Session 2: Iron and Steel making Processes

Keynote Address: Prof Kazuki Morita
Development of New Application of Iron- and Steelmaking Slags in Japan

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Contents

Introduction

Generation of Iron- and Steelmaking Slags in Japan

An Example of Fundamental Research
  - Resource Recovery from Steelmaking Slags-

Activities of ISIJ Research Groups on Slag Utilization

Recent Topics on the Utilization of Slags
Iron and Steel Slag Products and Production Process

Nippon Slag Association (http://www.slq.jp/e/slag/process.html)

BF Slag (Ironmaking Slag)

Steelmaking Slag
Uses of Iron- and Steelmaking Slags in FY2012

Nippon Slag Association  (http://www.slg.jp/e/statistics/index.html)

BF Slag
24,639 kt
(81,918 kt-HM)

Converter Slag
11,036 kt
(82,846 kt-Steel)

EAF Slag
2,726 kt
(24,458 kt-Steel)

Raw Materials
0.5%
Concrete Aggregate
5.3%
Cement
47.3%
Others
3.7%
Land Filling
0.5%
Recycling
6.6%
Road
19.5%
Soil Improvement
1.3%
Civil
15.4%

Recycling
Land Filling
BF Slag
Converter Slag
EAF Slag
Cement
Concrete Aggregate
Raw Materials
Others

2013 International Sustainability Symposium
SMaRT@UNSW
Rocky-Shore Denudation (ISOYAKE)

Declines the fish catches in Japan.

HOKKAIDO

TOYAMA
Benchmark Test of Steelmaking Slag Utilization around Japanese Coastal Area

- Carbonated Solid of SM Slags
- SM Slags + Organic Acid
- Combination
Microwave Treatment for Metal Recovery
Interaction between Microwave and Materials

(A) ABSORBER (Lossy insulator)

(B) TRANSPARENT (Low loss insulator)

(C) OPAQUE (Conductor)

(B)+(C) ABSORBER (Mixed)

Fe and P Recovery by Microwave Carbothermic Reduction (Endothermic)

\[
(\text{FeO}) + C(s) = \text{Fe}(l) + \text{CO}(g) \\
(\text{P}_2\text{O}_5) + 5C(s) = 2\text{P} + 5\text{CO}(g)
\]
Example of Slag Heating Behavior ($C_{eq.} = 1.5$)

![Graph showing temperature vs. processing time for a slag heating behavior example with a carbon equivalent of 1.5. The slag composition is 45CaO-35SiO$_2$-20Fe$_2$O$_3$.](image-url)
Carbon Equivalent vs Recovery Ratio and Fe Content in Slag

![Graph showing the relationship between Carbon Equivalent and Recovery Ratio and Fe Content in Slag.]

**Fig.** Particles of Fe-C-P alloy reduced from slag by microwave treatment. (Processing time = 7min, Carbon equivalent = 1.5)
Carbon Equivalent vs Phosphorus Contents in Slag and Metal
Material Flow of Slag Resurrection

- Raw Mater.
- B F
- Cement
- Clinker
- Fertilizer
- De-Si
- Fe-C
- SiO₂
- Fertilizer K₃PO₄
- Phosphorus Extraction
- De-P
- CaO based Slags
- Microwave Carbothermic Reduction
- BOF or Hot Metal Treatment
- Fe
- P₂
- Fe-Csatd.
- Metals
- K₂CO₃ Flux
- CaO-SiO₂ Slags
- Microwave Carbothermic Reduction
- CaO-SiO₂ Slags
Research Groups on Slags Established in Iron and Steel Institute of Japan –1–

1. 1977–82 Fundamental Research Group on the Effective Utilization of Iron and Steelmaking Slags


4. 1999–02 Research Group on Enhancement of Photosynthetic CO$_2$ Fixation by Marine Phytoplankton with Steelmaking Slag as a Nutrient Source

5. 2000–03 Research Group on Slag Utilization for Prefabricated Structure in Upgrading Urban Infrastructure
If 2.86 Mt of steelmaking slag is dispersed in a subpolar zone of 1082 km x 1082 km in a year, 10% of CO$_2$ generation from Japan can be cancelled.

7. 2010–12  Innovative Program of ISIJ for Advanced Technology: Utilization of Steelmaking Slag as a Rehabilitation Material for Coastal Environment

8. 2010–     Forum on New Functions of Iron and Steelmaking Slags

9. 2012–14  Innovative Program of ISIJ for Advanced Technology: Recovery of Paddy Field Damaged by Tsunami Caused by Great Eastern Japan Earthquake Using Steelmaking Slag
Research Group in ISIJ:
Recycling of Slag by “Hydrothermal Slag Chemistry”
(Prof. T. Tanaka, Osaka Univ.)

