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ROLE OF IRON ORE PELLETS TO ACHIEVE TARGET OF PRODUCING 300 MT OF STEEL BY 2030

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SECRETARY GENERAL

PELLET MANUFACTURERS' ASSOCIATION OF INDIA (PMAI)

"Make in India" is an age-old concept for our country…

DANCING GIRL OF MOHENJODARO

A 10.8 centimeter high bronze statuette, sculpted using the
'lost wax' method around 2500 BC.
The 'lost wax' process pioneered by Indian craftsmen.

- excavated in 1926 from a house in the ancient city of Mohenjo-Daro, Pakistan.

Statue of Siva Nataraj, - the Lord of Dance

Made during the reign of Chola dynasty in South India (9^{th} to 10^{th} century).

Cast in bronze (alloy of copper and tin) – used extensively in statues of deities.

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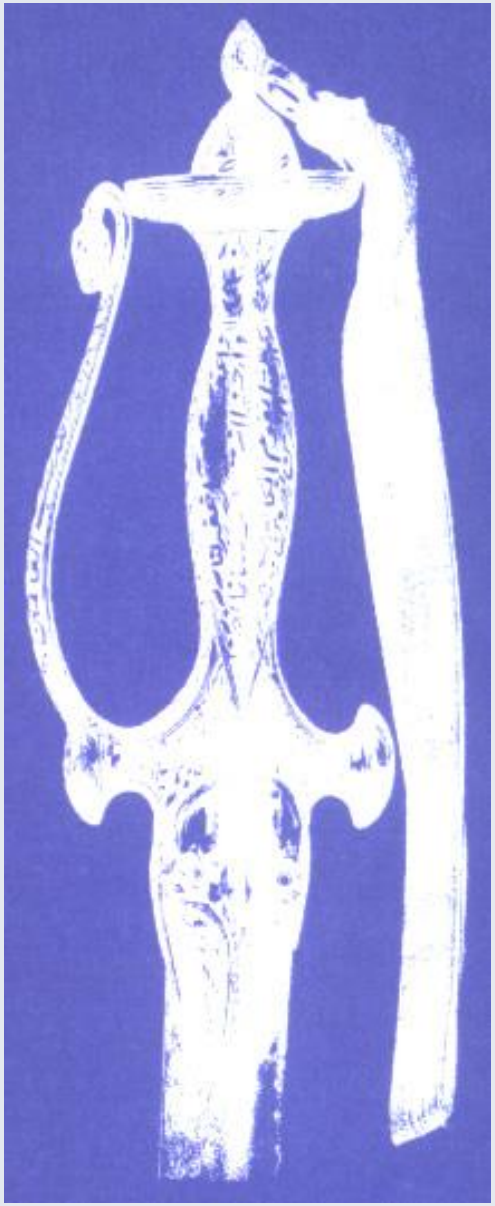
Sword of Damascus



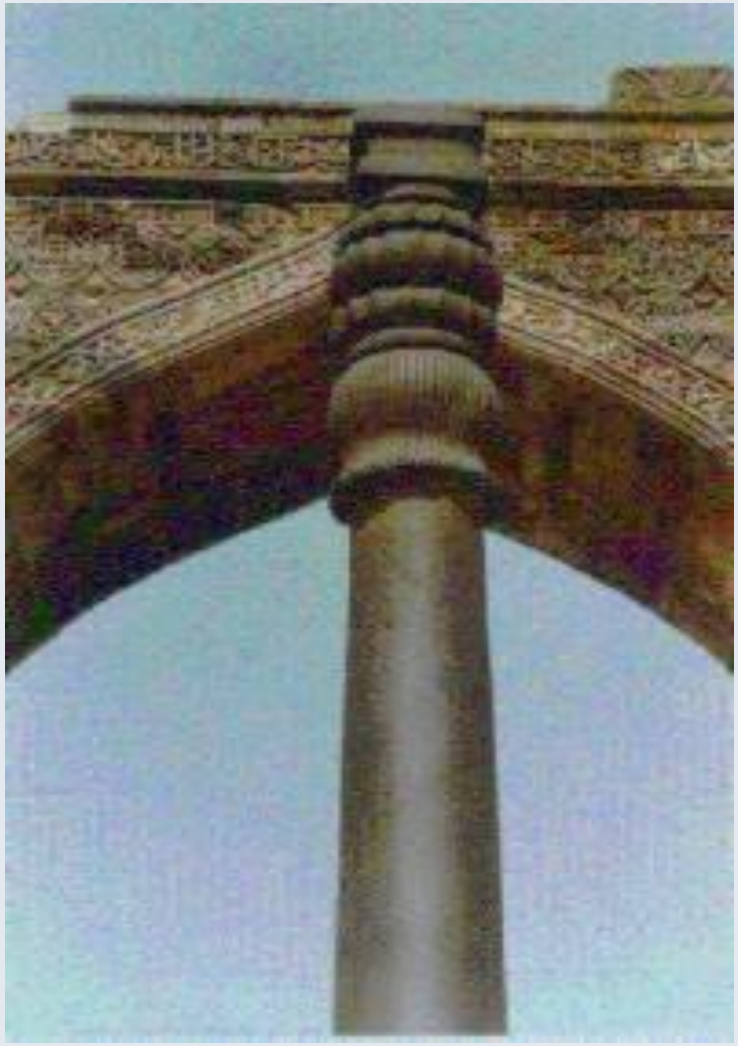
India's Legendary Wootz Steel

Wootz: taken from "ukku" Kannada word for steel

Iron Pillar at Mehrauli

- *the 'rust less wonder'!*

This pillar has not rusted in the last 1000 years.



India: rich tradition of steel making

A peep into the past……

- Indian Steel in arrows and swords:
  - Iron tipped arrows used by Indians in the Persian army (480 BC)
  - Alexander the Great prized a gift of 100 *talens* of steel from Porus in 326 BC
  - Indian 'Wootz' steel used for making Damuscus blades and became famous in Europe *('Wootz' derived from the Kannada word 'UKKU' meaning steel)*

  - British Royal Society made a detailed examination of Wootz Steel in 1790:
  - their report says…. *"the steel of India is decidedly the best I have yet met with!"*
  - Visionaries like Jamsetji Tata set up the first steel plant in India, early last century ….
  - ***"Should Tatas make steel rails to British specifications, I would undertake to eat every pound of it"***

    -Sir Fredrick Upcott, Chief Commissioner of Indian Railways.

