregate. If this be the case, though they are not unreserved in their statement, then the deflection of the segregate to the warmer side would seem pretty clear. As further evidence of segregation in the last cooling part, the cases of the ingots shown in Figs. 11 and 13 are particularly cited.

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## GLASS INDUSTRY OF THE UNITED STATES.

If we consider the minor factors of civilization, glass should certainly be accorded a very high place, as it enters into many of the daily affairs of life. It is one of the oldest industries in the world. Pliny states that certain Phœnician merchants were preparing a meal on the seashore, and set their cooking vessel on a mass of the sand and alkali, which, when subjected to the fire, resulted in vitrification. In all the ages glass manufacture was considered of prime importance, and was often regulated by government edicts.

Glass is a hard, transparent substance, formed by fusing together mixtures of the silicates of potash, soda, lime, magnesia, alumina, and lead in various proportions, according to the kind or quality of glass required. Silica in the form of sand is the only constituent of glass that is absolutely essential, and enters into the composition of all varieties of glass as its true foundation. Silica as sand occurs very abundantly in the United States. The proportion of silica used varies according to the character of glass desired. An increase in the percentage of silica in any glass increases the resistance to melting and fusing. The various grades of sand contain more or less impurities, which are removed or neutralized by washing or chemicals. Iron when present imparts to glass a greenish tint, which can be corrected by the use of manganese. The bases used include sodium carbonate, sodium sulphate, sodium nitrate, calcium carbonate, litharge, and potash. Other auxiliary chemicals used in glass making are arsenic, carbon, and manganese. Glass makers call arsenic the "great decarbonizer," while manganese dioxide is known as the "great decolorizer." Carbon is employed in glass making to lower the fusing point when salt cake is used as a base, and to impart color when a glass from a straw yellow to a dark amber is desired.

The question of fuel is undoubtedly the one most important to the glass maker. With the aid of a good fuel a glass maker can produce a comparatively good glass from impure materials, but he cannot make a good glass with a poor fuel, no matter how pure the materials may be. Manufacturers have naturally located where coal was cheap, or where natural gas was available. Natural gas is the ideal fuel for glass making, and as the supplies get exhausted, producer-gas is being substituted. Oil is used to some extent, but is expensive. The following figures showing the quantity and cost of materials used are from the bulletin relating to glass making issued by the Bureau of the Census for the year 1905, the latest available figures:

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| Materials used, total cost | $26,145,522 |
| Glass sand: | |
| Tons | 769,792 |
| Cost | $1,547,147 |
| Soda ash (carbonate of soda): | |
| Tons | 215,462 |
| Cost | $4,068,804 |
| Salt cake (sulphate of soda): | |
| Tons | 53,905 |
| Cost | $802,611 |
| Nitrate of soda: | |
| Tons | 11,915 |
| Cost | $511,854 |
| Limestone: | |
| Tons | 115,655 |
| Cost | $274,209 |
| Lime: | |
| Hundredweight | 933,074 |
| Cost | $241,755 |
| Arsenic: | |
| Pounds | 2,676,650 |
| Cost | $92,574 |
| Carbon: | |
| Tons | 3,750 |
| Cost | $22,333 |
| Manganese: | |
| Pounds | 3,096,939 |
| Cost | $101,279 |
| Litharge (red lead | |
| Pounds | 9,613,649 |
| Cost | $555,130 |
| Potash or pearlash: | |
| Pounds | 5,446,338 |
| Cost | $228,508 |
| Grinding sand: | |
| Tons | 410,856 |
| Cost | $332,013 |
| Rouge: | |
| Pounds | 1,098,566 |
| Cost | $29,869 |
| Plaster of Paris: | |
| Tons | 33,939 |
| Cost | $169,988 |
| Fire clay or pot clay | |
| Pounds | 42,910,286 |
| Cost | $290,444 |
| Pots, not including those made at works: | |
| Number | 9,343 |
| Cost | $432,591 |
| Flattening stones: | |
| Number | 410 |
| Cost | $22,266 |
| Fuel: | |
| Total cost | $6,243,006 |
| Natural gas, cost | $2,777,157 |
| Oil— | |
| Gallons | 18,346,660 |
| Cost | $526,868 |
| Coal— | |
| Tons | 1,488,476 |
| Cost | $2,748,766 |
| All other fuel | $190,215 |
| Rent of power and heat | $42,164 |
| Lumber, casks, barrels, boxes, etc | $4,750,213 |
| Caps, metal trimmings, and rubber supplies | $1,696,145 |
| Supplies used in repairs on tanks and furnaces | $741,953 |
| Mill supplies | $265,444 |
| All other materials | $2,192,528 |
| Freight | $490,594 |

Disregarding the processes of manufacture, which have been repeatedly dwelt upon in these columns, let us consider the finished product. The following figures are for the same period, and represent a year's product:

