Suitable Pelletizing Technology to DRI

- KOBELCO Pelletizing System -
Contents

1. Corporate Profile of KSL and Iron Unit Division

2. KSL’s Service Capability

3. KOBELCO Pelletizing System

4. Consideration on Indian Conditions

5. Contribution to DR Operators

6. Collaboration between KSL and FLS

7. Project Reference
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Corporate Profile

KSL is composed of:

- Iron & Steel
- Aluminum & Copper
- Welding
- Engineering Business
- Kobelco Construction Machinery
- Kobelco Cranes
- Other Businesses

Name: Kobe Steel, Ltd.

Founded: September 1, 1905

Net Sales: USD 17.92 billion*

Capital: USD 2.48 billion*

Related Companies: 206 subsidiaries
64 equity-valued affiliates

Employees: 36,018*

*Consolidated (KSL + subsidiaries, excluding affiliates)
*Ex-rate: JPY 94.05 / USD

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Products of Kobe Steel

Unique Products, Technology and Service

Iron & Steel Business Unit
High Strength Steel Sheet / Wire rod products for automobile

IPP Unit
Power Generation IPP (1,400MW)

Aluminum & Copper Business Unit
Aluminum forgings for automobile suspensions

Welding Business Unit
Various welding rods

Kobelco Cranes
Crawler Crane

Aluminum & Copper Business Unit
Copper alloy sheet for lead frame

Machinery Business Unit
- Various types of compressors
- Rolling Mills

Engineering Business Unit
Iron making processes
Outline of Iron Making Processes

Iron Ore
- Low-Grade Iron Ore
  - Steaming Coal
  - Coal
  - Natural Gas
  - Shale Gas

Iron Ore
- Beneficiation
  - Coal-Based DR Plant
    - FASTMET/ FASTMELT ITmk3
  - Molten Iron
  - Casted Pig Iron
  - DRI
  - Iron Nugget

Consumers
- BF
  - Gas-Based DR Plant
  - Pellet
  - DRI

Processes owned by KSL

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Business Foundation of Iron Unit Division

Creation of New Iron Making Technologies

Continuous R & D for New Iron Making Technologies in cooperation with MIDREX Technologies Inc.

Knowledge & Experience Accumulated in Engineering and Project Execution

Plant Supply: Since 1962 - Bangladesh Fertilizer Plant
Japan Standard Engineering Quality: Thoughtfulness and Seamless Engineering

Countries: 29
FTK/STK Plants: 51
FOB + SV: 25
1. Corporate Profile of KSL and Iron Unit Division

