Ductile Iron News

The Ductile Iron Society Spring 2013 Annual Meeting was held at the Westin - Indianapolis in downtown Indianapolis, Indiana from June 5-7, 2013. On Wednesday the DIS held the normal committee structured meetings. The day started off with the Research Meeting from 8:00 am to 12 noon. There were 48 members in attendance. Again I believe this set another record. The other operating committee meetings were held from 1:00 pm to 3:00 pm and these were followed by the Directors Meeting at 3:00 pm. The activities of the Research Committee can be found later in this publication under the Annual Meeting Report and remarks by the DIS President Patricio Gil of Blackhawk Foundry de Mexico. For the next fiscal year 2013/14 the Board of Directors approved the funding of two new research projects. They are Project #51 “Fatigue Resistance of Weld Repaired Ductile Iron Castings for $33,000 and investigated by EWI (Edison Welding Institute) in Columbus, Ohio and Project #52 - Evaluation of the Influence of B, Si and Inoculation in Counteracting the Effects of Increased Mn Levels on Varying Section Thickness of Ferritic Ductile Iron for $45,000 and investigated by Joyworks of Ann Arbor, MI and Element Materials Technology of Wixom, MI. The expected time of completion on both projects is 12 months. The total expenditure of $78,000 for one year is the largest in many years. Thanks to all the DIS members for their support that allows the Research Committee to spend this amount on two projects.

On Thursday, June 6th, the attendees received 9 excellent technical presentations and one panel presentation on Treatment Methods for quality Ductile Iron Production. The panel was made up of 6 panelists who are experts in the field of treatments. You can find more information about the presentations by clicking on the left side under each author. At lunch on Thursday, Patricio Gil, the DIS President delivered the Annual Members Meeting summary.

Here are the notes from Patricio’s presentation;

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 ductile iron foundry industry seems to be at near capacity. The Ductile Iron Marketing Group once again was out attending trade exhibitions throughout the year. They exhibited back in September at the 2012 Mining Show in Las Vegas, Nevada where it was reported that over 60,000 attended. Then in May 2013 the DIMG exhibited at the agricultural machinery conference in Waterloo, IA. This was the first time that the DIS organized a whole day continuing education course on ductile iron. Thanks go out to the volunteers and their companies who made this a great success.

They were;

John Lewensky of Pure Power Technologies
Jim Clifford of Pure Power Technologies
Bob O'Rourke of Charter Dura-Bar
Katie Norris of Charter Dura-Bar
Krista Billert of Charter Dura-Bar Tim Heagney of Charter Dura Bar
Ray Stuttle of Charter Dura-Bar
Christof Heisser of Magma Corporation
Vasko Popovski of Applied Process
Henry Frear of Applied Process
Marc King of Globe Metallurgical  
Jim Stevenson of Bluewater Thermal  
Dave Gilson of Sintercast  
Gene Muratore of Rio Tinto America  
Vadim Pikhovich of Oshkosh  
Larry Helm of Seneca Foundry  
Kirk McCullough of Seneca Foundry

Both shows were a great success and we were able to connect with design engineers as well as help out some consumers of ductile iron castings find a supplier.

In addition, the Member Services Committee organized our table top display in April for the AFS 2013 Casting Congress. Our booth and the volunteers, who manned it, were very busy during the whole show. Thanks go out to Jeff Hall, Mark Beers, Jim Wood, and committee members and volunteers.

We are striving to make our library available to the members through the website. More news will be available as the changes are made. These books were a collection of Art Spangler, Lyle Jenkins, P.H. Mani and Keith Millis. The DIS has hired a temporary employee who graduated in library sciences from Kent State University. She will be categorizing and organizing the library books.

The society will end the 2012/2013 fiscal year in the black even while absorbing some increased expenses. Once again the proposed budget for the fiscal year 2013-2014 looks very positive as a result of the increase in new members. We should be able to increase our scholarship money through the FEF and we should be able to increase our funding of research projects.

This past fiscal year we gained a few new members.

BRILLION IRON WORKS (FOUNDRY)  
METAL TECHNOLOGIES (FOUNDRY)  
PACIFIC ALLOY CASTINGS (FOUNDRY)  
THE MINSTER MACHINE COMPANY (FOUNDRY)  
CARBONES IMR, INC (ASSOCIATE)  
COBRA TRADING (ASSOCIATE)  
REX HEAT TREAT (ASSOCIATE)  
SNAM ALLOYS (ASSOCIATE - INDIA)  
TRIPLE M METALS LP (ASSOCIATE)  
ARIEL CORPORATION (RESEARCH PATRON)  
VALD. BIRN A/S (OVERSEAS - " DENMARK)

We also would like to welcome back some previous members who re-joined in this fiscal year;

ANVIL INTERNATIONAL (FOUNDRY)  
CIFUNSA DEL BAJIO (FOUNDRY-MEXICO)  
OMNISOURCE (ASSOCIATE)

During this past year we held two general meetings. The first one was our annual meeting held in Muskegon Michigan with a tour of CWC Textron and Anderson Pattern Shop with 106 attending including 11 spouses and guests. The second meeting held last fall, was in Peoria, IL, with tour of Caterpillar in Mapleton, IL. The attendance for that meeting was 152 including 26 spouses and guests.

The Ductile Iron Society held a production seminar back on March 5-6, 2013 at the Hilton Garden Inn at O'Hare Airport in Chicago. The attendance was 24 for this seminar. 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, Gene Muratore of Rio Tinto and Don Craig of Selee Corporation.

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 2012 College Industry Conference held on November 17-18, 2012 at the Westin Hotel in Chicago. I would like to thank John Keough of Applied Process and Gary Gigante of Waupaca Foundry for selecting this year's students. They were Brennon Holenda of Pittsburg State, Eric Nixon of Trine University, Coleman Housman of the University of Northern Iowa and Christopher Slinger of Wisconsin - Platteville. Each student received $2000.

Your DIS board has approved for 2013, an increase from $2000 to $3000 each for the deserving students. The board also approved that we will cover whatever shortfall amount so that we can hand out $12,000.00 in scholarships at the next FEF CIC conference in November 2013.

Your society continues to make a donation to the Keith Millis Scholarship Fund every year so it will continue to grow. This past year we made a one time donation of $25,000 and reached another goal of zirconium in donations to the fund.

Jim wood attended this past year's conference. We also had a booth for the industry information session where we distributed the "Flakes are for cereals not Ductile Materials" T-shirts. Thanks go out to Kathy Hayrynen & Chip Keough of Applied Process who donated their time to help out in the booth. Also we would like to thank those members who sponsored these T-shirts. They are ASK Chemicals, Applied Process, Buck Company, Benton Foundry, Bremen Castings, Blackhawk de Mexico, Carpenter Brothers, Caterpillar, Elkem, Farrar Corporation, Foreco, Hickman Williams, Hitachi Metals Automotive, Hofmann Ceramic, Magmasoft, Miller and Company, Pure Power Technologies, Rio Tinto Iron & Titanium, Superior Graphite, Waupaca Foundry. Also i should mention the hard work by your University Relations Committee members. Thanks go out to Bill Sorensen and Pam Lechner for their invitation to attend this important conference.
The Research Committee met three times during the past year. We completed one project in February 2013, Tracking Chemistry of Minor Elements-A DIS Foundry Survey completed by Doug White and the Process Sub-Committee. Also the Research Committee awarded 2 new projects, #48 - Evaluation of Normalizing Heat Treatment to Develop Improved Properties in Heavy Section Pearlitic Iron, and #49 - Analysis of Pearlitic Ductile Iron with Enhanced Mechanical Properties.

We will now proceed with the annual business meeting.

We have 2 Associate members retiring from the Board of Directors as of June 30th. They are Andy Adams of Foseco Metallurgical, and Fred Linebarger of Miller and Company. We would like to thank both board members for their participation and dedication to the society over the past 3 years. If there is anyone that might be interested in volunteering their time to join the DIS Board of Directors, please let Jim Wood know.

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, 2013;

Dave Williams of ASI International (Associate Member)

Christof Heisser of Magma Corporation (Associate Member)

The attendees approved the slate. There was total approval and no objections.

Patricio asked if there were any further questions from the audience. There were no questions or comments. Patricio then declared that this annual meeting was adjourned.

Thanks,
Patricio Gil
June 6, 2013

*******

The day then ended with an awesome reception and banquet. The master of ceremonies for the banquet was the DIS President Patricio Gil of Blackhawk de Mexico. Patricio first introduced the guests who were attending the meeting. They were;

Andy Binford, Dan Egenolf, Kyle Egenolf and Randy Lewis of iwis Drive Systems
Sandeep Deshpande and Greg Alexander of INTAT
John Boyd and Etienne van Niekerk of Goldens Foundry in Columbus, Georgia
Paul Kolbeck of Ferroloy in Wichita, Kansas

Patricio then presented membership certificates to the following new members of the DIS and the representative of that company in attendance;

Carbones IMR, Inc. - David Petry
Brillion Iron Works - Steve Kamykowski & Kyle Rabine
Metal Technologies - Lenny Basaj & Eddie Wise
The new members who were not in attendance were Associate - Triple M Metal LP, Foundry - The Minster Machine Company, Research Patron - Ariel Corporation, and Overseas member - Vald. Birn A/S. We thank all of these new members for joining the DIS since the last meeting in the fall 2012.

Patricio also called up to the front two members who re-joined the DIS after being away for a few years. They received a new membership certificate and they were;

**Omnisource Corp. - Brad van Zant & John Wassell**  **Anvil Corp. - Frank Desolis & Brandon Myers**

Patricio then introduced Jim Csonka from Hickman Williams & Company and asked him to come to the front as our morning technical Chairperson and present our DIS token of appreciation to the AM speakers.

**Dave Williams of ASI International & Jim Csonka**  **Dave Gilson of Sintercast, Inc. & Jim Csonka**

**Biil Pflug of Inductotherm Corp. & Jim Csonka**  **Peter Moulder of MSA**
Rick Gundlach of Element

Patricio then asked Kathy Hayrynen of Applied Process to come to the front as the afternoon technical Chairperson and present our DIS token of appreciation to the PM speakers.

John Davies-Lethbridge Iron Works & Kathy Hayrynen  Aaron Gesicki-Waupaca & Kathy Hayrynen

Vic Lafay of S&B Industrial Minerals & Kathy Hayrynen

Then Kathy presented our token of appreciation to the panel that presented on treatment methods. They were;
From left to right are Cesar Braga of Aarrowcast Foundry, John McGoldrick of Hodge Foundry, Jay Zins of Dotson Foundry, Kathy Hayrynen, Larry Carmack of Grede-St. Cloud and Brandon Reneau of Caterpillar Foundry

Patricio then introduced the retiring board of directors and asked them to come to the front for their service certificates. They were Andy Adams of Foseco and Fred Linebarger of Miller and Company. Thanks to Andy and Fred for the 3 years of service on the board.

Patricio then introduced the new directors who will start serving July 1, 2013 and serve for 3 years. They are Christof Heisser of Magma Corporation and Dave Williams of ASI International.

Patricio then invited John Tartaglia of Element Materials Technology to the front to introduce Rick Gundlach as the Ductile Iron Society's member of the year.

After the great introduction by John, Rick came to the front and accepted his award. Rick finished by thanking everyone from Element and the DIS for all the support over the years. Rick has been a great asset to the DIS as he in very involved in the Research Committee and offers his technical talent from time to time to members of the DIS. Congratulations Rick!
Patricio then invited Prem Mohla (retired) to the front to introduce this year’s DIS lifetime achievement award to Al Alagarsamy (Consultant).

Al received his Bachelor in Mechanical Engineering and his Masters in Foundry Science. His career started in 1970 with Woodruff and Edwards Foundry in Elgin, IL from 1970-1974. He then went to General Iron Works in Englewood, Co from 1974-1977 and then on to Grede Foundry from 1977-1992. In 1992 he moved to Intermet Corporation and in 1996 he then again moved to Citation Corporation to 2007 when he retired and went into the consulting business. He has served over time with the AFS committees including acting as the Research Board Chairman. He also served as the Ductile Iron Society Research Committee Chairperson. He has given many talks to the AFS and DIS. He is the recipient of the AFS Scientific Merit award. He now lives in Texas with his long term partner, Renuga and they have 2 daughters Maya & Manu and 6 grandchildren.

Al then accepted his award and spoke highly of the foundry industry and the Ductile Iron Society over the years. Congratulations Al!
Lastly Patricio invited our host foundry member, Pure Power Technologies and Kevin Bacon, the Plant Manager, to the front to say a few words about the history of the foundry and what the tour group was going to see the next day. Thanks to everyone at Pure Power for hosting the tour on the final day June 7th. Thanks to Kevin and the rest of the tour guides and folks that helped out with the tour.

Kevin Bacon of Pure Power Technologies

On Friday, June 7th the group then went on the tour of Pure Power Technologies in Indianapolis.

This concluded the spring annual meeting in Indianapolis and the DIS hopes to see everyone at the 5th Keith Millis Symposium in Nashville, TN from October 15-17, 2013 at the Loews Hotel. This symposium is co-presented by the DIS and the AFS. Please make note that the normal committee meetings including the DIS Research Committee, Operating committees and the DIS Board of Directors meetings will be held on Monday October 14th. There are some rooms set aside for Sunday evening at the Loews hotel in Nashville for those attending the Research Committee meeting.

Jim Wood
DIS Executive Director
“DESULFURIZATION AT WAUPACA PLANT #6”

AARON GESICKI


HE STARTED MAKING CASTINGS IN 1975 IN ALUMINUM DIE CASTING IN WAUSAU, WI. HE THEN MOVED ON TO DANVILLE, IL TO MAKE GRAY & MALLEABLE CASTINGS. HE THEN MOVED ON TO SARNIA, ONTARIO, CANADA TO MAKE GI ENGINE BLOCKS IN 1981. IN 1987 HE WAS BUILDING AND LAUNCHING A NEW DI FOUNDRY IN NEENAH, WI. IN 2001 HE MOVED TO MONCLOVA, MEXICO TO A CYLINDER LINER PLANT, AND IN 2005 HE MOVED TO BINZHOU, SHANDONG, PRC TO BUILD AND LAUNCH A GREENFIELD CENTRIFUGAL CASTING AND MACHINING FACILITY. IN 2010, AARON WAS WRITING PATENTS AND DESIGNING THE PROCESS FOR MANUFACTURING WOOD TURNING TOOLS AND FIXTURES IN BOULDER, CO. IN 2011 HE WAS MAKING STEEL CASTINGS IN MONETT, MO AND IN 2012 HE MOVED TO RESTARTING WAUPACA PLANT 6 IN ETOWAH, TN.
Desulfurizing at Waupaca Plant 6, Etowah, TN

Presenter:
Aaron Gesicki
Desulfurizing at Waupaca Plant 6, Etowah, TN

- Some Background
- Some Specifics
- Guided Virtual Tour
- Some Details and Some Data
Waupaca Foundry Plant 6, Etowah, TN

Gray & Ductile Foundry
200,000 Ton Annual Capacity
Cupola Melt
Four Vertical Molding Machines

397,000 square feet of building.
100 acres of property.
Serviced by rail and major highway.
Located in Etowah, TN.

Certifications:
OHSAS 18001
ISO 14001
ISO 9001
TS 16949

Gray Iron Metal Grades: Class 30/35 FC150/200/220
Ductile Metal Grades: 4512/5506 FCD 450/500

Employment: 44 Management, 480 Hourly, Total 524 (non-union)

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
P6 Re-start Milestones

- Plant idled in January 2010 at height of recession
- Plant maintained and equipment cycled by “care taker” crew.
- Re-start project initiated in November 2010
- Re-open AR submitted in March 2011
- Board approval received July 28, 2011
- First employees re-hired August 15, 2011
- First melt September 29, 2011
- First gray iron castings produced Oct. 5, 2011
- Gray iron drum production started Oct. 17, 2011 (two 12’s)
- Gray iron rotor production started Nov. 9, 2011 (one 12 Hr. shift)
- Initial ductile iron equipment installed Dec., 2011
- Ductile sampling began Feb. 13, 2012
- Ductile production March 30, 2012
P6 Re-start Investments

• Millroom expansion (four buildings)
• 5 millroom press cells with RF capability
• 4 new tub blasts
• Gate and sprue area upgrades and conveyor additions
• Replacement of current 32x46 VMM with 32x46 DI DP
• Replacement of AP’s #4,5,& 6 with new 20 Duca AP with Koins Pouring
• 2 new CB 36x44 core cells
• Upgrades to 3 LOR/Hottinger core cells
• Core storage area
• Recuperator tube bundle replacement
• New electric winch system for Cupola charge delivery
• Cupola de-sulfurization system (five 16 ton ladles, crane, lime/spar system)
• 5 new 10 ton treatment ladles and auto alloy system
P6 Melting Equipment

- 136” lined, hot blast Cupola with oxygen tuyere injection. Capacity of 80-100 tons per hour

- Five 16 ton dwell ladles
  - Cranes for handling
  - Desulfurization material handling system

- Two 100 ton channel induction, iron holding furnaces

- 10 ton hot metal delivery carrier
  - Five 10 ton treatment ladles
  - Automated alloy addition system

- Four pressure pour holding furnaces with auto pour
  - Including new 20 ton Duca/Koins at Line #4

- Complete Metallurgical Lab
P6 Lime and Fluorspar Systems
P6 Lime and Fluorspar Systems
P6 Lime and Fluorspar Systems
P6 Lime and Fluorspar Systems
P6 Lime and Fluorspar Systems
P6 Lime and Fluorspar Systems
P6 Dwell Ladle
P6 Dwell Ladle
P6 Dwell Ladle Repair
P6 Dwell Ladle
P6 Dwell Ladle Filling
P6 Base Iron Chemistry Data

**Cupola Sulfur**

- Mean Line
- Median

*Normal if Mean = Median*

Inter-quartile Range boxes
50% of values in box
Whiskers $\pm 1.5$ box height

**Dwell Sulfur**

**Furnace Sulfur**

*DIS Annual Meeting, June 5-7, 2013*
*Indianapolis, IN*
Thank You

I am – Waupaca

Aaron Gesicki
“SUCCESSFUL IMPLEMENTATION OF GREEN SAND ADDITIVES FROM FOUNDRY DUST”

VIC LAFAY

VIC FORTUNATELY HAS BEEN A SPEAKER AT THE DUCTILE IRON SOCIETY ON ANUMBER OF OCCASIONS. IN ADDITION TO THE DIS, HE IS A MEMBER OF THE AMERICAN FOUNDRY SOCIETY, CASTING INDUSTRY SUPPLIER ASSOCIATION, CLAY MINERAL SOCIETY, INDUSTRIAL MINERALS SOCIETY AND OTHERS.

