The spring Ductile Iron Society Annual Meeting was held June 1-3, 2011 in Dallas, Texas in conjunction with a plant tour of Oil City Iron Works in Corsicana, Texas. The first day included the Research Committee meeting in the morning and in the afternoon was the other DIS operating committee meetings and concluded with the Board of Directors meeting. On Thursday, the attendees enjoyed the technical presentations from 10 quality speakers. At noon, Scott Gledhill of TK Waupaca presented this year’s Annual Report to the DIS Members in attendance.

Here is Scott’s address;

“At this time I will recap the society’s activities during this past year before proceeding with the annual business meeting and the election of new officers.

The past year has been one where the foundry industry seems to have rebounded where the U.S. economy is showing a much slower pace. Your society has rebounded very slowly and there seems to be a chance to regain some lost members and even add some new members to the society. We have continued to keep our costs low like we did in previous years. The society will end the 2010/2011 fiscal year in the black. Your board of directors is very pleased with the results.

We can also see the effect of the times by just looking at the turnout at this meeting.

The proposed budget for the fiscal year 2011-2012 is once again projecting a small gain mainly due to the increase in the number of members. This past fiscal year we gained a few new members.
SINTERCAST INC. (ASSOCIATE)
LETHBRIDGE IRON WORKS (FOUNDRY – CANADA)
REJOINING MEMBER GREDE HOLDINGS, LLC (FOUNDRY)

During this past year we held two general meetings. The first one was our Annual Meeting held in Vancouver, British Columbia, Canada with a tour of Robar Industries Inc. and Century Pacific Foundry in Surrey, B.C. with 92 attending including 13 spouses. The second meeting last fall, was a special meeting as we held our first ever Heavy Section Ductile Iron Conference in Cleveland, Ohio. The attendance for that conference was 152.

The Ductile Iron Society did hold a Production Seminar on March 15 & 16, 2011 in Rolling Meadows, Illinois. The attendance was 25 for this seminar. As most of you may know we had to cancel 2009 and 2010 due to the economy. We were very delighted to see so many register for the seminar. Thanks go out to our very special instructors, Kathy Hayrynen of Applied Process, Fred Linebarger of Miller & Company and Gene Muratore of Rio Tinto.

Also, I want to thank all of those that contributed to our “Hot Topics” publications and those that wrote articles for the “Ductile Iron News”.

Four Keith D. Millis scholarships were awarded at the 2010 College Industry Conference held on November 18 & 19, 2010 at the Westin Hotel in Chicago. I would like to thank John Keough of Applied Process and Gary Gigante of TK Waupaca for selecting this year’s students. They are Rhiannon Bragg of the University of Alabama – Birmingham, Alexander Hoimes of Penn State, Scott Giese of the University of Northern Iowa and Russ Rosmait of Pittsburg State. Each student received $2000. Your DIS Board has agreed once again this year to make up whatever short fall amount so that we can continue to hand out $8000.00 in scholarships at the next FEF CIC Conference.

Your society continues to make a donation to the Keith Millis scholarship fund every year so it will continue to grow. Jim wood attended this past year’s conference. We also had a booth for the industry information session where we distributed the “Spheres of Influence” t-shirts. They were a very popular handout during this session as you would well understand. Once again thanks to the members that sponsored these t-shirts. They are Elkem, Bremen Castings, Foseco, Buck company, Dotson Foundry, Betz Industries, Applied Process, Farrar Corporation, Hitachi Automotive, Benton Foundry, Hickman Williams & Company, Penticton Foundry, Emsco, Seneca Foundry, Superior Graphite, Blackhawk de Mexico, and Thyssen Krupp Waupaca. Also I should mention the hard work by your University Relations Committee members. Thanks go out to Bill Sorensen for his invitation to the DIS to attend this important conference.

The Research Committee met three times during the past year. We completed two projects in 2010-2011 and we have currently one fairly large active project. Two years ago your Board of Directors approved the funding of $47,000 to be spent over 2 years on a new DIS project number #46. We are part of a group of investors consisting of AFS, DIS and a consortium of foundry companies on a Ductile iron structure/property optimization project. The total cost of this project is $155,000. Last year Stork Climax Research completed phase #1 and are well into phase #2. This project should be completed by the end of 2011.
We will now proceed with the annual business meeting.

We have 3 foundry member directors retiring from the Board of Directors as of June 30th. They are Jean Bye of Dotson Company, Richard Hicks of Farrar Corporation, and Bill Juergens of TB Woods. We also have 1 associate board member retiring this year. He is Rich Nelson of Superior Graphite Company. We would like to thank all four board members for their participation and dedication to the society over the past 3 years.

To replace those retiring board members, the nominating committee recommends the following slate to serve on the board of directors for a 3 year term effective July 1, 2011;

TIM BROWN OF BENTON FOUNDRY
ANDY FRANKS OF HITACHI METALS AUTOMOTIVE COMPANY
GREG SELIP OF ELLWOOD ENGINEERED CASTINGS
ALEX GYARMATY OF COORSTEK – FORMERLY SAINT GOBAIN CERAMICS (ASSOCIATE MEMBER)

The attendees approved the slate.

I declare that this Annual Meeting is now adjourned.”

***************************

On Thursday evening the attendees, as always, enjoyed the banquet with entertainment. Scott Gledhill again took the podium and was in charge of the proceedings. He acknowledged the 3 year service by the retiring Board members.

Jean Bye of Dotson Foundry
Richard Hicks of Farrar Corporation

Bill Juergens of TB Woods

Richard Nelson of Superior Graphite

Scott then called upon each new member of the Ductile Iron Society that joined since October 2010 to come to the front to receive their membership certificates. They are;
Mark Fritz of Ferrosource, A Division of Stemcor USA, Inc.

David Petry of Primetrade, Inc.

Tim Herring of ABP Induction
Thorsten Reuther of Hofmann Ceramic GmbH, Germany

John Davies of Lethbridge Iron Works – Alberta, Canada

Missing are:

Trigg Brothers Ltd. From Australia
Oshkosh Corporation

We also acknowledged our new members who were absent at our last fall 2010 meeting.
Scott then handed out the Ductile Iron Society's Service Citations to those who served on the Research Committee.
Absent

Carlos Leon of Pure Power Technologies Metalcastings Group
Retiring Properties Sub-Committee Chairman Research Committee

The Ductile Iron Society then celebrated the Annual Service Award. This year the “Member of the Year” award went to Pete Guidi of Hitachi Metals Automotive Group USA, LLC. Dick McMinn of Buck Company made the introductions and then proceeded to roast Pete in good fun.

Pete Guidi is a native Texan, born in Pasadena, Texas. Growing up in a small east Texas town of Lufkin.

At the age of 16 during summer breaks he started working for a sub-contractor that did the brick work (ovens & furnaces) for Texas Foundries. He was already familiar with the foundry industry; his father was Vice-President of Manufacturing at Texas foundries for 35 years.

He went on to Texas A&M and co-op at Texas Foundries and was an FEF scholarship recipient. After college he worked at Texas Foundries working in all departments eventually becoming Superintendent of the Steel Division. He moved on to Moline Corp, St Charles, Ill then to Grinnell corp. in Columbia, Pa and in 1993 moved to Ward Manufacturing in Blossburg, Pa.

He is currently President/CEO of Ward Manufacturing and Executive VP of Hitachi Metals Automotive Components USA in Lawrenceville, Pa.

He has been associated with ductile iron foundries his whole career, he is a board member and past President of the Pennsylvania Foundry Association, past board member and past President of the DIS from 2005 – 2007, and currently the Treasurer of the Ductile Iron Society.

He has been involved with the DIS since 1989 and was intimately involved with the society during the restructuring time to help steer the society to recovery. He also claims to have only missed three meetings since 1989.

The banquet concluded by Rodrigo Alpizar and Felipe Valdes making a presentation on next
The year's 70th World Foundry Congress & 18th Fundiexpo to be held in Monterrey, Mexico from April 25 to 27, 2012.

To end the banquet, Scott introduced Eric Meyers, the President of Oil City Iron Works, to give everyone a brief history of the foundry and also let everyone know what they were going to see on the tour on Friday morning. Thanks go out to Eric, Bill Riley, VP of Manufacturing, Bill Knuerr, Quality Manager, and the rest of the helpful staff at Oil City for the great tour they put on for our attendees.

Please mark your calendars now for the DIS fall T & O meeting to be held at the Wyndham Hotel in Gettysburg, PA from October 26-28, 2011 and in conjunction with a tour of TB Woods in Chambersburg, PA.

Jim Wood
DIS Executive Director
June 2, Morning Session

SPEAKER BIO'S

JIM CSONKA WITH KATHY HAYRYPNEN

JIM CSONKA


THE DIS WELCOMES JIM, WHO IS HERE TO TALK ABOUT “FOUNDRY ALLOYS, A WORLD WIDE PERSPECTIVE”
SERGE GRENIER  WITH KATHY HAYRYNEN

SERGE GRENIER

SERGE GRADUATED FROM MCgILL UNIVERSITY IN MONTREAL, CANADA IN 1989 WITH HIS BACHELORS DEGREE IN METALLURGICAL ENGINEERING. HE THEN COMPLETED A MASTERS DEGREE IN MATERIAL SCIENCE ALSO FROM MCgILL UNIVERSITY, ON THE PRODUCTION OF SILICON NITRIDE POWDERS BY THE CARBOTHERMAL REDUCTION PROCESS. IN 1996, SERGE OBTAINED HIS PhD FROM ECOLE POLYTECHNIQUE IN MONTREAL ON THE DEPOSITION OF TITANIUM NITRIDE FILMS USING A REACTIVE THERMAL PLASMA PROCESS. SINCE THEN, SERGE HAS WORKED 19 YEARS IN A WIDE VARIETY OF MATERIALS SCIENCE FIELDS RELATED TO METALLURGY, NANO-MATERIALS, THERMAL PLASMA COATINGS, HYDROGEN STORAGE SYSTEMS AND ULTRA-PURE MATERIALS. HE HOLDS 8 PATENTS AND IS THE AUTHOR OF SEVERAL TECHNICAL PAPERS ON VARIOUS METALLURGICAL TOPICS. SERGE JOINED RIO TINTO A YEAR AGO WHERE HE PRESENTLY HOLDS A RESEARCH ENGINEER’S POSITION IN THE FERROUS PRODUCTS GROUP.

THE DIS WELCOMES SERGE, WHO IS HERE TO TALK ABOUT “HEAVY SECTION DUCTILE IRON UPDATE”
STEVE THELEN

STEVE THELEN

STEVE GRADUATED FROM MICHIGAN TECHNOLOGY UNIVERSITY IN HOUGHTON, MI IN 1987 WITH A BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. STEVE IS CURRENTLY THE TECHNICAL MANAGER AT GREDE BISCOE IN BISCOE, NORTH CAROLINA. HIS FOUNDRY CAREER STARTED WITH GREDE FOUNDRIES IN KINGSFORD, MICHIGAN IN 1986 AS THE METALLURGICAL PROJECT TECHNICIAN AND THEN MOVED ON TO ANOTHER GREDE FOUNDRY IN VASSAR, MICHIGAN FROM 1988 TO 1989 AS THE ASSISTANT QUALITY ENGINEER AND CUPOLA MELTING SUPERVISOR. THEN IN 1989, STEVE CHANGED COMPANIES AND MOVED TO INTERMET CORPORATION IN RADFORD, VIRGINIA UNTIL 2003 WHERE HE HELD POSITIONS AS PLANT METALLURGIST AND LAB MANAGER, SR. QUALITY ENGINEER, AND RADFORD SHELL FOUNDRY MANAGER OF METALLURGY. HE THEN RETURNED TO HIS CURRENT POSITION WITH GREDE BISCOE IN 2003. STEVE IS THE CURRENT PUBLICITY & VICE CHAIR OF THE PIEDMONT CHAPTER OF THE AFS. HE HAS TRAVELED INTERNATIONALLY AS A TECHNICAL AND QUALITY REPRESENTATIVE WITH GREDE. HE ALSO HAS CO-AUTHORED TECHNICAL PAPERS ON SELECTIVE INDUCTION HARDENING WHICH WAS PRESENTED AT THE SAE 2002 WORLD CONGRESS.

THE DIS WELCOMES STEVE, WHO IS HERE TO TALK ABOUT “TREATMENT OF MICRO SHRINKAGE IN DUCTILE IRON WITH A FeSiLa INOCULANT”
DEVELOPMENT SPECIALIST PRIMARILY IN REFRATORY COATINGS. AFTER MOVING BACK TO THE UNITED STATES, HE HAS BEEN WORKING WITH FOUNDRIES TO IMPROVE THEIR OVERALL CASTING QUALITY AND REDUCE COST THROUGH COATING TECHNOLOGIES. HE IS AN ACTIVE MEMBER OF THE AFS AND A MEMBER OF THE AFS 4-F COMMITTEE.

THE DIS WELCOMES BRUCE, WHO IS HERE TO TALK ABOUT “THE INFLUENCE OF COATINGS ON THE GRAPHITE STRUCTURE IN THE RIM ZONE OF DUCTILE IRON CASTINGS”

ROB LOGAN WITH KATHY HAYRYNEN

ROBERT LOGAN

ROB LOGAN HAS BEEN WORKING IN THE IRON FOUNDRY AND STEEL BUSINESS FOR 22 YEARS.

HIS CAREER STARTED AT DOFASCO (NOW ARCELOR MITTAL) IN 1988, WORKING IN VARIOUS PROCESS AND PRODUCT DEVELOPMENT ROLES. ROB JOINED WESCASS INDUSTRIES IN 1994. WHILE AT WESCASS HE WORKED IN A VARIETY OF MANUFACTURING POSITIONS INCLUDING METALLURGICAL, QUALITY AND ENGINEERING MANAGEMENT ROLES. IN 2001 HE MOVED INTO THE WESCASS PRODUCT DESIGN AND R&D GROUP AS PRODUCT DEVELOPMENT LEADER AND SOON BECAME THE CORPORATE R&D LEADER.

IN 2008 HE JOINED ELKEM METALS INC., FOUNDRY DIVISION AS NATIONAL ACCOUNT MANAGER. IN THIS ROLE HE MANAGES ACCOUNTS FOR SALES IN PRIMARILY CANADA AND CONDUCTS TECHNICAL SUPPORT IN THE AMERICAS. ROB IS ALSO A MEMBER OF THE ELKEM RESEARCH COMMITTEE AND THE DUCTILE IRON SOCIETY (DIS) COMMITTEE.

ROB HAS PUBLISHED AND PRESENTED SEVERAL PAPERS AT SAE, DIS, AND MANY OTHER INDUSTRY FUNCTIONS IN NORTH AMERICA AND EUROPE.

ROB RECEIVED A BSC. DEGREE IN MATERIALS SCIENCE AND ENGINEERING AND AN MBA FROM MCMASTER UNIVERSITY AND CURRENTLY RESIDES WITH HIS WIFE AND TWO DAUGHTERS IN BRANTFORD, ONTARIO.
June 2, Afternoon Session

Speaker Bios

ALFRED SPADA


THE DIS WELCOMES AL WHO IS HERE TO TALK ABOUT “NORTH
MARK KENNEDY

MARK GRADUATED FROM THIEL COLLEGE IN GREENVILLE, PA IN 1974. MARK IS CURRENTLY THE SENIOR APPLICATION SPECIALIST FOR INDUSTRIAL METALS FOR HARBISON WALKER REFRACTORIES. BEFORE JOINING HARBISON WALKER, MARC WORKED FOR BOTH UNITED AND UNIVERSAL REFRACTORIES FOR A COMBINED 26 YEARS IN BOTH THE STEEL AND FOUNDRY INDUSTRIES. HE DEVELOPED VACUUM FORMED PRODUCTS AND REFRACTORIES FOR UNIVERSAL FOR THE FOUNDRY INDUSTRY AND PROJECT MANAGER AT MAJOR STEEL MILLS FOR DRY VIBES FOR TUNDISHES. THEN MARC SPENT THE NEXT 5 YEARS HAVING OWNERSHIP IN A MANUFACTURE’S REP COMPANY, REPRESENTING THERMAL CERAMICS, UNIVERSAL REFRACTORIES, UNITED REFRACTORIES, REFRACTORY SALES AND SERVICE.

