Ausmelt Limited
A.B.N 72 005 884 355

Design and Costing Study Report

Ausmelt Primary Smelter for Treating Browns Concentrates

for

Compass Resources

May 2001

Document No. AUS933 - 15000

Revision Details

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CONFIDENTIAL
SUMMARY

Ausmelt was contracted by Compass Resources NL to provide engineering and estimation services in support of a design and costing study evaluating the use of Ausmelt Technology for the primary treatment of Browns concentrates in the Northern Territory.

The proposed plant configuration will use an Ausmelt furnace system to continuously process 311,525 dry tonnes per annum of Browns concentrates. The process to treat the concentrates has been designed to maximise lead recovery to fume and cobalt recovery to matte. The Ausmelt plant will produce 78,930 tonnes of cobalt-copper-nickel-iron matte, 115,140 tonnes of discard slag and 103,480 tonnes of high lead fume per annum.

The overall design and costing study managed, by Hatch, encompasses all plant unit operations including feed handling, Ausmelt furnace, product handling, off gas handling and other auxiliary services. Ausmelt’s contribution is restricted to core aspects relating to the Ausmelt Primary Smelter and associated proprietary equipment.

The design and costing study completed by Ausmelt was carried out to an accuracy of ? 30%.

The estimated capital cost for the following Ausmelt plant equipment and services is AU$11,452,050:

- Process design and engineering
- Design of Ausmelt equipment including furnace, lances, lance handling, standby burner, instrumentation and control system
- Supply of Ausmelt equipment including the Ausmelt furnace, lances and lance handling system, lance seal device, standby burner and burner handling system, integrated process control system and lance burner flow control instrumentation
- On-site services including inspection of Ausmelt equipment installation, operator training, cold commissioning, hot commissioning and production support
- Technology license fee

The fuel coal, air, oxygen, water, power, reductant coal, maintenance and labour requirements for the Ausmelt plant have been estimated. An operating cost for the Ausmelt plant can be determined directly from these requirements.
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1 INTRODUCTION

Ausmelt was contracted by Compass Resources NL to provide engineering and estimation services in support of a design and costing study evaluating the use of Ausmelt Technology for the primary treatment of Browns concentrates.

The proposed Ausmelt furnace system will treat Browns concentrates to produce a matte containing cobalt, copper, nickel and iron, and a high lead fume. The high lead fume will be transferred to a second Ausmelt furnace to produce lead bullion (outside the scope of this study). It is expected that the matte will undergo mild pressure leaching, solvent extraction and electrowinning to recover metal values.

The overall design and costing study, managed by Hatch, encompasses all smelting plant unit operations including feed handling, Ausmelt furnace, product handling, off gas handling and other auxiliary services. Ausmelt’s contribution is restricted to core aspects of the Ausmelt primary smelter and associated proprietary equipment.

This report presents design and costing data for the Ausmelt furnace, proprietary equipment and design services to an accuracy of ±30%.

1.1 Ausmelt Technology

Ausmelt Technology is a low cost, high intensity system for smelting base metal ores and concentrates as well as recovering high value from wastes. Smelting is rapid and furnace residence times are low, yielding significantly lower capital and operating costs than alternative technologies.

Ausmelt Technology for treating Browns concentrates is based on a catalytic reaction between the oxidisable components of the concentrates and ferric oxide. Critical process phenomena (mass and energy transfer) occur in a slag layer. Feed material dissolution, reaction and primary combustion all take place in the slag layer. A schematic representation of a typical Ausmelt furnace is shown in figure 1.

Central to the Technology is a vertical suspended lance, submerged in a molten slag bath. The slag is well mixed by the injection of combustion gases (air and oxygen) and as a result the reaction rates in the furnace are high. Controlled, swirling of the combustion air in the lance provides sufficient cooling to cause a slag layer to form on the outer surface to protect the lance from attack in the highly aggressive environment.

