

Improving Inoculation in Thin Sectioned Ductile Iron Castings



Marc King
Metallurgist
Hiler Industries

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June 3-5, 2009 Lancaster, Pennsylvania

Hiler Industries - Kingsbury Castings Division
Kingsbury, Indiana

Shell molding foundry producing Pearlitic and Ferritic Ductile Cast Iron

At Hiler, our shell molding attracts thin sectioned work. Thin knife gates are used to allow the parts to break off easily and cleanly. Many parts < 1/4 in section size

Melting and pouring department –

- 2 6000 lb medium freq. Batch Coreless Furnaces,**
- 1 1,200 lb open tundish treatment ladle**
- 2 600 lb lip-pour pouring ladles**

- 2 shell mold pouring lines**



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Purpose of the Study:

Improve current inoculation to reduce chill in thin-wall ferritic DI castings

**Current Magnesium Treatment in 1200 lb Tundish
Ladle 6% MgFeSi 19 – 20 lbs, 8-12 lbs of Cover
steel per ladle**

Current Inoculation Practice

**For 600 lb pouring ladle holding treated ductile,
5 lbs of standard Calcium-bearing 75% FeSi +
17 gram Germalloy in mold insert per mold**



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Once a base point was established, trials were conducted to determine how we could improve inoculation without changing the final iron chemical makeup, especially the final %C, %Si, %Mg and %S.

Various results were obtained using several proprietary inoculants. Tests were performed using Sphere-o-dox S, Oxysulfide Booster and VP 216, High Aluminum inoculant combined with standard Calsifer, Ca-bearing 75% FeSi inoculation practices.



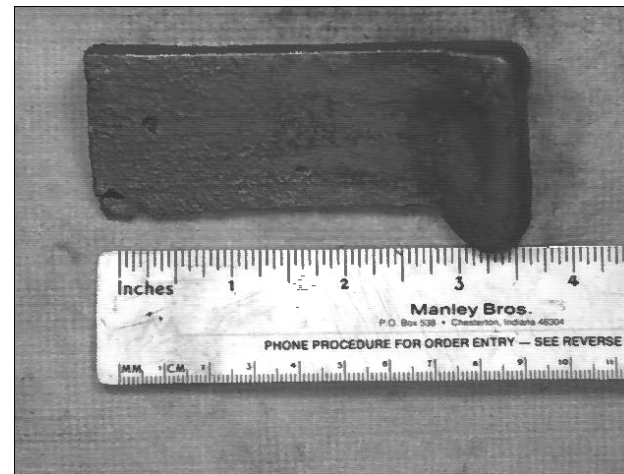
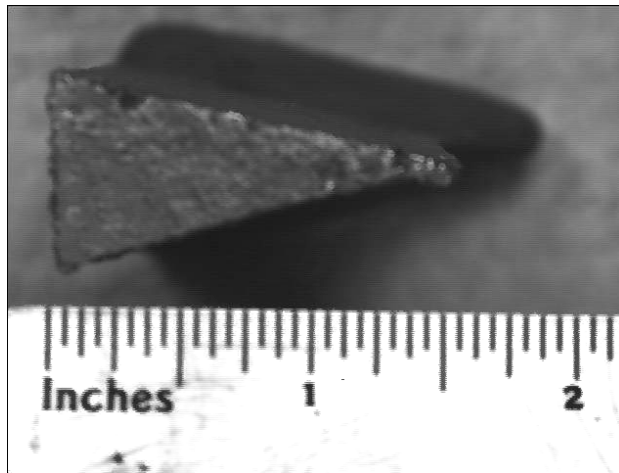
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One pouring ladle was used as the control group with standard inoculation practice, while the other one was used for experimental modified practice.

Sample Specimens taken after each test ladle:

A W3 chill wedge, a nodularity coupon, and a chilled iron disc were poured at the end of the ladle to document the results.

W3 Wedge: $\frac{3}{4}$ " wide at top, $1\frac{1}{2}$ " taper height, 3" Long w/ 1" riser.



To promote the production and application of ductile iron castings

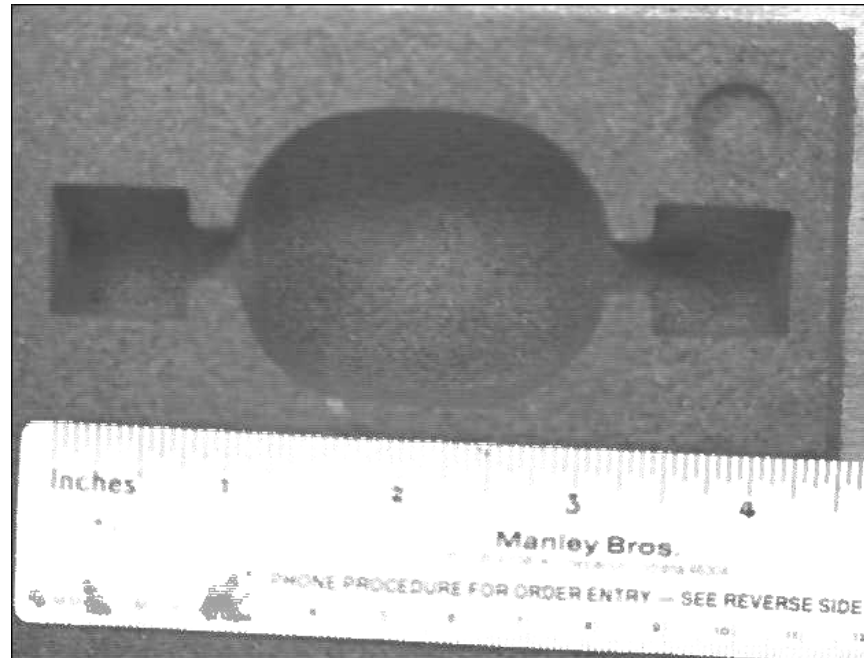


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Sample Specimens taken after each test ladle:

Nodularity Sample Mold



Chemical Analysis Equipment:

Spectro Max CCD Spectrometer

LECO CS 300 Carbon and Sulfur Analyzer

Metallographic Analysis:

Laboratory Analysis:

**Olympus PME3 with digital camera
and IA32 Analysis Software.**

**Shop Floor Analysis: %Nodularity – Every
Ladle Poured Olympus GX51 with
digital camera and IA32 Analysis Software.**



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Proposed Test Method for Inoculation Improvement

600 lb Pouring Ladle Additions / Modifications

| # | Standard | Experiment |
|---|-----------------------------------|---|
| 1 | 5# Ca-Bearing 75% FeSi | 5# Ca-Bearing 75% FeSi, 0.6 lb Oxysulfide Inoculant Booster |
| 2 | 5# Ca-Bearing 75% FeSi | 5# Ca-Bearing 75% FeSi, 0.3 lb Oxysulfide Inoculant Booster |
| 3 | 5# Ca-Bearing 75% FeSi | 4# Ca-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant Booster |
| 4 | 5# Ca-Bearing 75% FeSi | 5# Hi Ca/Al-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant Booster |
| 5 | 5# Ca-Bearing 75% FeSi | 5# Ca-Bearing 75% FeSi, 1 lb Oxysulfide Inoculant Booster |

5R2 Magnesium Ferrosilicon – Magnesium Treatment

| %Mg | %Si | %Ce | Total % R E | %Ca | %Al |
|-----------|---------|-------------|-------------|-----------|---------|
| 5.0 – 6.0 | 43 - 48 | 0.45 – 0.60 | 0.75 – 1.15 | 0.8 – 1.3 | 1.2 Max |

Calsifer 75% Calcium Bearing Ferrosilicon Inoculant

| %Si | %Al | %Ca |
|---------|------------|-----------|
| 74 - 79 | 0.75 – 1.5 | 1.0 – 1.5 |

VP216 High Aluminum Inoculant

| %Si | %Al | %Ca |
|--------|-----------|-----------|
| 68 -73 | 3.2 – 4.5 | 0.3 – 1.5 |

Sphere-o-dox S_(U.S Patent 6,293,988B1) Oxysulfide Inoculant Booster

| %Si | % (Ca + Al + S + O ⁻² + Mg) |
|---------|--|
| 36 - 37 | 32 - 35 |



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| # | Standard |
|---|-------------|
| 1 | 5# Calsifer |
| 2 | 5# Calsifer |
| 3 | 5# Calsifer |
| 4 | 5# Calsifer |
| 5 | 5# Calsifer |

Final Chemical Analysis: Standard Group

| # | C | Si | S | Mg | Mn | Cu | P | Cr | Mo | Ni | Ti | Al |
|---|------|------|------|------|-----|------|------|------|------|------|------|------|
| 1 | 3.65 | 2.58 | .009 | .038 | .28 | .089 | .019 | .032 | .003 | .035 | .005 | .011 |
| 2 | 3.62 | 2.63 | .011 | .040 | .28 | .092 | .018 | .031 | .003 | .029 | .005 | .012 |
| 3 | 3.63 | 2.61 | .009 | .041 | .27 | .090 | .018 | .032 | .003 | .030 | .005 | .011 |
| 4 | 3.65 | 2.58 | .009 | .037 | .27 | .057 | .016 | .035 | .004 | .024 | .005 | .013 |
| 5 | 3.66 | 2.57 | .008 | .033 | .28 | .058 | .017 | .035 | .003 | .027 | .005 | .012 |