THE DIS WELCOMES MARK, WHO IS HERE TO TALK ABOUT REFRACTORIES 101”
MINORU HIRATA WITH GENE MURATORE

MINORU HIRATA


THE DIS WELCOMES MINORU HIRATA WHO IS HERE TO TALK ABOUT “DEVELOPMENT OF AERATION MOLDING TECHNOLOGY AND ITS PRACTICAL APPLICATION”
JOE FUQUA WITH GENE MURATORE

JOE FUQUA

JOE GRADUATED FROM THE UNIVERSITY OF MISSOURI-ROLLA IN 1978 WITH A BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. JOE WAS ALSO A FEF STUDENT. JOE IS CURRENTLY EMPLOYED BY AMERICAN COLLOID COMPANY AS PRODUCT MANAGER FOR A RECENTLY DEVELOPED LINE OF CHEMICAL BINDER SYSTEMS. BEFORE JOINING AMERICAN COLLOID IN 2002, JOE WAS THE PRESIDENT AND CO-FOUNDER OF FNG INDUSTRIES WHICH BEGAN IN 1990. FNG WAS A PRODUCER OF SILICON CARBIDE AND FERROALLOY BRIQUETTED PRODUCTS FOR CUPOLA MELTING OPERATIONS. BEFORE GOING OUT ON HIS OWN TO START FNG, JOE SPENT 10 YEARS WITH ASHLAND CHEMICAL AS A TECHNICAL SERVICE REPRESENTATIVE TROUBLESHOOTING PROBLEMS RELATED TO CHEMICAL BINDER SYSTEMS AND PERFORMING CASTING DEFECT ANALYSIS. JOE HAS AUTHORED A NUMBER OF PAPERS FOR AFS PUBLICATIONS AND IS ACTIVE IN AFS AND FEF.

THE DIS WELCOMES JOE WHO IS HERE TO TALK ABOUT “HIGH PERFORMANCE, LOW VOC CHEMICAL BINDER SYSTEM”
DICK WINSEMIUS

DICK, AN ENGINEER, JOINED POWERIT SOLUTIONS CORPORATE ADVISORY BOARD IN SEPTEMBER 2010. IN THIS ROLE, HE SPEARHEADS INDUSTRY OUTREACH AND WORKS TO EXPAND POWERIT’S ALREADY IMPRESSIVE LIST OF FOUNDRY CUSTOMERS. DICK ASSISTS POWERIT IN DEVELOPING PARTNERSHIPS WITH INDUSTRY ORGANIZATIONS AND SUPPLIERS, AS WELL AS WITH PRODUCT DEVELOPMENT, APPLICATIONS AND TECHNICAL SUPPORT. PRIOR TO JOINING POWERIT SOLUTIONS, DICK WORKED AT CANNON-MUSKEGON NOW OWNED BY PCC/PRECISION CASTPARTS CORPORATION, FOR 30 YEARS. WHILE AT CANNON- MUSKEGON, DICK ENGAGED POWERIT SOLUTIONS TO ADDRESS ESCALATING ENERGY USE THAT WAS RESULTING IN PAINFUL PEAK DEMAND CHARGES. POWERIT’S SPARA ENERGY MANAGEMENT SYSTEM SEAMLESSLY INTEGRATED WITH THE FOUNDRY’S RECENTLY ADDED FURNACES TO REDUCE AVERAGE MONTHLY DEMAND WITHOUT EFFECTING PRODUCTION. PRIOR TO JOINING CANNON-MUSKEGON, DICK WAS A PLANT ENGINEER WITH CWC TEXTRON FROM 1997 TO 1980 AND AN ENGINEERING AIDE AT GENERAL TELEPHONE FROM 1976 TO 1977. DICK IS A FOUNDRY INDUSTRY VETERAN WITH EXPERTISE SPANNING PLANT MANAGEMENT, IMPROVEMENTS AND OPERATIONS. HE IS A PAST MEMBER WITH THE LOCAL AFS AND NATIONAL MANAGEMENT ASSOCIATION.

THE DIS WELCOMES DICK WHO IS HERE TO TALK ABOUT “REDUCING COSTS, MAINTAINING PRODUCTION: A TRUE STORY”

(NO PHOTO AVAILABLE)

DOUG WHITE

DOUG GRADUATED FROM McMASTER UNIVERSITY IN HAMILTON, ONTARIO, CANADA IN 1970 WITH HIS BACHELOR OF SCIENCE DEGREE IN METALLURGY. DOUG IS CURRENTLY THE TECHNICAL SERVICES MANAGER FOR ELKEM FOUNDRY PRODUCTS. AFTER A BRIEF PERIOD AT THE STEEL COMPANY OF CANADA R&D DEPARTMENT, HE JOINED CROUSE HINDS OF CANADA, A GRAY IRON AND ALUMINUM FOUNDRY, SERVING AS A METALLURGIST TO SET UP THE MELT AND POUR CYCLE OF A NEW CORELESS INDUCTION FURNACE LINE. IN 1974, HE JOINED UNION CARBIDE CANADA LTD., METALS DIVISION. THIS BUSINESS WAS LATER PURCHASED BY ELKEM AND BECAME ELKEM METAL CANADA INC. IN ADDITION TO CANADA, DOUG HAS HELD POSITIONS WITH ELKEM IN OSLO, NORWAY, ANTIBES, FRANCE, PITTSBURGH, PA AND ASHTABULA, OH. HIS ACTIVITIES HAVE INVOLVED FOUNDRY TECHNICAL SERVICE FOR GRAY AND NODULAR IRON MANUFACTURE, DESIGN AND MANUFACTURE OF NODULIZERS AND INOCULANTS, AND DESULFURIZATION TECHNOLOGY. DOUG HAS WRITTEN NUMEROUS

THE DIS WELCOMES DOUG WHO IS HERE TO TALK ABOUT “AVOIDING SHRINKAGE DEFECTS AND MAXIMIZING YIELD IN DUCTILE IRON”
Link to Presentation: The Influence of Coatings on the Graphite Structure in the Rim Zone of Ductile Iron Castings

BRUCE LUNDEEN - FOSECO WITH KATHY HAYRYNEN

BRUCE GRADUATED FROM IOWA STATE UNIVERSITY IN 1989 WITH A MASTERS DEGREE IN CERAMIC ENGINEERING. HE JOINED FOSECO INTERNATIONAL IN BIRMINGHAM, ENGLAND AS A PRODUCT DEVELOPMENT SPECIALIST PRIMARILY IN REFRACTORY COATINGS. AFTER MOVING BACK TO THE UNITED STATES, HE HAS BEEN WORKING WITH FOUNDRIES TO IMPROVE THEIR OVERALL CASTING QUALITY AND REDUCE COST THROUGH COATING TECHNOLOGIES. HE IS AN ACTIVE MEMBER OF THE AFS AND A MEMBER OF THE AFS 4-F COMMITTEE.

THE DIS WELCOMES BRUCE, WHO IS HERE TO TALK ABOUT “THE INFLUENCE OF COATINGS ON THE GRAPHITE STRUCTURE IN THE RIM ZONE OF DUCTILE IRON CASTINGS”
The Influence of Coatings on the Graphite Structure in the Rim Zone of Ductile Iron Castings

Bruce E. Lundeen
FOSECO

DIS Annual Meeting, June 2, 2011
Dallas, Texas
Introduction

• Degraded graphite structure can occur on all Ductile Iron castings, however is most noticeable on larger castings (i.e., Wind Energy)
• Many factors can influence rim zone graphite degradation.
• Irregular graphite development has been observed when cast in molds that contain sulfur.
• Case study focuses on how coatings can influence the graphite structure in the rim zone of ductile iron castings produced in sulfur containing mold media.
Increased demands on reclaim sand

• Pressure to reduce sand cost foundries are using higher levels of reclaim sand.
• Higher levels of mechanical reclaim sand increase the amounts of contaminants.
• In furan systems, sulfur is one component that will increase with higher reclaim additions.
• The increase sulfur content has been shown to create flake reversion in ductile iron.
Sulfur Build Up Curves

![Sulfur Build Up Curves](image)

- **90% Reclaim**
- **80% Reclaim**
- **70% Reclaim**
- **60% Reclaim**

Number of Cycles

**DIS Annual Meeting, June 2, 2011**
**Dallas, Texas**
Flake Reversion in Rim Zone

- Sulfur gases are formed at the mold/metal interface during casting
- The sulfur reacts with the nodular forming elements within the melt at the mold/metal interface
  - Formation of flake graphite at 1.3mm depths
- Resulting in the deterioration in the mechanical properties
  - High risk of cracks under dynamic loads
Testing Procedure

• Computer simulation of test casting to determine solidification times and in-mold temperatures during casting process
• Molds produced in furan reclaim sand of known sulfur content
  – Total Sulfur content 0.1%
• In-stream inoculation
  – 1.5% FeSiMg + 0.1% FeSi
• Four coatings of different refractory fillers
  – Applied at a dry thickness of 0.20 to 0.25 mm
Test Procedure

- U-shaped
  - 175mm x 195mm x 120 mm (l x w x h)
- Casting Wt
  - 25 kg
- Cast Temp
  - 1360 – 1380°C
- 1st solid iron 12 min. after casting
- Complete Solidification at 21 min.
- Rim Zone Formed after 12 – 13 minutes
<table>
<thead>
<tr>
<th>Coating</th>
<th>Filler System</th>
<th>Filler Density g/cm³</th>
<th>Applied Coating Density g/cm³</th>
<th>Porosity</th>
<th>% Sulfur Content</th>
<th>% Carbon Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Alumino-Silicate</td>
<td>2.70</td>
<td>1.05</td>
<td>0.611</td>
<td>0.027</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>Zircon</td>
<td>4.36</td>
<td>2.33</td>
<td>0.465</td>
<td>0.013</td>
<td>0.83</td>
</tr>
<tr>
<td>C</td>
<td>Coke Flour</td>
<td>2.21</td>
<td>1.16</td>
<td>0.475</td>
<td>0.082</td>
<td>25.7</td>
</tr>
<tr>
<td>D</td>
<td>Special</td>
<td>4.15</td>
<td>2.11</td>
<td>0.491</td>
<td>0.010</td>
<td>2.34</td>
</tr>
</tbody>
</table>
Sulfur Content

• % Sulfur Measurements
  – Uncoated molds
  – Coating layer
  – Rim zone layer in casting
    • 0.00 - 0.5 mm depth
    • 0.5 - 1.0 mm depth
%Sulfur of coating

![Graph showing sulfur content of coating before and after pouring.](DIS Annual Meeting, June 2, 2011 - Dallas, Texas)
Casting Structure using Coating A

- Formation of flake graphite in rim zone.

Test Block Micrograph (Coating A)
Casting Structure using Coating B

- Formation of flake graphite in rim zone.
Casting Structure using Coating C

- No formation of flake graphite in rim zone.
- Nodule structure is disturbed
Casting Structure using Coating D

- Best results in rim zone structure
%Sulfur in rim zone

Coating

Sulfur Content (%)
Initial Results

• % Sulfur of coating D showed an increase of 20x its initial value.
• % Sulfur in machined casting is less than the coating.
• Repeat test with just Coating D.
  – Observe the effect of Increasing sulfur content in molds.
%Sulfur Uncoated Molds

Sulfur virtually burned out after pouring
%Sulfur in Coating D with increasing sulfur content

Mold Number

M1  M2  M3  M4  M5

Sulfur Content (%)

Bonded Sand
Coating After Pouring
Coating Before Pouring
%Sulfur in Rim Zone Coating D

![Bar chart showing sulfur content in molding sand for different sizes of particles and a base iron.](chart.png)
Conclusions

• Rim Zone reversion in ductile iron due to sulfur contamination can be prevented by the use of a specialty coating.
• Controlling the dried coating layer between 0.20 – 0.25 mm can protect against sulfur levels of 0.2% in the molding sand.
• Thicker dry coating layers can protect against higher levels of sulfur in the molding sand as long as casting tolerances preserved.
• Higher levels of reclaim sand can therefore be used.
• Results in higher cost saving for the foundry.
Example of DI Axle Casting

- Flake formation
- Disturbed nodulation
Example of DI Axle Casting
Mold flow coated with special coating
Dried coating layer at 0.2mm
Example of DI Axle Casting

- Improved nodular formation
- Zero graphite flake formation.
For additional information, please contact:

• Bruce E. Lundeen
• FOSECO
• 815-347-6864
• Bruce.Lundeen@foseco.com
• www.foseco.com

THE DIS WELCOMES JIM. WHO IS HERE TO TALK ABOUT “FOUNDRY ALLOYS, A WORLDWIDE PERSPECTIVE”
Foundry Alloys, A World Wide Perspective

Jim Csonka
Hickman, Williams & Company
June 2, 2011
World Ferro Alloy Production

- Discuss World Ferro Alloy Producers.
- Ferro Silicon Production.
- Cast Iron Ferro Alloy Needs.
- Foundry Alloy Producers.
World Ferro Alloy Production

- Information from USGS (United States Geological Survey) that comes out yearly.
- Most recent printing, published in 2010 covers the year of 2008.
- Other information from Modern Casting, Census of World Casting Production.
- Printed every December, covers the previous year. December 2010 reports on 2009.
- Used 2008 data to maintain consistency.
World Ferro Alloy Production
Metric Tons

DIS Annual Meeting, June 2, 2011
World Ferro Alloy Production

- 16.9 million Metric Tons in 1992
- 36.1 million Metric Tons in 2008
- 1992 until 2002, 2.2 million MT gain
  - 16.9 million MT up to 20.1 million MT
- 2002 until 2003, 2.2 million MT gain
  - 20.1 million MT up to 22.3 million MT
- 2004 up to 2008, 13.8 million MT gain
  - Average of 2.76 million MT per year
World Ferro Alloy Production

• In 1992, 52 countries produced ferroalloys. Since that year 6 new countries started to produce ferroalloys of one type or another, but we also lost ferroalloy production in another 7 other countries.

• This brings our total in 2008 to 51 countries that are still producing some type of ferroalloy.
World Ferro Alloy Production

- Production grouped into Regions

- Africa: South Africa, Zimbabwe
- Asia: China, Japan, Korea
- CIS: Kazakhstan, Russia, Ukraine
- Europe: Finland, France, Norway, Spain
- Middle East: India, Turkey
- N. America: Canada, Mexico, United States
- S. America: Brazil, Columbia, Venezuela
- South East: Australia

DIS Annual Meeting, June 2, 2011
World Production of Ferro Alloys
1992
16,900,000 Metric Tons

- 27% Europe
- 25% Asia
- 19% North America
- 10% South America
- 8% Middle East
- 6% South East
- 4% CIS
- 1% Africa
- 1% North America

DIS Annual Meeting, June 2, 2011
World Production of Ferro Alloys 2000
19,800,000 Metric Tons

Africa: 16%
Asia: 27%
CIS: 20%
Europe: 6%
Middle East: 4%
North America: 6%
South America: 6%
South East: 1%

DIS Annual Meeting, June 2, 2011
World Ferro Alloy Production

• Bar Graph of grouped areas.

• Total ferroalloy production per area, not segregated into alloys produced.

• Beware the scale wrecker!