Oxygen enriched air and milled coal are injected through the lance and combusted at the lance tip to provide heat to the furnace. The degree of oxidation and reduction is controlled by adjusting the fuel to oxygen ratio supply to the lance, and the proportion of reductant coal to feed.
The containment vessel or furnace is a tall, cylindrical unit operated under a negative pressure, and designed to generate slag splash. Ausmelt furnaces are lined with refractory materials and depending on the application are shower-cooled, insulated or incorporate forced water or steam cooling/boiler panels to improve refractory life.

Feed material, fluxes and reductant coal are fed to the system by conveying the material to a port(s) located on the roof of the furnace and allowing it to drop into the molten bath. Fine material can be agglomerated or injected directly into the bath to minimise dust loss through entrainment by rising exhaust gases.

Ausmelt Technology has been applied to the commercial production of a broad spectrum of non-ferrous and precious metals and the high temperature treatment of various waste materials. Table 1 briefly summarises the commercial and development plants currently in operation, design and construction around the world. Further details on these plants are available at www.ausmelt.com.au.
### Table 1a Commercial Ausmelt Furnaces in Operation, Design & Construction

<table>
<thead>
<tr>
<th>No.</th>
<th>Client</th>
<th>Location</th>
<th>Starting year</th>
<th>ID (m)</th>
<th>Cont. or Batch*</th>
<th>Feed type</th>
<th>Design Feed Rate tpa</th>
<th>Product</th>
<th>Temp Range °C</th>
<th>Fuel</th>
<th>Reductant</th>
<th>Air or Oxygen*</th>
<th>Lance Tip*</th>
<th>Note 1</th>
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<tr>
<td>1</td>
<td>Rio Tinto</td>
<td>Eiffel Flats, Zimbabwe</td>
<td>1992</td>
<td>1.5</td>
<td>B2</td>
<td>Leach residue</td>
<td>7700</td>
<td>Desulphurisation Ni/Cu Matte</td>
<td>1250–1350</td>
<td>Coal</td>
<td>Coal</td>
<td>0.21</td>
<td>(1) O (2) R</td>
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<td>2</td>
<td>Korea Zinc(1)¹</td>
<td>F1 Onsan, Korea</td>
<td>1992</td>
<td>3.9</td>
<td>C1</td>
<td>QSL Furnace slag</td>
<td>100,000⁻⁴</td>
<td>Zinc/lead fume</td>
<td>1300</td>
<td>Coal</td>
<td>Coal</td>
<td>0.35</td>
<td>N or R</td>
<td></td>
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<tr>
<td>3</td>
<td>Mitsui</td>
<td>Hachinohe, Japan</td>
<td>1993</td>
<td>2.4</td>
<td>C1</td>
<td>ISF slag</td>
<td>80,000</td>
<td>Zinc fume</td>
<td>1300–1350</td>
<td>Heavy oil</td>
<td>Heavy oil/ Coke breeze</td>