VIC RECEIVED THE 2009 AFS PANGBORN GOLD METAL, AFS AWARD OF SCIENTIFIC MERIT AND OTHER INDUSTRY RECOGNITIONS. HE HAS BEEN A SPEAKER AT AFS CASTING CONGRESSES, FOUNDRY INDUSTRY CONFERENCES AND OTHERS.
Green Sand: Additives from “New Directions” in Ductile Iron Foundries

Victor S. LaFay
S&B Industrial Minerals
Vision of the Future
Two Topics for Review in this Presentation

- Introduction of a Slurry of Bentonite/Carbons from Foundry Dust to supplement a Preblend for the green sand molding process.
- The addition of core sand additives with green sand “friendly” materials
Slurry of Bentonite/Carbon Process Overview

- Two components are developed from foundry dust
  - Silica Sand available for foundry molding sand (not Silica Sand for the core room)
    - Support foundry industry due to possible shortages
  - A slurry with bentonite / carbon ratio similar to the current sand system
Benefits to Products Generated from Foundry Dust

- 80% of the available bentonite and carbons from foundry dust can be successfully removed from the foundry dust.
Benefits to Products Generated from Foundry Dust

- 80% of the available bentonite and carbons from foundry dust can be successfully removed from the foundry dust.
- Reduced bond usage in the foundry.
  - The bentonite/carbon slurry is substituted for the quantity of Preblend.
- Cost savings to the foundry because of reduced waste disposal and replacement of Preblend usage in the foundry.
Benefits to Products Generated from Foundry Dust

- 80% of the available bentonite and carbons from foundry dust can be successfully removed from the foundry dust.
- Reduced bond usage in the foundry.
  - The bentonite/carbon slurry is substituted for the quantity of Preblend.
  - Cost savings to the foundry because of reduced waste disposal and replacement of Preblend usage in the foundry.
- Positive impact on the environment!
  - Reduced waste stream from foundries.
Benefits to Products Generated from Foundry Dust

- 80% of the available bentonite and carbons from foundry dust can be successfully removed from the foundry dust.
- Reduced bond usage in the foundry.
  - The bentonite/carbon slurry is substituted for the quantity of Preblend.
  - Cost savings to the foundry because of reduced waste disposal and replacement of Preblend usage in the foundry.
- Positive impact on the environment!
  - Reduced waste stream from foundries.
- Hydrated clay results in improved bonding performance.
  - Bentonite in slurry mulls/mixes in quicker into green sand.
  - Resulting in improved foundry green sand properties.
Method for Slurry Application into the Molding Sand

Slurry can be Added at the Muller or at the Sand Cooler
Benefits to Bentonite/Carbon Slurry Generated from Foundry Dust

- Hydrated clay results in improved bonding performance.
- Bentonite in slurry mulls/mixes in quicker into green sand.
- Improves green sand properties
  - Hot Compression Strength (possible reduction in expansion defects and a reduction in mold wall movement)
  - Reduction in Friability of the Molding Sand (possible reduction of inclusion defects)
Deformation of Molding Sand

Deformation Comparison @ 982°C

Pressure (PSI)

Deformation (in)

- 1AQ
- Sample 278
- Sample 260
- Sample 284
- Sample 283

Rigid – No Picture
Comparison of Hot Compression Strength in Actual Foundry Application

Graph showing the comparison of hot compression strength across different temperatures. The graph includes three lines:
- Pretest
- During Trial
- After Trial

The y-axis represents compression strength in PSI, ranging from 0 to 700. The x-axis represents temperature in Celsius, ranging from 400 to 1200.

The graph indicates that the compression strength reaches its peak at a certain temperature during the trial phase.
Comparison of Friability in Actual Foundry Application
Comparison of Green Compression Strength in Actual Foundry Application

Green Compression Strength

- Green Strength Before Trial
- Green Strength During Trial
- Green Strength After Trial

Date:
- 9/1/2011
- 10/21/2011
- 12/10/2011
Green Sand Molding Properties that was not Negatively Impacted

- Historically the addition of foundry dust has negatively impacted green sand properties.
- Converting the foundry dust to a slurry and removing undesirable materials has resulted in a superior additive.
- These include:
  - Permeability
  - AFS Clay (Fines in the molding sand)
Comparison of AFS GFN in Actual Foundry Application

Molding Sand AFS Grain Fineness Number

Sample Number

AFS GFN

0 5 10 15 20

50 55 60 65 70 75 80 85 90
Comparison of Permeability in Actual Foundry Application
Benefits to Products
Generated from Foundry Dust

- Reduced bond usage in the foundry.
  - The slurry of bentonite / carbon becomes a supplement to the existing Preblend
    - As a direct replacement bond
    - Hydrate bentonite clay results in green sand molding improvements
      - Key measurement is green sand properties per unit of Clay.
Two Topics for Review in this Presentation

- Addition of Bentonite/Carbon materials for the green sand molding process.
- The addition of core sand additives with green sand “friendly” materials
The addition of core sand additives with green sand “friendly” materials

- Additives to Cold Box Cores
  - Seacoal based blend
    - Seacoal is an additive that is beneficial to green sand
    - Seacoal can be reduced in prepared Preblends when the cold box cores breakdown and are returned to the prepared molding sand
    - Seacoal for Ductile Iron Foundries require a Sulfur content less than 1% based upon the weight of the seacoal
Test Protocol for “Bending Strength”
The addition of core sand additives with green sand “friendly” materials

- Additives to Cold Box Cores
  - Seacoal based blend

![Bending Strength Graph]

- 0% Additive
- 2% Additive
- 4% Additive

Time:
- 1 hour
- 4 hours
- 24 hours

N/cm²
The addition of core sand additives with green sand “friendly” materials

- Additives to Cold Box Cores
  - Seacoal based blend

Test Casting with Additive

Test Casting without Additive
The addition of core sand additives with green sand “friendly” materials

- Additives to Cold Box Cores
  - Seacoal based blend
The addition of core sand additives with green sand “friendly” materials

- Additives to Cold Box Cores
  - Seacoal based blend
Conclusions

- Green Sand Additives can come from many sources:
  - Traditional Preblends at the Muller/Mixer.
  - Introduction of a Slurry of Bentonite/Carbons from Foundry Dust.
  - Carbon additions (Seacoal Blended Product) from Additives to Core Sand
Impact Specific to Ductile Iron Foundries

- Initial measurements have indicated that the sulfur content of the slurry containing bentonite / carbon is lower than the raw materials used in the Preblend.

- Using a seacoal with a sulfur content lower than 1.0% based on the weight of the seacoal as part of the blend for the core sand additive supports Ductile Iron.
Benefits to the Foundry

- Reduction in bond usage as a result of slurry addition from foundry dust.
Benefits to the Foundry

- Reduction in bond usage as a result of slurry addition from foundry dust.
- Reduction in seacoal formulated in a Preblend as a result of seacoal blended additive into prepared core sands.
Benefits to the Foundry

- Reduction in bond usage as a result of slurry addition from foundry dust.
- Reduction in seacoal formulated in a Preblend as a result of seacoal blended additive into prepared core sands.
- Reduction is waste going to landfills by recycling foundry dust.
For additional information, please contact:

Victor S. LaFay
S&B Industrial Minerals
513-378-5193
v.lafay@sandb.com
www.sandb.com
Question & Answers
“FOUNDARY PROCESS BENCHMARKING”

PETER MOULDER

PETER HAS AN UNDERGRADUATE DEGREE FROM THE UNIVERSITY OF NOTRE DAME. HE ALSO OBTAINED HIS MASTERS DEGREE FROM THE AMERICAN UNIVERSITY IN WASHINGTON, DC. PETER IS CURRENTLY IS AN ACCOUNT MANAGER WITH MANAGEMENT SCIENCE ASSOCIATES IN PITTSBURGH, PA. PETER’S ACTIVITIES INCLUDE DEFINING THE APPLICATION OF TECHNOLOGY FOR THE RESOLUTION OF OPERATIONAL, MATERIAL MANAGEMENT, AND ENERGY ISSUES FOR METALS COMPANIES THAT ARE IN THE PRIMARY OR MELTING SECTION OF THE INDUSTRY. SPECIFIC AREAS OF EXPERTISE INCLUDE MATERIAL OPTIMIZATION, PROCESS AUTOMATION AND INFORMATION TECHNOLOGY. HIS PRIME FOCUS NOW IS ASSISTING FOUNDRIES ACHIEVE BETTER AND OPTIMAL USE OF RAW MATERIALS AND RAW MATERIAL PURCHASING. PETER HAS BEEN A PARTICIPANT IN THIS INDUSTRY FOR THE LAST THIRTY YEARS. POSITIONS HAVE INCLUDED SOFTWARE ENGINEERING, SOFTWARE DEVELOPMENT MANAGEMENT, CONSULTING, AND SALES AND MARKETING.
Process Benchmarking for The Ductile Iron Industry

Peter Moulder
Management Science Associates

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
Agenda

- What is Benchmarking
- Value of Benchmarking
- Experience
- Candidate Ductile Iron Processes
- Case Studies
- How to start a Ductile Iron Benchmarking Service
What is Benchmarking?

• A Benchmark is a fixed reference point, accurately located, from which other measurements are made.

• Benchmarking is the process of comparing one’s practices, processes or procedures to Industry Peers.
Purpose and Value of Benchmarking

The goals of collaborative benchmarking include:

- **Identify world-class performance levels**
- **Lead companies from an internal focus to an external, competitive focus**
- **Determine the drivers of superior performance**
- **Quantify gaps between the current and world class performance**
- **Identify and share knowledge of best practices**
- **Build foundations for performance improvements**
- **Assist Industry Marketing and Lobbying Efforts**
- **Improve the collective performance of the global industry through the sharing of key performance indicators (KPIs) among peers.**
Examples of Value Proposition

Documented Benefits of collaborative benchmarking include:

• A 2008 study by the Global Benchmarking Network indicated an average financial return of $100,000 to $125,000 per best practice benchmarking project with over 20% in benefits of more than $250,000 per project.

• According to research conducted by the International Benchmarking Clearinghouse, a division of American Productivity & Quality Center (APQC), over 30 companies reported an approximate $76 million payback in the first year of their benchmarking implementation.

• Baosteel Co., Ltd. documented results from benchmarking just within their own company. The realization of benchmarking-related benefits in 2011 reached 1.102 billion Yuan, which equates to over US$173 million.
MSA Shared Industry Experience

- **Industry Shipment Data**
  - Confections – NCA
  - Tobacco – CRA
  - Foodservice – IFRA/NAFD
  - Single copy magazines
  - Broadcast media

- **Consumer Analysis & Forecasting**
  - Long-term econometric modeling
  - Coverage and inventory analysis
  - Project Apollo (Arbitron/Nielsen – multimedia)

- **Industry Order Data**
  - Steel Producers – Ferrous Scrap
  - Recyclers – Ferrous Scrap
  - AIST

- **Retail Store Data**
  - Scanner Data Syndication and POS
  - Vending Machines
## Data Statistics from Similar MSA Services

### Industry Pooled Shipment Data

<table>
<thead>
<tr>
<th>Service</th>
<th>Reporting Metric</th>
<th># Monthly Transactions</th>
<th>% of Market</th>
<th>Year Established</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA – Tobacco</td>
<td>Market Share</td>
<td>Thousands</td>
<td>90+%</td>
<td>1970s</td>
</tr>
<tr>
<td>Confectionary</td>
<td>Market Share</td>
<td>Thousands</td>
<td>75%</td>
<td>1998</td>
</tr>
<tr>
<td>Post Buy</td>
<td>Audience Share</td>
<td>Thousands</td>
<td>100% Cable</td>
<td>1987</td>
</tr>
<tr>
<td>Magazine</td>
<td>Single Copy</td>
<td>Thousands</td>
<td>80%</td>
<td>2000</td>
</tr>
<tr>
<td>Ferrous Scrap RMDAS</td>
<td>Price &amp; Volume</td>
<td>Thousands</td>
<td>60+% and growing</td>
<td>2003</td>
</tr>
<tr>
<td>AIST Process Benchmarker</td>
<td>Operational Data</td>
<td>Hundreds</td>
<td>Initial rollout ongoing</td>
<td>2012</td>
</tr>
</tbody>
</table>
Ductile Iron – Candidate Process

- Scrap Yard
  - Scrap Loading
- Melting
- Chem Lab
- Pattern Making
- Pouring
- Heat Treatment
- Cutting
- Grinding
- Finishing
MSA Benchmarking Case Studies

The following slides provide some detail into two different benchmarking services MSA provides to the metals industry. One is MSA’s Raw Material Data Aggregations Service (RMDAS)™ and the second is a service provided in conjunction with the Association of Iron and Steel Technologies (AIST) called the AIST Process Benchmarker (APB).

Raw Material Data Aggregation Service (RMDAS™)
RMDAS™ is an aggregated ferrous scrap price and volume tracking/reporting program based on actual order data. Access to a powerful reporting system is provided through a secure web portal. The regional RMDAS™ Ferrous Scrap Price Index is generated monthly from the transaction-based data.

AIST Process Benchmarker (APB)
The AIST Process Benchmarker allows the producer members of the AIST technology committees to define, track and benchmark important operational data metrics. The system provides powerful graphic representations, standard reports and user definable groupings and reporting options.
RMDAS is the only transaction-based, ferrous scrap price tracking and reporting service for the steel, foundry and recycling industries.

- Reporting accurate and timely regional price and volume information, based on participants’ actual purchase / sales order data.
- Allowing participants access to comparative aggregated market intelligence while maintaining confidentiality of each participant company’s proprietary data.
- Providing participants the ability to measure and benchmark their raw material purchasing performance against reliable and accurate data.
- Supporting Sarbanes-Oxley compliance for public companies.
Raw Material Data Aggregation Service

Providing actual regional aggregated scrap price and volume information

**MSA Process steps…**

- **data**
- **data conversion**
- **data cleansing**
- **data aggregating and matching**
- **data warehousing**

**deliverables**

- Prepared Reports

| Receive Purchase (or Sales) Order Data | Convert Data to Common Format | Review, Cleanse, Validate | Match & Store | Report Aggregated Data |

An aggregated scrap price tracking and reporting program, based on participants’ actual purchase / sales order data
## Management Science Associates - Raw Material Data Aggregation Service™