<table>
<thead>
<tr>
<th>Ia</th>
<th>IIa</th>
<th>IVb</th>
<th>Vlb</th>
<th>VIIb</th>
<th>VIII</th>
<th>Ib</th>
<th>IIb</th>
<th>IIIa</th>
<th>IVa</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{H}_2\text{O} )</td>
<td>H</td>
<td>Eco-friendly</td>
<td>Li</td>
<td>Na</td>
<td>Mg</td>
<td>MgO</td>
<td>Cr</td>
<td>Mn</td>
<td>Fe</td>
</tr>
</tbody>
</table>

Basic Oxides
Cutting Network

Slag
Acidic Oxide
Network -former

Controlling Slag Property by using \( \text{H}_2\text{O} \)

Hydrothermal reaction

Phase Diagram of \( \text{H}_2\text{O} \)

Slag powder

Advanced ceramic materials
Microwave-Hydrothermal Process

Fig. The system concept for microwave-hydrothermal experiment
Mechanism of Hydrothermal Reaction under Microwave Irradiation

Fig. Increase of temperature with time in microwave-hydrothermal system

BF slag → C-S-H and Tobermorite

Water
Slag
MW
Film of H_2O

7. 2010-13  Innovative Program of ISIJ for Advanced Technology: Utilization of Steelmaking Slag as a Rehabilitation Material for Coastal Environment

8. 2010-  Forum on New Functions of Iron and Steelmaking Slags

9. 2012-14  Innovative Program of ISIJ for Advanced Technology: Recovery of Paddy Field Damaged by Tsunami Caused by Great Eastern Japan Earthquake Using Steelmaking Slag
Utilization of steelmaking slag as a rehabilitation material for coastal environment

Supported by ISIJ (2010 Oct. – 2013 Sept.)

1: Dissolution of various elements into sea water: Fe, P, Ca, Si
2: Absorption of various elements into seaweed
3: Enhancement of growth of seaweed: Ferrous ion
4: Absorption of CO$_2$ by seaweed

Target: Technological development of effective utilization of steelmaking slag in coastal environment

0.65-22 CO$_2$ Mt/y
Research Groups on Slags Established in Iron and Steel Institute of Japan -2-


7. 2010–13  Innovative Program of ISIJ for Advanced Technology: Utilization of Steelmaking Slag as a Rehabilitation Material for Coastal Environment

8. 2010–  Forum on New Functions of Iron and Steelmaking Slags

9. 2012–14  Innovative Program of ISIJ for Advanced Technology: Recovery of Paddy Field Damaged by Tsunami Caused by Great Eastern Japan Earthquake Using Steelmaking Slag
Innovative Program of ISIJ for Advanced Technology:

Recovery of Paddy Field Damaged by Tsunami Caused by Great Eastern Japan Earthquake Using Steelmaking Slag

Prof. Kitamura et al.
Tohoku University
Tsunami came up along the Kitakami River. A few ten centimeter of Tsunami came into the rice fields. Tsunami deposit was 1 cm.

7. 2010–13 Innovative Program of ISIJ for Advanced Technology: Utilization of Steelmaking Slag as a Rehabilitation Material for Coastal Environment

8. 2010– Forum on New Functions of Iron and Steelmaking Slags

9. 2012–14 Innovative Program of ISIJ for Advanced Technology: Recovery of Paddy Field Damaged by Tsunami Caused by Great Eastern Japan Earthquake Using Steelmaking Slag
In October 2010, the forum was established with the aim of pursuing the new utilization way of the iron– and steelmaking slags.

- Reviewing the researches related to the new functions of slags.
- Promoting opinion exchanges among various groups (producers and consumers) through symposiums to promote the utilization of slags.
- Establishing a national project.
The First ISIJ–Tohoku Agricultural Research Organization Meeting
(January 25–26, 2012 @ Kisarazu and Kimitsu) (Morioka, Soma)

The Second ISIJ–Tohoku Agricultural Research Organization Meeting
(July 12–13, 2012 @ Kisarazu and Kimitsu)
The Third ISIJ–Tohoku Agricultural Research Organization Meeting
(June 26–27, 2013 @ Hirosaki, Kuroishi, Iwate-machi,)
19 March, 2013  Tokyo

Symposium

Utilization of Steelmaking Slags for Recovery from the Damage by the Great East Japan Earthquake and for the Coastal Environment

Organized by Iron and Steel Institute of Japan
Co-sponsored by Ministry of Economy, Trade and Industry
Only steelmaking slag can be used in a high pH conditions.
Utilization of Steelmaking Slags for Recovery from the Damage by the Great East Japan Earthquake

Rice fields are still flooded even after 2 months. (May, 2011)

Soma, FUKUSHIMA
Strawberry farm was 3km far from the coast.

