THE EFFECT OF SOME MELTING AND POURING FACTORS ON THE CHILLING TENDENCY OF GRAY CAST IRON

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THE EFFECT OF SOME MELTING AND POURING FACTORS ON THE CHILLING TENDENCY OF GRAY CAST IRON

By

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INTRODUCTION

Gray cast iron is essentially an alloy of iron, carbon, and silicon, containing from 2.50 to 3.60 percent carbon and from 1.20 to 2.50 percent silicon. Ordinary gray cast has most of the carbon in the form of graphite flakes, imbedded in a matrix of pearlite. The cooling rate of cast iron influences this structure; a high cooling rate resulting in a shorter type of graphite flake and finer pearlite.

In order to define the chilling tendency of cast iron, some consideration must be given to the mechanism of solidification of the alloy. Boyles investigated the mechanism of solidification of a hypo-eutectic cast iron and interpreted his results in terms of the iron-carbon-silicon phase diagram.[1] He concluded that solidification begins with the precipitation of primary dendrites of austenite, followed by the solidification of the eutectic liquid over a temperature range indicated by the phase diagram. Boyles also states that the eutectic liquid is nucleated from crystallization centers located in the interstices of the primary dendrites of austenite, and that the solidifying

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[1] Alfred Boyles, "The Structure of Cast Iron."

eutectic grows in a more or less radial fashion, forming eutectic cells.

This sequence of events is in accordance with the iron-carbon-silicon phase diagram and is characteristic of alloy systems in which a primary solid solution precedes the solidification of a eutectic. The nature of the eutectic matrix, however, cannot be predicted by a consideration of the phase diagram alone. If iron carbide is considered as a compound that is stable (there is no tendency toward decomposition at the eutectic temperature), the iron-iron carbide diagram would be applicable, and solidification of the eutectic could be described simply as an alternate precipitation of austenite and iron carbide. Such is not the case, however, as iron carbide can be decomposed at temperatures well below the eutectic temperature. Therefore, there is a tendency toward the formation of an austenite-graphite eutectic that obscures the exact mechanism of the solidification of the eutectic liquid. It is still uncertain for example if the austenite-graphite eutectic is formed directly from the melt or whether the graphite flakes result from the decomposition of previously precipitated carbides. Boyles advances arguments for both cases.[2]

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[2] Ibid., p. 33.

The chilling tendency of cast iron may be defined as the tendency of the eutectic liquid to solidify according to the metastable diagram (austenite-carbide eutectic) or according to the stable system (austenite-graphite eutectic). Cast iron is said to have a high chilling tendency when the composition and melting conditions favor the formation of the austenite-carbide eutectic, and conversely a low chilling tendency when the formation of an austenite-graphite eutectic is favored. A cast iron of high chilling tendency would tend to solidify according to the metastable system at moderate or even low cooling rates and thus would be unsuitable for casting thin sections.

From a consideration of the phase diagram it can be seen that the chilling tendency continues to influence the structure of cast iron after solidification is complete. As cast iron cools from the eutectic temperature to the eutectoid temperature the solubility of carbon in austenite decreases. This carbon may precipitate out as iron carbide or as graphite; a low chilling tendency favoring the precipitation of graphite. Again in the case of the eutectoid reaction (the decomposition of austenite) a low chilling tendency would favor the formation of a ferrite-graphite matrix. Cast iron that transforms according to the metastable equilibrium diagram is known as white iron, and its structure could be described as massive carbides in a matrix of pearlite. White iron is a hard unmachinable alloy used chiefly for its wear-resistant properties. On the other hand, cast iron solidifying according to the stable system at the eutectic temperature and according to the metastable system at the eutectoid temperature is known as gray iron. The graphite flakes characteristic of gray cast iron impart to this alloy its lack of ductility, good machinability, and relatively low strength properties.

The factors that influence the chilling tendency of cast iron are base composition (carbon and silicon), alloy content, the melting conditions of the iron, and the amount and type of late ladle additions to the molten iron. The effect of increasing the carbon and silicon content is to lower the chilling tendency of cast iron. Both are known as graphitizers, carbon being about three times as effective as silicon. Various alloys can be added to cast iron to increase or decrease the chilling tendency. Chromium and vanadium are characteristic of the carbide stabilizers, and serve to increase the chilling tendency markedly. Copper and nickel are both mild graphitizers and lower the chilling tendency. It is known that the melting conditions can exert a profound influence on the chilling tendency; oxidizing conditions are said to increase the chilling tendency. Other melting conditions that are influential are the type of melting unit and the character of the refractory lining. The effects of late ladle additions to the molten iron (inoculation) in reducing the chilling tendency have been understood and applied by the foundry industry in recent years. The chill reducing characteristics of inoculation are generally attributed to a "seeding effect" of the inoculant. This "seeding effect" in the melt is supposed to furnish nuclei for the solidifying iron.

Although the effect of rapid cooling of cast iron is to favor transformation according to the metastable equilibrium diagram, the cooling rate of cast iron is not considered as a factor affecting the chilling tendency. The chilling tendency is a property of the molten iron and the cooling rate is actually another factor that influences the structure from the time a casting is poured until the time it has cooled to room temperature.

The chilling tendency of cast iron is measured by pouring a sample of the iron into a mold where a continuous change in cooling rate can be produced across the section of the casting. One type of chill test employs the use of a wedge-shaped casting with a continuous change in cooling rate produced by the progressive change in section size. A second type of chill test employs the use of a chill block on one face of the mold, to produce the continuous change in cooling rate. A modification of the chill block test is called the

keyhole test and differs only by having an enlarged section well back from the chilled face. The keyhole chill test is helpful in determining the structure of the iron in heavy sections. Both the wedge chill test and the chill block test are interpreted by fracturing the casting and measuring the extent of the chilled iron.

Today, with the widespread use of inoculation to produce cast iron of high strength and good machinability, the use of the chill test is becoming an indispensable aid to the foundryman. By use of the chill test the gray-iron foundryman may sample the iron in the holding ladle and perform and interpret the test in time to make any adjustments necessary to insure the castings will be free of hard, unmachinable carbides. The use of chill testing is important in the malleable iron industry, where the results of the chill test may be correlated with the section size of the casting, to insure that the castings will not graphitize during solidification.

REVIEW OF LITERATURE

"Use of chill tests as we know them today probably began in foundries that specialized in the production of car wheels and iron rolls."[3] Since the introduction of the chill test much work has been done in determining the effect of various elements on the chilling tendency of cast iron. However, much less work has been done on the effects of melting conditions on the chilling tendency of cast iron and very little on the consistency of the chill test. The importance of chill testing has been recognized by the American Society for Testing Materials, as evidenced by their recent attempts to standardize the chill test.[4]

Since the introduction and use of the electric arc and induction furnaces, there has been considerable interest shown in the effect of superheating on the properties of gray cast iron. DiGiulio and White investigated the influence of superheating temperature and

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[3] E. A. Loria, "Trends for the Relation of Chill Test Depth and Carbon Equivalent of Cast Iron," Transactions of the American Foundrymen's Society, Preprint 53-28, 1953.

[4] Annual Meeting of the American Society for Testing Materials, June, 1953, Designation A 367-53T.

pouring temperature on the strength and hardness of cast iron, but did not report on the factors influencing the chilling tendency.[5]

Surls and Sefing repeated substantially the work of DiGiulio and White, but did not include the influence of melting conditions on the chilling tendency.[6] Massari and Lindsay were the first to report on the influence of superheating and pouring temperature on the chilling tendency of cast iron.[7] Massari and Lindsay melted a series of heats in an induction furnace, using a separate heat for each superheating temperature investigated. The effect of pouring temperature was investigated for each heat by allowing the furnace to cool slowly and tapping the furnace as the temperature of the iron dropped. They concluded that superheating cast iron increased the chilling tendency and that low pouring temperatures decreased the chilling tendency. The cast iron investigated by Massari and Lindsay

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[5] A. DiGiulio and A. E. White, "Factors Affecting the Structure and Properties of Gray Cast Iron," Transactions of the American Foundrymen's Association, 1933, vol. 43, pp. 531-565.

[6] Surls and Sefing, "The Properties of Gray Iron Castings as Affected by Superheating Temperatures," Transactions of the American Foundrymen's Association, 1935.

[7] S. C. Massari and R. W. Lindsay, "Some Factors Influencing the Graphitizing Behavior of Cast Iron," Transactions of the American Foundrymen's Association, vol. 49, p. 953.

was not a typical gray cast iron inasmuch as the carbon content was 3.60 percent and the silicon content was 0.55 percent. In determining the effect of pouring temperature on the chilling tendency, they did not consider the effect of holding time as another variable. In addition, they assumed the final analysis of each separate heat was in the same order, and did not give the final analysis of the chill test castings. Krause was the first to investigate the consistency of chill tests and to correlate the results from various types and sizes of chill tests.[8] Krause obtained his data from typical gray iron production foundries with all melting done in cupolas. Krause concluded that, although chill testing was not a substitute for chemical analysis, it did extend the usefulness of chemical analysis. Loria, in obtaining chill data from two cupolas used to melt cast iron on a production basis, attempted to establish a closer relationship between the carbon and silicon content (the carbon equivalent) and the chilling tendency.[9] Loria assumed that the melting conditions in cupolas operating on a production basis would be uniform and that changes in composition

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[8] D. E. Krause, "Chill Tests and the Metallurgy of Gray Cast Iron," Transactions of the American Foundrymen's Society, 1951, p. 79.

[9] E. A. Loria, op. cit.

of the iron would be reflected in changes of the chilling tendency. Loria found that plotting the chill depth versus the sum of the carbon content and 1.5 times the silicon content, reduced the spread of his data. The carbon equivalent varies inversely as the chill depth. This new carbon equivalent, however, implies that the silicon content is 1.5 times as effective as the carbon content in reducing the chilling tendency. Some justification for the usual carbon equivalent (total carbon plus one-third the silicon content) is that it conforms to the composition changes required to displace the eutectic point on the iron-carbon-silicon phase diagram. (A 2 percent increase in silicon content reduces the eutectic composition by 0.6 percent of carbon.)

PURPOSE AND SCOPE

During the course of a research project on chilled iron plowshares carried on at Michigan State College, some inconsistencies in the chill depth were noted that were difficult to explain on the basis of any reference to the subject in the literature. Quite a number of plowshares were poured from one ladle of inoculated cast iron and it was noted that the chill depth increased with the pouring order of the castings. If the pouring temperature was involved, the effect was opposite that to be expected from Massari and Lindsay's work. This increase in chilling tendency with holding time was attributed to a "wearing off" of inoculation, but seemed rather high in view of the short time required to handle the cast iron in the ladle. Therefore, it was decided to investigate the influence of pouring temperature and holding time in the ladle on the chilling tendency of inoculated and uninoculated cast iron.

In connection with another research project on the inoculation of cast iron it was noted that the chill test involving the use of a chill block sometimes gave erratic results. The depth of chill for two chill tests poured consecutively from the same ladle could vary

by a factor of two. On the basis of these observations it was decided to compare the consistency of the wedge chill test and the block chill test before attempting to determine the effect of the melting and pouring conditions on the chilling tendency of cast iron.

Although Massari investigated the influence of superheating cast iron on the chilling tendency, he used separate heats for each superheating temperature and assumed the final analysis of the chill blocks would be fairly constant. Therefore, it was decided to determine the influence of superheating cast iron on the chilling tendency.

The scope of this investigation has been limited to a consideration of unalloyed gray cast irons melted in the indirect arc electric furnace and the induction furnace. No attempt has been made to evaluate the effectiveness of various inoculants in reducing the chilling tendency. The calcium-silicon inoculant was selected because of its widespread use in the foundry industry. In determining the effect of superheating cast iron, no account was taken of the atmosphere above the charge.