"If Upcott had carried out this undertaking he would have had some slight indigestion" **(comment by Dorabjee Tata when the rails were sent to UK)**

Challenge: Raw Material Security – Increasing Supply of Iron Ore

- Installed capacity in India & Iron ore requirement (in Million TPA):

Pellet	85	100
Sponge Iron	48	80
Steel	110	200
Total Iron ore requirement		380 mTPA

With the Steel Ministry vision of 300mTPA production by 2030, the requirement of Iron ore will be around 550 mTPA .

Suggested Solutions :

- Iron ore production has to keep pace with capacity increase every year
- If supply side is adequate, price in auto correction mode
- Presently, supply of iron ore is throttled due to various reasons

Challenge: Long term Sustainability of Indian Iron Ore Resource

Pelletisation with Beneficiation will increase the feeding to Steel Plants by 15 years to achieve production of 300 MnT Steel (~500 MnT of Iron ore)

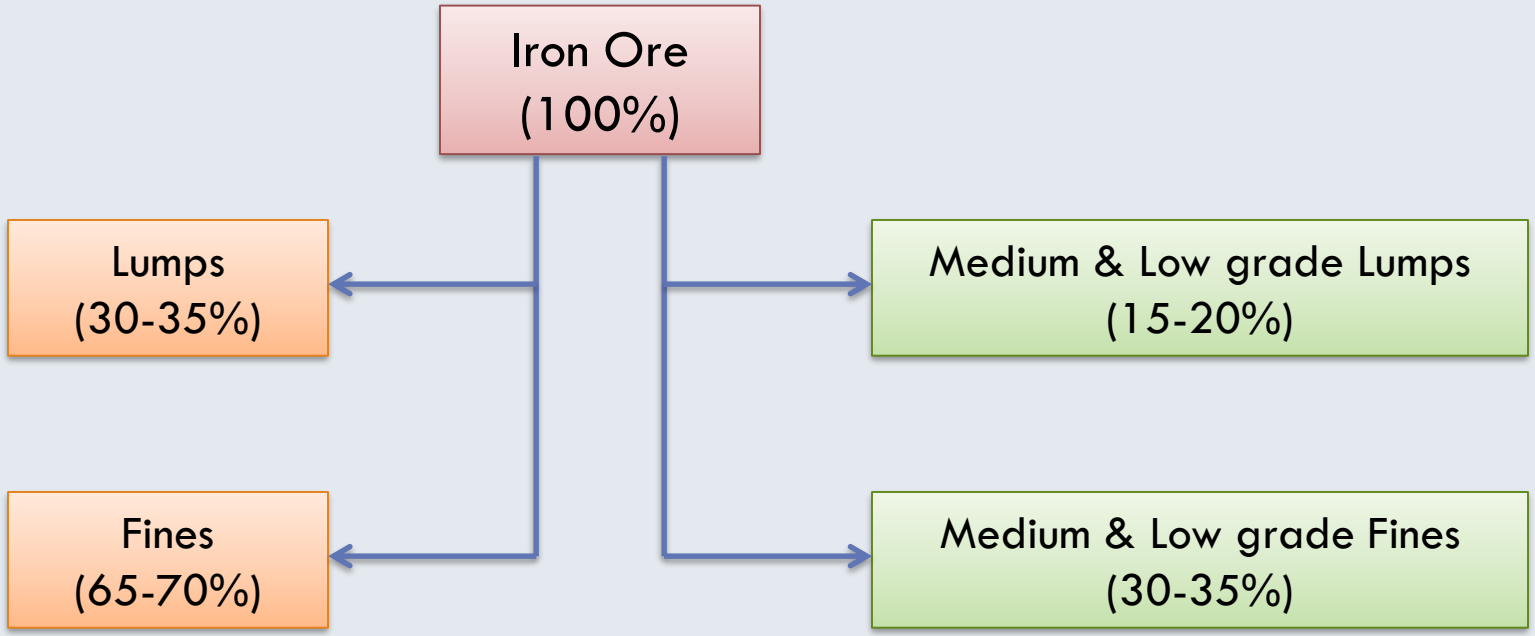
Figures are in '000 tonnes

Type	Proved	Probable	Remaining Resources	Grand Total
Hematite Ore, All India	5,982,042	2,111,504	9,788,551	**17,882,098**
Magnetite Ore, All India	15,973	5,783	10,622,305	**10,644,061**
TOTAL	5,998,015	2,117,287	20,410,856	**28,526,158**

- **Out of total 28.5 billion tonnes of iron ore; around 20% are of high grade, 30% of medium grade & 50% of low grade.**
- **Around 25 to 30% of low grade fines of grade 45 to 60% Fe being generated every year. These are continuously lying in dumps in the mining leasehold areas of the lessees.**

[Source: Indian Mineral Yearbook 2010, Indian Bureau of Mines]

Iron Ore Production – Overview



In total, around **75-80%** (Fines + Medium & Low grade Lumps) **of Annual production** is being stored at various mine-heads without any utilization.

Only solution is to do value addition of these ores through **beneficiation process**. After Beneficiation, concentrate produced can be used in iron & steel making **by making pellets**.

[Source: PMAI Research / Indian Bureau of Mines]

Pellets in Iron & Steel Making – Process Flow

Low grade Iron Ore Fines :
Fe: 58-60%
SiO_2: 5-7%
Al_2O_3 : 4-6%
LOI: 3-5%

Beneficiation

Pelletisation

Iron ore Pellets:
Fe: 64.0%
SiO_2: 3.0%
Al_2O_3: 2.7%
LOI ~ NIL

Iron Making Process

Sponge Iron / DRI

Blast Furnace

Corex

Steel Making

Pellet Industry in India

- Started in 1960s-Mandovi pellet plants in Goa
- Kudremukh (KIOCL) - 3MTPA plant in Mangalore 1987
- Tata Steel pellet plant -1980 s : 6MTPA plant
- Govt Policies gave a big fillip to pellet Industry :
- **FM Budget speech (2011-12):**

"Iron ore is also exported in a value-added , pelletized form. Full exemption from export duty is being provided to iron ore pellets to encourage the value addition process for fines"

Further , Budget speech of 2012-13 :

"To encourage enrichment of low-grade iron ore , of which we have huge reserves, I propose to reduce basic customs duty on plant and machinery imported for setting up or substantial expansion of iron ore pellet plants or iron ore beneficiation plants from 7.5% to 2.5%"

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Salient Statistics (India)

Estimated figures for 2016-17 in Million tonnes (mt)

