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Final Report

# EVALUATION OF STRONTIUM-BEARING POST-INOCULANTS (SUPERSEED) IN DUCTILE CAST IRONS

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SUMMARY

A new potent ladle inoculant for gray iron has been developed by the BCIRA and Union Carbide Laboratories consisting of a strontium bearing ferrosilicon. The purpose of the study was to investigate the effectiveness of this alloy as a post inoculant for ductile cast iron. Some preliminary experiments in England had indicated these alloys to be incompatible with cerium bearing magnesium ferrosilicon as the magnesium source material.

The data indicate that in general the properties obtained with the strontium bearing inoculants (called Superseed #1 and #2) are at least comparable with ferrosilicon inoculants. No conflict with cerium is apparent. An added advantage of the strontium bearing inoculants is greater reproducibility of mechanical properties. Also there is an absence of inferior graphite shape in heavy sections; particularly with MgFeSi.

The data provide in addition a general survey if the graphite shape, nodule count, and mechanical properties to be expected over a variety of sections (1/4 to 3 in.) for the three common magnesium inoculants: MgFeSi, CeMgFeSi, and NiMgSi.

## INTRODUCTION

Laboratory investigations plus foundry experience have shown the strontium-bearing ferrosilicon (Superseed) to be very effective as an inoculant for gray iron. A natural development is an extension of this use as a post-inoculant for ductile iron. Preliminary reports from the field have indicated some unfavorable interaction between Superseed and the cerium-bearing magnesium alloys. Therefore further work with Superseed was indicated before releasing it for general use.

As a start, it was agreed with the New Products Section to compare two grades of Superseed with 75% ferrosilicon. The experiments would also include three nodularizing alloys: MgFeSi, CeMgFeSi, and NiMg #2. The test parameters would be section sensitivity as measured by mechanical properties, nodule count, nodularity, and chill tendency. Although the normal late silicon addition in the foundry has been 0.5% Si, it was decided to also investigate 0.25% and 1.0% additions. Finally, the effect of fading of both the inoculant and post inoculant was of interest and was to be accelerated by holding in an induction furnace.

These experiments cover the variety of conditions under which post inoculants might be used by the cast metals industry in the manufacture of ductile iron. At a carbon equivalent of 4.5 it was not only possible to evaluate the post inoculant, but also to gain useful information about the nodularizing alloy.

The following sections point out the advantages and disadvantages of the inoculant-post inoculant combinations and the precautions necessary if Superseed is to be used.

## EXPERIMENTAL PROCEDURE

### Heats 4 Through 27—Effects of Inoculant and Post Inoculant

### MOLDING

The molds poured and their descriptions are listed below in the order in which they were poured.

| Description | Mold Material | Remarks |
|---|---|---|
| Wedge | Core Sand | Triangular-base 3/4" x height 1 1/2" |
| Chill wafer | Core Sand | 6" x 3" x 1" (Fig. 1-B) |
| 1/4" Y-Block | Dry Sand | Y-Block, all castings in one flask (Fig. 1-A) |
| 1/2" Y-Block | Dry Sand | |
| 1" Y-Block | Dry Sand | |
| 3" Y-Block | Dry Sand | |
| Wedge | Core Sand | See above |
| Chill Wafer | Core Sand | |

The chill wafer is poured against a graphite plate while the wedge chills at the acute angle of the triangular cross-section (Fig. 1-B). The sand used for the Y-blocks has the following composition: 4% Western bentonite; 0.3% dextrin; 0.7% woodflour; 3.5% water. After the molds have been made on a jolt-squeeze machine, they are dried in an oven at 300°F for 12 hours.

### MELTING

The raw materials charged to the 3000 cycle induction furnace are: Sorel pig iron, Armco iron, standard high carbon 75% FeMn, and high purity silicon metal (Table I). The FeMn and silicon metal are placed at the bottom of the furnace and as much pig iron as possible is added. The Armco iron is used to fill the voids. Upon initiation of melting the remainder of the pig iron is added. The amounts of these materials are controlled by the desired final carbon equivalent of 4.50.

When the metal is completely molten, 2 lb of $CaC_2$ (nut size) is added as a protective cover for the melt. The power is then turned off and the carbide cover is removed when the melt reaches 2900°F. Upon cooling to 2750°F, the metal is treated with the magnesium alloy by the transfer technique in an open ladle. The post-inoculant is added to the furnace and the metal is poured back in on top, which assures good mixing. Analyses of the inoculants and post-inoculants are also given in Table I.

Finally the 120 lb of metal is tapped into a teapot ladle for pouring.

## POURING

The castings are poured in the order mentioned previously. Samples for chemical analyses are taken before and after the inoculation. These are 6mm dia. rods obtained with suction bulbs and Vycor tubing. The pouring time for the entire heat has been controlled between 40 and 55 seconds. The pouring temperature range for each heat has been 50°F or less, with a maximum of 2620°F in one heat to a minimum of 2540°F in another. Temperature indication was with an optical pyrometer.

## TEST PROCEDURES

The Y-blocks are sectioned and tensile bars are machined with 0.500" dia. bars obtained from the 1" and 3" Y-blocks while 0.250" dia. bars are cut from the 1/2" Y-blocks.

In each case, the specimens are machined from well within the section to remove the possibility of edge effects. (Fig. 1A). Two samples are cut from the 3" Y-block and comparisons have shown the tensile results to be within the limit of error of the test procedure.

In early heats strain gauges had been mounted on the specimens while in the latter portion of the program a mechanical extensometer has been substituted for the gauges. A standard tensile test is therefore run which provides tensile strength, yield strength, breaking strength, percentage elongation, and percentage reduction in area at the neck. Due to the use of the mechancial extensometer it has been impossible to obtain an accurate measure of the elastic modulus; therefore these data are not included.

The bottom of the 1/4" Y-block is cut and is bent, as an index of the quality of the nodular iron in thin sections. The section is supported on two wedges 1-1/2" apart and a load is applied to the center of the bar through another wedge with a 1/2" radius in contact with the bar. Stress is applied with an arbor press until the bar fails. The bend angle is the total deflection from 180°. As an example, a 40° bend angle indicates each end deflected 20° from the horizontal or no-load position. Since the measurement is taken after failure, the bend angle is a measure of only the plastic deformation capability of the small section.

Sections are finally cut from the bend samples and the tensile specimens to check for nodularity and nodule count. In these tests, standard 100X photomicrographs are taken and are enlarged to 8" x 10" pictures. At least two are taken from each sample. The total number of nodular and flake graphite particles are counted. The percent nodularity is then the number of nodules divided by the number of nodules plus flakes. The nodule count is obtained by multiplying the number of nodules by 500, which gives nodules per square inch.

## Heats 28 Through 32—Effect of Amount of Silicon Added As Post Inoculant

In the previous heats the amount of late silicon added was 0.50 wt.%, while in Heats 28 through 32 the addition has been varied from 0.25% to 1.0%. The experimental procedure is therefore the same except that the charge silicon must also be varied in order to obtain a final silicon content of approximately 2.30 wt.%.

## Heats 35 Through 38—Fading of Inoculant and Post Inoculant

The melt procedure, inoculation, and post inoculation, is exactly the same as heats 4 through 27. After post inoculation in the furnace, the power is again turned on and a 3" Y-block is poured directly from the furnace. This sample constitutes zero time. A chemistry sample, chill wedge, and chill wafer are also poured. The procedure is repeated at 3 minutes and 6 minutes after the initial samples.

The power input to the furnace is controlled to maintain a constant temperature. A Pt-Pt 10%Rh thermocouple is used to indicate the temperature. All castings have been poured from 2550-2650°F.

The 3" Y-blocks are then sectioned as before and physical properties, nodularity, nodule count, chill depth, and chemistry is obtained as a function of holding time of the induction stirred melt.

## RESULTS AND DISCUSSION

Chemical analyses of all heats poured are included in Tables II-IV; while the corresponding mechanical properties are summarized in Tables V-VII. The data can be conveniently divided into four categories:

(1) Reproducibility of data-All heats

(2) Constant late silicon added as the post inoculant (0.5% Si)-Heats 4 through 27

(3) Variable late silicon added as the post inoculant (0.25-1.0% Si)-Heats 28 through 32

(4) Furnace holding time and effectiveness of inoculant and post inoculant-Heats 33 through 38

The data in the tables and figures are in the order of the discussion. The tables include all data taken in the study; however some heats do not have summary curves of properties. The castings poured from Heats 6,7,8,9,13,15, and 17 were either shaken out too early (high pearlite content) or the residual magnesium was too high. Therefore, summary curves are not included for these heats.

### REPRODUCIBILITY OF DATA

A summary of reproducibility of physical properties is given in Table VIII. The range of the measured parameters (tensile strength, elongation, nodularity, and nodule count) is seen to be dependent upon both the inoculant and post inoculant. It is well to appreciate however that chemistry variation has been omitted in the tabulation. Table IX on the other hand indicates the reproducibility of magnesium recovery in the same heats (Heats 4-27). Therefore, the following generalizations can be made about the reproducibility of these data:

(1) Common inoculant with variable post inoculant

(a) The Superseeds generally show better reproducibility for all measured physical property parameters. This is especially true in the heavier sections. SS #1 may also give better reproducibility than SS #2.

(b) The use of SS #1 gives the most reproducible magnesium recovery while SS #2 is the most erratic in magnesium recovery.

(c) A decrease in magnesium recovery is evident when the amount of late silicon is increased; probably due to an increase in oxidation of the melt.

(d) The magnesium recovery is not affected by the post inoculant except when the inoculant is MgFeSi, in which case 75% FeSi and SS #2 give better recovery than SS #1.

(2) <u>Common post inoculant with variable inoculant</u>

(a) Little or no relationship exists for the ability to reproduce nodularity and nodule count as the inoculant is varied.

(b) MgFeSi and NiMg appear to give better reproducibility of tensile strength and elongation for all three post inoculants.

(c) The order of decreasing magnesium recovery for the three inoculants is NiMg, MgFeSi, and CeMgFeSi.

(d) When 75% FeSi is used as the post inoculant more reproducible magnesium recovery is obtained with NiMg or CeMgFeSi as the nodularizer.

CONSTANT LATE SILICON ADDED AS THE POST INOCULANT (0.5%Si)-HEATS 4 THROUGH 27

The mechanical properties for all heats are included in Table V. Since most heats were conducted in duplicate, average values of the properties were taken and have been summarized in Figures 10 through 15. These summaries have been further categorized in the figures as to common inoculant, or common post inoculant. Therefore the same curve will appear in two different figures.

The plots are presented as a function of section size. If the range of properties is considered from the smallest (1/4") to the largest section (3"), it is possible to more easily see the relative effects of inoculants and post inoculants. Figures 25 and 26 are bar graphs of the experimental parameters. The height of each bar represents the range for the section size variation.

The following major conclusions can be drawn from Figures 10 through 15, 25, 26:

(a) The tensile strength generally increases slightly with section size. The amount of increase for 75% FeSi is greater. 75% FeSi also has a higher tensile strength than the Superseeds in heavy sections. This may indicate a tendency to stabilize pearlite.

(b) Superseed #2 shows the least variation in tensile strength as the section size is changed. (Fig. 25)

(c) Superseed #1 provides the highest elongations for all section sizes investigated. (Fig. 25)

(d) The range in nodule count as produced by section size variation shows Superseed #1 to give the lowest range (Fig. 26). Also when the nodularizing alloy is changed, Superseed #1 shows essentially the same nodule count for the three alloys.

(e) In general Superseed #2 shows a higher nodule count in all sections. The only exception is when CeMgFeSi is used, where the heavy sections show the same nodule count for all three post inoculants.

(f) MgFeSi and 75% FeSi in combination result in the poorest properties; especially nodularity and elongation. Other combinations provide nodularities in excess of 90% which indicates equal effectiveness in retention of spheroidal graphite.

(g) As a very general trend the order of increased effectiveness on any measured property to be optimized is MgFeSi, CeMgFeSi, NiMg. This trend follows for any of the three post inoculants.

VARIABLE SILICON ADDED AS THE POST INOCULANT (0.25-1.0% Si)-HEATS 28 THROUGH 32

The summary of chemical analyses and physical properties are included in Tables III and VI. The graphical presentation of the data is in Figures 16 through 20. It should be pointed out that duplicate heats were only run at the 0.50 Si level, therefore the summary curves have been averaged only at this silicon addition level.

The previous results for 0.50 silicon additions have shown 75% FeSi to give poor results in conjunction with MgFeSi. Therefore CeMgFeSi was used as the nodularizing alloy in order to provide a more meaningful comparison among the three post inoculants. Again the range of experimental parameters for 1/4" to 3" section sizes has been included in Figures 27 and 28. The following conclusions can be reached:

(a) There is no difference in nodularity with either the post inoculant used or its quantity (all nodularities greater than 90%).

(b) There is also little or no difference in nodule count. It is possible however that SS #1 gives a higher count in light sections if 0.25 Si is added, while 75% FeSi has a high count in light sections if 1.0 Si is added.

(c) The tensile strength and elongation and their variation with section size (range) show there is an optimum amount of post inoculant to be added to maximize each property. In general however the tensile strength is lowered and the elongation is increased as the amount of late silicon is increased.

(d) Since the major interest would be in the use of low amounts of silicon (0.25), there appears to be little justification for the use of the Superseeds over 75% FeSi if only tensile strength and elongation are considered.

Chill depth is also of importance as a function of the amount of silicon added and the post inoculant. Little information can be gained from a hardness survey of the chill samples poured (Figure 1-B). Therefore a metallographic examination of the chill wedges was performed. Below is a summary of these data where the indicated carbide is the amount present at the end or point farthest removed from the acute angle tip.

| | Amount of Silicon Added with Percentage Carbide | | |
|---|---|---|---|
| Post Inoculant | 0.25 Si | 0.50 Si | 1.0 Si |
| 75% FeSi | 25% Ca | 5% Ca | 0% Ca |
| SS #1 | 10% Ca | 5% Ca | * |
| SS #2 | 25% Ca | 5% Ca | 0% Ca |

* Heat of this analysis not run.

The obvious conclusions are therefore:

(a) Greatest chill reduction is evidenced between 0.25 and 0.5 late silicon addition.

(b) The three post inoculants are equivalent when the amount of silicon added is 0.50 or greater.

(c) When low amounts of silicon are added (0.25), SS #1 appears to be the most effective.

FURNACE HOLDING TIME AND EFFECTIVENESS OF INOCULANT AND POST INOCULANT-HEATS 33 THROUGH 38

In addition to the normal effect of post inoculation and the level of silicon addition, there is the well known problem of fading after the chemical additions. As an index of the effect the metal was held in the induction furnace with the power on to approximate the condition of a large quantity of metal held in a ladle to await pouring. Since induction stirring in the furnace increases the kinetics of fading, the experimental procedure is a more severe test than that normally encountered in the foundry.

Previous data have shown large section sizes to be most sensitive to the fading effect, therefore only 3" sections were poured, along with chill castings, in order to evaluate the parameters. Chemical analyses and mechanical properties as a function of time are presented in Tables IV and VII. The graphical summaries are shown in Figures 21 through 24. The comparsions are for two inoculants (MgFeSi and CeMgFeSi) and two post inoculants (75% FeSi and SS #2). The bar graph ranges of the mechanical properties are shown in Figures 29, 30.

These data do not correlate directly with previous heats for several reasons. First the metal was returned to the furnace and the power was turned on immediately. The castings were then poured directly from the furnace. The effect on the properties is the combined loss of the magnesium and the graphite nucleation properties of the post inoculant. Secondly, the 3" sections were in separate flasks which gave a more rapid cooling rate than the same sections poured in previous heats where the 1/4", 1/2", 1", and 3" sections were in the same flask. Therefore the tensile strengths are higher (more pearlite) and the elongations are lower.

Superseed #2 shows somewhat better magnesium recovery than 75% FeSi for either MgFeSi or CeMgFeSi as the nodularizing alloy. However the rate of loss of magnesium is greater for Superseed #2 in the first 3 minute interval. This is probably not due to the effect of Superseed, but is rather dependent upon the normal kinetic effect where the initial approach to equilibrium is faster if the relative position from equilibrium is farther removed. Other conclusions are as follows:

(a) Even though the residual magnesium is higher with Superseed #2 at the 6 minute interval, the nodularity is poorer for both nodularizing alloys when compared to 75% FeSi (Figs. 21, 22). This effect is also seen in the lower elongation. Therefore if Superseed #2 is used, it should not be held for a long time in the ladle. The difficulty can also be lessened if CeMgFeSi is used rather than MgFeSi. (Figs. 23, 24)

(b) Nodule counts are higher with 75% FeSi. Also holding time has very little effect on nodule count when 75% FeSi is used as the post inoculant. (Fig. 30)

(c) CeMgFeSi gives higher tensile strength, elongation, and nodularity than MgFeSi. This is evident for any degree of holding time and for either 75% FeSi or SS #2 as the post inoculant (Figs. 29, 30).

Possibly a more meaningful occurrence which takes place with increased furnace or ladle holding time is the change in microstructure. The effect is apparent in the previous data for large sections. Another approach is to study the chill tendency by one or both chill castings as shown in Figure 1-B. Hardnesses versus distance from the chill face of the wafer casting are shown in Figures 31, 32, and 33. The hardness tests were taken as Rockwell "D" which was found to be most sensitive within the hardness range considered. For convenience, Brinell Hardness conversions have also been included in the figures. The castings were poured at the same times as the 3" sections. Zero minutes refers to the first casting poured after post inoculation. These graphs are difficult to interpret since the following changes occur as the time increases:

(1) Carbide stability varies due to the loss in magnesium which results in less carbide and the loss of the post inoculation effect which results in more carbide.

(2) The nodule count decreases, and the graphite degenerates due to magnesium loss and post inoculation decay.

(3) The fineness of the pearlite also varies with post inoculation decay and cooling rate.

Therefore, a hardness change can be due to several simultaneous occurrences, and a microstructure study is also necessary. As an index of carbide stability the points tabulated below represent the distance from the chill face of the wafers at which low carbide first became evident (1 to 5%) In some cases a point existed which showed complete absence of carbide, although normally the the 1-5% Ca condition continued from the indicated point throughout the rest of the sample.

TIME OF HOLDING IN FURNACE (CHILL WAFERS)

| | 0 minutes | | 3 minutes | | 6 minutes | |
|---|---|---|---|---|---|---|
| Treatment | 1-5% Ca | 0% Ca | 1-5% Ca | 0% Ca | 1-5% Ca | 0% Ca |
| MgFeSi + 75% FeSi | 1-3/8" | * | 1-3/16" | * | 1-1/4" | 1-11/16" |
| MgFeSi + SS #2 | 1-1/16" | * | 1-3/8" | * | 1-1/2" | * |
| CeMgFeSi + 75% FeSi | 1-5/16" | 1-11/16" | 1" | * | 1" | * |
| CeMgFeSi + SS #2 | 1" | 1-9/16" | 1" | * | 1-5/16" | * |

*A point did not exist which was completely carbide free.

Chill wedges were also poured. The table below shows percentage carbide present at the end of the wedge or the farthest point from the tip.

TIME OF HOLDING IN FURNACE (CHILL WEDGES)

| Treatment | 0 minutes | 3 minutes | 6 minutes |
|---|---|---|---|
| MgFeSi + 75% FeSi | 15% Ca | 40% Ca | > 95% Ca |
| MgFeSi + SS #2 | 5% | 25% | 95% |
| CeMgFeSi + 75% FeSi | 5% | 1-2% | 1-2% |
| CeMgFeSi + SS #2 | <5% | 15% | 15% |

If these tables plus Figures 31,32,33 and the range of hardnesses shown in Figure 34 are compared, it can be seen that it is difficult to arrive at conclusions which are not somewhat contradictory. However, the following general statements can be made.

(a) At short holding times SS #2 shows better chill reduction than 75% FeSi for either nodularizing alloy. This trend may be reversed at longer times.

(b) The chill tendency is greater if MgFeSi is used as the inoculant than if CeMgFeSi is used. The occurrence of no carbide at 1-11/16" from the chill face of the wafer for MgFeSi-75% FeSi may be an exception. Unfortunately the same result is not obtained for the chill wedge at the 6 minute interval.

(c) Even though a lower hardness can be achieved with Superseed #2 at the 6 minute interval (Fig. 34) a greater degree of graphite degeneration has been noted for both nodularizing alloys. The same effect is evident in the 3" sections. (Fig. 24)

(d) The range of hardness values along a chill wafer indicates that 75% FeSi has a great sensitivity to cooling rate at short times and becomes less sensitive at longer times. The opposite effect occurs with Superseed #2 (Fig.34).

## CONCLUSIONS

1. Reproducibility of chemistries and physical properties is dependent upon both the nodularizing alloy and the post inoculant. The Superseeds give more reproducibile results for all parameters. MgFeSi and NiMg provide the most reproducible tensile strengths and elongations.

2. The use of MgFeSi results in deeper chill than CeMgFeSi, possibly becasue the magnesium recovery may be somewhat higher.

3. MgFeSi in combination with 75% FeSi results in the poorest properties, especially in heavy sections.

4. Superseed #1 gives the highest elongation in all sections at a addition 0.5% Si level. When the normal silicon addition is decreased from 0.5 to 0.25%, Superseed #1 also gives the best chill reduction.

5. At low silicon additions (0.25%) and with CeMgFeSi as the nodularizing alloy, 75% FeSi gives as good if not better tensile strengths and elongations than either of the Superseeds.

6. Superseed #2 shows a higher nodule count in sections less than 1". In larger sections all post inoculants give the same nodule counts.

7. The effectiveness of Superseed #2 wears off rapidly with time when compared to 75% FeSi for both elongation and chill reduction. However, for short holding times, Superseed #2 is more effective.

Therefore, there is no reason to prevent the use of Superseed in nodular cast iron. The necessity of short holding time with Superseed #2 may be the one exception. Unfortunately early experiments somewhat erroneously indicated Superseed #1 to be more effective than Superseed #1. It is therefore recommended that further evaluation of Superseed #1 be conducted to indicate its fading effect. The preliminary indications are that it should perform well with MgFeSi in the heavy sections where 75% FeSi was inadequate. Since Superseed #2 is not commercially produced at the present time, the importance of further experimentation with Superseed #1 is evident.