2. KSL’s Service Capability

3. KOBELCO Pelletizing System

4. Consideration on Indian Conditions

5. Contribution to DR Operators

6. Collaboration between KSL and FLS

7. Project Reference
Engineering Business - Overall Past Record

1. Fertilizer (Bangladesh)
2. Bar Mill (Bangladesh)
3. Pelletizing (Japan)
4. Pelletizing (Japan)
5. Integrated Mill (Bangladesh)
6. Fertilizer (Zambia)
7. Acrylic Fiber (Korea)
8. Pelletizing (Japan)
9. Pelletizing (Japan)
10. Pelletizing (Japan)
11. Pelletizing (Japan)
12. Polypropylene (Brazil)
13. Continuous Bar Mill (Qatar)
14. Direct Reduction (Qatar)
15. Pelletizing (Chile)
16. Oil Gathering (Kuwait)
17. Phenol Acetone (Korea)
18. Polypropylene (Singapore)
19. Cement (Japan)
20. Bar & Wire Rod Rolling (Nigeria)
21. Cement (Japan)
22. Vinyl Acetate (Taiwan)
23. Cement (Indonesia)
24. Cement (Jordan)
25. Sulfuric Acid (Zambia)
26. Bar & Section Mill (Libya)
27. Sulfuric Acid (Iraq)
28. Cement (Japan)
29. Cement (Japan)
30. Cement (Japan)
31. Cement (Jordan)
32. Pelletizing (Bahrain)
33. Cement (Japan)
34. Fertilizer (Indonesia)
35. Fertilizer (Malaysia)
36. Coal Liquefaction (Australia)
37. LPG Recovery (Algeria)
38. Aluminum Mill (Bahrain)
39. Wire Annealing (Nigeria)
40. Cement (Malaysia)
41. Polypropylene (Thailand)
42. Cement (Jordan)
43. Direct Reduction (Iran)
44. Direct Reduction (Egypt)
45. Steel Casting (Australia)
46. Refinery (Ecuador)
47. Cement (Egypt)
48. Direct Reduction (Venezuela)
49. Polyethylene (Nigeria)
50. Pelletizing (Venezuela)
51. Meltdown (Netherlands)
52. Spunbond (Korea)
53. Direct Reduction (Egypt)
54. Caustic Soda (Indonesia)
55. Direct Reduction (Venezuela)
56. Iron Ore Beneficiation (Iran)
57. Cement (Vietnam)
58. Spunbond (USA)
59. Spunbond (Indonesia)
60. Pelletizing (Venezuela)
61. Direct Reduction (Egypt)
62. FASTMET (Japan)
63. FASTMET (Japan)
64. Direct Reduction (Korea)
65. Cement (Italy)
66. FASTMET (Japan)
67. Iron Ore Beneficiation (Iran)
68. Direct Reduction (Qatar)
69. Pelletizing (Iran)
70. FASTMET (Japan)
71. Pelletizing (Bahrain)
72. Direct Reduction (Oman)
73. FASTMET (Japan)
74. FASTMET (Japan)
75. Iron Nugget (USA)
76. Direct Reduction (Bahrain)
Midrex - Midrex DR Plants all over the world

Since 1969, Midrex has built more than 70 Shaft Furnace Modules in 21 countries worldwide.

Note: Projects written in blue were implemented by KSL (main contractor) with Midrex

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Comprehensive Project Development Capabilities

- Plant Diagnosis
- Technical Assistance
- Marketing, Consultation & Finance Arrangement
- Training Service
- Spare Parts Supply
- Project Management
- ISO9001
- Plant Design & Engineering
- Procurement & Inspection Service
- Commissioning & Operation
- Construction & Site Management
- Shipment Haulage
- Engineering

Kobe Steel, Ltd. retains copyrights and all other proprietary rights related to this document.
KSL fulfills Customer’s requirement from multiple aspects;

## Project Design & Development Stage
- Project Study (Scoping / Conceptual / Preliminary Design)
  - (Conceptual Layout, Preliminary Financial Analysis, Sample Test etc.)
- Feasibility Study & Finance Arrangement

## Project Execution Stage
- Plant Construction (Engineering, Procurement & Construction)
- Project Management & Supervision

## O & M, Training Services
- Provision of Aftermarket Service: Technical Assistance, O&M, Training Service and **Spare Parts Supply** for the smooth and timely operation of the plant.
Long and rich experiences in pelletizing plant construction since 1966.

Delivery of the world largest grate kiln pelletizing plant for Bahrain Steel (former GlIC) No.2.

Capability to support operation & maintenance aspects as a pelletization plant operator.

Bahrain Steel No.2 (front side)
(Capacity: 6.0 MTPA)
Recently Built Plants - Unique Technologies

Pellet Plant – Vale Oman

Jindal Shadeed DRI Plant - Oman

Qatar Steel Company – HBI/DRI Combo plant

RHF based technology
Fastmet - Japan

Pellet Plant – Bahrain Steel No2 (Former GIIC)
1. Corporate Profile of KSL and Iron Unit Division

2. KSL’s Service Capability

3. KOBELCO Pelletizing System

4. Consideration on Indian Conditions

5. Contribution to DR Operators

6. Collaboration between KSL and FLS

7. Project Reference
1965: Kobe Steel was licensed Grate-kiln process by Allis-Chalmers.

Since 1966 Kobe Steel has provided Grate-Kiln Process all over the world.

Experience of Kobe Steel’s Own Plant

1966: 1st Pelletizing Plant (1mtpy) in Kobe Works, KSL Japan
1970: 2nd Pelletizing Plant (2mtpy) in Kakogawa Works, KSL Japan
1973: 3rd Pelletizing Plant (2mtpy) in Kakogawa Works, KSL Japan

1996: Kobe Steel acquired Grate-kiln Process, and “KOBELCO Pelletizing System” was born.