- Pellet Production = 48.50 mt
- Pellet Export = 8.26 mt(to China, Oman, Iran & others)
- Pellet Import = 0.34 mt (from Bahrain & Australia)
- Major Pellet users : TATASteel, JSPL, ESSAR, JSW, Bhushan Steel
- PSU Steel plants of SAIL & RINL, presently not using pellets : Exploring their use in BFs

Pellet /Beneficiation plants in India

- **43 pellet plants with a total capacity 85MTPA**
- **25 beneficiation plants :total capacity 117 MTPA**
- **Set up at a total cost of Rs45,000 cr**
- **Employment to 100,000 people**

State	Pellet Plants	Capacity (MTPA)	Benefication Plants	Capacity (MTPA)
Odisha	13	29.70	9	47.10
Chhattisgarh/ MP	12	9.30	6	19.40
Jharkhand/ WB	7	12.30	4	16.26
Karnataka	7	18.90	5	32.70
Andhra	1	8.00		
Maharashtra/ Goa	2	5.80		
Rajasthan	1	1.2	1	2.00
Total	**43**	**85.20**	**25**	**117.46**

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Agglomeration

- Briquette

- Sinter

- Pellet

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What are Pellets ?

- Pellets are ground iron ore fines converted to spherical shaped balls
- Have good physical properties for mechanical transportation over long distances
- Have excellent metallurgical properties (similar or better than lump iron ore - CLO)
- Vital raw material for all types of iron making
- Technology uses the powder that is generated during ore extraction process, once considered waste

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Why Pellets ?

- Affordable, high quality raw materials for iron making are steadily decreasing on a global scale.
- Fine and Ultra fine iron ores will command an ever-larger share of iron ore sales in future.
- Growing number of iron and steel producers increasing proportion of pellets in burden.
- Fluctuating prices of iron ore fines and pellets in world market can seriously affect cost-efficient iron making.
- Pellets preferred over sinter and lump ore due to their shape, size, strength and excellent metallurgical properties.

Pelletisation plants: Need of the Hour

- Non-availability of calibrated ore and rising prices of Iron ore fines
- Most optimum route for agglomeration
- Utilisation of low grade ores/fines/ slimes/ tailings
- Superior feed material compare to calibrated lump ore (CLO)

Advantages of Pellet Utilisation

- Utilisation of waste ores and lean ores as cheaper and abundant raw materials
- Higher tumbling index and lower abrasion index
- Good porosity
- Better reducibility
- Choice of size
- Built in flux
- Higher bulk density compared to sinter
- Improved productivity
- Reduced coal consumption

Existing Pelletisation Technologies

- Shaft Furnace Technology
- Grate-Kiln Process
- Travelling Grate or Straight Grate Process
- Circular Travelling Grate
- Steel Belt Sinter

Pelletisation Process

Step 1: Production of green balls in a disc/drum where fine grained iron ore with proper size distribution and mixed with a binder (usually bentonite) and additives such as limestone/dolomite and coke fines with additional water.

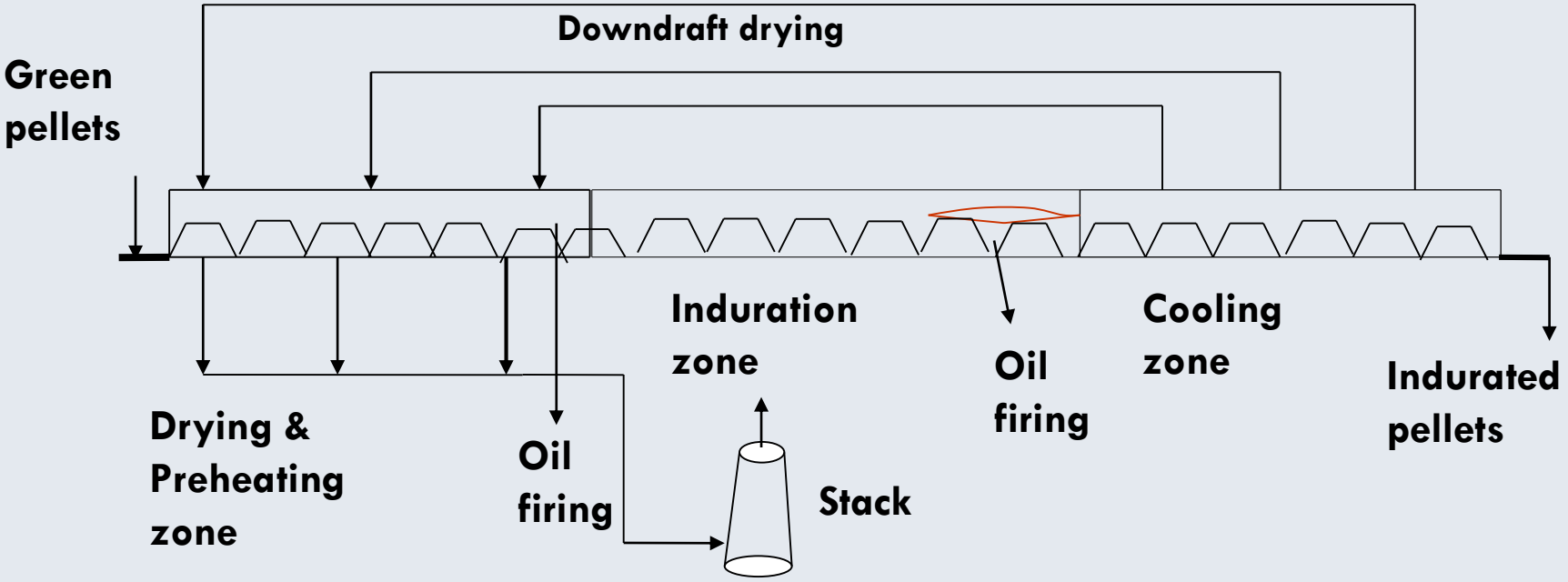
Step 2: Green balls are dried, preheated and heat hardened (indurated) by predetermined heating rates under oxidizing atmosphere to facilitate bond formation.

Step 3: Pellets are cooled carefully to avoid crack/fracture formation.

Travelling Grate Process

- Traveling grate process, originally designed for sintering, was modified to make it suitable for drying, preheating, firing and cooling pellets in one single unit.
- However, the individual thermal zones are separate.
- These zones could be designed to suit the ore types by controlling flow rates and temperatures.