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| Experiment | |
|-------------------|---|
| #1 | 5# Calsifer, 0.6 lb Sphere-o-dox S Inoculant Booster |
| #2 | 5# Calsifer, 0.3 lb Sphere-o-dox S Inoculant Booster |
| #3 | 4# Calsifer, 1 lb Sphere-o-dox S Inoculant Booster |
| #4 | 5# VP216, 1 lb Sphere-o-dox S Inoculant Booster |
| #5 | 5# Calsifer, 1 lb Sphere-o-dox S Inoculant Booster |

Final Chemical Analysis: Experimental Group

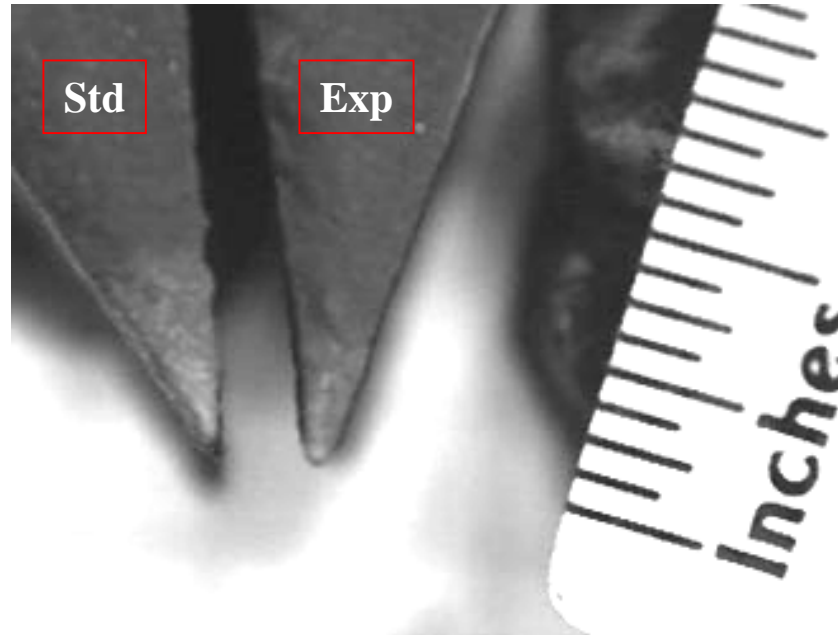
| # | C | Si | S | Mg | Mn | Cu | P | Cr | Mo | Ni | Ti | Al |
|----------|-------------|-------------|-------------|-------------|------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1 | 3.61 | 2.80 | .013 | .040 | .25 | .12 | .018 | .033 | .003 | .034 | .005 | .013 |
| 2 | 3.65 | 2.75 | .012 | .037 | .24 | .12 | .018 | .032 | .002 | .033 | .005 | .012 |
| 3 | 3.61 | 2.64 | .014 | .044 | .26 | .11 | .018 | .035 | .003 | .042 | .005 | .014 |
| 4 | 3.68 | 2.51 | .012 | .033 | .28 | .06 | .017 | .036 | .003 | .026 | .005 | .015 |
| 5 | 3.67 | 2.62 | .012 | .039 | .27 | .06 | .016 | .032 | .003 | .025 | .005 | .014 |



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Chill Depth Comparisons

#1 Sample, Standard vs Experiment

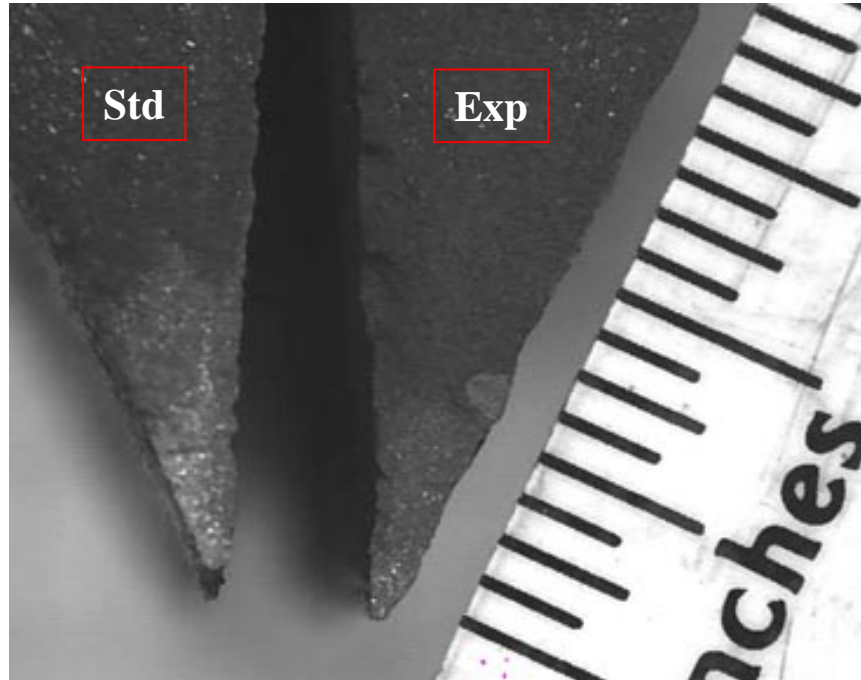


Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Ca-Bearing 75% FeSi, 0.6 lb Oxysulfide Inoculant

Chill Depth Comparisons

#2 Sample, Standard vs Experiment

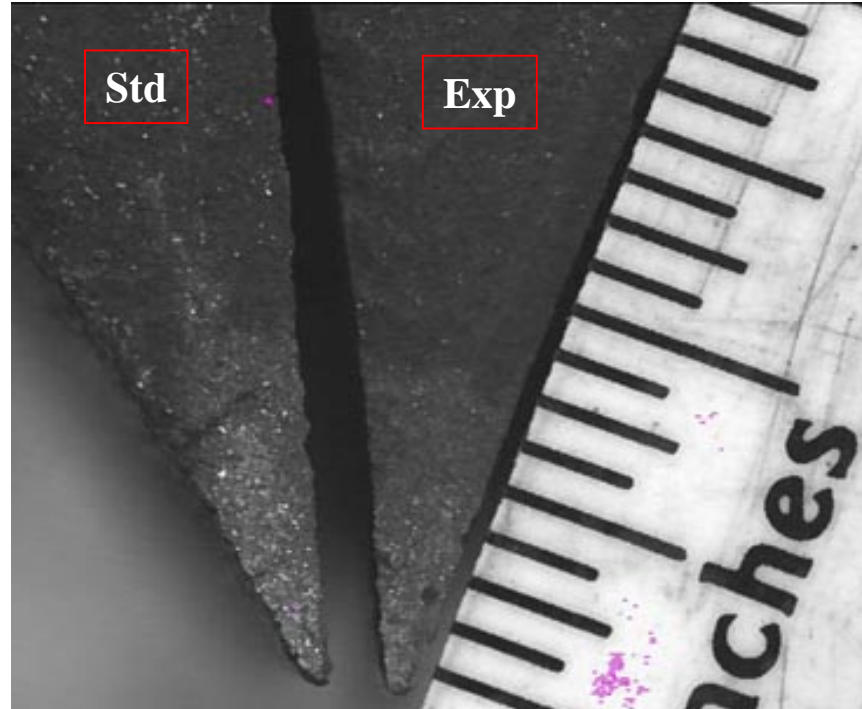


Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Ca-Bearing 75% FeSi, 0.3 lb Oxysulfide Inoculant