### Spot Market Purchases - Price/Volume Report

**Total US (USD/GT)**

Mar_2010

<table>
<thead>
<tr>
<th>Category</th>
<th>Reporting</th>
<th># PO's</th>
<th>Tons Purchased</th>
<th>% Tons Purchased</th>
<th>% Total Tons</th>
<th>% Total</th>
<th>Weighted Average</th>
<th>% Total Price</th>
<th>Weighted Price</th>
<th>% Total Volume</th>
<th>Price Change</th>
<th>Excludes Orders under 100 GT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Purchases</strong></td>
<td>53</td>
<td>18</td>
<td>2327</td>
<td>1,866,971</td>
<td>100.0 %</td>
<td>100.0 %</td>
<td>396.57</td>
<td>100.0 %</td>
<td>46.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Busheling / Clips</td>
<td>34</td>
<td>17</td>
<td>320</td>
<td>254,361</td>
<td>14.0 %</td>
<td>16.5 %</td>
<td>466.58</td>
<td>16.5 %</td>
<td>55.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredded Clips</td>
<td>13</td>
<td></td>
<td>11,059</td>
<td>481.32</td>
<td>.6 %</td>
<td>.7 %</td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slitter</td>
<td>9</td>
<td></td>
<td>2,232</td>
<td>441.76</td>
<td>.1 %</td>
<td>.1 %</td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># 1 Busheling</td>
<td>288</td>
<td></td>
<td>248,595</td>
<td>466.73</td>
<td>13.2 %</td>
<td>15.5 %</td>
<td>55.14</td>
<td>15.5 %</td>
<td>382.00</td>
<td></td>
<td>365.00</td>
<td>1,000</td>
</tr>
<tr>
<td># 2 Busheling</td>
<td>6</td>
<td></td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td>50.97</td>
<td>N/R</td>
<td>N/R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tin Plate Bush/Clips</td>
<td>4</td>
<td></td>
<td>660</td>
<td>366.52</td>
<td>.0 %</td>
<td>.0 %</td>
<td>64.23</td>
<td>64.23</td>
<td>360.00</td>
<td></td>
<td>360.00</td>
<td>250.00</td>
</tr>
<tr>
<td>Bundles</td>
<td>38</td>
<td>14</td>
<td>207</td>
<td>161,202</td>
<td>8.5 %</td>
<td>9.5 %</td>
<td>442.99</td>
<td>9.5 %</td>
<td>59.39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># 1 1/2 Bundles</td>
<td>19</td>
<td></td>
<td>21,786</td>
<td>483.95</td>
<td>1.2 %</td>
<td>1.4 %</td>
<td>67.50</td>
<td>1.4 %</td>
<td>450.00</td>
<td></td>
<td>450.00</td>
<td>150.00</td>
</tr>
<tr>
<td># 2 Bundles</td>
<td>77</td>
<td></td>
<td>93,205</td>
<td>462.59</td>
<td>4.9 %</td>
<td>5.8 %</td>
<td>54.09</td>
<td>5.8 %</td>
<td>355.00</td>
<td></td>
<td>355.00</td>
<td>406.00</td>
</tr>
<tr>
<td># 1/1 1/2 Bundles</td>
<td>61</td>
<td></td>
<td>20,923</td>
<td>388.62</td>
<td>1.1 %</td>
<td>1.1 %</td>
<td>39.99</td>
<td>1.1 %</td>
<td>289.89</td>
<td></td>
<td>289.89</td>
<td>1,018</td>
</tr>
<tr>
<td># 2 Bundles</td>
<td>19</td>
<td></td>
<td>4,490</td>
<td>330.89</td>
<td>.2 %</td>
<td>.2 %</td>
<td>42.92</td>
<td>.2 %</td>
<td>285.00</td>
<td></td>
<td>285.00</td>
<td>200.00</td>
</tr>
<tr>
<td>Tin Can Bundles</td>
<td>16</td>
<td></td>
<td>12,595</td>
<td>365.12</td>
<td>.7 %</td>
<td>.6 %</td>
<td>43.46</td>
<td>.6 %</td>
<td>300.00</td>
<td></td>
<td>300.00</td>
<td>1,000</td>
</tr>
<tr>
<td>Tinplate Bundles</td>
<td>15</td>
<td></td>
<td>8,204</td>
<td>431.27</td>
<td>.4 %</td>
<td>.5 %</td>
<td>70.38</td>
<td>.5 %</td>
<td>360.00</td>
<td></td>
<td>360.00</td>
<td>330.00</td>
</tr>
<tr>
<td>Shredded Scrap</td>
<td>46</td>
<td>18</td>
<td>683,419</td>
<td>387.69</td>
<td>36.2 %</td>
<td>35.4 %</td>
<td>49.22</td>
<td>35.4 %</td>
<td>26,900</td>
<td></td>
<td>365.00</td>
<td>2,000</td>
</tr>
<tr>
<td># 1 Shredded</td>
<td>18</td>
<td></td>
<td>59,400</td>
<td>401.00</td>
<td>3.1 %</td>
<td>3.2 %</td>
<td>60.28</td>
<td>3.2 %</td>
<td>365.00</td>
<td></td>
<td>365.00</td>
<td>2,000</td>
</tr>
<tr>
<td># 2 Shredded</td>
<td>236</td>
<td></td>
<td>620,049</td>
<td>386.61</td>
<td>32.9 %</td>
<td>32.1 %</td>
<td>48.19</td>
<td>32.1 %</td>
<td>425.03</td>
<td></td>
<td>425.03</td>
<td>1,500</td>
</tr>
<tr>
<td>Tin Can Shred</td>
<td>1</td>
<td></td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td>48.00</td>
<td>N/R</td>
<td>N/R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muri Shred</td>
<td>5</td>
<td></td>
<td>2,770</td>
<td>367.22</td>
<td>.1 %</td>
<td>.1 %</td>
<td>63.19</td>
<td>.1 %</td>
<td>330.00</td>
<td></td>
<td>330.00</td>
<td>170.00</td>
</tr>
<tr>
<td>Plate &amp; Structural</td>
<td>46</td>
<td>18</td>
<td>434</td>
<td>260,495</td>
<td>13.8 %</td>
<td>13.3 %</td>
<td>44.07</td>
<td>13.3 %</td>
<td>355.00</td>
<td></td>
<td>355.00</td>
<td>150.00</td>
</tr>
<tr>
<td>Flame Cut</td>
<td>3</td>
<td></td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
<td>60.44</td>
<td>N/R</td>
<td>N/R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P &amp; S - 3 ft.</td>
<td>32</td>
<td></td>
<td>14,998</td>
<td>379.95</td>
<td>.8 %</td>
<td>.8 %</td>
<td>46.55</td>
<td>.8 %</td>
<td>415.00</td>
<td></td>
<td>415.00</td>
<td>200.00</td>
</tr>
<tr>
<td>P &amp; S - 5 ft.</td>
<td>399</td>
<td></td>
<td>243,998</td>
<td>380.81</td>
<td>12.9 %</td>
<td>12.4 %</td>
<td>43.78</td>
<td>12.4 %</td>
<td>440.00</td>
<td></td>
<td>440.00</td>
<td>200.00</td>
</tr>
</tbody>
</table>
AIST Process Benchmarker (APB) is a robust, on-line, analytical tool that will allow users to benchmark Key Performance Indicators against industry peers.
The main features of the APB include:

- **Importing Data**
- **Dashboard** – Four unique Saved Query charts can be displayed
- **Ad-Hoc Querying** – create data views and graphs
  - Per Month – showing desired parameters and facilities on a “per month” basis
  - Aggregated – showing aggregated data over time or facilities/groups
  - Histogram – Bar charts of single parameters
- **Standard Reports**
- **Configuration**
Import Data Parameter Definitions

Each Technology Committee needs to provide detailed parameter information to be used in the APB, including:

- Short Names
- Unit of Measure
- Min/Max Values
- Precision, etc.

<table>
<thead>
<tr>
<th>Category</th>
<th>Parameter</th>
<th>Short Name</th>
<th>Impartial Unit</th>
<th>Metric Unit</th>
<th>Sig Digit</th>
<th>Min Value</th>
<th>Max Value</th>
<th>Data Type</th>
<th>Age Type</th>
<th>Is Calculation</th>
<th>Is Required</th>
<th>Report If No Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Import Data</td>
<td>BOF in Operation</td>
<td>BOF in Op</td>
<td>Alpha</td>
<td>Alpha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Method of HMS from Blast Furnace</td>
<td>HMS Supply</td>
<td>Alpha</td>
<td>Alpha</td>
<td></td>
<td></td>
<td></td>
<td>Character</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Number of HM Supply Unit</td>
<td>Qty HM Units</td>
<td>Count</td>
<td>Count</td>
<td>0 1</td>
<td>100</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>HMS Size</td>
<td>HM Unit Size</td>
<td>nt</td>
<td>mt</td>
<td>0 1</td>
<td>1000</td>
<td>Character</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Number of mixers</td>
<td>Qty Mixers</td>
<td>Count</td>
<td>Count</td>
<td>0 0</td>
<td>10</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Size of mixers</td>
<td>Mixer Size</td>
<td>nt</td>
<td>mt</td>
<td>0 0</td>
<td>5000</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Number of HM Pretreat Stations - Sulphur Removal</td>
<td>HM-S Remove</td>
<td>Count</td>
<td>Count</td>
<td>0 0</td>
<td>3</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Number of HM Pretreat Stations - Phos Removal</td>
<td>HM-P Remove</td>
<td>Count</td>
<td>Count</td>
<td>0 0</td>
<td>3</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Number of HM Pretreat Stations - Silicon Removal</td>
<td>HM-Si Remove</td>
<td>Count</td>
<td>Count</td>
<td>0 0</td>
<td>3</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Hot Metal slag removal</td>
<td>HMSlag Remove</td>
<td>Alpha</td>
<td>Alpha</td>
<td></td>
<td></td>
<td></td>
<td>Character</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Desulfurization Location</td>
<td>De-S Locate</td>
<td>Alpha</td>
<td>Alpha</td>
<td></td>
<td></td>
<td></td>
<td>Character</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot metal supply</td>
<td>Desulfurization Reactant</td>
<td>De-S React</td>
<td>Alpha</td>
<td>Alpha</td>
<td></td>
<td></td>
<td></td>
<td>Character</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Number of high level hoppers</td>
<td>Num Hoppers</td>
<td>Count</td>
<td>Count</td>
<td>0</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Volume of smallest hopper</td>
<td>VolumSmallestHop</td>
<td>Cubic Feet</td>
<td>Cubic Meters</td>
<td>0 0</td>
<td>2000</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Volume of Largest Hopper</td>
<td>VolumLargestHop</td>
<td>Cubic Feet</td>
<td>Cubic Meters</td>
<td>0 0</td>
<td>20000</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Total Capacity of Hoppers</td>
<td>Tot Hop Cpt</td>
<td>nt</td>
<td>mt</td>
<td>0 0</td>
<td>5000</td>
<td>Integer</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Number of trickle feeders</td>
<td>TrickFeed</td>
<td>Count</td>
<td>Count</td>
<td>0 0</td>
<td>10</td>
<td>Character</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Iron ore min rate</td>
<td>Fe Ore Min</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.03</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Iron ore max rate</td>
<td>Fe Ore Max</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.03</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Lime min rate</td>
<td>Lime Min</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.05</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Lime max rate</td>
<td>Lime Max</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.05</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>FeSi min rate</td>
<td>FeSi Min</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.05</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>FeSi max rate</td>
<td>FeSi Max</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.05</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Coke min rate</td>
<td>Coke Min</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.05</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessel addition hoppers</td>
<td>Coke max rate</td>
<td>Coke Max</td>
<td>nt/min</td>
<td>mt/min</td>
<td>2 0.05</td>
<td>10</td>
<td>Float</td>
<td>Avg (mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Authorized users select a facility from a drop down and then browse to the file on their computer or network. Users will be given a message if the data was imported successfully or if there were any validation errors.
The APB Dashboard is displayed on log in, and shows four Saved Queries and any System Messages.
APB Ad-Hoc Query – Per Month

The Per Month Query allows for the comparisons of multiple facilities and multiple parameters.
The Aggregated view shows data over a given time frame or for a specific grouping, or both.
APB Ad-Hoc Histogram

The Histogram view shows data for selected facilities over a given time frame, arranged from largest to smallest.
The Facility Parameter Report shows an aggregation of data for a selected time frame and for a selected number of Facilities or Groups.
The Key Parameters configuration allows the user to create and edit groups of parameters. These Key Parameters are then selectable in the other reporting options. There are identical management tools for Saved Queries, Key Facilities, and Key Aggregation Groups.
The Key Facility configuration allows the user to create and edit groups of facilities. These Key Facilities are then selectable in the other reporting options. This allows for comparative reporting to be done on like facilities.
The User Profile allows customization of default settings (Units, Default Facility, etc.) as well as the ability to update contact information.
Export Capabilities

All graphs, charts, data tables and reports generated by the system can be exported into a number of standard formats. These data can then be used in reports, presentations and for further analysis.
Process Benchmarking for Ductile Iron Foundries

- Create DIS Committee
- Identify interested companies
- Identify candidate process
- Identify Benefits
- Collect and process data
- Determine Cost
- Present to DIS
- Determine ‘Critical Mass’ needed to proceed
Thank You

For additional information please contact:
Peter Moulder, pmoulder@msa.com, 724.265.6442
“STAFFING THE 21ST CENTURY”

JOHN DAVIES

JOHN GRADUATED FROM THE UNIVERSITY OF ALBERTA WITH A DEGREE IN ELECTRICAL ENGINEERING AND THEN OBTAINED HIS MBA. TWO YEARS LATER HE JOINED THE FAMILY FOUNDRY AND HAS INTRODUCED LEADING EDGE TECHNOLOGY TO THE COMPANY’S EQUIPMENT AND SYSTEMS. JOHN IS CURRENTLY THE PRESIDENT OF LETHBRIDGE IRON WORKS....WHEN HE IS NOT AWAY ON VACATION SCUBA DIVING IN EXOTIC LOCATIONS.
“REVIEW OF SLAGS FOR DUCTILE IRON IN MELTING, HOLDING AND POURING”

DAVE WILLIAMS

Evaluating Ductile Iron Slags

David Williams
ASi International Ltd
Columbus, Ohio
SLAGS, a byproduct of molten metal.
What is SLAG?

- Slag is the separation or precipitation of various oxides, sulfides and other ceramic compounds that coexist in molten metals other than alloying elements.

Examples of Slag components are SiO$_2$, Al$_2$O$_3$, CaO, Cu$_2$O$_3$, ZnO, FeO, MnO, MgO, CaS, MgS, Na$_2$O, B$_2$O$_3$, TiO$_2$, and others.

- Melting temperatures of Slag (or Dross) can vary depending on its chemical composition.

Lower melt temperature Slags can remain liquid and be entrained in the molten metal.

Higher melt temperature Slags will separate out and may float on the surface.
Slag Sources in Ductile Iron Melting

Excess Temperature Loss

Excess Fines
Surface Oxidation, Rust
Oily, Greasy stampings

©2012 ASI International Ltd.

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
CHARGE Size does matter!! Finer relates to more $O_2$ dissolved
Cleanliness does matter!! $H_2O$ presence
More Slag Sources in DI Melting

- Dirt
- Excess Oxygen
- Excess Flux/Coagulant
- Moisture
- Turbulence
- Low Temp Metal Saturation / Eroding Refractory
Examples of Low temperature slag components are
FeO.SiO$_2$  $2200^\circ F$,  MnO.SiO$_2$  $2300^\circ F$
CaO.Al$_2$O$_3$.SiO$_2$  $2500^\circ F$

Examples of High temperature slag components are
Al$_2$O$_3$  $+3600^\circ F$,  MgO.SiO$_2$  $+2950^\circ F$
Al$_2$O$_3$.SiO$_2$  $+3100^\circ F$  CaS  $+3900^\circ F$
RE Oxides  $+3500^\circ F$

These represent melting temperatures of these compounds.
Examples of Oxide and Sulfide Formation during Melting and Holding of Ductile Iron

\[ 4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 \quad \text{UNSTABLE} \]
\[ \text{Fe}_2\text{O}_3 \rightarrow \text{FeO} + \text{O}_2 \quad \text{Heat req’d, STABLE} \]
\[ \text{Si} + \text{O}_2 \rightarrow \text{SiO}_2 \quad \text{STABLE} \]
\[ 4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3 \quad \text{STABLE} \]
\[ 2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO} \quad \text{STABLE} \]
\[ \text{Mg} + \text{S} \rightarrow \text{MgS} \quad \text{STABLE} \]
\[ 2\text{Ca} + \text{O}_2 \rightarrow 2\text{CaO} \quad \text{STABLE} \]
\[ \text{Ca} + \text{S} \rightarrow \text{CaS} \quad \text{STABLE} \]
\[ 2\text{Mn} + \text{O}_2 \rightarrow 2\text{MnO} \quad \text{STABLE} \]
Examples of Complex Oxide Formations during Melting and Holding of Molten Ductile Iron

\[ 2\text{FeO} + \text{SiO}_2 \Rightarrow 2\text{FeO.SiO}_2 \]

\[ 2\text{MnO} + \text{SiO}_2 \Rightarrow 2\text{MnO.SiO}_2 \]

\[ 3\text{Al}_2\text{O}_3 + 2\text{SiO}_2 \Rightarrow 3\text{Al}_2\text{O}_3.2\text{SiO}_2 \]

\[ 2\text{MgO} + \text{SiO}_2 \Rightarrow 2\text{MgO.SiO}_2 \]

\[ \text{Al}_2\text{O}_3 + \text{MgO} \Rightarrow \text{MgO.Al}_2\text{O}_3 \]

\[ \text{CaO} + \text{Al}_2\text{O}_3 + 2\text{SiO}_2 \Rightarrow \text{CaO.Al}_2\text{O}_3.2\text{SiO}_2 \]

These compounds can be identified through X-ray diffraction. The presence can be detected but actual % may be difficult to determine.
### Insoluble Compounds in Ductile Iron
#### Melting and Pouring

<table>
<thead>
<tr>
<th>Formula</th>
<th>Mineral</th>
<th>Melting Point (°F)</th>
<th>ΔG° @ 2700°F (Cal/Mole °F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeO</td>
<td>Wustite</td>
<td>2,514</td>
<td>-77,370</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>Hematite</td>
<td>2,957</td>
<td>-59,630</td>
</tr>
<tr>
<td>Fe₃O₄</td>
<td>Magnetite</td>
<td>2,912</td>
<td>-67,250</td>
</tr>
<tr>
<td>FeOAl₂O₃</td>
<td>Hercynite</td>
<td>3,236</td>
<td>-5,404</td>
</tr>
<tr>
<td>MnOAl₂O₃</td>
<td>Galaxite</td>
<td>3,362</td>
<td>-9,346</td>
</tr>
<tr>
<td>2FeOSiO₂</td>
<td>Fayalite</td>
<td>2,223</td>
<td>-3,680</td>
</tr>
<tr>
<td>2MnO₂SiO₂</td>
<td>Tephroite</td>
<td>2,453</td>
<td>-4,240</td>
</tr>
<tr>
<td>3Al₂O₃2SiO₂</td>
<td>Mullite</td>
<td>3,380</td>
<td>-3,177</td>
</tr>
<tr>
<td>MgOAl₂O₃</td>
<td>Spinel</td>
<td>3,875</td>
<td>-5,972</td>
</tr>
<tr>
<td>2MgO₂Al₂O₃5SiO₂</td>
<td>Cordierite</td>
<td>2,872</td>
<td>-25,704</td>
</tr>
<tr>
<td>2MgO₂SiO₂</td>
<td>Forsterite</td>
<td>3,434</td>
<td>-13,017</td>
</tr>
<tr>
<td>2(Fe,Mg)OSiO₂</td>
<td>Olivine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaOAl₂O₃2SiO₂</td>
<td>Anorthite</td>
<td>2,835</td>
<td>-33,564</td>
</tr>
<tr>
<td>CaS</td>
<td>Oldhamite</td>
<td>4,577</td>
<td>-86,573</td>
</tr>
<tr>
<td>CaOMgO₂SiO₂</td>
<td>Diopside</td>
<td>2,536</td>
<td>-33,922</td>
</tr>
</tbody>
</table>
Characterization of Various Oxides:

**Acidic -> Basic**

P₂O₅, B₂O₃, S, SiO₂, TiO₂, Al₂O₃, ZrO₂, FeO, PbO, Na₂O, MgO, MnO, CaO

Acidic  Neutral  Basic

General Tendencies of Slags:

More Acidic = More fluid, more Corrosive, low melt temperature

More Basic = More Viscous, Heavy, higher melt temperature
## Residual Metals in Any Alloy Additions