Over 40 years experience of Pelletizing Plant Supply and Operation.
**Typical Process Flow**

- **IRON ORE**
- **LIMESTONE**
- **BENTONITE**

**Typical Flow of KOBELCO-Pelletizing Process**

- **Drying**
- **Grinding**
- **Pre-Wetting**
- **Balling**

**Products**

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<table>
<thead>
<tr>
<th>Raw Material Utility</th>
<th>Unit Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron Ore</td>
<td>1,000-1,050 kg/t-pellet (depending on LOI) (All spillages are recycled)</td>
</tr>
<tr>
<td>Limestone</td>
<td>Depending on requirements</td>
</tr>
<tr>
<td>Bentonite</td>
<td>5 -8 kg/t-pellet</td>
</tr>
<tr>
<td>Anthracite (or Coke Breeze)</td>
<td>5-10 kg/t-pellet (for hematite ore)</td>
</tr>
<tr>
<td>Fuel</td>
<td>190 Mcal/t-pellets (incl. Anthracite heat)</td>
</tr>
<tr>
<td>Power</td>
<td>23 kWh/t-pellets (for induration area)</td>
</tr>
<tr>
<td>Water</td>
<td>0.07 m3/t-pellets (In case of receiving wet concentrate)</td>
</tr>
</tbody>
</table>
# Typical Products Quality

<table>
<thead>
<tr>
<th>Quality Items</th>
<th>Criteria</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>for BF</td>
<td>for DR</td>
</tr>
<tr>
<td>Size distribution (9-16mm)</td>
<td>&gt; 93%</td>
<td>ISO2194</td>
</tr>
<tr>
<td>(- 5mm)</td>
<td>&lt; 0.5%</td>
<td>ISO2194</td>
</tr>
<tr>
<td>Cold compression strength (Ave)</td>
<td>&gt; 300kg</td>
<td>ISO4700</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.5%</td>
<td>ISO4700</td>
</tr>
<tr>
<td>Tumble index (+ 6.3mm)</td>
<td>&gt; 97%</td>
<td>ISO3271</td>
</tr>
<tr>
<td>Abrasion index (-0.5mm)</td>
<td>&lt; 3.5%</td>
<td>ISO3271</td>
</tr>
<tr>
<td>Porosity</td>
<td>&gt; 24%</td>
<td>JIS M8716</td>
</tr>
<tr>
<td>Swelling index</td>
<td>&lt; 16%</td>
<td>---</td>
</tr>
<tr>
<td>Reducibility</td>
<td>&gt; 65%</td>
<td>---</td>
</tr>
<tr>
<td>Metalization</td>
<td>---</td>
<td>&gt; 95%</td>
</tr>
<tr>
<td>Fragmentation (+6.3mm)</td>
<td>---</td>
<td>&gt; 99%</td>
</tr>
<tr>
<td></td>
<td>---</td>
<td>&lt; 0.5%</td>
</tr>
</tbody>
</table>

**Note:** Pellet quality is adjustable in accordance with the client’s requirement.
1. Capacity Lineup

Small Range: 2.0 - 2.5 mtpa
Medium Range: 3.0 mtpa
4.0 mtpa
5.0 mtpa
Large: 6.0 mtpa (Largest KPS in operation in Bahrain)

2. Tailor-Made Design

In accordance with the customers’ requirements (capacity of the plant, characteristics of raw materials, product quality, kind of fuel, etc.), KSL can deliver tailor-made plant with the following standard equipment.

- Traveling Grate: Width: 4.716 m, 5.782 m
- Rotary Kiln: Shell i.d.: 5.8 m, 6 m, 6.6 m, 6.9 m, 7.2 m
- Annular Cooler: Nominal dia.: 17 m, 18.5 m, 20 m, 22 m
Compact Layout

Typical Plant Layout (6mtpa KOBELCO Pelletizing System)

- Balling Area
- Travelling Grate
- Rotary Kiln
- Annular Cooler

Dimensions:
- Length: 280m
- Height: 190m
1. Corporate Profile of KSL and Iron Unit Division
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5. Contribution to DR Operators
6. Collaboration between KSL and FLS
7. Project Reference
Indian ore application

Issues on Indian Iron Ore

- **Hematite**
  Less oxide heat than magnetite generates.