Chill Depth Comparisons

#3 Sample, Standard vs Experiment

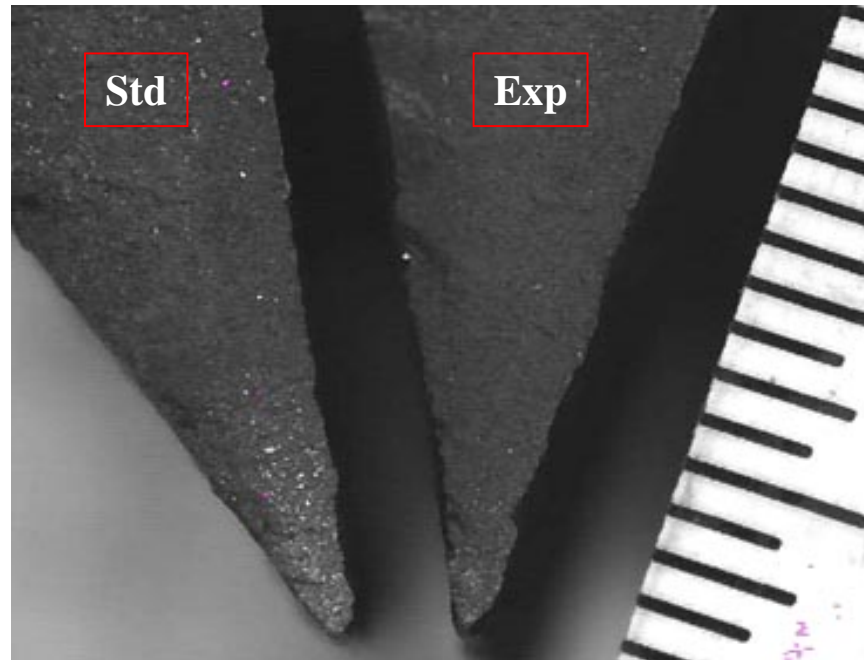


Std. 5# Ca-Bearing 75% FeSi

Exp. 4# Ca-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant

Chill Depth Comparisons

#4 Sample, Standard vs Experiment

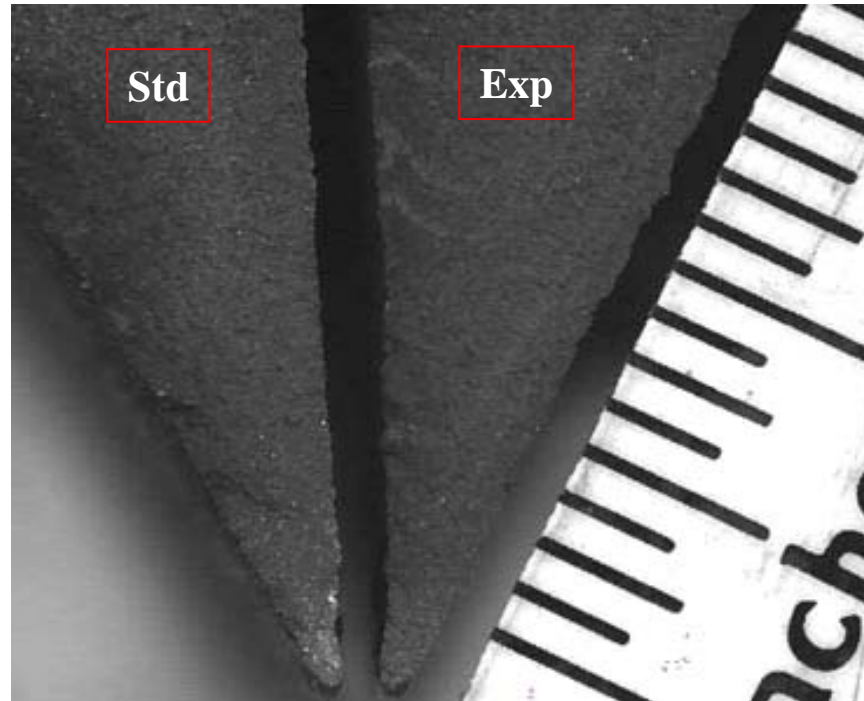


Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Hi Ca/Al-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant

Chill Depth Comparisons

#5 Sample, Standard vs Experiment



Std. 5# Ca-Bearing 75% FeSi

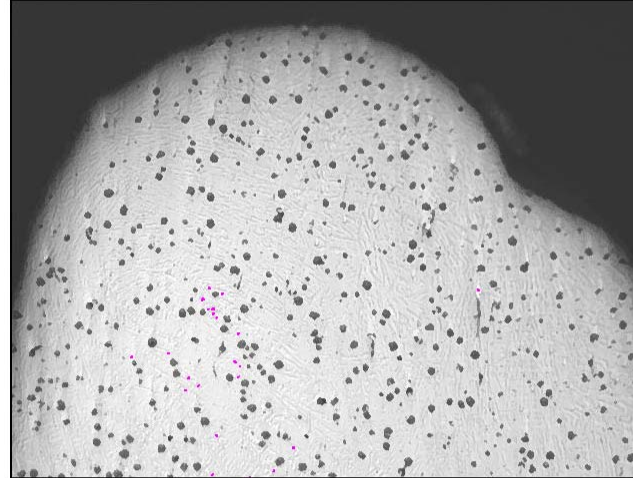
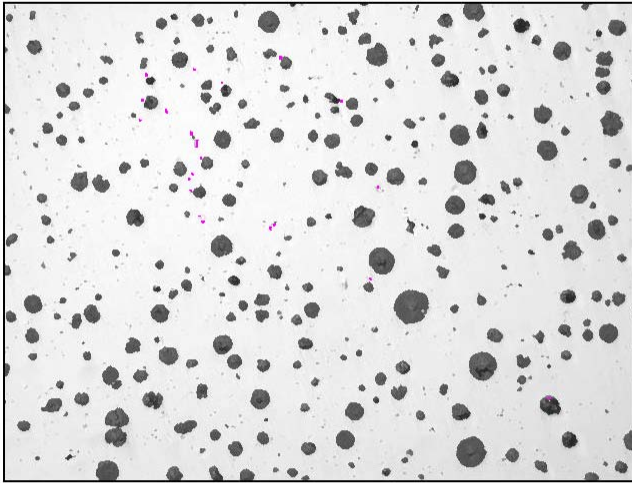
Exp. 5# Ca-Bearing 75% FeSi, 1 lb Oxysulfide Inoculant

Chill Depth Comparisons

Chill Depth in Inches: Experimental Group

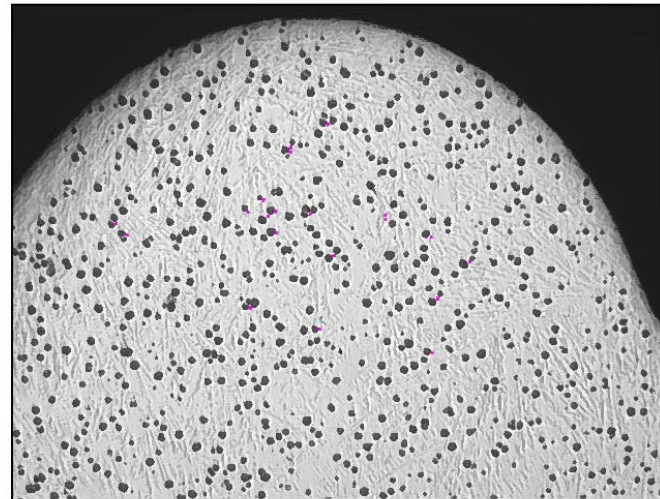
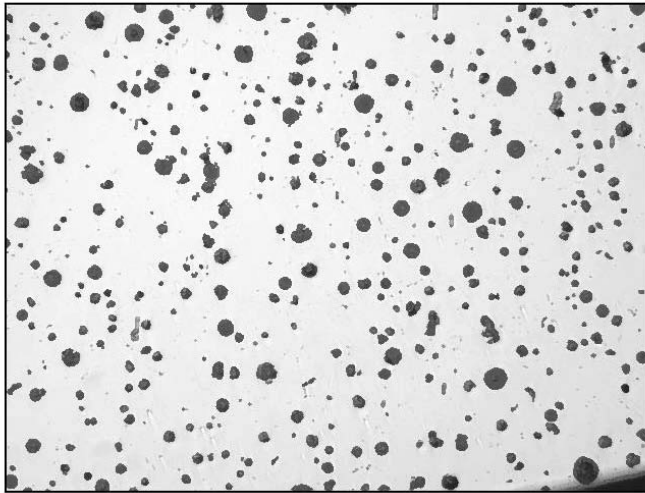
| # | Standard | Experiment | Difference |
|---|----------|------------|------------|
| 1 | .35 | .20 | .15 |
| 2 | .46 | .30 | .16 |
| 3 | .61 | .42 | .19 |
| 4 | .38 | .10 | .28 |
| 5 | .37 | .20. | .17 |

Chill Wedge Sample #1 Standard Microstructure Comparison Top vs Tip of Chill Wedge, 100X Unetched



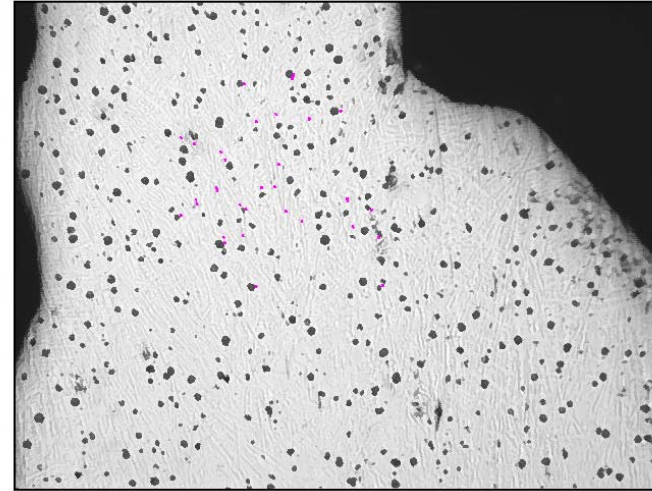
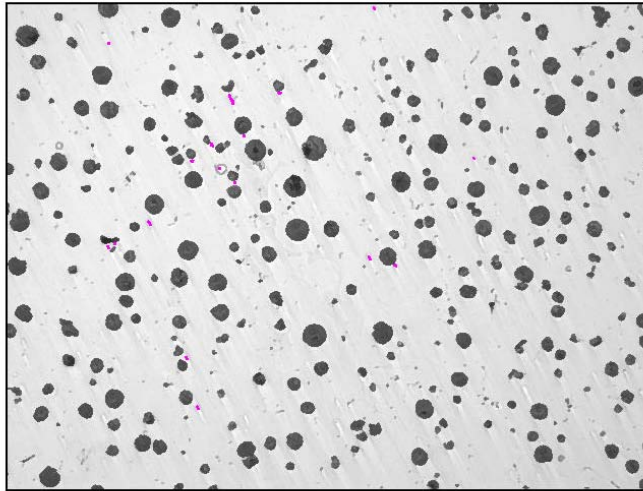
Std. 5# Ca-Bearing 75% FeSi

Chill Wedge Sample #1 Experiment Microstructure Comparison Top vs Tip of Chill Wedge, 100X Unetched