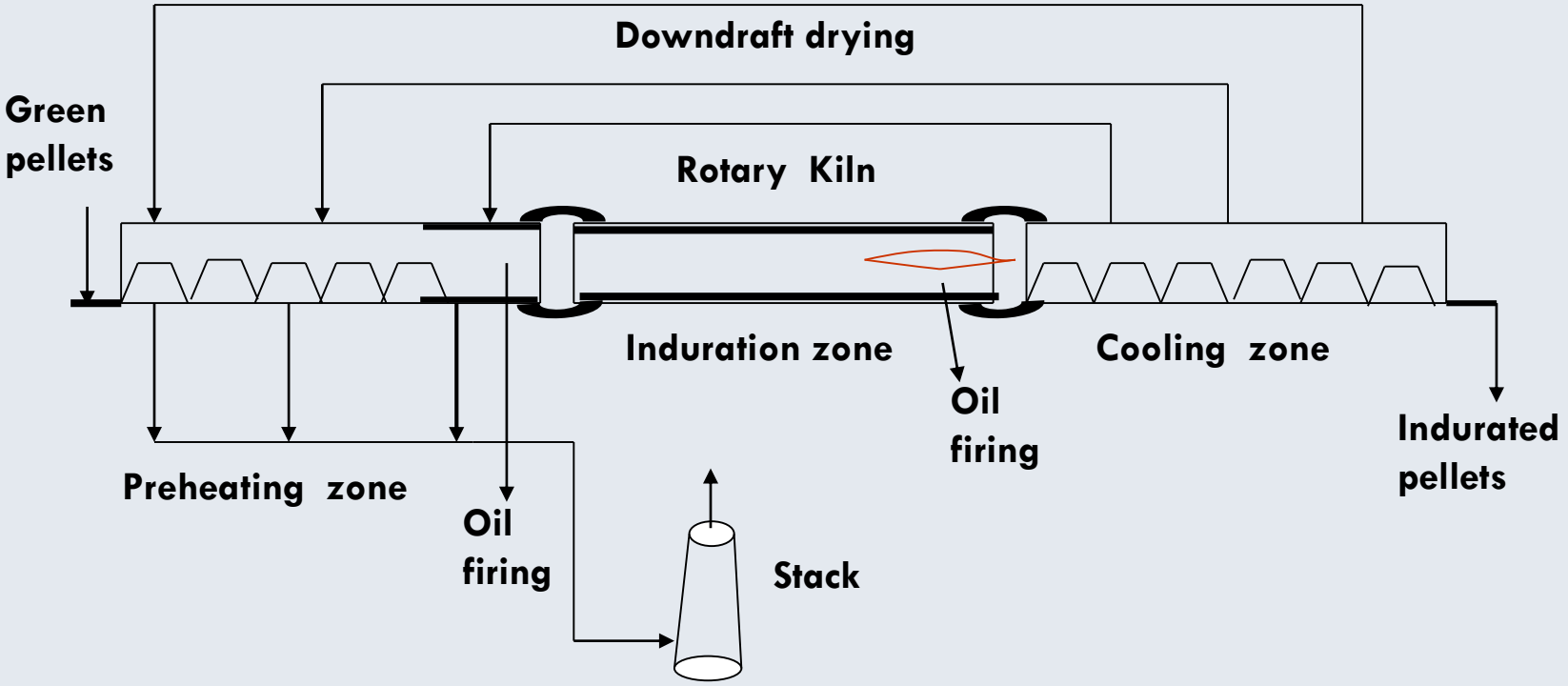
Traveling Grate Process



Grate Kiln Process

- The grate-kiln process has three units for meeting radically different thermal conditions.
- Drying, pre-heating and oxidation are carried out in a traveling grate while pellets are fired in a rotary kiln by radiation. Hot pellets are cooled in a rotary cooler.
- Hot air from the rotary kiln is used in the grate for drying and preheating. The hot air from the cooler is recirculated in the rotary kiln.
- Heat supply for various types of one can be regulated very easily because of three units being separate.