- **High LOI** (Crystal water content)
  Crystal water needs to be dehydrated.
  Porous pellet after dehydration

- **High Al2O3 content**
  Higher melting temperature of high Al2O3 containing slag
Indian ore application

Solutions for Indian Ore Application

- **Hematite**
  - Need more heat than magnetite
  - Addition of Anthracite or coke breeze
  - More heat recuperated from cooler
  - Additional heat source (Air Heater)

KSL has experiences of 100% hematite utilization.
- Bahrain Steel No.1 & No.2 (Bahrain),
- Vale Sohar (Oman)
- FMO (Venezuela)
Solutions for Indian Ore Application

- **High LOI** (Crystal water content)
  Longer retention time in TPH is required for de-hydration.
  Need more heat to harden porous pellet after de-hydration

- >> Appropriate grate section design
- >> Addition of Anthracite or coke breeze
- >> More heat recuperated from cooler
- >> Additional heat source (Air Heater)
Indian ore application

Solutions for Indian Ore Application

• **High Al2O3 content**
  Need higher temperature in induration process

  -> Kiln system can provide higher induration temperature easily, because heat is transferred by radiation of Kiln burner flame.
Flexibility in Fuel selection

1. COG, Heavy Oil or Natural gas is usable as the Kiln burner fuel.

2. Coal (Bituminous coal, Anthracite Coal, and Charcoal) and Coke Breeze are also usable as the Kiln burner fuel, being different from Straight Grate Technology,

3. BFG and/or Mixed gas (COG & BFG) are usable;
   - As partial fuel of Kiln Burner, which reduces the main fuel consumption according to the use of such lean fuel gas.
   - As fuel of Air heater, which provides additional heat on Travelling Grate.
Solutions for Indian Situation

Anthracite (CB) pre-mixture

Air heater

BFG utilization

Traveling grate

Kiln burner

NG, HFO, Coal, COG or Mixed Gas utilization

Rotary kiln

Annular cooler

Traveling grate

Rotary kiln

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Quality Requirements of DR Plant Operators

Important elements of pellets for better operation of DR plant

1. High Fe in pellets
2. Good CCS
3. Less fine generation = Good CCS & Uniform Quality
4. Reducibility

Highly important

Source; KSL’s independent research

KPS can produce the most suitable pellets for DR operation.
High Fe in Pellets

1. High quality of pellet feed → Beneficiation

1. Less additives in pellet making
   • Less limestone addition
   • Binder less operation

KPS can produce the most suitable pellets for DR operation.
High Fe in Pellets

Limestone addition case

**Slag bonding**
- Low melting temperature slag
- Making bridge
- Lower temperature

Fe2O3 Fe2O3-SiO2-CaO slag

Less limestone addition case

**Oxide bonding**
- Diffusion of core material
- Higher temperature required

Better induration (such as Kiln) is preferable.
High Fe in Pellets

Reference:
Binder-less operation at Kakogawa pellet plant, KSL

- Utilizing very fine BOF dust
- Part of ore is ground up to higher Blaine

No binder is mixed for balling
Pellets produced by KPS have more uniform quality and high CCS (\(=\) Less Fine Generation), which result in good DR plant operation.
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7. Project Reference
KSL and FLS made collaboration agreement for sales and project execution of pellet plant project in India.