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Table

TABLE I

CHEMICAL ANALYSES OF RAW MATERIALS

| Material | % C | % Si | % Mn | % P | % S | % Mg | % Ca | % Al | % Sr | % Ni | % Ce | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Charge | | | | | | | | | | | | |
| Pig Iron | 4.25 | --- | 0.08 | 0.022 | 0.015 | --- | -- | -- | -- | -- | -- | 0.020 Ti |
| ARMCO Iron | 0.015 | --- | 0.03 | 0.005 | 0.025 | --- | -- | -- | -- | -- | -- | -- |
| FeMn | 7.00 | 1.00 | 75.0 | --- | --- | --- | -- | -- | -- | -- | -- | -- |
| Si Metal | --- | 98.98 | --- | --- | --- | --- | 0.01 | 0.09 | -- | -- | -- | 0.54 Fe |
| Additions | | | | | | | | | | | | |
| MgFeSi | --- | 46.52 | --- | --- | --- | 8.49 | 1.48 | 0.75 | -- | -- | -- | -- |
| CeMgFeSi | --- | 48.19 | --- | --- | --- | 8.60 | 1.20 | 0.93 | -- | -- | 0.51 | -- |
| NiMg (#2) | --- | 31.2 | --- | --- | --- | 14.65 | -- | -- | -- | 50.1 | -- | 0.06 Cu |
| 75% FeSi | --- | 75.94 | --- | --- | --- | --- | 1.05 | 1.30 | -- | -- | -- | -- |
| SS #1 | --- | 72.13 | --- | --- | --- | --- | 0.09 | 0.02 | 1.03 | -- | -- | -- |
| SS #2 | --- | 69.63 | --- | --- | --- | --- | 0.09 | 0.85 | 0.88 | -- | -- | -- |

TABLE II

CHEMICAL ANALYSES OF CASTINGS POURED

(0.5% Silicon Added as Post Inoculant)

| Heat No. | Inoculant | Post Inoculant | C | Mc | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | CeMgFeSi | 75% FeSi | 3.90 | 0.39 | 0.019 | 0.016 | 2.11 | -- | 0.032 | 4.60 |
| 14 | | | 3.89 | 0.45 | 0.019 | 0.013 | 2.41 | -- | 0.042 | 4.69 |
| 5 | MgFeSi | 75% FeSi | 3.78 | 0.40 | 0.022 | 0.013 | 2.14 | -- | 0.039 | 4.49 |
| 23 | | | 3.78 | 0.44 | 0.018 | 0.012 | 2.32 | -- | 0.053 | 4.55 |
| 6 | NiMg | 75% FeSi | 3.60 | 0.41 | 0.023 | 0.012 | 2.39 | 1.12 | 0.11 | 4.40 |
| 16 | | | 3.89 | 0.39 | 0.018 | 0.012 | 2.30 | -- | 0.045 | 4.66 |
| 24 | | | 3.86 | 0.45 | 0.016 | 0.014 | 2.30 | 0.48 | 0.051 | 4.63 |
| 8 | CeMgFeSi | SS #1 | 3.76 | 0.43 | 0.019 | 0.017 | 2.28 | -- | 0.037 | 4.52 |
| 13 | | | 3.70 | 0.43 | 0.018 | 0.013 | 2.25 | -- | 0.038 | 4.45 |
| 19 | | | 3.95 | 0.45 | 0.024 | 0.013 | 2.38 | -- | 0.039 | 4.74 |
| 21 | | | 3.89 | 0.43 | 0.020 | 0.011 | 2.32 | -- | 0.036 | 4.66 |
| 7 | MgFeSi | SS #1 | 3.76 | 0.42 | 0.014 | 0.017 | 2.52 | 0.18 | 0.032 | 4.60 |
| 15 | | | 3.96 | 0.43 | 0.013 | 0.015 | 2.28 | -- | 0.041 | 4.72 |
| 18 | | | 3.81 | 0.43 | 0.022 | 0.015 | 2.23 | -- | 0.042 | 4.55 |
| 9 | NiMg | SS #1 | 3.70 | 0.36 | 0.011 | 0.012 | 2.33 | 0.50 | 0.066 | 4.48 |
| 17 | | | 3.80 | 0.37 | 0.018 | 0.016 | 2.73 | 0.48 | 0.040 | 4.71 |
| 20 | | | 4.04 | 0.43 | 0.020 | 0.012 | 2.30 | 0.36 | 0.043 | 4.81 |
| 22 | | | 3.79 | 0.45 | 0.018 | 0.011 | 2.43 | 0.47 | 0.042 | 4.60 |
| 11 | CeMgFeSi | SS #2 | 3.75 | 0.40 | 0.019 | 0.014 | 2.46 | -- | 0.061 | 4.57 |
| 26 | | | 3.78 | 0.42 | 0.018 | 0.012 | 2.61 | -- | 0.030 | 4.65 |
| 10 | MgFeSi | SS #2 | 3.66 | 0.43 | 0.017 | 0.012 | 2.24 | -- | 0.037 | 4.41 |
| 25 | | | 3.75 | 0.38 | 0.019 | 0.014 | 2.34 | -- | 0.054 | 4.53 |
| 12 | NiMg | SS #2 | 3.78 | 0.46 | 0.012 | 0.011 | 2.29 | 0.66 | 0.056 | 4.54 |
| 27 | | | 3.77 | 0.40 | 0.019 | 0.012 | 2.42 | 0.42 | 0.050 | 4.58 |

TABLE III

CHEMICAL ANSLYSES OF CASTINGS POURED

(Varying Amounts of Silicon Added as Post Inoculant)

| Heat No.* | % Silicon Added Late | Post Inoculant | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 | 0.25 | 75% FeSi | 3.87 | 0.46 | 0.018 | 0.017 | 2.22 | -- | 0.042 | 4.61 |
| 31 | 1.0 | | 3.72 | 0.44 | 0.018 | 0.019 | 2.28 | -- | 0.036 | 4.48 |
| 29 | 0.25 | SS #1 | 3.83 | 0.45 | 0.024 | 0.014 | 2.17 | -- | 0.038 | 4.55 |
| 30 | 0.25 | SS #2 | 3.79 | 0.46 | 0.027 | 0.014 | 2.18 | -- | 0.036 | 4.52 |
| 32 | 1.0 | | 3.81 | 0.43 | 0.020 | 0.017 | 2.30 | -- | 0.029 | 4.58 |

*The nodularizing inoculant was CeMgFeSi.

TABLE IV

CHEMICAL ANALYSES OF CASTINGS AS FUNCTION
OF FURNACE HOLDING TIME—EFFECT OF FADING

| Heat No. | Inoculants | Holding Time (min) | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 35 | MgFeSi SS #2 | 0 | 3.72 | 0.38 | 0.019 | 0.011 | 2.40 | -- | 0.027 | 4.52 |
| | | 3 | 3.75 | -- | --- | --- | 2.43 | -- | 0.025 | 4.56 |
| | | 6 | 3.71 | -- | --- | --- | 2.45 | -- | 0.015 | 4.53 |
| 36 | MgFeSi SS #2 | 0 | 3.67 | 0.33 | .0.018 | 0.010 | 2.47 | -- | 0.042 | 4.49 |
| | | 3 | 3.74 | -- | --- | --- | 2.41 | -- | 0.027 | 4.54 |
| | | 6 | 3.68 | -- | --- | --- | 2.42 | -- | 0.019 | 4.49 |
| 37 | CeMgFeSi 75% FeSi | 0 | 3.87 | 0.50 | 0.016 | 0.012 | 2.44 | -- | 0.035 | 4.68 |
| | | 3 | 3.78 | -- | --- | --- | 2.55 | -- | 0.031 | 4.63 |
| | | 6 | 3.78 | -- | --- | --- | 2.51 | -- | 0.019 | 4.62 |
| 38 | CeMgFeSi SS #2 | 0 | 3.76 | 0.51 | 0.018 | 0.012 | 2.58 | -- | 0.045 | 4.62 |
| | | 3 | 3.75 | -- | --- | --- | 2.69 | -- | 0.032 | 4.65 |
| | | 6 | 3.80 | -- | --- | --- | 2.72 | -- | 0.024 | 4.71 |

TABLE V

SUMMARY OF MECHANICAL PROPERTIES

(0.5% Silicon Added as Post Inoculant)

| Heat No. | Inoculants | "Y" Block (in.) | T.S. (psi x $10^3$) | B.S. (psi x $10^3$) | Y.S. (psi x $10^3$) | Elongation (%) | R.A.-Neck (%) | Bend Angle (°) | Nodularity (%) | Nodules (per $in.^2$ x $10^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1/4 | -- | -- | -- | -- | -- | 29 | 96 | 211 |
| 5 | MgFeSi | 1/2 | 63.3 | 59.8 | 42.3 | 26.5 | 20.5 | -- | 97 | 138 |
| | 75% FeSi | 1 | 63.8 | 63.8 | 42.8 | 14.2 | 11.6 | -- | 92 | 96 |
| | | 3 | 69.5 | 69.5 | 50.0 | 2.5 | 1.6 | -- | 64 | 49 |
| | | 1/4 | -- | -- | -- | -- | -- | 16 | 97 | 107 |
| 23 | MgFeSi | 1/2 | 62.2 | 58.6 | * | 27.0 | 27.2 | -- | 97 | 101 |
| | 75% FeSi | 1 | 62.2 | 58.0 | * | 24.5 | 24.7 | -- | 95 | 87 |
| | | 3 | 60.5 | 60.5 | * | 10.0 | 7.8 | -- | 73 | 68 |
| | | 1/4 | -- | -- | -- | -- | -- | 10 | 54 | 66 |
| 7 | MgFeSi | 1/2 | 55.7 | 55.1 | 38.2 | 11.0 | 9.4 | -- | 89 | 45 |
| | SS #1 | 1 | 54.6 | 51.0 | 37.8 | 9.0 | 6.8 | -- | 67 | 39 |
| | | 3 | 56.1 | 56.1 | 39.8 | 8.0 | 5.6 | -- | 81 | 34 |
| | | 1/4 | -- | -- | -- | -- | -- | 26 | 99 | 229 |
| 15 | MgFeSi | 1/2 | 68.8 | 66.0 | 42.0 | 16.0 | 25.5 | -- | 98 | 267 |
| | SS #1 | 1 | 68.5 | 66.0 | 42.0 | 13.5 | 14.8 | -- | 95 | 200 |
| | | 3 | 73.0 | 73.0 | 45.2 | 6.0 | 5.2 | -- | 95 | 52 |
| | | 1/4 | -- | -- | -- | -- | -- | 23 | 98 | 120 |
| 18 | MgFeSi | 1/2 | 60.5 | 56.4 | * | 29.0 | 29.3 | -- | 97 | 146 |
| | SS #1 | 1 | 61.5 | 56.5 | * | 22.5 | 26.2 | -- | 97 | 112 |
| | | 3 | 62.2 | 62.2 | * | 13.0 | 9.7 | -- | 91 | 50 |
| | | 1/4 | -- | -- | -- | -- | -- | 17 | 94 | 267 |
| 10 | MgFeSi | 1/2 | 63.4 | 59.3 | 44.4 | 28.1 | 21.1 | -- | 96 | 191 |
| | SS #2 | 1 | 61.3 | 56.6 | 38.3 | 26.0 | 25.6 | -- | 96 | 199 |
| | | 3 | 61.8 | 61.8 | 40.5 | 10.0 | 13.8 | -- | 98 | 168 |
| | | 1/4 | -- | -- | -- | -- | -- | 10 | 94 | 140 |
| 25 | MgFeSi | 1/2 | 59.0 | 56.1 | * | 28.0 | 29.0 | -- | 94 | 105 |
| | SS #2 | 1 | 65.5 | 56.5 | 39.0 | 24.0 | 22.8 | -- | 98 | 73 |
| | | 3 | 60.2 | 60.0 | 40.0 | 10.0 | 17.5 | -- | 98 | 50 |
| | | 1/4 | -- | -- | -- | -- | -- | 38 | 99 | 276 |
| 4 | CeMgFeSi | 1/2 | 59.8 | 54.0 | 37.8 | 28.0 | 24.7 | -- | 97 | 111 |
| | 75% FeSi | 1 | 61.7 | 58.4 | 37.6 | 24.7 | 21.6 | -- | 96 | 60 |
| | | 3 | 66.4 | 64.3 | 38.8 | 19.5 | 15.2 | -- | 87 | 36 |

*Data not taken.

TABLE V (Concluded)

| Heat No. | Inoculants | "Y" Block (in.) | T.S. (psi x $10^3$) | B.S. (psi x $10^3$) | Y.S. (psi x $10^3$) | Elongation (%) | R.A.-Neck (%) | Bend Angle (°) | Nodularity (%) | Nodules (per in.$^2$ x $10^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | | 1/4 | -- | -- | -- | -- | -- | 22.5 | 99+ | 278 |
| | NiMg | 1/2 | 67.6 | 60.8 | 42.5 | 21.0 | 23.0 | -- | 95 | 273 |
| | 75% FeSi | 1 | 68.0 | 61.0 | 46.0 | 24.0 | 29.6 | -- | 93 | 111 |
| | | 3 | 71.0 | 69.0 | 42.0 | 15.0 | 15.3 | -- | 98 | 184 |
| 24 | | 1/4 | -- | -- | -- | -- | -- | 25 | 98 | 141 |
| | NiMg | 1/2 | 66.2 | 63.2 | * | 24.0 | 24.6 | -- | 98 | 100 |
| | 75% FeSi | 1 | 65.0 | 60.5 | * | 23.5 | 24.7 | -- | 93 | 67 |
| | | 3 | 69.0 | 67.6 | * | 16.5 | 13.9 | -- | 91 | 45 |
| 9 | | 1/4 | -- | -- | -- | -- | -- | 19 | 96 | 140 |
| | NiMg | 1/2 | 64.2 | 59.6 | 42.5 | 28.0 | 25.5 | -- | 93 | 133 |
| | SS #1 | 1 | 67.6 | 64.3 | 44.4 | 20.8 | 21.2 | -- | 89 | 88 |
| | | 3 | 82.0 | 82.0 | 51.0 | 10.5 | 7.6 | -- | 91 | 52 |
| 17 | | 1/4 | -- | -- | -- | -- | -- | 18.5 | 99+ | 384 |
| | NiMg | 1/2 | 65.4 | 61.6 | 42.0 | 25.0 | 22.0 | -- | 98 | 200 |
| | SS #1 | 1 | 63.5 | 58.0 | 41.1 | 25.0 | 25.0 | -- | 96 | 126 |
| | | 3 | 66.7 | 62.5 | 42.5 | 20.0 | 18.0 | -- | 96 | 67 |
| 20 | | 1/4 | -- | -- | -- | -- | -- | 25 | 99+ | 142 |
| | NiMg | 1/2 | 63.0 | 58.6 | * | 28.0 | 30.0 | -- | 95 | 127 |
| | SS #1 | 1 | 64.0 | 60.5 | * | 24.0 | 24.1 | -- | 95 | 87 |
| | | 3 | 66.5 | 64.5 | * | 18.2 | 16.3 | -- | 93 | 52 |
| 22 | | 1/4 | -- | -- | -- | -- | -- | 24 | 98 | 125 |
| | NiMg | 1/2 | 63.8 | 60.2 | * | 27.0 | 27.2 | -- | 94 | 104 |
| | SS #1 | 1 | 64.0 | 59.0 | * | 24.0 | 25.5 | -- | 96 | 97 |
| | | 3 | 66.8 | 65.0 | * | 18.0 | 16.3 | -- | 95 | 53 |
| 12 | | 1/4 | -- | -- | -- | -- | -- | 18.5 | 99 | 275 |
| | NiMg | 1/2 | 75.5 | 73.4 | * | 21.8 | 20.3 | -- | 96 | 184 |
| | SS #2 | 1 | 67.0 | 64.0 | 44.0 | 23.0 | 21.2 | -- | 95 | 138 |
| | | 3 | 70.5 | 67.2 | 45.5 | 16.2 | 17.6 | -- | 94 | 136 |
| 27 | | 1/4 | -- | -- | -- | -- | -- | 23 | 97 | 257 |
| | NiMg | 1/2 | 62.0 | 58.0 | * | 28.0 | 28.2 | -- | 94 | 105 |
| | SS #2 | 1 | 62.5 | 58.5 | 42.0 | 23.0 | 20.7 | -- | 97 | 81 |
| | | 3 | 65.5 | 63.3 | 42.5 | 16.5 | 12.6 | -- | 96 | 59 |

TABLE V (Continued)

| Heat No. | Inoculants | "Y" Block (in.) | T.S. (psi x $10^3$) | B.S. (psi x $10^3$) | Y.S. (psi x $10^3$) | Elongation (%) | R.A.-Neck (%) | Bend Angle (°) | Nodularity (%) | Nodules (per in.$^2$ x $10^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | CeMgFeSi 75% FeSi | 1/4 | -- | -- | -- | -- | -- | 9 | 99+ | 236 |
| | | 1/2 | 68.4 | 66.2 | 42.5 | 21.5 | 23.0 | -- | 99 | 230 |
| | | 1 | 73.0 | 71.0 | 50.2 | 14.0 | 14.8 | -- | 98 | 87 |
| | | 3 | 80.0 | 80.0 | 48.5 | 10.5 | 8.5 | -- | 97 | 62 |
| 8 | CeMgFeSi SS #1 | 1/4 | -- | -- | -- | -- | -- | 32 | 88 | 150 |
| | | 1/2 | 62.3 | 57.0 | 38.2 | 26.5 | 25.2 | -- | 92 | 86 |
| | | 1 | 61.0 | 50.0 | 39.5 | 27.3 | 24.4 | -- | 97 | 47 |
| | | 3 | 66.8 | 66.8 | 40.7 | 14.5 | 15.2 | -- | 75 | 31 |
| 13 | CeMgFeSi SS #1 | 1/4 | -- | -- | -- | -- | -- | 26.5 | 99+ | 422 |
| | | 1/2 | 61.7 | 58.4 | 39.0 | 25.0 | 28.5 | -- | 99 | 188 |
| | | 1 | 89.0 | 88.0 | 48.5 | 9.5 | 8.0 | -- | 95 | 53 |
| | | 3 | 97.0 | 97.0 | 57.9 | 7.0 | 3.6 | -- | 93 | 76 |
| 19 | CeMgFeSi SS #1 | 1/4 | -- | -- | -- | -- | -- | 23 | 99+ | 141 |
| | | 1/2 | 61.2 | 57.4 | * | 28.0 | 28.0 | 22 | 97 | 107 |
| | | 1 | 63.0 | 59.0 | * | 24.0 | 25.2 | -- | 95 | 84 |
| | | 3 | 68.5 | 67.0 | * | 14.7 | 16.5 | -- | 92 | 39 |
| 21 | CeMgFeSi SS #1 | 1/4 | -- | -- | -- | -- | -- | 24 | 95 | 122 |
| | | 1/2 | 64.0 | 60.2 | * | 25.2 | 25.0 | -- | 95 | 111 |
| | | 1 | 63.2 | 59.0 | * | 23.0 | 26.0 | -- | 93 | 63 |
| | | 3 | 66.2 | 64.0 | * | 20.5 | 18.1 | -- | 95 | 46 |
| 11 | CeMgFeSi SS #2 | 1/4 | -- | -- | -- | -- | -- | 16.5 | 99 | 134 |
| | | 1/2 | 68.3 | 67.3 | 45.0 | 21.9 | 22.6 | -- | 97 | 95 |
| | | 1 | 64.5 | 60.0 | 42.7 | 23.5 | 21.6 | -- | 97 | 86 |
| | | 3 | 70.0 | 66.5 | 42.5 | 15.5 | 14.5 | -- | 91 | 46 |
| 26 | CeMgFeSi SS #2 | 1/4 | -- | -- | -- | -- | -- | 26 | 96 | 298 |
| | | 1/2 | 64.2 | 64.0 | * | 21.0 | 16.0 | -- | 94 | 102 |
| | | 1 | 65.5 | 64.5 | 44.0 | 11.0 | 7.1 | -- | 83 | 84 |
| | | 3 | 62.5 | 62.5 | 43.0 | 7.5 | 4.7 | -- | 92 | 38 |
| 6 | NiMg 75% FeSi | 1/4 | -- | -- | -- | -- | -- | 11 | 85 | 137 |
| | | 1/2 | 83.6 | 81.6 | * | 14.0 | 11.0 | -- | 94 | 64 |
| | | 1 | 107.0 | 107.0 | * | 6.8 | 4.0 | -- | 97 | 38 |
| | | 3 | 89.2 | 89.2 | * | 2.5 | 0.8 | -- | 84 | 35 |

TABLE VI

SUMMARY OF MECHANICAL PROPERTIES

(Varying Amounts of Silicon Added as Post Inoculant)

| Heat No. | Inoculants (Silicon added late) | "Y" Blocks (in.) | T.S. (psi x $10^3$) | B.S. (psi x $10^3$) | Y.S. (psi x $10^3$) | Elongation (%) | R.A.-Neck (%) | Bend Angle (°) | Nodularity (%) | Nodules (per in.$^2$ x $10^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 | CeMgFeSi 75% FeSi (0.25%) | 1/4 | -- | -- | -- | -- | -- | * | 95 | 254 |
| | | 1/2 | 59.0 | 55.1 | * | 28.0 | 27.1 | - | 97 | 92 |
| | | 1 | 60.5 | 55.0 | 38 | 24.0 | 25.2 | - | 96 | 52 |
| | | 3 | 65.0 | 63.3 | 40.5 | 14.5 | 16.5 | - | 98 | 95 |
| 31 | CeFeMgSi 75% FeSi (1.0%) | 1/4 | -- | -- | -- | -- | -- | 19 | 98 | 225 |
| | | 1/2 | 61.0 | 57.0 | * | 27.0 | 28.0 | - | 96 | 150 |
| | | 1 | 61.0 | 57.0 | 39.0 | 23.0 | 23.6 | - | 99 | 100 |
| | | 3 | 62.7 | 60.5 | 39.5 | 20.0 | 17.9 | - | 95 | 70 |
| 29 | CeMgFeSi SS #1 (0.25%) | 1/4 | -- | -- | -- | -- | -- | 23 | 97 | 214 |
| | | 1/2 | 59.2 | 57.3 | * | 20.0 | 24.0 | - | 98 | 200 |
| | | 1 | 61.0 | 58.0 | 39.0 | 21.0 | 18.0 | - | 94 | 56 |
| | | 3 | 69.0 | 67.8 | 43.0 | 12.5 | 11.7 | - | 98 | 44 |
| 30 | CeMgFeSi SS #2 (0.25%) | 1/4 | -- | -- | -- | -- | -- | 15 | 94 | 206 |
| | | 1/2 | 67.1 | 66.0 | * | 19.0 | 15.3 | - | 94 | 88 |
| | | 1 | 62.5 | 60.5 | 39.0 | 19.0 | 16.9 | - | 93 | 62 |
| | | 3 | 71.5 | 71.0 | 43.0 | 10.5 | 10.0 | - | 94 | 42 |
| 32 | CeMgFeSi SS #2 (1.0%) | 1/4 | -- | -- | -- | -- | -- | 20 | 92 | 231 |
| | | 1/2 | 60.0 | 58.0 | * | 28.0 | 27.0 | - | 95 | 91 |
| | | 1 | 61.5 | 60.5 | 38.0 | 17.5 | 15.3 | - | 95 | 91 |
| | | 3 | 67.7 | 65.5 | 43.5 | 16.5 | 15.8 | - | 99 | 59 |

*Data not taken.

TABLE VII

SUMMARY OF MECHANICAL PROPERTIES—EFFECT OF FURNACE HOLDING TIME

| Heat No. | Inoculant | Post Inoculant | Holding Time (min) | T.S. (psi x $10^3$) | B.S. (psi x $10^3$) | Elongation (%) | R.A.-Neck (%) | Nodularity (%) | Nodules (per in.$^2$ x $10^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 35 | MgFeSi | 75% FeSi | 0 | 65.0 | 65.0 | 9.0 | 6.5 | 91 | 87 |
| | | | 3 | 59.7 | 59.7 | 5.5 | 3.9 | 73 | 61 |
| | | | 6 | 50.5 | 50.5 | 4.0 | 2.7 | 51 | 65 |
| 36 | MgFeSi | SS #2 | 0 | 75.7 | 75.7 | 9.7 | 7.6 | 95 | 69 |
| | | | 3 | 58.0 | 58.0 | 3.5 | 2.8 | 54 | 40 |
| | | | 6 | 51.2 | 51.2 | 2.5 | 2.2 | 23 | 17 |
| 37 | CeMgFeSi | 75% FeSi | 0 | 75.7 | 75.2 | 12.0 | 12.2 | 97 | 75 |
| | | | 3 | 71.0 | 71.0 | 7.5 | 5.7 | 83 | 62 |
| | | | 6 | 60.5 | 60.5 | 4.7 | 5.5 | 72 | 65 |
| 38 | CeMgFeSi | SS #2 | 0 | 80.0 | 80.0 | 9.2 | 8.0 | 89 | 75 |
| | | | 3 | 75.5 | 75.5 | 7.5 | 5.7 | 89 | 83 |
| | | | 6 | 61.2 | 61.2 | 3.7 | 2.5 | 40 | 38 |

TABLE VIII

REPRODUCIBILITY OF EXPERIMENTAL PARAMETERS BETWEEN HEATS

| Heats Compared | Property Ranges Between Heats for Various Section Sizes | | | | | | | | | | | | | | Figure Number with Graphical Data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tensile Strength (psi x $10^3$) | | | Elongation (%) | | | Nodule Count (per in.$^2$ x $10^3$) | | | | Nodularity (%) | | | | |
| | 1/2" | 1" | 3" | 1/2" | 1" | 3" | 1/4" | 1/2" | 1" | 3" | 1/4" | 1/2" | 1" | 3" | |
| 5,23 - MgFeSi + 75% FeSi | 1.1 | 1.6 | 9.0 | 0.5 | 10.3 | 7.5 | 104 | 37 | 9 | 19 | 1 | 0 | 3 | 9 | 2 |
| 10,25 - MgFeSi + SS #2 | 4.4 | 4.2 | 1.6 | 0.1 | 2.0 | 0 | 127 | 86 | 126 | 118 | 0 | 2 | 2 | 0 | 3 |
| 4,14 - CeMgFeSi + 75% FeSi | 8.6 | 11.3 | 13.6 | 6.5 | 9.3 | 9.0 | 40 | 119 | 27 | 26 | 0 | 2 | 2 | 10 | 4 |
| 19,21 - CeMgFeSi + SS #1 | 2.8 | 0.2 | 2.3 | 2.8 | 1.0 | 5.8 | 19 | 4 | 19 | 7 | 4 | 2 | 2 | 3 | 5 |
| 11,26 - CeMgFeSi + SS #2 | 4.1 | 1.0 | 7.5 | 0.9 | 12.5 | 8.0 | 165 | 7 | 2 | 8 | 3 | 3 | 14 | 1 | 6 |
| 16,24 - NiMg + 75% FeSi | 1.4 | 3.0 | 2.0 | 3.0 | 0.5 | 1.0 | 137 | 173 | 44 | 139 | 1 | 3 | 0 | 7 | 7 |
| 20,22 - NiMg + SS #1 | 0.8 | 0 | 0.3 | 1.0 | 0 | 0.2 | 17 | 23 | 10 | 1 | 1 | 1 | 1 | 2 | 8 |
| 12,27 - NiMg + SS #2 | 13.5 | 4.5 | 5.0 | 6.2 | 0 | 0.3 | 18 | 79 | 57 | 77 | 2 | 2 | 2 | 2 | 9 |