PROCEDURE

Two types of melting units were used in this investigation, the indirect arc furnace being used in the beginning of the investigation, with some of the later heats melted in a thirty-pound high frequency induction furnace. A typical charge used in the rocking furnace is given below with the analysis of each component of the charge.

Component of Charge	Weight (lbs.)	Composition (pct.)				
		Carbon	Silicon	Mn	P	S
Hanna pig iron . . .	86	4.14	1.19	0.72	0.13	0.038
Small pig iron . . .	39	4.13	1.23	0.40	0.23	0.033
FeSi	9.5	0.42	27.5	0.84		
Mild steel .	66	0.12	0.17	0.41	0.023	0.023
FeMn	0.6			83.3		

The charge was designed to give a final analysis of 2.80 percent carbon, 2.20 percent silicon, and 0.90 percent manganese. Iron sulphide and ferro phosphorus were added after the charge began melting

down. The sulphur content was in the order of 0.08 percent and the phosphorus was 0.14 percent for each heat.

Both the wedge chill test and the chill block test were poured in baked core sand molds. The chill block casting was 4 inches long, 7/8 inch thick, and 2-1/4 inches wide. The 4 by 7/8 face was poured against a cast iron chill block set vertically in the mold. The wedge chill test was 5 inches long, the base of the wedge was 1/2 inch thick, and the distance from the apex of the wedge to the base was 2-1/8 inches. Except as noted, all pouring temperatures were measured with a platinum-platinum rhodium thermocouple calibrated by the Bureau of Standards.

Before attempting to determine the effects of pouring temperature and holding time in the ladle on the chilling tendency, it was decided to determine the consistency of the wedge chill test and the chill block test for both inoculated and uninoculated cast iron. It was also decided to compare results from pouring the chill test against a vertical and horizontal chill block. The heat designated as R15 was melted to determine the consistency of the wedge chill test, the vertical chill block test, and the horizontal chill block test. The dimensions of the chilled face for the horizontal and the vertical chill tests were the same, and both were poured against a cast iron chill block.

The charge given above was melted in the rocking furnace and a fifty-pound ladle of metal tapped from the furnace. When the temperature of the iron in the ladle had dropped to 2650°F, six of each of the three types of chill tests were poured. Each type of chill test was poured consecutively. This procedure was repeated for a second ladle, the second ladle being inoculated with 110 grams of calcium-silicon. No information could be obtained about the consistency of horizontal chill tests as the castings fused onto the chill blocks. The wedge chill castings and the vertical chill block castings were identified according to the pouring order and fractured for examination. Photographs of these chill tests are presented in Figures 1 through 6, and the chill data in Tables I through IV, in the Discussion.

The purpose of the next heat was to determine the effect of pouring rate on the depth of chill for the horizontal and vertical type of chill block test, in an attempt to determine the reason for erratic results sometimes obtained in the chill block test. In order to avoid the problem of castings fusing to the chill block, the horizontal chill blocks used were steel. The difference in pouring rate was accomplished by use of strainer cores with two different size core holes; a quarter-inch diameter hole being used for a low pouring rate and a half-inch hole for the high pouring rate. Six castings were poured for each pouring rate and six were poured without the use of strainer cores. The heat for this determination was designated as R18, and was melted in the rocking furnace using the same charge as before. Three fifty-pound ladles of iron were tapped from the furnace, each ladle being inoculated with 110 grams of calcium-silicon. The chill tests poured without strainer cores were arranged in pairs so that two vertical chill tests were poured, two horizontal chill tests, et cetera, until six of each type had been poured from the first ladle. The chill tests poured through strainer cores were arranged so that six of one type were poured consecutively, the size of the strainer core hole being alternated. All of the horizontal chill tests and four of the vertical chill tests were poured from the second ladle, the last two vertical chill tests being poured from the third ladle of iron. The chill tests were identified according to the ladle number and order of pouring, and were fractured for examination. The data and photographs for this heat are given in Figures 7 through 11 and Tables V through VIII. The results of the first two heats indicated that the wedge chill test was the most reliable; therefore, the remainder of the work was done using the wedge chill test as a measure of chilling tendency.

The purpose of the next heat (R7) was to determine the effect of pouring temperature and holding time in the ladle on the chilling tendency of inoculated cast iron. Heat R7 was melted in the rocking furnace, using the same charge as before. The procedure consisted of tapping a fifty-pound ladle of iron from the furnace, inoculating with 110 grams of calcium-silicon, and pouring wedge chill tests at various time intervals after inoculation. The time intervals were spaced so that the temperature of the cast iron would drop approximately 100°F for each group of three chill tests poured. Five pouring temperatures were obtained, extending over a ten-minute period after inoculation. Inspection of the chill tests from this heat indicated that the longer holding time and lower pouring temperature both increased the chilling tendency. However, this data did not indicate which factor was the most important (see Table IX and Figure 12).

The second heat poured to determine the effect of pouring temperature and holding time in the ladle was designated as Heat R8 and was melted in the rocking furnace using a similar charge as before. The procedure was modified, however, in an attempt to isolate the effect of both variables. Two ladles were tapped from the furnace and both inoculated with 110 grams of calcium-silicon.

Part of the iron in the first ladle was transferred to a cold ladle to cool some of the iron to a low pouring temperature in a short time. The temperature of the iron in the preheated ladle and the cold ladle was measured and three chill tests poured from each ladle at the same time. This procedure eliminated holding time as a variable and resulted in two pouring temperatures. The chill tests from the preheated ladle were designated as R8-H and the chill tests from the cold ladle R8-C. The metal in the second ladle to be tapped from the furnace was allowed to cool slowly in the ladle, chill tests being poured periodically as the temperature fell. These castings were identified as R8-1, R8-2, et cetera, the last digit indicating the order of pouring. Tables X and XI and Figure 13 illustrate the results of this heat.

Heats R7 and R8 were poured to determine the effect of pouring temperature and holding time on the chilling tendency of inoculated cast iron. The next heat (R9) was carried out in the same manner as R8, with the exception that the iron was not inoculated. The same system of identification of the chill tests was used as in R8, and the data and photograph are given in Table XIII through XV and Figure 14.

Heat R10 was melted in order to determine the effect of superheating cast iron on the chilling tendency. This heat was melted in the rocking furnace using a charge similar to previous heats. As soon as the charge had melted down and was uniform, samples of iron were tapped periodically from the furnace with the furnace running on full power. Each sample of iron was tapped into a ten-pound ladle and the temperature measured with a platinum-platinum rhodium thermocouple, as all chill tests were poured at the same temperature. Three chill tests were poured for each time interval. The tapping temperature was measured by sighting an optical pyrometer into the furnace at the beginning and end of the tapping period. The carbon and silicon content was determined for each set of chill tests poured at different time intervals. The tapping schedule, chill data, and photograph of the chill tests for this heat are given in Tables XVI and XVII and Figure 15.

The series of the last six heats was melted in a thirty-pound high-frequency induction furnace, the first four heats being melted in a silica crucible and the last two in a magnesia crucible. The purpose of these heats was to determine the effect of pouring temperature and holding time on the chilling tendency of inoculated and uninoculated cast iron. It was felt that a measure of these two variables could be refined by using the induction furnace. The high-frequency induction furnace, being much smaller, can be more closely controlled from a standpoint of melting temperature, and is easier to tap at any convenient time. The procedure for these heats consisted of melting the charge and superheating to 2800°F. If the heat was to be inoculated, the inoculant was added at this time and the temperature and time of inoculation noted. Three chill tests were then poured directly from the furnace and at the same time a small ladle of iron was tapped from the furnace. The temperature of the iron in the ladle dropped to about 2300°F in approximately a minute, and three chill tests were poured from this ladle. The remainder of the metal in the furnace was held at 2800°F for thirty minutes, a set of chill tests being poured directly from the furnace every five minutes of this holding time. This tapping schedule was planned to eliminate the effect of holding time for the first two sets of chill tests, and to eliminate the factor of pouring temperature for the last five sets of chill tests poured. This procedure differed from that followed when using the rocking furnace, in that both factors were separated in these last heats. The optical pyrometer was used to measure the pouring temperature of the metal in the induction furnace. Past experience indicated the optical pyrometer checked closely (within 20°F) with a noble metal thermocouple when the temperature of the iron was above the transition point (2550°F).

The first heat melted in the high-frequency induction furnace was designated as R11, and the iron was poured without inoculation. The charge consisted of cylindrical cast iron slugs containing 2.78 percent carbon and 1.98 percent silicon. The silicon content was increased to 2.30 percent in the uninoculated heats by the addition of 0.35 pound of FeSi to the charge. In the case of an inoculated heat, the addition of the inoculant increased the silicon content to 2.30 percent. No conclusions could be drawn from Heat R11 as the chill tests were chilled completely through the cross section of the casting. Heat R12 was melted and poured the same way as R11, with the exception that the iron was inoculated. These chill tests were chilled completely through, also. The next two heats melted in the high-frequency induction furnace (R13 and R14) were carried out the same way as R11 and R12 with the exception that the charge was modified slightly in an effort to overcome the high chilling tendency of the iron. Heat R13 was melted as an uninoculated heat and R14 was inoculated with calcium-silicon. The data and photograph of the chill tests for R13 are given in Tables XIX and XX and Figure 16. The data and photograph of R14 are given in Tables XXI through XXIII and Figure 17.

The last two heats melted in the high-frequency induction furnace (R16 and R17) were melted and poured exactly as Heats R13 and R14 with the exception that a magnesia crucible was used instead of a silica crucible. Heat R16 was poured without inoculation and the chill tests chilled completely through the cross section of the castings. Heat R17 was inoculated with 70 grams of calcium-silicon. The data and photograph of these chills are given in Tables XXIV through XXVI and Figure 18.

RESULTS AND DISCUSSION

The results from Heat R15 seem to indicate the consistency of both types of chill tests is very good. Each group of chill tests photographed together were poured from the same ladle of metal in the order indicated. The time involved in pouring six chill tests was short enough so that changes in the chilling tendency were minimized and any inconsistencies in the chill depth could be attributed to differences in heat transfer properties of the individual chill test molds. Figure 1 illustrates the consistency for six wedge chill tests poured from an uninoculated cast iron. It can be seen that even the chill arising from corner cooling at the base of the wedge shows a consistent depth. The analysis of these castings was 2.79 percent carbon, 2.35 percent silicon, and 0.81 percent manganese.

Table I shows the depth of chill resulting from six wedge chill tests poured from an uninoculated cast iron.

The vertical chill block tests shown in Figure 2 were poured consecutively from the same ladle used to pour the wedge tests shown in Figure 1. The consistency for these chill tests is good.

Table II shows the depth of chill resulting from six vertical chill block tests poured from uninoculated cast iron.

