STORK
Materials Technology

Effect of Cooling Rate on Pearlitic Ductile Iron Mechanical Properties

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Effect of Cooling Rate on Pearlitic Ductile Iron Mechanical Properties

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AFS Research Project Goals

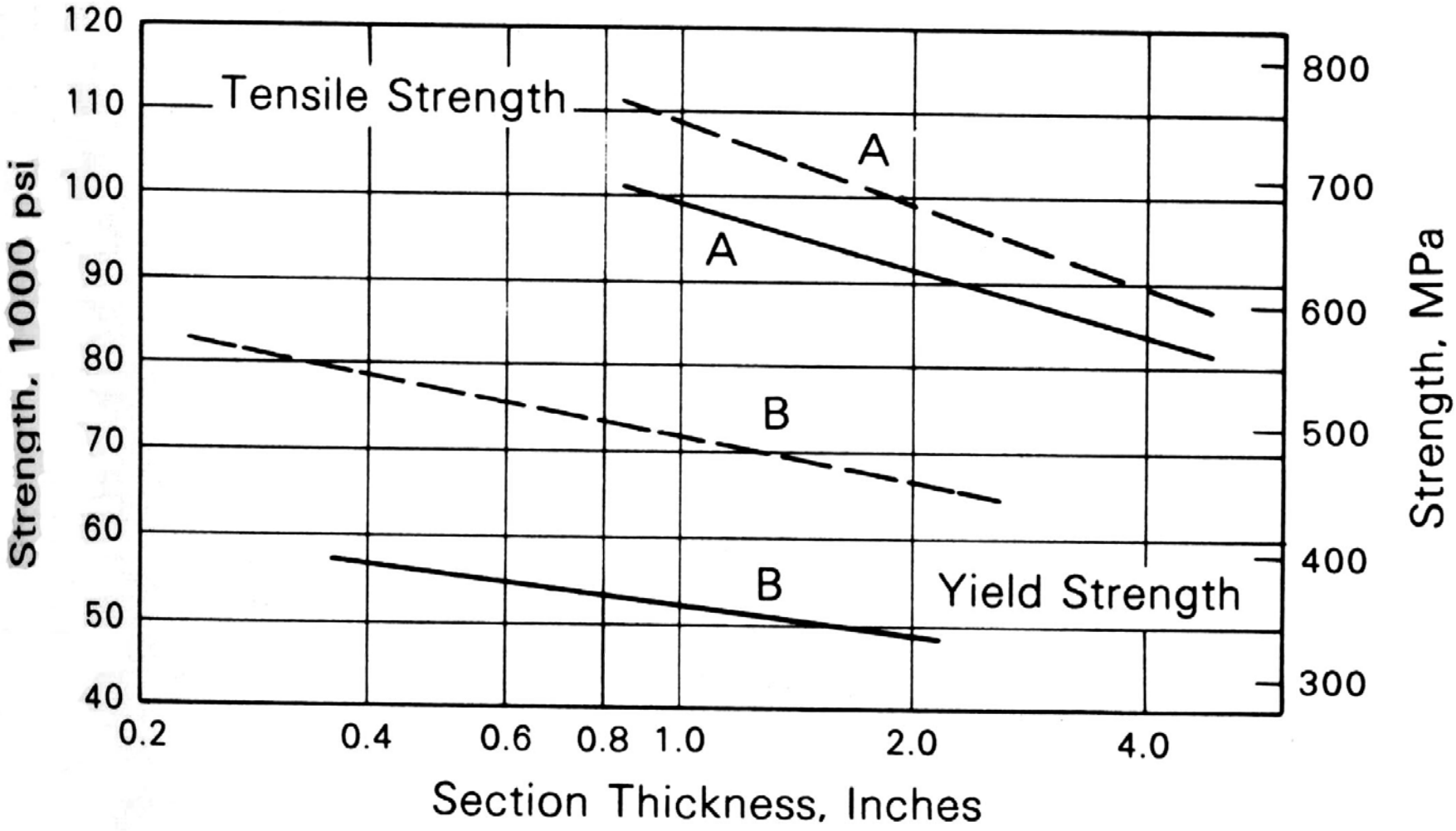
- Determine the effect of cooling rate (section size) on mechanical properties of 80-55-06 ductile iron
- Determine how cooling rate from different molding materials affect mechanical properties

AFS Research Project Goals

- Determine how skin effect alters mechanical properties
- Determine how different molding materials alter the skin effect and corresponding mechanical properties

Literature Review

- Published information is scarce dating back to 1950.

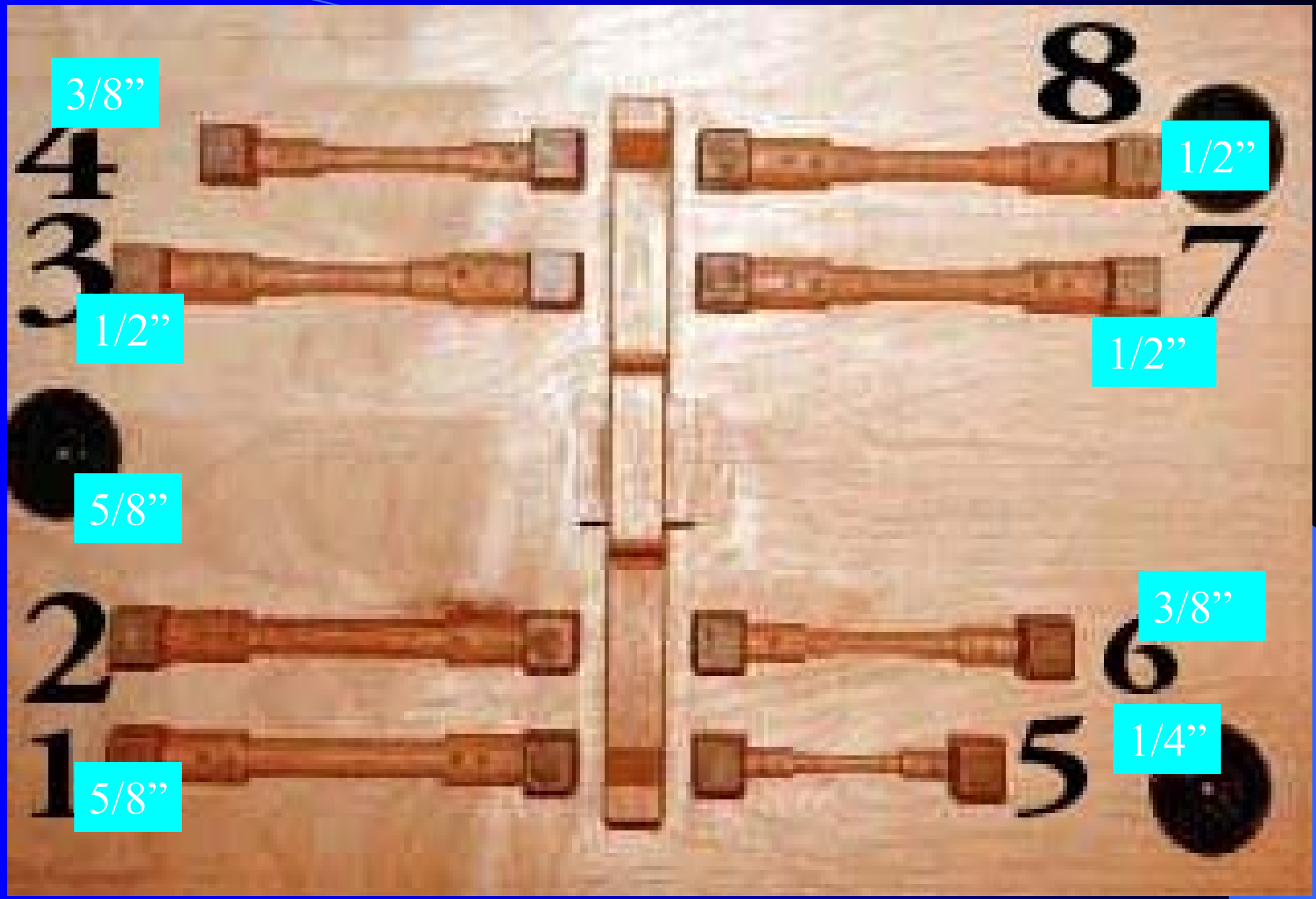

Tensile Strength
A
A
B
B
Yield Strength
Strength, 1000 psi
120
110
100
90
80
70
60
50
40
800
700
600
500
400
300
Strength, MPa
0.2
0.4
0.6
0.8
1.0
2.0
4.0
Section Thickness, Inches

Literature Review

- Published information is scarce dating back to 1950.
- Ferritic ductile iron AFS research 2002