TABLE IX

MAGNESIUM RECOVERY

| Heat No. | Nodularizing Alloy | Post Inoculant | Amount of Si Added | Mg Content* | % Mg Added | % Mg Recovered |
|---|---|---|---|---|---|---|
| 4 | CeMgFeSi | 75% FeSi | 0.50 | 0.032 | 0.225 | 14.2 |
| 14 | | | 0.50 | 0.042 | 0.225 | 18.6 |
| 28 | | | 0.25 | 0.042 | 0.225 | 18.6 |
| 31 | | | 1.00 | 0.036 | 0.225 | 16.0 |
| 5 | MgFeSi | 75% FeSi | 0.50 | 0.039 | 0.225 | 17.3 |
| 23 | | | 0.50 | 0.053 | 0.225 | 23.5 |
| 6 | NiMg | 75% FeSi | 0.50 | 0.11 | 0.333 | 33.1 |
| 16 | | | 0.50 | 0.045 | 0.125 | 36.0 |
| 24 | | | 0.50 | 0.051 | 0.125 | 40.8 |
| 8 | CeMgFeSi | SS #1 | 0.50 | 0.037 | 0.225 | 16.4 |
| 13 | | | 0.50 | 0.038 | 0.225 | 16.9 |
| 19 | | | 0.50 | 0.039 | 0.225 | 16.6 |
| 21 | | | 0.50 | 0.036 | 0.225 | 16.0 |
| 29 | | | 0.25 | 0.038 | 0.225 | 16.9 |
| 7 | MgFeSi | SS #1 | 0.50 | 0.032 | 0.225 | 14.2 |
| 15 | | | 0.50 | 0.041 | 0.225 | 18.2 |
| 18 | | | 0.50 | 0.042 | 0.225 | 18.6 |
| 9 | NiMg | SS #1 | 0.50 | 0.066 | 0.166 | 39.7 |
| 17 | | | 0.50 | 0.040 | 0.125 | 32.0 |
| 20 | | | 0.50 | 0.043 | 0.125 | 34.4 |
| 22 | | | 0.50 | 0.042 | 0.125 | 33.6 |
| 11 | CeMgFeSi | SS #2 | 0.50 | 0.061 | 0.225 | 27.1 |
| 26 | | | 0.50 | 0.030 | 0.225 | 13.3 |
| 30 | | | 0.25 | 0.036 | 0.225 | 16.0 |
| 32 | | | 1.00 | 0.029 | 0.225 | 12.9 |
| 10 | MgFeSi | SS 2 | 0.50 | 0.037 | 0.225 | 16.4 |
| 25 | | | 0.50 | 0.054 | 0.225 | 24.0 |
| 12 | NiMg | SS #2 | 0.50 | 0.056 | 0.166 | 24.9 |
| 27 | | | 0.50 | 0.050 | 0.125 | 40.0 |
| 35 | MgFeSi | 75% FeSi | 0.50 | 0.027 | 0.225 | 12.0 |
| 36 | | SS #2 | 0.50 | 0.042 | 0.225 | 18.6 |
| 37 | CeMgFeSi | 75% FeSi | 0.50 | 0.035 | 0.225 | 15.5 |
| 38 | | SS #2 | 0.50 | 0.045 | 0.225 | 20.0 |

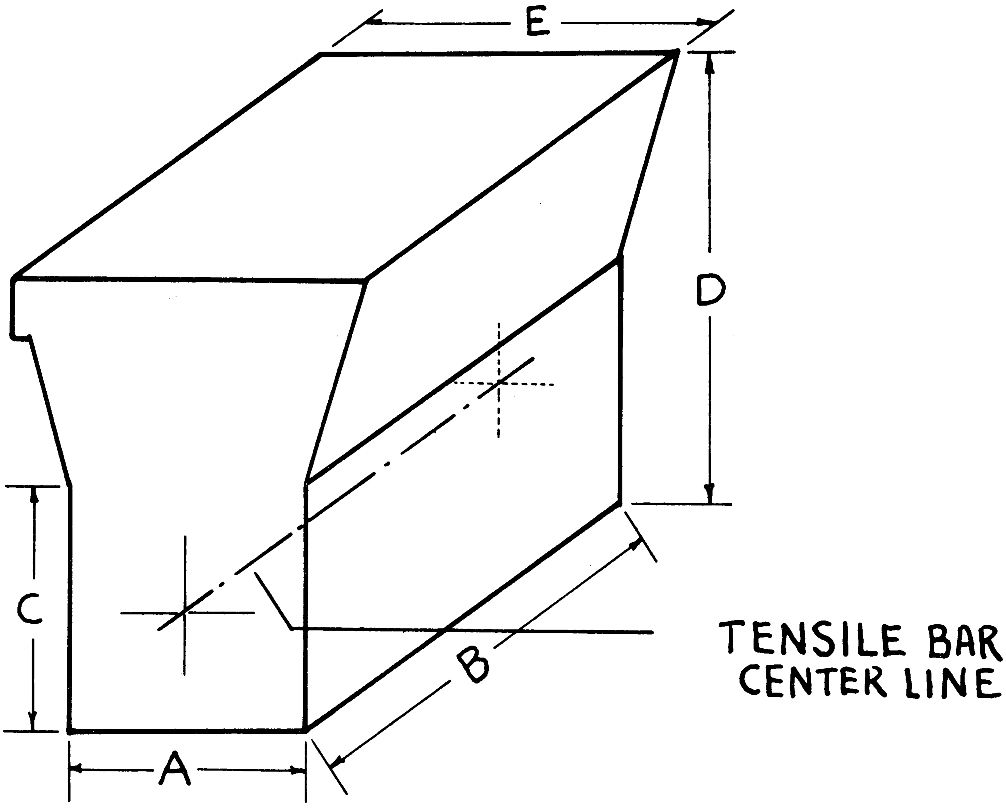
*Heats Nos. 35 through 38 were fading studies. Mg content is sample right after post inoculation.

## LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure

LIST OF FIGURES (Concluded)




| "Y" BLOCK (INCHES) | A (INCHES) | B (INCHES) | D (INCHES) | C (INCHES) | E (INCHES) |
|---|---|---|---|---|---|
| 3 | 3 | 6 | 5½ | 2½ | 4¾ |
| 1 | 1 | 6 | 4¼ | 1 | 2 |
| ½ | ½ | 6 | 3½ | 1 | 1½ |
| ¼ | ¼ | 6 | 2 | ½ | 1¾ |

Figure 1-A

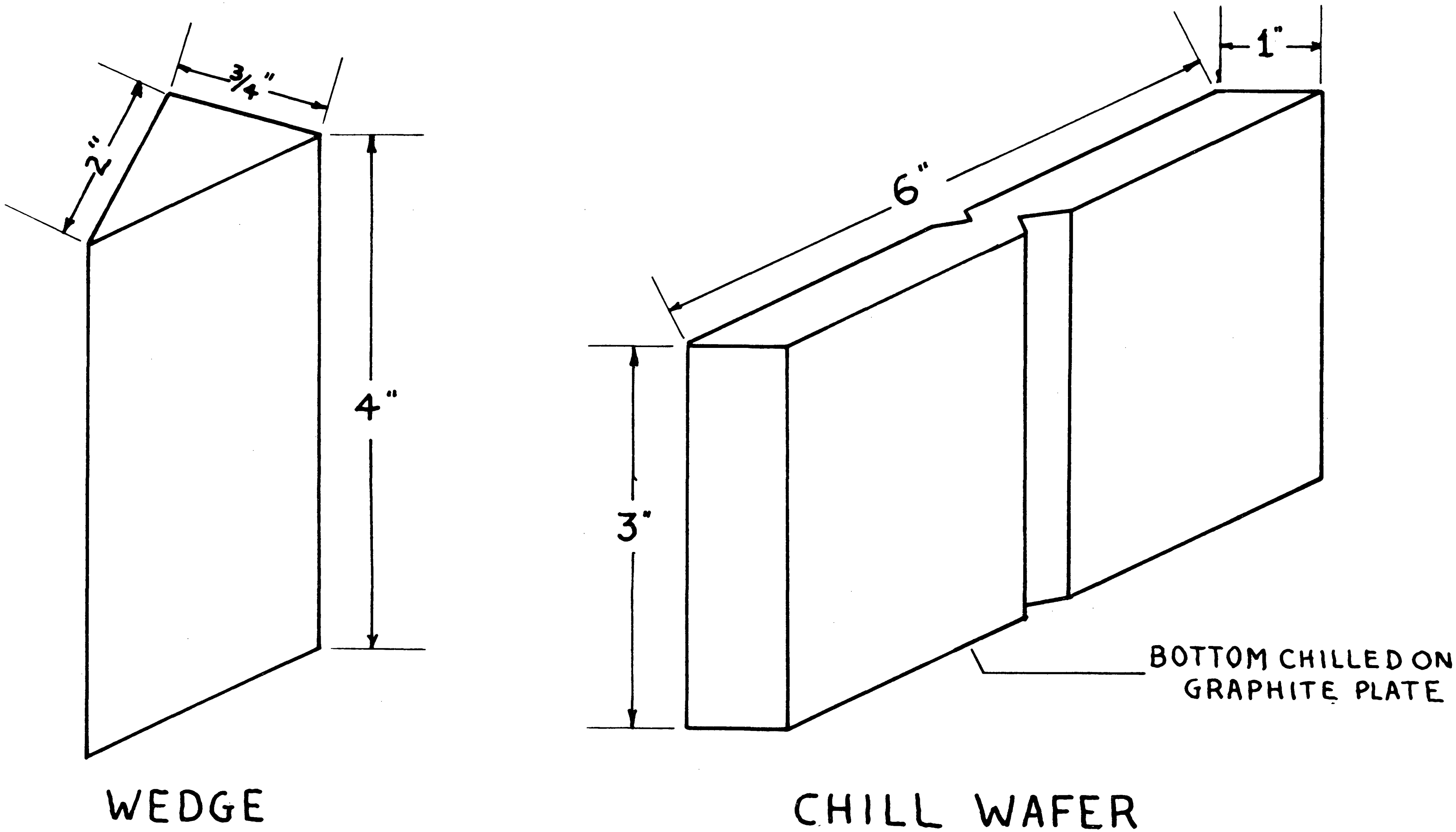

2"
3/4"
4"
WEDGE
6"
1"
3"
BOTTOM CHILLED ON
GRAPHITE PLATE
CHILL WAFER

Figure 1-B

Heats No. 5, 23

Inoculant: MgFeSi

Post-Inoculant: 75% FeSi

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (solid line) | 5 | 0.5 | 3.78 | .40 | .022 | .013 | 2.14 | - | .039 | 4.49 |
| (dashed line) | 23 | 0.5 | 3.78 | .44 | .018 | .012 | 2.32 | - | .053 | 4.55 |

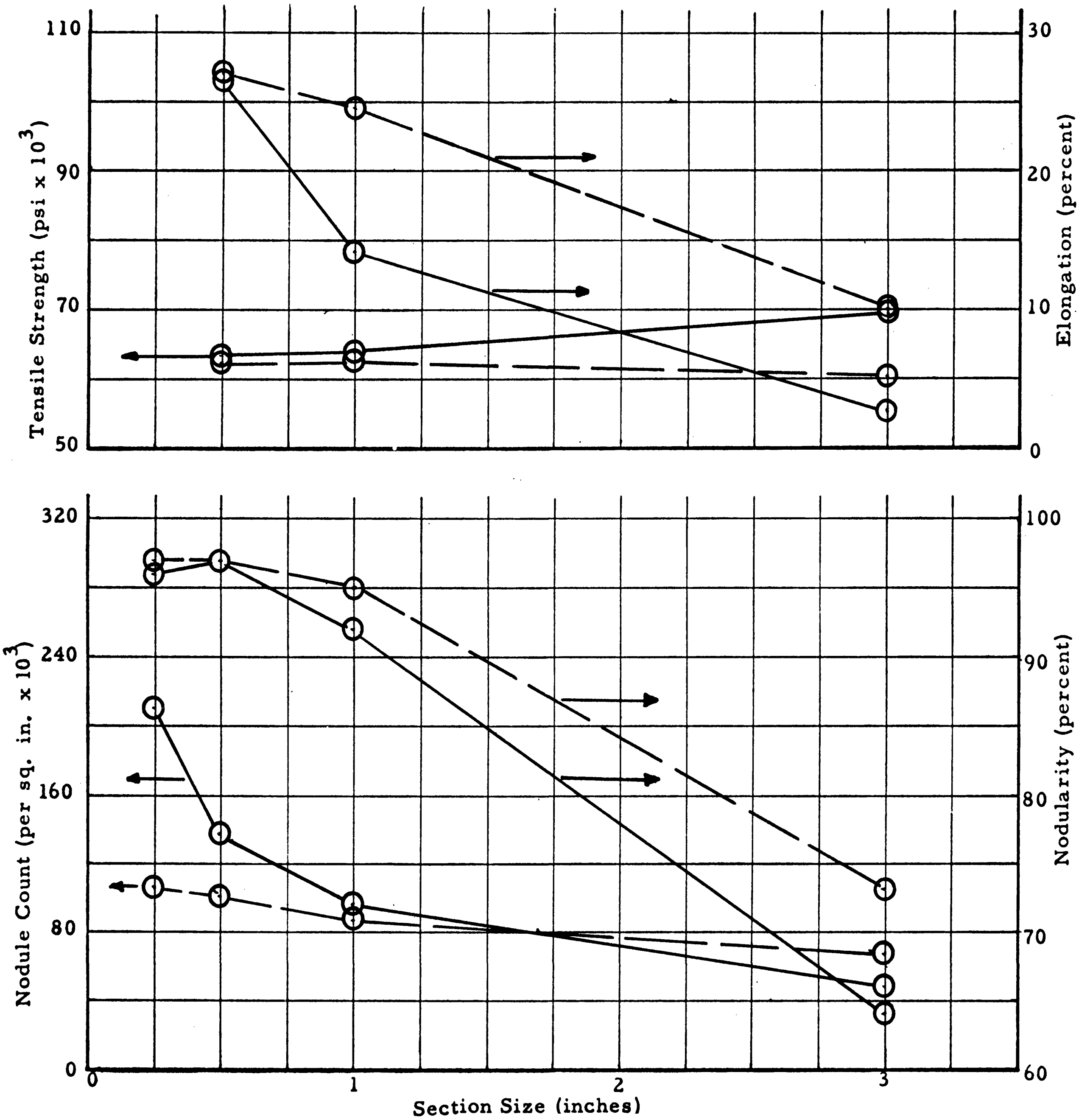



Figure 2

Heats No. 10, 25
Inoculant: MgFeSi
Post-Inoculant: SS # 2

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 10 | 0.5 | 3.66 | .43 | .017 | .012 | 2.24 | - | .037 | 4.41 |
| — — | 25 | 0.5 | 3.75 | .38 | .019 | .014 | 2.34 | - | .054 | 4.53 |

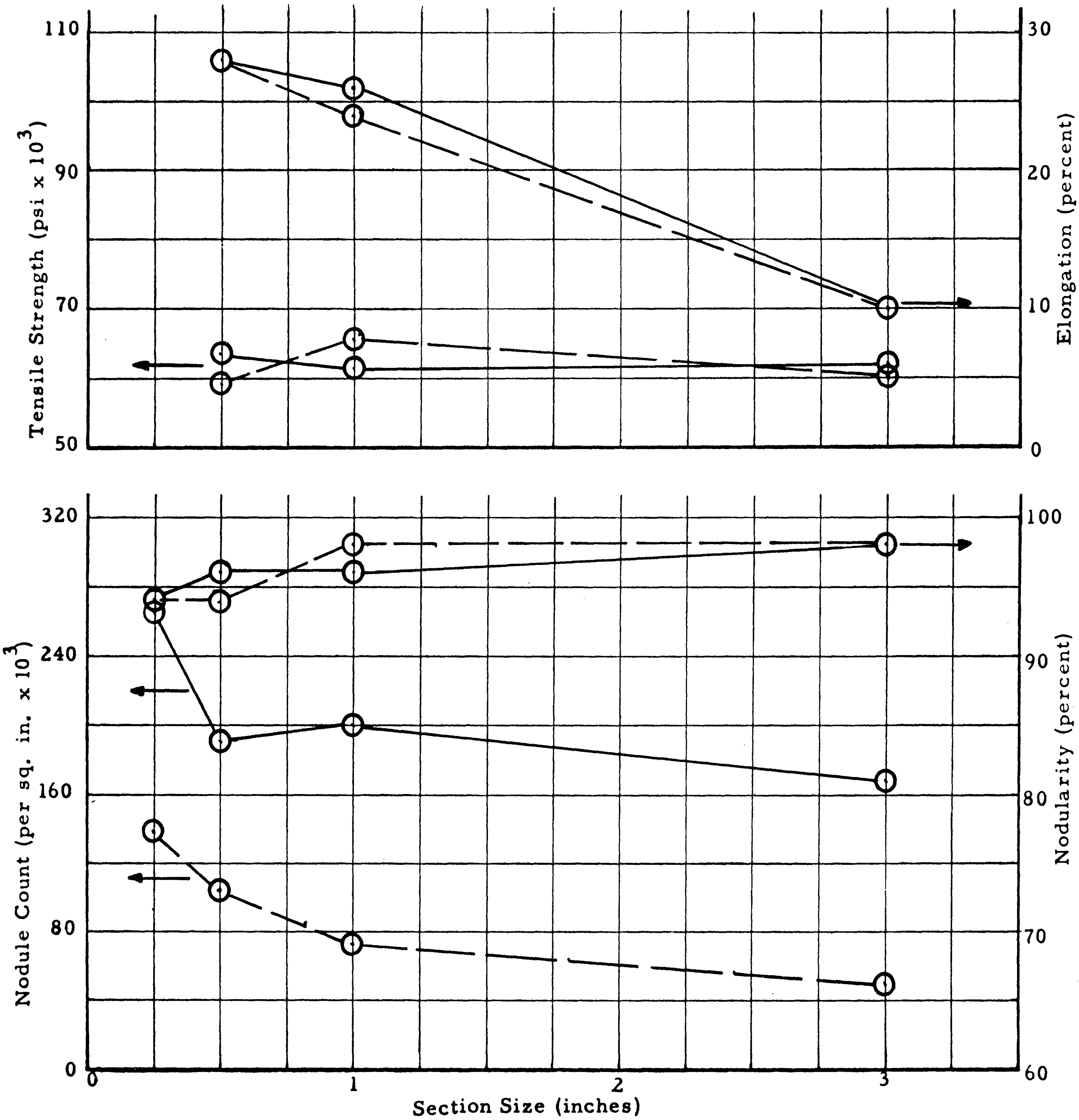



Figure 3

Heats No. 4, 14

Inoculant: CeMgFeSi

Post-Inoculant: 75% FeSi

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (solid line) | 4 | 0.5 | 3.90 | .39 | .019 | .016 | 2.11 | - | .032 | 4.60 |
| (dashed line) | 14 | 0.5 | 3.90 | .45 | .019 | .013 | 2.41 | - | .042 | 4.69 |

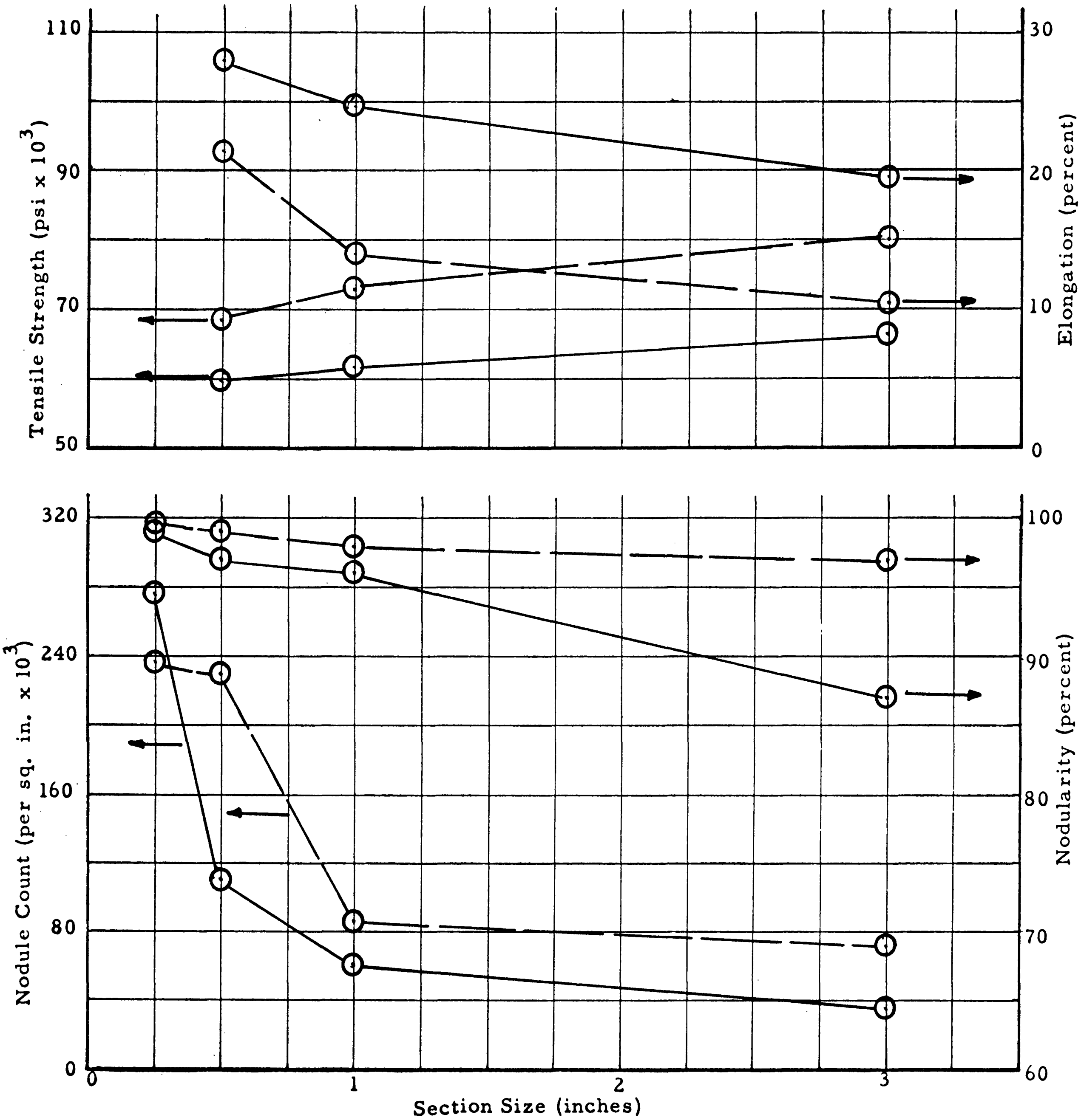



Figure 4

Heats No. 19, 21

Inoculant: CeMgFeSi

Post-Inoculant: SS # 1

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (solid line) | 19 | 0.5 | 3.95 | .45 | .024 | .013 | 2.38 | - | .039 | 4.74 |
| (dashed line) | 21 | 0.5 | 3.89 | .43 | .020 | .011 | 2.32 | - | .036 | 4.66 |
| | | | | | | | | | | |
| | | | | | | | | | | |

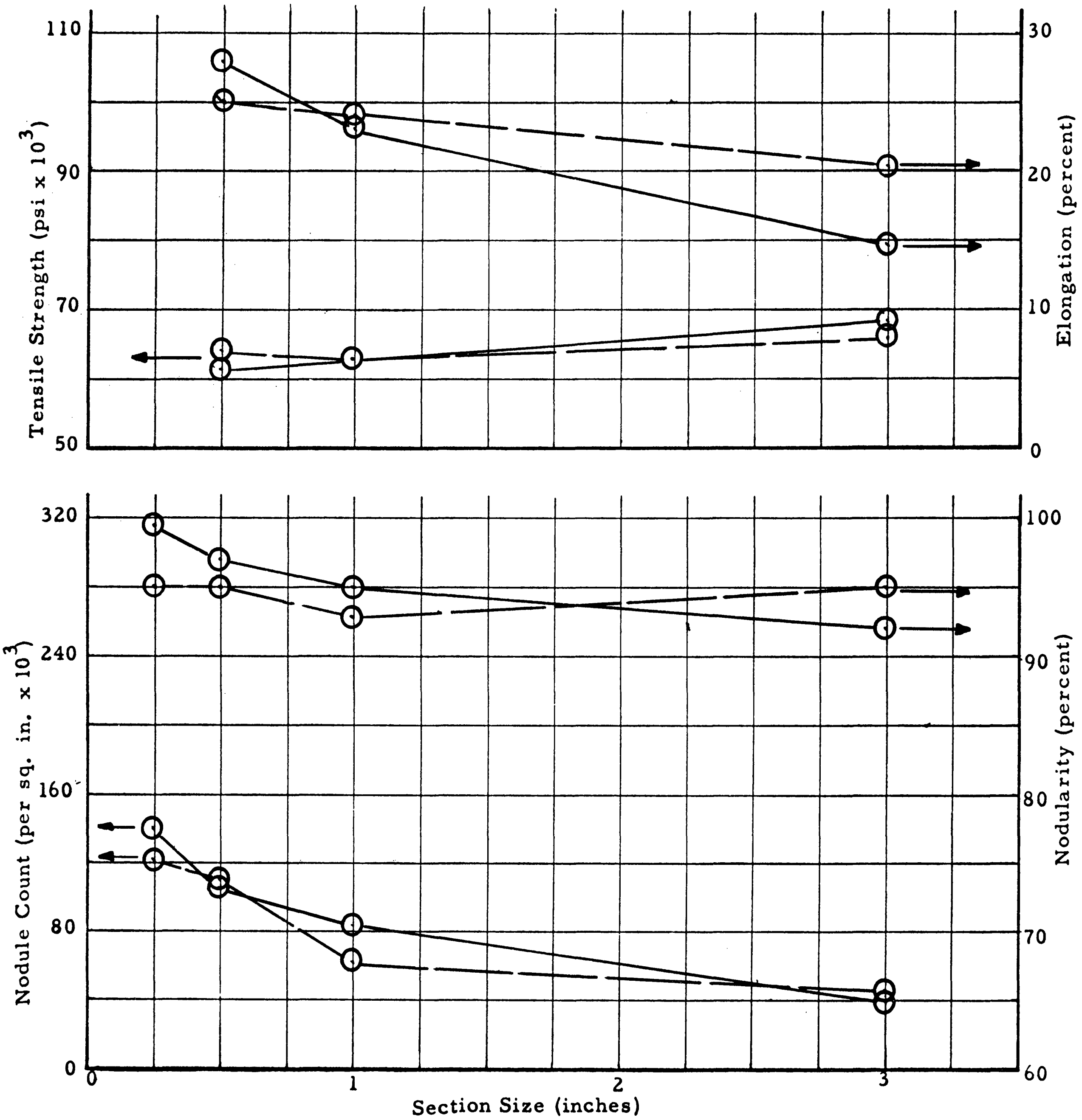



Figure 5

Heats No. 11, 26

Inoculant: CeMgFeSi

Post-Inoculant: SS # 2

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 11 | 0.5 | 3.75 | .40 | .019 | .014 | 2.46 | - | .061 | 4.57 |
| — — | 26 | 0.5 | 3.78 | .42 | .018 | .012 | 2.61 | - | .030 | 4.65 |