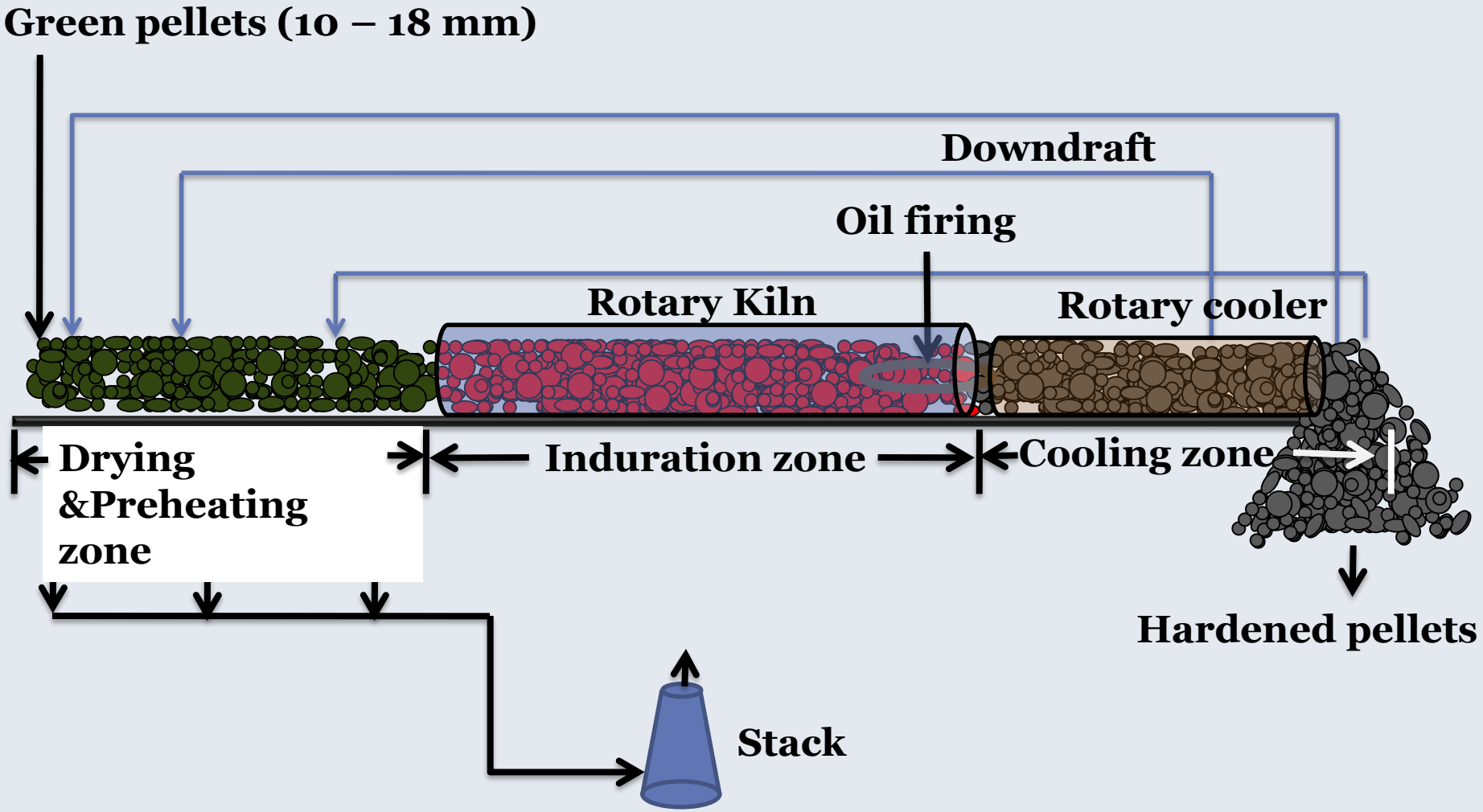
Grate Kiln Process



Circular Pelletizing Technology

- Introduced by Voest Alpine – Siemens
- The World's most compact pelletizing plant : facilities integration at the mine or within steel unit
- The core innovation of the CPT plant is the unique circular design of the induration furnace.
- Space requirement for the induration furnace building reduced by 50% : production efficiency vastly improved
- Pellet Productions capacities range from 0.8 to 3 MTPA
- Worlds first CPT plant of 1 MTPA set up by Pro-minerals Limited at Odisha.

Pelletization Equipment



Mechanism of Pellet Formation

- Granulation is a combination of three processes, namely wetting & nucleation, consolidation & growth, and attrition & breakage.
- Natural (physical) and applied (mechanical) forces contribute to the formation of green pellets. Natural forces include:
  - attraction forces between particles,
  - interlocking effects,
  - adhesional and cohesional forces; and
  - interfacial and capillary forces due to the presence of liquid phase

Size of the Pellets

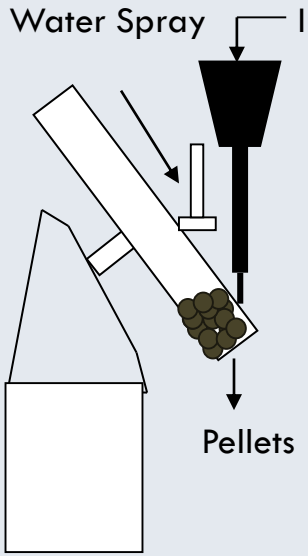
- At least 90 % of pellets should be between 9.0 mm and 18 mm with minus 5 mm material of no more than 5%. A close size distribution is preferred for a better permeability of the pellet bed in the induration machine.
- The pelletizing plant products are in the size range of 9 to 18 mm.
- With increasing pellet size, the sintering intensity, thermo-chemical conditions and formation of different phases vary across its cross section.
- The time required for various reactions within the pellet is directly proportional to the pellet size.
- Pellets in the size range of +8 to -12 mm show good strength and lower reduction degradation index (RDI). It has also been observed that the amount of hematite, magnetite, porosity, pore density, pore size and slag phase play a significant role on pellet strength and RDI.

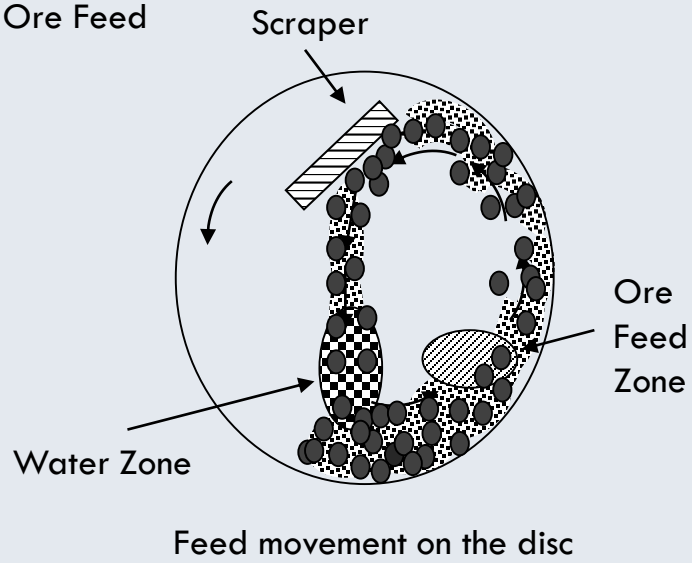
Pellet Quality

For blast furnace and direct reduction process

- Cold compression strength : 2500 N/pellet or 250 kg/pellet
- Tumble index : + 6.35 mm > 95%
- Abrasion index : - 0.5 mm < 5%
- Shatter index : + 10 mm > 85%
- Size of the pellet : 9-16 mm >85-90%
- Fines - 1 mm : <1 %
- High porosity, reducibility and degree of metallization