Research Plan

- Use the same pattern used in the ferritic study

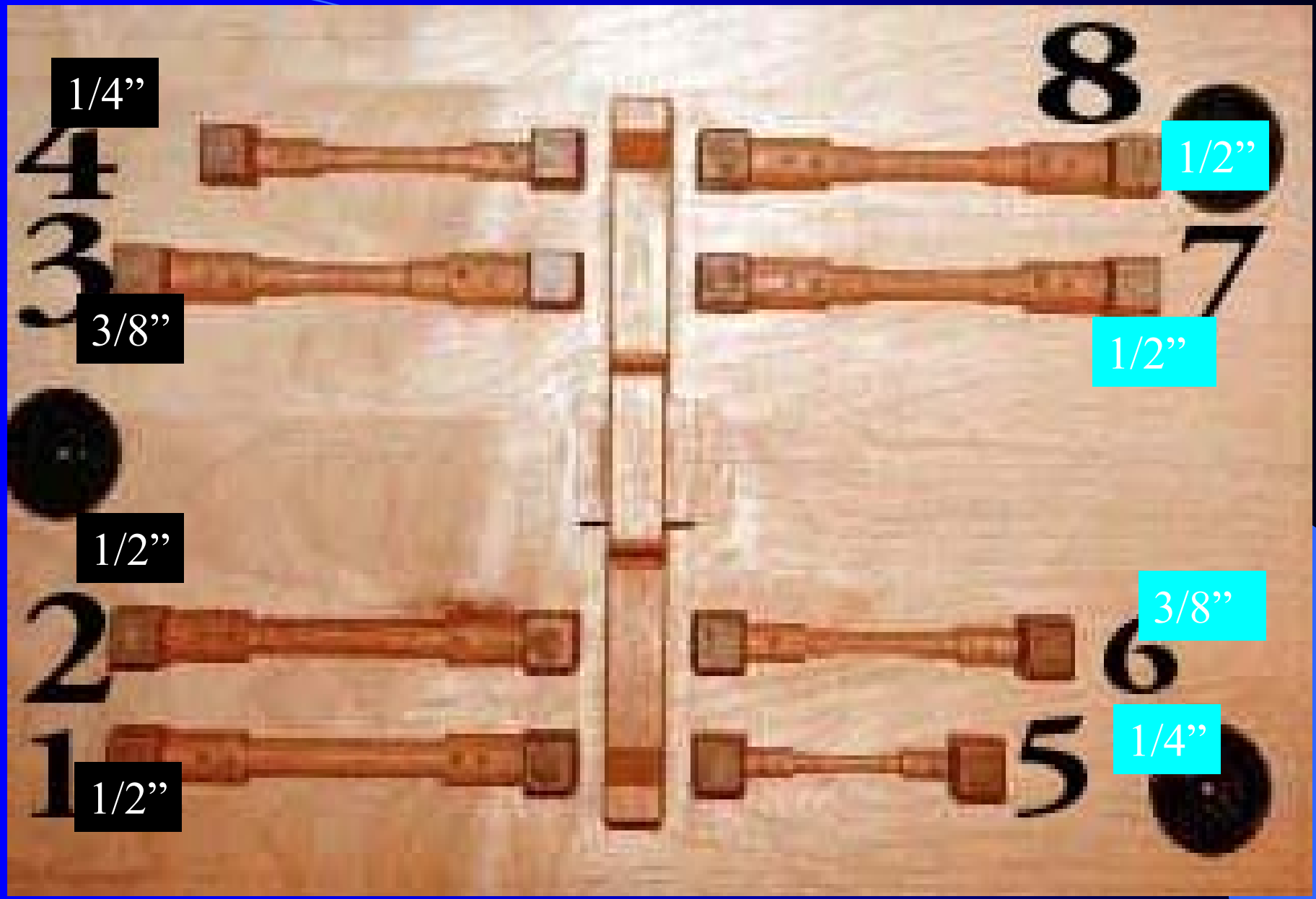

3/8”
4
8
1/2”
3
7
1/2”
1/2”
5/8”
2
3/8”
6
1
5
1/4”
5/8”

Research Plan Step 1

- Use the same pattern used in the ferritic study
- Cast 10 molds at a nobake foundry plus a Y-Block
- Cast 10 molds at a green sand foundry plus a Y-Block

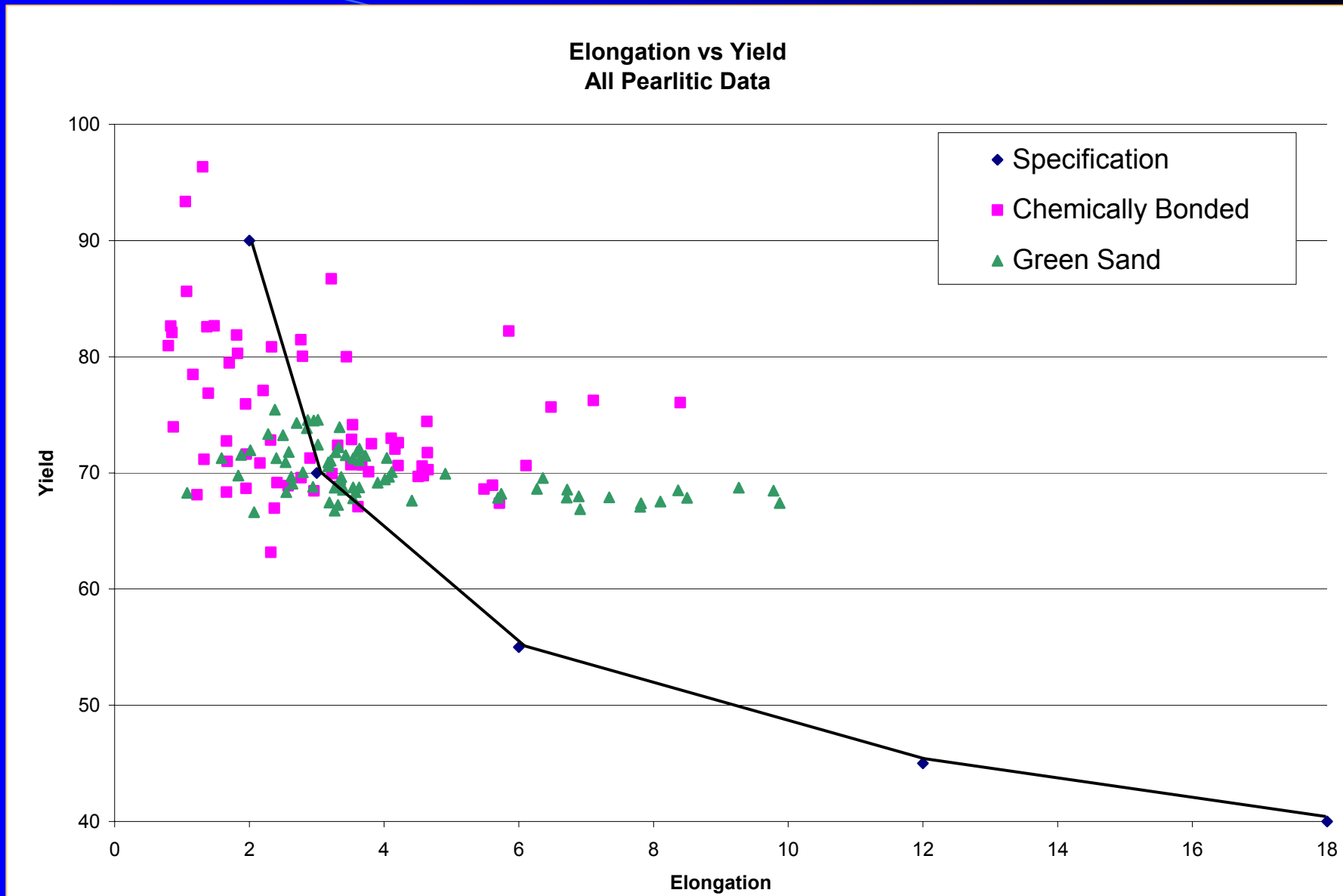
Research Plan Step 2

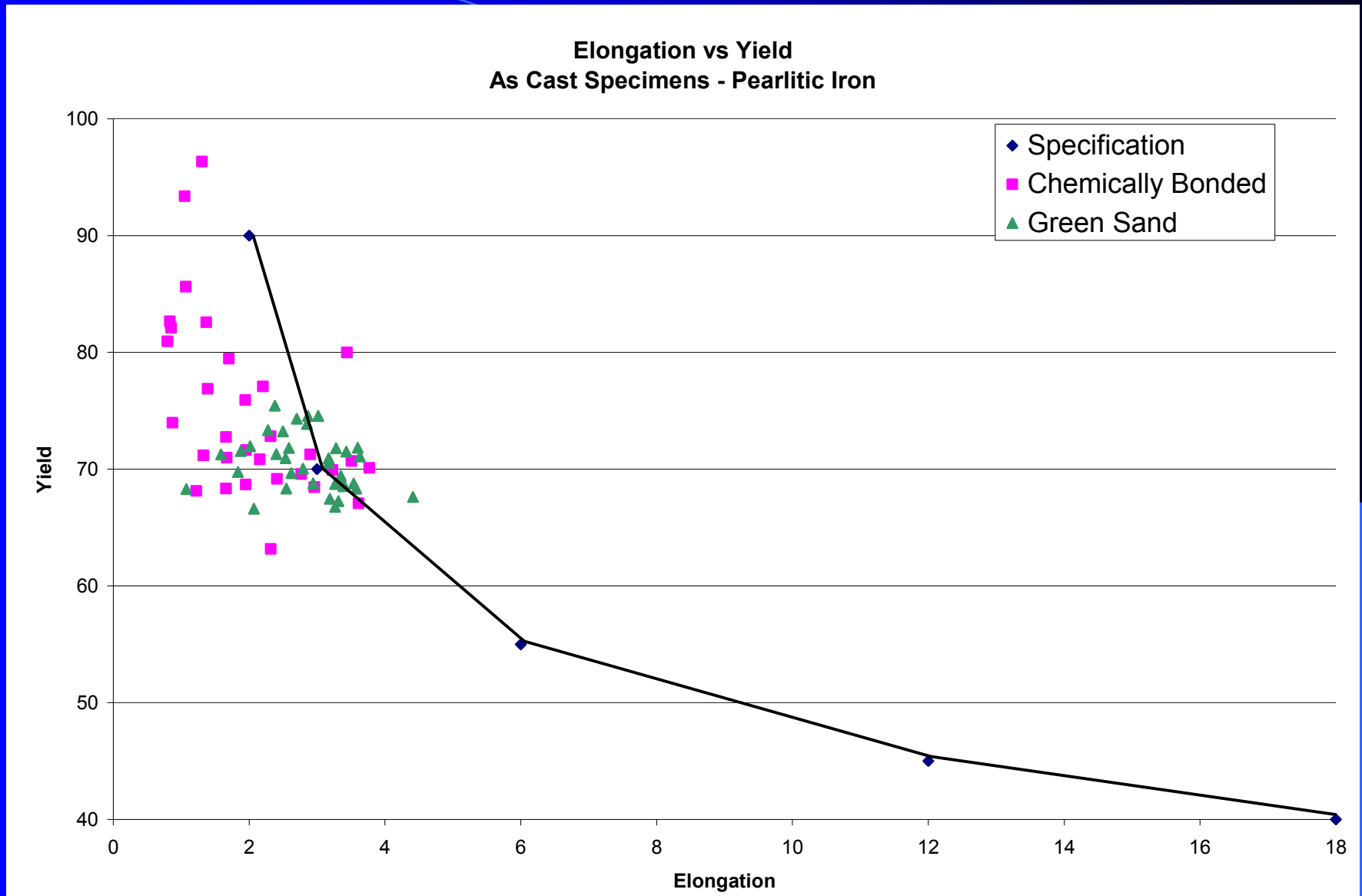
- Machine the castings and Y-Blocks
  - Grips machined on all
  - Gage section Machined on castings 1, 2, 3, & 4
  - Gage section left as-cast on castings 5, 6, 7, & 8
- Test the castings and Y-block samples