The Tsunami deposit was 10cm thick.
The recovered Strawberry House
Supporting Project by Tokyo Agricultural University
Prof. Itsuo GOTO

Elimination of Radioactive Effect

Desolination

Fukushima No. 1 nuclear power plant
The Initial Situation of Tested Rice Field Damaged by Tsunami
Harvested Rice after 2 Years Absence

Leaf and Stem

Soil

Detection Limit

Radioactive Cs Content

<table>
<thead>
<tr>
<th>斑料</th>
<th>放射性Cs</th>
<th>検出限界値</th>
</tr>
</thead>
<tbody>
<tr>
<td>134</td>
<td>137</td>
<td>134 137</td>
</tr>
<tr>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D. 9.3</td>
</tr>
<tr>
<td>表土</td>
<td>294 451</td>
<td>745 15.2</td>
</tr>
<tr>
<td></td>
<td>14.1</td>
<td></td>
</tr>
</tbody>
</table>
Due to the slag treatment, radioactive Cs has decreased by half!

**Tested Field**

<table>
<thead>
<tr>
<th>Slag Addition</th>
<th>pH(H2O)</th>
<th>Yield</th>
<th>Total Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.5</td>
<td>482kg/10a</td>
<td>29.3 Bq/kg</td>
</tr>
</tbody>
</table>

**Reference**

<table>
<thead>
<tr>
<th>No Addition</th>
<th>pH(H2O)</th>
<th>Yield</th>
<th>Total Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.0</td>
<td>414kg/10a</td>
<td>58.2 Bq/kg</td>
</tr>
</tbody>
</table>

pH 7.5 is far beyond the common value for wet-rice cultivation!
On the Newspaper of October 1, 2013
Success in the recovery of rice field damaged by Tsunami using steelmaking slags

NSSMC I&S Slag

Effective
Recent Endeavour by NSSMC in Slag Utilisation around Port District

Disaster Prevention

Roads & Lands

Underwater Forest

Sea Wall

Waste Depository

Embarkment

Treatment of Tsunami Deposit

Soil Stabilisation

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Key Policy for the Environmental Utilisation of Slags

Excess expectation as functional materials is NG!

Physical effect
  Utilisation as a bulk material

Chemical effect
  Utilisation for soil improvement

Problems to be solved for promotion
  Barriers among the following ministries, etc.
  - Ministry of Economy Trade and Industry,
  - Ministry of Land, Infrastructure, Transport and Tourism,
  - Ministry of the Environment
  - Ministry of Agriculture, Forestry and Fisheries
Session 2: Iron and Steel making Processes

Paul O’Kane
Environmentally sustainable EAF steelmaking through the introduction of recycled polymers

UNSW Sustainability Symposium

October 2013
Introduction

- The Rubber and Plastics Waste Situation
- Steelmaking Context
- Polymer Injection Technology
  - Benefits of Foaming Slag
  - Cost and Environmental Benefits of Polymer Injection Technology
- Steel Plant Results
- Engineered Charge Carbon
- Who is Arrium / OneSteel
Win for Steelmaking and a Win for the Environment

- Lower raw material cost
- Reduction in power on time
- Reduced quantity of injectant material required
- Improvement in yield

This technology is environmentally sustainable. CO2 emissions are reduced through lower electricity consumption and polymers that would be usually be diverted into landfill are recycled to value-added steel products.
Tyre End of Life Stream - Australia

66% of tyres have no current end of life use

Source
- Manufactured
- Imported
- Used Tyres

Export 18%
- 67% to Vietnam

Recycled 16%
- Reprocessed
- Tyre Derived Fuel

Waste Stream 66%
- Landfill
- Illegally Disposed

48.5 million EPU of tyres entered the waste stream in 2009-10. Up 14% on the previous year

Source: Study into domestic and international fate of end-of-life tyres – Final Report (Hyder Consulting Pty Ltd – 17/5/2012)
Steelmaking Context

- Steel is manufactured in two different types of facilities:
  - Integrated Mills (ore-based)
  - Electric Arc Furnace (EAF) facilities (mainly scrap-based).

- EAF facilities produce steel from steel scrap and other iron-bearing materials.

- EAF facilities use coal based injectants for their chemical and insulating properties in the steel making process.

- Energy costs represents a major proportion of the total manufacturing cost for steel.