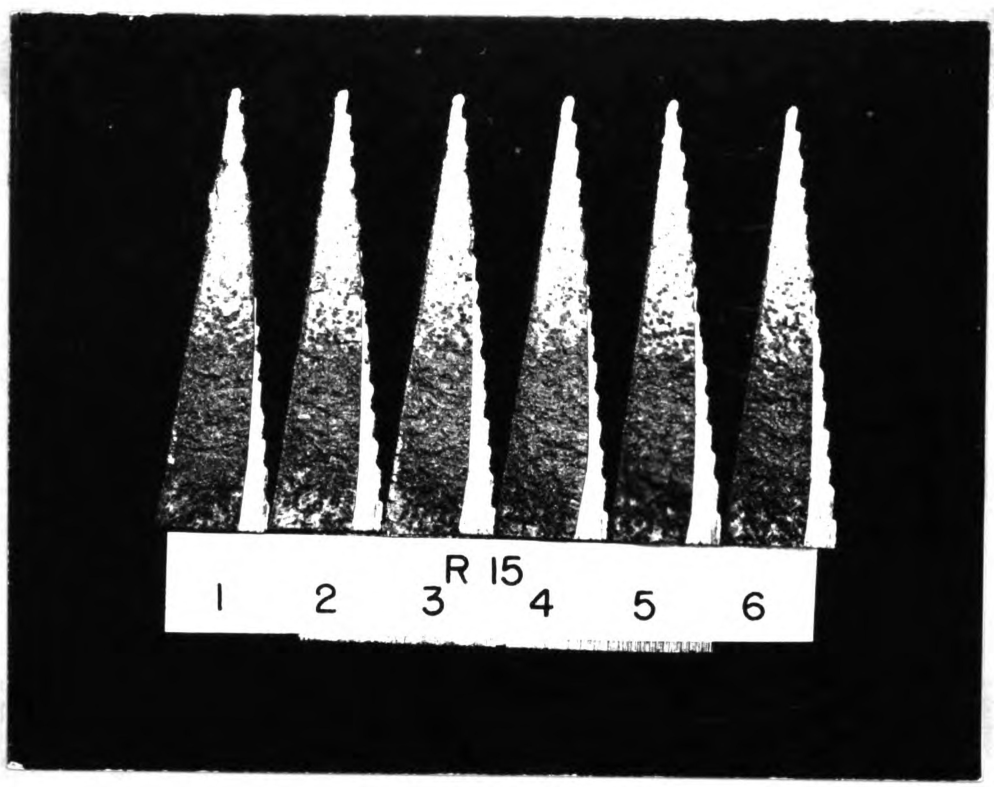

Figure 1. Consistency of wedge chill tests poured from uninoculated cast iron.

TABLE I

DEPTH OF CHILL RESULTING FROM SIX WEDGE CHILL TESTS POURED FROM UNINOCULATED CAST IRON

Chill Designation for Wedge Chill Test	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R15-1	56	79
R15-2	54	77
R15-3	56	78
R15-4	57	77
R15-5	55	76
R15-6	53	78

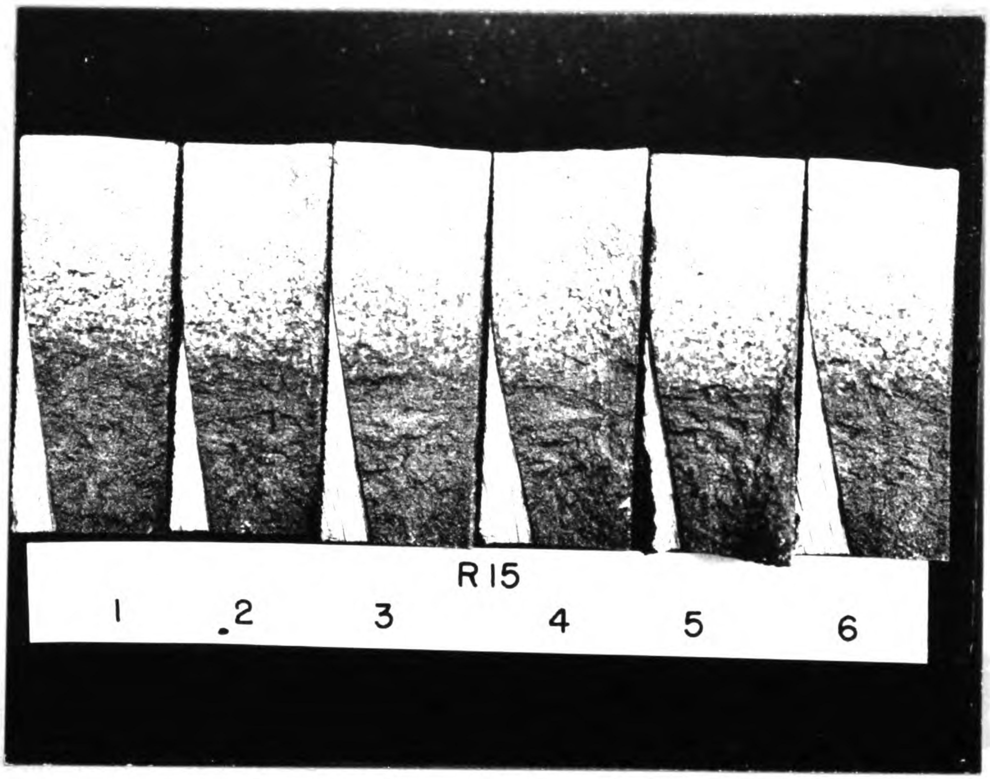

Figure 2. Consistency of chill block tests poured from uninoculated cast iron.

TABLE II

DEPTH OF CHILL RESULTING FROM SIX VERTICAL CHILL BLOCK TESTS POURED FROM UNINOCULATED CAST IRON

Chill Designation for Chill Block Test	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R15-1	45	73
R15-2	-	75
R15-3	44	75
R15-4	46	77
R15-5	44	79
R15-6	49	79

Figures 3 and 4 were taken of wedge chill tests and chill block tests poured from an inoculated iron from the same heat. With the exception of the fifth casting, the wedge chill tests showed a good consistency. The reliability of the chill block test does not appear to be as good for an iron of low chilling tendency as for an inoculated cast iron.

Tables III and IV show the depth of chill from wedge chill and chill block tests, respectively, poured from inoculated cast iron.

Figures 5 and 6 were photographed to illustrate the effects of cooling from the end of the casting on the chill depth. In each pair of specimens photographed, the one on the left was fractured an inch from the end of the casting, while the one on the right was fractured two inches from the end of the same casting. Examination of the chill tests would indicate that the wedge chill test is more susceptible to end cooling effects than the chill block test. This is particularly true for the wedge test poured from an uninoculated cast iron.

The chill block tests poured from Heat R18 do not show the same consistency noted in Heat R15. All of the chill tests poured in Heat R18 were poured against a vertical or horizontal chill block with an inoculated cast iron.

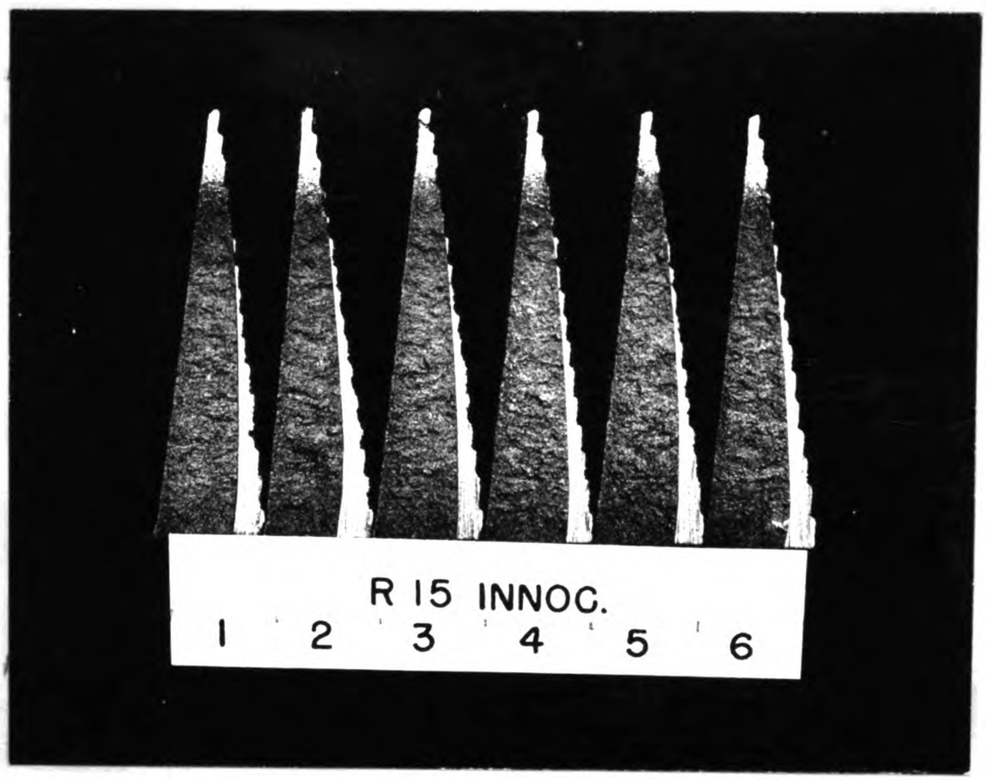

Figure 3. Consistency of wedge chill tests poured from inoculated cast iron.

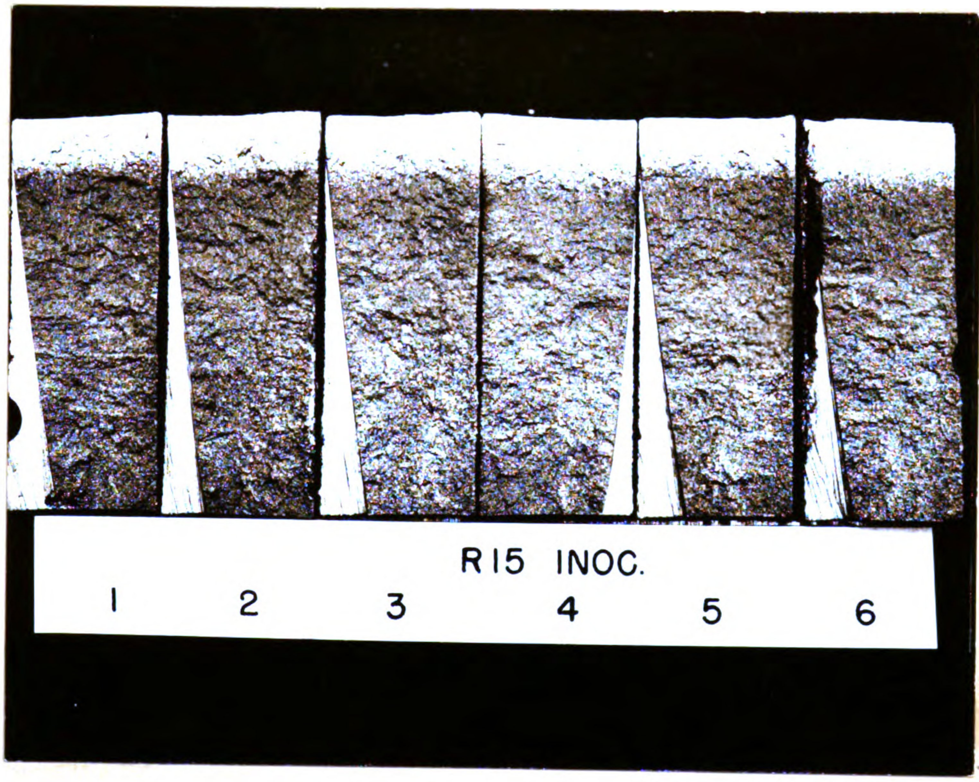

Figure 4. Consistency of chill block tests poured from inoculated cast iron.