High Capability of Project Execution in India

- Rich experiences & know-how in the mineral processing and cement plant
- Proven and Reliable in dealing with EPC projects in India
- Global sourcing, supply chain team and dedicated project management
Collaboration with FLS

Integrated Service to Customers from Beneficiation to DR production

- Collaboration with FLSmidth
  - Pellet Plant & DR Plant Engineering & Supply
  - Operation & Maintenance of Pellet & DR Plant

Note:
- Midrex is a KSL’s 100% subsidiary company.
- FLSmidth is a Licensee of KOBELCO Pelletizing System.
Collaboration with FLS

Value to Customers
- Smooth Project Execution in India
- Take Advantage of Local Procurement
- Keep High Quality
- Providing Integrated Service Around Pellet Plant (Beneficiation – Pelletizing - Direct Reduction)
1. Corporate Profile of KSL and Iron Unit Division

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7. Project Reference
<table>
<thead>
<tr>
<th>Location</th>
<th>Name of Customer</th>
<th>Plant Capacity (1,000tpy)</th>
<th>Raw Material</th>
<th>Scope of Work</th>
<th>Year of Completion (Completion of Service)</th>
<th>Present Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Kobe Steel, Ltd. Iron &amp; Steel Division</td>
<td>1,000</td>
<td>Mag.+ Hema.</td>
<td>EPC</td>
<td>1966</td>
<td>Closed down</td>
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<tr>
<td>Japan</td>
<td>Kobe Steel, Ltd. Iron &amp; Steel Division</td>
<td>2,000</td>
<td>Mag.+ Hema.</td>
<td>EPC</td>
<td>1970</td>
<td>Operation (4,000ktpy)</td>
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<tr>
<td>Japan</td>
<td>Kobe Steel, Ltd. Iron &amp; Steel Division</td>
<td>2,000</td>
<td>Mag.+ Hema.</td>
<td>EPC</td>
<td>1973</td>
<td>Closed down</td>
</tr>
<tr>
<td>Chile</td>
<td>Compañía de Acero del Pacífico S.A. de Inversiones</td>
<td>3,500</td>
<td>Magnetite</td>
<td>EP/SV/TR</td>
<td>1978</td>
<td>Operation</td>
</tr>
<tr>
<td>Bahrain</td>
<td>Bahrain Steel (former GIIC)</td>
<td>4,000</td>
<td>Hematite</td>
<td>EPC/TR</td>
<td>1985</td>
<td>Operation</td>
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<tr>
<td>USA</td>
<td>Inland Steel Company</td>
<td>-</td>
<td>Magnetite</td>
<td>OMA</td>
<td>(1985)</td>
<td>Closed down</td>
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<tr>
<td>Location</td>
<td>Name of Customer</td>
<td>Plant Capacity (1,000tpy)</td>
<td>Raw Material</td>
<td>Scope of Work</td>
<td>Year of Completion (Completion of Service)</td>
<td>Present Status</td>
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<td>---------------</td>
<td>-------------------------------------------</td>
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<td>Australia</td>
<td>BHP Steel Whyalla</td>
<td>-</td>
<td>Hematite</td>
<td>OMA</td>
<td>(1986)</td>
<td>Operation</td>
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<tr>
<td>Chile</td>
<td>Compañía Minera del Pacífico S.A.</td>
<td>-</td>
<td>Magnetite</td>
<td>WS</td>
<td>(1988)</td>
<td>Operation</td>
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<td>Bahrain</td>
<td>Bahrain Steel (former GIIC)</td>
<td>-</td>
<td>Hematite</td>
<td>OMA/TA</td>
<td>(1988)</td>
<td>Operation</td>
</tr>
<tr>
<td>Venezuela</td>
<td>C.V.G. Ferrominera Orinoco, C.A.</td>
<td>3,300</td>
<td>Hematite</td>
<td>EPC/TR</td>
<td>1994</td>
<td>Operation</td>
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<tr>
<td>Chile</td>
<td>Compañía Minera del Pacífico S.A.</td>
<td>-</td>
<td>Magnetite</td>
<td>WS</td>
<td>(1995)</td>
<td>Operation</td>
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<td>Chile</td>
<td>Compañía Minera del Pacífico S.A.</td>
<td>-</td>
<td>Magnetite</td>
<td>OMA</td>
<td>(1997)</td>
<td>Operation</td>
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<tr>
<td>Location</td>
<td>Name of Customer</td>
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<td>Raw Material</td>
<td>Scope of Work</td>
<td>Year of Completion (Completion of Service)</td>
<td>Present Status</td>
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<tr>
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<td>--------------------------</td>
<td>--------------</td>
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<td>-------------------------------------------</td>
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<tr>
<td>Venezuela</td>
<td>C.V.G. Ferrominera Orinoco, C.A.</td>
<td>3,300 ⇒ 4,000 (Capa. Increase)</td>
<td>Hematite</td>
<td>Revamping EPC</td>
<td>2007</td>
<td>Operation</td>
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<tr>
<td>Iran</td>
<td>Chador Malu Mining &amp; Industrial Co. (Ardakan)</td>
<td>3,400</td>
<td>Mag.+ Hema.</td>
<td>EPCM</td>
<td>2008</td>
<td>Operation</td>
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<tr>
<td>Bahrain</td>
<td>Bahrain Steel (former GIIC)</td>
<td>6,000</td>
<td>Hematite</td>
<td>EPC</td>
<td>2010</td>
<td>Operation</td>
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<tr>
<td>Malaysia</td>
<td>Vale International S.A</td>
<td>6,000</td>
<td>Hematite</td>
<td>BE</td>
<td>(2011)</td>
<td>-</td>
</tr>
<tr>
<td>Oman</td>
<td>Vale International S.A Vale Oman Pelletizing Company L.L.C.</td>
<td>9,000 (4,500 × 2)</td>
<td>Hematite</td>
<td>E/SV</td>
<td>2011</td>
<td>Operation</td>
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## Reference List (4/4)