- Steel products are a highly competitive globally traded commodity.
## Sydney Steel Mill

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up date</td>
<td>1992</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Danieli</td>
</tr>
<tr>
<td>Type</td>
<td>AC EBT</td>
</tr>
<tr>
<td>Transformer</td>
<td>66 MVA (Tamini)</td>
</tr>
<tr>
<td>Mean tapping weight</td>
<td>80 tonnes</td>
</tr>
<tr>
<td>Shell diameter</td>
<td>5.5m</td>
</tr>
<tr>
<td>Electrode diameter</td>
<td>22 inch (~560mm)</td>
</tr>
<tr>
<td>Chemical energy</td>
<td>2 BOC oxygen-natural gas burners</td>
</tr>
<tr>
<td></td>
<td>Fuchs combined oxygen and carbon door lance</td>
</tr>
<tr>
<td>Annualised production</td>
<td>600,000 t.p.a.</td>
</tr>
</tbody>
</table>
## Laverton Steel Mill

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up date</td>
<td>1988</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Fuchs</td>
</tr>
<tr>
<td>Type</td>
<td>AC OBT</td>
</tr>
<tr>
<td>Transformer</td>
<td>77 MVA (Tamini)</td>
</tr>
<tr>
<td>Mean tapping weight</td>
<td>84 tonnes</td>
</tr>
<tr>
<td>Shell diameter</td>
<td>5.5m, 0.95m offset</td>
</tr>
<tr>
<td>Electrode diameter</td>
<td>24 inch (600mm)</td>
</tr>
<tr>
<td>Chemical energy</td>
<td>Danieli/More Module System</td>
</tr>
<tr>
<td></td>
<td>3 oxygen-jet injectors</td>
</tr>
<tr>
<td></td>
<td>4 carbon-jet injectors (2 used)</td>
</tr>
<tr>
<td>Annualised production</td>
<td>700,000 t.p.a.</td>
</tr>
</tbody>
</table>
Polymer Injection
Introduction

• Current disposal options (landfill/incineration) for tyres and other polymer sources globally are not sustainable.

• OneSteel together with the University of New South Wales has developed a method for EAFs to use polymers as a slag foaming agent.

• OneSteel has been using this technology within its Sydney and Laverton EAF’s for five years and 58,000 heats, consuming over 1.68 million tyres in the process.

• The technology was successfully implemented at UMC Metals, Thailand in May 2011.

• Technology has been recognised internationally for its innovation and environmental credentials.

• The technology has been patented around the world - “Production of Ferro-Alloys”
Slag foaming in the EAF

- Developed after long-arc process
- Covers surface of bath and shrouds the arcs
  - Intercepts radiation and flare from arc
  - Increases thermal efficiency (by up to 20kWh/t)
  - Prevents damage to walls
- Induced through carbon injection into slag layer
  - Injectants include coke & coal
  - Reaction: \( C_{(s)} + FeO = CO_{(g)} + Fe \)
Principles of Foamy Slag

- The aim is to optimize slag foaming using the gases released during the combustion of coke.
- Adding polymers to coke has been proven to increase the volume of foamy slag.
The foaming efficiency of the slag is measured by the volume in the slag over time – or a Vt/V0 test.

- **Volume ratio of slag: Vt/V0**
  - Vt: foamed slag volume at time t
  - V0: initial dense slag volume

- **Percentage of reacted FeO in slag**
  - FeO% = \( \frac{n_{CO} + 2n_{CO2}}{n_{FeO}} \times 100\% \)
  - nCO: CO mole numbers until time t
  - nCO2: CO2 mole numbers until time t
  - nFeO: initial FeO mole numbers in slag
A combination of rubber and anthracite produces a superior foaming slag volume than anthracite alone.
Slag Foaming Phenomenon

100% Coke

Polymer Blend

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The rate of gas generation following the interaction of HDPE-Coke blend was seen to be the fastest, followed by the rate of gas generation from rubber-coke blends, while the lowest rate was seen when coke represented the carbon material.

Gas Generation (Gas Chromatographic)

Coke and HDPE/Coke Blend

The Benefits – Reduced Inject Carbon Consumption

- Improved slag foaming results in a reduction in the amount, or volume, of injectant (coke) consumed per heat.
- A blend of polymer and coke is able to reduce the slag rapidly, attaining over 80% reduction in less than 400 seconds; in comparison by 400 seconds the reduction by 100% coke is much less (only about 6%).
- This is a result of the extra reducing gases (CH₄ and H₂) generated as a result of the polymer addition.
- Very good results at an implementation in Thailand → 950kg average injectant per heat reduced to 680kg average injectant.
- Rubber properties are better than coke
  - Doesn’t absorb moisture
  - Not washed (potential chlorine)
  - Not as fine (less loss to bag house and less wear on injection pipes)
The Benefits – Raw Material Cost Reduction

- The chemical composition of tyre crumb is similar to high grade anthracite (87-90% fixed carbon and low ash).
- In most regions suitable rubber crumb can be purchased at a discount to the coke / anthracite price.
- The price of crumb is relatively stable – insulated from volatile steel input demand and supply (e.g. scrap).
The Benefits – Reduced Electrical Consumption