<table>
<thead>
<tr>
<th>Alloy Addition</th>
<th>Typical Chemistry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe-Si 50%</td>
<td>Si 48%</td>
<td>Al 1.25% max. X</td>
</tr>
<tr>
<td>Fe-Si 75%</td>
<td>Si 72-75%</td>
<td>Al 1.5% max.</td>
</tr>
<tr>
<td>Fe-Cr 0.05C, Low Carbon</td>
<td>Cr 70%</td>
<td>Si 1.0% max.</td>
</tr>
<tr>
<td>Fe-Cr 0.025C, Low Carbon</td>
<td>Cr 70-72%</td>
<td>Si 1.0% max.</td>
</tr>
<tr>
<td>Fe-Cr, High Carbon (Chrome Charg</td>
<td>Cr 60-70%</td>
<td>Cu 1.5% max.</td>
</tr>
<tr>
<td>Fe-Cr-Si</td>
<td>Si 40%</td>
<td>C 0.05%</td>
</tr>
<tr>
<td>Fe-Mn, Low Carbon</td>
<td>Mn 86%</td>
<td>Si 2% max.</td>
</tr>
<tr>
<td>Fe-Mn, High Carbon</td>
<td>Mn 78%</td>
<td>P 0.35% max.</td>
</tr>
<tr>
<td>Fe-Mo</td>
<td>Mo 80% min.</td>
<td>Si 1.2% max.</td>
</tr>
<tr>
<td>Fe-Ti</td>
<td>Ti 65-75%</td>
<td>Si 1% max.</td>
</tr>
<tr>
<td>Fe-V</td>
<td>V 70-80%</td>
<td>Si 6% max.</td>
</tr>
<tr>
<td>Fe-W</td>
<td>W 75-80%</td>
<td>Si 1.5-2.4%</td>
</tr>
<tr>
<td>Fe-Cb</td>
<td>Cb 67%</td>
<td>Ta 3.8%</td>
</tr>
<tr>
<td>Cb-Ta</td>
<td>Cb 60%</td>
<td>Ni 37%</td>
</tr>
<tr>
<td>Ni-Cb</td>
<td>Mg 78%</td>
<td>Ce 6%</td>
</tr>
<tr>
<td>Si-Mg</td>
<td>Mg 3-10%</td>
<td>Ce 0.4-1.2%</td>
</tr>
<tr>
<td>Fe-Si-Mg</td>
<td>Mg 46-50%</td>
<td>Si 60%</td>
</tr>
<tr>
<td>Graphitoid</td>
<td>Ti 10%</td>
<td>Si 50%</td>
</tr>
<tr>
<td>Superseed</td>
<td>Si 40-50%</td>
<td>Si 6%</td>
</tr>
<tr>
<td>Ca-Si</td>
<td>Si 60%</td>
<td>Ca 30%</td>
</tr>
<tr>
<td>CaSi Bar</td>
<td>Ba 16%</td>
<td>Ca 14%</td>
</tr>
<tr>
<td>Si-Zr</td>
<td>Zr 36%</td>
<td>Si 50%</td>
</tr>
<tr>
<td>Ni-Zr</td>
<td>Ni 54%</td>
<td>Zr 20%</td>
</tr>
<tr>
<td>Inconel</td>
<td>Ni 75%</td>
<td>Cr 15%</td>
</tr>
<tr>
<td>Ni-Mg</td>
<td>Ni 62%</td>
<td>Mg 15%</td>
</tr>
<tr>
<td>HiMu60</td>
<td>Ni 80%</td>
<td>Mo 6.0%</td>
</tr>
<tr>
<td>Electro Ni</td>
<td>Ni 99%</td>
<td>Ni 99%</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni 99%</td>
<td>Ni 99%</td>
</tr>
<tr>
<td>Chrome Metal</td>
<td>Cr 99%</td>
<td>Fe 0.10%</td>
</tr>
<tr>
<td>Silicon Metal</td>
<td>Si 99%</td>
<td>Fe 0.10%</td>
</tr>
<tr>
<td>Moly Metal</td>
<td>Mo 99%</td>
<td>Si 99%</td>
</tr>
<tr>
<td>Electro Mn</td>
<td>Mn 99.5%</td>
<td>Fe 0.10%</td>
</tr>
</tbody>
</table>
Reactivity and Stability of Various Oxides

Fig. 14-4. The standard free energy of formation of many metal oxides as a function of temperature. [From F. D. Richardson and J. H. E. Jeffes, substantially as in J. Iron Steel Inst. 160, 261 (1948).]
Dramatic Changes in Temperature within the Cupola

©2012 ASI International Ltd.
Cupola Slags - CaO/SiO₂ ratio.

**Limestone** Addition is done to help “cleanse” the charge “tramps” and the ash from the Coke.

It is absolutely IMPERATIVE that any slag generated, will exit out of the cupola, thru the tap hole and get separated by the Slag dam.

It is CRITICAL to keep the slag in a consistent CaO/SiO₂ ratio that matches the normal charge make-up, AVOIDING ANY BASIC TENDENCY.
Slags for Ductile-base Cupola

The CaO/SiO₂ ratio is the main concern, but the ever-changing presence of FeO and MnO will affect the slag chemistry and refractory durability, especially in ductile-base iron charges.

<table>
<thead>
<tr>
<th>(%)</th>
<th>SiO₂</th>
<th>38.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CaO</td>
<td>35.6</td>
</tr>
<tr>
<td></td>
<td>MgO</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>FeO</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>Al₂O₃</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>MnO</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>K₂O</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>TiO₂</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Cr₂O₃</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Na₂O</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>0.4</td>
</tr>
</tbody>
</table>
When considering a typical CaO/SiO₂ ratio in a cupola slag with an acidic practice, the SiO₂ content is approximately 30 to 40% by weight percent. The corresponding CaO content will range from 35 to 45% depending on the type of limestone that is used.

Increasing FeO, MgO and MnO will skew the slag towards basic nature. Higher S will require a desulfurization treatment downstream as it will affect the amount of Mg Needed for treatment.
Slags in Ductile-Base Iron Coreless Induction Furnaces

©2012 ASI International Ltd.

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
Importance of Charge Sequencing in Ductile Base Melting

Chemical Reactions of the Initial DI Charge Materials

Carbon/Silicon Contents of Metal Chemistries:

Grey Iron: \( C \ 3.0 - 3.6\%, \ Si \ 2.0 - 2.6\% \)
Ductile-base Iron: \( C \ 3.4 - 3.9\%, \ Si \ 0.7 - 1.8\% \)
Treated Ductile Iron: \( C \ 3.4 - 3.9\%, \ Si \ 1.9 - 2.5\% \)
\( \text{Mg} \ 0.030 - 0.040\% \)
Pig Iron - High C, Low Si Grade: \( C \ 3.5 - 5.0\%, \ Si \ 0.2 - 0.8\% \)
Carbon Steel: \( C \ 0.1 - 0.5\%, \ Si \ 0.2 - 0.8\%, \ Mn \ 0.2 - 1.0\% \)

©2012 ASI International Ltd.
Coreless Induction Furnace Slags –

consist of oxidized elements from the molten metal, some minor refractory aggregates and tramp oxides/sulfides. Primarily SiO₂ fluid slags.

FeO, MnO are common as well as SiO₂, Al₂O₃.

Other residuals - MgO, CaO, S, TiO₂, R.E.O, MoO₃.
Coreless Induction Melt
Ductile - Base Iron

An example of a typical Slag Analysis using XRF Spectroscopy

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>67.8</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>13.1</td>
</tr>
<tr>
<td>FeO</td>
<td>12.2</td>
</tr>
<tr>
<td>MgO</td>
<td>2.5</td>
</tr>
<tr>
<td>CaO</td>
<td>2.3</td>
</tr>
<tr>
<td>MnO</td>
<td>1.0</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>0.3</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>0.2</td>
</tr>
<tr>
<td>CeO$_2$</td>
<td>0.2</td>
</tr>
<tr>
<td>K$_2$O</td>
<td>0.2</td>
</tr>
<tr>
<td>MoO$_3$</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Ductile – Base Slags in Coreless Induction Furnaces

<table>
<thead>
<tr>
<th>Compound</th>
<th>Wt. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>67.8</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>13.1</td>
</tr>
<tr>
<td>MnO</td>
<td>1.0</td>
</tr>
<tr>
<td>FeO</td>
<td>12.2</td>
</tr>
<tr>
<td>CaO</td>
<td>3.9</td>
</tr>
<tr>
<td>MgO</td>
<td>2.5</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.2</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.3</td>
</tr>
<tr>
<td>MoO₃</td>
<td>0.2</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.2</td>
</tr>
<tr>
<td>S</td>
<td>0.2</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.1</td>
</tr>
<tr>
<td>CeO₂</td>
<td>0.2</td>
</tr>
<tr>
<td>ZrO₂</td>
<td>0.1</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.1</td>
</tr>
<tr>
<td>SrO</td>
<td>0.1</td>
</tr>
<tr>
<td>F</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compound</th>
<th>Wt. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>69.1</td>
</tr>
<tr>
<td>FeO</td>
<td>10.3</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>8.1</td>
</tr>
<tr>
<td>CaO</td>
<td>5.1</td>
</tr>
<tr>
<td>MnO</td>
<td>4.1</td>
</tr>
<tr>
<td>MgO</td>
<td>1.1</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.6</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.5</td>
</tr>
<tr>
<td>S</td>
<td>0.2</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.2</td>
</tr>
<tr>
<td>BaO</td>
<td>0.2</td>
</tr>
<tr>
<td>CeO₂</td>
<td>0.1</td>
</tr>
<tr>
<td>ZrO₂</td>
<td>0.1</td>
</tr>
<tr>
<td>SrO</td>
<td>0.1</td>
</tr>
<tr>
<td>F</td>
<td>0.1</td>
</tr>
<tr>
<td>Cl</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Typical ductile-base iron slag for coreless induction melting will range from, SiO₂ 45-70%, Al₂O₃ 5-20%, FeO 5-25%, MnO 5-10%, CaO 1-10%, MgO 0.5-5%, R.E.O 0.1 – 2.0%
Slags in Ductile –base Iron Channel Induction Furnaces

Slag is inevitable in a Melting Channel Induction Furnace. Periodic slag removal is needed to prevent any Restriction of Metal Flow in Throats or Inductor Channels.

©2012 ASI International Ltd.
Channel Induction Melt – Ductile-Base Iron

Courtesy of Waupaca Marinette Plt 4

©2012 ASI International Ltd.

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
### Slags from Ductile-base Vertical Channel Melting Fces

<table>
<thead>
<tr>
<th>Compound</th>
<th>Wt. (%)</th>
<th>Wt. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>2.81</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>8.32</td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td>59.56</td>
<td></td>
</tr>
<tr>
<td>La₂O₃</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>K₂O</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>CeO₂</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>3.38</td>
<td></td>
</tr>
<tr>
<td>BaO</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>V₂O₅</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td>3.11</td>
<td></td>
</tr>
<tr>
<td>FeO</td>
<td>11.98</td>
<td></td>
</tr>
<tr>
<td>CuO</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

**Main Constituents**
- **Al₂O₃**: 5 – 35%, **SiO₂**: 25-65%, **MgO**: 2-35%
- **FeO**: 10-39%, **MnO**: 5-30%
- **CaO**: 5-20%
- **CeO₂, La₂O₃**: heavy Residual Insoluble Rare earth Oxides

**Potentials for Chemical Attack**
- **FeO**: 10-39%, **MnO**: 5-30%

**Constituents in Refractories, Inoculants, Flux**

©2012 ASI International Ltd.

**DIS Annual Meeting, June 5-7, 2013**
**Indianapolis, IN**
As a continuous molten metal homogenizer and “reheater”, HOLDING Channel Furnace slags tend to be less aggressive but still require removal.
### Slags from Vertical DI Channel Holding Furnaces

<table>
<thead>
<tr>
<th>Element</th>
<th>(%o)</th>
<th>SiO₂</th>
<th>FeO</th>
<th>Al₂O₃</th>
<th>MnO</th>
<th>CaO</th>
<th>Cr₂O₃</th>
<th>TiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>41.2</td>
<td>37.3</td>
<td>35.0</td>
<td>10.8</td>
<td>7.5</td>
<td>6.1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>36.8</td>
<td>41.3</td>
<td>30.9</td>
<td>9.4</td>
<td>8.2</td>
<td>3.2</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>MgO</td>
<td>6.6</td>
<td>39.9</td>
<td>21.9</td>
<td>18.2</td>
<td>8.5</td>
<td>8.3</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>FeO</td>
<td>5.2</td>
<td>37.0</td>
<td>36.8</td>
<td>9.2</td>
<td>10.7</td>
<td>3.1</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>CaO</td>
<td>4.3</td>
<td>32</td>
<td>31</td>
<td>61</td>
<td>32</td>
<td>83</td>
<td>31</td>
<td>6</td>
</tr>
<tr>
<td>MnO</td>
<td>2.7</td>
<td>37</td>
<td>32</td>
<td>83</td>
<td>32</td>
<td>83</td>
<td>31</td>
<td>6</td>
</tr>
<tr>
<td>CeO₂</td>
<td>1.4</td>
<td>43</td>
<td>43</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>La₂O₃</td>
<td>0.6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>ZrO₂</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Gd₂O₃</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>BaO</td>
<td>Present</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Nd₂O₃</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Pr₂O₃</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Typical ductile-base iron slag for channel induction holding slags will range from, SiO₂ 25-40%, Al₂O₃ 30-45%, FeO 5-15%, MnO 5-15%, MgO 0.5-10.0%, R.E.O 0.1 – 2.0%
Pressure Pouring Channel Furnaces holding Treated Ductile Iron
The Standard Free Energies of Formation of the Nitrides per Pound-Mole (or Gram-Mole) of N₂(gas).

Temperature, °C

The reference states are the pure phases which are stable at one atmosphere pressure and the designated temperature.
What is the composition of the Insoluble Slag Build-Up in Treated Ductile Iron?

MgO - Magnesium Treatment / Magnesium FADE
MgS from reversion of Sulfur from the Melt
RE Oxides, Sulfides from Rare Earth additions

FeO, MgO from exposure to Air atmosphere AND/OR Oxygen Lancing

Al₂O₃ from the refractories and tramp elements within the melt

*All of these oxides/sulfides have high melting temperatures, typically above normal pouring ranges of treated ductile iron.*
R.E.O’s and R.E.S’s  (Rare Earth Metals)

The benefits of Rare Earth Metals: (Oxides and Sulfides)
Nucleate, Nodularize, Neutralize tramps
All beneficial in the inoculation process/ Microstructure enhancement

Strong Gibb’s Free Energies of Formation for Rare Earth Oxides and Sulfides creating cleanliness issues in Furnaces and Ladles

Figure 8: Effect of cerium on the chilling tendency of gray iron (1.1X).

©2012 ASI International Ltd.
Pressure Pouring and Auto Pouring Vessels

<table>
<thead>
<tr>
<th></th>
<th>(%)</th>
<th></th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>39.8</td>
<td>SiO₂</td>
<td>38.0</td>
</tr>
<tr>
<td>MgO</td>
<td>31.6</td>
<td>FeO</td>
<td>29.1</td>
</tr>
<tr>
<td>CaO</td>
<td>10.9</td>
<td>MgO</td>
<td>23.2</td>
</tr>
<tr>
<td>La₂O₃</td>
<td>7.6</td>
<td>MnO</td>
<td>4.4</td>
</tr>
<tr>
<td>CeO₂</td>
<td>5.1</td>
<td>Al₂O₃</td>
<td>3.7</td>
</tr>
<tr>
<td>FeO</td>
<td>2.8</td>
<td>S</td>
<td>0.4</td>
</tr>
<tr>
<td>Nd₂O₃</td>
<td>0.9</td>
<td>MoO₃</td>
<td>0.3</td>
</tr>
<tr>
<td>F</td>
<td>0.5</td>
<td>CaO</td>
<td>0.3</td>
</tr>
<tr>
<td>Pr₂O₃</td>
<td>0.3</td>
<td>ZnO</td>
<td>0.2</td>
</tr>
<tr>
<td>MnO</td>
<td>0.2</td>
<td>TiO₂</td>
<td>0.1</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.2</td>
<td>CeO₂</td>
<td>0.1</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.1</td>
<td>Cr₂O₃</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Rare Earth Oxides and Sulfides creating cleanliness issues.

Under **Nitrogen atmosphere**, the slag chemistry in the Pressure pour will range from **MgO 20-55%, S 0.5 – 45.0% (MgS, R.E.S.), CaO 5-15%**.