Pellet Making

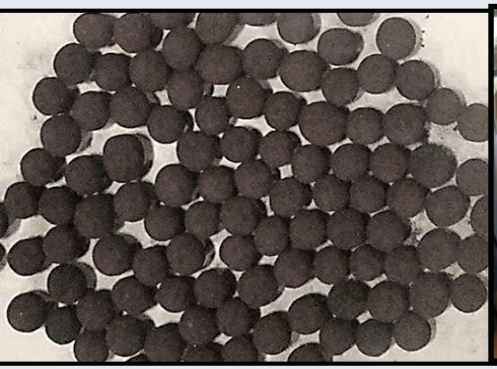




Feed movement on the disc

Disk pelletizer

Rpm = 18
Diameter = 1m
Angle = 45˚



Green Pellets

Pellets in Muffle furnaces

Indurated pellet

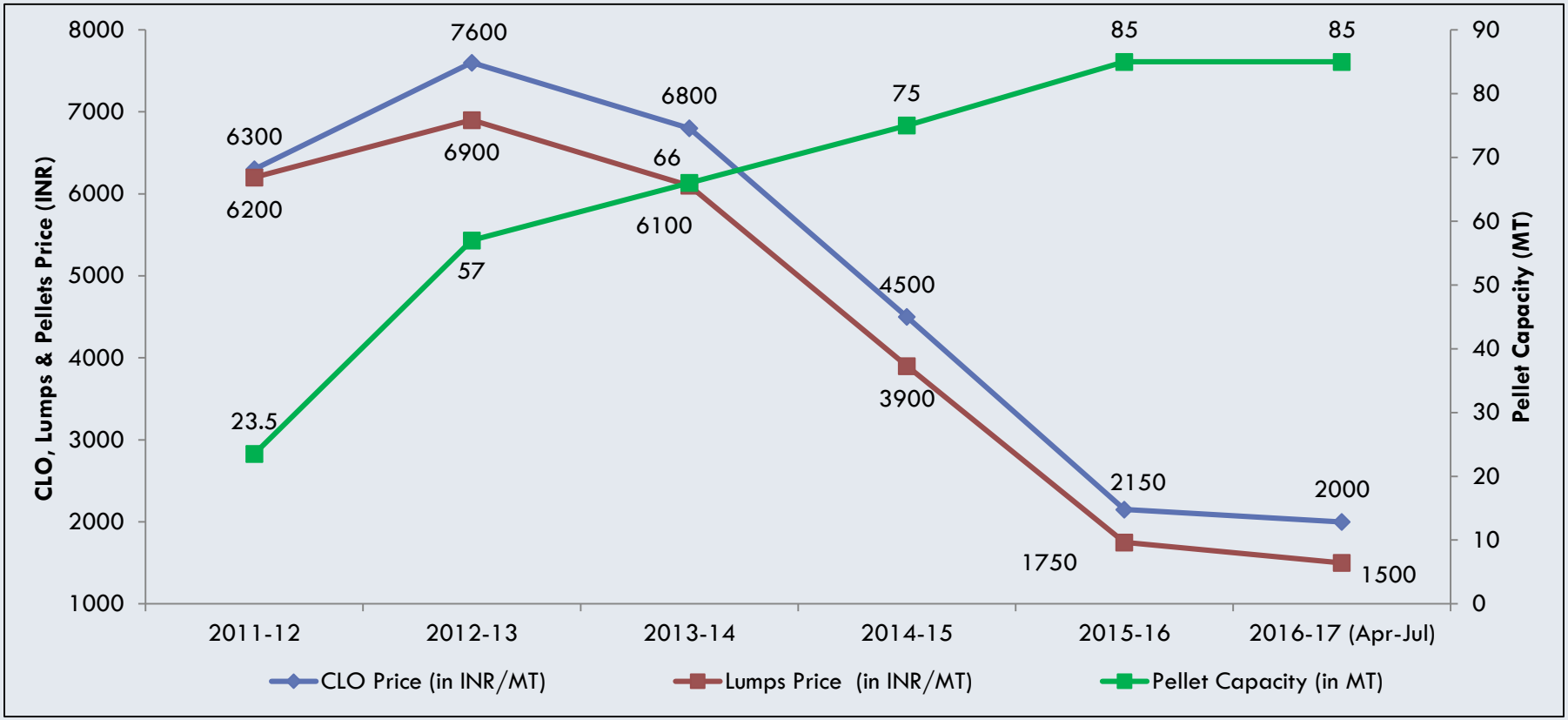
Benefits of Pellets In Iron & Steel Making

- Good quality pellets can be produced at low SiO_2 levels (1.5 to 3.5%) whereas it is difficult to produce quality sinter at a SiO_2 level of less than 4.5%, which helps **slag volume reduction** by 40 to 45%. ⬇
- Uniform quality & superior chemistry will **enhance production** by nearly 15 to 20% of their rated capacity. ⬆
- Specific **consumption of coal/coke/heat energy** will **come down** by 10 to 15%. ⬇
- **Campaign life** will increase to **almost double**. ⬆
- High porosity (20 to 25%) leads to **faster reduction**. ⬆
- About **10-15% less power consumption** compared to sponge iron from lump ore. ⬇
- As there will be no accretion and no fused lump formation, the **refractory repairing cost** will be **reduced by 50%.** ⬇

[Source: C-Tempo, Ministry of Mines / LKAB, Sweden / Association for Iron & Steel Technology]

Support of Pellet Industry to Steel Industry

As pellets replace Lumps & CLO for Iron & Steel manufacturing, Prices of Lumps & CLO are progressively reduced with increase in pellet capacity, which in turn helped the Steel Industry.



[Source: SteelMint / Indian Bureau of Mines / OMC]

Economic Benefits of Beneficiation

(Iron ore Beneficiation capacity – 117 MT)

Change in Parameter after Beneficiation	Outcome in Final Product
Fe – 1% ↑	Hot Metal productivity 1.5-2% ↑ Coke rate 0.8-1.2% ↓ Production Cost/tHM 60-70 INR ↓
Al_2O_3 – 1% ↓	Production Cost/tHM 200-250 INR ↓
SiO_2 – 1% ↓	Production Cost/tHM 50-100 INR ↓
Undersize in iron ore – 1% ↓	Production Cost/tHM 50-60 INR ↓
Fluctuation in Fe Chemistry – 1% ↓	Production Cost/tHM 40-50 INR ↓

[Source: Industry Data]

Benefits of Pellets in Sponge Iron/DRI

- **Higher Yield**

  Pellets having higher Fe content (63-65%) **yields in higher metallic iron** in P-DRI.

- **Higher Production**

  Pellets with their high & uniform mechanical strength and higher abrasive strength **increase production of sponge iron by 20-25%** with same amount of fuel.

- **Higher Metallization**

  Because of low gangue content in pellets, it gives about **90% or higher metallization** compared to lump ore (85 to 87%).

- **Less fine generation**

  Pellets having higher tumbler index, generates very **less amount of fines during reduction** (about 5-7% compared 25-30% for lump ore).

[Source: UNCTAD / Steel Times International]

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IRON ORE PELLETS FOR DIRECT REDUCTION PROCESSES – SPECIFICATION (Second Revision)

Chemical Composition

The iron ore pellets shall conform to the following chemical analysis (dry LOI free basis):

Constituent	***Percentage***
Fe (Total)	*66.5 Min*
$S_iO_2 + Al_2O_3$	*4.0 Max*
CaO + MgO	*0.5 Min*
CaO + MgO	*shall be as agreed mutually*
$S_iO_2 + Al_2O_3$	*shall be as agreed mutually*
S	*0.01 Max*
P	*0.04 Max*

Size range for iron ore pellets at the point of dispatch

+19 mm - 5%, Max	**-19 +9 mm - 85 %, Min**
-9 +5 mm - 5%, Max	- 5 mm - 5 % Max

Physical attributes of Pellets

Compressive Strength Before Reduction

(in accordance with IS 8625)