- The improved slag foaming results in:
  - Superior insulation of molten bath
  - Improved shrouding of the electrodes
  - Longer arc

- This results in:
  - Reduced Power on time
  - Improved active power
  - Reduced electrode wear
The Benefits – Environmental

- Reduced carbon footprint through reduced CO$_2$ emissions as a result of the potential to reduce electricity consumption produced by coal-fired power stations.
- Technology reduces carbon per tonne of steel produced by 8-11kg (based on results from Australian mills) partially mitigating against potential cost of carbon trading schemes.
- In addition rubber that is often diverted to landfill are recycled into value-added steel products.
- High temperature reactions in slag layer – therefore no noxious fumes or foul odours around EAF, reduced Dioxin and Nitrogen Oxide levels.
OneSteel has worked with the NSW DECC (EPA) and conducted analysis of heavy metals in inject polymer supply.

- Modelling of air emissions show minimal change in emission levels.

A written material specification for inject polymer supply has been developed to ensure environmental air emissions are maintained and even bettered.
Environmental Results at OneSteel
SSM / LSM Dioxin Control

- Tests of stack dioxin emissions conducted at three plants
  - Once at Site 2: February 2008
  - Once at Site 3: August 2008

- Coke and polymer/coke mixes used within 36 hours of each other to ensure valid results, except at Site 3, where the tests were a week apart.
Environmental Results for Rubber Injection

<table>
<thead>
<tr>
<th>Dioxin Emissions</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Point 1</td>
<td>75%</td>
<td>26%</td>
<td>17%</td>
</tr>
<tr>
<td>Data Point 2</td>
<td>45%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Point 3</td>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Point 4</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Positive percentage values are percentage decreases. It is the experience of OneSteel that scrap quality and blend, as well as operational delays, have a major impact on air emission results; the scrap blend at Site 3 was altered between tests.

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile Organic Compounds</td>
<td>-75%</td>
<td>-40%</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>12%</td>
<td>-37%</td>
</tr>
<tr>
<td>Sulphur Dioxide</td>
<td>14%</td>
<td>21%</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>2%</td>
<td>-6%</td>
</tr>
</tbody>
</table>
# Summary of Benefits

<table>
<thead>
<tr>
<th>Benefit Area</th>
<th>Sydney Steel Mill</th>
<th>Laverton Steel Mill</th>
<th>UMC Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of raw material – Coke v Rubber</td>
<td>15%</td>
<td>28%</td>
<td>35-40%</td>
</tr>
<tr>
<td>($USD cost per tonne)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in Electrical consumption</td>
<td>2.8%</td>
<td>2.4%</td>
<td>NFP</td>
</tr>
<tr>
<td>(KWh per billet tonne)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in inject carbon</td>
<td>12.0%</td>
<td>16.2%</td>
<td>12%</td>
</tr>
<tr>
<td>(kilograms per heat)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in productivity</td>
<td>3.0%</td>
<td>1.9%</td>
<td>NFP</td>
</tr>
<tr>
<td>(Tonnes per minute of POT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in inject oxygen</td>
<td>2.3%</td>
<td>1.9%</td>
<td>NFP</td>
</tr>
<tr>
<td>(cubic metres per billet tonne)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in Natural Gas</td>
<td>1.9%</td>
<td>–</td>
<td>NFP</td>
</tr>
<tr>
<td>(cubic metres per billet tonne)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen to inject carbon ratio</td>
<td>3.4%</td>
<td>2.8%</td>
<td>NFP</td>
</tr>
</tbody>
</table>

NFP = Not for publication
OneSteel continues to enhance its current product as well as develop new products and services

- Carbon/Polymer composite briquettes
- Uses recycled plastics and carbon fine to replace traditional charge carbon and recarburiser
- Initial process trials have shown considerable improvement in carbon pickup, electrical energy consumption and productivity
- Further development in progress
• In May 2012 an Extraordinary General Meeting decided to change the name of OneSteel Limited to **Arrium Limited**.

• The new name reflects the change of the nature of the company’s business over recent years. OneSteel is now a **mining**, **mining consumables** and **steel** business with an increasingly global orientation, rather than a domestic focused steel company.
### Who is Arrium?

- Arrium is Australia and New Zealand’s premier manufacturer of steel long products and mining consumables, as well as a leading miner of iron ore.
- The company has revenues in excess of **AUD6 billion**.
- The company markets more than 40,000 products to over 30,000 customers.
- Arrium employs over **12,000 people** and has operations in **13 countries**.
- Arrium is **vertically integrated** from raw materials through to distribution.