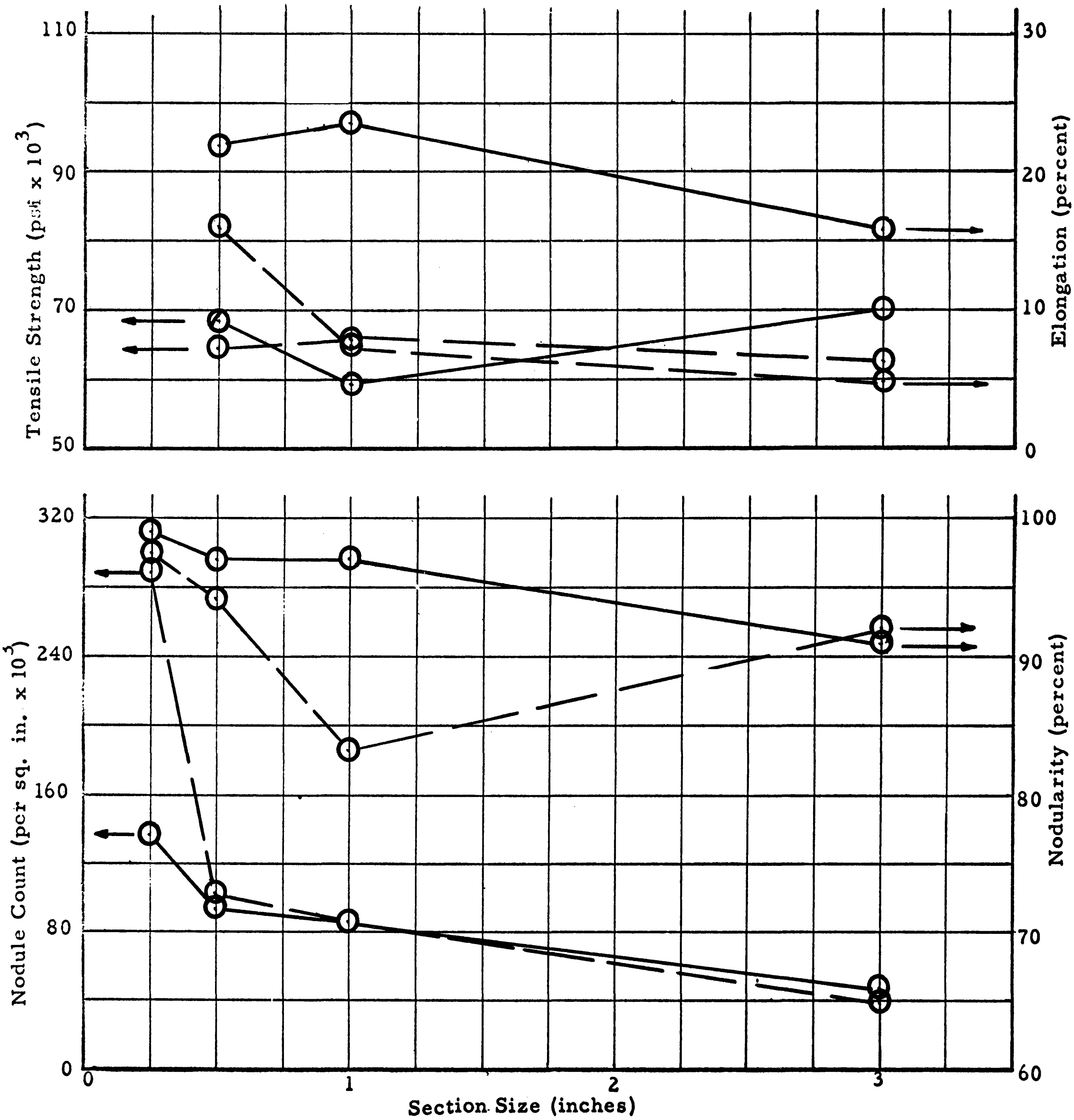



Figure 6

Heats No. 16, 24

Inoculant: NiMg

Post-Inoculant: 75% FeSi

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 16 | 0.5 | 3.89 | .39 | .018 | .012 | 2.30 | - | .045 | 4.66 |
| — · — | 24 | 0.5 | 3.86 | .45 | .016 | .014 | 2.30 | .48 | .041 | 4.63 |

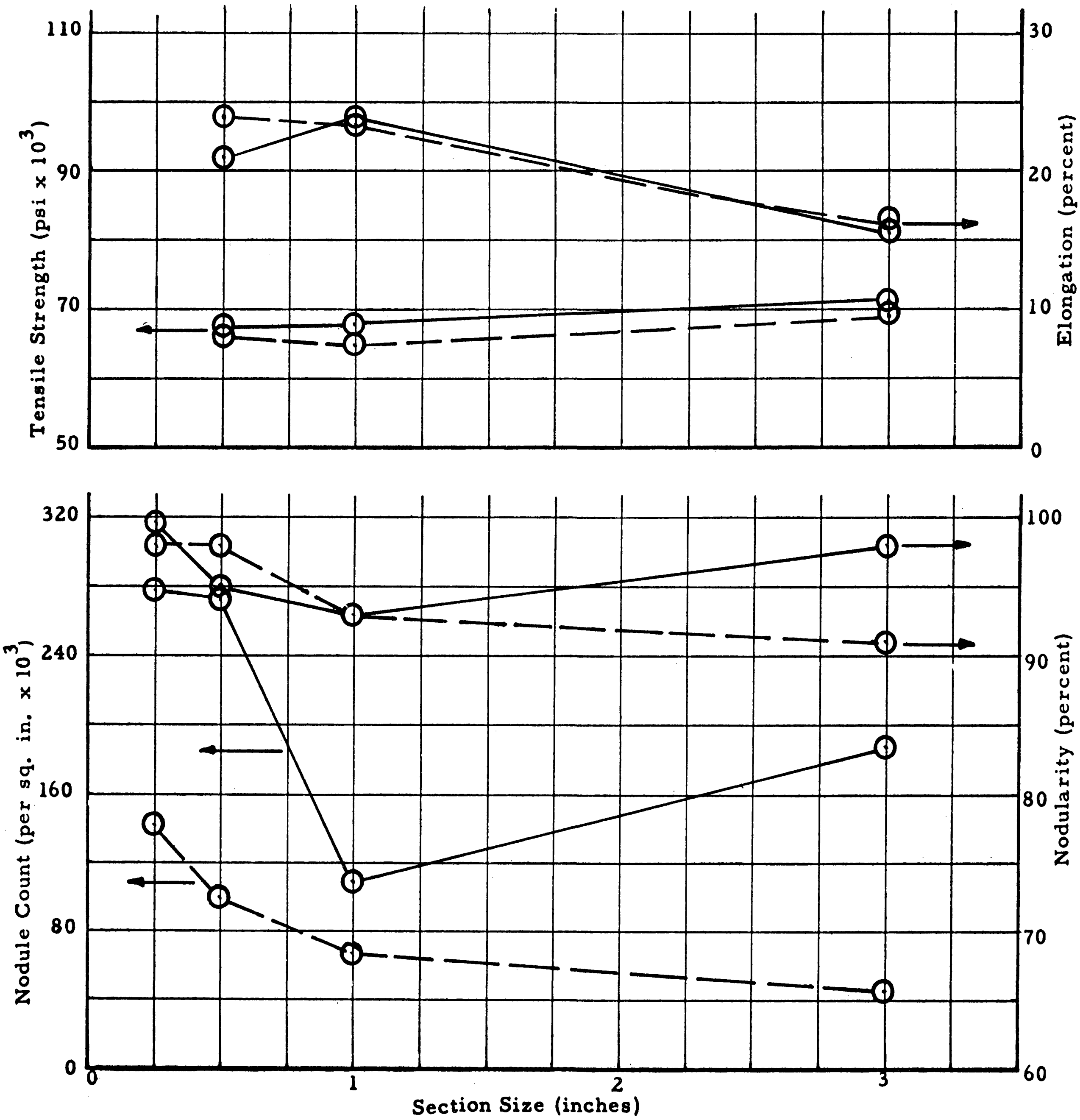



Figure 7

**Heats No.** 20, 22
**Inoculant:** NiMg
**Post-Inoculant:** SS # 1

**Purpose:** Reproducibility of data

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (solid line) | 20 | 0.5 | 4.04 | .43 | .020 | .012 | 2.30 | .36 | .043 | 4.81 |
| (dashed line) | 22 | 0.5 | 3.79 | .45 | .018 | .011 | 2.43 | .47 | .042 | 4.60 |

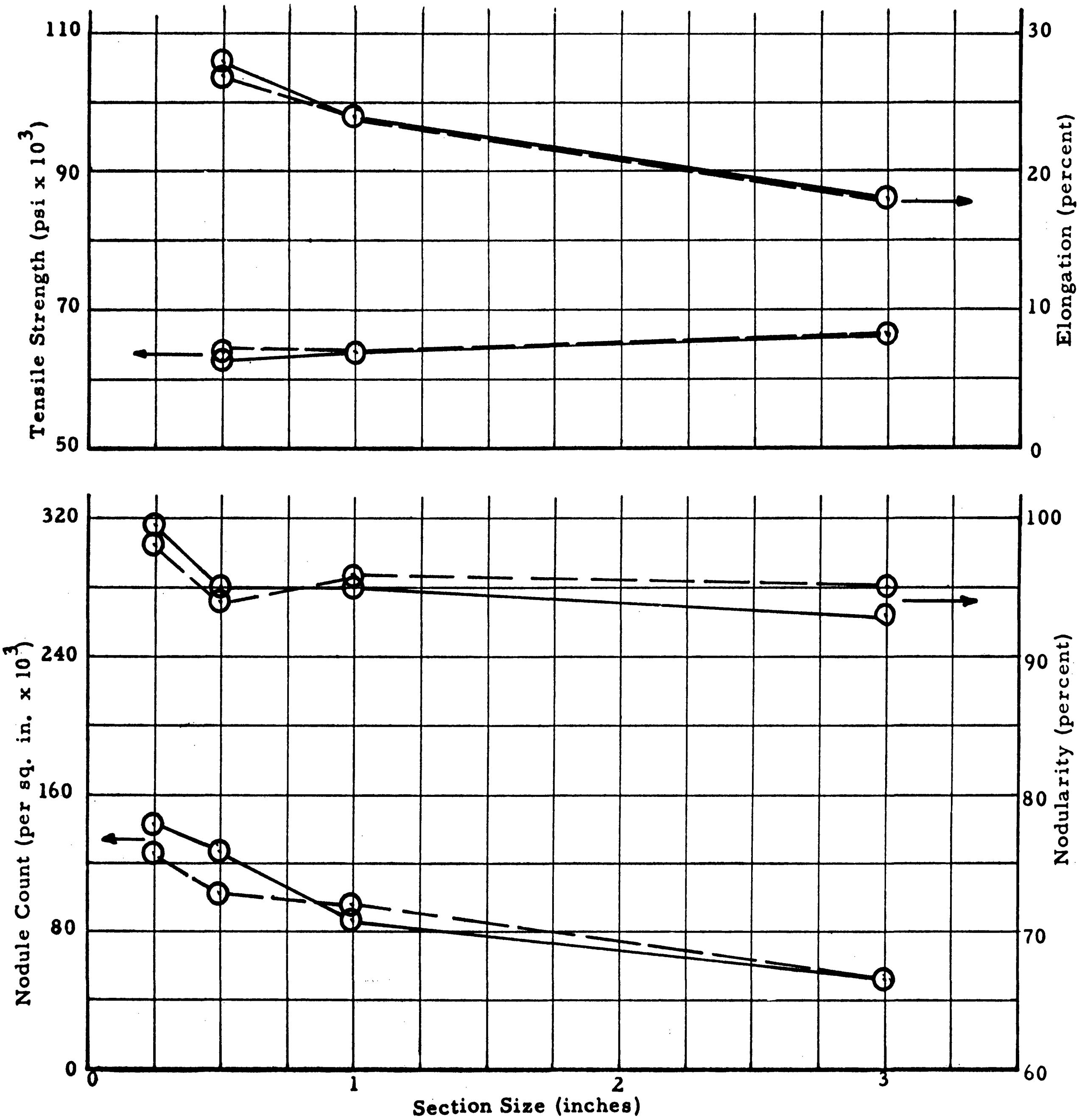



Figure 8

Heats No. 12, 27
Inoculant: NiMg
Post-Inoculant: SS # 2

Purpose: Reproducibility of data.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (——) | 12 | 0.5 | 3.78 | .46 | .012 | .011 | 2.29 | .66 | .056 | 4.54 |
| (— —) | 27 | 0.5 | 3.77 | .40 | .019 | .012 | 2.42 | .42 | .050 | 4.58 |

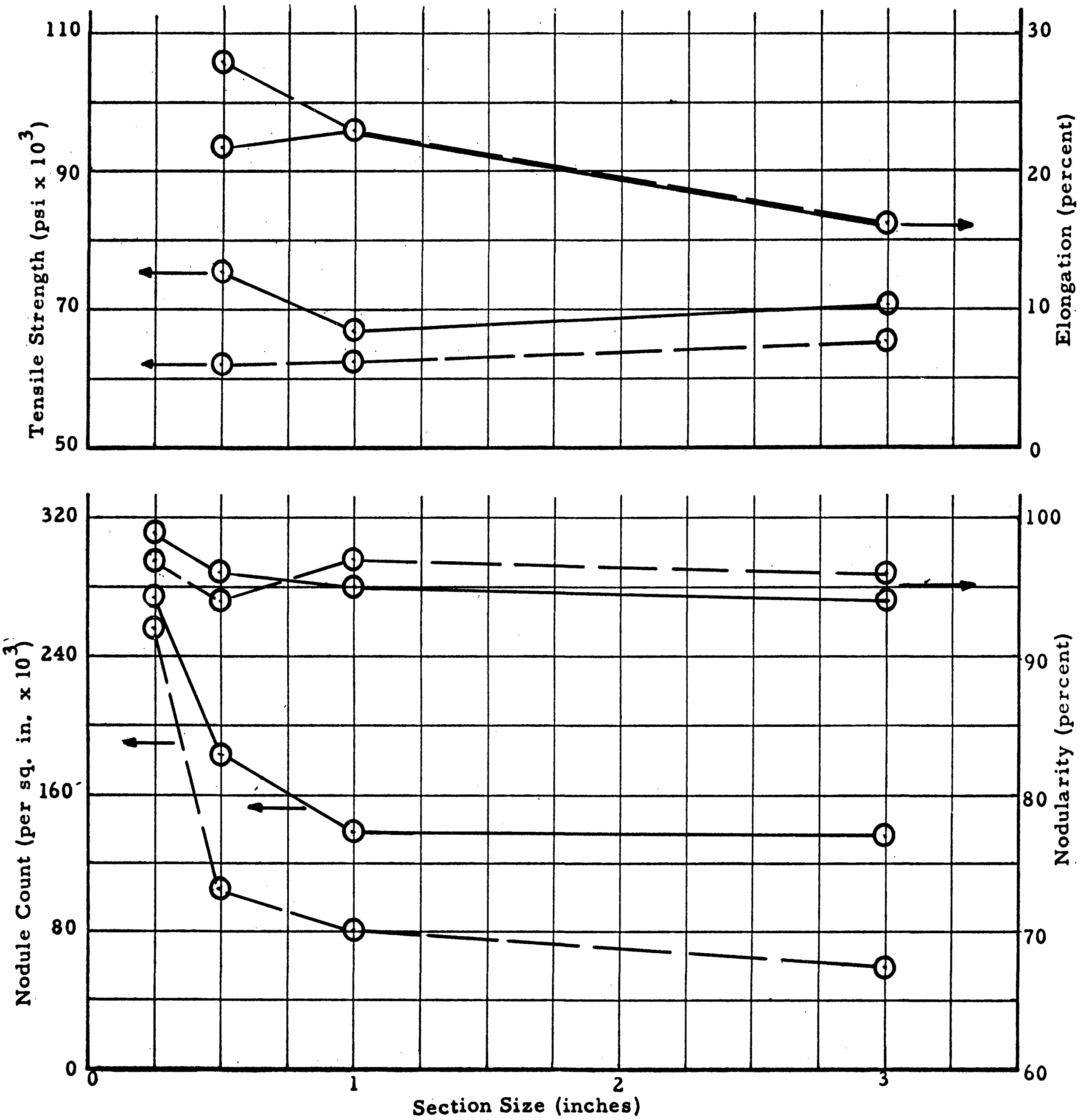



Figure 9

Heats No. 5+23, 18, 10+25

Inoculant: MgFeSi

Post-Inoculant: Varied

Purpose: Common inoculant; variable post inoculant. (Average values plotted)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 5+23 * | 0.5 | 3.78 | .42 | .020 | .013 | 2.23 | - | .046 | 4.52 |
| — — — | 18 ** | 0.5 | 3.81 | .43 | .022 | .015 | 2.23 | - | .042 | 4.55 |
| —·—·— | 10+25*** | 0.5 | 3.71 | .41 | .018 | .013 | 2.29 | - | .046 | 4.47 |

* 75% FeSi ** SS # 1 *** SS # 2

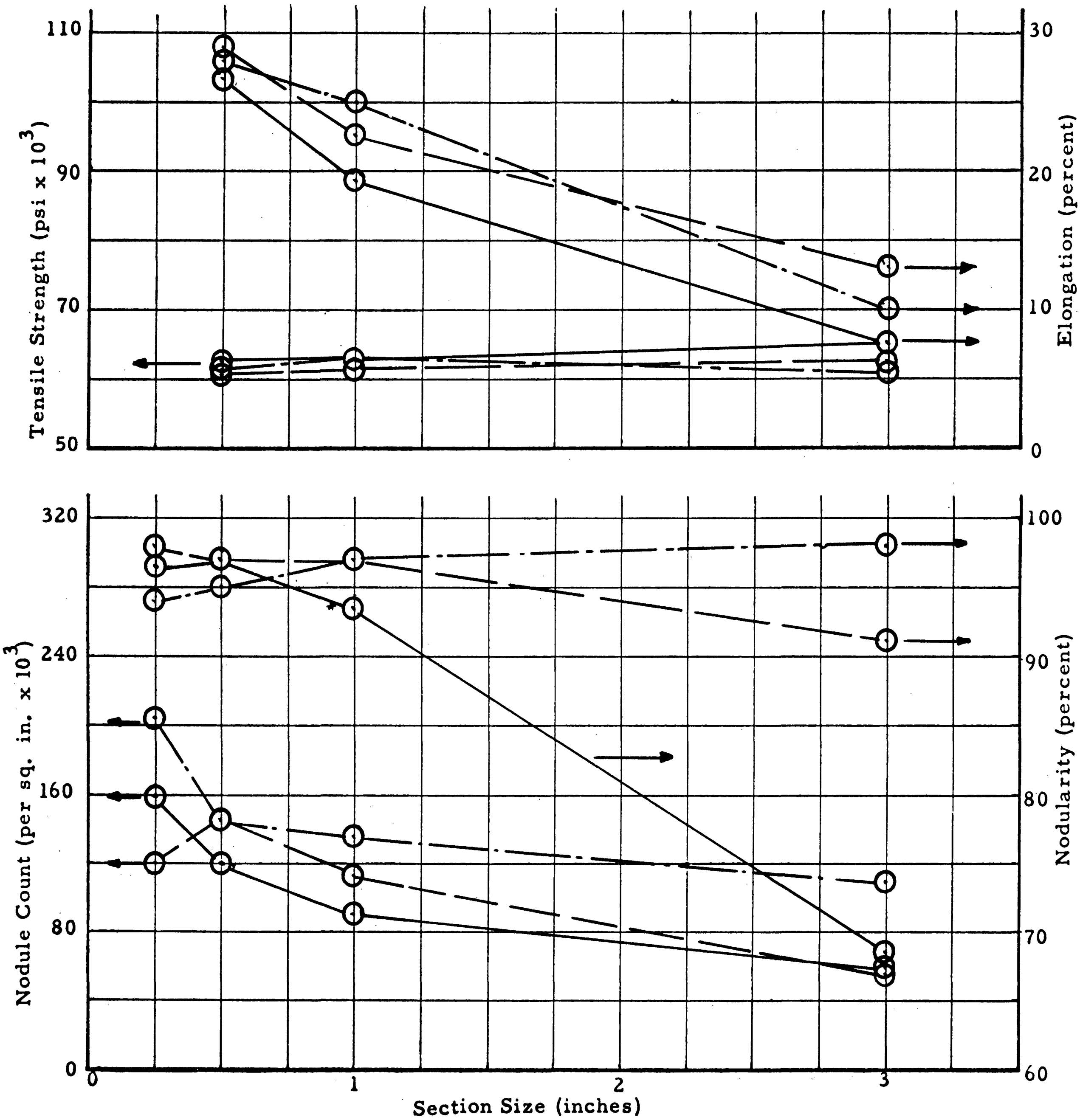



Figure 10

Heats No. 4+14, 19+21, 11+26
Inoculant: CeMgFeSi
Post-Inoculant: Varied

Purpose: Common inoculant; variable post inoculant. (Average values plotted)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (———) | 4+14 * | 0.5 | 3.89 | .42 | .019 | .014 | 2.26 | - | .037 | 4.65 |
| (— — —) | 19+21** | 0.5 | 3.81 | .43 | .022 | .015 | 2.23 | - | .042 | 4.55 |
| (— · —) | 11+26*** | 0.5 | 3.77 | .41 | .018 | .013 | 2.54 | - | .046 | 4.61 |