<td>0.21</td>
<td>R</td>
<td></td>
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<tr>
<td>4</td>
<td>Anglo American Corp.</td>
<td>Bindura, Zimbabwe</td>
<td>1995</td>
<td>2.2</td>
<td>B3</td>
<td>Leach residue</td>
<td>10,000</td>
<td>Blister copper</td>
<td>1250–1300</td>
<td>Coal</td>
<td>Coal</td>
<td>0.21</td>
<td>(1) N (2) SO (3) R</td>
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<td>5</td>
<td>Korea Zinc(2)</td>
<td>F1 Onsan, Korea</td>
<td>1995</td>
<td>3.9</td>
<td>C2</td>
<td>Leach residue</td>
<td>120,000</td>
<td>Zinc/lead fume</td>
<td>1250–1300</td>
<td>Coal</td>
<td>Coal</td>
<td>0.35</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Korea Zinc(2)</td>
<td>F2 Onsan, Korea</td>
<td>1995</td>
<td>3.2</td>
<td>C2</td>
<td>F1 slag (liquid)</td>
<td>100,000</td>
<td>Zinc fume</td>
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<td>Coal</td>
<td>Coal</td>
<td>0.21</td>
<td>R/N</td>
<td></td>
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<td>7</td>
<td>Metaleurop</td>
<td>Nordenham, Germany</td>
<td>1996</td>
<td>3.4</td>
<td>C1/B2</td>
<td>Battery paste/ High Pb conc.</td>
<td>122,000</td>
<td>Lead bullion</td>
<td>950–1250</td>
<td>Natural gas</td>
<td>Coal/ Petrol. coke</td>
<td>0.21 - 0.40</td>
<td>N/O/R</td>
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<td>8</td>
<td>Minsur</td>
<td>F1 Pisco, Peru</td>
<td>1996</td>
<td>3.4</td>
<td>B2</td>
<td>Sn Conc.</td>
<td>40,000</td>
<td>Tin metal</td>
<td>1150–1300</td>
<td>Bunker C oil</td>
<td>Coal</td>
<td>0.21 - 0.30</td>
<td>N/R</td>
<td></td>
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<tr>
<td>9</td>
<td>Consolidated Gold Fields</td>
<td>Tsumeb, Namibia</td>
<td>1997</td>
<td>4.4</td>
<td>B2</td>
<td>Low Pb Conc./ Pb/Cu conc.</td>
<td>120,000</td>
<td>Pb bullion/Cu matte</td>
<td>1150–1250</td>
<td>Heavy furnace oil</td>
<td>Coal</td>
<td>0.21</td>
<td>O/N/R</td>
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<tr>
<td>10</td>
<td>Portland Aluminium/AIcoa</td>
<td>Portland, Australia</td>
<td>1997</td>
<td>2.8</td>
<td>B2</td>
<td>Spent Pot Lining</td>
<td>12,000</td>
<td>AlF₃</td>
<td>1250</td>
<td>Natural gas</td>
<td>Coal</td>
<td>0.40</td>
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<td>11</td>
<td>Hindustan Copper Limited</td>
<td>Ghatsila, India</td>
<td>1998</td>
<td>0.5</td>
<td>B2</td>
<td>Anode slimes</td>
<td>72</td>
<td>Silver – gold doré</td>
<td>1000–1100</td>
<td>Light diesel oil</td>
<td>-</td>
<td>0.21</td>
<td>(1) N (2) O</td>
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Notes for Table I:

- *1 C1 = continuous one stage, C2 = continuous two stage,
- *2 B1 = batch one stage, B2 = batch two stage, B3 = batch three stage
- *3 O = Oxidising, N = Neutral, R = Reducing, S Prefix = Strongly
- *4 100,000 tpa for liquid slag, 50,000 tpa for solid slag
- *5 Oxygen fraction, Air = 0.21, Oxygen ? = 0.21
### Table 1b  Commercial Ausmelt Furnaces in Operation, Design & Construction (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Client</th>
<th>Location</th>
<th>Starting year</th>
<th>ID (m)</th>
<th>Cont. or Batch*</th>
<th>Feed Type</th>
<th>Design Feed Rate tpa</th>
<th>Product</th>
<th>Temp Range °C</th>
<th>Fuel</th>
<th>Reductant</th>
<th>Air or Oxygen*²</th>
<th>Lance Tip*³</th>
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<td>12</td>
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<td>C</td>
<td>Cu concentrates</td>
<td>200,000</td>
<td>Copper matte</td>
<td>1180</td>
<td>Coal</td>
<td>-</td>
<td>0.40</td>
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<td>B</td>
<td>Cu matte</td>
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<td>Blister copper</td>
<td>1300</td>
<td>Coal</td>
<td>-</td>
<td>0.21</td>
<td>SO</td>
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<td>14</td>
<td>Minsur F2 (standby furnace)</td>
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<td>3.4</td>
<td>B2</td>
<td>Sn concentrates</td>
<td>40,000</td>
<td>Tin metal</td>
<td>1150 – 1300</td>
<td>Bunker C oil</td>
<td>Coal</td>
<td>0.21 - 0.30</td>
<td>N/R</td>
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<td>15</td>
<td>Auirn/SASE⁶</td>
<td>Whyalla, Australia</td>
<td>2000</td>
<td>*⁷</td>
<td>C</td>
<td>Fe Ore</td>
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<td>C</td>
<td>Pb secondaries</td>
<td>100,000</td>
<td>Lead bullion</td>
<td>1000</td>
<td>Coal</td>
<td>Coal</td>
<td>0.40</td>
<td>R</td>
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<td>17</td>
<td>Yunnan Tin Corporation</td>
<td>Gejiu City, China</td>
<td>2001</td>
<td>4.4</td>
<td>B</td>
<td>Sn concentrates</td>
<td>50,000</td>
<td>Tin metal</td>
<td>1150 - 1250</td>
<td>Coal</td>
<td>Coal</td>
<td>0.21</td>
<td>N/R</td>
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<td>Korea Zinc F2 for (1)</td>
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<td>C</td>
<td>QSL Furnace slag</td>
<td>100,000</td>
<td>Zinc fume</td>
<td>1300</td>
<td>Coal</td>
<td>Coal</td>
<td>0.21</td>
<td>R</td>
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<td>Onsan, Korea</td>
<td>2002</td>
<td>3.9</td>
<td>C</td>
<td>Pb tailings</td>
<td>100,000</td>
<td>Lead fume</td>
<td>1200</td>
<td>Coal</td>
<td>Coal</td>
<td>0.40</td>
<td>N</td>
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<td>Korea Zinc (4) F2</td>
<td>Onsan, Korea</td>
<td>2002</td>
<td>3.9</td>
<td>C</td>
<td>F1 slag (liquid)</td>
<td>80,000</td>
<td>Lead/zinc fume</td>
<td>1250</td>
<td>Coal</td>
<td>Coal</td>
<td>0.21</td>
<td>R</td>
</tr>
<tr>
<td>21</td>
<td>Amplats F1</td>
<td>Rustenburg, South Africa</td>
<td>2002</td>
<td>4.4</td>
<td>B2</td>
<td>Granulated Ni/CuPGM matte</td>
<td>213,000</td>
<td>Ni/Cu converter matte</td>
<td>1300</td>
<td>Coal</td>
<td>Coal</td>
<td>0.40/0.25</td>
<td>SO</td>
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<td>22</td>
<td>Anhui Tongdu Copper</td>
<td>Tongling City, China</td>
<td>2002</td>
<td>4.4</td>
<td>C</td>
<td>Cu concentrates</td>
<td>330,000</td>
<td>Copper matte</td>
<td>1180</td>
<td>Heavy furnace oil/Coal</td>
<td>Coal</td>
<td>0.40</td>
<td>O</td>
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<td>23</td>
<td>Amplats F2</td>
<td>Rustenburg, South Africa</td>
<td>2004</td>
<td>4.4</td>
<td>B2</td>
<td>Granulated Ni/CuPGM matte</td>
<td>213,000</td>
<td>Ni/Cu converter matte</td>
<td>1300</td>
<td>Coal</td>
<td>Coal</td>
<td>0.40/0.25</td>
<td>SO</td>
</tr>
</tbody>
</table>