TABLE III

DEPTH OF CHILL RESULTING FROM SIX WEDGE CHILL TESTS POURED FROM INOCULATED CAST IRON

Chill Designation for Wedge Chill Test	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R15 innoc.-1	20	27
R15 innoc.-2	21	29
R15 innoc.-3	19	24
R15 innoc.-4	20	27
R15 innoc.-5	16	23
R15 innoc.-6	21	26

TABLE IV

DEPTH OF CHILL RESULTING FROM SIX CHILL BLOCK TESTS POURED FROM INOCULATED CAST IRON

Chill Designation for Chill Block Test	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R15 innoc.-1	11	20
R15 innoc.-2	14	21
R15 innoc.-3	14	22
R15 innoc.-4	14	22
R15 innoc.-5	13	21
R15 innoc.-6	15	24

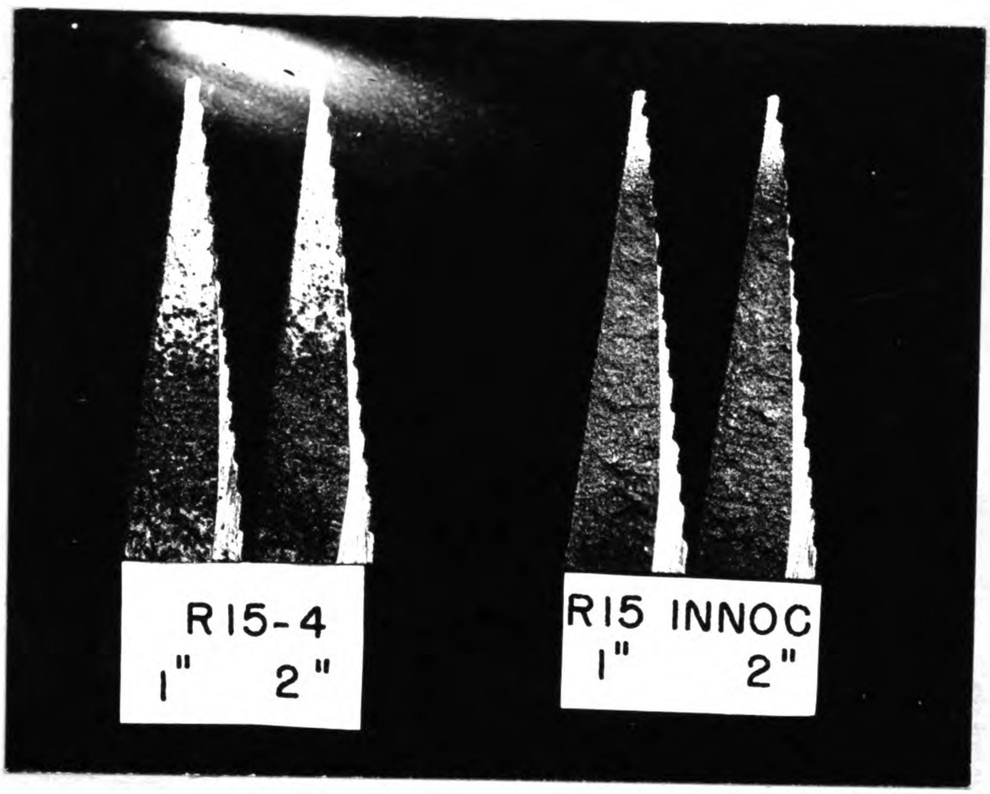

Figure 5. End cooling effect on chill depth for wedge test.

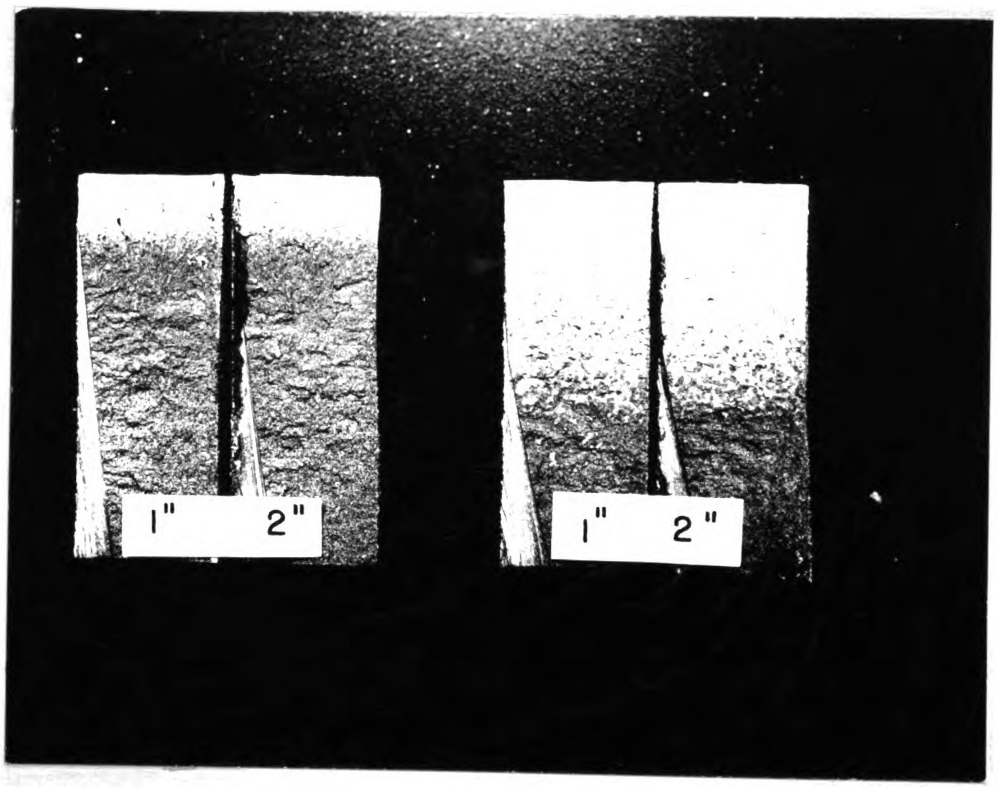

Figure 6. End cooling effect on chill depth for chill block test.

Figures 7 and 9 were taken of the vertical chill block test and horizontal chill block test, respectively. These chill tests were poured without strainer cores and all twelve were poured from the same ladle. The chill tests poured against a vertical chill block were fairly consistent with the exception of castings 1 and 9, both of which show about half the chill depth of the others (see Figure 7). It was noted that the surfaces of the chilled faces of the tests giving a low value were uneven and pitted, suggesting that gas had been trapped between the cast iron and the chill block during pouring. Figure 8 was taken of the chilled face of two of the castings shown in Figure 7. The casting on the left showed a low depth of chill and has the most pitted surface on the chill face. Probably the gas trapped between the molten iron and the chill block acts as an insulation, causing the chill tests to read low.

Table V shows the depth of chill resulting from six vertical chill block tests poured from inoculated cast iron.

The horizontal chill block tests shown in Figure 9 do not show a better consistency than the vertical chill tests poured from the same ladle. The chill depth is very uneven across the width of the casting and this unevenness may be a result of pouring the cast iron directly on the chill block.

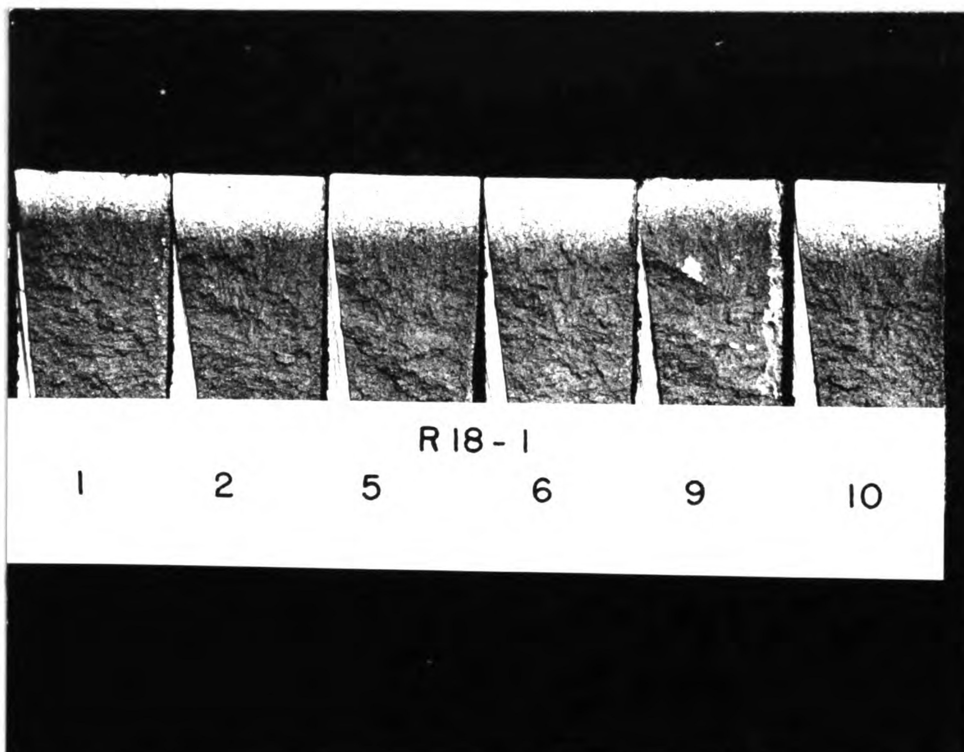

Figure 7. Consistency of vertical chill block test poured from inoculated cast iron.

Figure 8. Surface condition of chilled face for chill block test.

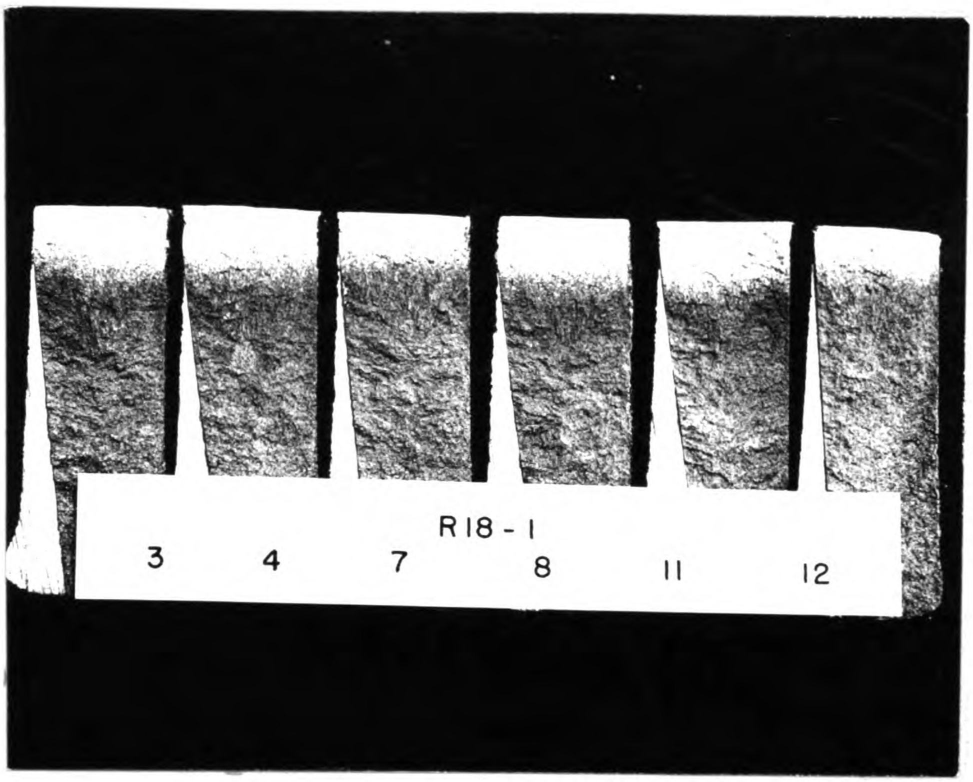

Figure 9. Consistency of horizontal chill block test poured from inoculated cast iron.

TABLE V

DEPTH OF CHILL RESULTING FROM SIX VERTICAL CHILL BLOCK TESTS POURED FROM INOCULATED CAST IRON

Chill Designation for Vertical Chill Blocks	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R18-1-1	8	14
R18-1-2	14	20
R18-1-5	14	21
R18-1-6	16	23
R18-1-9	6	15
R18-1-10	17	24

Table VI shows the depth of chill resulting from six horizontal chill block tests poured from inoculated cast iron.