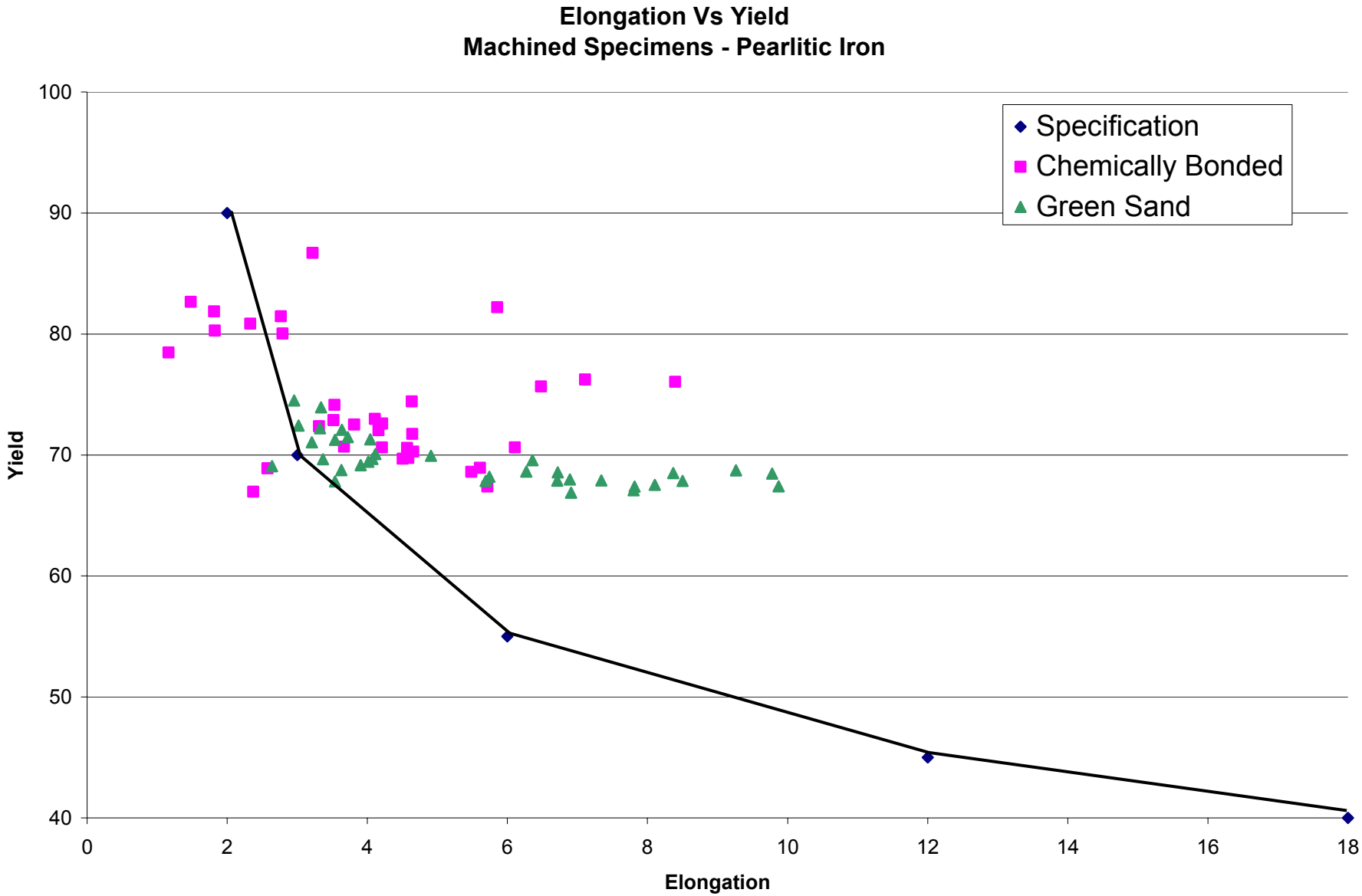

1/4”
4
3
3/8”
1/2”
2
1
1/2”
8
1/2”
7
1/2”
6
3/8”
5
1/4”