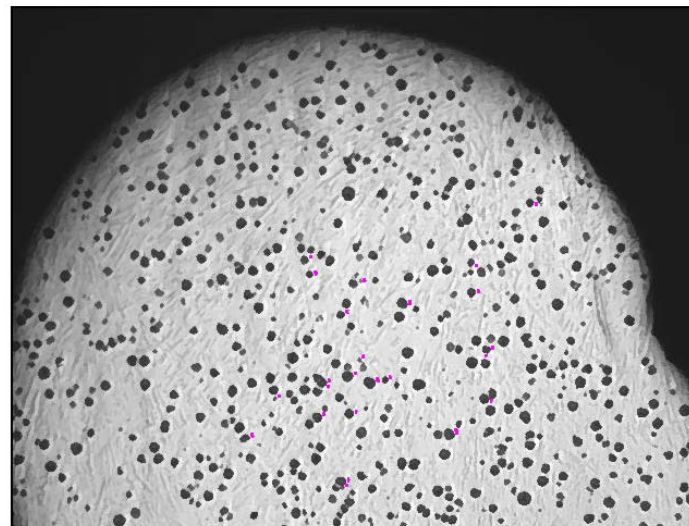
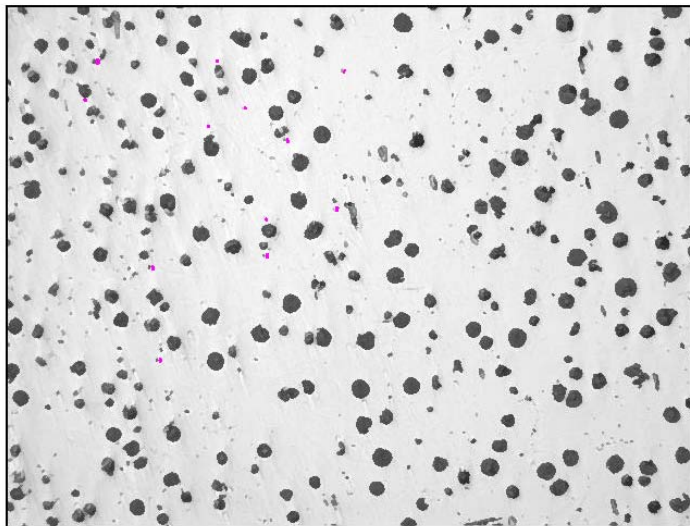
Exp. 5# Ca-Bearing 75% FeSi, 0.6 lb Oxysulfide Inoculant

Chill Wedge Sample #2 Standard Microstructure Comparison Top vs Tip of Chill Wedge, 100X Unetched



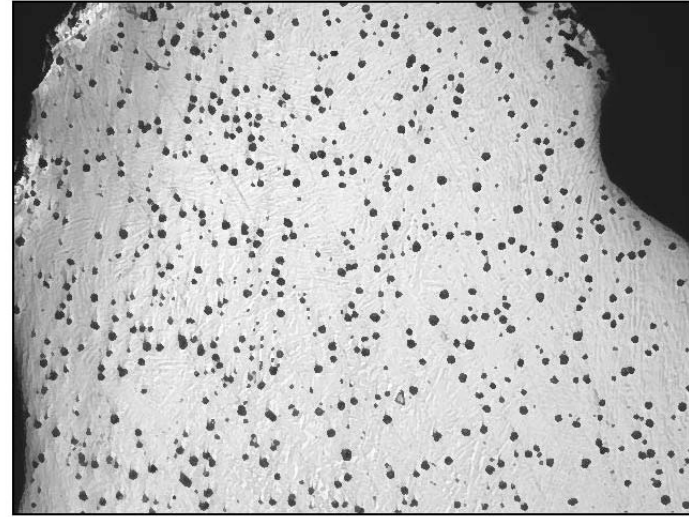
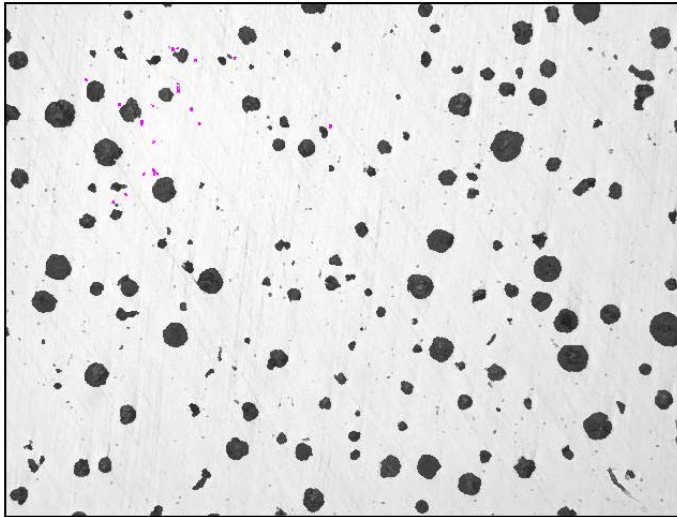
Std. 5# Ca-Bearing 75% FeSi

Chill Wedge Sample #2 Experiment Microstructure Comparison Top vs Tip of Chill Wedge, 100X Unetched



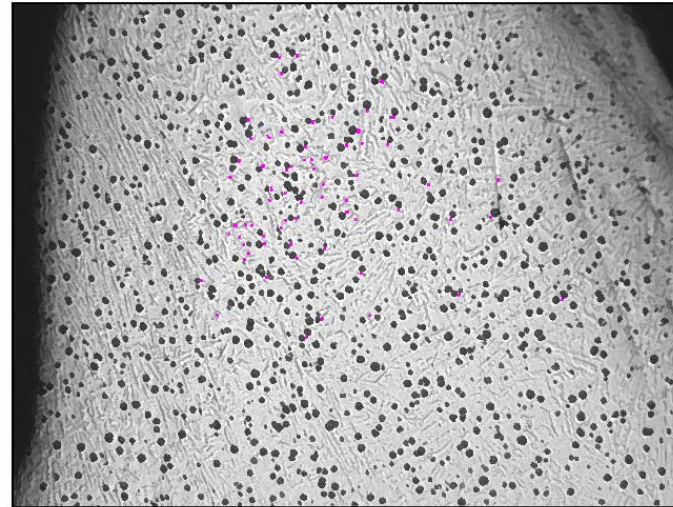
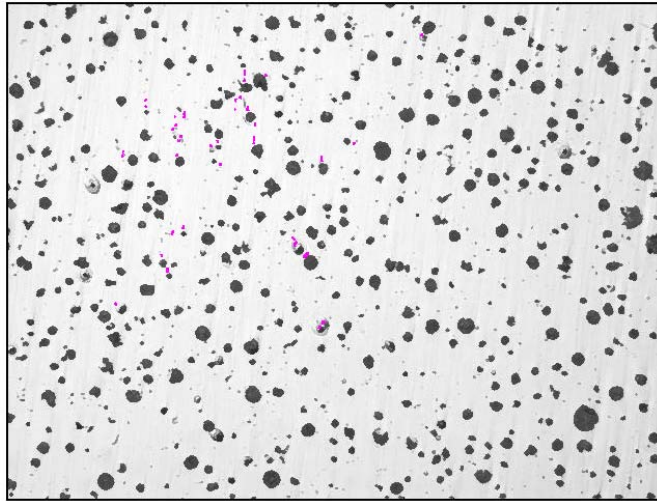
Exp. 5# Ca-Bearing 75% FeSi, 0.3 lb Oxysulfide Inoculant

Chill Wedge Sample #3 Experiment Microstructure Comparison Top vs Tip of Chill Wedge , 100X Unetched



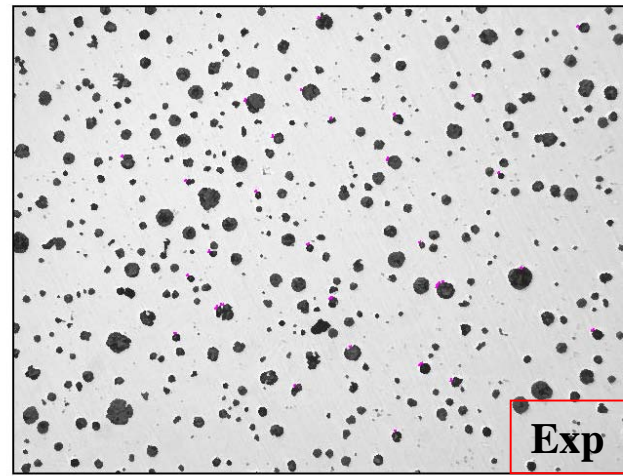
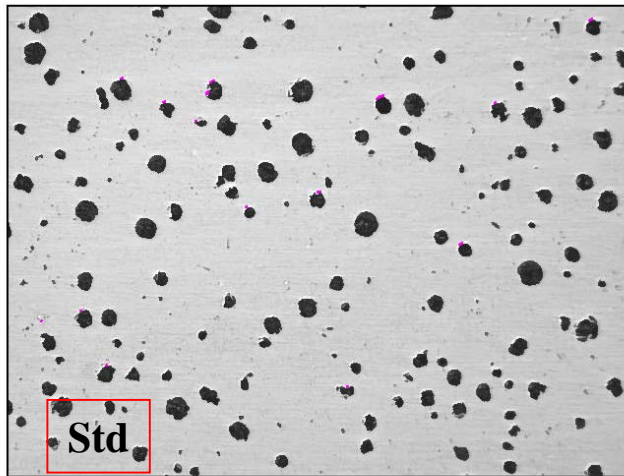
Exp. 4# Ca-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant

Chill Wedge Sample #4 Experiment Microstructure Comparison Top vs Tip of Chill Wedge, 100X Unetched



Exp. 5# Hi Al-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant

Chill Wedge Sample #5 Standard / Experiment Microstructure Comparison: Standard vs Experiment Chill Wedge Tops 100X Unetched



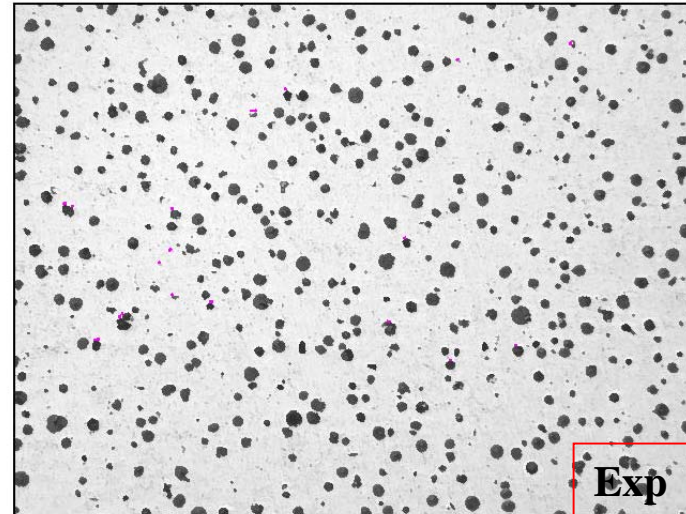
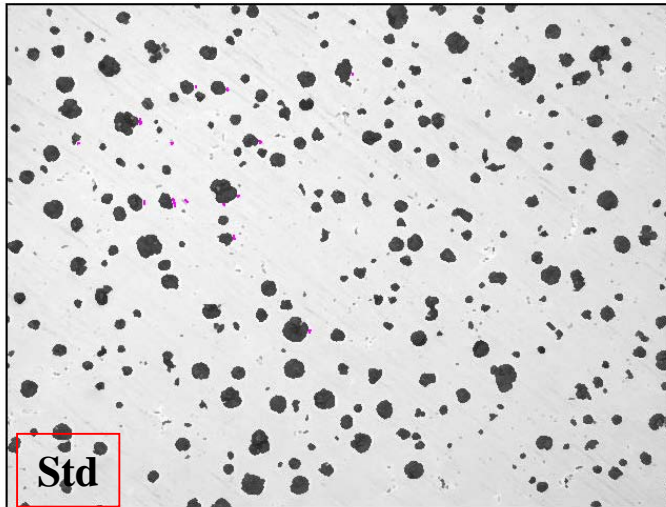
Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Ca-Bearing 75% FeSi, 1 lb Oxysulfide Inoculant

Metallographic Analysis: Chill Wedges

| # | Ladle | % Nod. | NC Tip | NC Middle | NC Top |
|---|-------|--------|--------|-----------|--------|
| 1 | Std. | 95 | 200 | 150 | 125 |
| 1 | Exp. | 95 | 300 | 175 | 150 |
| 2 | Std. | 91 | 250 | 150 | 125 |
| 2 | Exp. | 93 | 300 | 175 | 150 |
| 3 | Std. | 92 | 175 | 150 | 125 |
| 3 | Exp. | 94 | 275 | 175 | 150 |
| 4 | Std. | 95 | 200 | 150 | 125 |
| 4 | Exp. | 95 | 300 | 200 | 150 |
| 5 | Std. | 93 | 200 | 150 | 125 |
| 5 | Exp. | 95 | 250 | 175 | 150 |

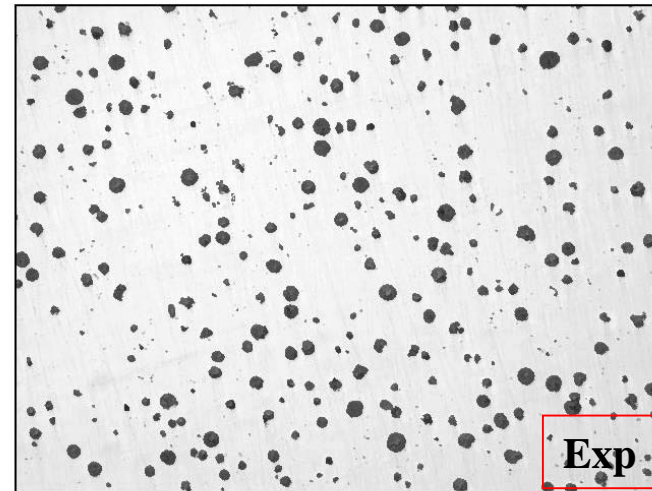
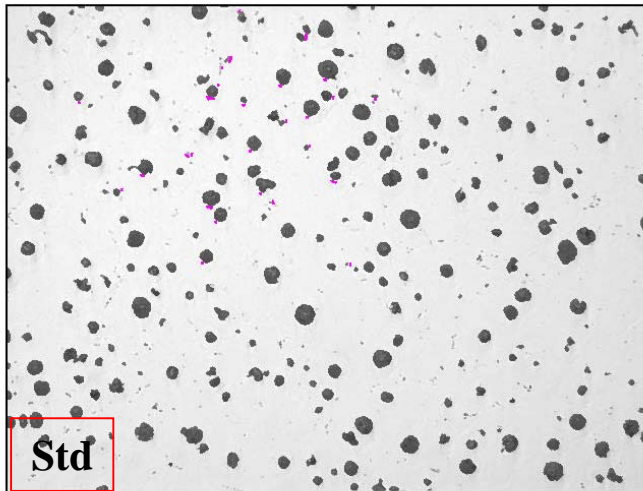
Comparison of Nodularity Coupons Sample #1 100X Unetched



Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Ca-Bearing 75% FeSi, 0.6 lb Oxysulfide Inoculant

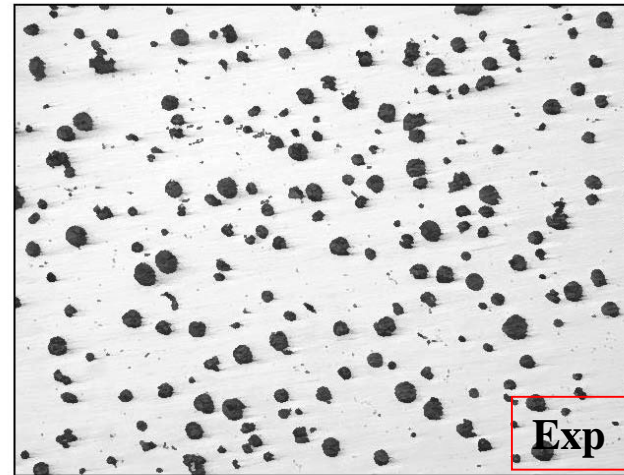
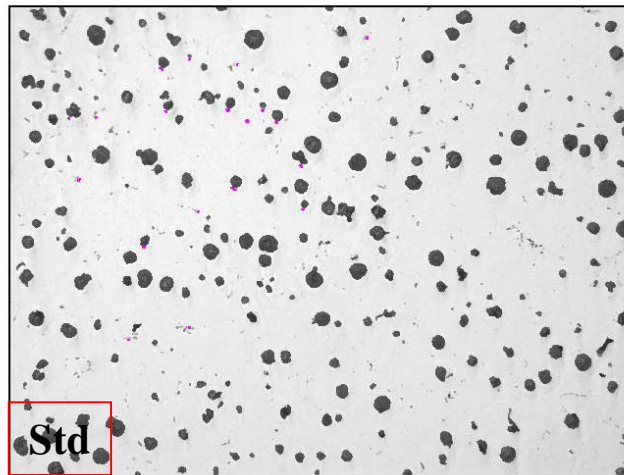
Comparison of Nodularity Coupons Sample #2 100X Unetched



Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Ca-Bearing 75% FeSi, 0.3 lb Oxysulfide Inoculant

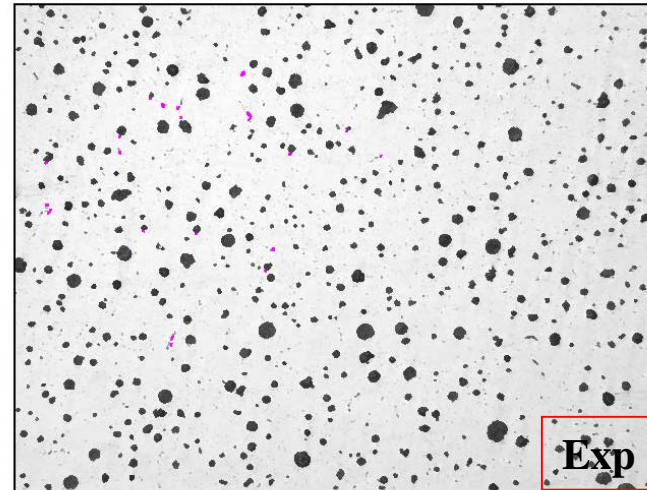
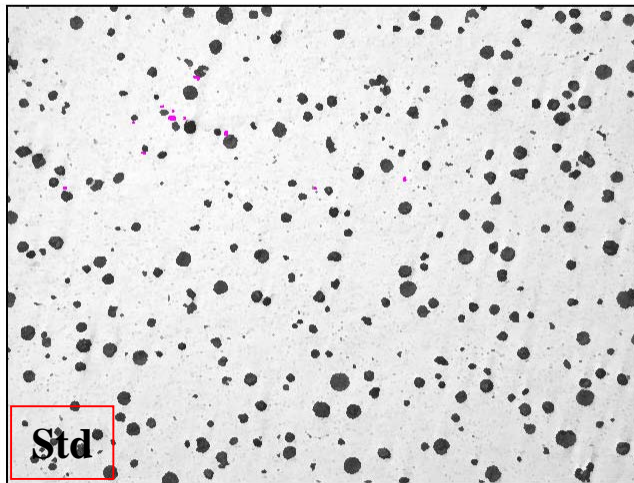
Comparison of Nodularity Coupons Sample #3 100X Unetched