The procedure for pouring the second and third ladles from Heat R18 was changed somewhat. All of these chill tests were poured through strainer cores of two different core hole sizes, with the horizontal chill block tests being poured consecutively, followed by pouring the vertical chill block tests consecutively. The core hole size was alternated for both types of chill block tests, however, as indicated by Tables VII and VIII. Figure 10 was taken of the horizontal chill block tests poured through strainer cores, the first chill being poured through a half-inch core hole, the second through a quarter-inch core hole, et cetera. The pouring rate seems to have no effect on the depth of chill for these tests (see Figure 10). Moreover, the results do not seem to be more consistent than without the use of strainer cores.

The same conclusions could be drawn in regard to the effect of pouring rate on the depth of chill for the vertical chill block test. Again there is no consistent variation of chill depth with pouring rate and the chill tests show very little improvement in consistency over those poured without the use of strainer cores. Figure 11 was taken of the vertical chill blocks poured through strainer cores, the last two chills being poured from the third ladle of metal tapped from the furnace.

TABLE VI

DEPTH OF CHILL RESULTING FROM SIX HORIZONTAL CHILL BLOCK TESTS POURED FROM INOCULATED CAST IRON

Chill Designation for Horizontal Chill Blocks	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R18-1-3	17	27
R18-1-4	19	27
R18-1-7	16	23
R18-1-8	21	31
R18-1-11	22	29
R18-1-12	14	21

TABLE VII

DEPTH OF CHILL RESULTING FROM SIX HORIZONTAL CHILL BLOCK TESTS POURED THROUGH STRAINER CORES FROM INOCULATED CAST IRON

Chill Designation	Core Hole Size (inches)	Depth of Chill (in 64ths of an inch)	
		Clear Chill	Total Chill
R18-2-1	1/2	15	22
R18-2-2	1/4	12	18
R18-2-3	1/2	14	24
R18-2-4	1/4	16	22
R18-2-5	1/2	16	24
R18-2-6	1/4	20	26

TABLE VIII

DEPTH OF CHILL RESULTING FROM SIX VERTICAL CHILL BLOCK TESTS POURED THROUGH STRAINER CORES FROM INOCULATED CAST IRON

Chill Designation	Core Hole Size (inches)	Depth of Chill (in 64ths of an inch)	
		Clear Chill	Total Chill
R18-2-7	1/4	12	20
R18-2-8	1/2	13	19
R18-2-9	1/4	15	24
R18-2-10	1/2	16	21
R18-3-1	1/4	8	14
R18-3-2	1/2	11	17

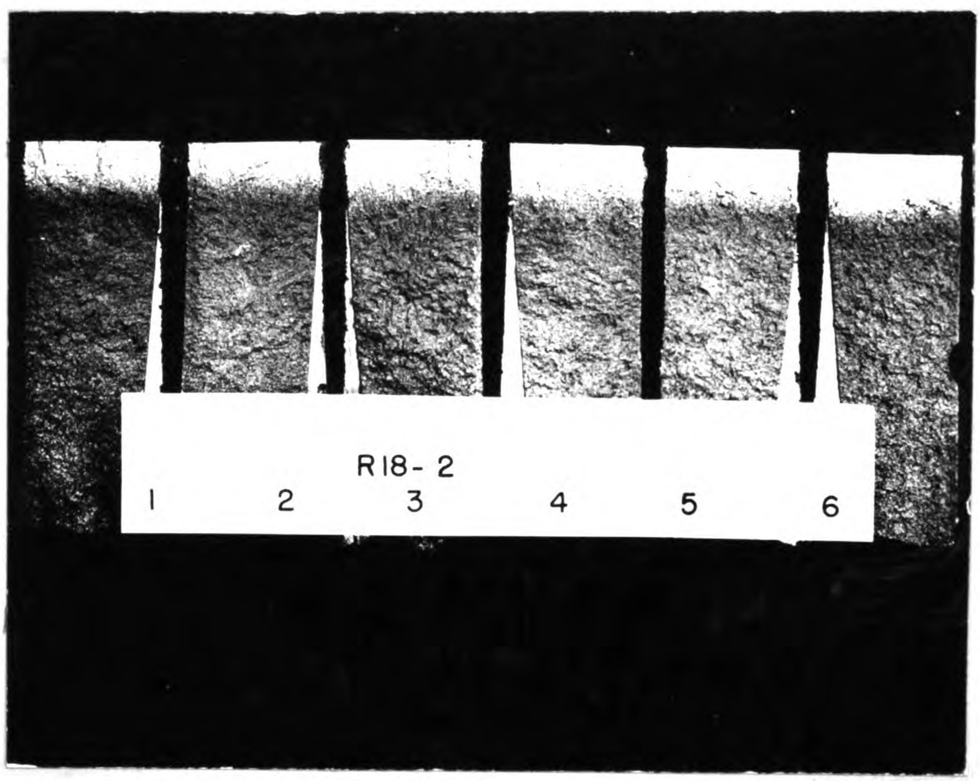

Figure 10. Effect of pouring rate on chill depth of horizontal chill block test poured from inoculated cast iron.

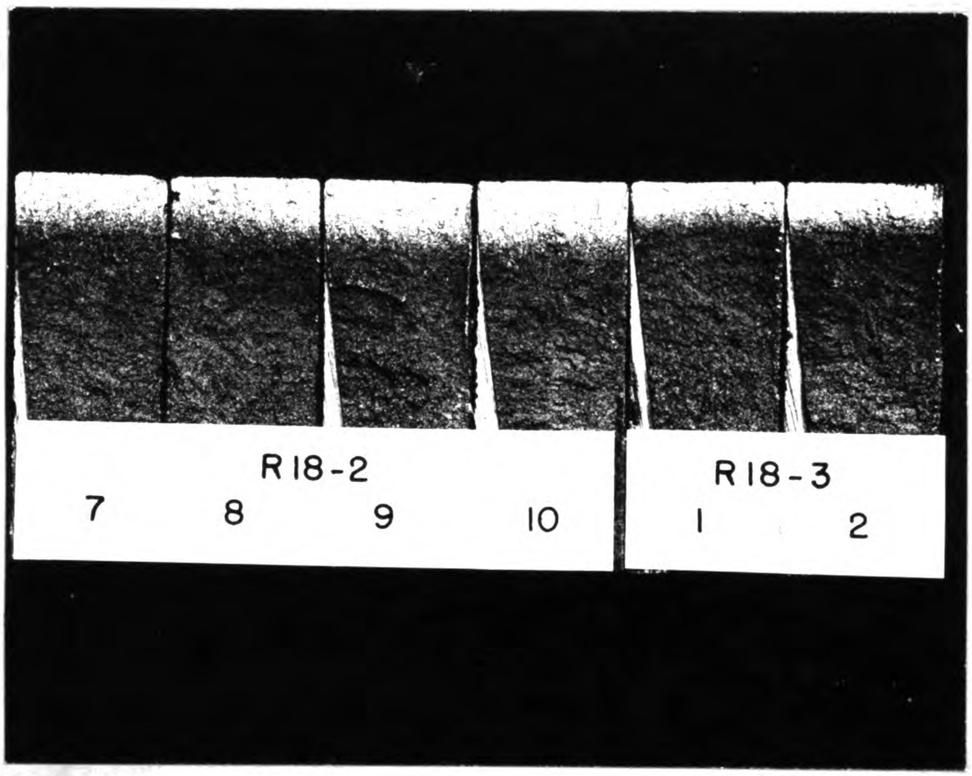

Figure 11. Effect of pouring rate on chill depth of vertical chill block test poured from inoculated cast iron.

The analysis of the castings from Heat R18 was 2.88 percent carbon, 2.62 percent silicon, and 0.84 percent manganese.

On the basis of Heats R15 and R18, the wedge chill test definitely appears to be the most reliable. The advantages of the wedge chill test in other respects include the smaller samples of cast iron required to pour the test, the shorter period of time required for the wedge test to solidify and cool, and the ease with which the casting can be fractured and measured. Use of the chill block test also necessitates some effort in cleaning and maintaining a uniform surface on the chill blocks. Therefore, the wedge chill test was used to determine the chilling tendency of cast iron for the remainder of this project.

The results obtained from Heat R7 clearly indicate that lower pouring temperatures combined with the effect of holding time in the ladle increase the chilling tendency of an inoculated cast iron. The chill tests shown in Figure 12 were arranged in the order they were poured, and the data in Table IX indicate the pouring temperature of each group of three chill tests poured, and the depth of chill measured from the castings. All of these castings were poured from the same ladle in the order indicated, the ladle having been inoculated with 75 grams of calcium-silicon. The holding period from the time

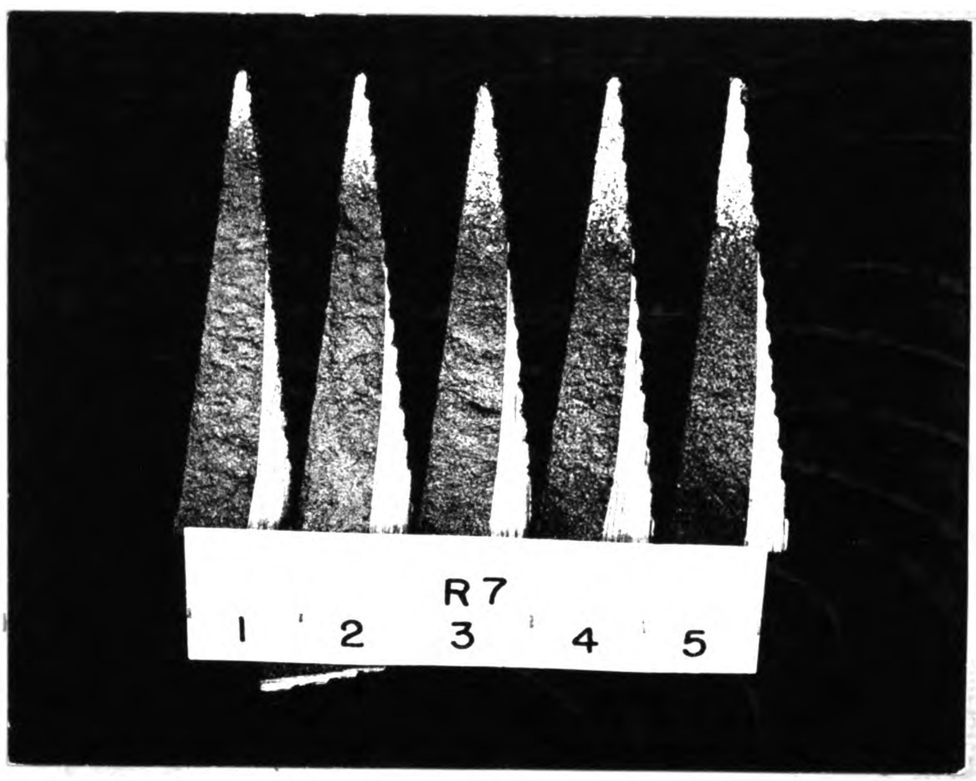

Figure 12. Effect of pouring temperature and holding time on chilling tendency of inoculated cast iron (Heat R7).

TABLE IX

DEPTH OF CHILL RESULTING FROM FIFTEEN WEDGE CHILL TESTS POURED AT VARIOUS TEMPERATURES FROM INOCULATED CAST IRON

Chill Designation	Pouring Temperature	Depth of Chill (in 64ths of an inch)	
		Clear Chill	Total Chill
R7-1	2885	15	24
R7-1	2885	16	23
R7-1	2885	13	16
R7-2	2770	25	32
R7-2	2770	17	27
R7-2	2770	25	34
R7-3	2625	30	43
R7-3	2625	27	40
R7-3	2625	28	38
R7-4	2540	35	48
R7-4	2540	31	43
R7-4	2540	31	48
R7-5	2300	37	49
R7-5	2300	39	50
R7-5	2300	-	-

the inoculant was added until the last castings were poured amounted to ten minutes. The greatest change in the depth of chill was obtained in the first three sets of castings poured, the last two showing about the same chill depth. The last chill tests poured show more than twice the depth of chill as the first.