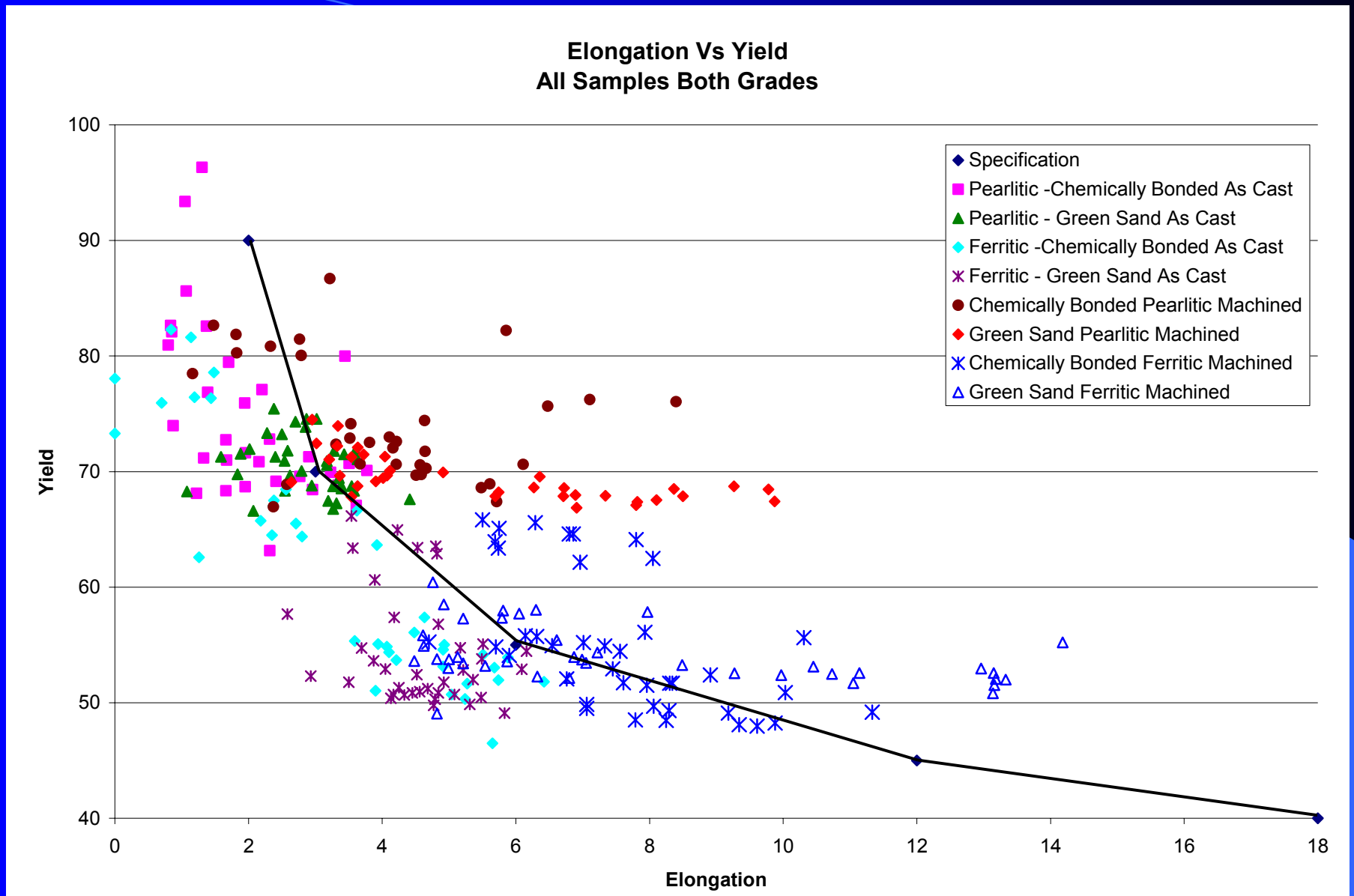
Test Results

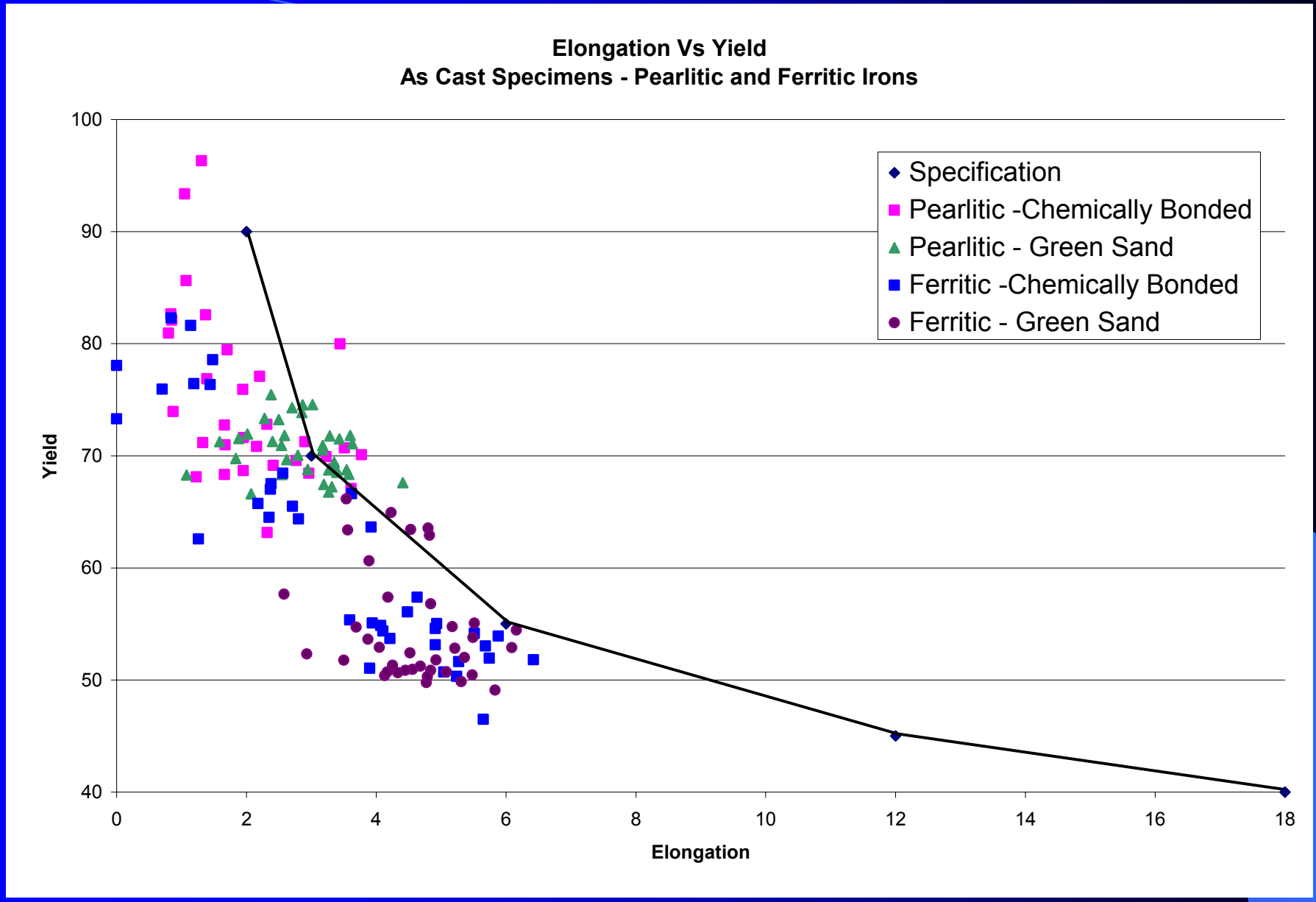
- Skin Effect

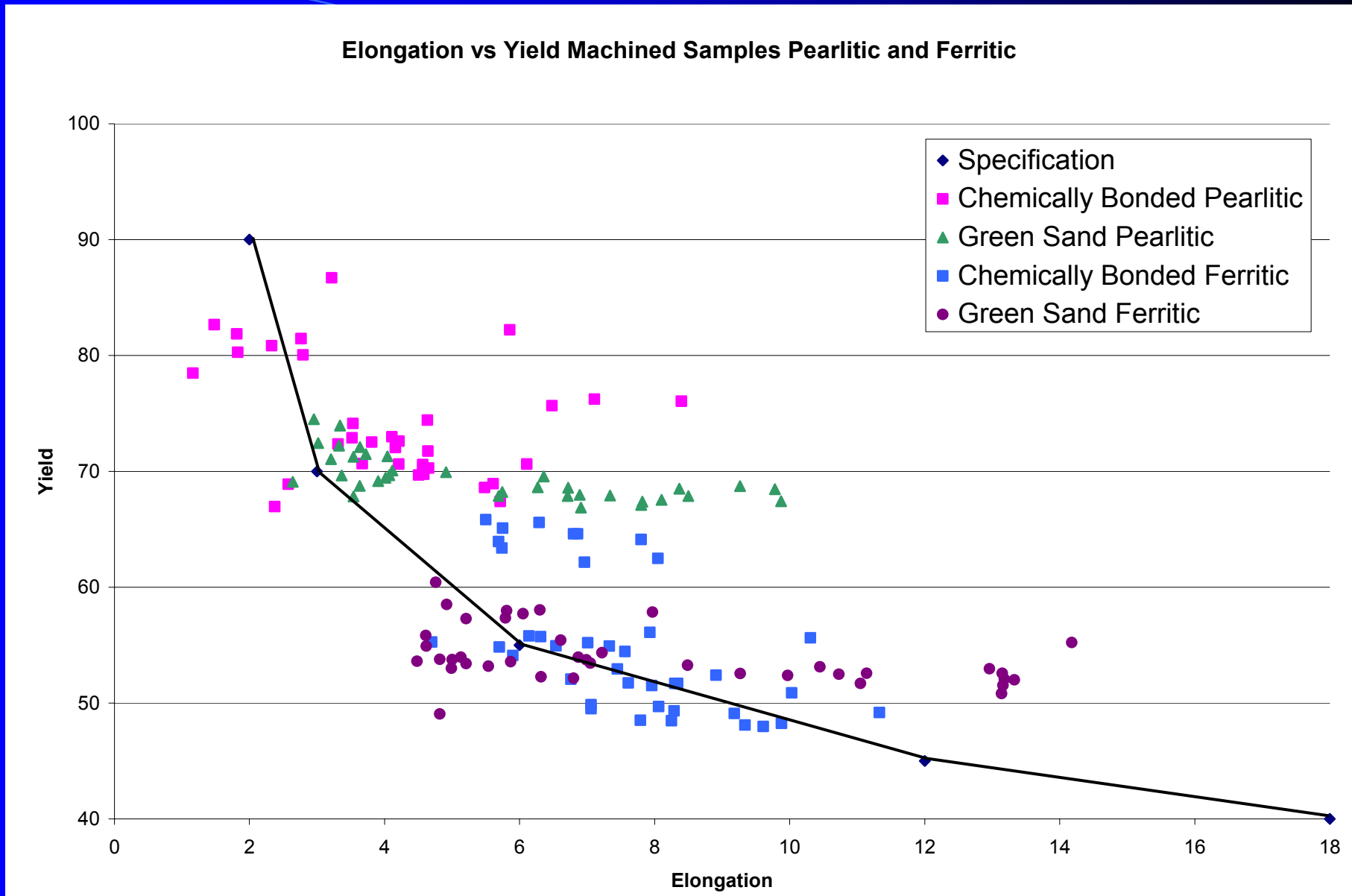

Elongation vs Yield
All Pearlitic Data
Specification
Chemically Bonded
Green Sand
Yield
Elongation
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18


Elongation vs Yield
As Cast Specimens - Pearlitic Iron
Specification
Chemically Bonded
Green Sand
Yield
Elongation
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18


Elongation Vs Yield
Machined Specimens - Pearlitic Iron
Specification
Chemically Bonded
Green Sand
Yield
Elongation
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18