DIS Annual Meeting, June 2, 2011
World Ferro Alloy Production
Metric Tons

- Africa
- Middle East

DIS Annual Meeting, June 2, 2011
World Ferro Alloy Production

Metric Tons


CIS
Europe

DIS Annual Meeting, June 2, 2011
World Ferro Alloy Production
Metric Tons

- North America
- South America


DIS Annual Meeting, June 2, 2011
World Ferro Alloy Production
Metric Tons


Asia
South East

DIS Annual Meeting, June 2, 2011
Top Ferro Alloy Producers 2008
Metric Tons

DIS Annual Meeting, June 2, 2011
Top 15 Producing Countries
2008
Metric Tons

China
South Africa
Russia
Kazakhstan
Ukraine
Brazil
India
Japan
Norway
France
South Korea
Australia
Finland
United States
Mexico

DIS Annual Meeting, June 2, 2011
# World Ferro Alloy Production

- Ferro Alloys produced in either Electric or Blast Furnaces.
- Alloys include:
  - BF Ferro Manganese: 728 thousand MT
  - EF Ferro Chromium: 7.84 million MT
  - EF Ferro Manganese: 4.97 million MT
  - EF Ferro Silicon: 7.32 million MT
  - EF Silicon Manganese: 7.46 million MT
  - EF Silicon Metal: 609 thousand MT
  - Other alloys: 5.21 million MT

*DIS Annual Meeting, June 2, 2011*
World Ferro Alloy Production

- “Other” Ferro Alloys would include:
  - Spiegeleisen (Mirror Iron, 15% Manganese)
  - Ferro Chromium Silicon
  - Ferro Molybdenum
  - Ferro Nickel
  - Ferro Niobium (Ferro Columbium)
  - Ferro Titanium
  - Ferro Vanadium
  - Silicon Metal
World Ferro Alloy Production
1992 to 2008
Metric Tons

DIS Annual Meeting, June 2, 2011
Top Alloy Producers, 8 to 15
by Product
Metric Tons

DIS Annual Meeting, June 2, 2011
Countries 3 to 7 by Product
China and South Africa removed

DIS Annual Meeting, June 2, 2011
Ferro Silicon Production

• Although we also use some amounts of Ferro Molybdenum in ductile iron, and both Ferro Manganese and Ferro Chromium in gray iron, by far, the king of the ferroalloys in the cast iron community is:

• Ferro Silicon
"America's" Ferro Silicon Production
Metric Tons

Brazil
United States
Venezuela

DIS Annual Meeting, June 2, 2011
"European" Ferro Silicon Production
Metric Tons

<table>
<thead>
<tr>
<th>Year</th>
<th>Iceland</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>90,000</td>
<td>340,000</td>
</tr>
<tr>
<td>1996</td>
<td>100,000</td>
<td>450,000</td>
</tr>
<tr>
<td>2000</td>
<td>150,000</td>
<td>500,000</td>
</tr>
<tr>
<td>2004</td>
<td>100,000</td>
<td>300,000</td>
</tr>
<tr>
<td>2008</td>
<td>70,000</td>
<td>400,000</td>
</tr>
</tbody>
</table>
"CIS and South Africa" Ferro Silicon Production Metric Tons

Russia
Ukraine
South Africa

DIS Annual Meeting, June 2, 2011
"Top Four" Ferro Silicon Production
Metric Tons

<table>
<thead>
<tr>
<th>Year</th>
<th>Norway</th>
<th>United States</th>
<th>Russia</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>500,000</td>
<td>1,500,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1996</td>
<td>500,000</td>
<td>2,000,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>500,000</td>
<td>2,500,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>1,000,000</td>
<td>3,000,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2008</td>
<td>2,500,000</td>
<td>3,500,000</td>
<td>0</td>
<td>5,000,000</td>
</tr>
</tbody>
</table>

DIS Annual Meeting, June 2, 2011
Foundries

• This section discusses the number of foundries, world wide, by nation.

• The tons of ductile iron and gray iron castings produced, by nation.

• Amounts of melted tons of ductile and gray iron are then back figured to allow us to calculate the tons of MgFeSi, FeSi and Inoculants that were needed to support this production level.
Cast Iron Foundries "America's"

DIS Annual Meeting, June 2, 2011
Top 10 Countries by Number of Cast Iron Foundries

- China
- Turkey
- United States
- Brazil
- Korea
- Japan
- Ukraine
- Germany
- Mexico
- Italy

DIS Annual Meeting, June 2, 2011
Ductile Iron Castings
Top 5 Countries
17,440,000 Metric Tons of DI Castings in 2008

China
United States
Japan
Germany
Russia

DIS Annual Meeting, June 2, 2011
Ductile Iron Castings
Countries 6 to 10
3,840,000 Metric Tons of DI Castings in 2008

Metric Tons of Castings

1,200,000
1,000,000
800,000
600,000
400,000
200,000
0


France
India
Brazil
Italy
Spain

DIS Annual Meeting, June 2, 2011
Gray Iron Castings
Top 5 Countries
30,500,000 Metric Tons of Castings in 2008

DIS Annual Meeting, June 2, 2011
Gray Iron Castings
Countries 6 to 10
7,055,000 Metric Tons in 2008

Metric Tons of Castings

Germany
Brazil
Korea
Italy
France

DIS Annual Meeting, June 2, 2011
Ductile Iron Castings

• In 2008, 23.8 million metric tons of DI castings were made.

• Top 10 countries accounted for 21.2 million MT.

• Top 5 countries, China, US, Japan, Germany and Russia account for 17.4 million MT.
Ductile Iron Melted

• The following assumptions were used for the upcoming calculations:

• Average Casting Yield, Ductile Iron was 60%.

• Average MgFeSi addition rate percentage was 1.20%.
Ductile Iron Melted

- Ratio of Ductile Iron inoculation with 75% foundry grade to proprietary inoculant was 50:50 based upon tons of ductile iron treated.
- Average inoculation rate of 75% FeSi was 10 pounds per ton (0.5%).
- Average inoculation rate of proprietary inoculants used was 6 pounds per ton (0.3%).
Gray Iron Melt

- Average Casting Yield, Gray Iron was 70%.
- Ratio of Gray Iron inoculation with 75% foundry grade FeSi to proprietary inoculation was 35:65.
- Average inoculation rate of 75% FeSi was 8 pounds per ton (0.4%).
- Average inoculation rate of proprietary inoculants was 4 pounds per ton (0.2%).
World Ductile Iron, 2008

• 23.8 million Metric Tons of Ductile Iron castings made in 2008.

• 39.3 million Metric Tons of Ductile Iron melt.

• 472,000 MT of MgFeSi products, based upon 100% of all foundries making Ductile Iron using only MgFeSi.

• 377,600 MT is probably closer to the real number (80%).
World Ductile Iron, 2008

- Of the 39.9 million MT of DI melted, 19.6 million MT needs to be inoculated by foundry grade FeSi and 19.6 million MT by proprietary inoculants.

- 98,300 MT of 75% FeSi foundry grade inoculants.

- 59,000 MT of proprietary inoculants.
World Ductile Iron, 2008

- Ferro Silicon alloy contribution for treatment of Ductile Iron base iron would be:
  - 377,600 MT of MgFeSi
  - 98,300 MT of 75% FeSi foundry grade.
  - 59,000 MT of Proprietary Inoculants.
  - 534,900 MT total.

DIS Annual Meeting, June 2, 2011
World Gray Iron, 2008

- 42.9 million MT of Gray Iron Castings.
- 61.3 million MT of Gray Iron melt.
- 85,800 MT of 75% FeSi foundry grade.
- 79,700 MT of proprietary inoculants.
- 165,500 MT 75% FeSi based products needed for inoculation.
World Cast Iron Needs

- 377,600 MT of MgFeSi
- 98,300 MT of 75% FeSi foundry grade, (DI).
- 59,000 MT of Proprietary Inoculants, (DI).
- 85,800 MT of 75% FeSi foundry grade, (GI).
- 79,700 MT of proprietary inoculants, (GI).
- 700,400 MT total treatment alloys needed.
World Cast Iron Needs

• 700,400 MT of FeSi based products.

• 7,320,000 MT of Ferro Silicon Ferroalloys were produced in 2008.

• 9.5% of world Ferro Silicon production.

• 1.94% of world Ferro Alloy production.

- 3.6 million MT of Ductile Iron castings.
- 5.94 million MT of Ductile Iron melt.
- 71,000 MT of MgFeSi at 1.20% for 100% of the U.S. foundries.
- 46,000 MT of MgFeSi (51,000 Net Tons) if we figure 65% (treated tons) are MgFeSi produced.

- 5.94 million MT of Ductile Iron melt.
- 2.97 million MT inoculated with 75% FeSi foundry grade and 2.97 million MT with proprietary inoculants.
- 14,850 MT of 75% FeSi foundry grade needed.
- 8,900 MT of proprietary inoculants needed.

• U.S. Ferro Silicon needs are:

• 46,000 MT MgFeSi.
• 14,850 MT of 75% FeSi foundry grade.
• 8,900 MT of proprietary inoculants.

• 67,750 MT of Ferro Silicon based products for treatment of Ductile Iron.

- 3.5 million MT of Gray Iron castings.
- 5.0 million MT of Gray Iron melt.
- 7,012 MT of 75% FeSi foundry grade.
- 6,511 MT of proprietary inoculants.
- 13,523 MT of 75% FeSi based products for inoculation.
U.S. Cast Iron Needs

- 46,000 MT MgFeSi.
- 14,850 MT of 75% FeSi foundry grade (DI).
- 8,900 MT of proprietary inoculants (DI).
- 7,012 MT of 75% FeSi foundry grade (GI).
- 6,511 MT of proprietary inoculants (GI).
- 83,273 MT total treatment alloys needed.
U.S. Cast Iron Needs

• 83,273 MT total treatment alloys needed.
• 7,320,000 MT of Ferro Silicon Ferroalloys were produced in 2008.
• 1.13% of world Ferro Silicon production.
• 0.23% of world Ferro Alloy production.
Ferro Silicon Production

• Although we also use some amounts of Ferro Molybdenum in ductile iron, and both Ferro Manganese and Ferro Chromium in gray iron, by far, the king of the ferroalloys in the cast iron community is Ferro Silicon.

• Compare US production and imports to the tons that are consumed.
Ferro Silicon Production in the US
Metric Tons

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>350,000</td>
</tr>
<tr>
<td>1996</td>
<td>400,000</td>
</tr>
<tr>
<td>2000</td>
<td>250,000</td>
</tr>
<tr>
<td>2004</td>
<td>300,000</td>
</tr>
<tr>
<td>2008</td>
<td>150,000</td>
</tr>
</tbody>
</table>

DIS Annual Meeting, June 2, 2011
US Imports for Consumption, 75% Ferro Silicon
Metric Tons

DIS Annual Meeting, June 2, 2011
US Imports for Consumption, Magnesium Ferro Silicon
Metric Tons

DIS Annual Meeting, June 2, 2011
Reported US Consumption of Ferro Alloys
2008
Production vs. Consumption

- US Ferro Silicon Consumption: 542,000 MT
- US Ferro Silicon Production: 228,000 MT
- US Ferro Silicon Imports: 250,000 MT
- MgFeSi imports: 12,000 MT
- US MgFeSi Production: 40,000 MT
- Total Production/Import: 530,000 MT
Production & Imports vs. Consumption, FeSi products
2008

DIS Annual Meeting, June 2, 2011
NA Produced FeSi, FeMn, FeCr

• In 1992, there were 8 companies that operated a total of 10 Ferro Alloy plants in North America.

• 8 Ferro Silicon plants.
• 1 Ferro Manganese/Silico Manganese plant.
• 1 Ferro Chromium plant.
• With few exceptions, small, locally owned companies.
NA Produced FeSi, FeMn, FeCr

- Currently, those 10 plants have been reduced to 8 operating plants, owned by 4 companies.
- Globe Metallurgical, 4 plants (2 FeSi, 2 SilMet).
- Elkem Metals, 1 plant (FeSi).
- Felman, 2 plants (1 FeSi, 1 SiMn)
- Eramet, 1 plant (FeMn/SiMn).
NA Produced FeSi, FeMn, FeCr

- 8 Ferro Silicon plants reduced to 4.
  - 2 Ferro Silicon plants converted to Si Metal.
  - 1 Ferro Silicon plant converted to Silico Manganese.
  - 1 Ferro Silicon plant closed.

- 1 FeMn/SiMn plant increased to 2.

- 1 Ferro Chrome plant closed.
World Ferro Alloy Producers

- World wide, Ferro Alloy plants are being bought by Trading Companies, or Corporations. Gone are the days where local companies own and operate these facilities.

- A different attitude is being taken when it comes to what alloys to make, or why.
## World Ferro Alloy Producers

- The following countries have plants that are serving the foundry industry.

<table>
<thead>
<tr>
<th>Country</th>
<th>Count</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Canada</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Iceland</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>China</td>
<td>???</td>
<td></td>
</tr>
</tbody>
</table>

DIS Annual Meeting, June 2, 2011
In Review

- Of the 51 countries that are currently producing Ferro Alloys, only 10 countries are producing “foundry type ferro silicon” products.
- 36,100,000 Metric Tons of Ferro Alloys
- 7,320,000 Metric Tons of Ferro Silicon
- 700,400 Metric Tons of “foundry” alloys
- 1.94% of all Ferro Alloys
- 9.57% of all Ferro Silicon alloys

DIS Annual Meeting, June 2, 2011
### In Review, Metric Ton Units

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castings, DI + GI</td>
<td>67.8 mil</td>
<td>7.1 mil</td>
<td>24.6 mil</td>
</tr>
<tr>
<td>Ferro Silicon Produced</td>
<td>7.32 mil</td>
<td>228,000</td>
<td>4.9 mil</td>
</tr>
<tr>
<td>MgFeSi</td>
<td>377,600</td>
<td>46,000</td>
<td>138,006</td>
</tr>
<tr>
<td>75% FG Ferro Silicon</td>
<td>184,100</td>
<td>21,862</td>
<td>66,657</td>
</tr>
<tr>
<td>Proprietary Inoculants</td>
<td>138,700</td>
<td>15,411</td>
<td>50,782</td>
</tr>
<tr>
<td>Foundry FeSi based %, local FeSi produced</td>
<td>700,400</td>
<td>82,273</td>
<td>255,445</td>
</tr>
<tr>
<td></td>
<td>9.57%</td>
<td>36.08%</td>
<td>5.21%</td>
</tr>
</tbody>
</table>
In Review

- USGS information incomplete due to “proprietary data” being withheld (US).
  - Si Metal, Ferro Manganese, Silico Manganese
- Lack of data on “foundry type” alloys.
  - Magnesium Ferro Silicon Production
  - Foundry grade 75 vs. Regular grade 75
In Review

- Traders will produce products that make the most financial sense.
- Tons vs. dollars
- Trend toward more Silicon Metal
  - $1\#$ Si Metal = $2\#$ 75% FeSi = $4\#$ 50% FeSi
  - Growing business sector vs. Steady or Declining
In Review

• Lack of Foundry Dedicated alloy plants.

• Instead of pricing alloys to move tons, we now have plants producing alloys to chase the money.

• As margins shrink, product mixes will change.
In Review

• It truly is a World Market.

• In spite of what discounts that we think we deserve, the price is the price.

• Currently, it is a sellers market.
In Review

• The US is still a major factor in the Cast Iron industry.
  – #2 in ductile iron by tons of castings.
    # 3 in gray iron by tons of castings, India #2.

• Do not forget the scale wrecker.
Questions?

• Thank You for your attention!

• jcsonka@hicwilco.com
FEATURERs

2011 ANNUAL MEETING HIGHLIGHTS

• Speaker Bios - Morning Session
• Speaker Bios - Afternoon Session
• Exhibit and Visitor Record at GIFA, METEC, THERMPROCESS, NEWCAST 2011
• Influence of Coatings on the Graphite Structure in the Rim Zone of DI Castings - Bruce Lundeen
• Foundry Alloys, A Worldwide Perspective - Jim Csonka
• Heavy Section Ductile Iron Update - Serge Grenier
• Treatment of Microshrinkage in DI with FeSiLa Inoculant - Steve Thelen
• High Performance, Low VOC Chemical Binder System - Joe Fuqua
• Avoiding Shrinkage Defects and Maximizing Yield in Ductile Iron - Doug White

DEPARTMENTS

• News Briefs
• Back Issues
• DIS Home Page

SERGE GRENIER - RIO TINTO WITH KATHY HAYRYNEN

SERGE GRADUATED FROM McgILL UNIVERSITY IN MONTREAL, CANADA IN 1989 WITH HIS BACHELORS DEGREE IN METALLURGICAL ENGINEERING. HE THEN COMPLETED A MASTERS DEGREE IN MATERIAL SCIENCE ALSO FROM McgILL UNIVERSITY, ON THE PRODUCTION OF SILICON NITRIDE POWDERS BY THE CARBOThERMAL REDUCTION PROCESS. IN 1996, SERGE OBTAINED HIS PhD FROM ECOLE POLYTECHNIQUE IN MONTREAL ON THE DEPOSITION OF TITANIUM NITRIDE FILMS USING A REACTIVE THERMAL PLASMA PROCESS. SINCE THEN, SERGE HAS WORKED 19 YEARS IN A WIDE VARIETY OF MATERIALS SCIENCE FIELDS RELATED TO METALLURGY, NANO-MATERIALS, THERMAL PLASMA COATINGS, HYDROGEN STORAGE SYSTEMS AND ULTRA-PURE MATERIALS. HE HOLDS 8 PATENTS AND IS THE AUTHOR OF SEVERAL TECHNICAL PAPERS ON VARIOUS METALLURGICAL TOPICS. SERGE JOINED RIO TINTO A YEAR AGO WHERE HE PRESENTLY HOLDS A RESEARCH ENGINEER’S POSITION IN THE FERROUS PRODUCTS GROUP.

