Comparison of pelletizing technologies with specific reference to the Iranian market

2nd Metal Bulletin Iranian Iron and Steel Conference
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Contents

1) Acknowledgements

Author(s)	Title	Source	TG : GK
Ken Oja; Cliffs Technical Group	Straight Grate vs. Grate/Kiln	COREM Pellet Symposium, Quebec City, October 2013	9 : 9
Cameron, Huerta, Bolen, Okrutny, O'Leary, Hatch	Guidelines for Selecting Pellet Plant Technology	AusIMM, Perth, July 2015	12 : 9
Brahma, Patnaik, Majumder; MECON	Realizing state of the art "All Indian Pellet plant" by MECON	MECON Seminar on Mines and Steel, Ranchi January 2016	3 : 0
Tsutomu Nomura; Kobe Steel Ltd.	KOBELCO Pelletizing System - Latest and Future Prospects on Pellet Technologies	4th Metal Bulletin DRI- and Pellet Conference, Dubai, April 2016	0 : 6
			24 : 24

1) Introduction

Elham Kordzadeh

M.Sc. in Corrosion Science and Engineering from Shahid Bahonar University of Kerman, Iran
14 years in the industry with NICICO, Samangan, Dyto, ITOK, Pamdico, TIV Energy, Fakoor Sanat
Pelletizing experience from Khorasan, Gohar Zamin, Sangan, Se Chahun

Georg Strüber

Mechanical Engineer, Energy and Environment from University of Applied Science Bremen, Germany
8 years in the industry with Outotec, Vale, Paul Wurth
Pelletizing experience from LKAB, Tata Jamshedpur, S-GOK, Baotou, Samarco, Vale Sohar

Thomas Schwalm

Dipl.-Ing. Mechanical Process Engineering from Technical University Freiberg, Germany
24 years in the industry with Lurgi, Outotec, Paul Wurth
Pelletizing Experience from LKAB, Vale Kobrasco, São Luís, Samarco 3 and 4, Gol-e-Gohar 1, Tata Jamshedpur, S-GOK

2a) Plant Capacity

Biggest Single Strand Capacity

• Grate/Kiln	6mtpy	Bahrain Steel 2, Bahrain	(2011)
• Travelling Grate	8.5mtpy	Samarco 4, Brazil	(2013)