Shall not be less than 200 kg/Pellets

Pellets with the strength < 80kg per pellets shall not exceed 5%

Compressive Strength After Reduction

(in accordance with IS 8604)

Shall not be less than 50kg/Pellets to minimize fines generation in furnace and handling systems

Reducibility *(dR/dt at 40% reduction)*

Shall be 0.6%/minimum (in accordance with IS 8167)

Swelling Index *(in accordance with IS 8624)*

Shall be 18% Max

Softening Characteristics *(In accordance with IS 9660)*

A typical value of start of softening tempr should be 1 125°C minimum

Tumbler Index: *Shall be 92% min on +6.3 mm and 6%Max on -0.500 mm*

(in accordance with IS 6495)

Benefits of Pellets in Iron & Steel making

- **Reduction in Slag volume**

  Good quality pellets can be produced at low SiO_2 levels (1.5 to 3.5%) whereas it is difficult to produce quality sinters at a SiO_2 level of less than 4.5%, which helps **slag volume reduction by 40-45%.**

- **More Production**

  Pellets, having uniform quality & superior chemistry, **enhance production by nearly 15-20%** of their rated capacity.

- **Reduction in coal / coke / heat energy consumption**

  Specific consumption of coal/coke/heat energy will **come down by 10-15%.**

- **Less Power consumption**

  About **10-15% less power consumption** compared to sponge iron from lump ore.

[Source: C-Tempo, Ministry of Mines / LKAB, Sweden / Association for Iron & Steel Technology]

Benefits of Pellets in Iron & Steel making

- **Faster Reduction**

  High porosity (20-25%) leads to **faster reduction.**

- **Longer Campaign life**

  Campaign life will increase to **almost double.**

- **Reduction in Refractory repairing cost**

  As there will be no accretion and no fused lump formation, the **refractory repairing cost** will be **reduced by 50%.**

- **Less fine generation**

  Pellets have very high cold crushing strength resulting in **negligible generation of fines** in stock house. Only 2-3% will be –5mm range.

[Source: C-Tempo, Ministry of Mines / LKAB, Sweden / Association for Iron & Steel Technology]

Benefits of Pellets in Iron & Steel making

- **Lower emission rate**

Emissions in sintering process are much higher than compared to pelletizing process. **Decreases the emission rate** CO_2 by 85%, SO_X by 90%, NO_x by 20% compared to sinters.

A table of emission details is shown below:

Process	SO_x (gm/t)	NO_x (gm/t)	CO (Kg/t)	CO_2 (Kg/t)	Particulate Matter (gm/t)
Sintering	**1670**	**640**	38	**220**	260
Pelletising (hematite ore)	**200**	**500**	1	**30**	80-85
Pelletising (magnetite ore)	100	200	< 1	25	125

[Source: *Research Papers, US Environment Protection Agency & BTG Pactual*]

Energy Demand

Total energy required per ton of

- sinter: 515 kwh
- pellet: 335 kwh
- Net energy savings w.rt Pellet Plant: 180kwh/ Ton
- Annual gross energy reduction: 720 Million Units

(Source: Global Consultancy Services, USA)

BENEFITS OF PELLETS IN IRON & STEEL MAKING

- how Pellets contribute to reduction in CO_2 emmission

Considering 100 Million Tonnes of Steel production & 85 Million Tonnes of Pellet production per year, following CO_2 emissions can be reduced per year.

1) Mining – As per FIMI, around 100 million tonnes of iron ore fines stocks are available in our country. Existing Iron ore Beneficiation units shall use these fines' dumps, which in turn reduce further mining & reduction in CO_2 emission by 0.09 Mil. Tonnes (0.9 KgCO2/t X 100 Mil. Tonnes)

2) Pipeline – Around 40 MTPA Iron ore slurry is being transported through underground pipeline from various Beneficiation Plants to respective Pellet Plants. It reduces CO2 emission by 1.14 Mil. Tonnes ((32.2-3.8) Kg CO2/t X 40 Mil. Tonnes) per annum comparing to road transport.

3) Agglomeration – 85 MTPA Iron ore pellet production will reduce CO2 emission by 16.2 Mil. Tonnes ((220-30) Kg CO2/t X 85 Mil. Tonnes) per annum comparing to sintering process.

4) Iron & Steel Making – By use of 85 MTPA Iron ore pellets for iron & steel making will reduce CO2 emission by 26.7 Mil. Tonnes ((1255-941) Kg CO2/t X 85 Mil. Tonnes) per annum comparing to the use of sinters.

In total; around **44 Million Tonnes of CO_2 emission per year** can be reduced by use of pellets.

[Source: United States Environmental Protection Agency (US EPA),
Analysis Report, Department of Energy & Climate Change (DECC), Government of UK]

Ratifying Paris climate deal - an imperative for India: Pellets can contribute

- Capping temp rise < 2 deg c
- 35% reduction in emission levels by 2030 from 2015 level
- $2.5 trillion estimated investment required
- 40% of overall energy must be non-fossil fuel based by 2030
- Above 25 yrs old coal based power plants to be shutdown
- 34,278 mw thermal power plants to be closed.
- Total coal based capacity 211,640 mw (2015 CEA report)

SLURRY TRANSPORTATION

Environmental benefits

Why Pipeline Transportation ?

- Environmental friendly
- No Surface Visuals
- Almost nil noise pollution
- Reliable
- No empty returns
- Safe
- Less space
- Low operating costs
- Very Low energy cons
- Durable
- Less susceptible to theft
- No over ground occupation
- On and offshore
- Shorter trajectory
- Enormous transport capacity
- Continuous flow
- Weatherproof

Belowground Pipelines Transportation

- CO_2 emission is much lower compared to surface transport. CO_2 emission is reduced by above 90% of that of surface transport.
- More efficient use of energy. Reduce 95% energy consumption comparison to surface transport.
- Requires around 20% water for transportation & Total reuse & recycle.
- In conclusion, pipeline mode transportation is more eco-friendly and environmental benefit to all.
- Slurry pipe-lines in India: ESSAR, BRPL & KIOCL

Pipeline Transportation

- Space requirement of pipeline transport is minimal. To compare to other mode of transportation:
  - Inland shipping needs 100 times.
  - Road transport needs 50 times.
  - Rail needs 12 times
- Ministry of Steel : Tie up with Indian Railways to build Slurry Pipe lines next to Railway tracks

Belowground Pipelines Transportation

- No traffic related hazards compared to alternative modes of transportation.
- The life of the pipelines generally above 30 years and after pipelines laid, the land will be restored to original state and can be put to normal use.
- It is economical and independent.