THE DIS WELCOMES SERGE, WHO IS HERE TO TALK ABOUT “HEAVY SECTION DUCTILE IRON UPDATE”
Presentation Outline

• Objectives
• Experimental Procedures
• Analyses Performed
  - Image Analysis (Nodularity, Nodules Count, Pearlite, Ferrite Grain Size, etc.)
• Results - Mappings Obtained
• Conclusions
Objectives

• Characterize the distribution of nodules in a heavy section (HS) casting.
• Look at the distribution of other parameters (ie. pearlite, ferrite grain size, etc.) in a HS casting.
• Perform an element mapping of the blocks.
• Quantify precisely the microstructure in order to eventually establish a correlation with mechanical properties.
Effect of Location on Impact Strength

Impact Strength

Energy (J)

Temperature (C)

-60 -40 -20 0 20 40

HS19
HS20
HS22
HS23
Experimental Procedures

**Furnace**

- Induction (125 kW)
- Charge transferred in a pouring ladle (capacity of 160 kg)
- Ductile iron is cast in two 7-8 inches square moulds.
- Mg is introduced in the melt using a plunger.
Image Analysis

Size Distribution of Nodules

11-119_HS-19_3C.xls

Nodule Diameter (Microns)

DIS Annual Meeting, June 2, 2011
Dallas, Texas
Image Analysis

Example: 5 trap
Image Analysis

Interpreting the Results

Trap size used will influence the nodule counts obtained.

<table>
<thead>
<tr>
<th>Trap Size</th>
<th>HS20-2 AIB4-6</th>
<th>HS20-2 AIC4-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Pixels)</td>
<td>(µm)</td>
<td>Nb/mm²</td>
</tr>
<tr>
<td>5</td>
<td>3,4</td>
<td>232</td>
</tr>
<tr>
<td>7</td>
<td>4,7</td>
<td>159</td>
</tr>
<tr>
<td>10</td>
<td>6,7</td>
<td>119</td>
</tr>
</tbody>
</table>
# Image Analysis - Uncertainty

**HS19 – 3C – 7 Pixels Trap**

<table>
<thead>
<tr>
<th>Test #</th>
<th>Nod/mm²</th>
<th>Nod/part</th>
<th>% Pearlite</th>
<th>Ferrite Grain Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>156,3</td>
<td>95,3%</td>
<td>0,84%</td>
<td>27,7 µm</td>
</tr>
<tr>
<td>2</td>
<td>158,3</td>
<td>95,8%</td>
<td>1,13%</td>
<td>26,3 µm</td>
</tr>
<tr>
<td>3</td>
<td>155,9</td>
<td>94,9%</td>
<td>1,47%</td>
<td>26,3 µm</td>
</tr>
</tbody>
</table>
# Image Analysis - Uncertainty

**HS19 – 9C – 5 Pixels Trap**

<table>
<thead>
<tr>
<th>Test #</th>
<th>Nod/mm²</th>
<th>Nod/part</th>
<th>Pearlite</th>
<th>Ferrite Grain Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>258,7</td>
<td>97,1</td>
<td>0,74%</td>
<td>25,0 µm</td>
</tr>
<tr>
<td>2</td>
<td>257,3</td>
<td>96,5</td>
<td>1,27%</td>
<td>24,3 µm</td>
</tr>
<tr>
<td>3</td>
<td>259,3</td>
<td>96,4</td>
<td>0,92%</td>
<td>23,9 µm</td>
</tr>
</tbody>
</table>
Results - Mapping

B Slice

C Slice

19 cm (7-1/2 inches)

Regions Analyzed

DIS Annual Meeting, June 2, 2011
Dallas, Texas
Results - Mapping

- Chemical composition of block analyzed:
  Charge: 1/3 electrolytic iron + 2/3 pig

C = 3.36%   S = 0.011%
Si = 2.40%   Mn = 0.021%
Mg = 0.054%  CE = 4.17
### Nodules Count Mapping

**Nodule count (Nod/mm²)**

<table>
<thead>
<tr>
<th>132</th>
<th>117</th>
<th>142</th>
<th>124</th>
<th>142</th>
<th>117</th>
<th>132</th>
</tr>
</thead>
<tbody>
<tr>
<td>141</td>
<td>148</td>
<td>98</td>
<td>133</td>
<td>98</td>
<td>148</td>
<td>141</td>
</tr>
<tr>
<td>128</td>
<td>132</td>
<td>118</td>
<td>153</td>
<td>118</td>
<td>132</td>
<td>128</td>
</tr>
<tr>
<td>133</td>
<td>113</td>
<td>160</td>
<td>111</td>
<td>122</td>
<td>119</td>
<td>134</td>
</tr>
<tr>
<td>145</td>
<td>105</td>
<td>140</td>
<td>134</td>
<td>140</td>
<td>105</td>
<td>145</td>
</tr>
<tr>
<td>174</td>
<td>156</td>
<td>114</td>
<td>135</td>
<td>114</td>
<td>156</td>
<td>174</td>
</tr>
<tr>
<td>257</td>
<td>208</td>
<td>164</td>
<td>139</td>
<td>164</td>
<td>208</td>
<td>257</td>
</tr>
</tbody>
</table>

*10 trap*
## Nodules Count Mapping

*10 trap - HS20-2B*

<table>
<thead>
<tr>
<th></th>
<th>132</th>
<th>117</th>
<th>142</th>
<th>124</th>
<th>142</th>
<th>117</th>
<th>132</th>
</tr>
</thead>
<tbody>
<tr>
<td>141</td>
<td>148</td>
<td>98</td>
<td>133</td>
<td>98</td>
<td>148</td>
<td>141</td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>132</td>
<td>118</td>
<td>153</td>
<td>118</td>
<td>132</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>133</td>
<td>113</td>
<td>160</td>
<td>111</td>
<td>122</td>
<td>119</td>
<td>134</td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>105</td>
<td>140</td>
<td>134</td>
<td>140</td>
<td>105</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td>174</td>
<td>156</td>
<td>114</td>
<td>135</td>
<td>114</td>
<td>156</td>
<td>174</td>
<td></td>
</tr>
<tr>
<td>257</td>
<td>208</td>
<td>164</td>
<td>139</td>
<td>164</td>
<td>208</td>
<td>257</td>
<td></td>
</tr>
</tbody>
</table>

**Ave. = 130**

<table>
<thead>
<tr>
<th></th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>140</td>
</tr>
<tr>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>200</td>
<td>Max</td>
</tr>
</tbody>
</table>

**Ave. = 159**

**Max**

---

*DIS Annual Meeting, June 2, 2011*

*Dallas, Texas*
## Nodules Count Mapping

10 trap - HS20-2B

<table>
<thead>
<tr>
<th>Count</th>
<th>0-100</th>
<th>101-150</th>
<th>151-200</th>
<th>201-250</th>
<th>&gt;251</th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>117</td>
<td>142</td>
<td>124</td>
<td>142</td>
<td>117</td>
</tr>
<tr>
<td>141</td>
<td>148</td>
<td>98</td>
<td>133</td>
<td>98</td>
<td>148</td>
</tr>
<tr>
<td>128</td>
<td>132</td>
<td>118</td>
<td>153</td>
<td>118</td>
<td>132</td>
</tr>
<tr>
<td>133</td>
<td>113</td>
<td>160</td>
<td>111</td>
<td>122</td>
<td>119</td>
</tr>
<tr>
<td>145</td>
<td>105</td>
<td>140</td>
<td>134</td>
<td>140</td>
<td>105</td>
</tr>
<tr>
<td>174</td>
<td>156</td>
<td>114</td>
<td>135</td>
<td>114</td>
<td>156</td>
</tr>
<tr>
<td>257</td>
<td>208</td>
<td>164</td>
<td>139</td>
<td>164</td>
<td>208</td>
</tr>
</tbody>
</table>

Averages:
- 0-100: **130**
- 101-150: **174**
- 151-200: **199**
- 201-250: **195**
- >251: **257**

*DIS Annual Meeting, June 2, 2011*
*Dallas, Texas*
### Nodularity Mapping (%nb)

<table>
<thead>
<tr>
<th></th>
<th>Ave. = 86,5</th>
<th>Ave. = 90,5</th>
<th>Ave. = 95-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85-89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90-94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95-100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 7 trap - HS20-2B

<table>
<thead>
<tr>
<th></th>
<th>87</th>
<th>82</th>
<th>90</th>
<th>95</th>
<th>90</th>
<th>82</th>
<th>87</th>
</tr>
</thead>
<tbody>
<tr>
<td>88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table Values

- **Ave. = 86,5**
- **Ave. = 90,5**
- **Ave. = 95-100**
# Nodularity Mapping (%nb)

## 7 trap - HS20-2C

<table>
<thead>
<tr>
<th></th>
<th>Ave. = 90,0</th>
<th>Ave. = 91,4</th>
<th>Ave. = 95-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>86</td>
<td>90</td>
<td>90</td>
<td>86</td>
</tr>
<tr>
<td>86</td>
<td>91</td>
<td>91</td>
<td>86</td>
</tr>
<tr>
<td>93</td>
<td>92</td>
<td>88</td>
<td>93</td>
</tr>
<tr>
<td>87</td>
<td>88</td>
<td>91</td>
<td>88</td>
</tr>
<tr>
<td>87</td>
<td>88</td>
<td>92</td>
<td>87</td>
</tr>
<tr>
<td>95</td>
<td>94</td>
<td>93</td>
<td>95</td>
</tr>
<tr>
<td>95</td>
<td>92</td>
<td>87</td>
<td>95</td>
</tr>
</tbody>
</table>

Ave. = 90,0

Ave. = 91,4

Ave. = 95-100
## % Pearlite Mapping

7 trap - HS20-2C

<table>
<thead>
<tr>
<th></th>
<th>&lt;1,0</th>
<th>1≤x&lt;2</th>
<th>2≤x&lt;3</th>
<th>3≤x&lt;4</th>
<th>4≤x&lt;5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave.</td>
<td>1,5</td>
<td>1,1</td>
<td>1,5</td>
<td>3,2</td>
<td>1,9</td>
</tr>
<tr>
<td>2,0</td>
<td>0,9</td>
<td>2,9</td>
<td>0,5</td>
<td>2,9</td>
<td>0,9</td>
</tr>
<tr>
<td>2,9</td>
<td>0,6</td>
<td>1,6</td>
<td>2,0</td>
<td>1,6</td>
<td>0,6</td>
</tr>
<tr>
<td>1,0</td>
<td>1,5</td>
<td>2,1</td>
<td>1,1</td>
<td>2,1</td>
<td>1,5</td>
</tr>
<tr>
<td>1,0</td>
<td>1,5</td>
<td>1,0</td>
<td>0,0</td>
<td>0,9</td>
<td>1,4</td>
</tr>
<tr>
<td>3,2</td>
<td>1,8</td>
<td>0,2</td>
<td>1,0</td>
<td>0,2</td>
<td>1,8</td>
</tr>
<tr>
<td>0,0</td>
<td>0,5</td>
<td>0,2</td>
<td>0,8</td>
<td>0,2</td>
<td>0,5</td>
</tr>
<tr>
<td>1,9</td>
<td>1,3</td>
<td>1,1</td>
<td>1,2</td>
<td>1,1</td>
<td>1,3</td>
</tr>
<tr>
<td>Ave.</td>
<td>1,5</td>
<td>1,1</td>
<td>1,5</td>
<td>3,2</td>
<td>1,9</td>
</tr>
</tbody>
</table>

*Ave.*: Average value of the percentage of pearlite in each category.
Ferrite grain size mapping involves calculating ferrite grain size using:

- ISO 643 (3 circles technique)
- ASTM E112-96 routine in an image analyzer.
Ferrite Grain Size Mapping

HS20-2B

Ave. = 24.8 μm

Ave. = 23.7 μm
**d50 Mapping**

Use of Finite Difference Method proposed by C.B. Basak & A.K. Sengupta


1000 nodules of 4.7μm occupy the same volume as 1 nodule of 47μm
d50 Mapping – 2D
7 trap - HS20-2B

Ave. = 16,1μm

Ave. = 19,6μm
**d50 Mapping – 3D**

7 trap - HS20-2B

<table>
<thead>
<tr>
<th>44,3</th>
<th>47,6</th>
<th>47,6</th>
<th>46,3</th>
<th>47,6</th>
<th>47,6</th>
<th>44,3</th>
</tr>
</thead>
<tbody>
<tr>
<td>48,4</td>
<td>42</td>
<td>41,3</td>
<td>42</td>
<td>41,3</td>
<td>42</td>
<td>48,4</td>
</tr>
<tr>
<td>47,7</td>
<td>42,6</td>
<td>40,7</td>
<td>41,3</td>
<td>40,7</td>
<td>42,6</td>
<td>47,7</td>
</tr>
<tr>
<td>45,1</td>
<td>37,4</td>
<td>41,8</td>
<td>38,1</td>
<td>35</td>
<td>46,2</td>
<td>47,9</td>
</tr>
<tr>
<td>40,8</td>
<td>34,2</td>
<td>44,1</td>
<td>38,7</td>
<td>44,1</td>
<td>34,2</td>
<td>40,8</td>
</tr>
<tr>
<td>36</td>
<td>41,5</td>
<td>38</td>
<td>42,7</td>
<td>38</td>
<td>41,5</td>
<td>36</td>
</tr>
<tr>
<td>26,9</td>
<td>36,8</td>
<td>44,1</td>
<td>46,5</td>
<td>44,1</td>
<td>36,8</td>
<td>26,9</td>
</tr>
</tbody>
</table>

Ave. = 44,5µm

Ave. = 38,7µm
Future Work –  
Elemental Mapping

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.33</td>
<td>3.37</td>
<td>3.31</td>
<td>3.34</td>
<td>3.31</td>
<td>3.37</td>
<td>3.33</td>
</tr>
<tr>
<td>3.32</td>
<td>3.29</td>
<td>3.16</td>
<td>3.36</td>
<td>3.37</td>
<td>3.38</td>
<td>3.32</td>
</tr>
<tr>
<td>3.26</td>
<td>3.44</td>
<td>3.35</td>
<td>3.38</td>
<td>3.35</td>
<td>3.44</td>
<td>3.26</td>
</tr>
<tr>
<td>3.32</td>
<td>3.36</td>
<td>3.36</td>
<td>3.36</td>
<td>3.40</td>
<td>3.36</td>
<td>3.32</td>
</tr>
<tr>
<td>3.31</td>
<td>3.29</td>
<td>3.37</td>
<td>3.27</td>
<td>3.37</td>
<td>3.29</td>
<td>3.31</td>
</tr>
</tbody>
</table>

C (wt%)  
Ave. = 3.32 wt%

Ave. = 3.35 wt%
Conclusions

• Nodules size distributions were obtained in both 2D and 3D.
• The central section of a HS casting was mapped in terms of nodules count, nodularity, pearlite content, ferrite grain size, d50-2D and d50-3D.
• Pearlite content and ferrite grain size were uniform throughout the central section of the casting.
Conclusions

• Visualization of the nodules distribution revealed that a large number of very small nodules (<10μm) are present in the bottom corners of the casting, whereas the cope side shows larger nodules.
• The elemental mapping of carbon was uniform, despite the difference in nodules size.
• The trap size can have a significant impact on the nodule count and the nodularity reported.
For additional information, please contact:

• Serge Grenier
• 1625 Marie-Victorin, Sorel-Tracy, Qc, Canada
• 1-450-746-3078
• 1-450-746-9412
• serge.grenier@riotinto.com
• www.qit.com
FEATURES

2011 ANNUAL MEETING HIGHLIGHTS

- Speaker Bios - Morning Session
- Speaker Bios - Afternoon Session
- Exhibitor and Visitor Record at GIFA, METEC, THERMPROCESS, NEWCAST 2011
- Influence of Coatings on the Graphite Structure in the Rim Zone of DI Castings - Bruce Lundeen
- Foundry Alloys, A Worldwide Perspective - Jim Csonka
- Heavy Section Ductile Iron Update - Serge Grenier
- Treatment of Microshrinkage in DI with FeSiLa Inoculant - Steve Thelen
- High Performance, Low VOC Chemical Binder System - Joe Fuqua
- Avoiding Shrinkage Defects and Maximizing Yield in Ductile Iron - Doug White

DEPARTMENTS

- News Briefs
- Back Issues
- DIS Home Page

Link to Presentation: Treatment of Microshrinkage in DI with FeSiLa Inoculant

STEVE THELEN - GREDE BISCOE WITH KATHY HAYRYNEN

STEVE THELEN

STEVE GRADUATED FROM MICHIGAN TECHNOLOGY UNIVERSITY IN HOUGHTON, MI IN 1987 WITH A BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. STEVE IS CURRENTLY THE TECHNICAL MANAGER AT GREDE BISCOE IN BISCOE, NORTH CAROLINA. HIS FOUNDRY CAREER STARTED WITH GREDE FOUNDRIES IN KINGSFORD, MICHIGAN IN 1986 AS THE METALLURGICAL PROJECT TECHNICIAN AND THEN MOVED ON TO ANOTHER GREDE FOUNDRY IN VASSAR, MICHIGAN FROM 1988 TO 1989 AS THE ASSISTANT QUALITY ENGINEER AND CUPOLA MELTING SUPERVISOR. THEN IN 1989, STEVE CHANGED COMPANIES AND MOVED TO INTERMET CORPORATION IN RADFORD, VIRGINIA UNTIL 2003 WHERE HE HELD POSITIONS AS PLANT METALLURGIST AND LAB MANAGER, SR. QUALITY ENGINEER, AND RADFORD SHELL FOUNDRY MANAGER OF METALLURGY. HE THEN RETURNED TO HIS CURRENT POSITION WITH GREDE BISCOE IN 2003. STEVE IS THE CURRENT PUBLICITY & VICE CHAIR OF THE PIEDMONT CHAPTER OF THE AFS. HE HAS TRAVELED INTERNATIONALLY AS A TECHNICAL AND QUALITY REPRESENTATIVE WITH GREDE. HE ALSO HAS CO-AUTHORED TECHNICAL PAPERS ON SELECTIVE INDUCTION HARDENING WHICH WAS PRESENTED AT THE SAE 2002 WORLD CONGRESS.