* 75% FeSi  ** SS # 1  *** SS # 2

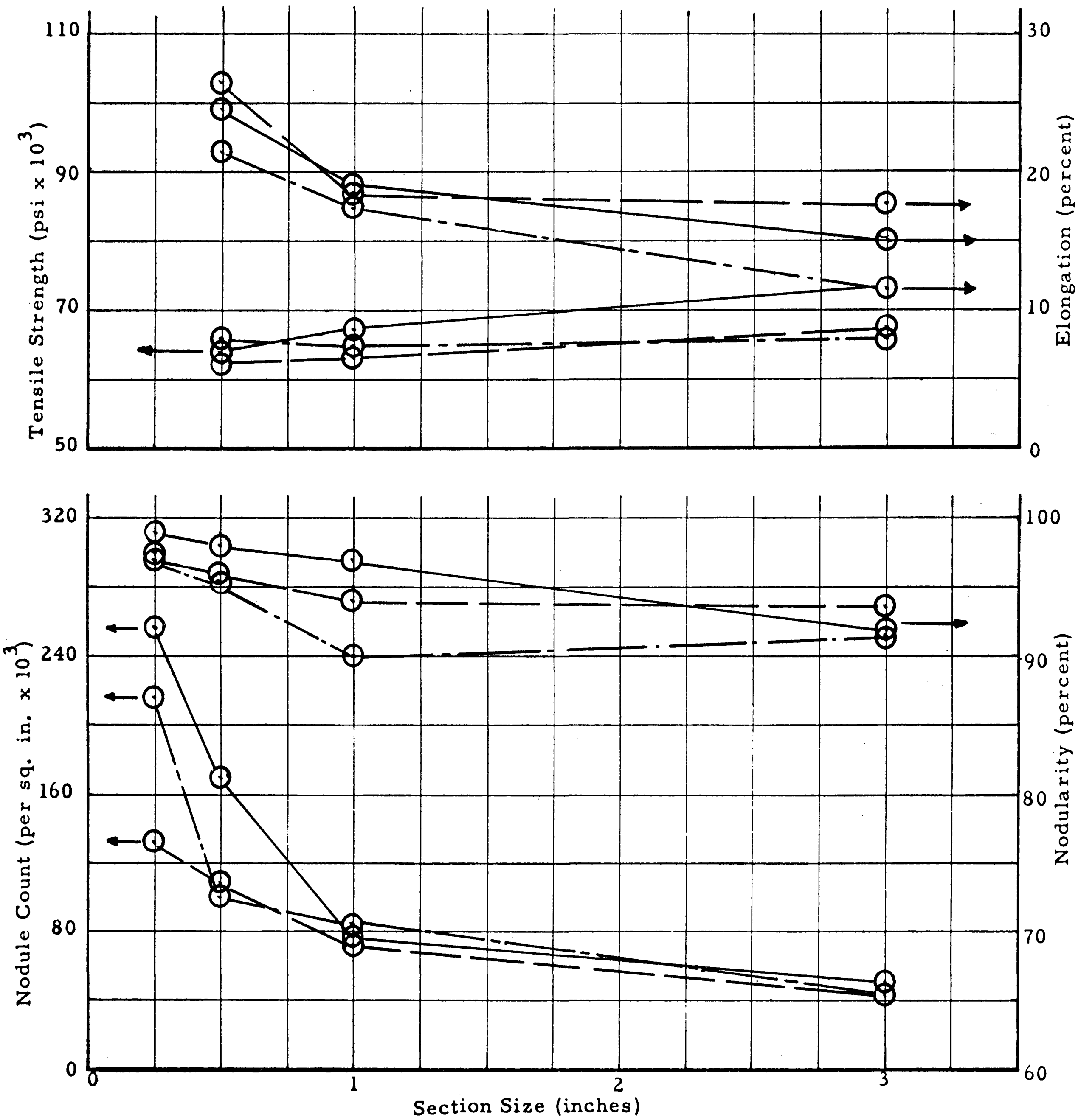



Figure 11

Heats No. 16+24, 20+22, 12+27
Inoculant: NiMg
Post-Inoculant: Varied

Purpose: Common inoculant; variable post inoculant. (Average values plotted)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 16+24* | 0.5 | 3.87 | .42 | .017 | .013 | 2.30 | - | .048 | 4.63 |
| — — | 20+22** | 0.5 | 3.91 | .44 | .019 | .011 | 2.37 | - | .042 | 4.71 |
| —·— | 12+27*** | 0.5 | 3.77 | .43 | .016 | .011 | 2.36 | - | .053 | 4.56 |

* 75% FeSi  ** SS # 1  *** SS # 2

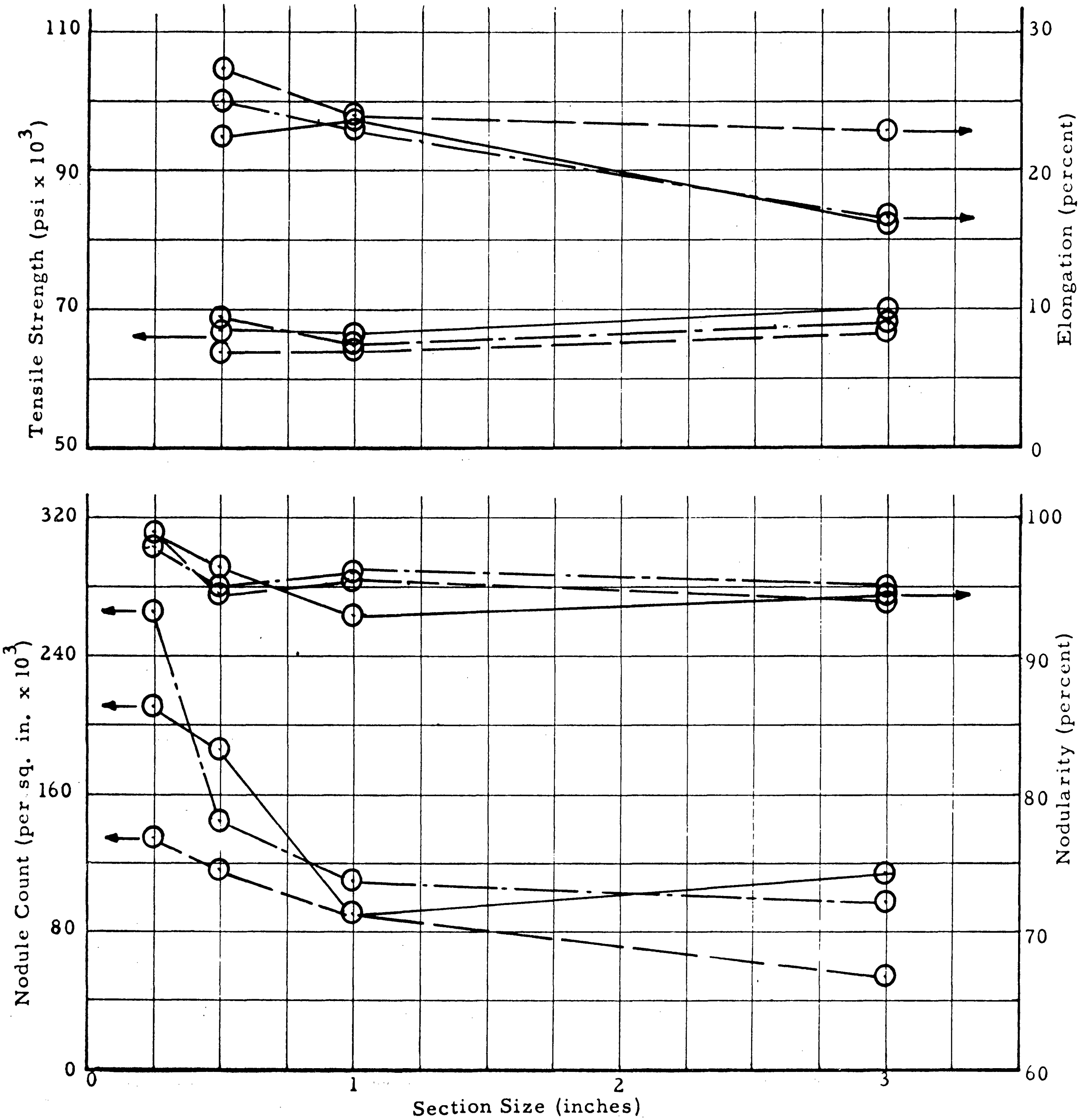



Figure 12

Heats No. 4+14, 5+23, 16+24

Inoculant: Varied

Post-Inoculant: 75% FeSi

Purpose: Variable inoculant; common post inoculant. (Average values plotted)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 4+14* | 0.5 | 3.89 | .42 | .019 | .014 | 2.26 | - | .037 | 4.65 |
| — — | 5+23** | 0.5 | 3.78 | .42 | .020 | .013 | 2.23 | - | .046 | 4.52 |
| —·— | 16+24*** | 0.5 | 3.87 | .42 | .017 | .013 | 2.30 | .48 | .048 | 4.63 |

* CeMgFeSi ** MgFeSi *** NiMg

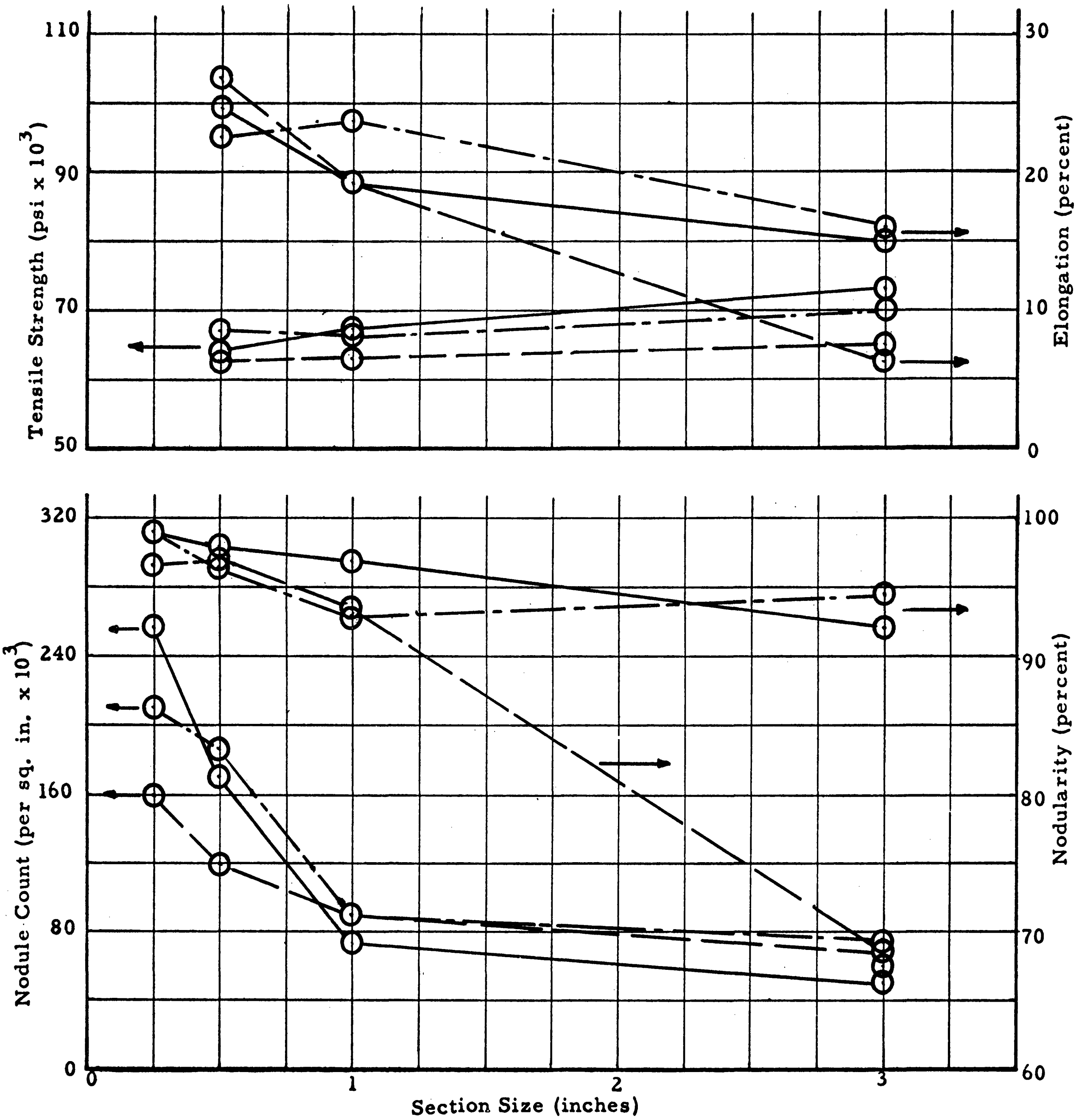



Figure 13

Heats No. 19+21, 18, 20+22
Inoculant: Varied
Post-Inoculant: SS # 1

Purpose: Variable inoculant; common post inoculant. (Average values plotted)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| —— | 19+21* | 0.5 | 3.92 | .44 | .022 | .012 | 2.35 | - | .037 | 4.60 |
| — — | 18** | 0.5 | 3.81 | .43 | .022 | .015 | 2.23 | - | .042 | 4.55 |
| —·— | 20+22*** | 0.5 | 3.91 | .44 | .019 | .011 | 2.37 | .42 | .042 | 4.71 |

* CeMgFeSi  ** MgFeSi  *** NiMg

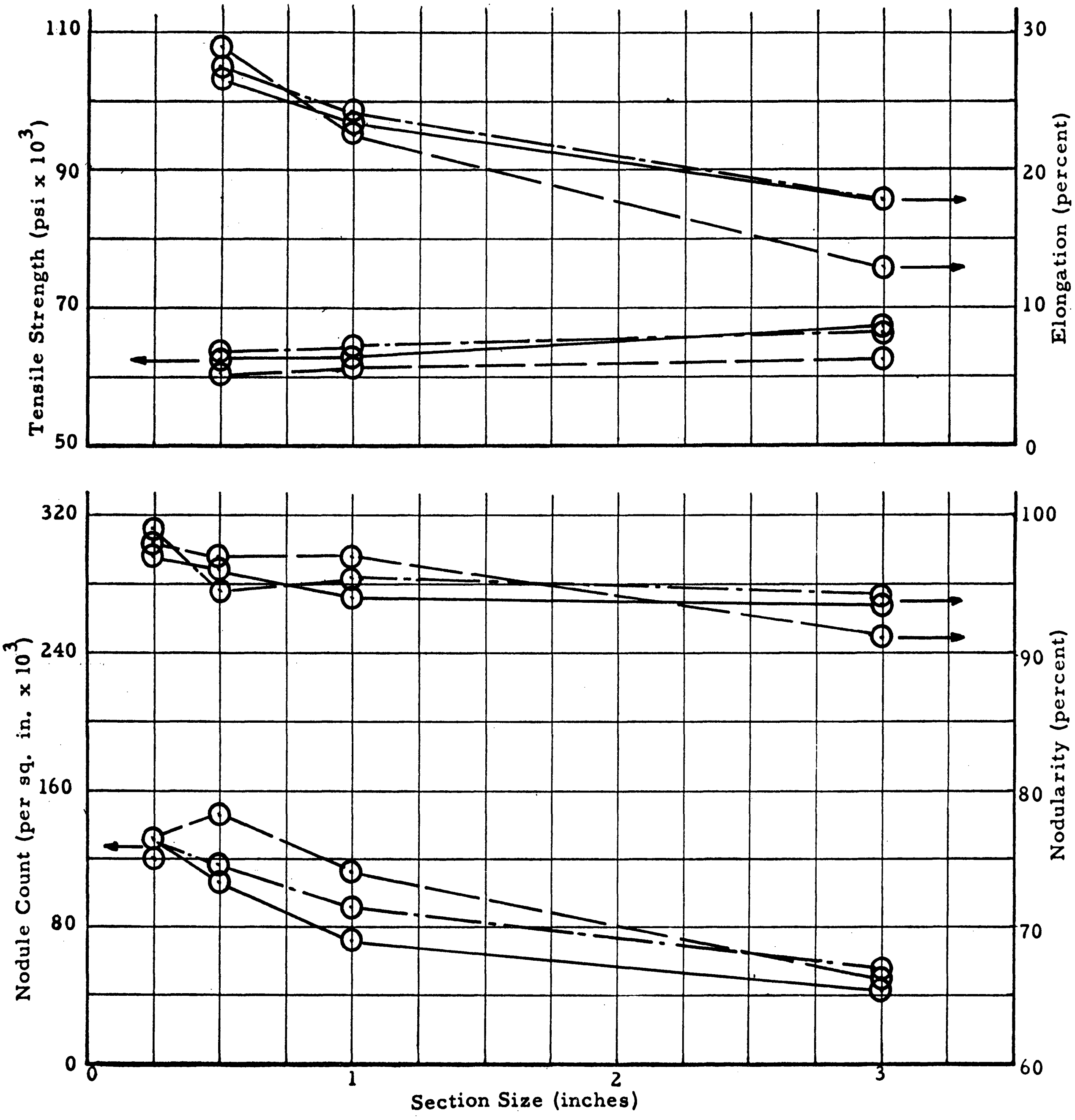



Figure 14

Heats No. 11+26, 10+25, 12+27

Inoculant: Varied

Post-Inoculant: SS # 2

Purpose: Variable inoculant; common post inoculant. (Average values plotted)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 11+26* | 0.5 | 3.77 | .41 | .018 | .013 | 2.54 | - | .046 | 4.61 |
| — — | 10+25** | 0.5 | 3.71 | .41 | .018 | .013 | 2.29 | - | .046 | 4.47 |
| —·— | 12+27*** | 0.5 | 3.77 | .43 | .016 | .011 | 2.36 | .54 | .053 | 4.56 |

* CeMgFeSi  ** MgFeSi  *** NiMg

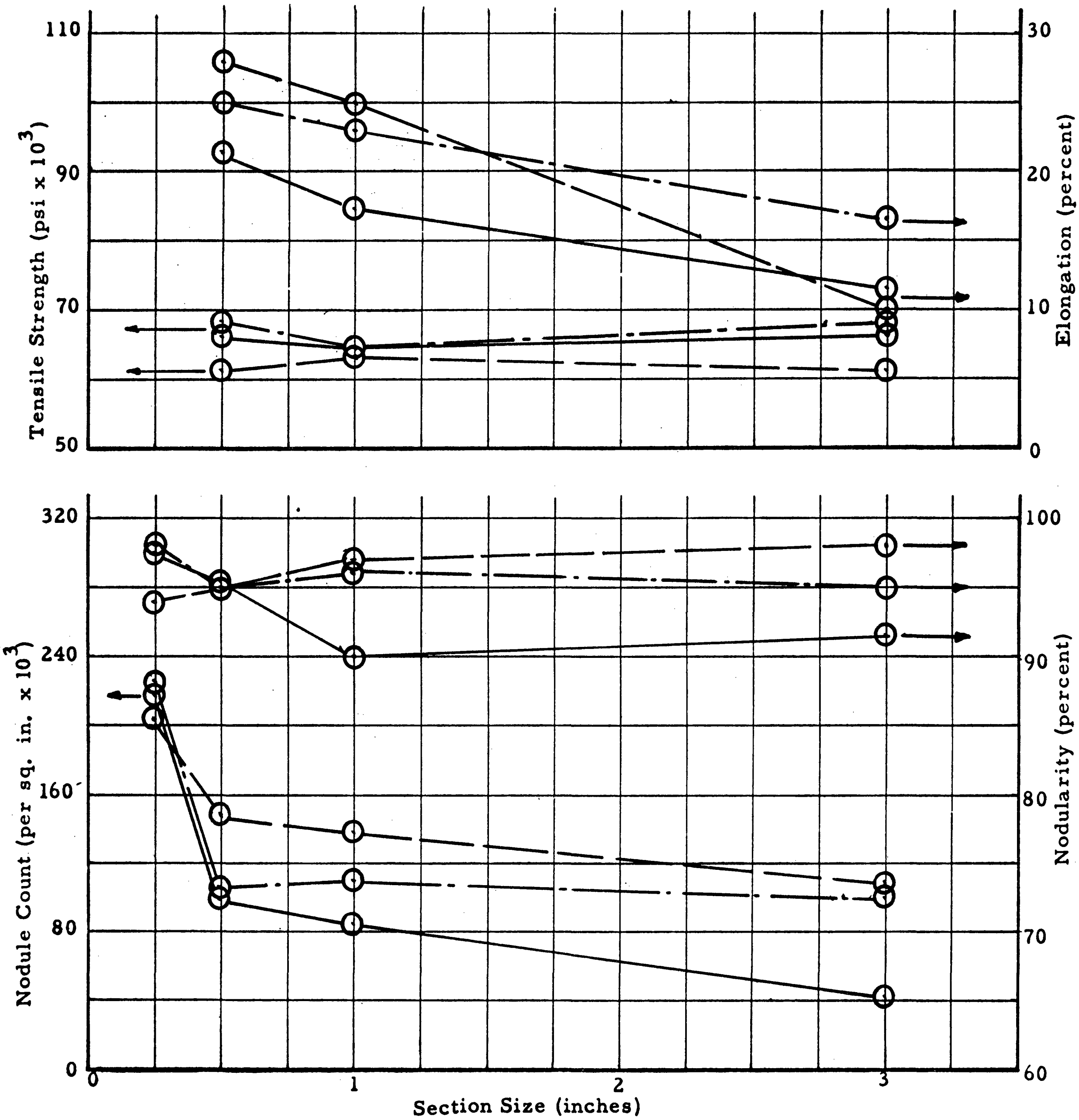



Figure 15

Heats No. 4+14, 28, 31
Inoculant: CeMgFeSi
Post-Inoculant: 75% FeSi

Purpose: Effect of variable amounts of silicon added as post inoculant.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 4+14 | 0.5 | 3.90 | .42 | .019 | .015 | 2.26 | - | .037 | 4.65 |
| — — | 28 | 0.25 | 3.87 | .46 | .018 | .017 | 2.22 | - | .042 | 4.61 |
| —·— | 31 | 1.0 | 3.72 | .44 | .018 | .019 | 2.28 | - | .036 | 4.48 |

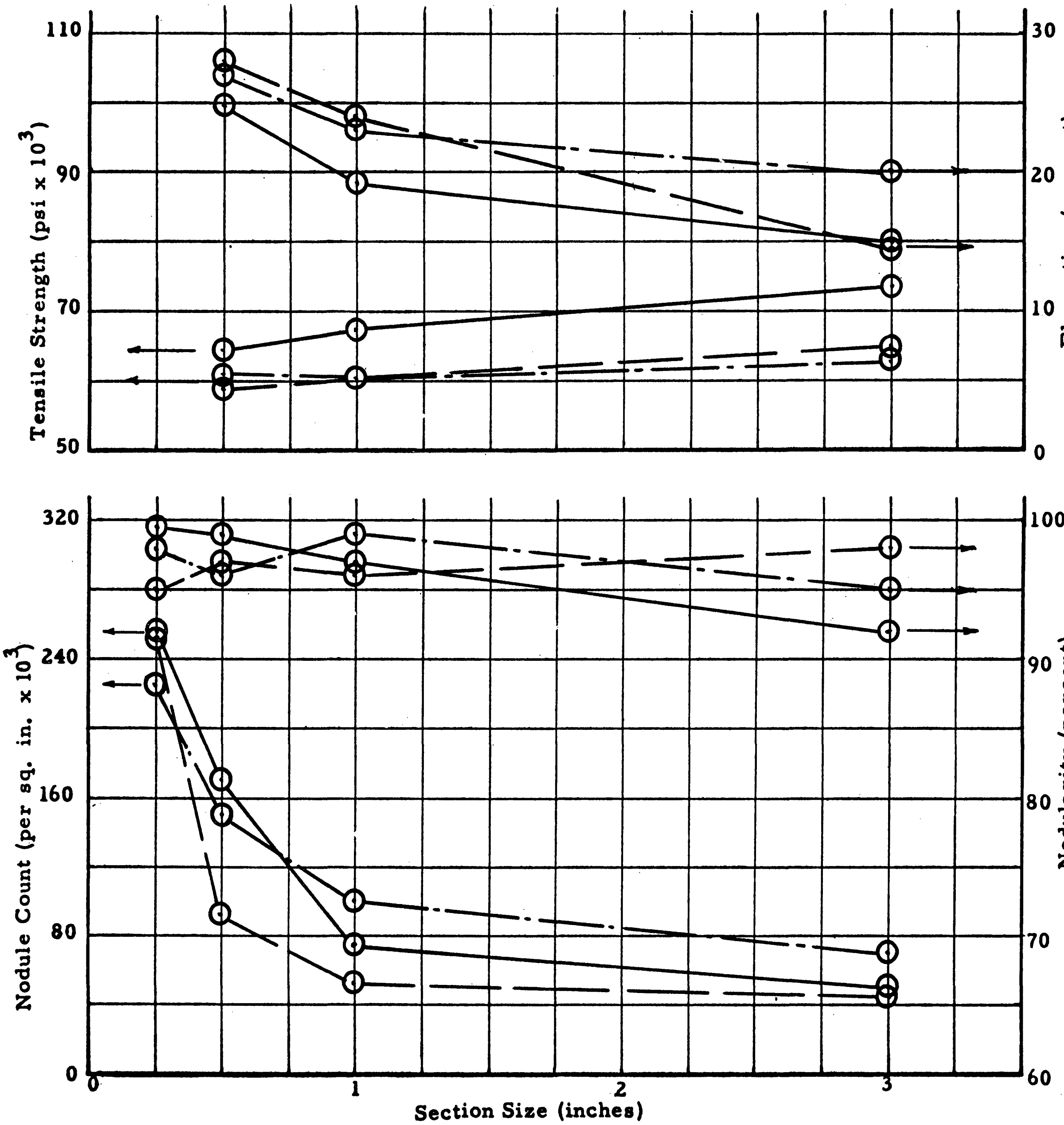



Figure 16

**Heats No.** 19+21, 29

**Inoculant:** CeMgFeSi

**Post-Inoculant:** SS # 1

**Purpose:** Effect of variable amounts of silicon added as post inoculant.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 19+21 | 0.5 | 3.92 | .44 | .022 | .012 | 2.35 | - | .038 | 4.70 |
| — — | 29 | 0.25 | 3.83 | .45 | .024 | .014 | 2.17 | - | .038 | 4.55 |