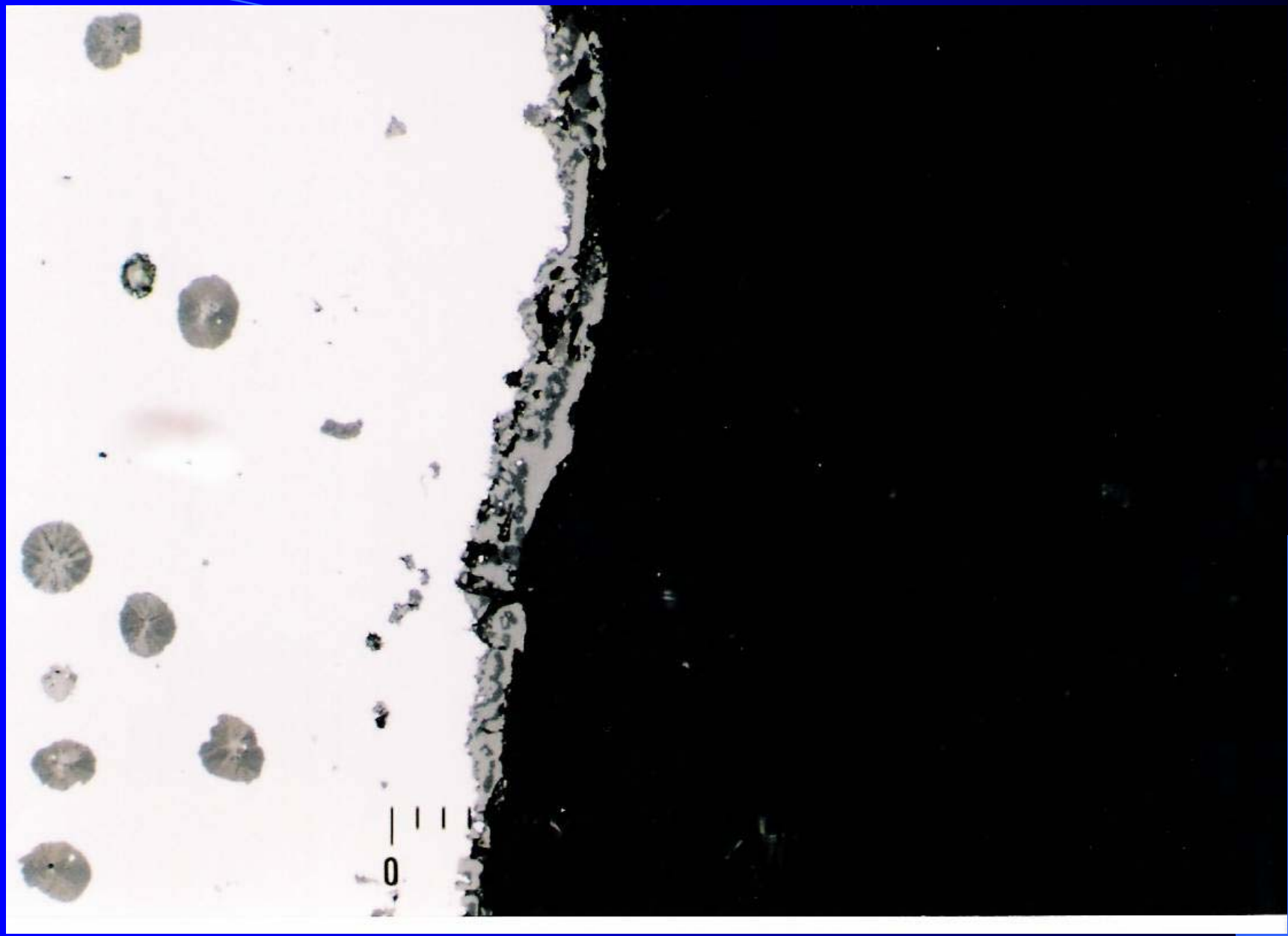

Elongation Vs Yield
All Samples Both Grades
Yield
Elongation
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18
Specification
Pearlitic -Chemically Bonded As Cast
Pearlitic - Green Sand As Cast
Ferritic -Chemically Bonded As Cast
Ferritic - Green Sand As Cast
Chemically Bonded Pearlitic Machined
Green Sand Pearlitic Machined
Chemically Bonded Ferritic Machined
Green Sand Ferritic Machined


Elongation Vs Yield
As Cast Specimens - Pearlitic and Ferritic Irons
Yield
Elongation
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18
Specification
Pearlitic -Chemically Bonded
Pearlitic - Green Sand
Ferritic -Chemically Bonded
Ferritic - Green Sand


Elongation vs Yield Machined Samples Pearlitic and Ferritic
Yield
Elongation
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18
Specification
Chemically Bonded Pearlitic
Green Sand Pearlitic
Chemically Bonded Ferritic
Green Sand Ferritic

Test Results

- Skin Effect
  - Reaction Products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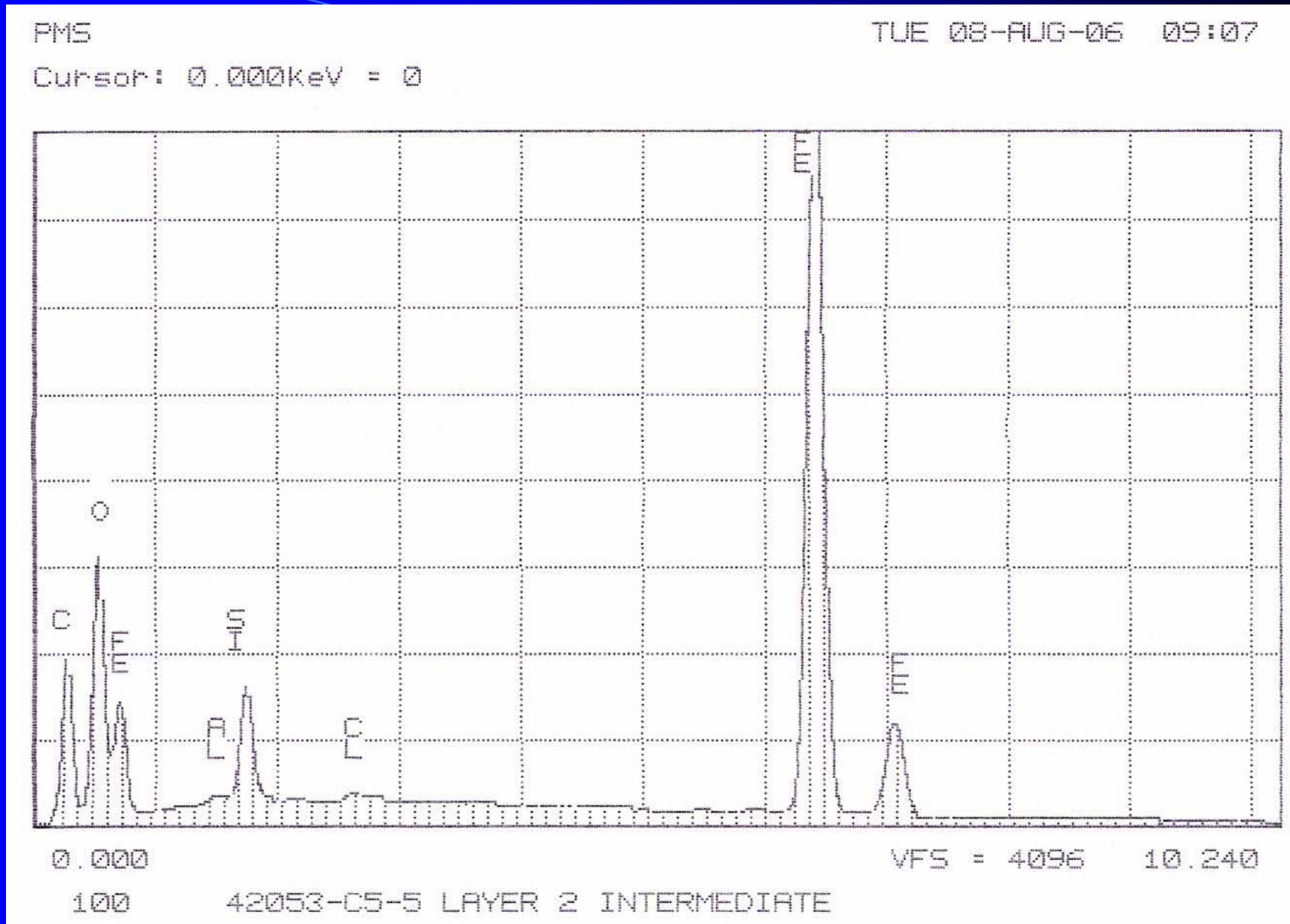
PMS
TUE 08-AUG-06 09:07
Cursor: 0.000keV = 0
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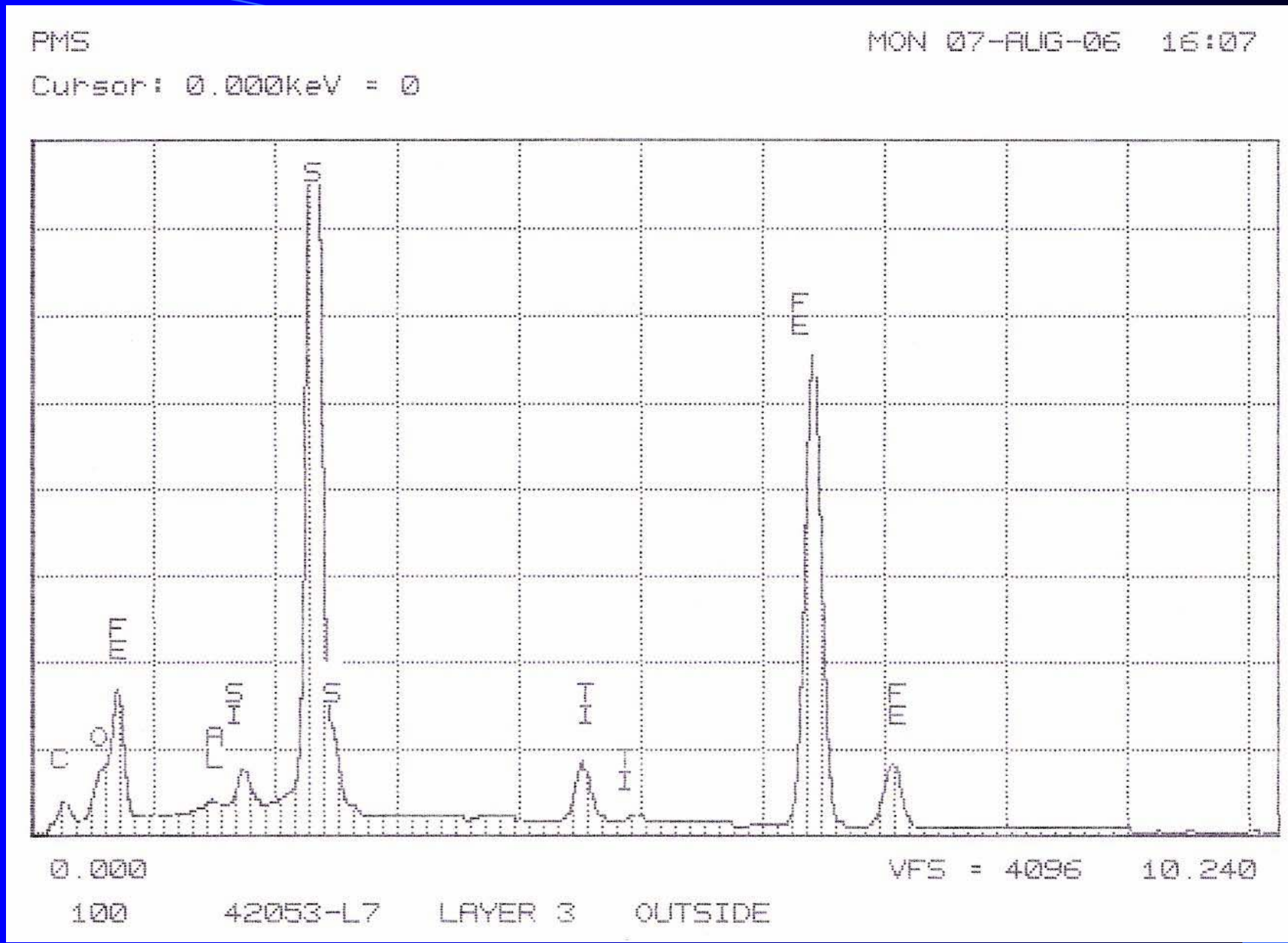
VFS = 4096 10.240
100 42053-C5-5 LAYER 2 INTERMEDIATE