<table>
<thead>
<tr>
<th>Raw Materials</th>
<th>Steelmaking</th>
<th>Manufacturing</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Iron ore mines supply internal demand &amp; sells 6mtpa of iron ore and by products</td>
<td>- Steelmaking capacity of 3.1mtpa</td>
<td>- Structural, rod and bar mills</td>
<td>- 150+ locations</td>
</tr>
<tr>
<td>- 2nd largest scrap recycler in Aus</td>
<td>- 4 EAF plants located close to end markets</td>
<td>- Largest grinding media producer</td>
<td>- Australia’s largest reinforcing business</td>
</tr>
<tr>
<td></td>
<td>- 1 BOF plant in Whyalla close to iron ore mines</td>
<td>- Rail and forge plants</td>
<td>- Distributes plate, pipe, steel sections, valves, sheet and coil</td>
</tr>
</tbody>
</table>
Arrium’s Global Footprint

North America
- EAF
- Mining Consumables in Canada, USA, and Mexico
- Recycling in USA

South America
- Mining Consumables in Chile and Peru

Australasia
- Mining Consumables in Australia and Indonesia
- Blast Furnace
- Distribution in Australia and New Zealand (Steel and Tube NZ)
- EAF’s
- Recycling in Australia and Asia
Session 2: Iron and Steel making Processes

John Tsalapatis
UNSW 2013 International Sustainability Symposium

Friday 4th October

“The Whyalla Operations, our key business drivers and our operating approach”

[Extracts from the actual presentation]

John Tsalapatis
Metallurgy Manager Ironmaking
Arrium (formally OneSteel), is an international diversified mining and materials company with three key businesses. These are Arrium Mining, Arrium Mining Consumables and Arrium Steel.

In July 2012, the company name changed from OneSteel Limited to Arrium Limited.
Arrium Mining is an exporter of hematite iron ore with operations in South Australia.

The business also supplies pellets now made from magnetite ore feed (since late 2007) and hematite lump ore to the company’s integrated steelworks at Whyalla.

Both the magnetite feed for the pellets and the hematite lump ore for the OneSteel Whyalla Steelworks are sourced exclusively from the Middleback Ranges Mines, approximately 60 km from Whyalla.

The pellets are made at the company’s Pellet Plant in Whyalla.

Metallurgical fluxes are also mined, dolomite at Ardrossan, quartz close to the Middleback Ranges and limesand at Coffin Bay.

Imported raw materials include coal from New South Wales and Queensland, limestone from Japan and ferrous alloys from various sources.
Middleback Ranges*
- 44.4Mt Reserve @ 59.5%Fe
- 143.8Mt total resource @ 58.0%Fe
- 66Mt Magnetite Reserve @ 41.8%Fe
- 187Mt Magnetite Resource @ 36.7%Fe
* ARI Reserve / Resource Statement YEJ2013

Southern Iron Region*
- 16.4Mt @ 63.1%Fe
- 40.9Mt DSO resource @ 61.7%Fe
* ARI Reserve / Resource Statement YEJ2013

Ardrossan
- Dolomite Mine Resource 71Mt
The OneSteel Whyalla Steelworks is the major source of both Special Bar Quality (SBQ) and commercial grade billet feed for the business.

Current output is approximately 1.2 million tonnes of steel per annum which includes semi-finished steel products (billets, slabs and blooms), structural products (columns, beams, channels, angles) and rail products (rails, sleepers and fasteners).

Approximately 60 % of the product is transferred by rail to OneSteel’s Market Mills in billet form for further value-added processing. The balance of the steel is converted to finished structural and rail products in the Whyalla Rolling Mill.

OneSteel Whyalla Steelworks is the only manufacturer of rails in Australia.
The OneSteel Whyalla Steelworks integrated plant comprises:

- Coke Ovens
- Blast Furnace
- Power and Services
- BOS Steelmaking
- Billet Caster / Slab Caster
- Structural / Rail Products Mill
Whyalla Process Flowsheet

Iron Ore → Pellets & Lump Ore 1.8 Mtpa → Blast Furnace 1.2 Mtpa → BOS Steelmaking 1.22 Mtpa → Billet Caster → Rod & Bar Mills

Coke Ovens 0.7 Mtpa → Hot Metal → Slag → Slab/Bloom Caster → Structural Mill Domestic / Export Rerolling

Export 12.0 Mtpa
Aerial View of the Whyalla Site
As OneSteel Whyalla Steelworks is a single Blast Furnace operation the key operational objective is to maintain high process availability, stability and process efficiency. Rigorous process benchmarking is practiced.

Aside from the ever present need to control raw material costs, there is the continuous challenge of diminishing absolute quality / increased variability raw material inputs.