THE DIS WELCOMES STEVE, WHO IS HERE TO TALK ABOUT “TREATMENT OF MICRO SHRINKAGE IN DUCTILE IRON WITH A FeSiLa INOCULANT”
Treatment of Micro Shrinkage in Ductile Iron with a FeSiLa Inoculant

Steve Thelen
Grede Biscoe
Shrinkage categories

Suck-in

0.2-0.5 mm

Macro Shrinkage

20 mm

Micro Shrinkage

5 mm
Ductile Iron metallurgy: Solidification modes

Hypoeutectic

Liquid

Austenite + Graphite

L + Austénite

Hypereutectic

L + Graphite

Eutectic Point

Ferrite + Graphite

1150 °C

723 °C

20 °C

Fe – C Phase diagram (stable)

DIS Annual Meeting, June 2, 2011
Ductile Iron metallurgy: **Hypereutectic mode**

1. **A** Liquid
2. **B** Formation of nuclei of primary graphite
3. **C** Growing of primary graphite in the liquid
4. **D** Formation Eutectic Austenite coated Graphite

**Progression of the Eutectic solidification & growth of graphite nodules**

**Temp °C**

- 1150 °C
- 723 °C
- 20 °C

**Ceq %**

- 3
- 4
- 5

**DIS Annual Meeting, June 2, 2011**
Shrinkage formation versus solidification

Fe – C Phase diagram (stable)  Typical Ductile Iron Thermal Analysis curve
Cooling and dilatation curves

Temp °C

1150°C

1155°C

1150°C

ΔL

Eutectic solidification

1
2
3

time

1 min

T

Courtesy R. Hummer

20mm

5mm

20mm

15 mm

DIS Annual Meeting, June 2, 2011
Micro shrinkage
“La” mechanisms to eliminate Micro Shrinkage

- These works have been done in collaboration with:

  IRC University of Birmingham (United Kingdom)
  R A Harding, J Campbell

  Pechiney’s Research Central Laboratory (France)
  T Margaria

Interdisciplinary Research Centre & Laboratory Central Research
Lanthanum effect is well known...

• History:
  - Improved machinability
  - FR Patent 024855 – 1979
  - La efficient element to counter Micro Shrinkage

“La” bearing MgFeSi : In-Mold process = success

• “La” bearing MgFeSi : Ladle process = low repeatability due to the difficulty in an industrial environment of maintaining the adequate and repeatable amount of La content in order to exercise on the molten metal the desired effects. Rapid fade as La fades quicker than Mg in molten iron.
Stages of Solidification

• Columnar Solidification
  – First solids appear on the mold walls, near locations of severe heat loss. Grains grow in the opposite direction of heat flow, usually perpendicular to the mold walls.

• Equiaxed Solidification
  – After heat flow through the walls is reduced, particles of the columnar grains detach and grow freely in the liquid. “Equally” on every “axis”.
Solidification mode:

- **Stages of solidification in a mold**
  - Columnar, perpendicular to mold walls, opposite to the direction of heat flow.
  - Equiaxed, When the heat flow reduced, particles from columnar zone detach and grow freely.
Solidification mode: **Influencing factors**

- **Influencing factors:**

  + High nucleation favors the Equiaxe mode by developing more solidification sites in the liquid.

  + Stirring motions favors the Equiaxe mode

  + Other phenomena affect the transition between the columnar to Equiaxe mode
    - heat flow
    - nature of solute elements at the solidification interface (segregation, ...)

*DIS Annual Meeting, June 2, 2011*
Experiments

• Principle
  – Measurements of the columnar zone thickness at given solidification times & “La” addition rates, to demonstrate the effect of “La” on an iron solidification growth process.
  – 0.15% addition of a late stream inoculant.
  – La amount in the inoculant varied from 0% to 2.4%.
  – Treatments are poured at the same temperature into a mold.
  – At a given time and targeted 50% liquid/solid ratio the molds are emptied of their remaining semi solid iron.
  – The solidified iron shell thickness was measured.
Experimental procedure

- Melting
- FeSiLa
- Treatment and pouring in the mold
- Solidification
- Emptying

**DIS Annual Meeting, June 2, 2011**
Experimental procedure: Results

• On 60 mm diameter molds (IRC):

<table>
<thead>
<tr>
<th>% La in Inoculant</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>6 mm</td>
</tr>
<tr>
<td>0,8%</td>
<td>2 mm</td>
</tr>
<tr>
<td>2,4%</td>
<td>0,5 mm</td>
</tr>
</tbody>
</table>

• On 100 mm diameter molds (LCR):

<table>
<thead>
<tr>
<th>% La in Inoculant</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>8 mm</td>
</tr>
<tr>
<td>0,8%</td>
<td>2 mm</td>
</tr>
<tr>
<td>2,4%</td>
<td>1,1 mm</td>
</tr>
</tbody>
</table>
Experimental procedure: Results

Without La 0%

Diameter 60 mm
Thickness 6 mm
Experimental procedure: **Results**

With La 0.8%

Diameter 60 mm

Thickness 2 mm
Experimental procedure: **Results**

<table>
<thead>
<tr>
<th>Without La 0%</th>
<th>With La 0.8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter 60 mm</td>
<td>Diameter 60 mm</td>
</tr>
<tr>
<td>Thickness <strong>6 mm</strong></td>
<td>Thickness <strong>2 mm</strong></td>
</tr>
</tbody>
</table>
Lanthanum effect on solidification

• Lanthanum promotes the equiaxe solidification mode by:
  ➔ Developing a higher nucleation power, therefore more solidification sites are within the molten iron.
  ➔ Modifying the molten iron viscosity, favoring stirring motions within the molten iron.
  ➔ Restricting the growth of columnar grains.
Consequences for Micro Shrinkage

• At a given solidification stage, when “La” is added, the equiax solidification is favored:
  – Thickness of the columnar zone is reduced: a larger volume of free flowing liquid is created allowing molten iron to travel within channels thus aiding the feeding of the casting.
  – Semi-solid iron contains more solid particles after filling of a given volume chamber: less liquid is needed to compensate the solidification contraction.
  – Promotion of Late eutectic graphite precipitation.
Industrial examples: Crankshafts

Without La

With La

- The use of FeSiLa allows Microstructure – Castings per mold

Courtesy Française de Mécanique

DIS Annual Meeting, June 2, 2011
US Trials, The Casting

1. Gate Height: 0.030" max

2. Parting Fin: 0.030" max
The Casting

2. Parting Fin: 0.030" max
The Problem

• An 11 pound crankshaft adapter.
• Originally ran >10% for shrinkage.
• Gating changes brought shrinkage down to about 3% at level 3.
• Inoculation practice, 5 pounds per ton of 75% Foundry Grade Ferrosilicon.
The Solution

- Maintain current gating system.
- Remove 5 pounds per ton of 75% Foundry Grade Ferrosilicon inoculant.
- Add 5 pounds per ton of FeSiLa inoculant.
  - Silicon 45 to 50%
  - Calcium 1.50 to 2.50%
  - Aluminum 1.25% maximum
  - Lanthanum 1.80 to 2.20%
  - This is a 0.005% La addition.
The First Test

- Tightened acceptable shrinkage from level 3 down to level 2.

- Ran 138 pieces with FeSiLa alloy inoculant.
  - The 138 pieces were captured and placed into 1 bin.

- Ran 333 pieces with Foundry Grade inoculant.
  - The 333 pieces were captured and placed into 2 bins.
    - 122 pieces in bin # 2.
    - 211 pieces in bin # 3.
The Results

- Bin #1, with FeSiLa inoculant ran shrinkage free with 138 out of 138 pieces showing no level of shrinkage.
- Bin #2, with Foundry Grade FeSi inoculant.
  + 122 total pieces, 10 pieces with shrinkage
    × 4 pieces level 2, accepted
    × 6 pieces level 3 or higher, rejected
- Bin #3, with Foundry Grade FeSi inoculant.
  + 211 total pieces, 10 pieces with shrinkage
    × 4 pieces level 2 or less, accepted
    × 6 pieces level 3 or higher, rejected.
- 12 pieces scrapped from 333 pieces in Bins #2 and 3 for a scrap rate of 3.60%.
First Test, Bin Results

- Bin 1 FeSiLa: 138 Pieces
- Bin 2 FeSi: 122 Pieces
- Bin 3 FeSi: 211 Pieces

Shrinkage:
- Bin 1 FeSiLa: 0 Shrink, Total, 0 Rejectable
- Bin 2 FeSi: 10 Shrink, Total, 6 Rejectable
- Bin 3 FeSi: 10 Shrink, Total, 6 Rejectable
First test, shrinkage breakdown

- Bin 1 FeSiLa: 0% Shrink, 0% Reject
- Bin 2 FeSi: 8.2% Shrink, 4.92% Reject
- Bin 3 FeSi: 4.74% Shrink, 2.84% Reject

DIS Annual Meeting, June 2, 2011
The Mistake

• The foundry mistakenly reverted back to the original practice, making another 1,455 pieces, 6 bins, without the FeSiLa inoculant.

• The choice was to either scrap the entire run, or 100% inspect by x-ray sort. They decided to 100% inspect.

• Of the 1,455 pieces, 37 were rejected and 1,419 were acceptable for a 2.54% scrap rate.
The Results from the Mistake

• All bins had Foundry Grade 75% FeSi inoculant.
  – Bin # 1 had 231 pieces.
    • 5 pieces with level 3 shrinkage, rejected.
  – Bin # 2 had 234 pieces.
    • 10 pieces with level 3 or higher shrinkage, rejected.
  – Bin # 3 had 271 pieces.
    • 3 pieces with level 3 shrinkage, rejected.
  – Bin # 4 had 259 pieces.
    • 6 pieces with level 3 shrinkage, rejected.
  – Bin # 5 had 263 pieces.
    • 10 pieces with level 3 shrinkage, rejected.
  – Bin # 6 had 197 pieces.
    • 3 pieces had level 3 shrinkage, rejected.
  – Overall scrap rate 2.54%
Second Run, Bin Results

DIS Annual Meeting, June 2, 2011
Second Run, Shrinkage Results

<table>
<thead>
<tr>
<th>Bin 1 FeSi</th>
<th>Bin 2 FeSi</th>
<th>Bin 3 FeSi</th>
<th>Bin 4 FeSi</th>
<th>Bin 5 FeSi</th>
<th>Bin 6 FeSi</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Shrink</td>
<td>2.16</td>
<td>4.27</td>
<td>2.32</td>
<td>3.8</td>
<td>1.52</td>
</tr>
<tr>
<td>% Reject</td>
<td>1</td>
<td>1.11</td>
<td>1.52</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The Ending

- The foundry did not conduct another “Trial with the FeSiLa inoculant” due to the cost of 100% x-ray inspection of the 1,455 pieces.
- Since that time, the foundry has shipped over 9,000 pieces to their customer while using the FeSiLa inoculant.
- The foundry has not had a single complaint for porosity since the implementation of the FeSiLa inoculant as standard practice for this part.
Thank You

• The presenter would like to acknowledge and thank:
  – R Siclari, T Margaria, E Bethelet and J Fourmann for their paper titled “Micro-shrinkage in Ductile Iron / Mechanism & Solution” which was originally presented at the 2003 Keith Millis Symposium on Ductile Cast Iron.
  – Jim Csonka, Hickman, Williams & Company for the technical assistance in preparing this presentation.
Questions?
JOE FUQUA WITH GENE MURATORE

JOE FUQUA

JOE GRADUATED FROM THE UNIVERSITY OF MISSOURI-ROLLA IN 1978 WITH A BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. JOE WAS ALSO A FEF STUDENT. JOE IS CURRENTLY EMPLOYED BY AMERICAN COLLOID COMPANY AS PRODUCT MANAGER FOR A RECENTLY DEVELOPED LINE OF CHEMICAL BINDER SYSTEMS. BEFORE JOINING AMERICAN COLLOID IN 2002, JOE WAS THE PRESIDENT AND CO-FOUNDER OF FNG INDUSTRIES WHICH BEGAN IN 1990. FNG WAS A PRODUCER OF SILICON CARBIDE AND FERROALLOY BRIQUETTED PRODUCTS FOR CUPOLA MELTING OPERATIONS. BEFORE GOING OUT ON HIS OWN TO START FNG, JOE SPENT 10 YEARS WITH ASHLAND CHEMICAL AS A TECHNICAL SERVICE REPRESENTATIVE TROUBLESHOOTING PROBLEMS RELATED TO CHEMICAL BINDER SYSTEMS AND PERFORMING CASTING DEFECT ANALYSIS. JOE HAS AUTHORED A NUMBER OF PAPERS FOR AFS PUBLICATIONS AND IS ACTIVE IN AFS AND FEF.

THE DIS WELCOMES JOE WHO IS HERE TO TALK ABOUT “HIGH PERFORMANCE, LOW VOC CHEMICAL BINDER SYSTEM”
The subject of this presentation is a relatively new low HAP, low VOC, low odor chemical binder system which exhibits a number of unique performance features. For the purposes of this write-up it will be referred to by its tradename – Lovox. In terms of the low HAP/VOC/odor properties, there is nothing really new about this system. Efforts to improve the environmental aspects of chemical binder systems have been ongoing for decades and these efforts have brought about a long list of products which can be categorized as Inorganic Modified Silicates, Organic Modified Silicates, Biodiesel, and Low Emission Organic.

The Lovox system falls into the class of Low Emission Organics. This is a two part urethane system in which the Part 1 resin is phenol and formaldehyde free. This is what differentiates it from a typical phenolic urethane. The phenol/formaldehyde components have been replaced with a reactive solvent system which contains no aromatics. This modification results in a very low VOC/HAP and virtually odor free binder.

The Part 2 resin is a modified isocyanate blend which also contains no aromatic solvents. In its current state of development, the system is catalyzed with a liquid catalyst as a third part component, making it a no-bake binder. Further work on the system is aimed at developing a vapor cured binder for cold box applications.
System Benefits

- Excellent thermal properties yields superior veining resistance w/o use of sand additives.
- In certain applications, casting weights up to 100#, core washes may be eliminated.
- Appears to eliminate certain types of gas defects.
- Superior shake-out properties.
- Zero phenol, zero formaldehyde Part 1 replacement for Phenolic Urethanes.
- Phenol formaldehyde free chemistry drastically reduces odor at mixing station.
- Significant reduction in VOCs and HAPs.
- Core sand input may have minimal impact on green sand molding systems.

The primary features of the Lovox system are listed here in what could be considered an order beginning with most attractive. The first property is the thermal stability. This yields excellent veining resistance which can be achieved without the use of dry sand additives, which can be very costly to purchase and increases resin demand of the sand mix. In some casting applications, core washes can be eliminated and still provide very good surface finish. This is not a universal, across-the-board product benefit, but is something that is evaluated on a case by case basis. In most smaller casting applications, this practice has been fairly successful. In addition, there have been applications in which certain types of gas defects have been eliminated. This was an unexpected product attribute and to date, a sound explanation has not been formulated. Lovox also provides excellent shake-out properties which can help reduce costs associated with sand reclamation and also reduces the amount of resin input into green sand systems utilizing chemically bonded cores.