Pellets Technology and R&D

Project Funded by Ministry of Steel under SDF

Title: Development of Pilot Scale Pelletisation Technology for Indian Goethite / Hematite Ore with Varying Degree of Fineness

Objectives:

- To set up a pilot scale pelletisation facility for iron ore fine concentrate of capacity 40-60 kg / batch at RDCIS

- To develop relevant technological parameters for producing heat hardened pellets from goethite / hematite iron ores

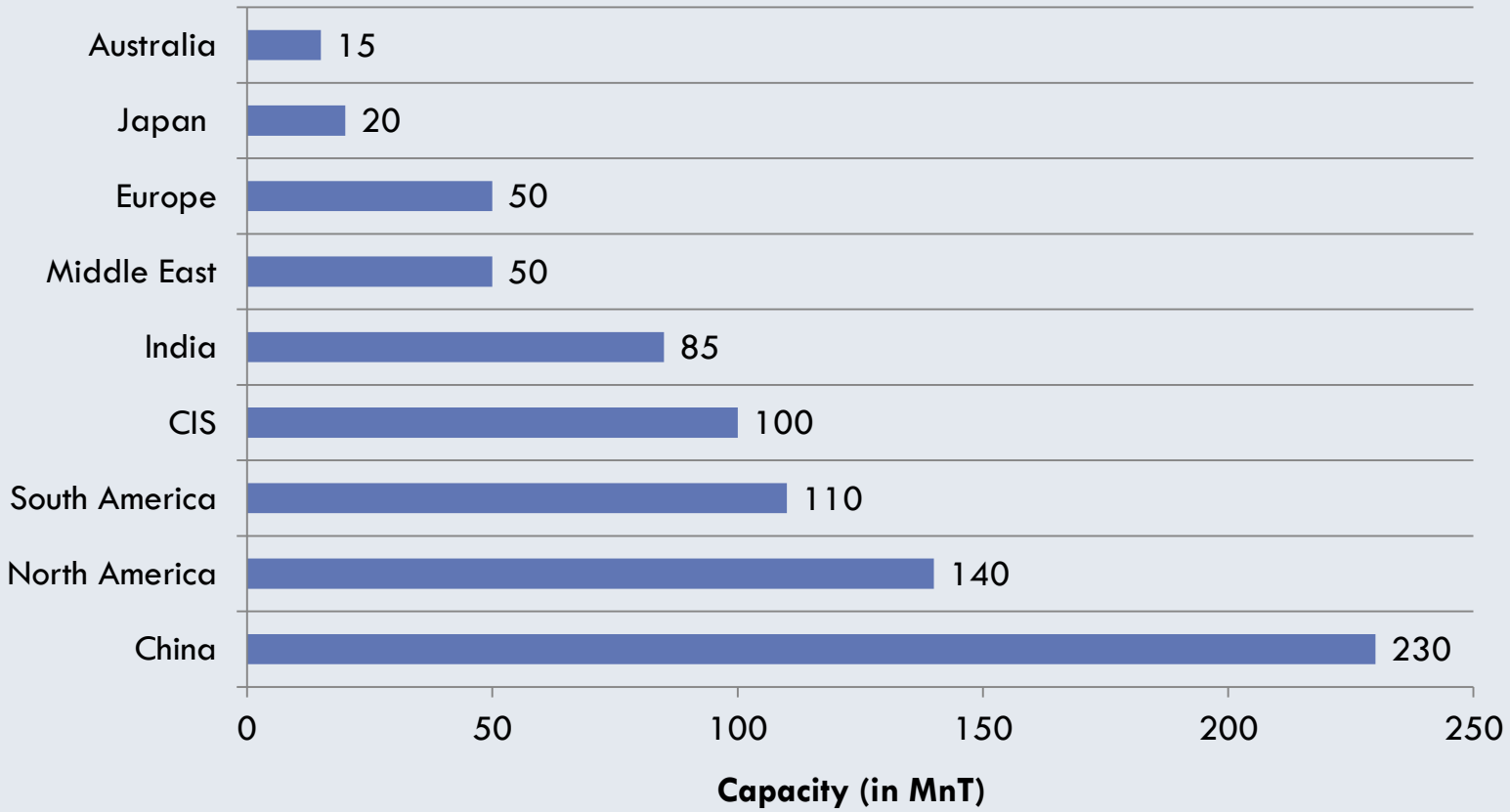
Project partners and budget Rs. 41.9 Crores:

- RDCIS (SAIL) - 31.4
- IMMT (Bhubaneswar) - 6.8
- IIT (Khargpur) - 1.0
- NML (Jamshedpur) - 2.7

Back Ground of SAIL R&D Project

- Various SAIL iron ore mines have about 100 mt of dumped fines & slimes (low grade iron ores) as waste
- Corporate plan envisages use of these low grade ores in future
- These ores have to be ground upto micron level at first for its beneficiation
- Utilization of these micro fines is limited in sintering process
- Pelletization is the only route for its effective utilization
- Study in the field of grinding, green pellet preparation and development of proper induration cycle

WORLD PELLET INDUSTRY



Total World Capacity ~ 800 MTPA

[Source: UNCTAD / Steel Times International]

PLANT PHOTOGRAPHS

IRON ORE BENEFICIATION PLANT

PLANT PHOTOGRAPHS

IRON ORE PELLET PLANT

SLURRY PUMPING SYSTEM

Introduction of PMAI

- Principal Objective of PMAI – Promote use of Indian Pellet in sponge iron and steel manufacturing industry in India – "Make in India" objective.
- **Pellet Manufacturers Association of India** (PMAI) : **25 members** represent
  - investment of over 25,000 crores INR,
  - employment of around 70,000 Nos. &
  - over 53 Million Tonnes Per Annum (MTPA) Iron ore pellet manufacturing capacity in India. (Total Pellet Production capacity in India – 85 MTPA)
- Platform for ensuring sustenance and promotion of the Pellet industry.
- Iron ore Pellet is a value added manufactured product and excise duty is levied on the same.
- PMAI is officially recognised by Ministry Of Steel (our parent Ministry) to represent the pellets industry in India . Regular interface for Policy interventions with Departments of Steel , Mines, MoEF, Railways , Finance , Commerce and NITI Aayog.

India can become a GLOBAL LEADER in manufacturing of pellets to the world steel industry for the benefit of

- **conservation of non-renewable iron ore resource,**
- **economic growth,**
- **environment protection,**
- **employment opportunity &**
- **to support "Make in India" campaign.**

THANK YOU

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