PMS
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Cursor: 0.000keV = 0
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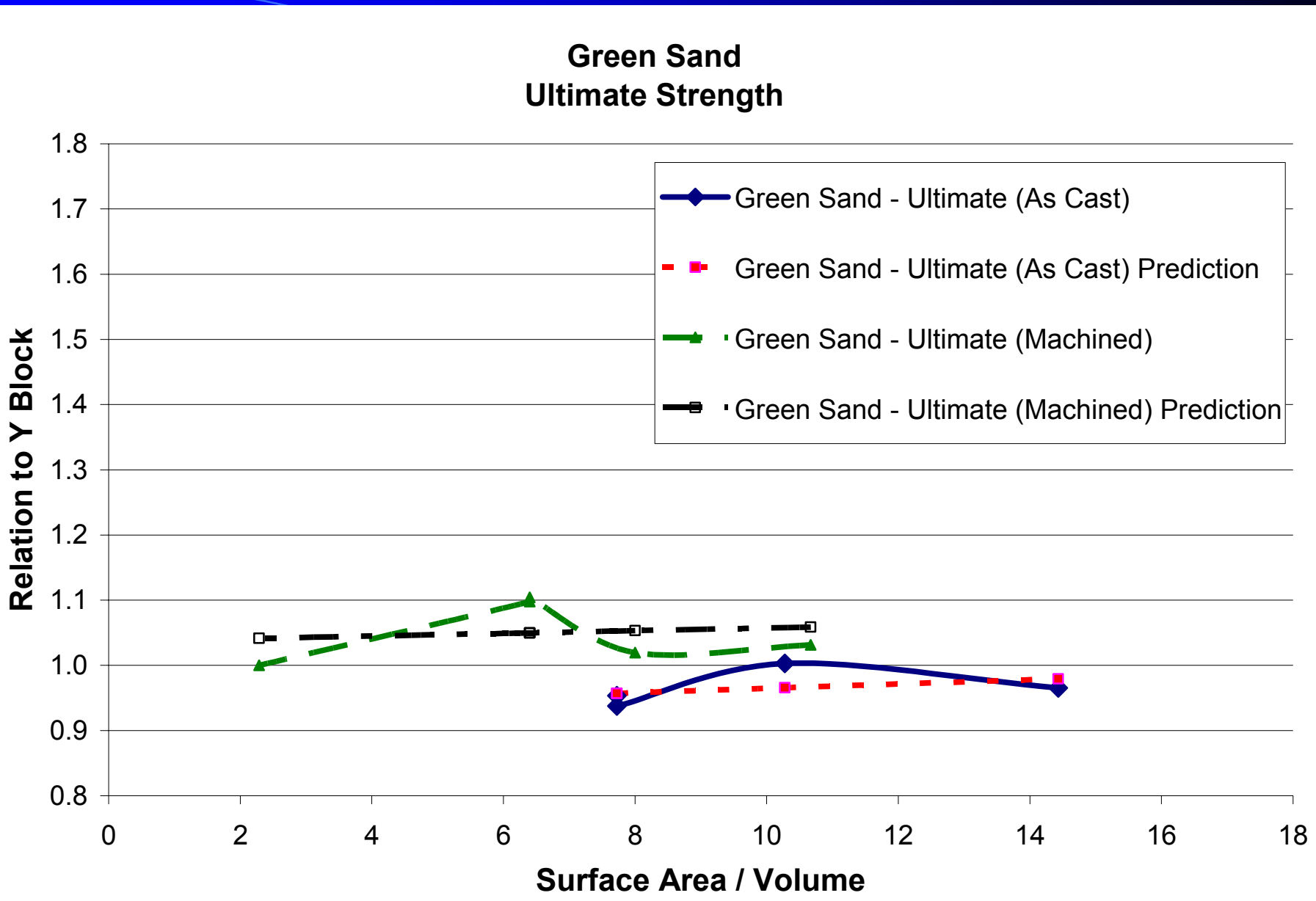
VFS = 4096 10.240
100 42053-L7 LAYER 3 OUTSIDE

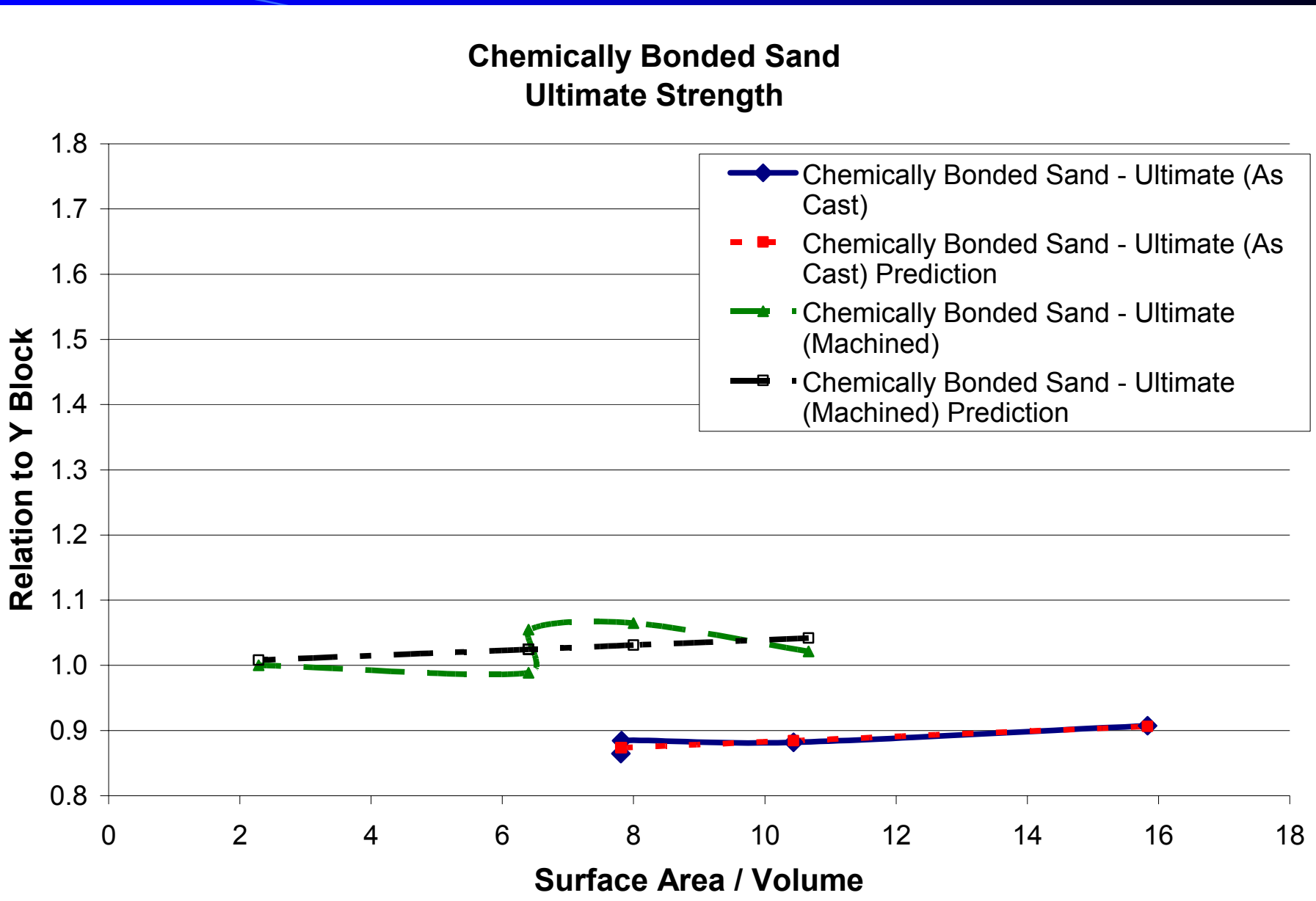
Test Results

- Skin Effect
  - Reaction Products
    - Oxides on green sand bars
    - Sulfides on chemically bonded sand bars