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| Products, aggregate value | $79,607,998 |
| Building glass: | |
| Total value | $21,697,861 |
| Window glass— | |
| 50-foot boxes | 4,852,315 |
| Value | $11,610,851 |
| Obscured glass— | |
| 100-foot boxes | 70,774 |
| Value | $376,030 |
| Plate glass— | |
| Total cast, square feet | 34,804,986 |
| Rough made for sale— | |
| Square feet | 17,784 |
| Value | $3,529 |
| Polished— | |
| Square feet | 27,293,138 |
| Value | $7,978,253 |
| Cathedral— | |
| Square feet | 6,615,093 |
| Value | $293,623 |
| Skylight— | |
| Square feet | 15,255,541 |
| Value | $678,391 |
| All other building glass, value | $757,184 |
| Pressed and blown glass: | |
| Total value | $21,956,158 |
| Tableware— | |
| 100 pieces | 1,283,974 |
| Value | $4,897,537 |
| Jellies, tumblers, and goblets— | |
| Dozens | 7,346,214 |
| Value | $1,639,167 |
| Lamps— | |
| Dozens | 487,017 |
| Value | $1,247,628 |
| Chimneys— | |
| Dozens | 7,039,756 |
| Value | $3,061,334 |
| Lantern globes— | |
| Dozens | 1,765,247 |
| Value | $852,823 |
| Globes and other electrical goods— | |
| Dozens | 1,901,415 |
| Value | $1,106,317 |
| Shades, globes, and other gas goods— | |
| Dozens | 878,244 |
| Value | $1,949,069 |
| Blown tumblers, stemware, and bar goods— | |
| Dozens | 6,282,606 |
| Value | $2,928,198 |
| Opal ware— | |
| Dozens | 1,091,208 |
| Value | $870,221 |
| Cut glass— | |
| Dozens | 83,736 |
| Value | $987,556 |
| All other pressed and blown glass, value | $2,416,308 |
| Bottles and jars: | |
| Total value | $33,631,063 |
| Prescription vials and druggists' wares— | |
| Gross | 3,202,586 |
| Value | $6,638,508 |
| Beers, sodas, and minerals— | |
| Gross | 2,351,852 |
| Value | $7,927,287 |
| Liquors and flasks— | |
| Gross | 2,157,801 |
| Value | $5,555,815 |
| Milk jars— | |
| Gross | 253,651 |
| Value | $1,160,743 |
| Fruit jars— | |
| Gross | 1,061,829 |
| Value | $3,436,047 |
| Battery jars and other electrical goods— | |
| Gross | 19,974 |
| Value | $105,632 |
| Patent and proprietary— | |
| Gross | 1,657,372 |
| Value | $3,709,510 |
| Packers and preservers— | |
| Gross | 1,237,065 |
| Value | $2,989,557 |
| Demijohns and carboys— | |
| Dozens | 64,450 |
| Value | $247,856 |
| All other bottles and jars, value | $1,860,108 |
| All other products, value | $2,322,916 |

We have chosen the graphical method of presentation, and have translated the quantities into mammoth jars, boxes, bottles, lamps, and chimneys. The Singer Building looks well protected from the elements in the immense bottle. The Statue of Liberty holds her torch aloft in the goblet, which symbolizes the tableware, tumblers, etc., without touching the brim. The use of oil lamps in the United States is decreasing, due to the wider use of gas and electricity, still the lamp shown represents more than a million dollars' worth. In our comparison building-glass looms up very large, the magnitude of the industry being shown by the figures. Many of the most important inventions connected with glass are due to Americans, and the industry is a typical American one.

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### The Current Supplement.

The great wall of China, which even to this day represents the original idea of Chin, the first emperor, is described and illustrated in the opening article of the current Supplement, No. 1738. A. W. Gibbs writes on the smoke nuisance and the railroad. He takes up the subject in a new way and shows that the railroads must produce power with the fuel of the country through which they run, and that bituminous coal is the fuel with which the whole question must be settled. Somewhat of a novelty is the incandescent lamp device which is mounted upon the Eiffel Tower at Paris, so as to show the hour and minute. Our Paris correspondent writes on the subject. Water and salt solutions as dust preventives are discussed by Prevost Hubbard. Robert Grimshaw writes on iron-bronze alloys. Our interest in the effects of radium rays on living organisms is enhanced by the discovery that radio-activity is widely distributed in nature and that all plants and animals are influenced by radio-activity. Prof. C. Stuart Gager, of the University of Missouri, contributes an excellent article to the literature of the subject, in which article he shows the influence of radium rays on a few life processes of plants. Emil Freund tells how artificial gems have been made in the past and how they are made now. Prof. Jacob Reighard's monograph on subaqueous photography is continued. Animal fats and oils is the subject of another technological article of interest.