<table>
<thead>
<tr>
<th>Location</th>
<th>Name of Customer</th>
<th>Plant Capacity (1,000tpy)</th>
<th>Raw Material</th>
<th>Scope of Work</th>
<th>Year of Completion (Completion of Service)</th>
<th>Present Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ukraine</td>
<td>Ferrexpo AG</td>
<td>-</td>
<td>Magnetite</td>
<td>WS</td>
<td>2011</td>
<td>Operation</td>
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<tr>
<td>Oman</td>
<td>Vale International S.A Vale Oman Pelletizing Company L.L.C.</td>
<td>9,000 ⇒ 11,000 (4,500 × 2 ⇒ 5,500 × 2)</td>
<td>Hematite</td>
<td>BE</td>
<td>2012</td>
<td>Under study</td>
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<tr>
<td>Oman</td>
<td>Vale International S.A Vale Oman Pelletizing Company L.L.C.</td>
<td>6,000</td>
<td>Hematite</td>
<td>BE</td>
<td>2012</td>
<td>-</td>
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</tbody>
</table>

BE: Basic Engineering  
EPC: Engineering, Procurement and Construction  
EPCM: Engineering, Procurement and Construction Management  
OMA: Operation and Maintenance Assistance  
WS: Works Survey and Basic Engineering  
MG: Management Service  
TR: Off-site Training Service  
TA: Technical Assistance  
SV: Supervisory Service
Kobe Steel, Kakogawa Works

- Year of Completion: 1970
- Capacity: 4.0 mtpa
- Present status: In operation
FMO, Venezuela

- Year of Completion: 1994
- Capacity: 4.0 mtpa
  (Upgraded by KSL from 3.3mtpa in 2007)
- Iron ore: Hematite
- Present status: In operation
Ardakan, Iran

- Year of Completion: 2008
- Capacity: 3.4 mtpa
- Present status: In operation
GIIC No.1, Bahrain

- Year of Completion: 1985
- Capacity: 4.0 mtpa
- Iron ore: Hematite
- Present status: In operation
GIIC No.2, Bahrain (1/2)

- Year of Completion: 2010
- Capacity: 6.0 mtpa
- Iron ore: Hematite
- Present status: In operation
GIIC No.2, Bahrain (2/2)

No.1 Pellet plant
(4 mtpa – Hematite)

No.2 Pellet plant
(6mtpa – Hematite)
Vale / Sohar, Oman

- Year of Completion: 2011
- Capacity: 4.5 mtpa x 2 lines
- Iron ore: Hematite
- Present status: In operation
Conclusion

• KOBELCO Pelletizing system (KPS) is grate – kiln system which has been supplied widely all over the world for long years.
• Taylor made KPS design can adapt to Indian ore to produce good quality pellet.
• KPS can produce suitable pellet for DR use.
• Collaboration between KSL and FLS realize advantages for Indian customers.
Thank you very much for your kind attention!