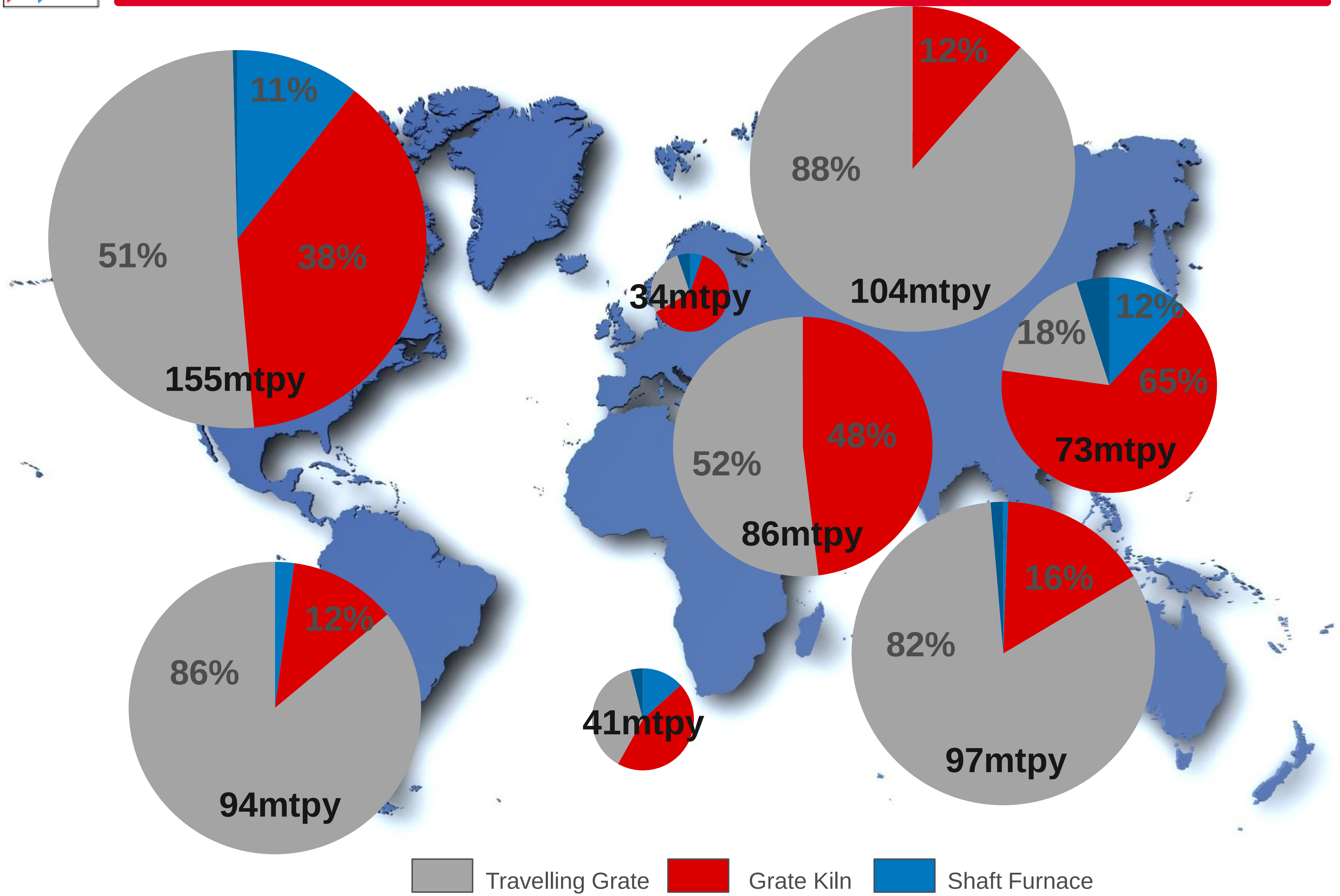
Biggest Pelletizing Complexes

- Vale, Southern System, Brazil
  39mtpy (100% travelling grate)
- LKAB, Sweden
  16.5mtpy (66% grate/kiln)
- IOC, Canada
  13 mtpy (100% travelling grate)