Std. 5# Ca-Bearing 75% FeSi

Exp. 4# Ca-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant

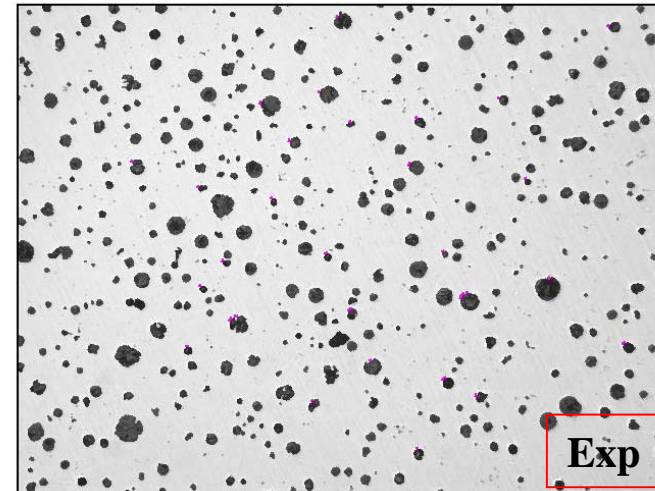
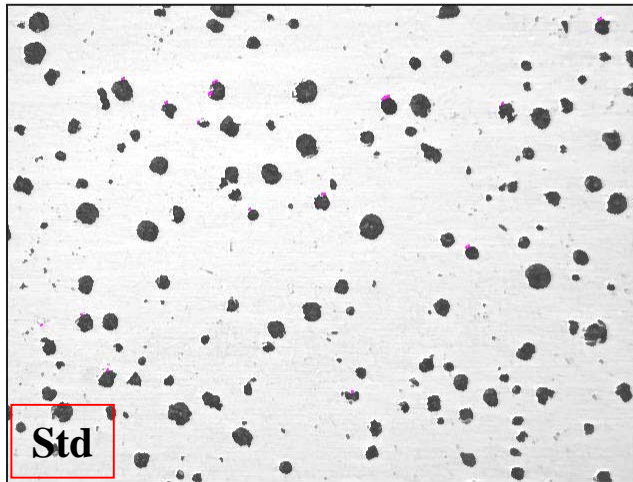
Comparison of Nodularity Coupons Sample #4 100X Unetched



Std. 5# Ca-Bearing 75% FeSi

Exp. 5# Hi Al-Bearing 75%FeSi, 1 lb Oxysulfide Inoculant

Comparison of Nodularity Coupons Sample #5 100X Unetched



Std. 5# Ca-Bearing 75% FeSi

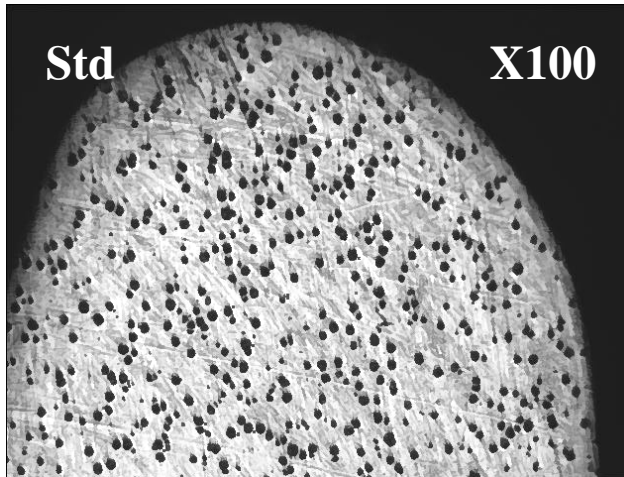
Exp. 5# Ca-Bearing 75% FeSi, 1 lb Oxysulfide Inoculant

Metallographic Analysis: Nodularity Coupons

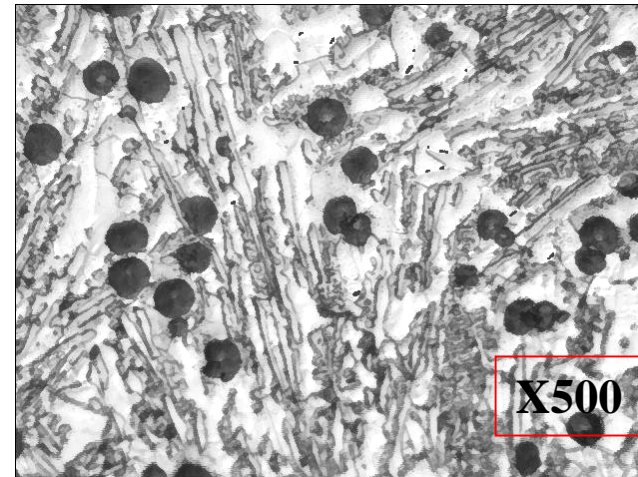
| # | Ladle | % Nod. | NC Tip |
|---|-------|--------|--------|
| 1 | Std. | 95 | 125 |
| 1 | Exp. | 97 | 175 |
| 2 | Std. | 91 | 125 |
| 2 | Exp. | 93 | 150 |
| 3 | Std. | 92 | 125 |
| 3 | Exp. | 97 | 150 |
| 4 | Std. | 93 | 150 |
| 4 | Exp. | 95 | 175 |
| 5 | Std. | 95 | 125 |
| 5 | Exp. | 97 | 150 |

Comparison of Standard and Experiment Tip Micros

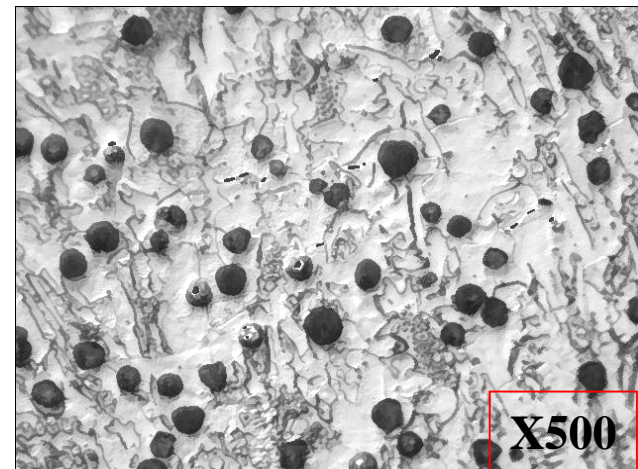
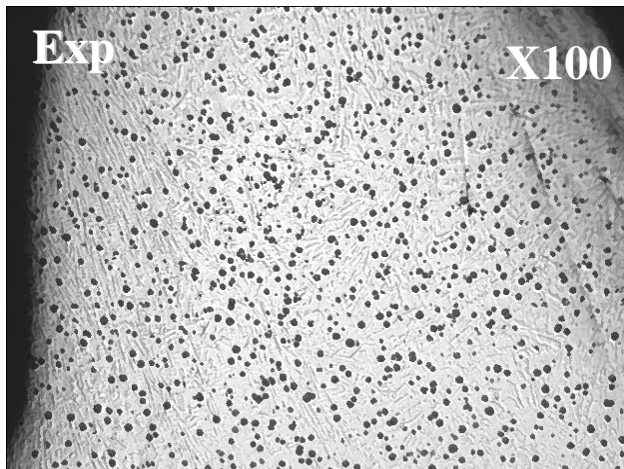
Unetched vs Etched Sample#4