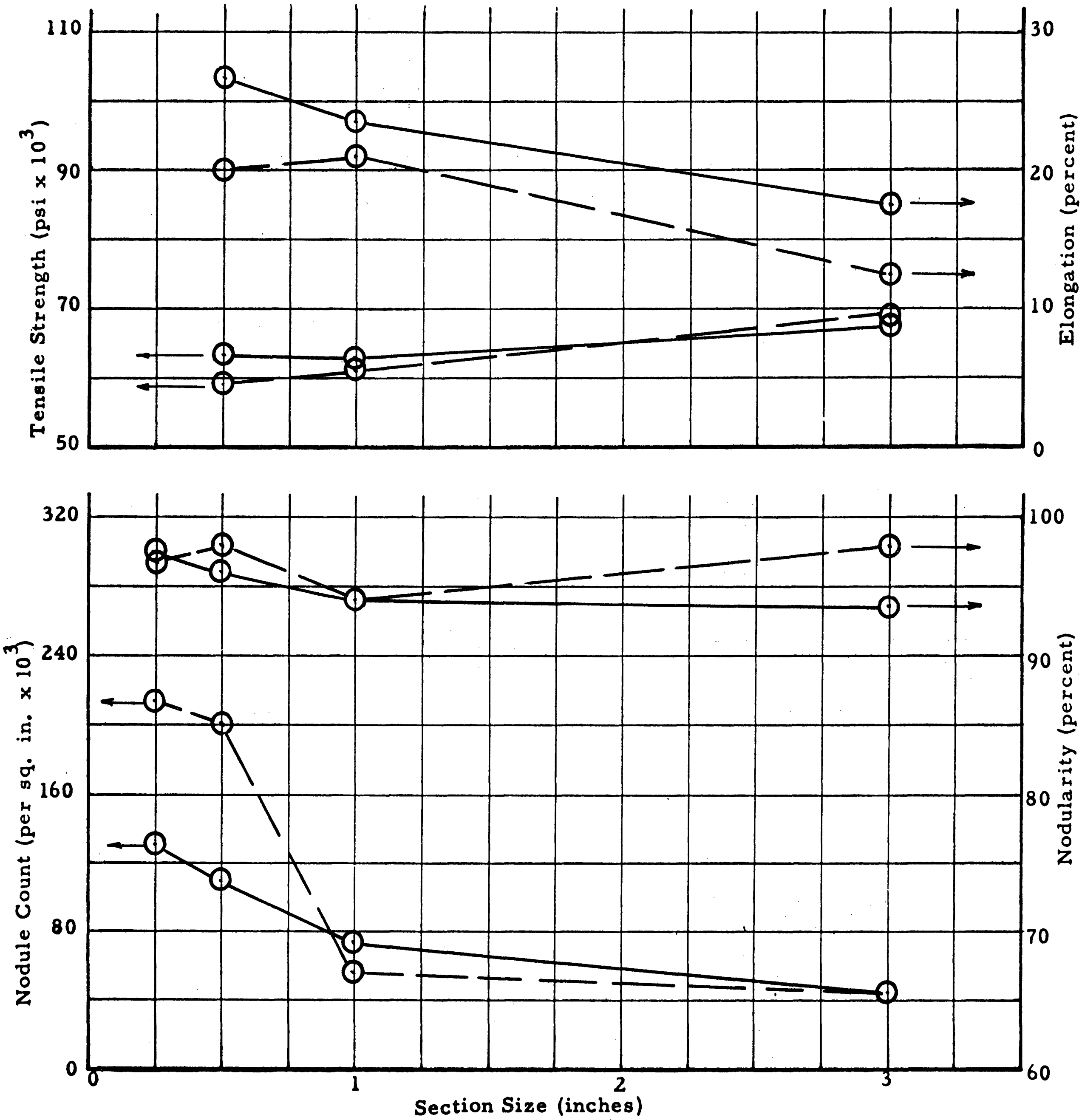



Figure 17

**Heats No.** 11+26, 30, 32
**Inoculant:** CeMgFeSi
**Post-Inoculant:** SS # 2

**Purpose:** Effect of variable amounts of silicon added as post inoculant.

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 11+26 | 0.5 | 3.77 | .41 | .018 | .013 | 2.54 | - | .046 | 4.61 |
| — — — | 30 | 0.25 | 3.79 | .46 | .027 | .014 | 2.18 | - | .036 | 4.52 |
| —·—· | 32 | 1.0 | 3.81 | .43 | .020 | .017 | 2.30 | - | .029 | 4.58 |

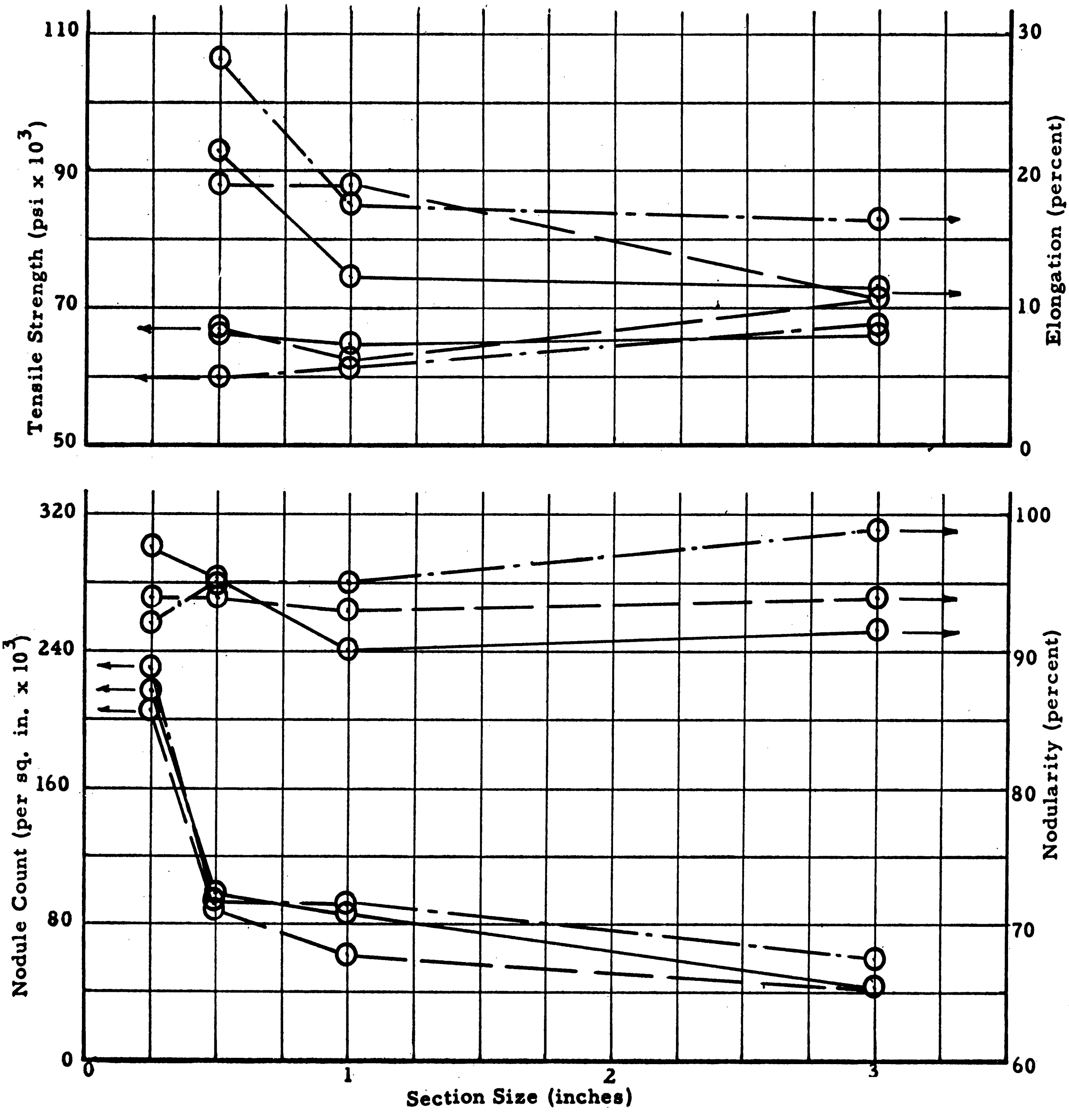



Figure 18

**Heats No.** 28, 29, 30
**Inoculant:** CeMgFeSi
**Post-Inoculant:** Varied

**Purpose:** Effect of low amounts of silicon added as post inoculant (Variable)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 28* | 0.25 | 3.87 | .46 | .018 | .017 | 2.22 | - | .042 | 4.61 |
| — — | 29** | 0.25 | 3.83 | .45 | .024 | .014 | 2.17 | - | .038 | 4.55 |
| —·— | 30*** | 0.25 | 3.79 | .46 | .027 | .014 | 2.18 | - | .036 | 4.52 |

* 75% FeSi ** SS # 1 *** SS # 2

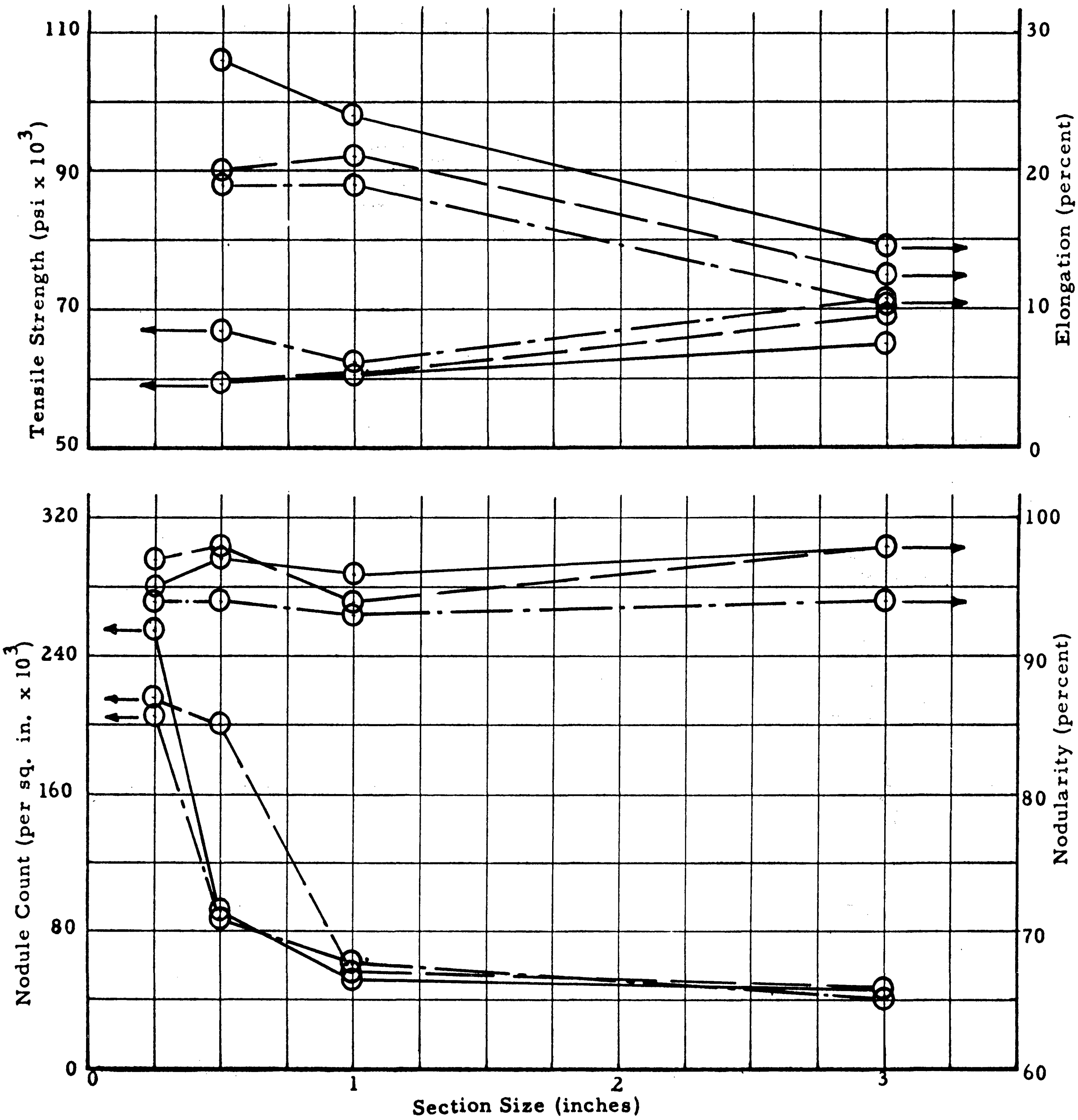



Figure 19

**Heats No.** 31, 32
**Inoculant:** CeMgFeSi
**Post-Inoculant:** Varied

**Purpose:** Effect of high amounts of silicon added as post inoculant. (Variable)

| Legend | Heat No. | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| (solid line) | 31* | 1.0 | 3.72 | .44 | .018 | .019 | 2.28 | - | .036 | 4.48 |
| (dashed line) | 32** | 1.0 | 3.81 | .43 | .020 | .017 | 2.30 | - | .029 | 4.58 |

* 75% FeSi  ** SS # 2

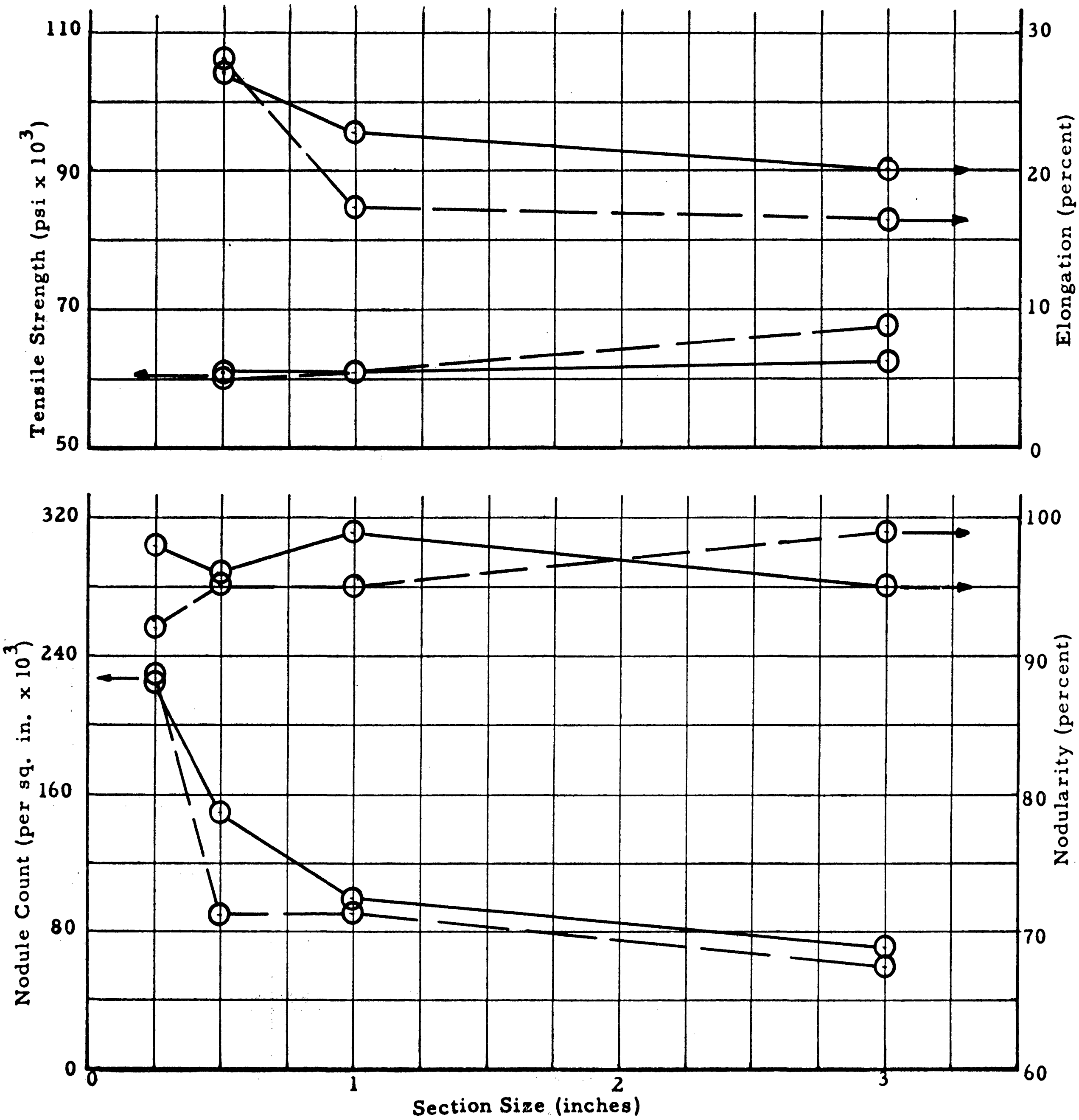



Figure 20

Heats No. 35, 36
Inoculant: MgFeSi
Post-Inoculant: Varied

Purpose: Effect of fading with variable post-inoculant

| Legend | Heat | Time | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| —— | 35* | 0 | 0.5 | 3.72 | .38 | .019 | .011 | 2.40 | - | .027 | 4.52 |
| —— | | 3 min. | - | 3.75 | - | - | - | 2.43 | - | .025 | 4.56 |
| —— | | 6 min. | - | 3.71 | - | - | - | 2.45 | - | .015 | 4.53 |
| — — | 36** | 0 | 0.5 | 3.67 | .33 | .018 | .010 | 2.47 | - | .042 | 4.49 |
| — — | | 3 min. | - | 3.74 | - | - | - | 2.41 | - | .027 | 4.54 |
| — — | | 6 min. | - | 3.68 | - | - | - | 2.42 | - | .019 | 4.49 |

* 75% FeSi  ** SS # 2

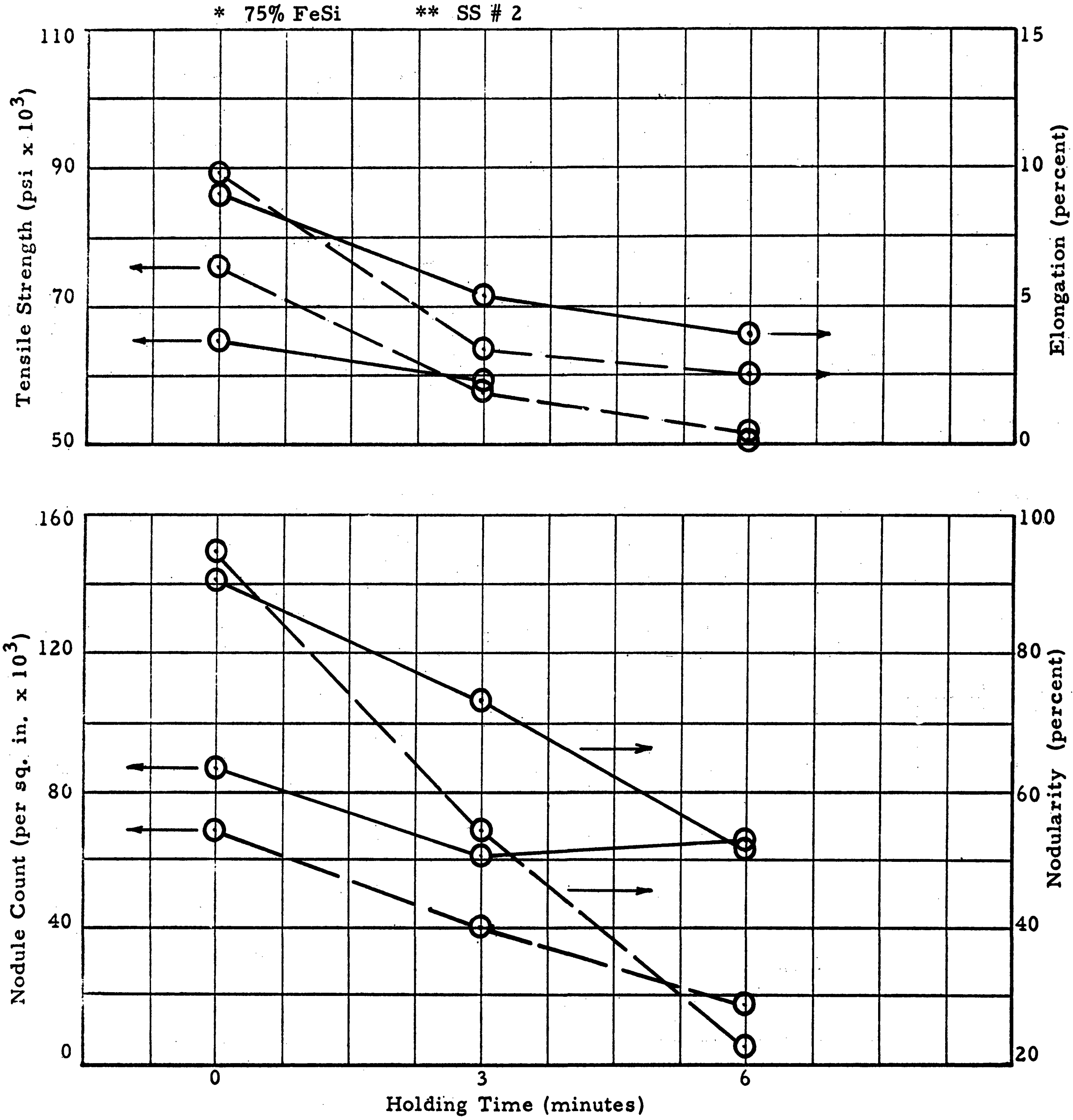



Figure 21

Heats No. 37, 38
Inoculant: CeMgFeSi
Post-Inoculant: Varied

Purpose: Effect of fading with variable post-inoculant.

| Legend | Heat | Time | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 37* | 0 | 0.5 | 3.87 | .50 | .016 | .012 | 2.44 | - | .035 | 4.68 |
| | | 3 min. | - | 3.78 | - | - | - | 2.55 | - | .031 | 4.63 |
| | | 6 min. | - | 3.78 | - | - | - | 2.51 | - | .019 | 4.62 |
| | 38** | 0 | 0.5 | 3.76 | .51 | .018 | .012 | 2.58 | - | .045 | 4.62 |
| | | 3 min. | - | 3.75 | - | - | - | 2.69 | - | .032 | 4.65 |
| | | 6 min. | - | 3.80 | - | - | - | 2.72 | - | .024 | 4.71 |

* 75% FeSi ** SS # 2

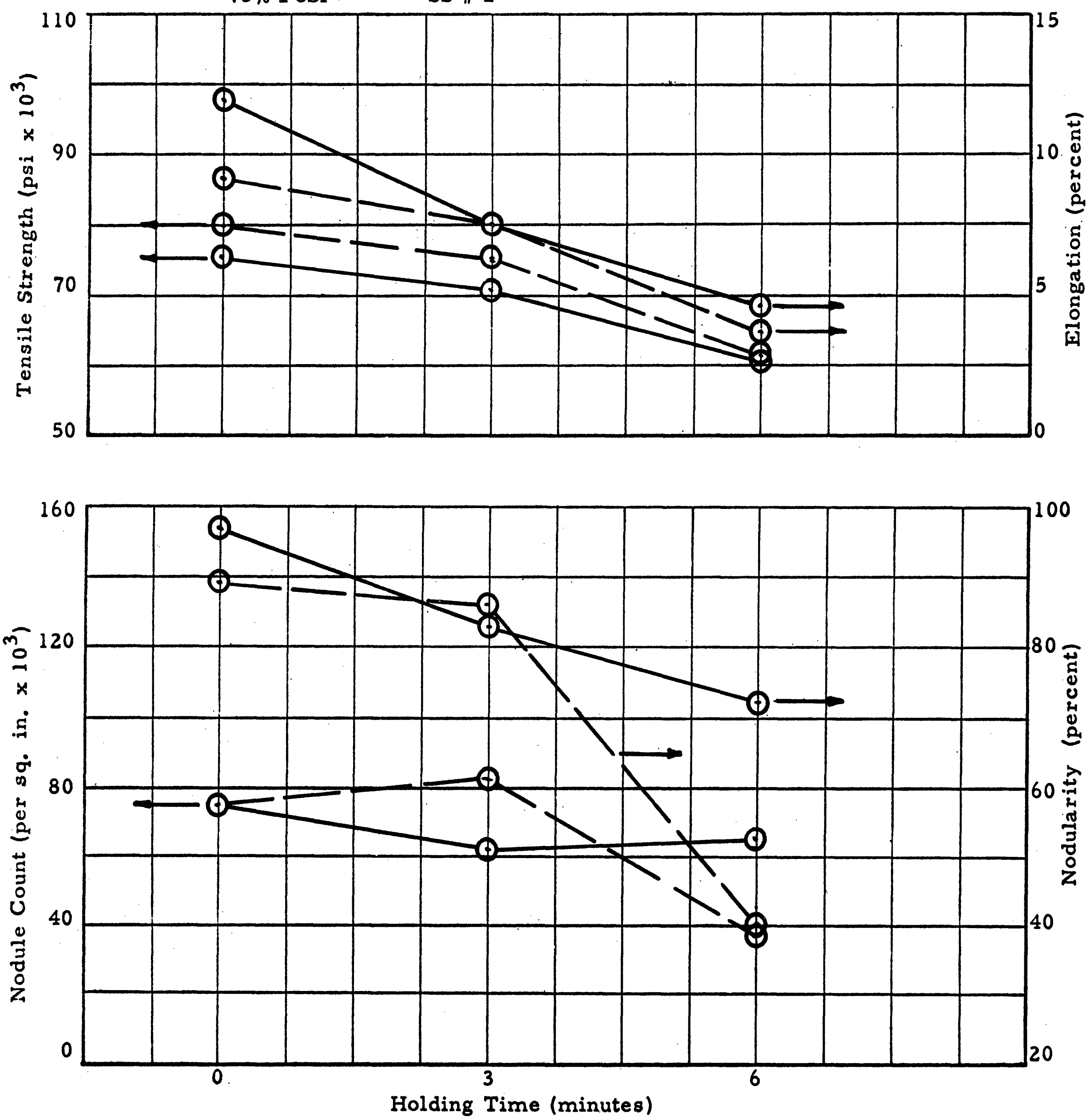



Figure 22

Heats No. 35, 37
Inoculant: Varied
Post-Inoculant: 75% FeSi

Purpose: Effect of fading with variable inoculant.