The base premise behind the system is its environmental characteristics, and as described earlier, the phenol/formaldehyde/aromatic solvent free chemistry yields an almost odor free sand mixture and an emission profile which emits less than 50% of the hazardous air pollutants of a phenolic urethane resin at pour-off.
Before the benefits of any binder system can be realized, it must provide the strength properties needed to produce a mold or core and get it to the pouring floor intact. The ability of a binder system to do this is usually measured in tensile strength, and graph above shows the relative strength properties of Lovox against four other commercially established systems. In this graph, the Lovox is the red line data identified on the graph as “B107”.

All of the testing was run with a 55 GFN silica sand at 1.2% total binder. As seen, Lovox follows a similar strength build-up as that of phenolic urethane. In practice, the removal of the phenol/formaldehyde and aromatics results in a resin with somewhat less reactivity so to achieve comparable strength development, catalyst requirements may be greater.

Typical binder levels are 1.0% to 1.25% although in some applications levels as low as 0.8% have been used successfully. The resin viscosity for both components is on the order of 150 cps to 200 cps and the resultant sand mix is flowable and easily compacted. The following photos illustrate the range of applications in which the system has been used successfully.
Photo above is a mold cope half weighing approximately 8500#. Mold was made in thermally reclaimed sand at 1.0% binder; strip time was 35 minutes.

The above photo depicts small oil passage cores for cast iron manifold. Cores were produced at 1.5% total binder in a 58 GFN silica. Core thickness is ½”. Weight is 9 ounces. Cores were made on a no-bake core blower.
As described previously, one of the most attractive features of the Lovox system is its thermal stability and resistance to expansion defects. The graph above represents data generated through a thermal distortion test developed by Dr, Sam Ramratten of Western Michigan University. In this procedure, a bonded sand test specimen is placed in a fixture and subjected to a constant temperature of 1832° F and a physical load equivalent to an 8” ferrostatic head height for a 90 second time period. These conditions were calculated to represent the conditions in which a bonded sand core would be exposed to in a medium sized ferrous casting application. The movement of the specimen during the test interval is recorded as either positive or negative displacement. Positive displacement is defined as thermal expansion. It is the thermal expansion of the core or mold sand which creates the surface cracks that lead to veining defects. As seen in the graph, phenolic urethane, phenolic ester, and furan resins go through relatively significant expansion. The Lovox systems tested (identified on the graph as “B107”, “B108”, and “E100”) remain fairly stable under these conditions before exhibiting negative displacement. This movement is defined as plastic distortion. It is not entirely clear if this plastic distortion manifests itself as a particular casting problem, but to date there has been nothing detected in production use.
In practice, the thermal expansion properties of Lovox translate into a virtually veining resistant binder system. The stepcone castings shown in the above photo were both produced in a silica sand at 1.0% total binder. The core used to produce the casting on the left was bonded with phenolic urethane and included a 5% anti-veining additive. The casting on the right was bonded with Lovox and contained no sand additives. Both cores were coated with a graphite core wash. Both castings were produced with gray iron and poured at 2530°F.
In actual production, the properties seen graphically in the thermal distortion test data and visually in the stepcone castings translate very well. The cored surface seen in the above photo was previously produced with a phenolic urethane system at 1.0% resin and 5% of an anti-veining additive. The core was also washed as an added measure against veining defects. Despite these measures, veining was generally a problem, and in many cases the small cored opening seen on the casting interior was closed off with iron as the thin core section which produces the opening would split and allow metal to flow in. The casting in the picture was produced with Lovox at 1.0% resin without the sand additive and without the core coating. With the exception of a small fin at the thin section opening, the cored surface requires no further cleaning.

The castings pictured above are Ni-Hard wear components. The casting on the left side of the photo was produced with a sodium silicate sand mix which included a 4% - 5% anti-veining additive. The core produces the interior section of this casting and veining is readily apparent. Being a Ni-Hard casting, this surface can be difficult to clean. The casting on the right is the same part which was produced with a Lovox core at 1.2% binder and no sand additives. The cores for both castings were coated with a ceramic-graphite coating. This particular core had been made in phenolic urethane as well. It was felt that sodium silicate was the only system...
which could be used successfully in this application. There was also a noticeable improvement in surface finish.

The preceding discussion, data, and pictures illustrating the excellent thermal stability of the system are just a few examples of this property which has been demonstrated on a large number of different casting applications.

As shown on the list of product features, it appears that in some applications, the Lovox eliminates certain types of gas defects. In the instance of the casting pictured above, the scrap rate for blow defects through the radius of this pipe was about 80%. The casting had been produced with phenolic urethane. A variety of binder levels, sand additives, and coatings had been utilized as remedial steps to eliminate this problem. The casting in the photo was produced with a Lovox core at 1.0% total binder with no additives or coatings. The gas problem has basically been eliminated.

This feature of the product was not anticipated, so there has been no scientific explanation as to why it works this way. It is speculated that the gas evolution rate of the resin during pouring
is much greater than phenolic urethane and this allows the decomposition gases to escape the mold cavity earlier in the solidification process. Suffice it to say that this property has been demonstrated in a number of applications.

This is a graphical comparison of the relative shake-out properties of Lovox, designated here as “B107”, and phenolic urethane. In this test, a 3 pound mold was used to produce a 1 pound cast iron step casting. At a 3:1 sand to metal ratio, this represents a typical no-bake mold or core application. Both mold and casting are cylindrical in shape to allow even thermal transfer from metal to sand mass. The molds were produced with 1.2% total binder. Castings were poured at 2500°F. After cooling to room temperature, the casting was removed, and the mold was agitated for ten seconds to loosen all burnt out sand. The loose sand was measured as a percentage of the actual starting mold weight. The data above represent results from five samples of each.

In foundry practice, the differences seen in the above graph have been demonstrated in a wide variety of applications. The photo immediately below shows two racks of vertical molds one hour after being poured.
The molds seen in the left hand photo were produced with phenolic urethane in a reclaimed sand at 0.9% total binder. The molds in the right hand photo were produced with Lovox at 1.0% (new sand was used since this was a product test run and access to the primary mixer was unavailable). As a control, one phenolic urethane mold was placed with the rack of Lovox molds (this mold is seen at the right end of rack). As seen in the photo, the collapsibility of this binder system is significantly better.

In no-bake foundries with reclamation systems, this property can result in improved throughput of the reclaim equipment, reduced energy consumption, and lower LOI’s in the reclaimed sand. In one control study in a thermal reclamation system, the throughput of the Lovox shakeout sand increased by 33% over the existing phenolic urethane system at equivalent binder levels.
In a core applications, the differences in shakeout properties can be just as dramatic. This is a gray iron casting produced in a green sand mold with a no-bake core producing the interior and exterior cast surfaces. The casting on the left was produced with a phenolic urethane cores; the casting on the right was produced with Lovox cores. Both sets of cores were run at 1.0% binder. At the time of shake-out, the Lovox core sand was essentially thermally reclaimed with little more than a few small core butts. The phenolic urethane showed very little thermal breakdown, as depicted on the left. Aside from the obvious advantage of requiring little time and effort to remove the core from the casting, there is very little sand carryout with the casting and resin coated sand being introduced to the sand system can be greatly reduced.
In terms of the environmental characteristics of Lovox binders, the low VOC and low odor properties can be illustrated in the above graph. This data was generated with a procedure developed by the Ohio Cast Metals Association to determine the VOC content of various foundry materials. In this test, a measured quantity of sand, resin, and catalyst are mixed in a container and set aside to cure for a 12 hour period. At 30 minutes, one hour, and every hour following, the container is reweighed and the accumulated weight loss is calculated. For this test, both binder systems were tested at 1.2% total binder in a 55GFN silica sand. The data represented by the black bars on the graph are from low VOC phenolic urethane system. The blue bar data is from the Lovox, identified on the graph as “B107/108”. As illustrated in the graph, the Lovox contains almost ½ of the VOC content of the low VOC phenolic urethane. This property translates to the core and mold production areas as a better air quality for the operating personnel with virtually no odor and significantly reduced irritants to the eyes and nose.
**MPTE** – Maximum Potential to Emit measured as micrograms of VOC/HAP compound per gram of sample material tested. Testing conducted at 982°C (1800°F).

Samples were silica sand bonded with 1.0% total binder.

**PUNB** – phenolic urethane no-bake.
The graphs above are results from an emission test study comparing Lovox to a phenolic urethane no-bake. In this procedure, a known quantity of bonded sand is burned off at 1800°F and all gaseous components are captured. Select species of emissions (HAPs) can be analyzed individually and all measurements are reported as micrograms of gaseous compound per gram of sample tested. As seen in the graphs, total emissions from Lovox are significantly lower, almost 70%, than those from phenolic urethane. Obviously, the removal of phenol from the system has the predicted effect of eliminating phenol emissions, and this is a major contributor to the total reduction. However, in terms of the other HAPs analyzed, benzene generation is less than half, toluene is reduced by 75%, and xylenes are about 25% of PUNB levels. With environmental regulations showing no signs of relaxing, emissions reduction is becoming increasingly critical to foundry operations. A chemical binder system featuring these levels of emissions reduction, along with some attractive casting performance benefits is certainly worth evaluating.

While the Lovox system offers a great deal of unique performance benefits, it is also unique in its chemical make-up. As a result, it is a more expensive than most conventional systems. The raw materials are expensive, and the processing is expensive. On the basis of cost per ton of mixed sand, Lovox resins are roughly 40% more expensive than phenolic urethanes. With such a cost differential, it might appear on the surface that there is no economic justification for using it. With this as a concern, a cost/benefit analysis was conducted with one long term Lovox consumer. The objective was to track all costs associated with producing the subject castings and identify all cost variances which were a direct result of replacing the phenolic urethane standard with Lovox. These variances could be positive or negative.

It was determined that the base premise of the study would be to select five individual casting jobs ranging in benefits from the resin conversion which could be considered significant to none. It was also assumed that for the purpose of this analysis that these five castings would represent the entire product mix of this foundry. In this way, a weighted average could be calculated for all cost variances being evaluated. The study was conducted over a three month period.

The chart shown immediately below defines the basic parameters for the castings selected for the study. Each casting was identified according to type, total production cost, individual casting weight, and the production weighting which represents the quantity of each casting produced relative to the total production of all five.
## Cost/Benefit Analysis

<table>
<thead>
<tr>
<th></th>
<th>Elbow</th>
<th>Spool</th>
<th>Housing</th>
<th>Pump</th>
<th>Valve Body</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting Cost</td>
<td>$16.21</td>
<td>$15.67</td>
<td>$6.08</td>
<td>$10.84</td>
<td>$14.04</td>
<td>$14.31</td>
</tr>
<tr>
<td>Casting Weight</td>
<td>22.8#</td>
<td>16.28#</td>
<td>8.54#</td>
<td>15.24#</td>
<td>9.5#</td>
<td>14.24#</td>
</tr>
<tr>
<td>Production Weighting</td>
<td>32.5%</td>
<td>2.3%</td>
<td>3.9%</td>
<td>5.2%</td>
<td>56.1%</td>
<td></td>
</tr>
</tbody>
</table>

## Cost Analysis - Core

<table>
<thead>
<tr>
<th></th>
<th>Elbow</th>
<th>Spool</th>
<th>Housing</th>
<th>Pump</th>
<th>Valve Body</th>
<th>Weighted Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Weight</td>
<td>10#</td>
<td>12.5#</td>
<td>0.68#</td>
<td>7.5#</td>
<td>10.25#</td>
<td>9.70#</td>
</tr>
<tr>
<td>Std. Core Cost</td>
<td>$.5190</td>
<td>$.3300</td>
<td>$.0179</td>
<td>$.1980</td>
<td>$.2706</td>
<td>$.3391</td>
</tr>
<tr>
<td>B107 Core Cost</td>
<td>$.3690</td>
<td>$.4613</td>
<td>$.0251</td>
<td>$.2768</td>
<td>$.3783</td>
<td>$.3581</td>
</tr>
<tr>
<td>Variance</td>
<td>$.1500</td>
<td>-.1313</td>
<td>-.0072</td>
<td>-.0788</td>
<td>-.1077</td>
<td>-.0191</td>
</tr>
</tbody>
</table>

The most obvious first comparison deals with core costs. The line defined as Standard Core Cost represents those standards costs as established with the material costs when this foundry
was using the phenolic urethane system. The B107 Core Cost represents the new costs for each core after the conversion to the Lovox system. In most cases, the core cost increased by about 40% which is expected since the Lovox resin cost is about 40% higher than typical phenolic urethanes. The notable exception is with the Elbow casting core which shows a significant cost reduction. This is due to the elimination of a 5% anti-veining additive that was in the standard core sand mix. As seen here, the use of these additives can be very costly. However, as seen in the weighted average, the overall cost difference between the phenolic urethane and Lovox was an increase of $.0191 per core.

The next step in the evaluation was to look at the impact of any changes made to the core wash practices. The first line in the above chart is the core cost variance which is just the bottom line from the first chart carried down. The next two lines show the core wash cost per job as established for the Standard practice and again for the Lovox (B107) core practice. As seen in the figures, the core wash was eliminated from the Elbow and Spool casting jobs and resulted in considerable savings for the weighted average. This savings takes the cumulative variance for the overall casting mix from a $.0191 loss to a $.3388 savings per core. This cumulative variance will be seen again as the first line in the next chart which compares costs associated with casting cleaning.

<table>
<thead>
<tr>
<th>Core Variance</th>
<th>Elbow</th>
<th>Spool</th>
<th>Housing</th>
<th>Pump</th>
<th>Valve Body</th>
<th>Weighted Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std. Wash per Unit</td>
<td>$.9816</td>
<td>$1.4725</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$.3529</td>
</tr>
<tr>
<td>B107 Wash per Unit</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>Coatings variance</td>
<td>$.9816</td>
<td>$1.4725</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$.3529</td>
</tr>
<tr>
<td>Cumulative Variance</td>
<td>$1.1316</td>
<td>$1.3412</td>
<td>-.0072</td>
<td>-.0788</td>
<td>-.1077</td>
<td>$.3388</td>
</tr>
</tbody>
</table>
The majority of these cleaning costs are related to grinding of veining defects and rough surfaces on the castings. As seen on the third line, the conversion to the Lovox (B107) system had essentially eliminated the need for grinding. The cleaning room variance thus adds another $.0592 savings average to each casting and brings three of the five castings into a positive variance.
The final evaluation consists of any scrap reduction related to the Lovox core room conversion. These reductions are associated with elimination of gas defects or veining defects which were inaccessible with cleaning tools. These savings are listed in the second line of the chart.

With the cumulative variance from the previously analyzed variables added to the scrap savings, it is seen that in four of the five castings the conversion to the Lovox binder system resulted in a lower total casting production cost. The individual changes ranged from a 13.6% savings to a 0.6% loss. The overall variance as calculated through the weighted average shows a savings of 3.9% per casting.

The contents of this presentation describe and illustrate a binder system with a list of very attractive performance features. Although it is fairly expensive, there are many casting applications in which the additional costs may be easily justified. For example, elimination a 4–5% addition of an anti-veining material in phenolic urethane will result in an equivalent mixed sand cost. Lovox is not being presented as a panacea by any means. No binder system is. That’s why there are literally dozens of them. But, in terms of a low VOC, low HAPs, low odor organic binder it has shown itself to be truly high-performance.
DOUG GRADUATED FROM McMASTER UNIVERSITY IN HAMILTON, ONTARIO, CANADA IN 1970 WITH HIS BACHELOR OF SCIENCE DEGREE IN METALLURGY. DOUG IS CURRENTLY THE TECHNICAL SERVICES MANAGER FOR ELKEM FOUNDRY PRODUCTS. AFTER A BRIEF PERIOD AT THE STEEL COMPANY OF CANADA R&D DEPARTMENT, HE JOINED CROUSE HINDS OF CANADA, A GRAY IRON AND ALUMINUM FOUNDRY, SERVING AS A METALLURGIST TO SET UP THE MELT AND POUR CYCLE OF A NEW CORELESS INDUCTION FURNACE LINE. IN 1974, HE JOINED UNION CARBIDE CANADA LTD., METALS DIVISION. THIS BUSINESS WAS LATER PURCHASED BY ELKEM AND BECAME ELKEM METAL CANADA INC. IN ADDITION TO CANADA, DOUG HAS HELD POSITIONS WITH ELKEM IN OSLO, NORWAY, ANTIBES, FRANCE, PITTSBURG, PA AND ASHTABULA, OH. HIS ACTIVITIES HAVE INVOLVED FOUNDRY TECHNICAL SERVICE FOR GRAY AND NODULAR IRON MANUFACTURE, DESIGN AND MANUFACTURE OF NODULIZERS AND INOCULANTS, AND DESULFURIZATION TECHNOLOGY. DOUG HAS WRITTEN NUMEROUS PAPERS, HELD TECHNICAL SEMINARS, AND MADE MANY FOUNDRY VISITS IN CANADA, EUROPE, SE ASIA, AUSTRALIA AND THE UNITED STATES. DOUG SERVED AS PRESIDENT OF THE ONTARIO CHAPTER OF AFS FROM 1981 TO 1982, AND CURRENTLY SERVES ON THE DIS RESEARCH COMMITTEE.