The composition of this cast iron does not represent a typical cast iron inasmuch as the carbon content was 2.63 percent, the silicon 2.61 percent, and the manganese 0.88 percent. Although the results of Heat R7 indicate the combined influence of holding time and pouring temperature, they do not reflect the relative importance of these two factors. Therefore, Heat R7 was repeated using two ladles of inoculated cast iron in an attempt to separate the effects of these two variables. The analysis was also modified in an attempt to represent a typical high-strength inoculated cast iron.

The first ladle of metal tapped from Heat R8 was inoculated with 75 grams of calcium-silicon, and part of this iron was transferred to a cold ladle in an attempt to cool some of the iron to a low pouring temperature rapidly. As soon as temperature readings had been taken on both ladles, three chill tests were poured from each ladle at the same time. The chill data for this ladle are given in Table X. The second ladle of iron tapped from Heat R8 was again

TABLE X

DEPTH OF CHILL RESULTING FROM SIX WEDGE CHILL TESTS POURED FROM FIRST LADLE OF HEAT R8

Chill Designation	Pouring Temperature (°F)	Depth of Chill (in 64ths of an inch)	
		Clear Chill	Total Chill
R8-H	2650[a]	17	23
R8-H	2650[a]	17	23
R8-H	2650[a]	21	26
R8-C	2250	24	34
R8-C	2250	-	-
R8-C	2250	-	-

[a] Measured with optical pyrometer.

inoculated with 75 grams of calcium-silicon. The cast iron in this ladle, however, was allowed to cool slowly in the ladle and chill tests were poured at various time intervals until the metal had cooled to a low pouring temperature. The chill data for this ladle are given in Table XI, and the chill tests from both ladles are shown in Figure 13. The difference in pouring temperature for the casting from the first ladle (400°F) was enough to produce a slight increase in depth of chill for the castings poured at a low pouring temperature. The combined effect of holding time and lower pouring temperature in the second ladle definitely results in a greater increase in chill depth, however, even though the difference in pouring temperature for the second ladle was only 275°F. The results from Heat R8 would suggest that holding time after inoculation is more effective than lower pouring temperatures in increasing the chilling tendency of inoculated cast iron (see Figure 13 and Tables X and XI).

Table XII shows the composition of castings poured from Heat R8.

Heat R9 was carried out in the same manner as Heat R8, with the exception that the cast iron was not inoculated. Again the first ladle tapped from the furnace was poured so that holding time in the ladle would be eliminated as a variable. The chill data and

TABLE XI

DEPTH OF CHILL RESULTING FROM SEVENTEEN WEDGE CHILL TESTS POURED FROM SECOND LADLE OF HEAT R8

Chill Designation	Pouring Temperature (°F)	Pouring Time	Depth of Chill (in 64ths of an inch)	
			Clear Chill	Total Chill
R8-1	2625	12:37	13	17
R8-1	2625	12:37	14	19
R8-1	2625	12:37	15	21
R8-2	2585	12:38	17	23
R8-2	2585	12:38	17	26
R8-2	2585	12:38	16	21
R8-3	2530	12:39	17	24
R8-3	2530	12:39	18	23
R8-3	2530	12:39	18	28
R8-4	2455	12:41	18	28
R8-4	2455	12:41	-	-
R8-4	2455	12:41	-	-
R8-5	2400	12:42	19	26
R8-5	2400	12:42	21	31
R8-5	2400	12:42	19	27
R8-6	2350	12:43	19	31
R8-6	2350	12:43	18	24

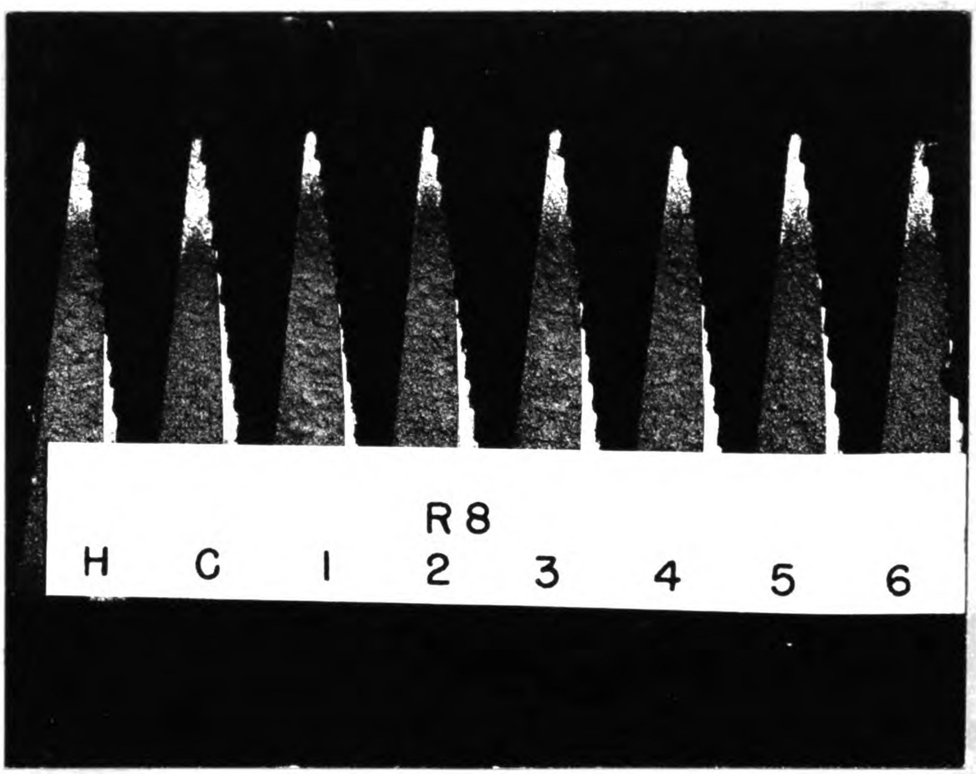

Figure 13. Effect of pouring temperature and holding time on chilling tendency of inoculated cast iron (Heat R8).

TABLE XII

COMPOSITION OF CASTINGS POURED FROM HEAT R8

Ladle	Carbon	Silicon	Manganese
First	2.80	2.71	0.925
Second	2.77	2.78	0.881

and photograph indicate that pouring temperature is the most important factor for an uninoculated cast iron. The chill depth increased considerably in the castings poured from the first ladle, as the pouring temperature was decreased. (Compare R9-H and R9-C in Figure 14.) However, the combined effect of longer holding time and lower pouring temperatures did not cause as much increase in depth of chill for castings poured from the second ladle. Inasmuch as the difference in pouring temperature was substantially the same for both ladles, this indicates that holding time in the ladle has no effect on the chilling tendency of an uninoculated cast iron. The fact that holding time is a factor in increasing the chilling tendency of an inoculated cast iron suggests that inoculation does show a "wearing-off effect."

Table XIII shows the depth of chill resulting from six wedge chill tests poured from the first ladle of Heat R9. Table XIV shows the depth of chill resulting from eighteen wedge chill tests poured from the second ladle of Heat R9. Table XV shows the composition of castings poured from Heat R9.

Figure 14 shows the effect of pouring temperature and holding time on the chilling tendency of uninoculated cast iron.

TABLE XIII

DEPTH OF CHILL RESULTING FROM SIX WEDGE CHILL TESTS POURED FROM FIRST LADLE OF HEAT R9

Chill Designation	Pouring Temperature (°F)	Depth of Chill (in 64ths of an inch)	
		Clear Chill	Total Chill
R9-H	2815[a]	24	38
R9-H	2815[a]	23	38
R9-H	2815[a]	24	42
R9-C	2350	27	43
R9-C	2350	33	47
R9-C	2350	27	40

[a] Measured with optical pyrometer.

TABLE XIV

DEPTH OF CHILL RESULTING FROM EIGHTEEN WEDGE CHILL TESTS POURED FROM SECOND LADLE OF HEAT R9

Chill Designation	Pouring Temperature (°F)	Pouring Time	Depth of Chill (in 64ths of an inch)	
			Clear Chill	Total Chill
R9-1	2840[a]	12:26	31	53
R9-1	2840[a]	12:26	31	53
R9-1	2840[a]	12:26	36	57
R9-2	2760[a]	12:27	37	56
R9-2	2760[a]	12:27	41	59
R9-2	2760[a]	12:27	41	55
R9-3	2685	12:28	40	50
R9-3	2685	12:28	41	56
R9-3	2685	12:28	42	60
R9-4	2610	12:29	42	56
R9-4	2610	12:29	40	56
R9-4	2610	12:29	40	58
R9-5	2450	12:30	38	53
R9-5	2450	12:30	42	53
R9-5	2450	12:30	39	53
R9-6	2400	12:31	37	55
R9-6	2400	12:31	36	51
R9-6	2400	12:31	39	56

[a] Measured with optical pyrometer.

TABLE XV

COMPOSITION OF CASTINGS POURED FROM HEAT R9

Ladle	Carbon	Silicon	Manganese
First	2.83	2.55	0.892
Second	2.78	2.60	0.892

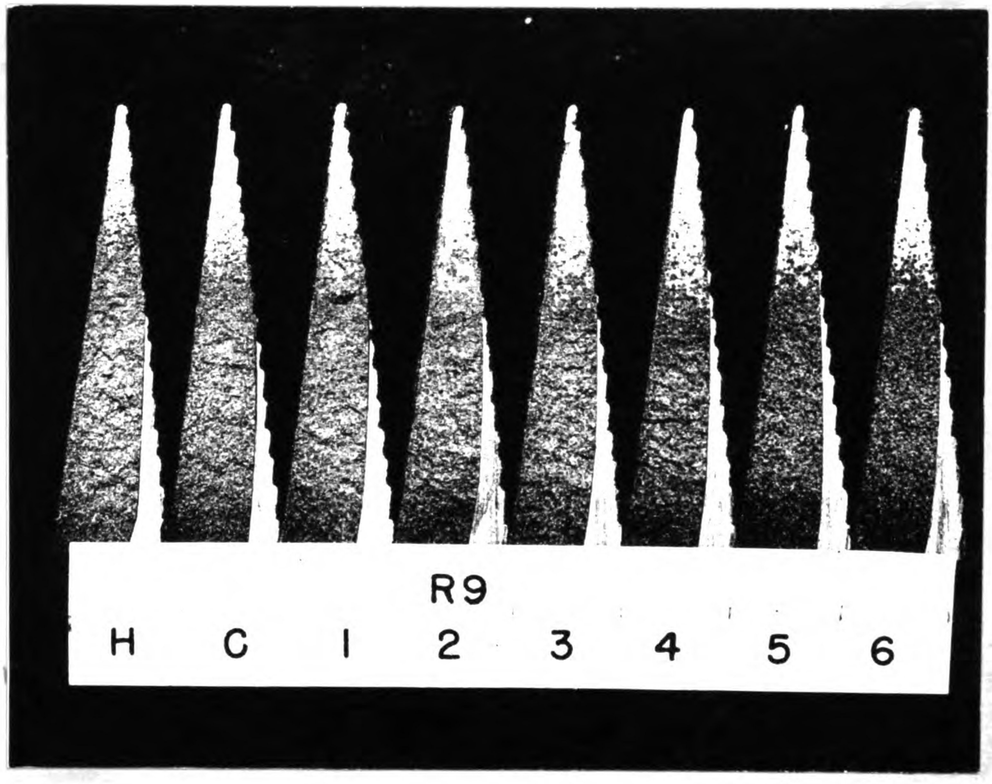

Figure 14. Effect of pouring temperature and holding time on chilling tendency of uninoculated cast iron (Heat R9).