| Legend | Heat | Time | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ——— | 35* | 0 | 0.5 | 3.72 | .38 | .019 | .011 | 2.40 | - | .027 | 4.52 |
| ——— | | 3 min. | - | 3.75 | - | - | - | 2.43 | - | .025 | 4.56 |
| ——— | | 6 min. | - | 3.71 | - | - | - | 2.45 | - | .015 | 4.53 |
| — — | 37** | 0 | 0.5 | 3.87 | .50 | .016 | .012 | 2.44 | - | .035 | 4.68 |
| — — | | 3 min. | - | 3.78 | - | - | - | 2.55 | - | .031 | 4.63 |
| — — | | 6 min. | - | 3.78 | - | - | - | 2.51 | - | .019 | 4.62 |

* MgFeSi ** CeMgFeSi

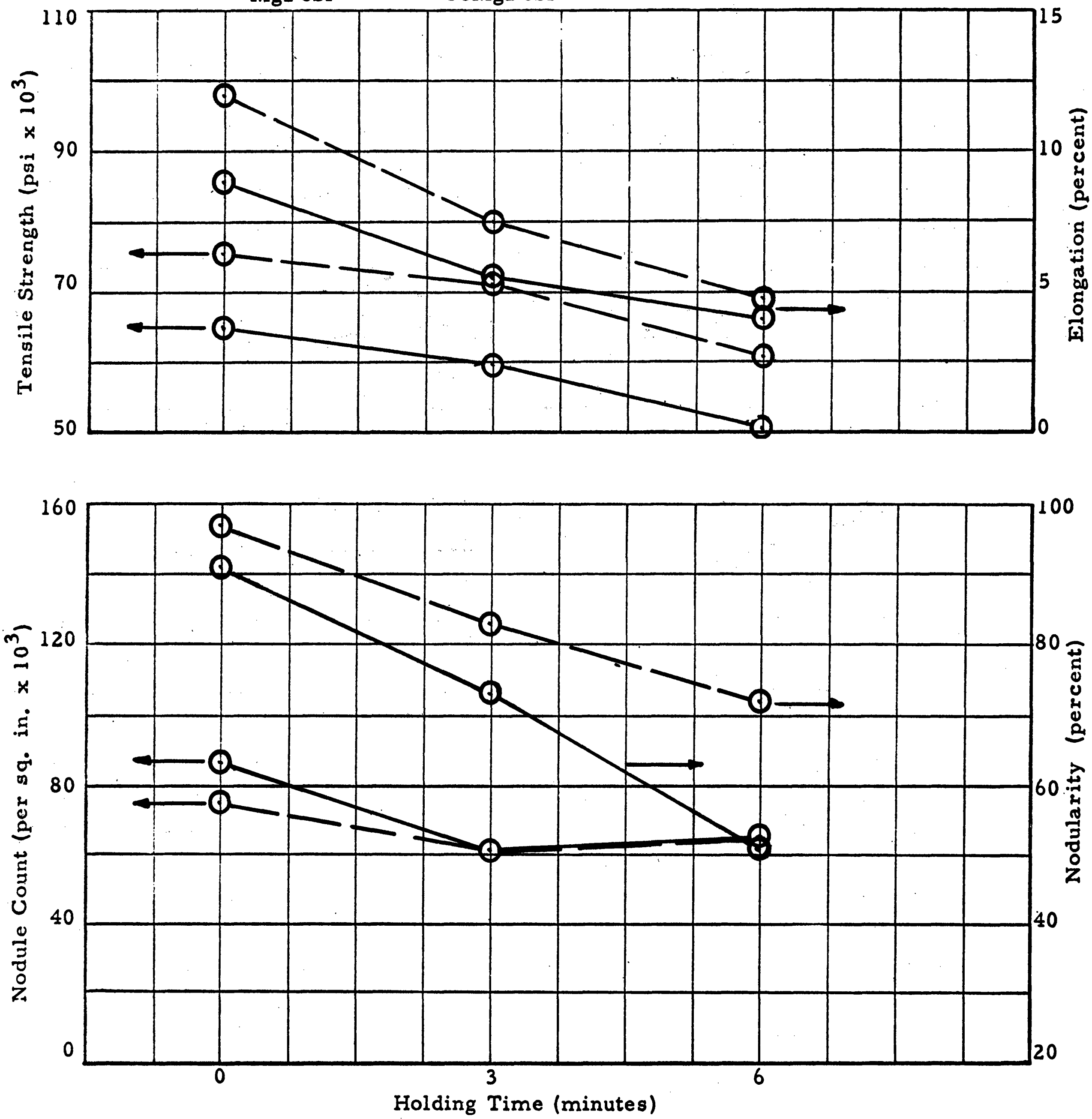



Figure 23

Heats No. 36, 38
Inoculant: Varied
Post-Inoculant: SS # 2

Purpose: Effect of fading with variable inoculant.

| Legend | Heat | Time | Si Added | C | Mn | P | S | Si | Ni | Mg | C.E. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| solid | 36* | 0 | 0.5 | 3.67 | .33 | .018 | .010 | 2.47 | - | .042 | 4.49 |
| solid | | 3 min. | - | 3.74 | - | - | - | 2.41 | - | .027 | 4.54 |
| solid | | 6 min. | - | 3.68 | - | - | - | 2.42 | - | .019 | 4.49 |
| dashed | 38** | 0 | 0.5 | 3.76 | .51 | .018 | .012 | 2.58 | - | .045 | 4.62 |
| dashed | | 3 min. | - | 3.75 | - | - | - | 2.69 | - | .032 | 4.65 |
| dashed | | 6 min. | - | 3.80 | - | - | - | 2.72 | - | .024 | 4.71 |

* MgFeSi ** CeMgFeSi

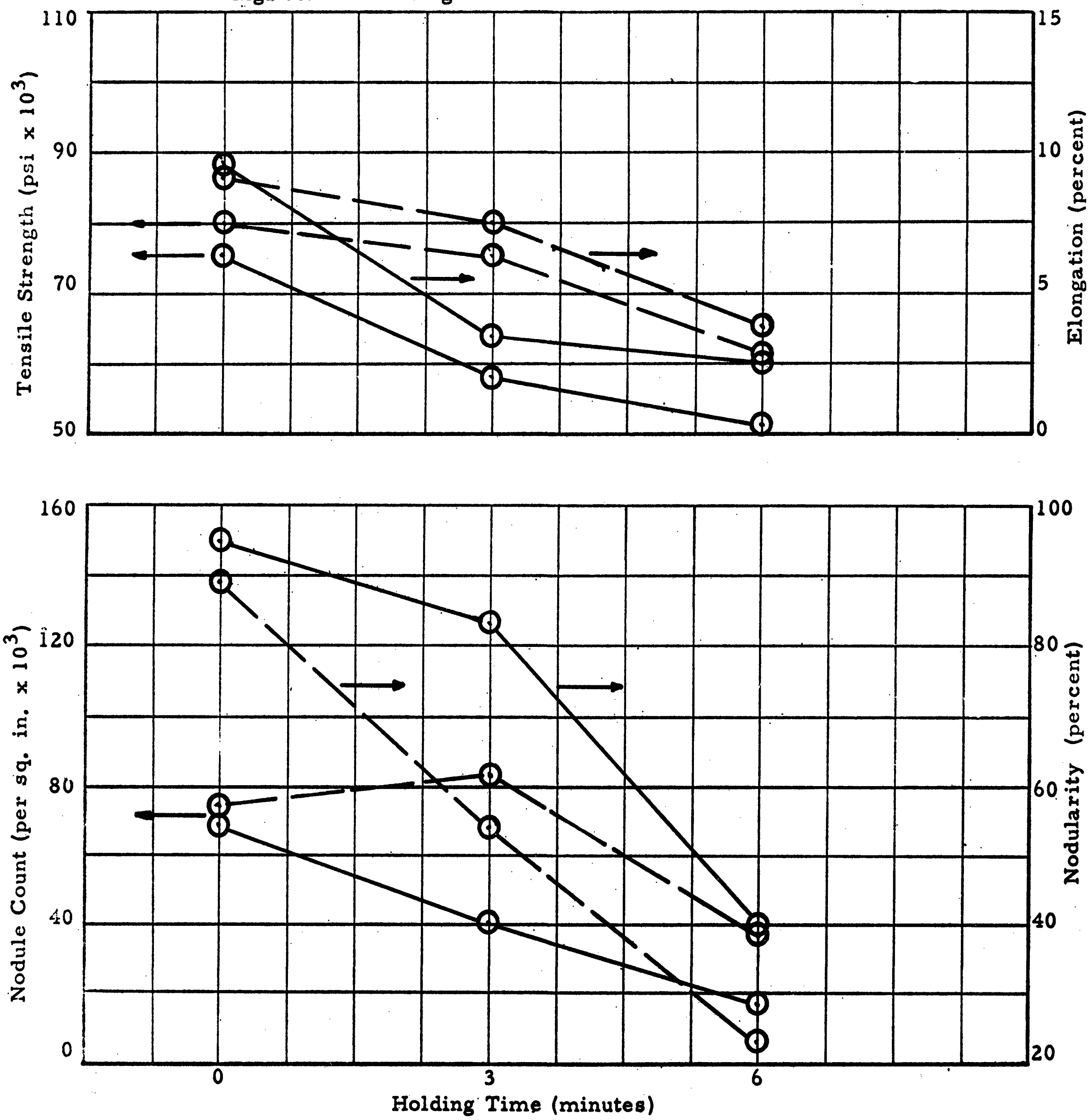
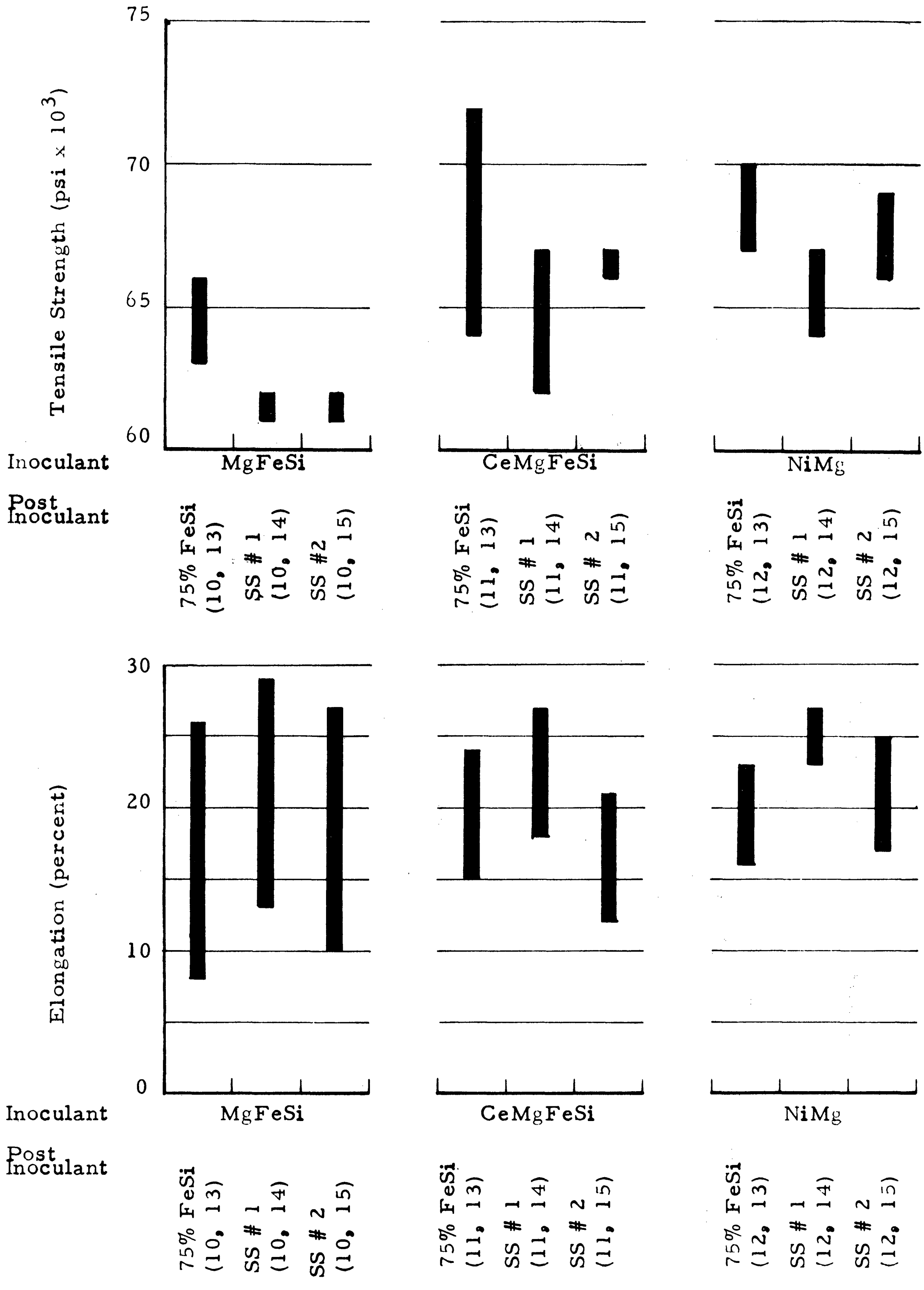
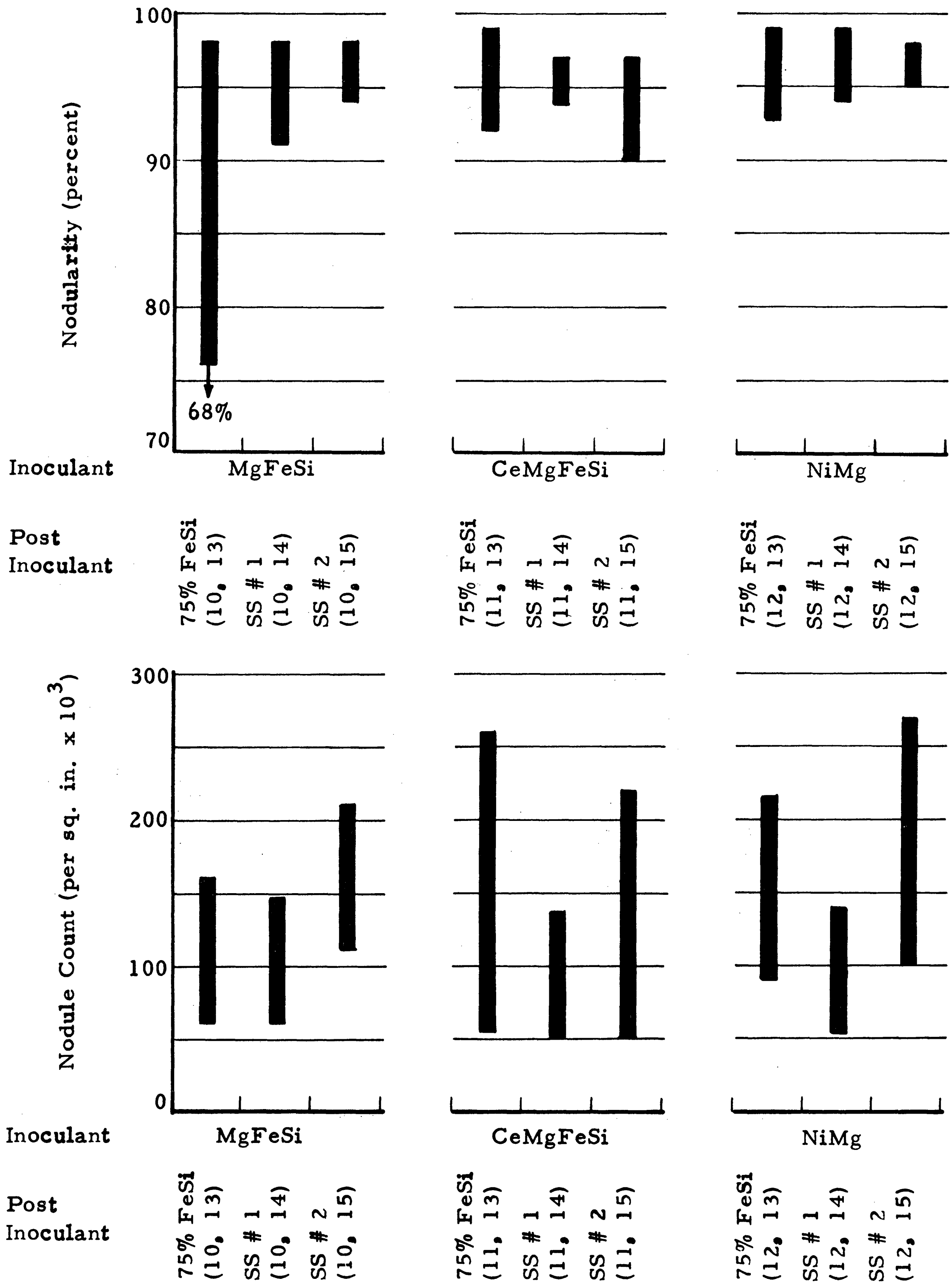



Figure 24



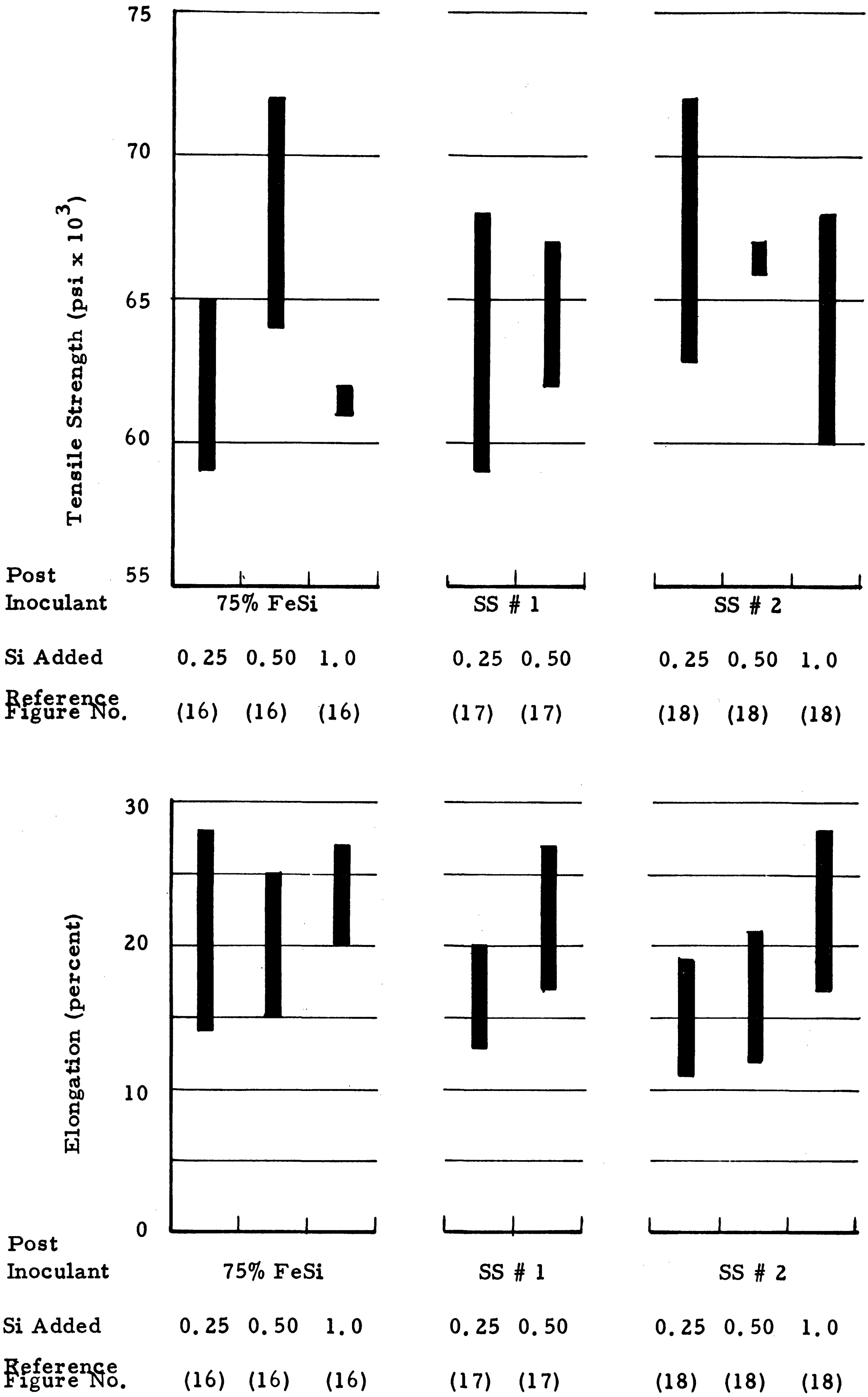

(Numbers in parentheses refer to figures showing size dependency)

Figure 25



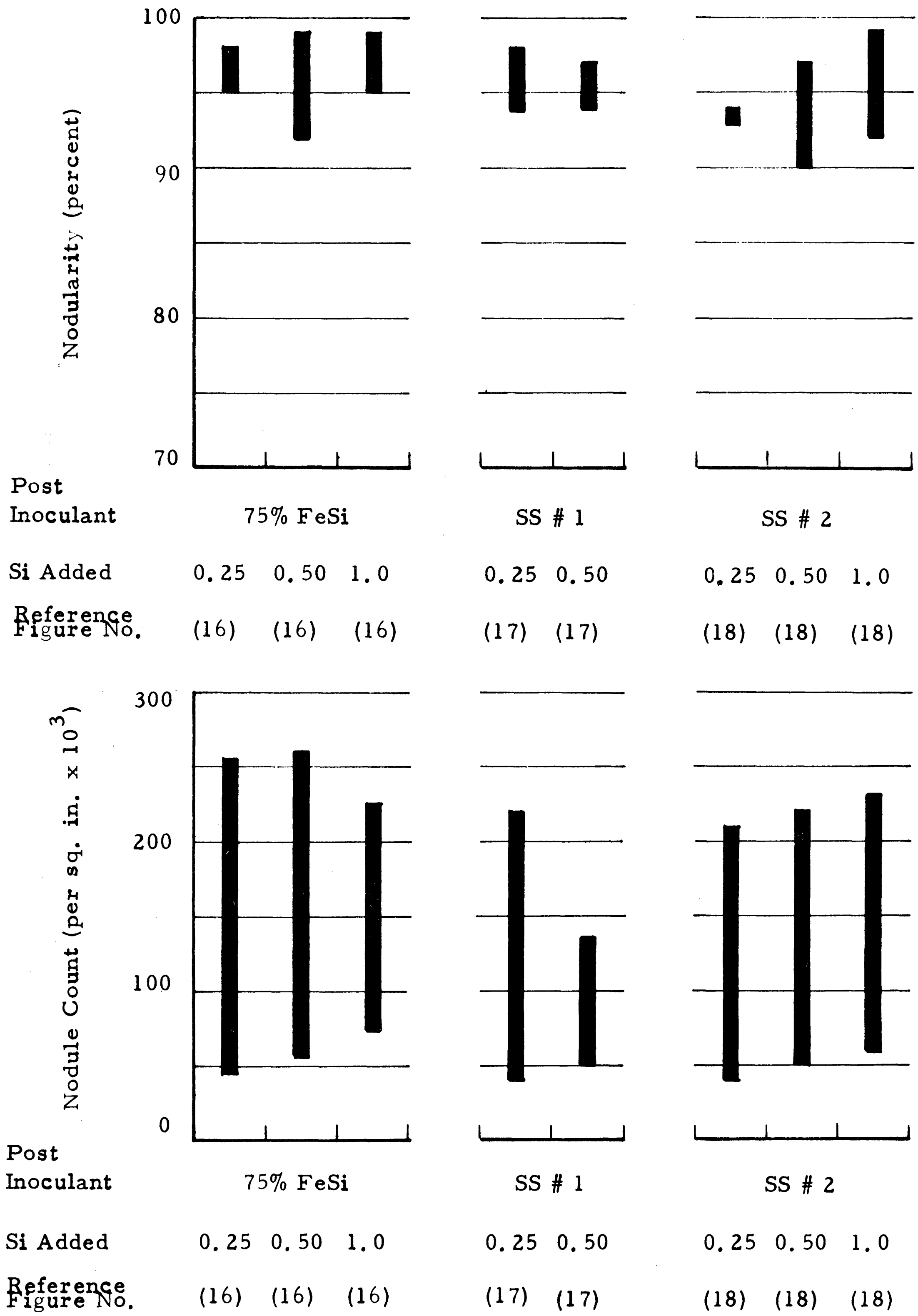

(Numbers in parentheses refer to figures showing size dependency)