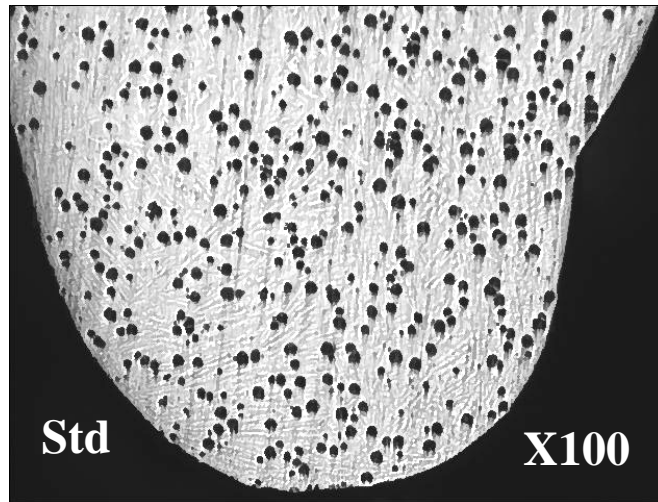
Unetched



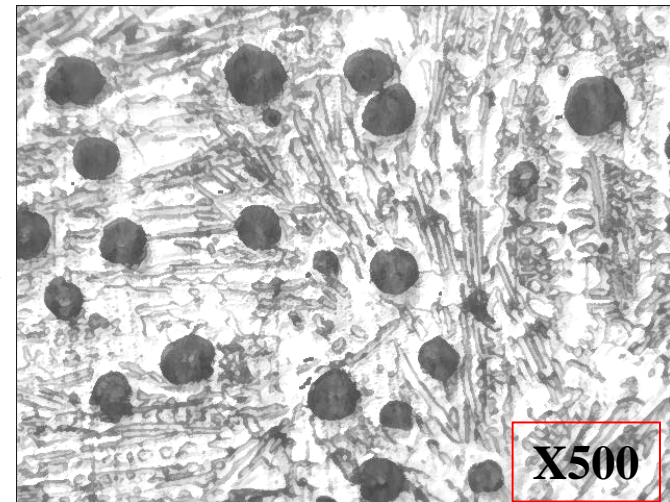
Etched



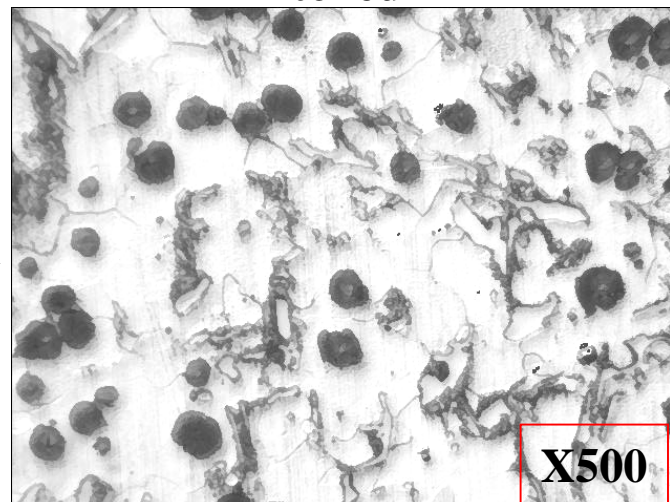
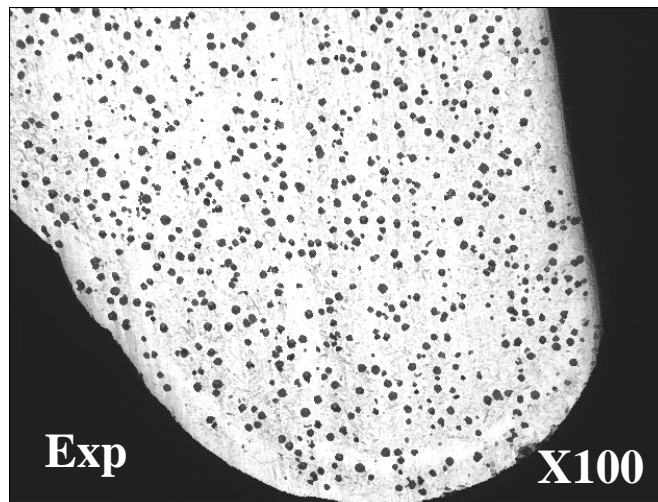
Comparison of Standard and Experiment Tip Micros Unetched vs Etched Sample#5



Unetched

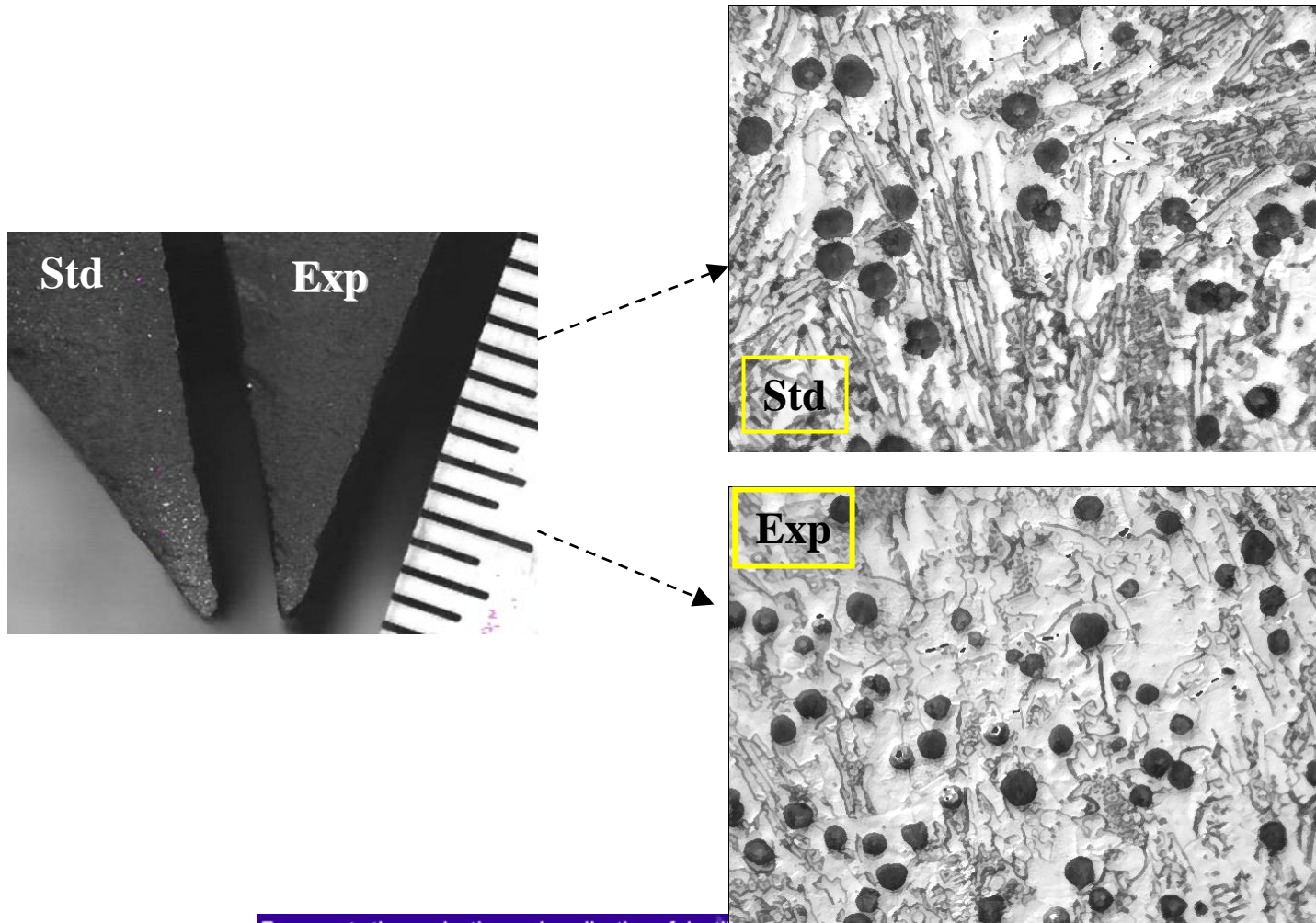


Etched



Conclusions:

Reduction or elimination of Chill was achieved.



To promote the production and application of ductile iron castings

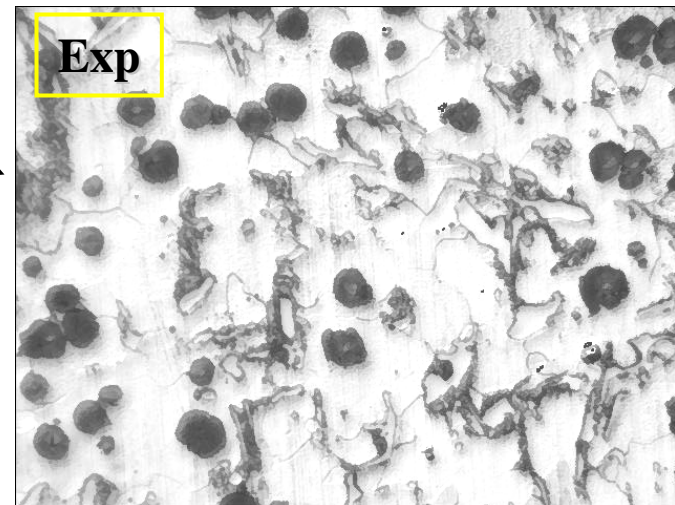
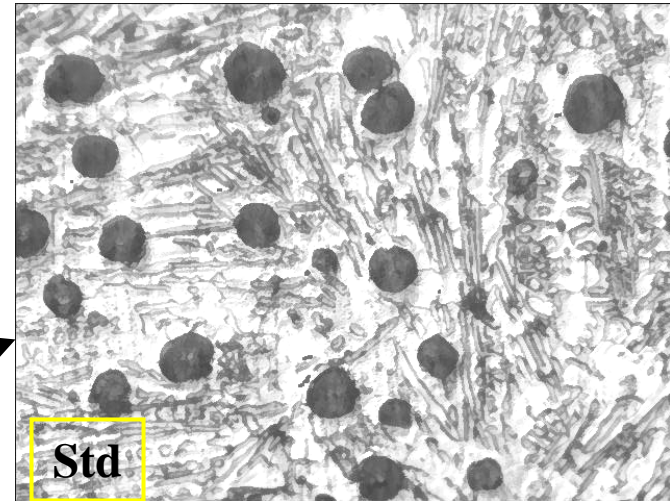
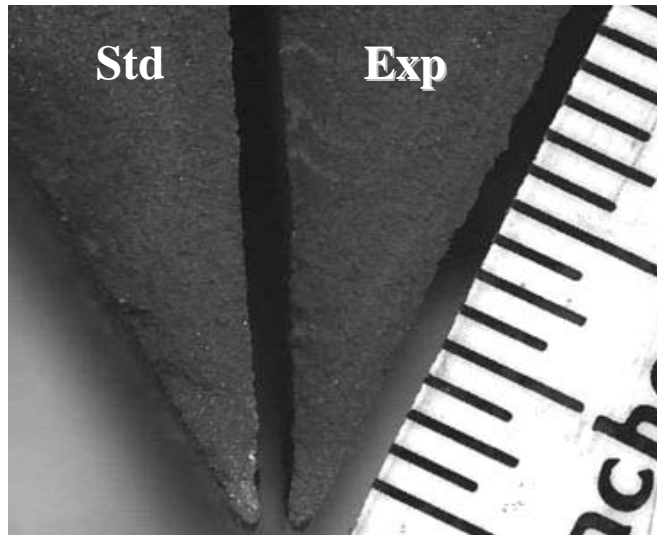