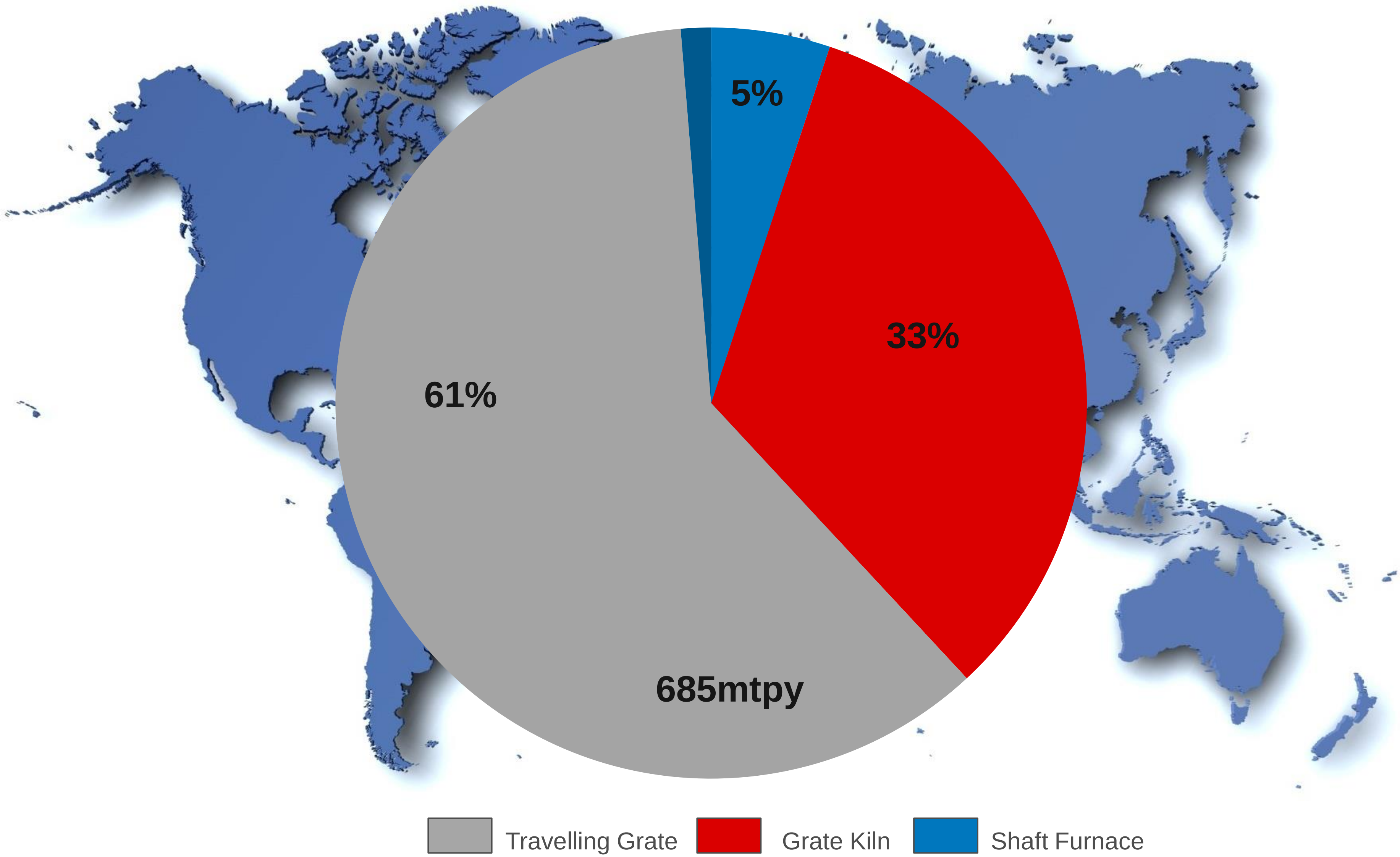
Ever Installed Capacity

- Grate/Kiln 226 mtpy
- Travelling Grate 410 mtpy

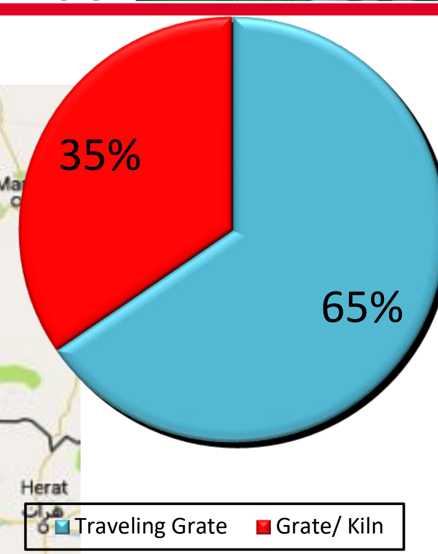
2b) Total World Capacity, ever installed: 685 mtpy

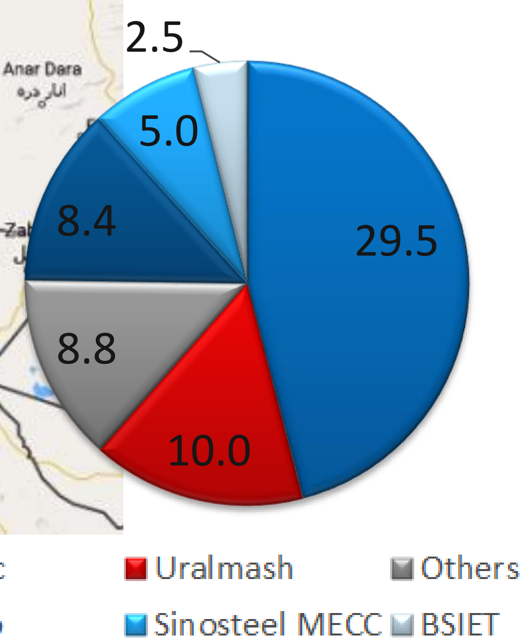


2b) Total World Capacity, ever installed: 685 mtpy



2b) Capacity Iran: Total Capacity under Installation 64 mtpy



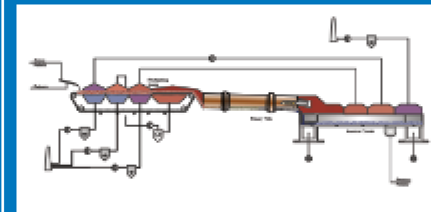
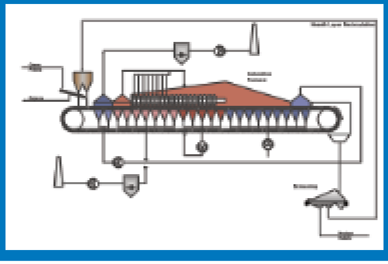


2b) Capacity Iran – Operating Plants

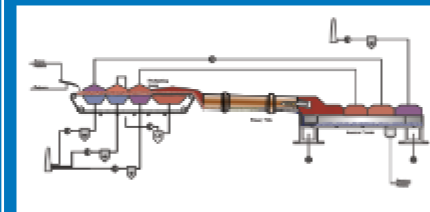
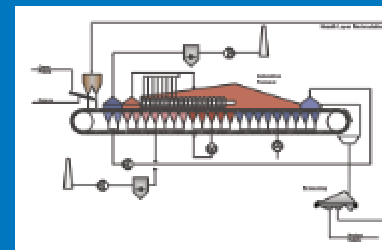
Start-Up	Plant Name	Technology	Design Capacity	Current Capacity
1977	Khouzestan	Travelling Grate	2 x 2.5 mtpy	6.2 mtpy
1980	Mobarakeh	Travelling Grate	4.5 mtpy	7.2 mtpy
2005	Ardakan	Grate Kiln	3.4 mtpy	2.75 mtpy
2007	Gol-e-Gohar	Travelling Grate	5 mtpy	5.3 mtpy
2016	Zarand	Grate Kiln	2.5 mt/y	Ramp-up