THE DIS WELCOMES DOUG WHO IS HERE TO TALK ABOUT “AVOIDING SHRINKAGE DEFECTS AND MAXIMIZING YIELD IN DUCTILE IRON”
Avoiding Shrinkage Defects and Maximizing Yield in Ductile Iron

Doug White
Manager Technical Services
Elkem Metals, Inc

ABSTRACT
The presentation discusses factors to control to avoid shrinkage defects and maximize casting yields. These are:

- maximizing %CE just below the level where flotation will occur, while using the minimum final Si and Mg contents,
- maintaining base S as steadily as possible,
- use of nodulizer containing a low level of pure La and/or proprietary S and O coated inoculant, to generate a nodule size distribution skewed to the finer nodule sizes,
- adjusting for loss of nucleation in base iron and/or treated iron, due to excessive holds times,
- using means to accelerate freezing at appropriate places rather than riser, including metal chills, chill fins, or chilling inserts that freeze within the casting, and
- maintaining mold strength.

What Carbon Equivalent to Use?
Figure 1 shows guideline trends to avoid problems by selecting a suitable CE. To avoid shrinkage defects we must also avoid flotation of graphite nodules. The chart advises that the total C plus 1/3rd Si should not exceed 4.3. This diagram was developed as a general rule for sections varying from about ½” to about 1 ½” thick. For very thin sections such as for manifolds, the CE may be higher. For thicker sections, it must be lower to avoid flotation and an increased risk of shrinkage. When carbon precipitates from liquid iron during freezing, there is an expansion effect. Shrinkage will be minimized at the highest possible C content, where the iron freezes in the eutectic mode, just below the content where primary graphite precipitates and nodule flotation occurs.

Use the Highest CE - While Avoiding Nodule Flotation.

Figure 2 is a table that was produced by BCIRA as a research project for AFS. It shows much more detail regarding the maximum C for various Si values to avoid flotation of graphite nodules for various section thicknesses of different shapes. This is also the maximum value to minimize shrinkage. A correction for variations in pouring temperature is also included.

Generally shrinkage is reduced as the % C increases, provided that freezing continues to follow a eutectic process. Eutectic freezing involves simultaneous precipitation and growth of graphite contained within austenite shells. If the %C becomes too high however and primary graphite starts the solidification process, a great deal of the expansion effect available from graphite precipitation is consumed very early during freezing. This is due to the very rapid precipitation of graphite as it floats in the liquid metal. This can result in insufficient graphite expansion effect during the latter stages of freezing, within the last isolated pools of iron to freeze.

This chart in Figure 3 is a plot of the data from the previous slide for square bar shapes. There are 3 curves shown for 3 different Si levels. These lines have been extended to the CE = 4.3 line. This shows the thickness where the CE must be at or below eutectic. All thicker sections must also be at or below 4.30% CE to avoid primary graphite precipitation, flotation, and a jump to a higher level of shrinkage.

For square bars, this transition point is with thicknesses from 95 to 108mm (3.8” to 4.3”), depending upon base Si from 1.8 to 2.6%.

The same data has been converted to the equivalent diameter for round bars in Figure 4. When round
sections reach 83mm (3.3 in.) with 1.8% Si, the CE needs to be 4.30 or less.

In Figure 5 the square bar data has been converted to the equivalent thickness of a plate shape. For 1.8% Si ductile iron, the CE would need to be 4.30 or less as the section thickness reaches or exceeds 42mm (1.7"

In Figure 6, the data for the square bars has been converted to equivalent modulus of the part in millimeters. Modulus is the ratio of the cast part volume divided by the cast part area. Extending the lines to the CE = 4.3 line, shows the modulus where the CE must be 4.30 or less to avoid flotation.
For 1.8% Si, the modulus is 21mm (0.84")
For 2.2% Si, the modulus is 22mm (0.88")

Timing the Expansion from Carbon Precipitation

Carbon precipitation as graphite nodules is required at the start of freezing to ensure that carbon does not take the iron carbide form as edge chill. Too much early graphite precipitation must be avoided however, or the result will be too little graphite precipitation during the end of freezing, when the gating system and risers can no longer deliver more liquid to compensate for contraction. It is important to understand which foundry variables alter the amount of graphite precipitation at each stage of freezing.

Higher silicon leads directly to higher nodule count, more ferrite, and more early C precipitation. To minimize shrinkage, it is recommended that the CE be on target, with the maximum C content and the minimum Si content. C provides the expansion effects, and too much Si can lead to excessive initial expansion effect and too little in the last iron to freeze. Si should be used at a level to avoid carbides and provide strengthening of ferrite to meet mechanical properties, but not excessively more. Normally excessive nodule count that leads to shrinkage has a structure where the nodule size looks identical for most nodules. In such a case all the nodules started forming at the same time, early during freezing. The structure is pleasing to the eye, but bad for shrinkage. Figure 7 shows how nodule count can increase with higher silicon.

Other factors that can lead to high nodule counts with very uniform size are excessive inoculant addition rate or the use of Bi to increase nodule count. Later we will see that high nodule counts can be useful to turn off shrinkage, but only if a nodule size distribution can be produced that has a wide distribution of nodule sizes. This implies that graphite precipitation (C expansion) proceeds at a steadier pace from start to end of freezing, and not too fast during the first part of freezing.

Mg content is another factor that needs to be controlled to minimize shrinkage. Figure 8 is a graph that shows that shrinkage increases as the final Mg content increases. Enough Mg is required to produce good nodules but a large excess should be avoided. Excessive Mg should be avoided for a number of other reasons such as slag defects, spiky graphite formation, etc…

Keep Base S Content Consistent

The base iron S content can have a large impact on nodule count and nodule size distribution. Figure 9, shows the result of some Japanese work measuring nodule count as base S was changed. As the base S increased from the nodule count increased. For very thin castings, prone to carbides, some foundries will intentionally operate with higher base S. This can be a useful strategy when making thin sections to avoid carbides. These nodules appear to be very similar in size and may lead to shrinkage problems if nodule count becomes too high, with all similarly sized early forming nodules, especially if this occurs in heavier sections. For reproducible nodule count, it is important that base S be uniform from one treatment to the next. Large variations in base S, such as when converting between gray and ductile iron, could lead to variable nodule counts and nodule size distributions, and shrinkage propensity.

Avoid Long Hold Times for Base Iron

As base iron is held, the state of nucleation changes over time. After holding for about 30 minutes at tapping temperature, the subsequently Mg treated and inoculated iron will become both shrinkage and carbide prone. Ladle and stream inoculation may be unable to eliminate the carbides.

Some of the lost nucleation effect can be restored by adding crystalline graphite to the iron while replacing the carbon losses during holding. 100% graphite electrode turnings are reported by a foundry in Texas to be the best type of carbon replacement material to eliminate the carbide tendency.

Avoid Long Holds for Mg Treated Iron

A similar phenomenon occurs for Mg treated iron as for base iron. After 25 to 30 minutes of holding iron in an autopour, without any freshly treated iron additions, the state of nucleation of the iron changes.
and becomes shrinkage prone. Chad Moder from Neenah Foundry presented a paper on this subject, and showed that thermal analysis could be used as a tool to study this problem, and means to rapidly return the iron to a suitable low shrinkage state. They learned to recover “dead iron” by adding 0.1% by weight of a proprietary S and O coated inoculant to the iron while 1 new treatment ladle of freshly melted iron was added to the autopour. They learned to rejuvenate iron after holding it over a weekend with this technique. Prior to this, several freshly treated ladles of iron were normally required and sometimes a considerable amount of treated iron in the autopour had to be pigged.

Special MgFeSi Alloy that Reduces Shrinkage

Historically MgFeSi alloys have been alloyed with RE metals. The RE elements are intended to neutralize tramp element effects such as from lead, to avoid edge carbides at low pouring temperature, and to optimize nodule count. For many years mischmetal was the most common type of RE added into these alloys.

Special alloys have been developed that use pure La metal rather than the mixture of RE elements. When the amount of La in the MgFeSi alloy is optimized, a high nodule count with a very different nodule size distribution is observed. The number of large early forming nodules is reduced slightly and there is a large increase in the number of medium and smaller nodule sizes. This is an indication that graphite precipitation has been steadier through freezing, with more expansion effect during the latter stages of freezing.

Figure 10 shows the 2 different chemistries of MgFeSi alloys compared with an ON THE MOLD treatment process. One alloy employed a high level of a traditional mischmetal type RE. The other used about 1/3rd the amount as pure La metal with no other RE elements present. It is important to note that the La input from these 2 alloys is about the same. The mischmetal based RE type adds a significant amount more of other RE elements. We will see the negative effect of this upon shrinkage. In these experiments, iron was delivered from an autopour, so the molds containing the 2 different alloys were poured just a few seconds apart. This means that the base iron was at a constant chemistry and temperature for both molds, providing ideal test conditions for a comparison. Figure 11 shows the microstructures obtained from the iron treated with the mischmetal containing MgFeSi and the pure La containing MgFeSi alloy. The ductile iron produced using MgFeSi containing pure La metal provided a structure with fewer large nodules and a high population of medium and small nodules. This can be seen visually in the microstructure as well as in the nodule size distribution graphs. Please note that the nodule size distribution is skewed to the finer nodule size, and is not a bimodal distribution as sometimes described.

Since nodule size can be related to the time they precipitated and started to grow, we can see that the mischmetal based alloy precipitated more graphite during the early stage of freezing and less graphite during the later stages of freezing. The MgFeSi alloy with pure La type RE is therefore predicted to reduce shrinkage, since there is more C precipitation just before the end of freezing, when risers can no longer deliver more liquid feed metal to accommodate for shrinkage.

Special Inoculant that Reduces Shrinkage

It is also possible to gain a nodule size distribution which is skewed to the finer sizes by using a proprietary inoculant coated with S and O compounds. In Figure 13, we see the microstructure of ductile irons inoculated with a conventional inoculant and that proprietary inoculant. In the thin sections (5mm = ¼”) the structures are similar. In the thicker sections the structures are not similar. The iron treated with a conventional inoculant shows a drop in nodule in the thicker section, and the large nodules are quite a bit bigger due to the longer freezing time which provided more time for the nodules to grow. The iron treated with the proprietary S and O coated inoculant did not show a drop in nodule count in the thicker section as is normally expected. It surprisingly showed an even higher nodule count with only a few large nodules, and a very high number of medium and small nodules.

In Figure 14 we see the profound difference in shrinkage for this iron treated with different inoculants, with shrinkage minimization correlating with a structure that has a wide nodule size distribution which is highly skewed toward the medium and finer nodule sizes.
Thermal Analysis, Nodule Size Distributions, and Shrinkage

Studies of iron produced with these 2 alloys that produce nodule size distributions skewed to the fine sizes have included thermal analysis. Traditional alloys tend to result in curves which are rounded off during the last half of solidification. Curves with a nodule size distribution skewed to the fine sizes tend to produce flatter curves. This is due to steadier precipitation of C (and austenite) throughout freezing. Figure 15 show cooling curves generated from iron inoculated with a conventional material and with the proprietary O and S coated inoculant. You can see that the iron treated with conventional inoculant showed a cooling curve with a quite rounded finish compared to the flatter curve for the proprietary S and O coated inoculant. The cooling curve treated with the O and S coated inoculant was different in other ways as well. Freezing occurred with less undercooling and less recalescence. High recalescence is a sign of rapid initial freezing, i.e. rapid austenite and C precipitation. Flatter curves are preferred, since these correlate with reduced shrinkage or elimination of shrinkage.

Figure 16 shows the differences in the first derivatives of the 2 cooling curves. The smaller angle around the freezing point is an indication of lower shrinkage tendency.

There used to be an old foundry axiom saying that you needed to be careful that you did not over inoculate, as you might turn on shrinkage defects. Studies have shown this to be true, if you are increasing the nodule count simply by adding more nodules of the same size. In the graph shown in Figure 17, increasing from 175 to 225 nodules per square millimeter increased shrinkage.

If however the nodule count is increased to much higher numbers, and the size distribution becomes skewed to the finest sizes, shrinkage can be greatly reduced. Simply having a higher nodule count will not help reduce shrinkage; in fact it may increase it. It is necessary to have the skewed nodule size distribution to the finer sizes.

Increasing Freeze Rate Rather than Risering

Many foundries have flow and solidification modeling software. This software can be very useful to predict where shrinkage is likely to occur in castings. At that point there is a decision to make to avoid that problem. Should we add risering to feed more liquid iron longer to the spot where shrinkage is predicted or should we somehow make that part of the casting freeze more quickly by some chilling technique? In large castings it is sometimes a struggle to produce structures with high nodule counts and high nodularity. It may be useful in such situations to use chilling to avoid the shrinkage effect since there can also be an improvement with the structure. Risers may make the structure worse by extending the freezing time in addition to reducing the iron yield.

There are a number of ways to chill the heavy shrink prone areas of castings

The 2 photos in Figure 18 show holes drilled into cores and the subsequent cooling pins cast during mold filling. These pins of iron serve as “radiators” to transfer heat from the casting into the sand more rapidly, to avoid shrinkage in those areas. In some cases pins or fins can simply be added to a pattern. Drilling is only done if they cannot be included automatically with patterns or core boxes. The fins or pins will be removed from the castings after cleaning. Sometimes this can be done automatically if a de-finishing operation is already being done.

In the 2 photos of Figure 19, we see a coiled spring shape used to very rapidly freeze a section of a casting prone to shrinkage. The greater surface area of a spring can chill the iron more rapidly than a straight wire or bolt. The photo on the right shows the spring fused into the casting with a shrink free result. In some cases a hole is drilled through the center of the area where the spring is located, and in other castings the spring is entirely machined out. In both cases the drilled surface must not reveal shrinkage voids of any size.

Figure 20 includes 2 photos that show an application where chills are embedded into a core as the core is produced, in order to provide chilling of the iron at places subject to shrinkage defects. The metal chills do not melt into the casting but simply extract heat more quickly from those shrinkage prone sections of the casting. Metal chills must have clean dry surfaces and are often coated with a ceramic wash.

Figure 21 shows an application where 2 bolts have been formed into a mold as “ram-up” type inserts. These were set into the pattern before forming the mold section. The objective was to accelerate freezing at an area prone to shrinkage in this greensand mold.

Figure 22 shows the cast part from the prior photo. Ultimately it was decided to use 3 bolts to quench the iron to avoid shrinkage in that area of the casting. The 3 bolt heads will later be cut off.

Producing Uniformly Strong Rigid Molds

It is well known that ductile iron can be produced without risers if molds are suitably strong. This
Carbon and Silicon in Ductile Iron

Summary of Techniques to Minimize Shrinkage

1) Using the graphs generated in the paper, select a C content that is coordinated with a minimum Si level, your maximum pouring temperature, for the maximum casting modulus or section size. That C will be as high as possible for your situation, while just avoiding nodule flotation.

2) Avoid producing high nodule counts with an apparently uniform nodule size. This is sometimes seen if the iron is over-inoculated or treated with Bi.

3) Keep base S and final S at uniform levels, as these can make considerable changes to nodule count.

4) Avoid hold periods of base iron over about 30 minutes without adding new freshly melted base iron. If this occurs, and freshly melted iron is not available, replaced carbon lost during the hold period with 100% crystalline graphite, preferably crushed graphite electrodes or electrode turnings.

5) Avoid long hold periods of Mg treated ductile iron in autopours. The use of proprietary O and S coated inoculant added with 1 treatment of freshly treated iron can restore the nucleation effect to treated iron in the autopour.

6) Consider use of MgFeSi alloyed with pure La metal rather than other rare earth metals or rare earth mixtures and/or proprietary inoculant coated with S and O compounds. These materials can generate nodule size distributions that are skewed to the finer sizes which can reduce or eliminate shrinkage defects.