The purpose of Heat R10 was to determine the effect of superheating cast iron on the chilling tendency. This was accomplished by holding a molten charge in the electric-arc furnace with the power turned on, and tapping small amounts of iron from the furnace as the superheating temperature increased. All of the chill tests were poured at the same pouring temperature, from a ten-pound ladle. Table XVI indicates the tapping schedule from the furnace. Due to the time required to measure the temperature in the furnace, not all of the tapping temperatures could be taken; however, it should be safe to assume the temperature in the furnace increased progressively with the power turned on full. The chill data and composition of each of three castings are given in Tables XVII and XVIII. Figure 15 indicates the magnitude of the increase in chilling tendency with higher superheating temperatures.

As indicated by Table XVII, the carbon content decreased considerably with longer holding time in the furnace, and the silicon content increased. When cast iron is melted in a silica-lined furnace open to the atmosphere, the melt reacts with the lining according to the equation: $SiO_2 + 2C \longrightarrow Si + 2CO$.[10]

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[10] E. A. Lange and R. W. Heine, "Some Effects of Temperature and Melting Variables on Chemical Composition and Structure of Grey Irons," Transactions of the American Foundrymen's Society, 1951, pp. 472.

TABLE XVI

TAPPING SCHEDULE FOR HEAT R10

Chill Designation	Tapping Time	Tapping Temperature (°F)	Pouring Temperature (°F)
R10-1	3:25	2595[a]	2500
R10-2	3:27		-
R10-3	3:32		2500
R10-4	3:35		2550
R10-5	3:37		2560
R10-6	3:40	2900[a]	2530
R10-7	3:42		2520
R10-8	3:45	3060[a]	2480

[a] Measured with optical pyrometer.

TABLE XVII

COMPOSITION CHANGES IN CASTINGS FROM HEAT R10

Chill Designation	Composition (%)			Carbon Equivalent	
	Carbon	Silicon	Manganese	T.C. + 0.3 Si	T.C. + 1.5 Si
R10-1	2.80	2.36	0.832	3.51	6.33
R10-2	2.71	2.39		3.43	6.30
R10-3	2.67	2.53		3.43	6.47
R10-4	2.68	2.58	0.832	3.45	6.55
R10-5	2.66	-		-	-
R10-6	2.63	2.62		3.42	6.56
R10-7	2.63	2.64		3.42	6.59
R10-8	2.61	2.65	0.784	3.41	6.59

TABLE XVIII

DEPTH OF CHILL RESULTING FROM TWENTY-FOUR WEDGE CHILL TESTS POURED FROM HEAT R10

Chill Designation	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R10-1	24	35
R10-1	25	36
R10-1	24	37
R10-2	33	43
R10-2	-	-
R10-2	-	-
R10-3	32	46
R10-3	33	45
R10-3	38	42
R10-4	-	-
R10-4	39	56
R10-4	35	48
R10-5	48	68
R10-5	48	59
R10-5	45	60
R10-6	52	68
R10-6	49	66
R10-6	47	66
R10-7	48	67
R10-7	52	65
R10-7	52	65
R10-8	54	73
R10-8	54	74
R10-8	-	-

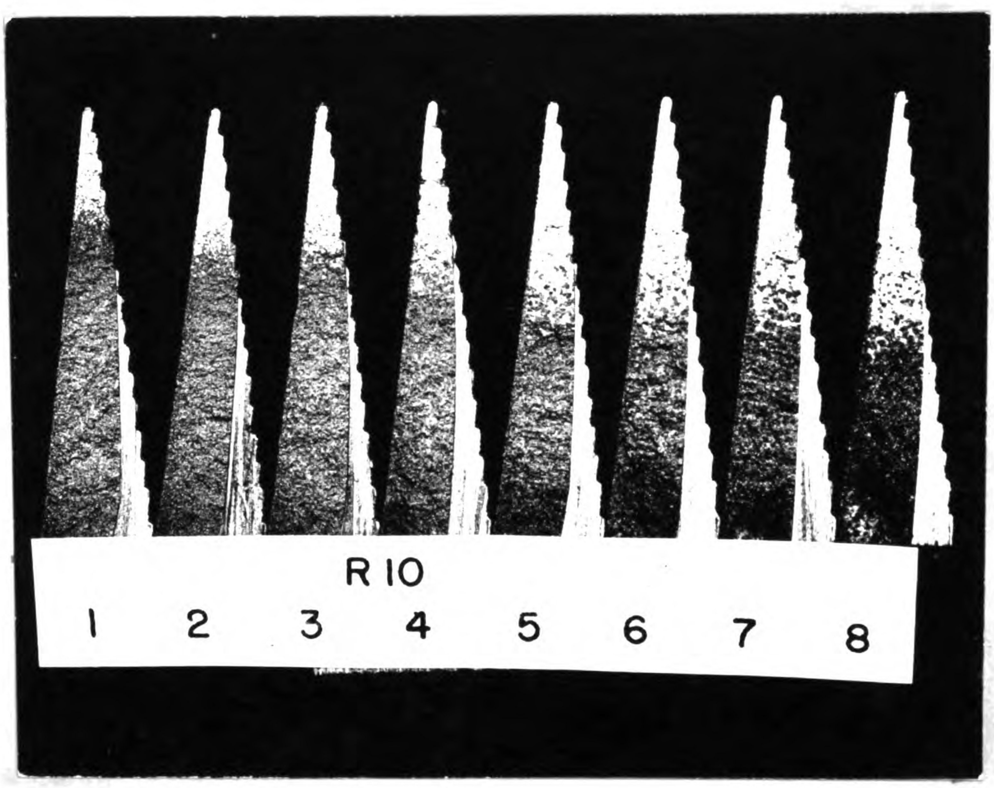

Figure 15. Effect of melting conditions on chilling tendency of uninoculated cast iron.

This reaction proceeds spontaneously to the right when the temperature of the melt is above 2671°F.[11] Undoubtedly the composition changes in Heat R10 took place according to this equation. Although the chill depth more than doubled with the higher superheating temperatures, the carbon equivalent remained about constant. If Loria's carbon equivalent were adopted (total carbon plus 1.5 times the silicon), the chill depth would actually increase as the carbon equivalent increases. Since the chill depth is supposed to vary inversely with the carbon equivalent, some idea can be gained of the importance of oxidizing conditions in effecting the chilling tendency of cast iron.

The last six heats poured for this project were melted in the high-frequency induction furnace. Three of these heats did not yield any information as the chilling tendency was so high that the castings chilled completely through. This was rather surprising, as the composition of the iron was identical to that used in heats melted in the rocking furnace.

Although the depth of chill was very high for the castings poured from Heat R13, some information can be derived from the

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[11] Ibid., p. 472.

chill tests. This heat was poured as uninoculated cast iron, and the pouring procedure was designed to separate the effect of holding time at constant temperature from the effect of pouring temperature. The tapping schedule and pouring temperatures for this heat are given in Table XIX. With the exception of chill test R13-C, all of the castings were poured directly from the furnace, the metal used for chill test R13-C being transferred to a small ladle to cool quickly to a low pouring temperature. The chill tests for Heat R13 are shown in Figure 16. The lower pouring temperature obtained for R13-C definitely is responsible for some increase in chill (compare R13-H and R13-C). The cast iron used to pour chill test castings R13-H and R13-C was probably of the same composition and the same degree of oxidation, as the metal was tapped from the induction furnace at the same time. The slight increase in depth of chill for R13-C may be due to a thermal effect in the mold, the iron poured at the lower temperature having a higher cooling rate than the metal poured from a high temperature. It is difficult to explain the decrease in chilling tendency noted for castings R13-1 and R13-2. It is possible the crucible had a slight inoculating effect at this point. Even though this behavior is difficult to explain, the point can be made that the cast iron did not increase markedly in chilling tendency with holding

TABLE XIX

TAPPING SCHEDULE FROM THE INDUCTION FURNACE FOR HEAT R13

Chill Designation	Tapping Time	Pouring Time	Pouring Temperature
R13-H	11:35	11:35	2775[a]
R13-C	11:35	11:36	2415
R13-1	11:40	11:40	2770[a]
R13-2	11:46	11:46	2760[a]
R13-3	11:51	11:51	2770[a]
R13-4	11:56	11:56	2770[a]
R13-5	12:00	12:00	2760[a]

[a] Measured with optical pyrometer.

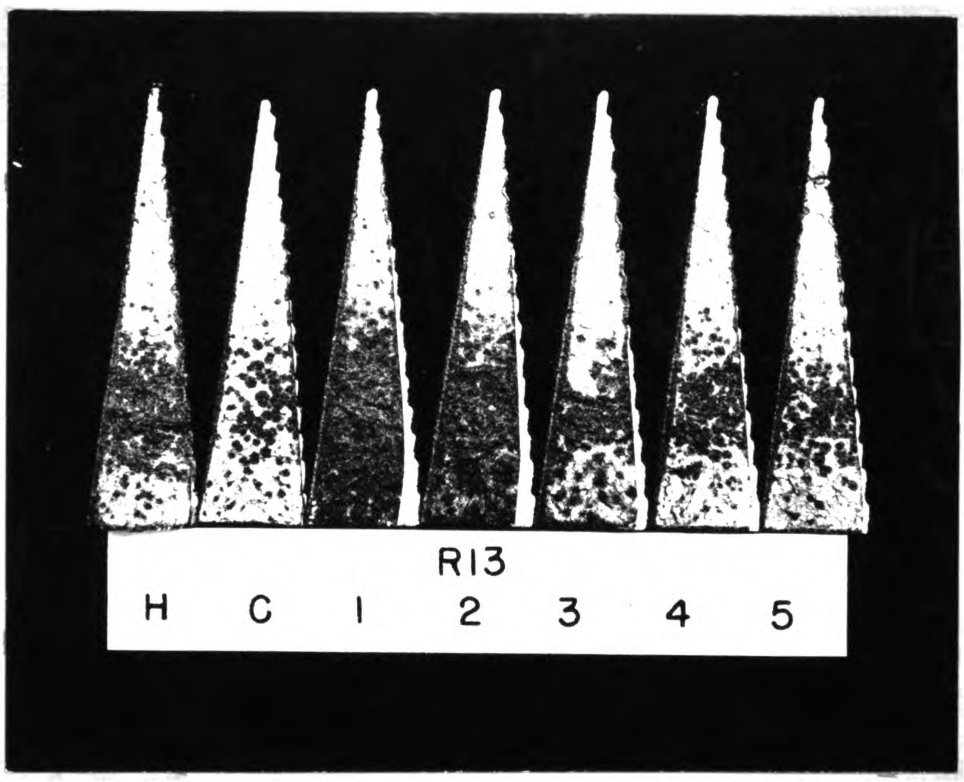

Figure 16. Effect of holding time and pouring temperature on chilling tendency of uninoculated cast iron (Heat R13).

time. A slight increase would be expected in line with the composition changes.

Table XX shows the composition of castings poured from Heat R13.

The heat designated as R14 was tapped and poured identically to R13 with the exception that R14 was inoculated with 70 grams of calcium-silicon as soon as the melt had reached a temperature of 2775°F. The tapping schedule and pouring temperatures are given in Table XXI, and the specimens are shown in Figure 17. The effect of lower pouring temperature in increasing the depth of chill is very pronounced, the chill tests poured at 2400°F having more than twice the depth as those poured at 2775°F. This lower pouring temperature has approximately the same effect in increasing the chilling tendency as about eight minutes of holding time at 2770°F. (R14-C has a chill depth between that noted for R14-1 and R14-2.) In view of the high holding temperature, the effect of inoculation seems to persist for a long period of time. Chill test R14-4 was poured 22 minutes after inoculation, and the inoculant was still effective. The five-minute interval after pouring R14-4 appears to eliminate any further inoculating effect, however.