In **Air atmosphere**, Increased % FeO, Increased % SiO₂, MgO 15-30%, Lower S.
Deslagging Pressure Pour Channel Furnace
Throat and Uppercase Build-Up Maintenance
Ladle Slags Ductile Iron
Treatment Ladles for Ductile Iron
Treatment Ladles for Ductile Iron

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na₂O</td>
<td>0.20</td>
</tr>
<tr>
<td>MgO</td>
<td>25.17</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.56</td>
</tr>
<tr>
<td>SiO₂</td>
<td>6.32</td>
</tr>
<tr>
<td>S</td>
<td>6.35</td>
</tr>
<tr>
<td>CaO</td>
<td>24.89</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.38</td>
</tr>
<tr>
<td>V₂O₅</td>
<td>0.16</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.03</td>
</tr>
<tr>
<td>MnO</td>
<td>0.00</td>
</tr>
<tr>
<td>FeO</td>
<td>35.00</td>
</tr>
</tbody>
</table>

TREATED ductile iron slag BUILD-UP for Magnesium Treatment Ladle will range from,

MgO 15-35%, S 0.5 – 15%, SiO₂ 5 -20%, Al₂O₃ 0.5-15%, FeO 5-25%, MnO 0.1.5-5%, R.E.O 0.1 – 3.0% (Major Sulfur presence)

©2012 ASI International Ltd.
# Fischer Converter slags

<table>
<thead>
<tr>
<th></th>
<th>Wt. %</th>
<th></th>
<th>Wt. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td>39.5</td>
<td>MgO</td>
<td>41.5</td>
</tr>
<tr>
<td>SiO₂</td>
<td>12.3</td>
<td>FeO</td>
<td>28.6</td>
</tr>
<tr>
<td>S</td>
<td>11.8</td>
<td>SiO₂</td>
<td>11.7</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>11.1</td>
<td>S</td>
<td>8.7</td>
</tr>
<tr>
<td>FeO</td>
<td>9.8</td>
<td>Al₂O₃</td>
<td>2.7</td>
</tr>
<tr>
<td>Na₂O</td>
<td>5.7</td>
<td>CaO</td>
<td>2.5</td>
</tr>
<tr>
<td>CaO</td>
<td>4.4</td>
<td>MnO</td>
<td>1.0</td>
</tr>
<tr>
<td>SiO₂</td>
<td>45.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>26.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FeO</td>
<td>18.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MoO₃</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

©2012 ASI International Ltd.
Insoluble Slag in Ladles and Unheated Pouring boxes

The slag chemistries are similar to Treatment Ladle Slags but with the influence of the post inoculation practice., i.e. more Al₂O₃, BaO, REOs, CaO, SiO₂ etc
Metal / Slag Contact Tests
Rotary Slag Dynamic Tests
## Use of Slag Coagulant

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>33.8</td>
</tr>
<tr>
<td>Aluminum</td>
<td>7.2</td>
</tr>
<tr>
<td>Potassium</td>
<td>3.5</td>
</tr>
<tr>
<td>Sodium</td>
<td>3.4</td>
</tr>
<tr>
<td>Iron</td>
<td>0.6</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.6</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.2</td>
</tr>
<tr>
<td>Trace</td>
<td>0.2</td>
</tr>
<tr>
<td>Oxygen (by difference)</td>
<td>47.5</td>
</tr>
<tr>
<td>Net Total</td>
<td>97.0</td>
</tr>
<tr>
<td>Bound Water</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*DIS Annual Meeting, June 5-7, 2013, Indianapolis, IN*
Slag Defects in Cast Ductile Iron Castings

RUST common in all facets of iron-based charge materials is known to many chemists as Hematite, Fe₂O₃. When exposed to heat, the following reaction occurs (i.e., during melting),

$$2\text{Fe}_2\text{O}_3 \rightarrow 4\text{FeO} + 3\text{O}_2 \uparrow$$

As the melting continues, the oxygen will oxidize other alloying elements in the melt such as Silicon, Carbon, Manganese, Magnesium, etc., while continuing to add more FeO to the melt. The FeO will react with the SiO₂ in the melt to form an Iron Oxide Silicate, shown below;

$$2\text{FeO} + \text{SiO}_2 \rightarrow 2\text{FeO.SiO}_2, \quad \text{Melt point of 2223F(1217C)}$$

This compound is called Forsterite and can and will remain liquid in the Ductile-base iron until solidification of the iron takes place in the sand mold which can lead to slag inclusions.
Suggestions of Controlling Iron Oxide Silicate Casting Inclusion

Many suggestions to lower or remove the Rust include;

• shot blast charge/pig iron
• use a small addition of Aluminum to tie up $O_2$
• add a small addition of Flux to float the complex silicate out of melt
• add high purity SiC to react with the FeO and MnO to reduce each to either Fe and Mn.
Slag Defects in Cast Ductile Iron Castings

Another slag inclusion occurrence in Ductile Iron castings is the formation of Manganese Oxide Silicates, known as Tephroite. Its origin in a ductile iron charge is typically from carbon and manganese steel charge/plate but has been introduced through some “pig irons” as well.

Manganese is typically desirable in most cases for certain grades of Ductile iron but in limited quantities, to help attain properties. It is often added in the melting sequence along with other charge materials.

Unfortunately, with any presence of Oxygen within the melt, the Manganese can readily oxidize to form MnO. The MnO will then easily react with any SiO₂ within the melt or slag to form the following:

\[
2\text{MnO} + \text{SiO}_2 \rightarrow 2\text{MnO}.\text{SiO}_2, \text{Melting Point of 2453F (1345C)}
\]

At typical treated Ductile iron pouring temperatures, this compound can remain Liquid until solidification of the casting in the sand mold.
Suggestions of Controlling Manganese Oxide Silicate Casting Inclusion

Many suggestions to lower or remove the Rust include:

- shot blast charge/pig iron
- use a small addition of Aluminum to tie up $O_2$
- add a small addition of Flux to float the complex silicate out of melt
- add high purity SiC to react with the FeO and MnO to reduce it to Fe and Mn.
Slag Fundamentals for Ductile Iron

Understand your internal Melt, Metallurgy and Pouring Process

Understand the slag that is generated in your foundry

Run random slag analyses for various iron and steel grades on a semi-continuous basis. As examples;
- At the beginning of the production week after a long holding period,
- Whenever there is a change in charge materials,
- If there is a change in the Inoculant package being used,
- If there is an addition in FLUX to the furnace or ladle,
- A change in melt or pouring temperature,
- A change in the treatment alloy or process of the Ductile Iron.

FeO, MnO levels within your slag will influence lining performance and potential propagation of casting defects in your castings. Attempt to gain control of both of these oxides will only reap you benefits for your foundry.
In Ferrous Melting Holding and Pouring Applications, it is imperative to get the chemistry and microstructure of the molten iron to meet the desired metallurgical requirements of the grade of metal to be cast.

What is often overlooked is the generated slag chemistry and how it may affect the eventual casting.

Hopefully we have presented some thoughts on what might be expected for the given molten metal application in your iron foundry.
Thank You…
Any Questions ??

dcwilliams007@yahoo.com, 614-440-4007
“ADVANCES IN DUCTILE IRON PROCESS CONTROL THROUGH THERMAL ANALYSIS”

DAVID GILSON

DAVID GRADUATED FROM THE UNIVERSITY OF WISCONSIN-MADISON WITH HIS BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. HE STARTED HIS CAREER IN THE FOUNDRY INDUSTRY AT MOTOR CASTINGS COMPANY IN MILWAUKEE, WISCONSIN FOR 3 YEARS. HE THEN RETURNED TO SCHOOL TO OBTAIN HIS MASTERS OF BUSINESS ADMINISTRATION DEGREE FROM THE UNIVERSITY OF WISCONSIN-MILWAUKEE. HE THEN JOINED ASHLAND CHEMICAL FOUNDRY PRODUCTS DIVISION AFTER GRADUATING. DAVID STARTED IN THE TECHNICAL SERVICE GROUP EVENTUALLY BECOMING THE TECHNICAL SERVICE MANAGER PRIOR TO RELOCATING TO MONTERREY TO LEAD ASHLAND’S FOUNDRY BUSINESS IN MEXICO. AFTER 3 YEARS, HE RETURNED TO THE US TO BECOME THE GOLBAL MARKETING MANAGER. IN 15 YEARS AT ASHLAND, HE AUTHORED MANY ARTICLES FOR PUBLICATION IN THE AFS TRANS-ACTIONS AND OTHER TECHNICAL JOURNALS, GAVE INTERNATIONAL, NATIONAL AND REGIONAL PRESENTATIONS, AND WAS PART OF A TEAM THAT OBTAINED A PATENT ON RISER SLEEVE TECHNOLOGY. HE THEN JOINED REXNORD INDUSTRIES IN 2008 IN MILWAUKEE IN AN EXECUTIVE MARKETING POSITION TO WORK IN THE POWER TRANSMISSION AND WIND ENERGY MARKETS. IN 2011, HE CAME BACK TO THE FOUNDRY INDUSTRY TO LEAD SINTERCAST’S GLOBAL COMMERCIAL GROUP.
“A NEW APPROACH TO AUTOMATED POURING, AN EXAMINATION OF THE OVERALL POURING PROCESS”

BILL PFLUG

BILL GRADUATED WITH A BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING. BILL STARTED HIS FOUNDRY CAREER AFTER JOINING INDUCTOTHERM IN 1977. HE STARTED AS A SERVICE ENGINEER, INSTALLING AND TROUBLESHOOTING VARIOUS INDUCTION AND POURING SYSTEMS. HIS CARRIER PATH INCLUDED POSITIONS IN ENGINEERING, APPLICATIONS, PRODUCT MANAGER AND MOST RECENTLY IN SALES AND MARKETING MANAGEMENT. BILL HOLDS A NUMBER OF PATENTS RELATED TO AUTOMATIC POURING AND MOLTEN METAL HANDLING. HE IS PAST CHAIRMAN FOR THE AFS 8D CHANNEL FURNACE COMMITTEE AND THE AUTOMATIC POURING SUB-COMMITTEE. CMI HAS USED BILL AS AN INSTRUCTOR ON AUTOMATED POURING IN THE PAST. HE STAYS ACTIVE IN THE FOUNDRY INDUSTRY BY SPENDING A GREAT DEAL OF HIS TIME IN CASTING FACILITIES THROUGHOUT THE WORLD, PRESENTING PAPERS AND PROVIDING SEMINARS ON AUTOMATIC POURING. BILL LIVES IN MOUNT LAUREL, NJ WITH HIS WIFE, MARY LOU AND 3 DAUGHTERS. REMODELING A 200 YEAR OLD FARM HOUSE, HE CLAIMS, IS GOOD THERAPY. BILL IS CURRENTLY THE GLOBAL MANAGER OF AUTOMATED POURING SYSTEMS.
AN OVERVIEW OF THE AUTOMATED POURING PROCESS

William R. Pflug

Synopsis
The success of all automated pouring systems hinges on accurately metering metal, at a consistent temperature and quantity into a mold designed to complement the product you are producing. Matching the delivery system with the mold is the key to minimizing rejects and maximizing profitability. This paper will describe methods and devices for dispensing iron and how best to combine this technology with sprue cup/pouring basin and gating to best tune the process for success.

1 Ductile Iron Society, Indianapolis, Indiana, June 5-7, 2013
2 Manager Automated Pouring Systems, Inductotherm Corp
INTRODUCTION

The competitive nature of today's global market for iron components has forced us to examine all of the different ways in which we produce our castings. Ever increasing quality standards create new benchmarks for more precisely repeatable processes requiring us to control and automate all facets of the foundry. And although every molten drop of production still must pass over a ladle lip or spout, truly automated iron pouring has now come of age.

New generations of automated pouring systems have been developed to meet this challenge. The advent of intelligent sensors and programmable logic controllers with sophisticated algorithms make it possible to adapt to the many variables associated with holding and pouring iron. Numerous foundries around the world have adopted these new pouring technologies. These systems have produced castings with a great degree of accuracy and repeatability along with being very reliable.

1. Growing needs for Automated Pouring

Modern foundries are in constant need to:

- Reduce labor costs to match competitive needs by centralizing the pouring process and reducing maintenance

- Improve working environment—Enhance safety by moving the worker away from the heat and danger.

- Increase casting production on molding lines. Pouring speeds are now in excess of 500 molds per hour—impossible to maintain a good manual pouring process accurately at this rate—automation is a must.

- Reduce metal loss by eliminating costly over pours and quality-robbing under pours.

- Assure casting quality by always filling the mold quickly and repeatably

- Maintain process control with the latest technology and equipment.
2. **Available Technologies and Applications**

2.1 *Pressure Pour – Heated Systems*

![Figure 1: Pressure Pour Furnace](image)

Having heated metal at the mold line enables the user more flexibility with their metal deliveries to the pouring area. It is typical to provide a fresh ladle of iron every 20 to 25 minutes whether it is gray or ductile iron with little overall effect on the product. Appropriate sizing of the vessel to a given production rate will enhance its operation, maximize lining life and reduce maintenance. So, how small it too small? It makes little economic sense to install a heated system where the production rate falls below 2 tons per hour.

The pneumatic furnace control is meant to maintain a constant metal level in the pouring head. Common thinking is that due to this perception the pouring controls may be simplified as in a Teach-in system. Be careful! The slow response of the pneumatics often produces oscillations in the metal level and a Teach-in system may not produce the desired results.

Metallurgically speaking, the heated furnace will have a homogenizing effect simply due to its storage capacity.

Advantages of the pressure pour system do not come without cost. Electricity, refractory linings, maintenance, natural gas for burners and compressed air or nitrogen in the case of ductile and chrome iron production increase the operating cost over other methods of delivering metal to the mold.
2.2 **Tundish – Unheated Systems**

![Unheated Tundish](image)

Figure 2: Unheated Tundish

Development of the unheated system started as a method to eliminate the hardships associated with pouring ductile iron. This system has no siphons for filling or pouring, or the associated maintenance. There is no inductor (channel or coreless) to provide an area to grow slag.

Temperature loss is a fact of life when operating a tundish. Energy stored by the iron and linings are the only source of heat to minimize losses. Temperature loss from 1.5 to 3 degrees per minute are normal and must be expected.

Metal level fluctuations are a fact with the unheated tundish. Therefore, adaptive control is required to accept the changing head pressure at the pouring nozzle to have similar pouring results.

How much production is too much? Typically the current tundish designs limit throughput to 15 tons per hour.

How does the use of a tundish system impact operating costs? Compared with a heated system they are 1/3 to 1/4 the cost.

2.3 **Advantages and Limitations of Each Type**

A pressurized furnace offers a means to provide very clean metal, at a precise temperature very accurately to the molding system. The ability to lessen the effects of atmosphere greatly reduce oxidation and slag generation which enhances lining life and reduces that form of maintenance.

The ability to partially empty the furnace by tilting assists with alloy changes, but completely emptying the furnace, whether a channel or coreless inductor is not suggested. Higher production rates require a holding vessel so as to minimize the risk of extended periods of low or no production. The benefit of limited number of iron transfers tends to smooth out a larger operation.

As stated before, the operating cost, if comparisons can be made to the unheated vessel, are considerably higher.

Automated pouring with the unheated product is the least cost method to get metal into the mold. It is a flexible system with the ability to convert to other alloys, sometimes in line with a pattern change due to the ability to tilt fully to empty. Lining changes are as simple as removing one tundish box and replacing with another. Simplicity and number of components make it a very reliable tool.
Metal delivery on a regimented basis is necessary for an unheated tundish to perform and a process plan for temperature loss needs to be addressed.

Limits of production and the configuration of the melting plant help predict the selection of either style of automated pouring devices.

3. System Basics

3.1 Controlling metal flow

![Figure 3: Metal Flow Through the Nozzle](image)

The open area under the stopper rod controls metal flow. When the rod opens fully, the area of the wall of the cylinder is greater than the area of the nozzle and the rod is no longer in control. Very small vertical movement is needed to make this happen therefore very precise control of the stopper is required to achieve accurate results.

It is well known that typical rod and nozzle combinations provide limited flow control. This has led most suppliers to implement servo motor control for their stopper actuation. It is important to note for later review that this portion of the system has a response measured in hundredths of a second.

3.2 Level sensing

There are two schools of thought regarding the determination of metal level or area in the pouring basin.

One utilizes a specially fitted laser to project a line across the round sprue cup. A camera is used to “see” the line for level sensing and positioning.

Digital cameras are employed in the second type of sensing. They utilize the contrast between the black sand and the molten metal to “see” the iron. In this case an area of metal is distinguished for feedback to the controller.

It would appear although both lasers and cameras are available some form of camera is utilized to view either a laser line or the metal in the sprue cup. Metal movement in the sprue cup is measured in hundredths or thousands of a second.
As stated previously, metal head control in a pressure pour is not absolute due to it being a pneumatic system with a slow response. We also know the unheated tundish, by design, has a changing metal level. How as equipment manufacturers do we address this variable? Adaptive, intelligent, real-time control is employed. This makes it possible to sense the nuances of changing head pressure and nozzle diameter simply from what the pouring basin shows us along with the actions of the stopper mechanism. Like our intelligence, the control corrects the response to the changes and accurately pours the mold.

3.3 **Controllers**

Today it is typical to utilize a combination of PLC for the brute force control of the process and a PC for data storage, collection and communication with other equipment, processes and the customer’s information highway.

![Figure 4: Pouring Graphic Interface](image)

### 4.0 Mold and Gating Design- Interaction with the Pouring System

Successfully pouring metal into a mold and producing a quality casting is a complete process. Affecting this process is:

- **Stopper rod shape**
- **Stopper rod stroke**
- **Nozzle shape and diameter**
- **Metal head**
- **Metal viscosity**
- **Sprue cup volume**
- **Mold Gating**
- **Mold gas evolution/permeability**
- **Metal free-fall distance**
The pouring equipment manufacturer has the opportunity to control:

- Stopper Rod Shape
- Stopper Rod Stroke
- Nozzle Shape and Diameter
- Metal Head (sometimes)
- Metal free-fall distance (limited)

What is outside their control:

- Metal Head (sometimes)
- Metal viscosity
- Sprue cup volume
- Mold gating
- Mold gas evolution/permeability
- Metal free-fall distance (limited)

Pattern layout has evolved to optimize the mold surface and increase yield. Along with this sprue cup volumes have been reduced as a function of pattern layout-spacing and yield. Here is where the contribution of gating and sprue cup design to the whole system may not be well defined. What is the requirement of a sprue cup? It needs to get the poured metal into the runner system. The shape of the cup/basin should assist in preventing slag from entering the down sprue. It ought to contain the metal in the cup and not on top of the mold. AND – it should contribute little to the overall pouring system gain. What do we mean by this?

**Figure 5:** Simplified Pattern Layout
It is imperative that the sprue cup design be an integral portion of the pouring process. These factors must be considered:
- Very small sprue cups can make the pouring process unstable.
- Large sprue cups decrease your profitability.
- The optimized sprue cup complements the pouring process and enables very accurate pouring which will increase quality and maximize your profits.

We need to consider another facet of the pouring, that being metal in transit:

The time it takes a metal stream to fall from the stopper and nozzle control to the surface of the mold is governed by gravity:

\[ s = \frac{1}{2} a t^2, \quad \text{where:} \]
\[ s = \text{distance (mm)} \]
\[ a = \text{acceleration due to gravity (mm/sec}^2\text{)} \]
\[ t = \text{time (sec)} \]

Rearranging:
\[ t = \sqrt{\frac{s}{1/2 a}} \]

Nozzle elevation above the mold is governed by the sensor and the volume of metal poured. Too close to the mold and the sensor will not see the metal and metal splash will adhere to the nozzle and pouring device obscuring the view and require mechanical removal. The optimum distance is between 100 and 200 mm.