7) Maintain mold strength to uniformly high levels through sand controls and

8) Use flow and solidification simulation software to predict and minimize shrinkage. Compare various chilling techniques versus risering to increase yield and structure quality for heavy slow freezing sections that are shrinkage prone.

FIGURE 1
Max % C to Avoid Nodule Flotation

AFS Transactions, 1986 – paper 86-150
(Fuller and Blackman – BCIRA)

Section Size of sample (mm)
20  30  50  80  Square Bars (mm)
4.79 7.06 11.34 17.23  Volume-to-surface area ratios (mm) (Modulii)
10  15  23  35  Cooling rate thickness in large plates (mm)
19  28  45  70  Cylindrical sections diameters (mm)**

% Silicon*  MAX. % Carbon to Avoid Nodule Flotation
1.8   4.00  3.96  3.88  3.76
2.2   3.90  3.86  3.78  3.65
2.6   3.80  3.76  3.67  3.55
3.0   3.69  3.65  3.57  3.45
3.4   3.59  3.55  3.47  3.34
3.8   3.49  3.45  3.36  3.24
4.2   3.38  3.34  3.26  3.13
4.6   3.28  3.23  3.16  3.03
5.0   3.18  3.13  3.05  2.93

For pouring Temperature =1400°C (2550°F)

Carbon contents should be decreased by 0.05% for each 50°C (90°F) increase in pouring temperature.
*Silicon contents must include additions made in magnesium treatment and inoculation.
**Plus lengths greater than 5x the diameter.

FIGURE 2
Max. CE for Square Bars

Max CE for Square bars poured at 2550F with various final Si levels

Max. CE to Avoid Nodule Flotation

1.8
2.2
2.6
Linear (1.8)
Linear (2.2)
Linear (2.6)

FIGURE 3

Max. CE for Round Bars

Max. CE for Round Bars, poured at 2550F for various % Si contents

1.8
2.2
2.6
Linear (1.8)
Linear (2.2)
Linear (2.6)

FIGURE 4
Max. CE for Flat Plate Sections

Max. CE for Thick Plates to Avoid Nodule Flotation poured at 2550F with various % Si levels

Max. CE versus Modulii (mm)

FIGURE 5

Max. CE to Avoid Nodule Flotation pouring at 2550F for various Si levels

FIGURE 6
Silicon in Ductile Iron

Higher silicon leads directly to higher nodule count, more ferrite, and more early C precipitation. Keep % Si steady at the minimum level – enough to avoid carbides. Avoid very high nodule counts of uniformly sized nodules from over-inoculation, Bi additions, ..

FIGURE 7

Magnesium vs. Shrinkage

FIGURE 8
Nakae and Igarashi Nuclei Studies
Nodule Count Increases as Base S Increases

On-the-mold Nodularizing

Objective:
Compare samples of ductile iron made by the on-mould process using:

<table>
<thead>
<tr>
<th></th>
<th>Misch-based nodulariser</th>
<th>La type nodulariser</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Si</td>
<td>47.0</td>
<td>46.0</td>
</tr>
<tr>
<td>% Mg</td>
<td>4.5</td>
<td>5.5</td>
</tr>
<tr>
<td>% Ca</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>% RE</td>
<td>1.25</td>
<td>0.35</td>
</tr>
<tr>
<td>% Al</td>
<td>0.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

FIGURE 9

FIGURE 10
Graphite Nodule Size Distribution Skewed to the Fine Sizes that Reduce Shrinkage

Reduced Shrinkage - La Alloyed MgFeSi Alloy
Nodule Count/ Size Distribution vs. Section Size

![Image of nodule count and size distribution with S and O coated inoculant and conventional inoculant comparisons.]

Shrinkage in Crossbar Samples

![Image of shrinkage in crossbar samples with S and O coated inoculant, Ba-FeSi, and Sr-FeSi comparisons.]

**FIGURE 13**

**FIGURE 14**
Thermal Analysis of Inoculated Iron

**Figure 15**

- Conventional
  - $T_{E_{low}} = 1139^\circ C$
  - Undercooling = 25$^\circ C$
  - Recalescence = 6.2

- O & S coated
  - $T_{E_{low}} = 1145^\circ C$
  - Undercooling = 19$^\circ C$
  - Recalescence = 2.3

Thermal Analysis of Inoculated Iron

**Figure 16**

- Conventional
  - GRF2 = 115

- O and S coated inoculant
  - GRF2 = 70
Nodule Count, Nodule Size Distribution and Shrinkage

FIGURE 17

Chill pins cast from holes drilled into cores - Caterpillar

FIGURE 18
Chill wire (Caterpillar)

FIGURE 19

Metal Chills (Caterpillar)

FIGURE 20
Neenah – Bolts formed into a mold at a heavy casting section

FIGURE 21

Neenah – 3 bolts fused into a casting to avoid shrinkage

FIGURE 22
MEETINGS

The Ductile Iron Society Fall Meeting will be held October 26-28, 2011 at the Wyndham Hotel in Gettysburg, Pennsylvania. There will be a visit to TB Wood's in Chambersburg, Pennsylvania.

BUSINESS

Controlling Slag Buildup

The formation of slag in the melting of ferrous metals is inevitable. Three important physical characteristics of slags:

- melting point
- viscosity
- ‘wetting’ ability

Slag should remain liquid at temperatures likely to be encountered during melting, molten metal treatment or molten metal handling.
Viscosity of slag needs to be such that removal from the metal surface is easy. At the same time, a fluid slag of low melting point promotes good slagging reactions and prevents buildup in channel furnace throats and loops as well as coreless furnace sidewalls.

Slags must have a high interfacial surface tension to prevent refractory attack (wetting) and to facilitate their removal from the surface of the molten metal.

Redux – controls and minimizes buildup in pouring ladles, melting furnaces, pressure pour furnaces and magnesium treatment vessels with minimal to no adverse effects on refractory linings. Click here to learn more about Redux.

Want to learn more about controlling slag? Click here for a Whitepaper on Control of Slag and Insoluble Buildup in Ladles, Melting and Pressure Pour Furnaces by Rod Naro, President, ASI International.

Press Release

Technological leaders in foundry chemicals

ASK Chemicals steps forward as newly established complete global foundry supplier

Düsseldorf, June 28, 2011 – ASK Chemicals GmbH will present itself for the first time as a newly established global player in the foundry chemicals industry in Hall 12, Stand A24 at GIFA 2011, the international platform for foundry industry developments, which opens today.

With 1,600 employees, a global presence and a complete portfolio of foundry chemicals and auxiliaries, ASK Chemicals, founded on December 1, 2010 as a joint venture bundling the foundry activities of Ashland Inc. Dublin OH, USA and Süd Chemie AG (Munich, Germany), is one of the
Press Release

Technological leaders in foundry chemicals

ASK Chemicals steps forward as newly established complete global foundry supplier

Düsseldorf, June 28, 2011 – ASK Chemicals GmbH will present itself for the first time as a newly established global player in the foundry chemicals industry in Hall 12, Stand A24 at GIFA 2011, the international platform for foundry industry developments, which opens today.

With 1,600 employees, a global presence and a complete portfolio of foundry chemicals and auxiliaries, ASK Chemicals, founded on December 1, 2010 as a joint venture bundling the foundry activities of Ashland Inc. (Dublin OH, USA) and Süd Chemie AG (Munich, Germany), is one of the leading partners of the foundry industry. In terms of expertise and professionalism, the new entity is built on the developments, products and qualifications of all the incorporated companies and their employees, some of which can look back on more than 100 years in their respective specialist fields. The new positioning of the company is based on these strong foundations, as CEO Stefan Sommer explains: “The combination of years of experience, innovative strength and a global presence enables us to make a significant contribution to the further dynamic development of the foundry industry across the world. Meanwhile, the principle of sustainable business is a particular focus of our mission.”

Whether globally or locally, ASK Chemicals offers tailored products, highly qualified expertise supported by constant research and development, above average technical service and excellent problem-solving capabilities.

Growth potential for the future driven by a variety of factors

Mechanical engineering, the automotive industry and plant engineering remain growth segments of Europe’s established industries. Consequently, most of the technological standards for new products and material requirements are also set in Europe. This growth drives requirements for saving fuel whilst retaining or even increasing performance in engines by measures such as the use of turbochargers, which will soon feature in almost every new car. These cast products in turn place higher requirements on casters to manufacture more complex geometry with more sophisticated materials, which can only be implemented with the aid of specialist support and new products for the casting process. As a supplier of foundry chemicals and application engineering expertise, ASK Chemicals takes these challenges head-on and provides new products for technical implementation.

North and South America represent further sources of considerable growth potential for ASK Chemicals. In the USA, also driven by the need to save fuel, stricter requirements for engines are leading to similar trends and potential for growth to those in Europe. In South America and the emerging Asian economies, infrastructure, energy production and individual mobility are at the top of the agenda. In Russia, alongside equipment for oil and gas exploration, it is the expansion of rail-based infrastructure that is providing significant forward momentum. ASK Chemicals is represented locally on these markets with products and services and supports the technical requirements and capacity expansions of the domestic industries in these countries just as it does the international activities of its European and American customers. With research and development sites on three continents, ASK Chemicals can offer targeted solutions to problems arising during the production process in a foundry that are specific to particular countries or regions. The company also has access to extensive simulation know-how, which strongly accelerates development.
Sustainable business is an ever more important topic

Other challenges facing the foundry industry include massive pressure from legislators and society to move towards sustainable production, as well as energy and material efficiency. These topics are high on the agenda not only in developed Western countries, but also in Russia, China, India and South America. Sustainable production processes and environmentally friendly technologies are today among the most important strategic challenges for the industry.

“Economic success and sustainable business alignment go hand in hand as far as we are concerned and define the shape of further product development for our researchers and developers”, comments Stefan Sommer. In this respect, ASK Chemicals has in recent years taken a wide range of products through to series maturity which enable casters to reduce or even prevent emissions – and this applies to all product groups. In addition to additives to reduce emissions and organic and inorganic binder systems, these products include absorbent coatings, fluorine-free feeder systems and solvent-free release agents. Efficient new developments and product lines support sustainable production in both environmental and economic terms. The application and modes of operation of these products – identifiable by the symbol created especially for them – are presented at the ASK Chemicals stand. Representatives from R&D will be available to answer any technical questions.

As the subject of sustainability is one of such significance, ASK Chemicals has invited noted experts to a panel discussion entitled “Sustainability – buzzword or crucial factor for success in the global economy of the 21st century?”. “The intellectual debate surrounding the opportunities and risks of growth must be part of our corporate activities”, asserts the CEO. “We want to use this debate to create the momentum that is just as important for the industry, as we always do through our products.”

About ASK Chemicals GmbH

ASK Chemicals GmbH is one of the world’s largest suppliers of foundry chemicals, with a comprehensive product and service portfolio of binders, coatings, feeders, filters and release agents, as well as metallurgical products including inoculants, inoculation wires and master alloys for iron casting. The new company has 30 locations in 24 countries, in 16 of which it has its own production plant, and has a global workforce of around 1,600 people. With research and development in Europe, America and Asia, ASK Chemicals sees itself as the driving force behind industry-specific innovations committed to offering customers a consistently high level of quality. Flexibility, speed, quality and sustainability as well as cost-effective products and services are of key importance here.

Press contacts
**EXHIBITOR AND VISITOR RECORD AT GIFA, METEC, THERMPROCESS, NEWCAST 2011**

The Concurrent Staging Of The Four Technology Trade Fairs GIFA 2011 - International Foundry Trade Fair With WFO Technical Forum, METEC 2011 - 8th International Metallurgical Technology Trade Fair With Congress, THERMPROCESS 2011 - 10th International Trade Fair And Symposium For Thermo Process Technology, And NEWCAST 2011 - 3rd International Trade Fair For Precision Castings In Dusseldorf, Germany Closed With Record Exhibitor And Visitor Participation: 1,958 Exhibitors From All Over The World Met With 79,000 Visitors From 83 Countries. With These Results, The Four Events Impressively Confirmed Their Status As The Leading Trade Fairs For Their Respective Sectors.

The High Percentage Of International Exhibitors And Visitors Reflects The Global Reputation Of These Trade Fairs. The Share Of International Visitors Increased Compared To The Events' Last Staging In 2007: Over 54% Of The Visitors Traveled To Dusseldorf From Abroad, Especially From India, Italy, France, Austria And The U.S. A Total Of 98% Of All Attendees Were Pleased With Their Participation And 97% Reported That They Accomplished Their Goals At The Four Trade Shows. The Number Of Experts From Top Management Was Also Outstanding. Some 80% Of The Visitors Plan Investments Over The Next Two Years – And The Majority Of Them Attended GIFA, METEC, THERMPROCESS And NEWCAST 2011 In Order To Prepare For This Purpose. In Addition, Concrete Business Deals Were Concluded On Show Site, Such As The $ 54 Million Deal Between A German Casting Machinery Manufacturer And The Uzbek Railway Company. A German Induction Furnace Producer Also Reported The Sale Of One Of The World’s Most Powerful Melting Furnace To An Indian Steel Producer.

According To Joachim Schafer, Managing Director Of Messe Dusseldorf, Both The International Flair And The Percentage Of Decision-Makers Present Are Important Indicators Of The Success Of A Trade Fair: “The Trade Fairs Have Hit The Bull’s Eye At The Right Point In Time. Those Looking Into The Trade Fair Halls Over The Past Five Days Could See That We Were Host To The Entire International Expert Audience.”

This Was Also Confirmed By Leading Spokespeople From Associations And Companies Of The Exhibiting Industries. They Especially Praised The Visitors’ High Professional Competence. Dr. Ioannis Loannidis, Board Spokesman Of Oskar Frech GmbH And President Of GIFA, Noted That GIFA 2011 Took Place In A Positive Economic Environment: “We Were Visited By A Great Number Of International Customers With Concrete Intentions To Buy. The Atmosphere Was Fantastic.” For Dieter Rosenthal, Board Member At SMS Siemag AG
And President Of METEC, The Trade Fair Has Entirely Fulfilled And In Part Even Exceeded All His Company’s Expectations: “We Were Particularly Impressed By The High Quality Of Conversations With Interested Parties And Business Associates From Throughout The World. This Provides Us With A Very Good Basis For Developing These Contacts, Following Up Conversations And Intensifying Business Relations.” Dieter Rosenthal Also Reported That A Company Of The SMS Group Had Already Received An Order For An Inductive Combined Heat And Power Plant By A Russian Producer Of Forged Spheres For Milling Units. Dr. Hermann Stumpp, Chairman Of The LOI Italimpianti Group, LOI Thermprocess GmbH And President Of THERMPROCESS, Underlined How The Trade Fair Has Pooled The Entire Competence Of The Industry In Terms Of Both Exhibitors And Visitors: “THERMPROCESS Is The Unique Center For International Thermal Process Engineering Worldwide! We Succeeded In Making Many New Contacts, Welcoming A Particularly High Number Of Experts From India To Our Stand. THERMPROCESS 2011 Was Once Again A Top-Notch Event – We Are Very Satisfied!”

The Industry Partner Associations VDMA (German Engineering Federation) And Bdguss (German Foundry Industry) Reported That Their Innovative Member Companies Were Delighted With The Wide Representation Of The Machinery Market And The High Internationality Of Well-Informed Visitors With Specific Purchasing Intentions. “After Overcoming The Economic Crisis, This Global Meeting Of The Metallurgy Sectors In 2011 Has Proven Once Again To Be An Efficient Platform For Making New Contacts, Current Trends Were Discussed At A Very High Level And The Trade Fairs Also Served As Marketplaces For Preparing And Concluding Business Deals. The Trade Fairs Took Place At A Perfect Point In Time. Investments In Cutting-Edge Technologies Are Imminent In Our Companies,” Stated Dr. Gutmann Habig, General Manager Of VDMA.


A Highlight For The Trade Visitors Was The “EcoMetals” Campaign For Energy Efficiency And Saving Resources In Which 28 International Exhibitors Participated. With This, The Four Technology Trade Fairs Also Served As Forums For Discussing Medium And Long-Term Sustainability Strategies And For The Development Of Metallurgical Technologies Of The Future. In Addition, The Exhibits At Each Of The Four Events Were Supported By Congresses, Seminars And Discussion Forums.

A Special Feature At GIFA 2011 Was The Successful North American Pavilion, Organized By Messe Dusseldorf North America And Supported By The American Foundry Society (AFS). Twelve Companies Displayed Their Latest Products For The Foundry Industry Within This