Test Results

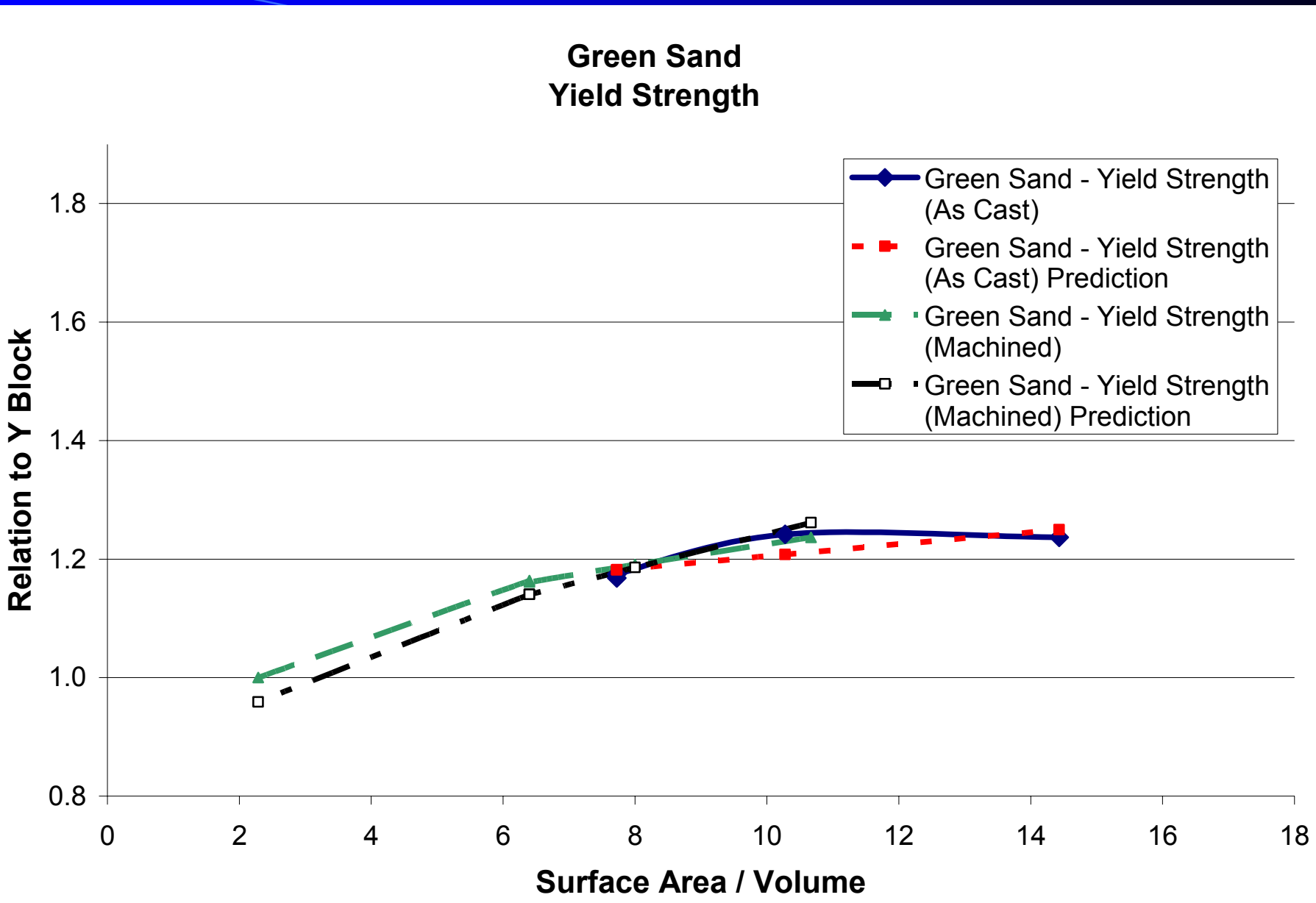
- Skin Effect
  - Reaction Products
    - Oxides on green sand bars
    - Sulfides on chemically bonded sand bars
- Cooling Rate Effect
  - Ultimate Tensile

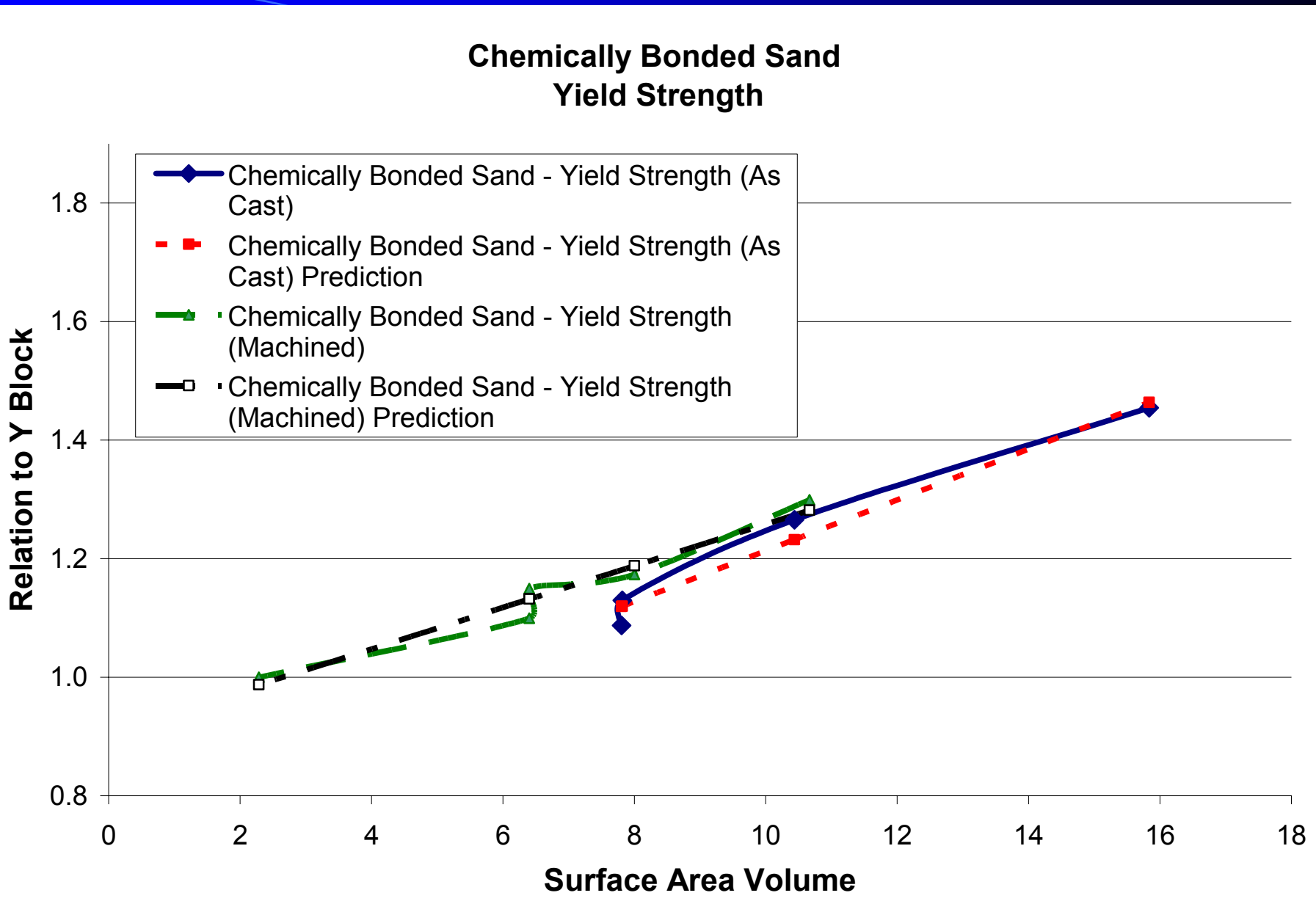

Green Sand
Ultimate Strength
Relation to Y Block
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0
2
4
6
8
10
12
14
16
18
Surface Area / Volume
Green Sand - Ultimate (As Cast)
Green Sand - Ultimate (As Cast) Prediction
Green Sand - Ultimate (Machined)
Green Sand - Ultimate (Machined) Prediction


Chemically Bonded Sand
Ultimate Strength
Relation to Y Block
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0
2
4
6
8
10
12
14
16
18
Surface Area / Volume
Chemically Bonded Sand - Ultimate (As Cast)
Chemically Bonded Sand - Ultimate (As Cast) Prediction
Chemically Bonded Sand - Ultimate (Machined)
Chemically Bonded Sand - Ultimate (Machined) Prediction