Let’s assume the bottom of the nozzle is 150 mm from the mold and the length of the nozzle is 205 mm therefore:
\[ s = 150 \text{ mm} + 205 \text{ mm} = 355 \text{ mm} \]
\[ a = 9814 \text{ mm/sec}^2 \]
\[ t = \sqrt{\frac{s}{1/2 a}} \]
\[ t = 0.27 \text{ sec (the free fall time from the stopper seat to the mold)} \]
We do not expect all molds to pour easily. There are more than a few pattern makers/designers with their own idea on how best to gate a mold. Invite them to discuss how they can enhance the overall system for pouring.

-How each item affects the pouring

![Figure 7: Metal Flow vs Time](image)

![Figure 8: Comparison of Nozzle Flow vs Metal Flow](image)
The graphics of Figure 8 shows two curves offset by the metal free-fall time. What this demonstrates is that the metal flow rate leaving the nozzle enters the sprue cup roughly ¼ second later.

![Typical Pouring Curve](image)

Figure 9 shows a disparity between the metal leaving the nozzle and what can enter the sprue/mold.

Why does this happen? When the flow rate into the mold reduces drastically, as after the initial fill, the sensor determines this change and calls for a reduction in flow. At this point, metal continues to fall from the nozzle at the higher flow rate. The volumetric difference between the high "in transit" flow and the lower flow of the mold during that time has to fit within the sprue cup volume or it runs on top of the mold.

5. **Metal Quality and Temperature**

Both affect the end product. Knowledge of the metallurgical condition of the metal at any one time is paramount to quality castings. Good ductile iron treatment practice improves the operation of both the pressure pour and unheated tundish. Minimizing alloy additions is a benefit for a number of reasons. A treatment with a lower alloy addition requires a lower tap temperature from the furnace. Reducing the tap temperature aids in the magnesium recovery. Smaller quantities of treatment alloy means minimal calcium and tramp elements in your slag--- these are the slags which are difficult to remove from the furnace/siphons and nozzle. One side benefit regarding coreless melting in silica linings is that your lining life will improve. All in all, being more aggressive as it relates to magnesium levels and additions shows on the profit side.

Iron types and temperature changes the fluidity of the iron and how it flows from the nozzle.
6. **Advanced Predictive Software**

The ability of today’s pouring devices make intelligent decisions and are flexible enough to adapt to a multitude of applications and patterns. The deviations in real time pouring control brought about by in-transit flow are nearly eliminated with the advent of predictive pouring control. Algorithms place disturbances along the pouring cycle and modify control parameter to better accommodate appropriate process control.

New developments limit the number of parameters required for good pouring results. It is now possible to automate the tuning throughout the pouring sequence. As molding speeds continue to increase the speed and accuracy is being tracked and perfected.

7. **The System Approach – New Enhancements**

![Typical Pouring System](image)

*Figure 10: Typical Pouring System*

But you can not tune a pouring process to optimum performance simply by the controls.

Three critical areas that must be coordinated properly:
- Stopper and nozzle configuration
- Design of the sprue cup
- Mold gating
Paying attention to these details offers the most accurate and repeatable pouring. If your process in under control the benefits are higher overall yields, lower scrap rates and more competitive advantages.

Selecting automated pouring equipment can be a difficult task. Questions you should ask of your potential supplier might be:
How accurately does the system track the changes in sprue level?
How quickly and precisely does it respond by adjusting the stopper rod?
Is the pouring process controller able to use the pouring profile optimized for the each mold being poured?
Can the system adjust for a change in sprue cup location?
Will the pouring sensor work with a standard sprue cup or is a special cup size or shape required?
Does it terminate the pour if there is a mold failure?

7.1 Auxiliary devices
Stopper rod turning devices to maintain a seal with the nozzle
Hydraulic nozzle cleaners in use with ductile and chrome irons
Inoculant feeders
Metal stream temperature indicators

7.2 Software controls
• Inoculant verification
• Advanced metal flow sensors (stream alignment and built in pyrometers)
• Mold machine to pouring system communications
• Boosting production and cutting cycle time (Prepour, Dual Pour)
• Ease of use
• Customer data collection
• Clear representation and graphical approach
• Multiple pouring and positioning modes
• Built in exportable files (Excel)
• Links to the outside world via Ethernet

8. Field Examples
Results of properly matching the automated pouring device to the mold fluid dynamics are well known

8.1 Example No. 1

8.1.1 Initial Arrangement
Hand pouring
Iron type - ductile
Molding machine – 96 molds/hr maximum – actual was approximately 60 mold/hr due to metal temperature issues with the hand ladles.
Metal loss/remelt – 3%
Mold yield – 61%
Average daily production – 100 tons

8.1.2 Following Automated Pouring Installation
Unheated tundish with Visipour
Molding machine – 96 molds/hr maximum
Metal loss/remelt – 1%
Mold yield – 67%
Average daily production – 140 tons limited by melting capacity. Additional melting will enable 160 tons/day.

8.1.3 Other benefits:
Less temperature loss due to larger transfers and centralized pouring
Smaller sprue cup and optimized runner system
Limited Fading by controlled timing of metal replenishment
Enhanced safety – limited exposure to hazards.
Reduced labor costs
Rapid payback – 6 months

8.2 New Application
Automated Pouring via pressure pour
Pouring control via Visipour P³
Pressure and power modulation through distributed PLC
Iron Type – gray and ductile
Molding machine – 120 molds/hr double squeeze head (A and B molds)
Poured weight – up to 1 ton per mold
Maximum hourly production – 100 tons
Four furnaces supplied – two furnaces for gray iron and two for ductile iron, 50 ton total capacity, 35 ton usable.
1200 kW inductor power
Metal transfers of 13.5 ton
Dual inoculant feeders

9. Caution:
Automation will not answer all the questions.
Automated Pouring is one part of a larger pouring process system.
Treat it as a sum of the parts rather than a part of the whole to optimize your results.
Maintain constant analysis and improvement.

10. Conclusion
Finally, to be successful, all elements of a pouring process must be developed for the metal being poured, the processes being used, and the range of molds being filled.

“The human tendency to regard little things as important has produced very many great things”.
G.C. Lichenberg (1747-1799) – Physicist and Philosopher
“DIS PROJECT #48 AND PROJECT #49”

RICK GUNDLACH

RICK IS A SENIOR METALLURGICAL ENGINEER AT ELEMENT MATERIALS TECHNOLOGY LOCATED IN WIXOM, MICHIGAN. ELEMENT MATERIALS TECHNOLOGY WAS FORMERLY STORK CLIMAX RESEARCH SERVICES AND THE NAME CHANGED IN EARLY 2011. CLIMAX RESEARCH SERVICES WAS CO-FOUNDED BY RICK IN 1987 AND WAS PURCHASED BY STORK SMT IN 2006. PRIOR TO THE FORMATION OF CRS, RICK WAS THE METALLURGICAL ENGINEER AND RESEARCH SUPERVISOR FOR OVER 18 YEARS AT CLIMAX MOLYBDENUM COMPANY (AMAX) IN ANN ARBOR, MICHIGAN. RICK HOLDS HIS BS AND MS DEGREES IN METALLURGICAL ENGINEERING FROM THE UNIVERSITY OF MICHIGAN IN ANN ARBOR, MICHIGAN. RICK IS A WIDELY RECOGNIZED EXPERT IN THE FIELD OF CASTING METALLURGY. HE HAS AUTHORED & CO-AUTHORED MORE THAN 50 PAPERS, PUBLISHED IN THE AFS TRANSACTIONS, METALLURGICAL TRANSACTIONS, METALS PROGRESS, INTERNATIONAL CAST METALS JOURNAL, CASTING ENGINEERING, AND VARIOUS CONFERENCE PROCEEDINGS.

DIS Research Project No. 48

Normalizing Heat Treatments to Develop Improved Properties in Heavy Section Iron

June 6, 2013

Rick Gundlach
Element Wixom
Objective

Investigate the influence of super critical and intercritical heat treatments on the mechanical properties of heavy section ductile iron castings (2 inches and greater)

The combination of strength and ductility is very difficult to achieve in the pearlitic grades cast in heavy sections

Focus on ASTM Grades 80-55-06 and 100-70-03
Background

In DIS Research Project 46 -- Mechanical properties were determined in 1-inch and 3-inch Y-blocks

Tensile elongations of 6% never obtained, when a minimum yield strength of 55 ksi was reached.

• Normalizing is commonly employed in heavier sections to obtain 80-55-06 properties

• Intercritical heat treatments can also be very effective in raising mechanical properties
Phase 2 (R&D DOE) vs. Phase 1 (Commercial)

Heat 1 from Phase 2
Heat 2 from Phase 2
Heat 3 from Phase 2
Heat 4 from Phase 2
Heat 5 from Phase 2
Heat 6 from Phase 2
Heat 7 from Phase 2
Heat 11 from Phase 2
All Foundries from Phase 2
MINIMUM TARGET
Linear (All Foundries from Phase 1)

YS, ksi vs. % Elongation

YS = -0.9922*%EI + 67.875
Heat Treatment Improves As-Cast Properties

YS, ksi

% Elongation

YS = -0.9922*%EI + 67.875

DI Grade Specifications

MINIMUM TARGET

Linear (All Foundries from Phase 1)
Heat Treatment Promotes High Strength at High Ferrite Contents

Heat-Treated YS = -0.629*%Ferrite + 98.518

R² = 0.691

As-Cast YS = -0.1927*%Ferrite + 59.388

R² = 0.6486
Numerous keel block legs from Project 46 are available, particularly those from the 3-inch Y-blocks of the DOE study (Y-blocks from 9 heats)

- Supercritical and intercritical heat treatments will be performed.
- Heat treat Keel block legs according to parameters derived above and perform mechanical testing and metallography
- Heat treatments that successfully produced the minimum properties of Grade 80-55-06 will be defined.
- Determine the optimum intercritical temperature
Schematic Equilibrium Phase Diagram

Temperature

γ

γ+α

γ+α+G

γ+G

Wt. Pct. Carbon
As-Quenched Microstructure from Various Intercritical Temperatures per K. Hayrynen

(e) 1475°F, 72.1% ferrite

(f) 1450°F, 90.6% ferrite
As-Quenched Microstructure from Various Intercritical Temperatures per K. Hayrynen

(c) 1525°F, 31.9% ferrite

(d) 1500°F, 40.2% ferrite
Schematic of Heat Treatment Cycle

Temperature, deg. F

Time, minutes

UCT

LCT
Intercritical Normalizing
1545 F Intercritical plus Air Cool
Intercritical Normalizing
1545 F Intercritical plus Air Cool
Formation of Acicular Austenite by Intercritical Heat-Treatment
Yield Strength vs Elongation

Yield Strength, ksi

Elongation, %

Heat 2
Heat 4
Heat 6
80-55-06
Upper Critical Temp minus 5 deg. F
Upper Critical Temp minus 35 deg. F

50 µm
Slow-cooled from IC Heat Treatment Temperature
Upper Critical Temp PLUS 15 deg. F
Yield Strength vs IC Temperature

Yield Strength, ksi
Temperature, F

- Heat 2
- Heat 4
- Heat 6
SUMMARY

• Intercritical heating near the critical temperature produced a structure consisting of lenticular austenite in ferrite
• Upon air cooling, a fine-grained lenticular pearlite forms producing increased mechanical properties
• The strength and ductility of the IC heat-treated castings were much superior to the as-cast properties -- the 3-inch Y-blocks easily met 80-55-06 properties
• Some alloys responded better than others to IC heat treatment, i.e., there was less sensitivity to the IC temperature utilized
• There appears to be less sensitivity to poor nodularity
• With IC heat-treatment, high strength is achieved at higher ferrite contents
DIS Research Project No. 49

Analysis of Pearlitic Ductile Iron with Enhanced Mechanical Properties

June 6, 2013

Rick Gundlach
Element Wixom
Objective

Investigate the characteristics of pearlitic ductile iron when high strength and ductility were obtained.

Identify the characteristics that produce maximum strength and ductility in ductile iron, particularly for the pearlitic grades (ASTM Grades 80-55-06 and 100-70-03)
Background

- Mechanical properties in a large number of castings of the ferritic, ferritic-pearlitic, and pearlitic grades were determined in Project 46. A large set of industrial castings and a group of Y-blocks from a (DOE) statistical study were evaluated.

- Several castings met the minimum yield strength of 55 ksi and also achieved high elongations. Many others did not.

- Statistical analysis did not define the structural characteristics that produce the highest strength to ductility ratios

- Further investigation is required to explore the factors that affect properties
Phase 2 (R&D DOE) vs. Phase 1 (Commercial)

Heat 1 from Phase 2
Heat 2 from Phase 2
Heat 3 from Phase 2
Heat 4 from Phase 2
Heat 5 from Phase 2
Heat 6 from Phase 2
Heat 7 from Phase 2
Heat 11 from Phase 2
All Foundries from Phase 1
MINIMUM TARGET
Linear (All Foundries from Phase 1)

YS, ksi = -0.9922*%El + 67.875
3D Yield Strength, Ductility & Ferrite Content

- Ferrite content (shown in the plot legend and next to the plotted points).
- The diameter of the circular “bubble” is proportional to the ferrite content.
- The points inside the red square indicate the “ideal ferrite” content of about 40 to 60% for achieving the target combination of ≥55 ksi yield strength and ≥10% elongation.
Fracture Path Considerations

- Some properties in the table below are as-expected:
  - Higher pearlite content → higher yield and ultimate tensile strengths
- Some properties were unexpected:
  - Casting #13 with only 38% pearlite produced sufficient YS and UTS
- Consider castings #15 and #52:
  - They have essentially the same pearlite content.
  - However, casting #15 has both higher strength and ductility.
  - The ferrite colonies in casting #15 are less continuous than in casting #52, where the ferrite extended from nodule-to-nodule
- Discontinuous ferrite → higher strength and higher ductility

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Nodularity</th>
<th>Nodule Count</th>
<th>Pearlite Content</th>
<th>Yield Strength ksi</th>
<th>Tensile Strength ksi</th>
<th>Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>93.9%</td>
<td>144</td>
<td>68%</td>
<td>63.4</td>
<td>109</td>
<td>10.0%</td>
</tr>
<tr>
<td>15</td>
<td>95.7%</td>
<td>160</td>
<td>61%</td>
<td>62.6</td>
<td>104</td>
<td>13.3%</td>
</tr>
<tr>
<td>52</td>
<td>98.4%</td>
<td>214</td>
<td>62%</td>
<td>55.9</td>
<td>93</td>
<td>10.2%</td>
</tr>
<tr>
<td>13</td>
<td>97.1%</td>
<td>184</td>
<td>38%</td>
<td>56.0</td>
<td>92</td>
<td>13.7%</td>
</tr>
<tr>
<td>D5506</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>55</td>
<td>80</td>
<td>6%</td>
</tr>
</tbody>
</table>
Ferrite Continuity & Fracture Path

#11

#13

#15

#52
METHODOLOGY

• More than 70 test bars were available from Project 46 for this study. Each sample has been analyzed for composition, hardness and mechanical properties, and many have been evaluated for the traditional microstructure parameters. Review the complete sample set and test data already available from Project 46.

• Selected samples (the pearlitic samples) will be chosen and categorized according to mechanical properties.

• Prepare metallographic samples for those samples in the above Step that were not already examined, and conduct standard microstructural characterization

• Examine samples having comparable yield strengths and widely ranging tensile elongations. Look for unique differences in ferrite and pearlite distributions. Inspect the fracture faces of the broken tensile bars for additional clues.
Ductile (Shear) Fracture
Stress State around a Discontinuity (eg. Graphite Nodule)
Conditions for Localized Yielding

\[ P_1 > \frac{1}{3} P_Y \]
Ductile (Shear) Fracture
Progress of Cracking in Tensile Test

- Ferrite phase yields around nodules
- Voids form between the nodule and the metallic matrix
- Voids in neighboring nodules and ferrite grains merge
THE MECHANICS OF FRACTURE

\[ \sigma_c \approx E/10 \]

\[ \tau_c \approx G/10 \]

Fig. 2.1. Fracture viewed at the atomistic level in terms of the breaking of atomic bonds. (a) Cleavage. (b) Shear.
Fracture Modes

- **Cleavage Fracture:**
  Atomic bonds break when: $\sigma_{\text{local}} > \sigma_{\text{cohesive}}$
  $\sigma_{\text{cohesive}} \approx \frac{E}{10}$

- **Shear Fracture**
  Atomic bonds break when: $T_{\text{local}} > T_{\text{cohesive}}$
  $T_{\text{cohesive}} \approx \frac{G}{10}$
Progress of Cracking in Tensile Test

• Ferrite phase yields around nodules
• Void forms between the nodule and the metallic matrix
• Void merges with those in neighboring nodules
• Low strain-hardening in ferrite phase increases the stress on the pearlitic constituents
• Eventually pearlite becomes overstressed and transgranular cracks occur in the pearlite
• Cracks become too large to sustain the load
• Fast fracture occurs in the remaining metal ligaments
Mixed (Shear + Cleavage) Fracture
Brittle (Cleavage) Fracture
Fig. 2.12. The various processes by which fracture is initiated at or near the tip of a stopped crack or notch.
Cleavage Fracture
Mixed Mode Fracture
Brittle (cleavage) Fracture
Structure-Property Relationships Using Fractography

- Look for features on the fracture faces of broken tensile specimens
  - Stereomicroscopy
  - Scanning electron microscopy
Fracture Face of Tensile Bar
Ductile (Shear) Fracture
Brittle (Cleavage) Fracture
Mixed (Shear + Cleavage) Fracture
SUMMARY

• Fracture Path Considerations can be used to determine the optimum microstructure

• Pearlitic structures with bullseye ferrite exhibit higher elongations than fully pearlitic structures

• As ferrite levels increase, ductility increases

• When ferrite remains discontinuous, strength remains high

• As ferrite becomes more continuous, yield strength falls

• With further increases in ferrite content, pearlite becomes discontinuous

• Discontinuous ferrite ➔ higher strength and higher ductility
SUMMARY

- The yield strength of the pearlitic constituent may influence the amount of plasticity of pearlite and the overall ductility.
- Cleavage fracture occurs when the stress to produce cleavage in pearlite is below the bulk yield strength of pearlite.
FRED LINEBARGER

FRED GRADUATED FROM PITTSBURG STATE UNIVERSITY WHERE HE MAJORED IN FOOTBALL WITH A DOUBLE MINOR IN CAROUSING AND PHYSICS. ACTUALLY HE DID RECEIVE HIS MASTERS IN PHYSICS AND THEN RECEIVED HIS PhD IN PHYSICS FROM THE UNIVERSITY OF MISSOURI-COLUMBIA. HIS CAREER INCLUDED 10 YEARS IN MANAGEMENT AND/OR OWNERSHIP OF SMALL GRAY, DUCTILE AND ALLOYED IRON JOBING FOUNDRIES IN KANSAS CITY AND WICHITA. HE ALSO HAS BEEN THE GENERAL MANAGER AND BUSINESS GROUP MANAGER FOR CENTORR FURNACES/VACUUM INDUSTRIES IN NASHUA, NEW HAMPSHIRE. THESE COMPANIES WERE PRODUCERS OF ULTRA HIGH TEMPERATURE, CONTROLLED ATMOSPHERE FURNACES. FRED THEN SPENT 12 YEARS WITH ELKEM METALS (FORMERLY UNION CARBIDE) IN A VARIETY OF POSITIONS FROM PROJECT ENGINEER TO TECHNICAL MANAGER IN THE MARKET DEVELOPMENT DEPARTMENT. FRED JOINED MILLER & COMPANY AS DIRECTOR OF TECHNOLOGY IN MAY, 2001. HE HAS BEEN RESPONSIBLE FOR TECHNICAL SERVICE AND SUPPORT OF THEIR FOUNDRY ACTIVITIES IN NORTH AMERICA. HE HAS TAUGHT SEVERAL METALLUGY COURSES FOR THE AFS AND DIS.
Treatment Processes from a Supplier’s Perspective

Fred Linebarger
Miller and Company
The customer is always right.