TABLE XX

COMPOSITION OF CASTINGS POURED FROM HEAT R13

Chill Designation	Composition (%)		
	Carbon	Silicon	Manganese
R13-H	2.89	2.25	0.666
R13-3	2.76	2.30	
R13-5	2.76	2.31	0.665

TABLE XXI

TAPPING SCHEDULE FROM INDUCTION FURNACE FOR HEAT R14

Chill Designation	Tapping Time	Pouring Time	Pouring Temperature
R14-H	4:15	4:15	2775
R14-C	4:15	4:17	2400
R14-1	4:20	4:20	2785
R14-2	4:25	4:25	2740
R14-3	4:30	4:30	2775
R14-4	4:35	4:35	2770
R14-5	4:40	4:40	2765
R14-6	4:45	4:45	2775

NOTE: Inoculant added at 4:12. All temperatures measured with optical pyrometer except R14-C.

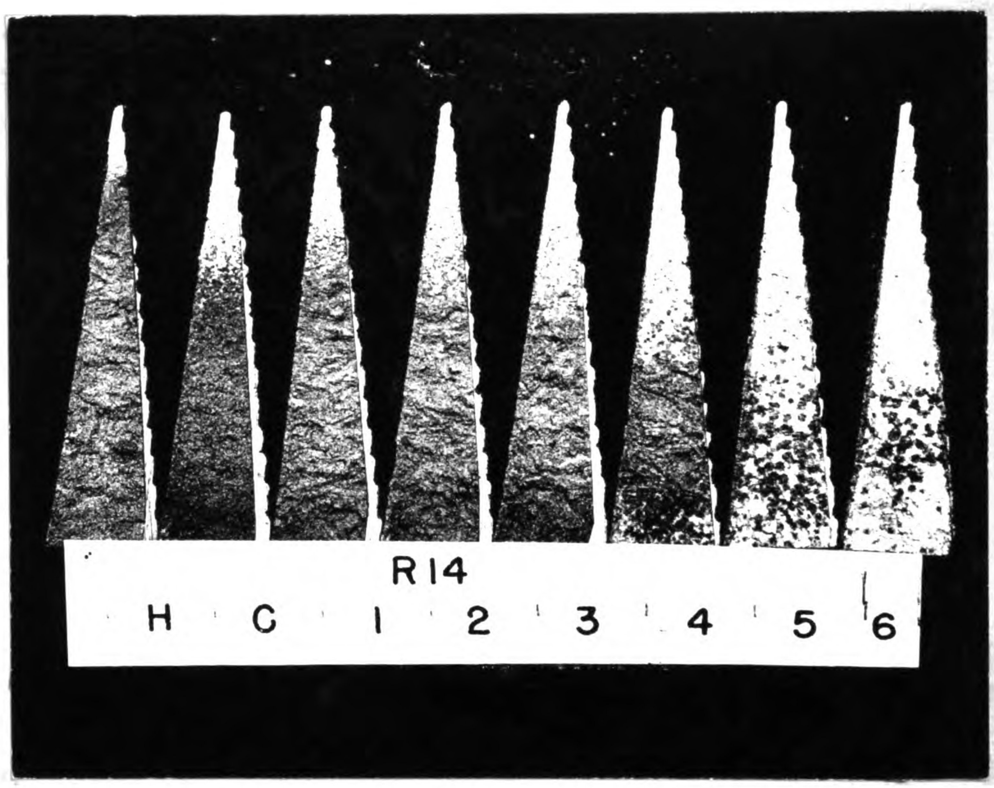

Figure 17. Effect of holding time and pouring temperature on chilling tendency of inoculated cast iron (Heat R14).

Table XXII shows the composition of castings poured from Heat R14. Table XXIII shows the depth of chill resulting from sixteen wedge chill tests poured from Heat R14.

The heat designated as R17 was carried out exactly as R14, with the exception that R17 was melted in a magnesia crucible. As mentioned before, when cast iron is held at a temperature above 2671°F, the charge reacts with the silica lining. Carbon is oxidized from the melt and is given off as CO, and silicon is reduced from the silica crucible. Therefore, the last heat melted in the high-frequency induction furnace was melted in a magnesia crucible to determine if the chemical changes were responsible for the change in chilling tendency of the iron. This heat was also inoculated with 70 grams of calcium-silicon. The tapping schedule and pouring temperatures are given in Table XXIV, and the chill tests are shown in Figure 18. The results of Heat R17 are in the same direction as those of R14. The increase in chilling tendency with holding time is more uniform for Heat R17 than for Heat R14. The effect of the decrease in pouring temperature is apparent in Figure 18, and approximately equivalent to five minutes of holding time. On the whole the results of Heats R17 and R14 are consistent with each other.

TABLE XXII

COMPOSITION OF CASTINGS POURED FROM HEAT R14

Chill Designation	Composition (%)			
	Carbon	Silicon	Manganese	Phosphorus
R14-H	2.83	2.12	0.650	0.113
R14-3	2.81	2.12	0.644	
R14-6	2.73	2.13	0.655	

TABLE XXIII

DEPTH OF CHILL RESULTING FROM SIXTEEN WEDGE CHILL TESTS POURED FROM HEAT R14

Chill Designation	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R14-H	16	22
R14-H	16	22
R14-C	34	54
R14-C	37	53
R14-1	33	49
R14-1	31	47
R14-2	40	58
R14-2	-	-
R14-3	45	64
R14-3	45	62
R14-4	57	75
R14-4	60	82
R14-5	a	a
R14-5	a	a
R14-6	a	a
R14-6	a	a

[a] Chill depth too deep to measure.

TABLE XXIV

TAPPING SCHEDULE FROM INDUCTION FURNACE FOR HEAT R17

Chill Designation	Tapping Time	Pouring Time	Pouring Temperature
R17-H	11:48	11:48	2760
R17-C	11:48	12:00	2420
R17-1	12:05	12:05	2785
R17-2	12:11	12:11	2785
R17-3	12:16	12:16	2770
R17-4	12:21	12:21	2755
R17-5	12:26	12:26	2765
R17-6	12:30	12:30	2780

NOTE: All temperatures were measured with an optical pyrometer except R17-C. Charge inoculated at 11:45.

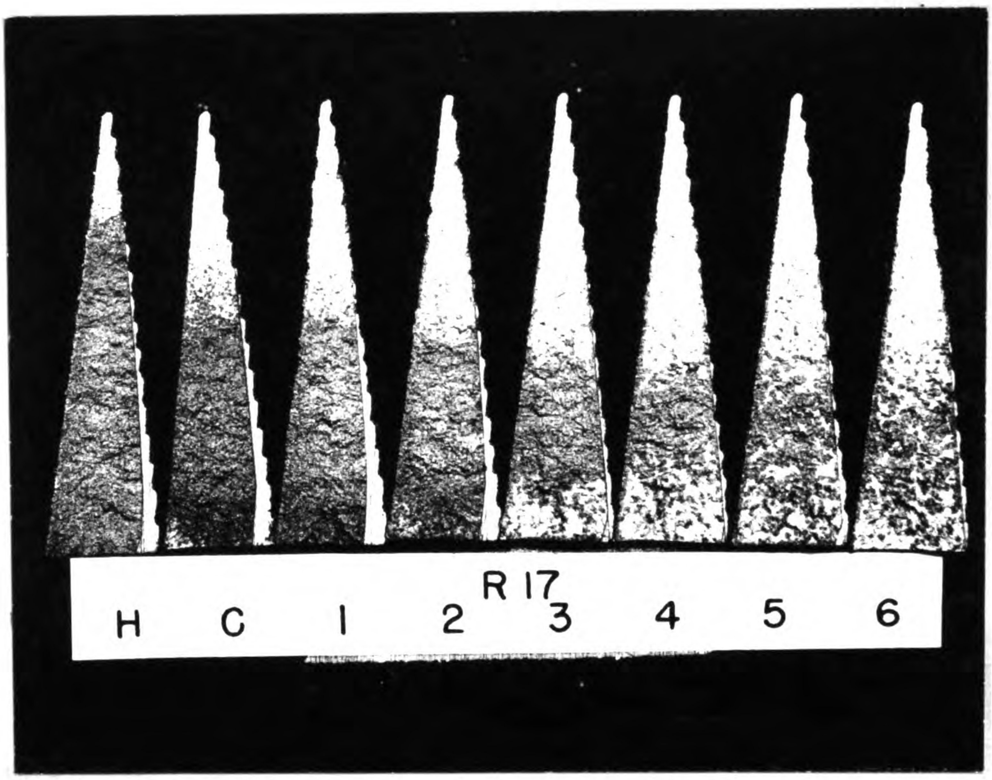

Figure 18. Effect of holding time and pouring temperature on chilling tendency of inoculated cast iron (Heat R17).

Table XXV shows the composition of castings poured from Heat R17.

Table XXVI shows the depth of chill resulting from sixteen wedge chill tests poured from Heat R17.

TABLE XXV

COMPOSITION OF CASTINGS POURED FROM HEAT R17

Chill Designation	Composition (%)		
	Carbon	Silicon	Manganese
R17-H	2.88	2.13	0.666
R17-3	2.82	2.13	0.676
R17-6	2.72	2.16	0.655

TABLE XXVI

DEPTH OF CHILL RESULTING FROM SIXTEEN WEDGE CHILL TESTS POURED FROM HEAT R17

Chill Designation	Depth of Chill (in 64ths of an inch)	
	Clear Chill	Total Chill
R17-H	27	35
R17-H	27	39
R17-C	45	63
R17-C	-	-
R17-1	54	68
R17-1	50	67
R17-2	57	73
R17-2	52	67
R17-3	68	80
R17-3	69	82
R17-4	71	86
R17-4	68	87
R17-5	a	a
R17-5	a	a
R17-6	a	a
R17-6	a	a

[a] Chill too deep to measure.

SUMMARY AND CONCLUSIONS

The results from Heats R15 and R18 indicate that the wedge chill test is the most reliable. The wedge chill test can also be poured and fractured for examination quicker than the chill block test. Results from Heat R18 indicate that some of the erratic results noted for the chill block test may be due to gas being trapped between the chill block and the molten cast iron.

It has been demonstrated that the chilling tendency may not bear any relation to the composition of cast iron when the iron is melted under oxidizing conditions. Some of the effects usually attributed to superheating cast iron may be related to the changes induced by strongly oxidizing melting conditions. The results of R10 indicated the depth of chill for the wedge test could be more than doubled by melting cast iron under oxidizing conditions, even though the carbon equivalent remained essentially constant. The type of melting unit can exert a profound influence on the chilling tendency, as it became apparent that a composition suitable for pouring chill tests from the rocking furnace was not suitable for melting in the high-frequency induction furnace.

The effect of pouring temperature and holding time in the ladle on the chilling tendency of cast iron is more pronounced for an inoculated iron than for uninoculated cast iron of the same composition. A decrease of 400°F in the pouring temperature of uninoculated cast iron is responsible for a slight increase in depth of chill. This increase in chill is probably due to a thermal effect in the mold. Holding time in the ladle seems to have little or no effect on the chilling tendency of uninoculated cast iron.

A decrease of 400°F in the pouring temperature of inoculated cast iron has been shown to increase the depth of chill by a factor of two. Inoculation of cast iron is subject to a "wearing-off effect" and the chilling tendency of inoculated cast iron will increase progressively with holding time in the ladle.

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