Regarding the ferrous feed, there are ongoing pellet chemistry redesigns and changes to the pellet / lump ore mix. These are aimed at best balancing the burden feed availability / cost / reducibility / high temperature melting properties.
Blast Furnace Top Gas Efficiency
CO2/(CO+CO2)
Blast Furnace Benchmarking

Metal Si % - Std. dev.

The bar chart shows the distribution of Metal Si % with standard deviation for each test period from 1 to 21.
Efficiency Initiatives / Cost Control

- Relentless drive to maximise Blast Furnace process efficiency / decrease Ironmaking costs at all required aim production rates.
- Substantial effort is being applied towards the decrease of Cokemaking costs via the systematic experimentation with alternate coal blends. The objective being to produce a cheaper, but still competent, coke for the Blast Furnace by not compromising too far critical coke properties. In addition, coke yield improvements have been achieved by further coke screening efficiency improvements and nut coke charging.
- Always driving to maximise the desulphurisation via the Blast Furnace process, thus ensuring lowest Steelmaking fluxing costs.
- Lower delivered HM Si % to the BOS is resulting in decreased consumption of fluxes at Steelmaking and allowing the running at higher CaO / SiO₂ ensuring lower wear of the BOS vessel lining.
- Recovery of metallics from Steelmaking slags is now in practice, producing a scrap / coolant replacement material.
Alternate Potential Uses for By-product Stream Materials

- Currently in the process of exploring novel recycling uses and realising better value from our large number of available by-product stream materials. Listed below are some materials under consideration.

<table>
<thead>
<tr>
<th>Chemical % Analyses of By-product Stream Under Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Coke Fines</td>
</tr>
<tr>
<td>Quencher Basin Dust</td>
</tr>
<tr>
<td>BF Dust</td>
</tr>
<tr>
<td>Millscale &amp; Metallic Fines</td>
</tr>
<tr>
<td>BOS Precipitate</td>
</tr>
<tr>
<td>Dolomite Fines</td>
</tr>
<tr>
<td>BF Slag</td>
</tr>
</tbody>
</table>
• OneSteel Whyalla Steelworks is Arrium’s largest energy consuming facility. However it generates more than 40% of its own energy through the reuse of process waste gases.
• We are striving to increase this percentage through a range of energy efficiency improvements.
• The Arrium Technical Energy Network (ATEN) has been established to focus on energy and resource efficiency. This includes the implementation of standard energy management systems, collation and monitoring of energy performance and abatement activity data, identifying and assessing opportunities for energy and greenhouse reduction.
• Arrium in partnership with BlueScope and the CSIRO have been conducting research into potential uses of biomass in steelmaking. The same parties have also been involved in a dry slag granulation project.
• OneSteel Whyalla Steelworks has an active water use reduction and dust reduction program in place.
Key Environment Activities

False Bay adjacent to the Steelworks 1990 & 2012
Recent photopoint comparisons showing seagrass expansion
Key Environment Activities - Dust

- Dust Monitoring
- Dust Control Network
- Risk Ranking for prioritised improvement
- Consolidated Source List
- Event Analysis
- Open Area & Point Source Modelling
- Contour Plots
- Fugitive Dust Ranking
- Consolidated Source List
- Contour Plots

Consolidated Source List
Many Thanks!
Session 2 : Iron and Steel making Processes

Murray Ackers
Low Cost / No Cost Energy Efficiency Improvement in the Manufacturing Environment
BlueScope Steel Environment
Murray Ackers
Background

BlueScope Steel is a flat steel products manufacturer with facilities including integrated steel production, coil coating and roll forming. The products that BlueScope produces includes well known domestic brands such as:

BlueScope Australia consumes in the order of 90 PJ of energy per annum. 90% of this energy is utilised by the integrated steel making facility at Port Kembla, NSW.

Recent structural changes within the Australian business has seen domestic steel production reduced from 5.3Mt to 2.6Mt per annum. In contrast, energy intensity has increased.
Business Improvement Initiative

In response to challenging domestic and international market conditions BlueScope Steel Australia initiated a business improvement program to reduce costs to the business.

The business improvement program engages over 300 natural work teams within business to identify projects that would achieve a cost saving of at least $5000 per annum.

The focus of the BlueScope Steel Savings Program is to provide each natural work team an opportunity to deliver a cost saving project. The program is designed to:

• Focus teams on eliminating waste, benchmarking and standardisation of practices.
• Deliver a system to monitor and report results monthly.
• Ensure projects have a business case and can demonstrate evidence of the savings.
• Provide a standardised approach in managing cost saving activities and offer a mechanism for sharing ideas.

Since 2008 the program has delivered over 1700 projects at a value of over $300M.
Incorporation of Energy as a Theme

While “energy saving” has been a theme of the business improvement initiative since its inception, a concerted effort has been made to raise the profile of energy saving projects prior to the FY13 cycle.
Key Strategies

- Engage Senior Management through presentations highlighting the impact of domestic carbon policy and future energy price projections on the business.
- Compile presentations for operations and maintenance teams which were tailored to their specific areas.
Emphasise the need to scrutinise data to fully understand its impact.