Test Results

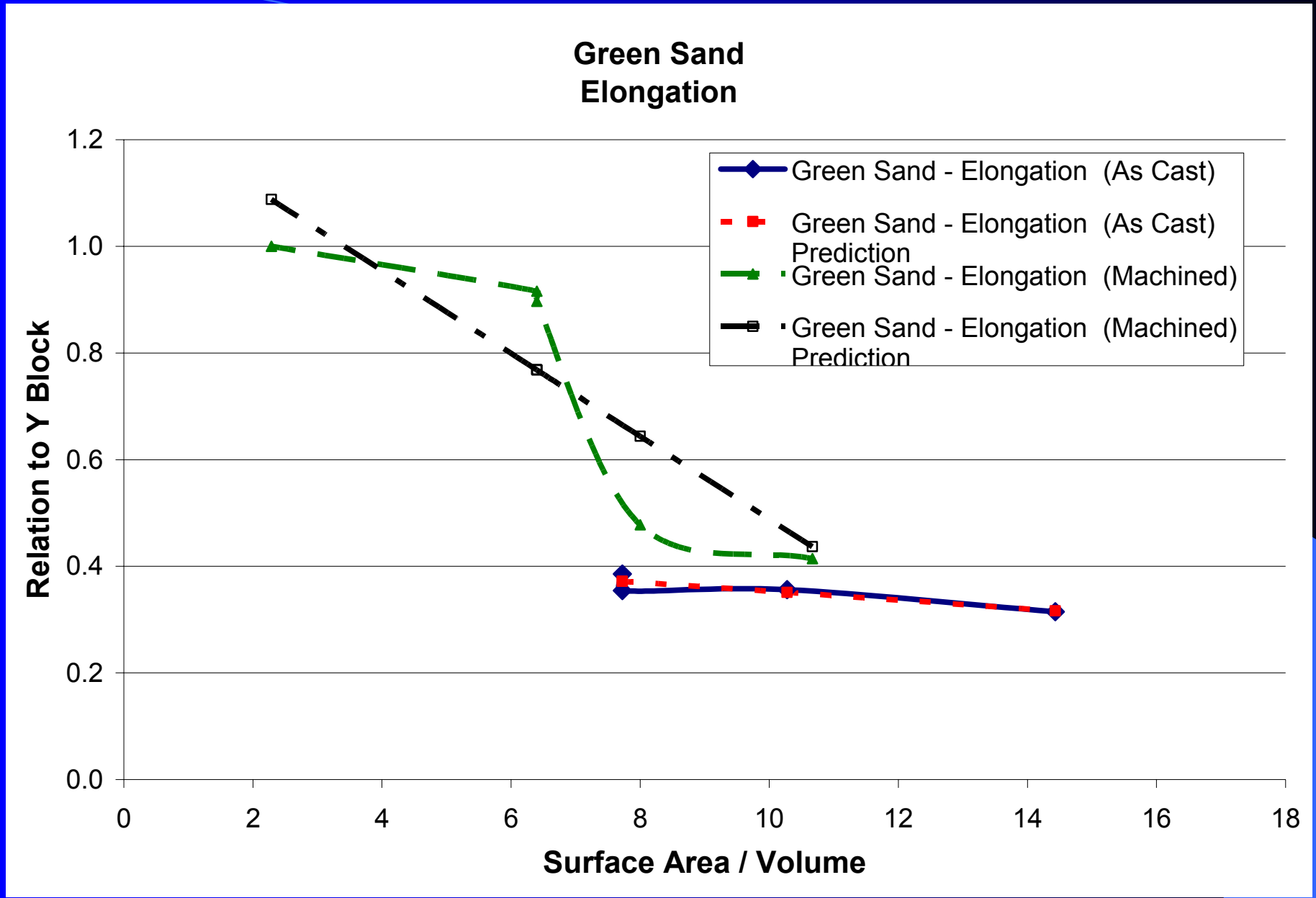
- Skin Effect
  - Reaction Products
    - Oxides on green sand bars
    - Sulfides on chemically bonded sand bars
- Cooling Rate Effect
  - Ultimate Tensile
  - Yield Strength

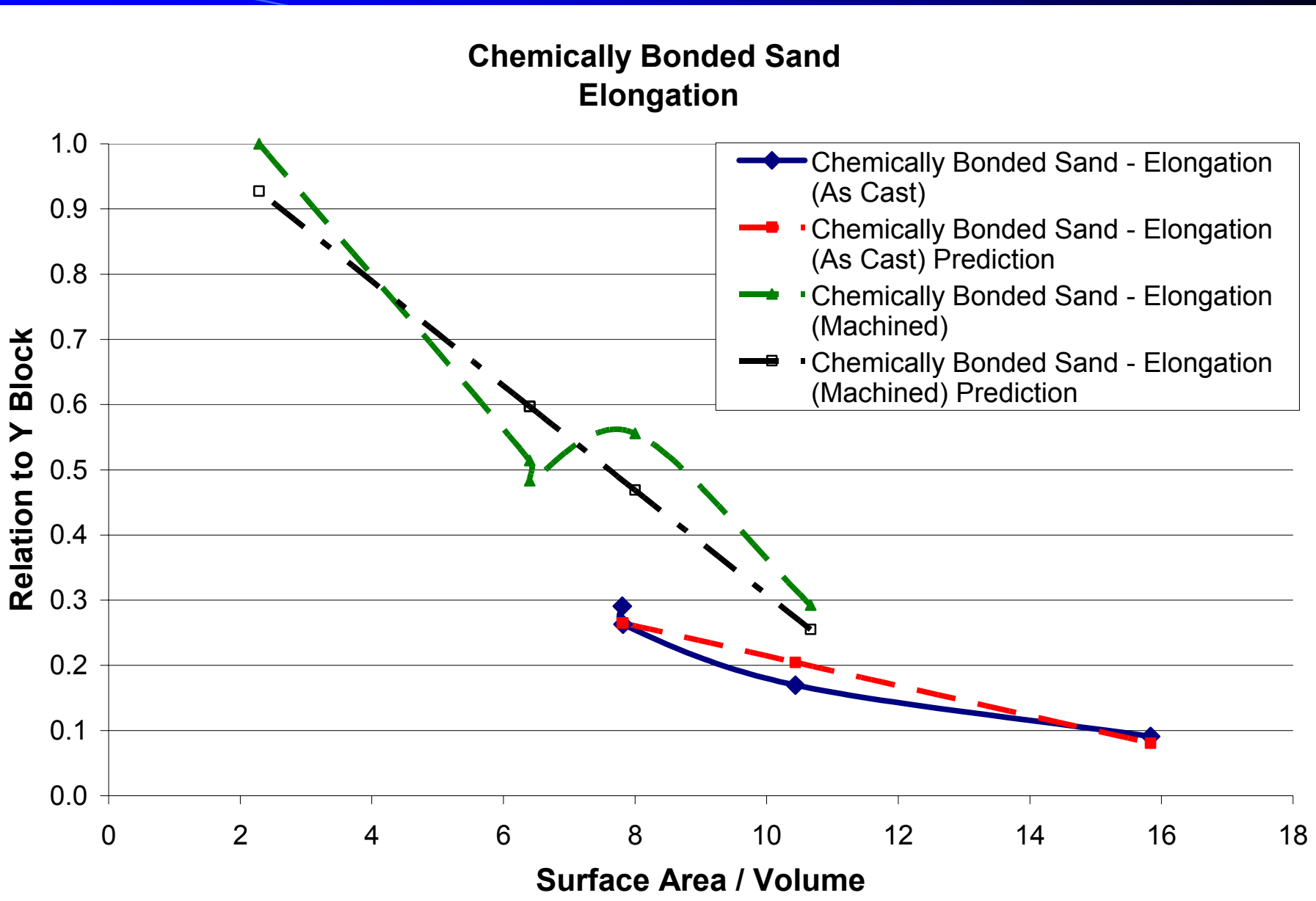

Green Sand
Yield Strength
Relation to Y Block
1.8
1.6
1.4
1.2
1.0
0.8
0
2
4
6
8
10
12
14
16
18
Surface Area / Volume
Green Sand - Yield Strength (As Cast)
Green Sand - Yield Strength (As Cast) Prediction
Green Sand - Yield Strength (Machined)
Green Sand - Yield Strength (Machined) Prediction


Chemically Bonded Sand
Yield Strength
Chemically Bonded Sand - Yield Strength (As Cast)
Chemically Bonded Sand - Yield Strength (As Cast) Prediction
Chemically Bonded Sand - Yield Strength (Machined)
Chemically Bonded Sand - Yield Strength (Machined) Prediction
Relation to Y Block
1.8
1.6
1.4
1.2
1.0
0.8
0
2
4
6
8
10
12
14
16
18
Surface Area Volume

Test Results

- Skin Effect
  - Reaction Products
    - Oxides on green sand bars
    - Sulfides on chemically bonded sand bars
- Cooling Rate Effect
  - Ultimate Tensile
  - Yield Strength
  - Elongation


Green Sand
Elongation
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Relation to Y Block
0
2
4
6
8
10
12
14
16
18
Surface Area / Volume
Green Sand - Elongation (As Cast)
Green Sand - Elongation (As Cast) Prediction
Green Sand - Elongation (Machined)
Green Sand - Elongation (Machined) Prediction


Chemically Bonded Sand
Elongation
Relation to Y Block
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
Surface Area / Volume
Chemically Bonded Sand - Elongation (As Cast)
Chemically Bonded Sand - Elongation (As Cast) Prediction
Chemically Bonded Sand - Elongation (Machined)
Chemically Bonded Sand - Elongation (Machined) Prediction

Test Results

- Cooling Rate Effect-Structure
  - As Surface Area To Volume Ratio Decreased (Larger Bars)
    - More Ferrite 15% to 30%
    - Less Carbides
    - More Carbides in Chemically Bonded Sand Castings

CONCLUSIONS

- 1. The Skin on Pearlitic Ductile Iron:
  - Lowers Ultimate Tensile Strength
  - Has a tendency to Lower Yield Strength but by and large no significant effect
  - Lowers Elongation

CONCLUSIONS

- 2. The Skin Effect Diminishes as Section Size Increases Due to Mass. Since the condition is on the surface, as the surface area to volume ratio decreases, Or as the bar becomes larger, the surface has less influence of properties.

CONCLUSIONS

- 3. As Surface Area to Volume Ratio Increases (Bars become smaller and cooling rate increases)
  - Ultimate strength is not significantly affected
  - Yield Strength Increases Linearly
  - Elongation Decreases Linearly
  - Structure Changed as Expected
    - Less Ferrite
    - More Carbides

RECOMMENDATIONS

- Expand the Scope to Include Other Ductile Iron Grades
- Investigate These Effects for Larger Section sizes
- Better Understand the Skin Effect to Minimize It
- Evaluate the Effects of Different Compositions for the Same Ductile Grades

ACKNOWLEDGEMENTS

- Sponsoring Committee 5J Cast Iron Quality Control and The Monitoring Committee
- Clearfield Machine Co, Clearfield, PA
- Calhoun Foundry Homer, MI
- Galesburg Foundry, Galesburg, IL
- Stork Climax Research Services, Wixom, MI
- Lobenhofer Consulting
- Professional Metallurgical Services

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THANK YOU

QUESTIONS?