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Conclusions:

Reduction or elimination of Chill was achieved.



To promote the production and application of ductile iron castings

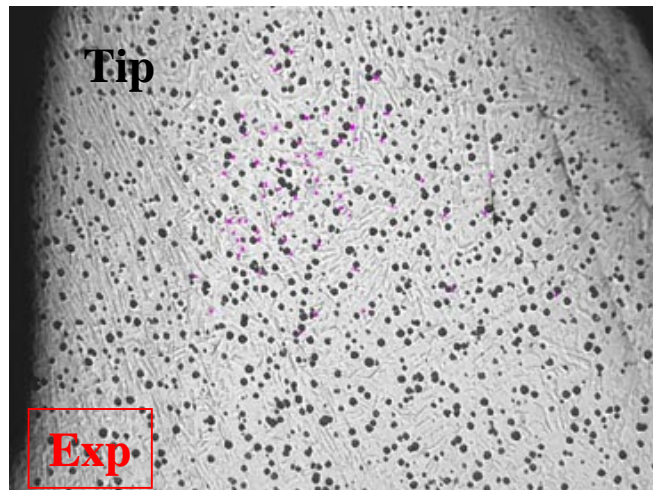
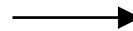
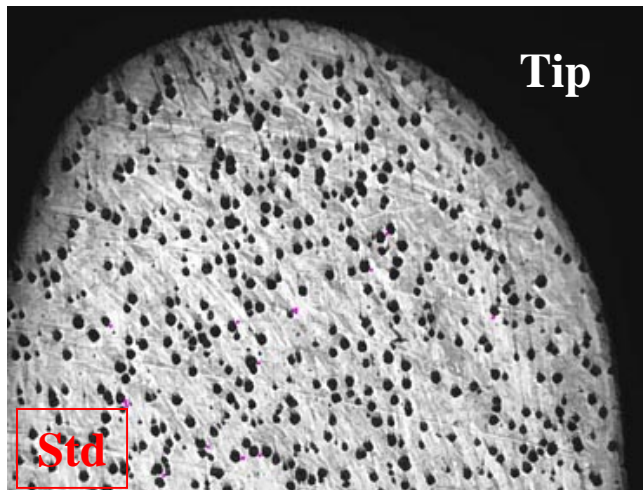
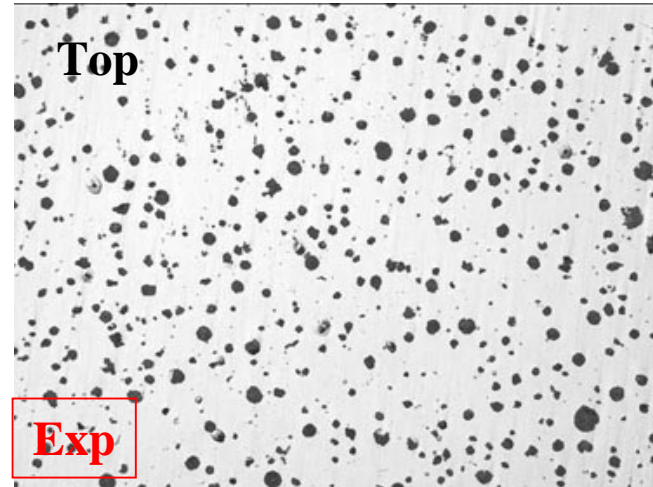
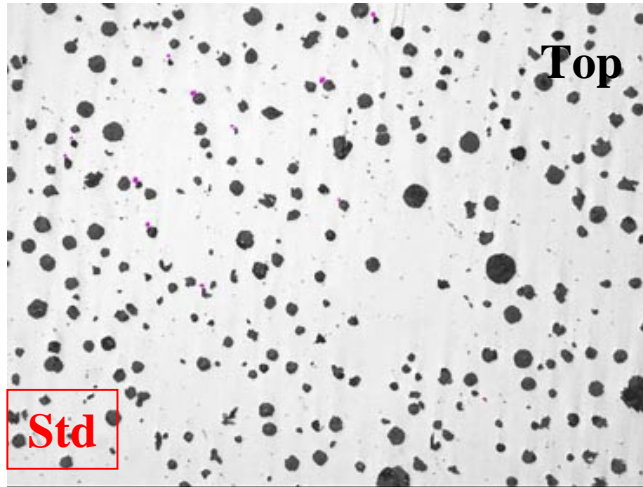


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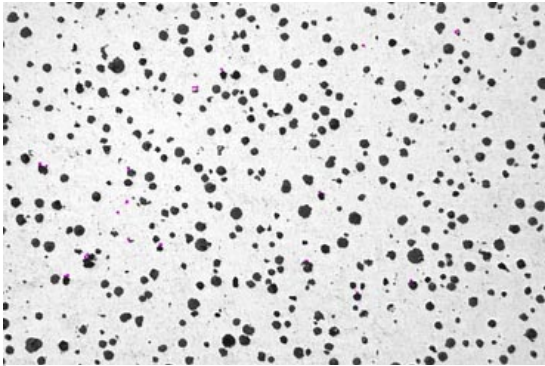
Conclusions:

Increased Nodule Count throughout thickness of Sample

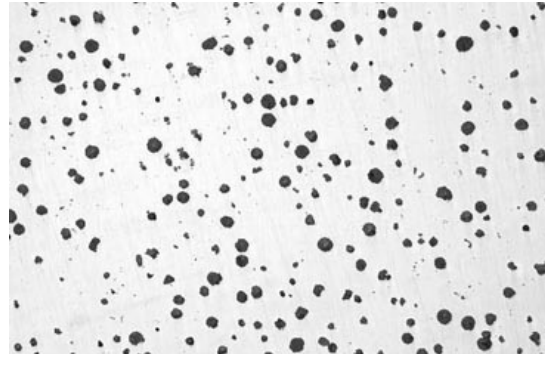


Conclusions:

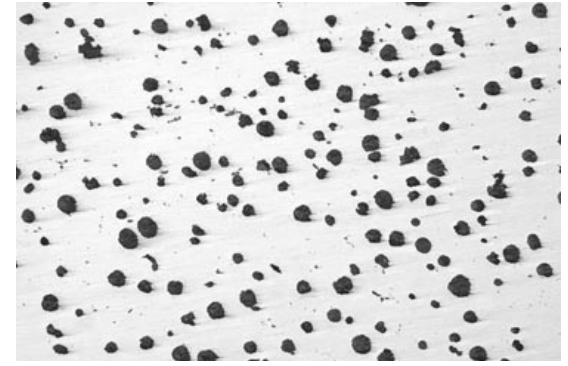
Increased Nodule Count throughout thickness of Nodularity Sample



+ 0.6 lb Sphere-o-dox S Booster
#1 EXP



+ 0.3 lb Sphere-o-dox S Booster
#2 EXP



4# Calsifer, 1 lb Sphere-o-dox S Booster
#3 EXP



5# VP216, 1 lb Sphere-o-dox S Booster
#4 EXP



5# Calsifer, 1 lb Sphere-o-dox S Booster
#5 EXP

Conclusions:

No melt control problems were experienced, i.e. major changes in any control elements

Using W3 wedge samples, this would simulate a knife edge casting. Verification of nodules out to the edge, representing thorough inoculation.

Possible reduction of inoculant level could be done without sacrificing chill formation and nodule count.

No significant loss of Magnesium within the metal.



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All of the trialing for Inoculation Improvement were based on metal chemistry control, chill depth, chill microstructure, % nodularity/ nodularity sample microstructure, both unetched and etched surfaces.

Although all of these tests had favorable results, no Physical property tests were done, and compared to The current standard inoculation practice. I plan to continue this inoculation study in the future, and plan to include this, to verify the positive outcomes.

Any information whether visual, verbal or written that is presented, is intended for education purposes only. These represent general suggestions of what foundries have found to be useful for their own operation. It may or may not work for you. This presentation must not be used as a reference for your melt, metallurgy or safety program unless written permission has been given by its author.



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THANK YOU .

Any Questions ??



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