$190,000 annualised saving potential
Data Formats

Comparison of data from Current base year compared to average annual result from 05/06 and 06/07

Based on Report 2009

<table>
<thead>
<tr>
<th>INPUT</th>
<th>Unit</th>
<th>Mar12 to Feb13</th>
<th>Unit/t</th>
<th>Jul05 to Jun07</th>
<th>Unit/t</th>
<th>% Change</th>
<th>Comments</th>
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<tbody>
<tr>
<td></td>
<td>Base Year</td>
<td>2009 Report</td>
<td>From 05/07 to current</td>
<td></td>
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<tr>
<td>COG</td>
<td>GJ</td>
<td>56,058</td>
<td>20.9</td>
<td>119,847</td>
<td>21.9</td>
<td>-4.2</td>
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<tr>
<td>Electricity</td>
<td>MWh</td>
<td>53,572</td>
<td>20.0</td>
<td>67,921</td>
<td>12.4</td>
<td>61.5</td>
<td>High base load still remaining</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>GJ</td>
<td>72,728</td>
<td>27.1</td>
<td>87,700</td>
<td>16.0</td>
<td>69.8</td>
<td>High base load still remaining</td>
</tr>
</tbody>
</table>
Assistance with Identification of Energy Saving Ideas

In-house Calculators available for an initial assessment:

130|13 intranet site....
On-line Resources

Heating, Ventilation and Air Conditioning
Significant savings are achievable in HVAC systems which typically account for up to 30% of energy use in commercial buildings.

Lighting
There are many low-cost and no-cost measures that can be implemented to reduce lighting costs without adversely affecting working conditions.

Motors and Motor Systems
Energy management focusing on electric motors and motor systems has the potential to save more electricity than in any other electricity end-use.

Pumps and Fans
Together, pumps and fans account for around 40% of the motive power used in Australian industry. Potential savings can be significant.

Compressed Air
There is significant potential to save energy in compressed air systems by reducing the need for compressed air services, optimising equipment and upgrading old systems.

Process Heat, Boilers and Steam Systems
Energy use in process heating systems can be reduced by lowering demand for heating services, improving efficiency and by recovering heat for reuse.
### Other Energy Savings Idea

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scarfer Area Power Project</strong></td>
<td>• Proposed methodology based on reduction in hours run.</td>
</tr>
<tr>
<td></td>
<td>• Energy Saving in the order of 5000 MWh per annum.</td>
</tr>
<tr>
<td><strong>De-sulfurisation Plant Operational Changes</strong></td>
<td>• Proposed methodology based on reduction in hours run.</td>
</tr>
<tr>
<td></td>
<td>• Energy Saving in the order of 766 MWh per annum.</td>
</tr>
<tr>
<td><strong>ST Duct Fan Operation</strong></td>
<td>• Only required when personnel in area. Manual switching control.</td>
</tr>
<tr>
<td></td>
<td>• Saving in the order of 150 MWh per annum.</td>
</tr>
<tr>
<td><strong>21 Area Fan</strong></td>
<td>• Installation of VSD control to reduce energy consumption.</td>
</tr>
<tr>
<td></td>
<td>• Saving in the order of 800 MWh per annum.</td>
</tr>
<tr>
<td><strong>No.3 Bag House Fan Operation</strong></td>
<td>• Modification of existing duct routing to allow No.3 Bag House Fan to be turned off.</td>
</tr>
<tr>
<td></td>
<td>• Allowed 1.2 MW motor to be shutdown saving in the order of 6800 MWh per annum.</td>
</tr>
</tbody>
</table>
Results
As a result of this work there was a significant increase in the number of energy efficiency projects pursued in the FY13 business improvement program.
Energy Saving Project Categories

Manufacturing Energy Savings Ideas
- 130/13 by Number and type.

- Process Improvement & Efficiency: 17
- Buildings, Lighting and HVAC: 6
- Turning Off Idle Equipment: 7
- Energy Balance and Generation: 14
- Yield: 9
Where were the Energy Savings

Manufacturing Energy Savings Ideas
- 130/13 by Energy (GJ) and type

- Process Improvement & Efficiency: 288,267
- Buildings, Lighting and HVAC: 546,164
- Turning Off Idle Equipment: 165,804
- Energy Balance and Generation: 1,436
- Yield: 1,436

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Summary

• Utilise existing systems.
• Maximise involvement of personnel at all levels of the business.
• Tailor information to engage the specific work team.
• “Energy” is not just utilities.
• Provide training and resources