- Under certain circumstances
- Up to a point
Partnering – It Really Can Work

- Composition of the alloy
- Particle sizing
- Alternative treatment ideas.
- Laboratory evaluations/customer experience.
EFFECT OF Mg IN NODULIZING ALLOY ON RECOVERY

MAGNESIUM RECOVERY IN IRON, PERCENT

MAGNESIUM IN NODULARIZING ALLOY, PERCENT
Silicon Added

Silicon input resulting from chosen alloy and process.
Rare Earths

- Ce, La, Balanced
- Level in the nodulizer
- For what purpose?
Other Ideas

- Mg, Ca ratio
  - Impact on Mg recovery
- Presence of Ba
  - At what level
  - For what purpose
  - In combination with what rare earths
Particle Size Distribution

- Smaller treatment ⇒
  - Finer particle size
- Inmold process
- Use of “fines”
Treatment Alternatives

- Inmold process
- Tundish
- Flotret
- To cover or not to cover (and with what)
Use Available Resources
PANEL – TREATMENT METHODS

“OPEN LADLE SANDWICH TREATMENT METHOD”

BRANDON RENEAU

BRANDON GRADUATED FROM THE UNIVERSITY OF MISSOURI-ROLLA IN 1997 WITH HIS BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. BRANDON’S CAREER STARTED AT INTERMET FOUNDRY IN DECATUR FOR 3 YEARS, THEN INTERMET HAVANA FOR 4 YEARS AND THEN MOVED TO CATERPILLAR – MAPELTON FOUNDRY AND HAS BEEN THERE FOR THE LAST 8 YEARS.

HE IS CURRENTLY A MEMBER OF THE AFS 5R COMMITTEE, AFS 5P COMMITTEE AND IS THE DIS RESEARCH COMMITTEE VICE CHAIRMAN. BRANDON HAS BEEN A PROACTIVE SUPPORTER OF THE AFS AND DIS RESEARCH BY CASTING SAMPLES AT CATERPILLAR. HE IS CURRENTLY THE PLANT METALLURGIST/MELTING GROUP MANAGER AT CATERPILLAR.
Open Ladle Sandwich Treatment

Brandon Reneau
Caterpillar, Inc.
Caterpillar - Mapleton Foundry

- 600 employees
- Produce engine components (Blocks, Heads, Liners, Brackets)
- Pour Gray, Ductile, CG iron
- Molds by Green Sand, Cold box, Airset, Furan
Types of Treatments at CAT

- Wire – focuses on large treatments
  - 21,500 lbs – 34,000 lbs
- Open Ladle – used for smaller treatments
  - 1,800 lbs – 6,000 lbs
Open Ladle Sandwich Treatment

• Ductile Iron
  – D45/12, D55/06, D70/03
  – Final Magnesium aim of 0.038%
  – Flywheel housings, Brackets, Liners

• Compacted Graphite Iron
  – 450 Mpa Ultimate, 320 Mpa Yield, 1% Elongation
  – Final Magnesium aim of 0.010%
  – Cylinder Heads
Open Ladle Sandwich Treatment - Basics

- Add alloy to ladle with or without a pocket
- Cover the treatment alloy with other material
- Tap iron from source into ladle
Open Ladle Sandwich Treatment - Comparison

- Methods are judged by Recovery
- Adding ways to control reaction improves Recovery
Open Ladle Sandwich Treatment - Keys

- Tap Temperature
- Tap speed
- Ladle design
- Pocket design
- Treatment alloy material
- Cover material
Open Ladle Sandwich Treatment - Keys

- Tap Temperature
  - Colder is better
  - Solubility of Magnesium is low
  - Magnesium boils at 2025 F; high vapor pressure at treatment temperatures
Open Ladle Sandwich Treatment - Keys

• Tap speed
  – Faster is better
  – Covers alloy before reaction starts
  – Ladle completely filled before reaction starts
Open Ladle Sandwich Treatment - Keys

• Ladle design
  – Height to diameter ratio = 2:1
  – Allows for efficient reaction
Open Ladle Sandwich Treatment - Keys

- Pocket design
  - Proper sizing, shape and location improves control of reaction
  - Sizing allows tight fit of alloy in pocket so iron can’t “seep” around or under to improve reaction control
  - Locate pocket out of direct contact of iron stream to control reaction
  - Requires consistent alloy addition; match volume of alloy needed
  - Use ratio of 2:1 (height to diameter)
  - Locate pocket under bottom of iron, no islands for homogenous treatment
Open Ladle Sandwich Treatment - Keys

• Treatment alloy material
  – Sizing makes dissolution easier
  – %Magnesium helps control reaction; less Mg improves recovery
Open Ladle Sandwich Treatment - Keys

- Cover material
  - Allows ladle to be filled before reaction starts; Mg specific gravity (1.74) vs. Fe (7.3) causes floatation of alloy
  - Use steel and other materials
Open Ladle Sandwich Treatment – Ductile Process

• Tap temp = 2750 F
• Tap speed is Melter operator dependent
• Well designed and placed pocket
  – Not able to have 2:1 cylinder
• Mg Recovery; Old = 50% New = 65%
Open Ladle Sandwich Treatment – Ductile Process
Open Ladle Sandwich Treatment – CG Process

• Tap Temp = 2650 F; Holding Furnace
• Tap speed controlled by Holding Furnace lift cylinders; our case is slow
• Well designed and placed pocket, low treatment temperature, use inoculant plus steel as cover
• Magnesium Recovery = 80%
Open Ladle Sandwich Treatment – CG Process
Open Ladle Sandwich Treatment – Quality Control

- Fade timer
- UT lug
- ATAS
- Chemistry button
Open Ladle Sandwich Treatment – Quality Control

Any Questions?
PANEL – TREATMENT METHODS

“INMOLD TREATMENT”

CESAR BRAGA

CESAR GRADUATED FROM THE FEDERAL UNIVERSITY OF MINAS GERAIS IN BELO HORIZONTE, BRAZIL WITH HIS BACHELORS IN METALLURGY. CESAR HAS BEEN AT AAROWCAST, INC. IN SHAWANO, WISCONSIN FOR 14 YEARS AND CURRENTLY IS THE VP OF TECHNICAL SERVICES.
Aarrowcast Inc.
Ductile Iron Inmold Process

Cesar Braga
V.P. Technical Services
Gating Sketch

INMOLD PRINCIPLE

- Pouring Rate
- Chamber Area
- Solution Factor

Solution Factor = Pour Rate/Chamber Area
Relationship between in-mold alloy addition (% of mold weight), solution factor and Magnesium content in the casting.
ADVANTAGES OF THE IN-MOLD PROCESS

• NO MAGNESIUM FADING, WHICH ALLOWS US TO USE LESS MAGNESIUM, REDUCING TENDENCY FOR SHRINKAGE AND CARBIDES.
• SUPERIOR NODULE COUNT DUE TO SHORT TIME BETWEEN TREATMENT/INOCULATION AND SOLIDIFICATION.
• NO POST INOCULATION REQUIRED.
• SILICON PICK UP ABOUT 0.50%, WHICH ALLOWS HIGHER %Si IN THE FURNACE (ABOUT 1.90%), BETTER UTILIZATION OF RETURNS AND IMPROVED LINING LIFE OF CORELESS ELECTRIC FURNACES.
• REDUCED USAGE OF FeSiMg ALLOY.
• NO INVESTMENT ON TREATMENT DEVICES.
• NO MAINTENANCE OF TREATMENT LADLES.
• LOWER TEMPERATURE LOSSES COMPARED TO OTHER PROCESSES, WHICH MEANS LOWER MELTING TEMPERATURE AND ENERGY SAVINGS.
• LESS PIGGING FROM POURING LADLES BECAUSE NO MAGNESIUM IS PRESENT.
• NO PROCESSING DELAYS RELATED TO IRON TREATMENT.
• POSSIBILITY TO TAILOR THE %Mg FOR PARTICULAR PART AND SECTION SIZE.
# Tensile Properties

(mold to mold consistency)

500# casting 1.25” wall

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial #</td>
<td>#001</td>
<td>#009</td>
<td>#017</td>
<td>#026</td>
<td>#033</td>
<td>#042</td>
<td><em>#050</em></td>
<td>#058</td>
<td>#066</td>
</tr>
<tr>
<td>Tensile kpsi</td>
<td>66.2</td>
<td>64.7</td>
<td>65.2</td>
<td>66.8</td>
<td>65.8</td>
<td>66.7</td>
<td>67.0</td>
<td>65.4</td>
<td>65.9</td>
</tr>
<tr>
<td>Yield kpsi</td>
<td>42.2</td>
<td>40.9</td>
<td>41.5</td>
<td>42.8</td>
<td>42.3</td>
<td>42.3</td>
<td>43.0</td>
<td>41.6</td>
<td>41.8</td>
</tr>
<tr>
<td>Elong. %</td>
<td>23.0</td>
<td>23.0</td>
<td>22.0</td>
<td>22.0</td>
<td>21.5</td>
<td>21.5</td>
<td>21.0</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Base %Si</td>
<td>1.58</td>
<td>1.55</td>
<td>1.53</td>
<td>1.54</td>
<td>1.53</td>
<td>1.54</td>
<td>1.56</td>
<td>1.52</td>
<td>1.51</td>
</tr>
<tr>
<td>Final %Si</td>
<td>2.15</td>
<td>2.13</td>
<td>2.05</td>
<td>2.16</td>
<td>2.08</td>
<td>2.14</td>
<td>2.15</td>
<td>2.09</td>
<td>2.13</td>
</tr>
<tr>
<td>Pickup %Si</td>
<td>0.57</td>
<td>0.58</td>
<td>0.52</td>
<td>0.62</td>
<td>0.55</td>
<td>0.56</td>
<td>0.57</td>
<td>0.63</td>
<td>0.58</td>
</tr>
<tr>
<td>%Mg</td>
<td>0.038</td>
<td>0.039</td>
<td>0.039</td>
<td>0.040</td>
<td>0.036</td>
<td>0.036</td>
<td>0.040</td>
<td>0.034</td>
<td>0.034</td>
</tr>
</tbody>
</table>

*From Casting*

<table>
<thead>
<tr>
<th>Top Left</th>
<th>Top Center</th>
<th>Top Right</th>
<th>Bottom Left</th>
<th>Bottom Center</th>
<th>Bottom Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile kpsi</td>
<td>61.3</td>
<td>61.6</td>
<td>61.4</td>
<td>62.1</td>
<td>61.0</td>
</tr>
<tr>
<td>Yield kpsi</td>
<td>40.8</td>
<td>40.9</td>
<td>41.0</td>
<td>41.1</td>
<td>40.9</td>
</tr>
<tr>
<td>Elong. %</td>
<td>19</td>
<td>21.5</td>
<td>22.5</td>
<td>20.5</td>
<td>20</td>
</tr>
</tbody>
</table>

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
Micros
1” Y BLOCK

100x
2 On Mold with 2 Chambers
4 On Mold with 2 Chambers
IN-MOLD TREATMENT REQUIRED PROCESS CONTROLS

• LOW BASE IRON SULFUR CONTENT (0.008 – 0.015%).
• CONSISTENT POURING RATE.
• POURING TEMPERATURE (IDEALLY 2525 TO 2650F).
• CONSISTENT MOLD WEIGHT (RUN OUTS AND RUN INS NOT TOLERATED).
• IN-MOLD ALLOY CONSISTENT WEIGHT IN THE CHAMBER. SCALE INTERLOCKED WITH THE LINE.
• IN-MOLD ALLOY CHEMISTRY AND SIZING (DENSITY) CONSISTENCY.
• MISTAKE PROOF SYSTEM TO MAKE SURE THE IN-MOLD ALLOY HAS INDEED BEEN INTRODUCED INTO THE REACTION CHAMBER. (CAMERA SYSTEM)
• 100% INSPECTION BY ULTRASONIC OR RESONANT FREQUENCY IS RECOMMENDED.
Alloy Verification Camera
Unloading Tube
Axles
Track Drive Components
Track Drive & Suspension
Coach Bus
Valves and Fittings

8” Water Valves

Hydrant Bonnets

Hydrant Stands
Valves

Swing Check Valve  Flow Control Valves  Dry Control Valves

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

500 and 1,000 pound practice bomb housings.
Suspension (ADI)
Tactical Vehicles

Front Axle Housings

Rear Axle Housings
Wind Energy
Tractor Frame Assembly

Standard Axles

- Main Frame
- 12 Bolt
- Class 5
- Class 4.5

Suspension Axles

- Main Frame
- 12 Bolt Susp
- Class 5 Susp
QUESTIONS?
PANEL – TREATMENT METHODS

“FISCHER CONVERTER TREATMENT PROCESS”

LARRY CARMACK

LARRY GRADUATED WITH HIS BACHELOR OF SCIENCE IN METALLURGICAL ENGINEERING IN 1967 FROM THE MISSOURI SCHOOL OF MINES, NOW THE MISSOURI UNIVERSITY OF SCIENCE & TECHNOLOGY. HE STARTED HIS CAREER AT THE JOHN DEERE DUBUQUE FOUNDRY IN 1966 AS A SUMMER STUDENT.

HE WAS HIRED FULL TIME IN JANUARY OF 1967 AS METALLURGICAL ENGINEER RESPONSIBLE FOR CUPOLA MELTING METALLURGY AND PROCESS ENGINEERING IN SAND AND CORE CONTROL. IN 1973 HE TRANSFERRED TO JOHN DEERE WATERLOO FOUNDRY AS SENIOR METALLURGIST. DURING HIS JOHN DEERE CAREER LARRY HELD MANY DIFFERENT POSITIONS WHICH INCLUDED MELTING GENERAL SUPERVISOR, MANAGER OF PROCESS ENGINEERING, QUALITY MANAGER AND TECHNICAL DIRECTOR. IN 2001 LARRY RETIRED FROM JOHN DEERE. FOLLOWING HIS RETIREMENT HE DID RETURN TO JOHN DEERE’S FOUNDRY AS A CONSULTANT.

IN MARCH 2003 LARRY JOINED THE GREDE FOUNDRY ST. CLOUD, MN AS MANAGER OF METALLURGY, WHERE HE CONTINUES TODAY. LARRY BRINGS 47 YEARS OF METALLURGICAL EXPERIENCE.
Grede - St. Cloud
Fischer Converter

Larry Carmack
Grede - St. Cloud
GREDE - ST. CLOUD FISCHER CONVERTER
MELTING DEPARTMENT FURNACE

- 2 – 12.5 MT coreless medium frequency 9000 KW induction furnaces
- 1 - 65 ton channel induction furnace
Pro’s and Con’s for Georg Fischer Convertors

Pro

• High Silicon returns are not a factor due to pure magnesium and cover material is not used which may contain silicon units in other processes.
• One step treatment and desulfurization.
• Mixing of alloys is very uniform.