Notes for Table I:  
*1 C1 = continuous one stage, C2 = continuous two stage,  
*6 SASE – South Australian Steel & Energy Project
B1 = batch one stage, B2 = batch two stage, B3 = batch three stage

*2  Oxygen fraction, Air = 0.21, Oxygen ? 0.21

*3  O = Oxidising, N = Neutral, R = Reducing, S Prefix = Strongly

Demonstration pig iron plant

*7  Elliptical furnace = 5 m x 3 m
2 PROJECT OVERVIEW

The proposed plant configuration will use an Ausmelt furnace system to process 311,525 dry tonnes per annum of Browns concentrates to produce 78,930 tonnes of cobalt-copper-nickel-iron matte, 115,140 tonnes of discard slag and 103,480 tonnes of high lead fume per annum.

Note: The concentrate grade and feed rate were altered part way through the study, as requested by Compass Resources. Ausmelt re-designed the smelter to treat dry injected, concentrates produced during Years 1 and 2 of operation.

As substantial work had been completed, process data sheets and the process flow diagram were not re-issued by Ausmelt. Consequently, the information presented in the data sheets and process flow diagram do not directly correspond to the final process design presented in Appendix A.

The information presented in this chapter is based on the process design outlined in Appendix A to treat concentrates of the grade, moisture content and feed rate detailed in table A.1.1.

2.1 Ausmelt Study Scope of Work

Ausmelt’s scope of work for this design and costing study is restricted to the following core technology components of the Ausmelt Primary Smelter:

Engineering
1. Process design
2. Design of Ausmelt equipment including furnace, lances, lance handling, standby burner, instrumentation and control system

Supply
3. Ausmelt furnace
4. Lances and lance handling system
5. Lance port sealing device
6. Standby burner and burner handling system
7. Integrated process control system
8. Lance burner flow control instrumentation

Site Services
9. Operator training
10. Cold commissioning
11. Hot commissioning
12. Production support

**License**

13. Technology license fee

### 2.2 Process Summary

A detailed description of the proposed Ausmelt process is presented in Appendix A, Ausmelt Process Design. The process design incorporates elemental distribution and combustion data from recently completed pilot scale trials. The Ausmelt plant and equipment is described in Appendix B, Engineering Concept Design.

The Ausmelt process to treat Browns concentrates is designed to maximise lead deportment to fume and cobalt recovery to matte. To ensure high recoveries the Ausmelt furnace will be operated under strongly reducing conditions at 1300°C. Lead, cobalt, copper and nickel recoveries are all in excess of 95%.

The concentrates will be treated in a single Ausmelt furnace. The plant will operate continuously, with a throughput of around 42 tonnes per hour of concentrates. The dry concentrates will be injected directly into the molten slag through a dedicated annulus of the Ausmelt lance.

The heat energy required to melt the concentrates and fluxes, impart energy for reactions and to maintain the bath at 1300°C, is provided by the sub-stoichiometric, submerged combustion of milled fuel coal, air and oxygen.

Sub-stoichiometric combustion conditions are achieved at the lance tip by limiting the combustion air to 80% of that required for complete combustion to CO₂ and H₂O. The combustion air is enriched to 40% oxygen to improve combustion efficiency and reduce the volume of off gas produced, thereby increasing the concentration of sulphur dioxide in the off gas.

Approximately 540 kilograms per hour of reductant coal will be required to help maintain the oxygen partial pressure between 10⁻⁹ and 10⁻¹⁰ atmospheres in the furnace.

Quick lime, haematite and silica will be fed to the furnace at rates of 2.0, 3.1 and 0.2 tonnes per hour respectively to adjust the composition of the product slag. The flux additions will generate a slag with functional viscosity and liquidus characteristics for the Ausmelt process, whilst minimising 'slag make'.

The product mate and slag will be continuously removed from the Ausmelt furnace and transferred into a settling furnace through an underflow weir.
3 CAPITAL COST ESTIMATE

The estimated capital cost for the Ausmelt plant equipment and services detailed in section 2.1 is AU$ 11,452,050 (± 30%).

A detailed capital cost breakdown and methods of estimation are presented in Appendix C, Capital Cost Estimate. The capital cost estimate has been prepared based on Australian design, fabrication and construction costs.

4 OPERATING CONSUMPTION AND LABOUR REQUIREMENTS

Estimates of the operating consumption, maintenance and labour requirements are detailed in Appendix D, Ausmelt Consumption Rates and Labour Requirements.

The operating consumption and maintenance rates have been determined from the process design calculations undertaken as part of the study.