Figure 26



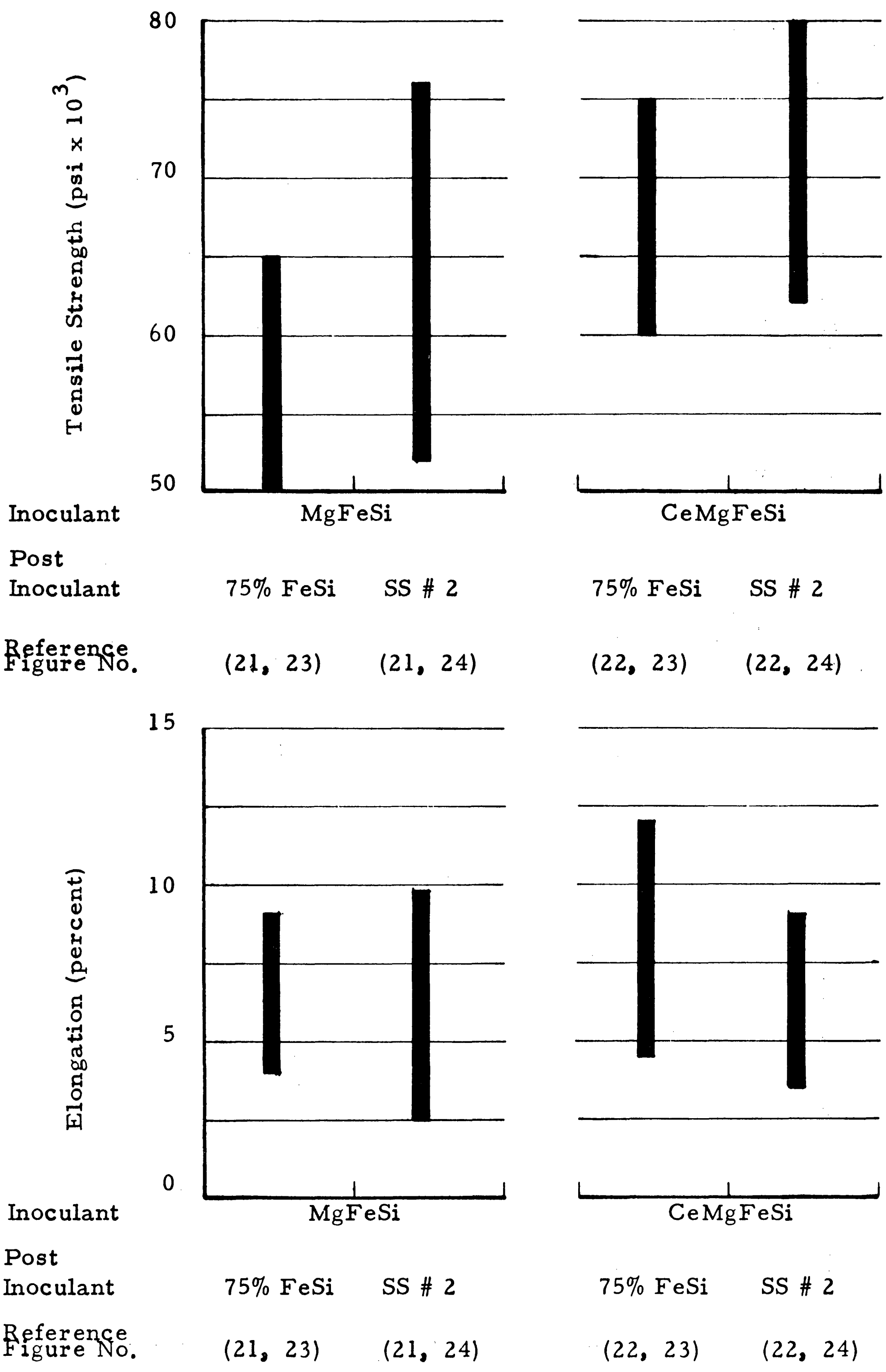

(Numbers in parentheses refer to figures showing size dependency)

Figure 27



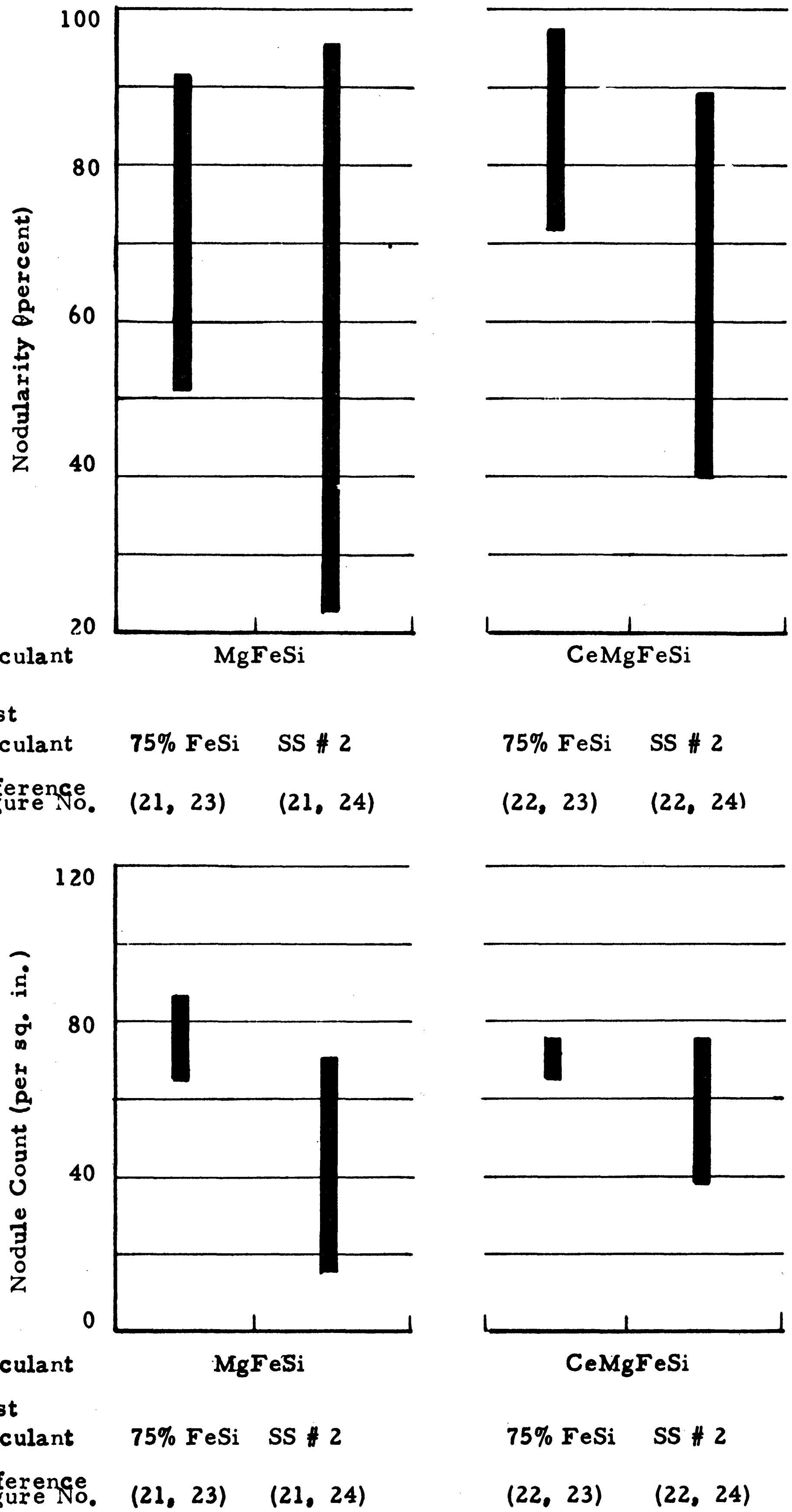

(Numbers in parentheses refer to figures showing size dependency)

Figure 28




(Numbers in parentheses refer to figures showing time dependency)

Figure 29




(Numbers in parentheses refer to figures showing time dependency)

Figure 30

| Legend | | Heat No. | Inoculant | Post Inoculant |
|---|---|---|---|---|
| ○ | ——— | 35 | MgFeSi | 75% FeSi |
| □ | — — | 36 | MgFeSi | SS # 2 |
| △ | —·— | 37 | CeMgFeSi | 75% FeSi |
| ◇ | ------ | 38 | CeMgFeSi | SS # 2 |

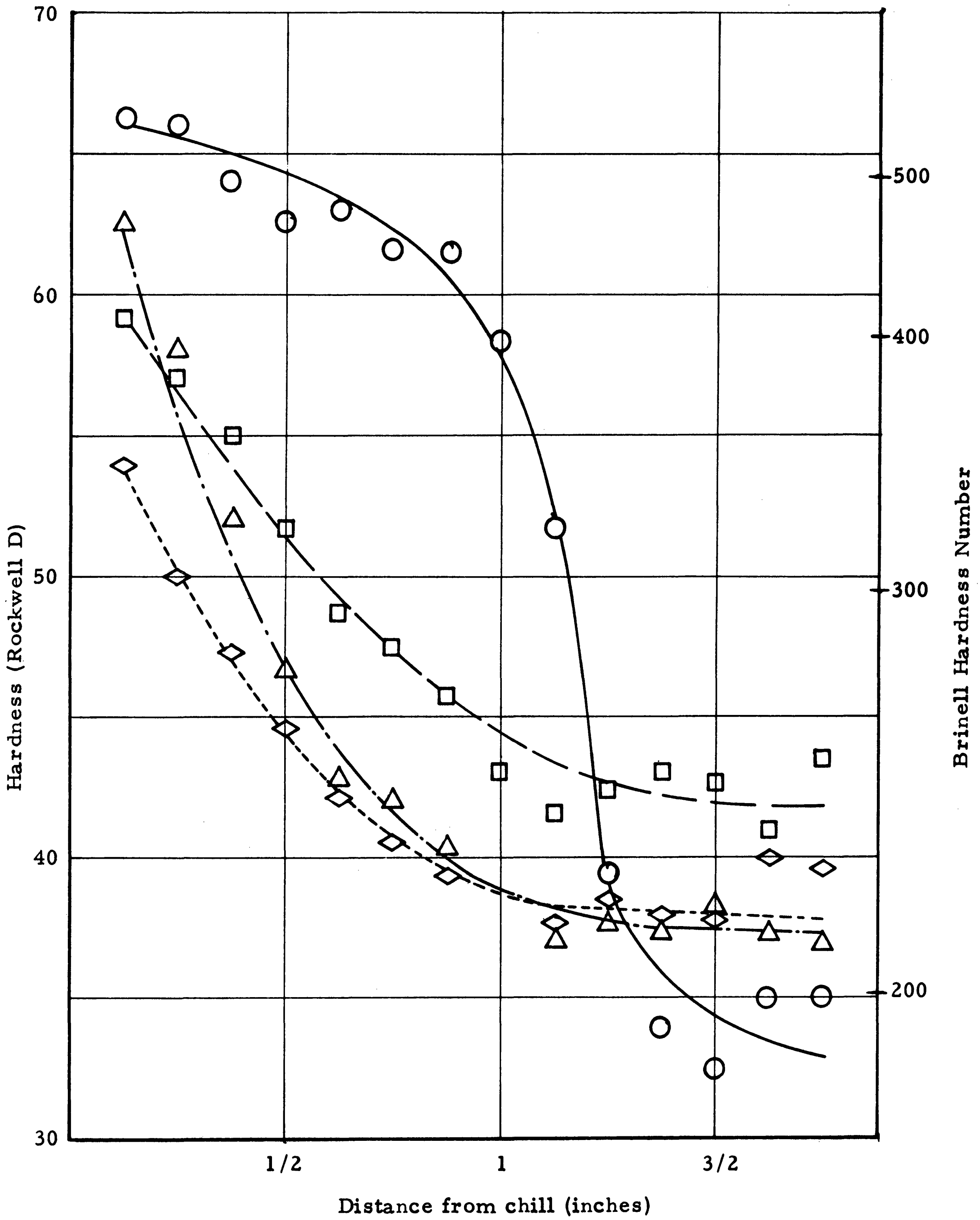



Figure 31

| Legend | | Heat No. | Inoculant | Post Inoculant |
|---|---|---|---|---|
| ○ | ——— | 35 | MgFeSi | 75% FeSi |
| □ | — — — | 36 | MgFeSi | SS # 2 |
| △ | — - — | 37 | CeMgFeSi | 75% FeSi |
| ◇ | - - - - - | 38 | CeMgFeSi | SS # 2 |

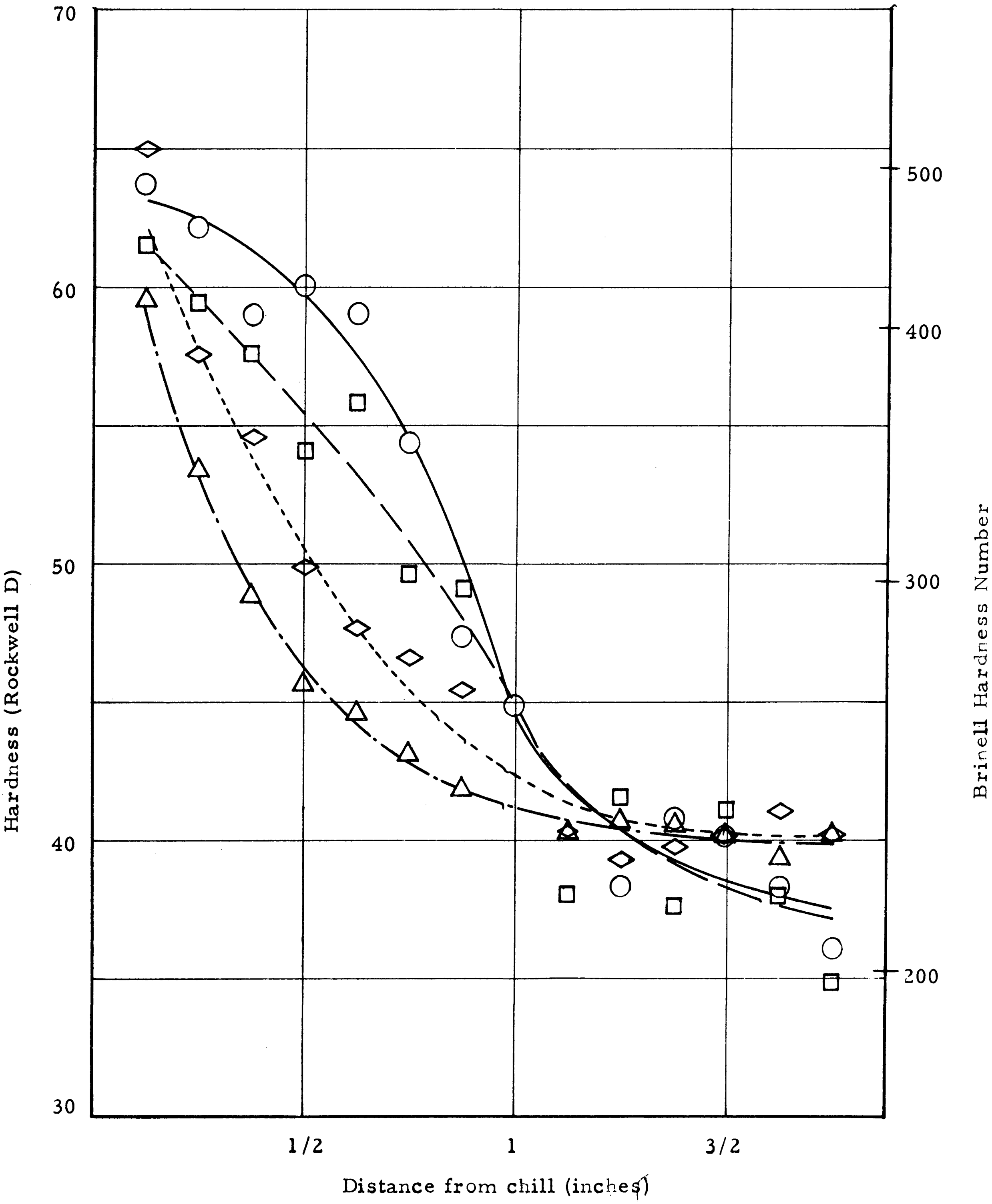



Figure 32

| Legend | Heat No. | Inoculant | Post Inoculant |
|---|---|---|---|
| ○ (———) | 35 | 75% FeSi | MgFeSi |
| □ (— — —) | 36 | SS # 2 | MgFeSi |
| △ (— - —) | 37 | 75% FeSi | CeMgFeSi |
| ◇ (- - - - -) | 38 | SS # 2 | CeMgFeSi |

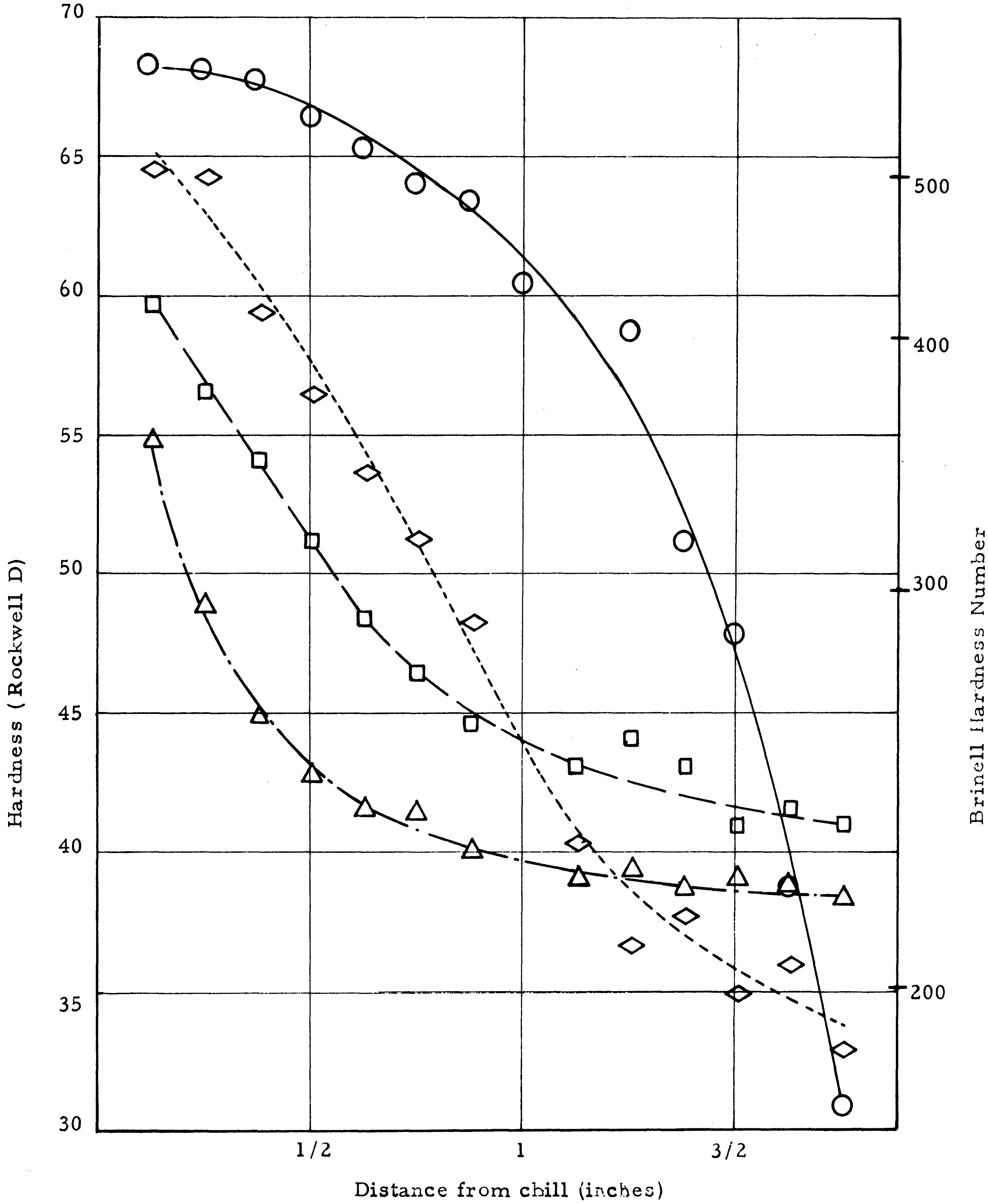



Figure 33

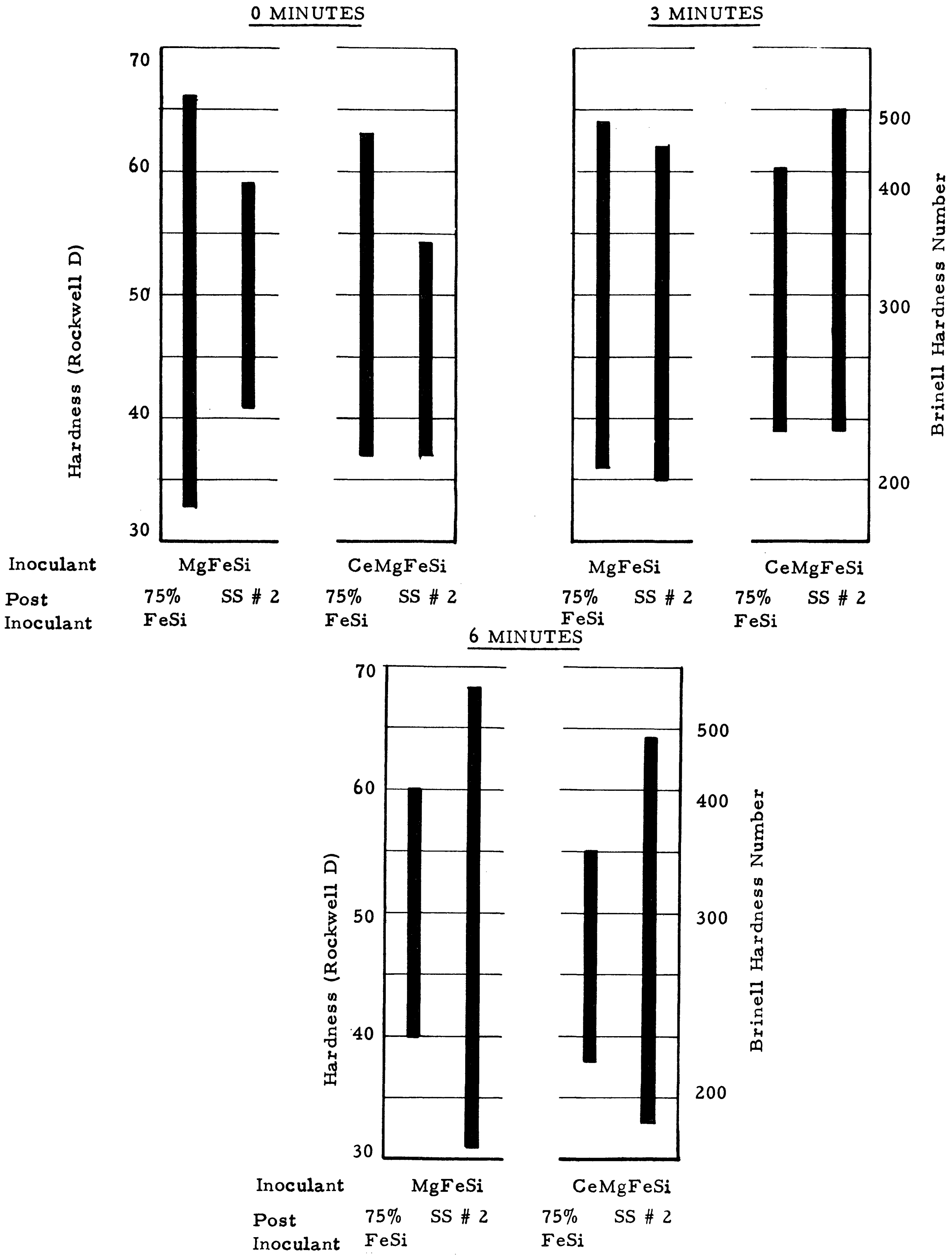

0 MINUTES
3 MINUTES
6 MINUTES
Hardness (Rockwell D)
Brinell Hardness Number
70
60
50
40
30
500
400
300
200
Inoculant
MgFeSi
CeMgFeSi
Post
Inoculant
75%
FeSi
SS # 2

Figure 34