Con

• Proprietary inoculation is usually required and when using automatic pouring In-stream Inoculation is required.
• Prep of alloy chamber is a must and needs to be consistent.
• Equipment is larger.
Foundry Control

Anatomy of a +GF+ Converter

- Alloy + iron
- Pure Mg + Flux
- Converter tilts, iron reacts with Mg → ductile iron
- Treated iron transferred to holding furnace

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
Convertor Filled from 65 Ton Holding Furnace

Pretreatment
Silicon and Pretreatment Additions
Delivery of 10,000 Pounds of Untreated Iron
Bulk Pure Magnesium
Alloy and Magnesium Weigh Station
Magnesium Chamber Opened for Mag Addition
Magnesium Chamber Plate

Six O’clock Hole
Filling Alloy Pocket
Cardboard Seal
Flux and Chamber Seal
Soaking Station

Salt

Cardboard
Seal
Soaking
Pocket Lid Torqueing
Alloy Addition
Treatment Cycle
Tapping Treated Iron
Slag Clean Cycle
Convertor Cleaning
PROCESS CONTROL
St. Cloud DISA Week Production Results

Time Series Plot of Magnesium

Worksheet: Disa Production.MTW; 5/2/2013 1:38:32 PM
Daily % Magnesium Control

Boxplot of Magnesium

Worksheet: Production Dis.MTW; 5/16/2013 10:33:45 AM

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
St Cloud Disa Magnesium
Week Production Results

Process Capability of Magnesium

Worksheet: Disa Production.MTW; 5/2/2013 1:34:25 PM
Holding Furnace Sulfur

Histogram of Sulfur

Normal

Mean 0.01506
StDev 0.001665
N 119

Worksheet: DIS Week 18.MTW; 5/15/2013 4:40:26 PM
Final Silicon Control

Process Capability of Silicon

- **Process Data**
  - LSL: 2.3
  - Target: \(*\)
  - USL: 2.5
  - Sample Mean: 2.40598
  - Sample N: 94
  - StDev(Within): 0.0185198
  - StDev(Overall): 0.0236761

- **Potential (Within) Capability**
  - Cp: 1.80
  - CPL: 1.91
  - CPU: 1.69
  - Cpk: 1.69

- **Overall Capability**
  - Pp: 1.41
  - PPL: 1.49
  - PPU: 1.32
  - Ppk: 1.32
  - Cpm: \(*\)

- **Observed Performance**
  - PPM < LSL: 0.00
  - PPM > USL: 0.00
  - PPM Total: 0.00

- **Expected Performance**
  - Exp. Within Performance
    - PPM < LSL: 0.01
    - PPM > USL: 0.19
  - Exp. Overall Performance
    - PPM < LSL: 3.80
    - PPM > USL: 35.76
    - PPM Total: 39.56

Worksheet: Wk19 Production.MTW; 5/15/2013 4:45:13 PM
PANEL – TREATMENT METHODS

“TUNDISH TREATMENT FOR DUCTILE IRON”

JAY ZINS

JAY GRADUATED IN 1976 FROM MUSKEGON COMMUNITY COLLEGE. HE HAS WORKED IN THE FOUNDRY INDUSTRY FOR 39 YEARS IN VARIOUS CAPACITIES. HE IS CURRENTLY A MEMBER OF THE DIS RESEARCH COMMITTEE. JAY IS CURRENTLY THE PROCESS CONTROL MANAGER AT DOTSON IRON CASTINGS IN MANKATO MINNESOTA.
Tundish Ladle Treatment at Dotson Iron Castings

E. Jay Zins
Dotson Iron Castings

DIS Annual Meeting, June 2, 2011
Dallas, Texas
Why tundish ladle treatment makes sense at Dotson

- Robust and reliable treatment method
- Flexible treatment size based on mold availability, and casting size
- Metal chemistry and solidification characteristics verified before pouring metal
- Consistent results
Historical Progression

Intermittent Cupola melt

Tap and plug operation

Ductile treatment with plunging bell and nickel mag alloy

DIS Annual Meeting, June 5-7, 2013
Indianapolis, IN
Porous Plug Treatment

- Intermittent Cupola melt
- Tap and plug operation
- Desulfurize with Calcium Carbide stirred with nitrogen
- Treat desulfurized iron with nickel mag to make ductile iron stirred by nitrogen
- Verify effectiveness of treatment by microstructure
Enter Induction Melting and Tundish Ladle Treatment

Melt in with chemistry closer to final desired chemistry
Ability to use Mag Ferro Silicon for treatment due to tundish ladle pocket
Sealed ladle improved magnesium recovery
Ductile treatment verified by microstructure
Three piece ladle design for quick disassembly, repair, and reassembly
Improvements

- Need to add insulation to hand-lined ladles
- Changed to one piece insert
- Ended run outs, broken dams, hotspots
- Decreased heat transfer rates
Ladle Redesign

Changed to two piece tundish ladle design with precast insert

Changed ladle pocket design to be more robust

Used funnel to assure alloy in right spot and eliminate popping of alloy at transfer

Increased tap rate by resizing tap hole and improved recovery

Verify treatment by thermal analysis before pouring
Factors that can influence the MgFeSi addition to a ductile iron ladle treatment process.
Questions?

For further information contact:

E. Jay Zins  
Process Control Manager  
Dotson Iron Castings  
Email: jzins@dotson.com  
Ph. 507-345-5018 ext. 228
JOHN MCGOLDRICK

JOHN GRADUATED FROM OHIO STATE UNIVERSITY IN METALLURGICAL ENGINEERING. HIS FIRST JOB WAS AT USS PIPE MILL IN LORAIN, OHIO. THEN JOHN ENTERED THE FOUNDRY INDUSTRY IN THE LAB AT STERLING FOUNDRY IN WELLINGTON, OHIO IN 1984. THERE HE SERVED AS LAB TECHNICIAN, MOLDING SUPERVISOR, MELTING SUPERVISOR AND THEN QUALITY CONTROL MANAGER MAKING IRON CASTINGS TO 30,000 POUNDS.

Magnesium Cored Wire Nodularization
Nodularizing w/ Mg Cored Wire

- Hodge produces ductile iron castings from 1 to 100 tons.
- Ladles range from 10T to 40T, frequently multiple ladles pour into one mold.
Treatment History at Hodge

- Treating large amounts of iron in pouring ladles.
- Porous plug treatment was problematic.
- Erratic recovery due to alloy sizing.
Treatment History at Hodge

- Large volumes of Mg5%FeSi needed – bucket loader sometimes used to add alloy to ladle.
- Treating in open ladles filled foundry with MgO dust.
Treatment History at Hodge

- Drossy.

- Chunky graphite difficult to control due to RE contained in MgFeSi.
White Cloud Blankets Greenville Neighborhood!

- 5 ladle treatment event caused headlines (and headaches)!
- DEP acknowledged no hazard, but we had to eliminate the nuisance emissions.
Parameters of the cored wire treatment practice

- Wire feed rate.
- Guide tube geometry.
- Treatment temperature.
- Sulfur of the base iron.
Parameters of the cored wire treatment practice

- Geometry of the treatment ladle - taller iron column results in better magnesium recovery.
- Mg content and chemical composition of the cored wire.
Mg Cored Wire Benefits

- Improved recovery percentage vs. plug.
- Flexible - Batch sizes from 500lbs to 40 tons can be treated.
Mg Cored Wire Benefits

- Iron with sulfur levels of up to 0.09% can be treated in a one-step operation without prior desulfurization.
Mg Cored Wire Benefits

- Treatment station can be strategically located in the foundry.
Mg Cored Wire Benefits

- Environmentally friendly because of fume control at the treatment station.
Mg Cored Wire Benefits

- Available with or without RE.
- Very easy to custom blend chemistry.
- Ergonomically friendly (no buckets).
Mg Cored Wire Benefits

- Close control of final magnesium, resulting in improved reproducibility.
- Exact wire (alloy) addition, which can be fully automated.
Mg Cored Wire Benefits

- Separate RE additions can be made (pretreatment).
- Inoculant wires are available.
Mg Cored Wire Benefits

- Lower alloy additions result in lower silicon additions ideal for low temperature impact properties.
Mg Cored Wire Benefits

- A “high” base furnace silicon is possible, extending the lining life of the electric furnace.
Mg Cored Wire Benefits

- Lower temperature loss vs. other practices.
- No cover steel needed.
- Less slag, dross = cleaner iron.
Mg Cored Wire Drawbacks

- Longer treatment time than pour-over methods.
- Mechanical failures.
- Collapsed wire.
Questions
MEETINGS - BUSINESS - PEOPLE

MEETINGS

BUSINESS

CASE STUDY

International Foundry X

Foundry: Green sand & No-Bake foundry, pouring gray and ductile iron, producing large castings up to 10 ft in diameter.

Project: Testing of furnaces with and without Redux EF40L Flux. Furnaces had been averaging 253 heats per lining without Redux EF40L.

Results: A total of 411 heats were tapped from the furnace before it required a reline, resulting in an increase of 62% in refractory life.

Foundry X found that continual Redux additions resulted in the following:

- Reduced Electrical Costs – elimination of superheating due to build-up!
- Reduced Labor Costs – elimination of chipping and patching repairs!
- Reduced Material Costs – measured a 62% increase in lining life!
- Increased Melting Efficiency – reduced slag build-up of linings!
- Increased Production – consistent furnace capacity throughout an extended service campaign!

How much is slag build-up costing your foundry?

Click here to learn more about the Foundry X Case Study

US Patent No 7,618,473B1

A mild fluoride-free, chloride-free flux. Redux EF40L is used successfully to combat most build-up conditions in ferrous melt and pouring conditions.

To find out how much Redux can save you...
Cast-Fab Technologies, Inc. to Supply Large Castings for Prime Defense Contractor

April 30, 2013

Cincinnati -- Cast-Fab Technologies, Inc. (Cast-Fab) has entered into a multi-year agreement with a prime defense contractor to supply large castings for the military. Cast-Fab expects to produce more than 12,000 tons of iron over the length of the project. Details of the project must remain confidential.

Cast-Fab is one of the nation's premier providers of gray and ductile iron castings, and metal fabrications. The company anticipates it will be adding more than 20 new jobs at its manufacturing facility located in the Oakley neighborhood of Cincinnati over the life of the contract.

"Quite simply, Cast-Fab's stated purpose is to reaffirm America's manufacturing excellence in everything we do. I can think of no better way to help us fulfill our purpose than in support of our nation's military," said J. Ross Bushman, Cast-Fab's president and CEO. "The timing of this project could not have been better given this is the company's 25th anniversary under my family's ownership. It also gives us a solid long-term customer relationship that can help fuel even more growth."

Cast-Fab Technologies is an ISO 9001:2008 certified company responsible for the manufacture and distribution of a broad family of metals-related products including iron castings up to 80,000 pounds as well as heavy plate and sheet-metal fabrications. Cast-Fab also owns the Security Systems Equipment (SSE) and Collier brands in the bank equipment market and the Coldwell-Wilcox Technologies brand in the water and waste-water treatment markets. All products produced by the Cast-Fab family of companies are designed, engineered and manufactured in the United States at its Cincinnati facility. For more information visit www.cast-fab.com.

For more information, please contact:
Gary Powers
Director of Sales and Marketing
Cast-Fab Technologies, Inc.
Phone: 513-758-1081
Email: gpowers@cast-fab.com
Web: www.cast-fab.com

Halberg expands Compacted Graphite Iron capacity for high volume series production

• New System 3000 installation at Halberg Leipzig foundry
• Upgrade of existing SinterCast System 2000 to full System 3000 standard
• High volume series production for commercial vehicle cylinder blocks and heads

[Saarbrücken and Stockholm, 13 May 2013] - Halberg Guss, one of the world's leading automotive foundry groups, has ordered an upgrade of its existing CGI process control system and an additional new System 3000 from the Swedish process control specialist SinterCast. The commissioning is scheduled for summer 2013, coinciding with the installation of increased liquid metal holding capacity at the Leipzig foundry. The two System 3000 installations are required to increase Halberg's CGI capacity and productivity in advance of increased production demand. The Halberg Leipzig foundry has been in production of CGI engine components for commercial vehicles since 2010 and currently has two heavy-duty CGI cylinder blocks in series production. The investment in increased CGI capability has been made to meet the potential near term demand for more than 15,000 tonnes per year of CGI commercial vehicle components.

"Building on our heritage as the first foundry in the world to support the series production of a Compacted Graphite Iron cylinder block, beginning with the Audi 3.3 litre V8 in 1999, and our CGI series production experience in both our Brebach and Leipzig foundries, we have made this strategic investment to support the needs of our customers and to position Halberg as one of the world's leading CGI providers" said Mr Matthias Schwabbauer, Managing Director of Halberg Guss.

"We are pleased that Halberg's successful CGI series production experience has led to this opportunity for repeat business, providing a clear endorsement of our technology and technical service" said Dr. Steve Dawson, President & CEO of SinterCast. "Halberg's commitment to increased CGI capacity provides another important indication of the growing demand for CGI, both in the passenger vehicle and the commercial vehicle markets."

For more information:

Mr. Heinrich Emanuel
Halberg Guss GmbH
e-mail: heinrich.emanuel@halberg-guss.de

Dr. Steve Dawson
SinterCast AB (publ)
e-mail: steve.dawson@sintercast.com

Halberg Guss GmbH is the European market and technology leader for the development and production of cast iron cylinder blocks and heads for passenger
SinterCast is the world's leading supplier of process control technology for the reliable high volume production of Compacted Graphite Iron (CGI). With at least 75% higher tensile strength, 45% higher stiffness and approximately double the fatigue strength of conventional grey cast iron and aluminium, CGI allows engine designers to improve performance, fuel economy and durability while reducing engine weight, noise and emissions. The SinterCast technology is used for the production of more than 50 CGI components, ranging from 2 kg to 17 tonnes, all using the same proven process control technology. The end-users of SinterCast-CGI components include Aston Martin, Audi, Cameron Compression, Caterpillar, Chrysler, DAF Trucks, Ford, Ford-Otosan, General Electric Transportation Systems, General Motors, Hyundai, Jaguar, Jeep, Kia, Lancia, Land Rover, MAN, Navistar, Porsche, PSA Peugeot Citroën, Renault, Rolls-Royce Power Engineering, Scania, Toyota, VM Motori, Volkswagen, Volvo and Waukesha Engine. The SinterCast share is quoted on the Small Cap segment of the NASDAQ OMX stock exchange (Stockholmsbörsen: SINT). For more information: www.sintercast.com

Press Release

New Chairman of the Supervisory Board of ASK Chemicals

Hilden, July 17, 2013 - Following a decision of the supervisory board of ASK Chemicals GmbH, Peter Steiner (53), has been named the new Chairman of the supervisory board. He has been a member of the board since the past year. In this role he follows Dr. Hans Juergen Wernicke (63).

Peter Steiner is a self-employed auditor and tax advisor. During the course of his professional career he has not only worked in senior management positions for well known investment and consulting companies, but also served as a management board member for industrial companies such as the GE Group AG and the Dyckerhoff AG.

Dr. Hans Juergen Wernicke has resigned his position as Chairman of the supervisory board. As a member of the management board of the Süd-Chemie AG, he was responsible, among other things, for the foundry consumables business. Since the acquisition of the Süd-Chemie AG by Clariant SE, he has served as a consultant for the Clariant management board. “Dr. Hans Juergen Wernicke has been instrumental in shaping the current ASK Chemicals, we are thankful for his long-term service to our company. With Peter Steiner our supervisory board will again be led by an experienced industry manager. We are looking forward to working with him in the future,” comments Stefan Sommer, the company’s CEO.

Indiana Foundry Records Two Years Without a Lost Time Accident

Bremen Castings Celebrates Two Years of Safety on May 30th

Foundries and machine shops have made great strides in improving safety over the last decade and one Indiana foundry is helping lead the way with its impressive milestone. On May 30th, Bremen Castings Inc. (BCI) in Bremen, Indiana reached two full years without a lost time accident. A lost time accident is defined as an occurrence that resulted in a fatality, permanent disability or lost time from work of one day or shift and possibly more.

President JB Brown notes, “We’ve implanted strategies and procedures to make sure that each and every employee is accountable for each others safety while at work,” says Brown. “We require all employees to file ‘near miss’ reports if they notice something is amiss. For example, if a cable is in the way or there is a slippery step, the employee is responsible for moving it and filing a report to inform upper management of the issue.” BCI’s last lost time accident occurred two years ago and required their employee to miss one full shift of work. Since then the foundry and machine shop have gone incident free.

BCI is working to establish a zero incident culture, and has already reached the 1,000,000 man hours lost work time milestone in addition to various awards. JB Brown is available to speak about this milestone and their safety initiatives within Bremen Castings. Please contact me to schedule an interview.

About Bremen Castings Inc.: this family owned foundry and machine shop was founded in 1939 in Bremen, Indiana. With over 70 years of experience, BCI is known worldwide for its quality gray and ductile iron machined castings. As a leader in the machining & foundry industry, Bremen houses its own machine shop & foundry. Keeping up with technology is high on the priority list with the Brown family as the company continually reinvests in new equipment for production, environmental, and automation improvements. BCI uses 92% recycled ferrous material to produce world class gray and ductile iron castings for our world market. For more information about Bremen Castings Inc. please visit their website at www.bremencastings.com

Claudia Maj | Publicist
Empower Public Relations
625 N. Michigan Avenue- Suite 2500
Chicago, IL 60611
O: 312.854.8816
C: 312.912.2706
cmaj@empowerpr.com
www.empowerpr.com

Applied Process Inc. Expands to Ensure Continued Quality

LIVONIA, Mich. June 7, 2013 – Shared office space and the sound of building construction will soon be a thing of the past at the Applied Process (AP) plant in Livonia, Mich., as a recent round of renovations come to an end.
The decision to pursue renovations was made based on increasing levels of incoming material to be heat treated. Business levels demanded more, and smarter, use of real estate at AP, including warehouse and office space. Through permits with the city, AP was able to build out closer to the road, bringing the final total of new and renovated warehouse space to 5500 sq. ft.

To make room for the extra office space, the old offices were moved from their original location. The new offices include a total of 3675 sq. ft. of new and renovated space.

AP also included a designated formal classroom space in their plans. “The classroom has served as a temporary home for our office staff,” stated Chris Bixler, Principal Process Engineer. “When everything is complete, we will have a great space that can be used for educational purposes.” Whether it is used as conference space, for employee education programs or for future AP University events, the new space will allow AP to continue to train innovative industry leaders.

Modifications were also made to the plant that directly affect the workday of Applied Process employees. “Not only do we want to make sure we are able to be everything our customers need,” said Bixler, “but we want to provide a quality work environment for our employees.” Updates that measurably cut down on noise and improve temperature regularity are among a few of the improvements.

These changes closely follow updates made to the plant in Oshkosh, Wisc., where AP installed the world’s largest integral atmosphere batch furnace. This furnace allows for revolutionary heat treatment of large components or for greater throughput of current part designs. This is a powerful factor in preventing capacity constraints going forward. “We are always working to ensure that Applied Process remains a world class company,” explained Bixler. “The added efficiency that was gained from these projects will only help AP moving into the future.”

**About Applied Process:**

Applied Process Inc. is a worldwide family of commercial heat treats specializing in the Austempering process. Applied Process makes iron and steel parts tougher, stronger, lighter, quieter and more wear resistant and is the world leader in the processing of Austempered Ductile Iron (ADI). For further information contact Vasko Popovski at vpopovski@appliedprocess.com or visit Applied Process’ website www.appliedprocess.com.

Photo Editor Reference: High-res photos available upon request.