IMIDRO, NISCO, CODAL

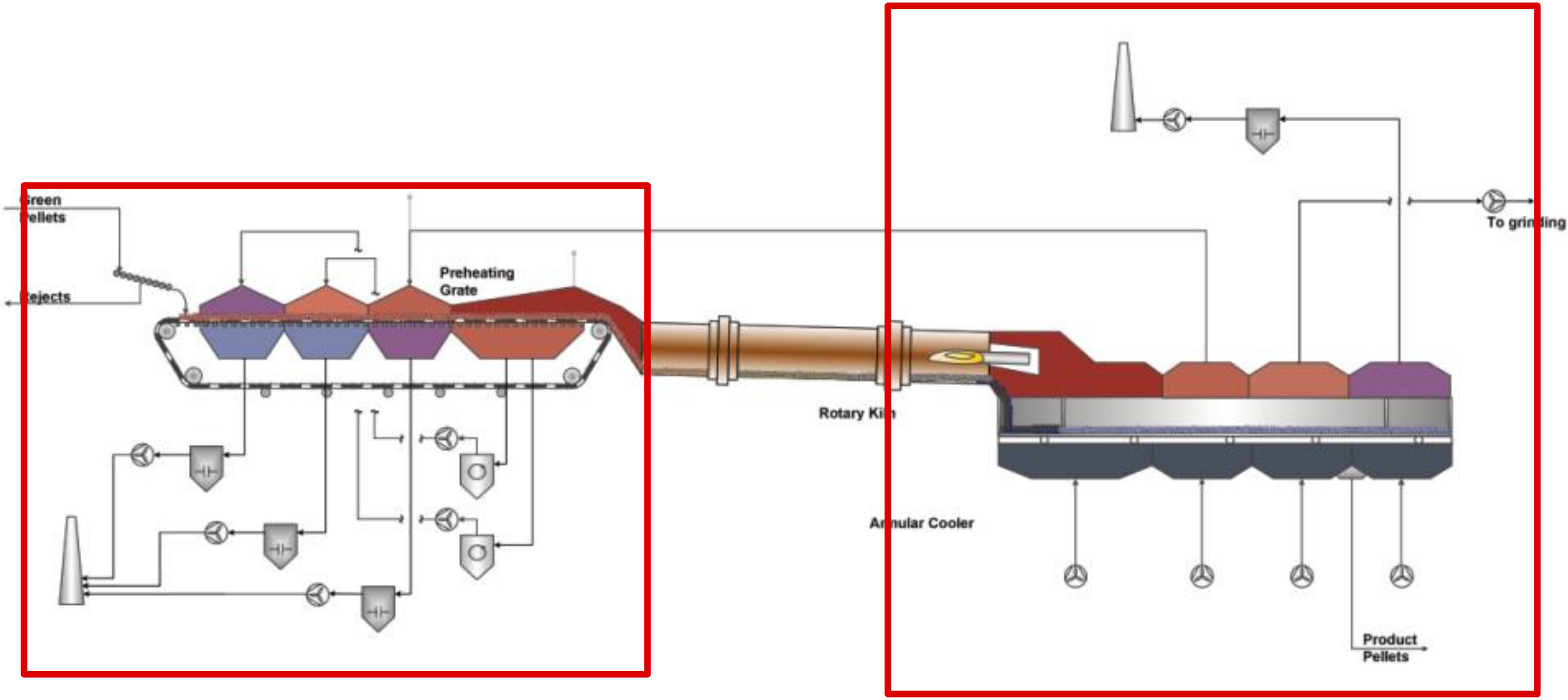
2c) Technological Key Features

			
Configuration	3 individual equipment: preheat grate – kiln - cooler	1 travelling grate	Intermediate strength for transfers in grate kiln required
Hearth Layer	Not required	Approx. 30% of total production being recycled	Hearth layer can deteriorate overall product quality
Bed Height	12 – 23cm on preheat grate and 60-100cm on cooler	typically 10+31cm	Higher bed height causes higher pressure drop
Material Transport	Stationary on grate and cooler, intensive tumbling in kiln->	Stationary throughout the travelling grate	

2c) Technological Key Features

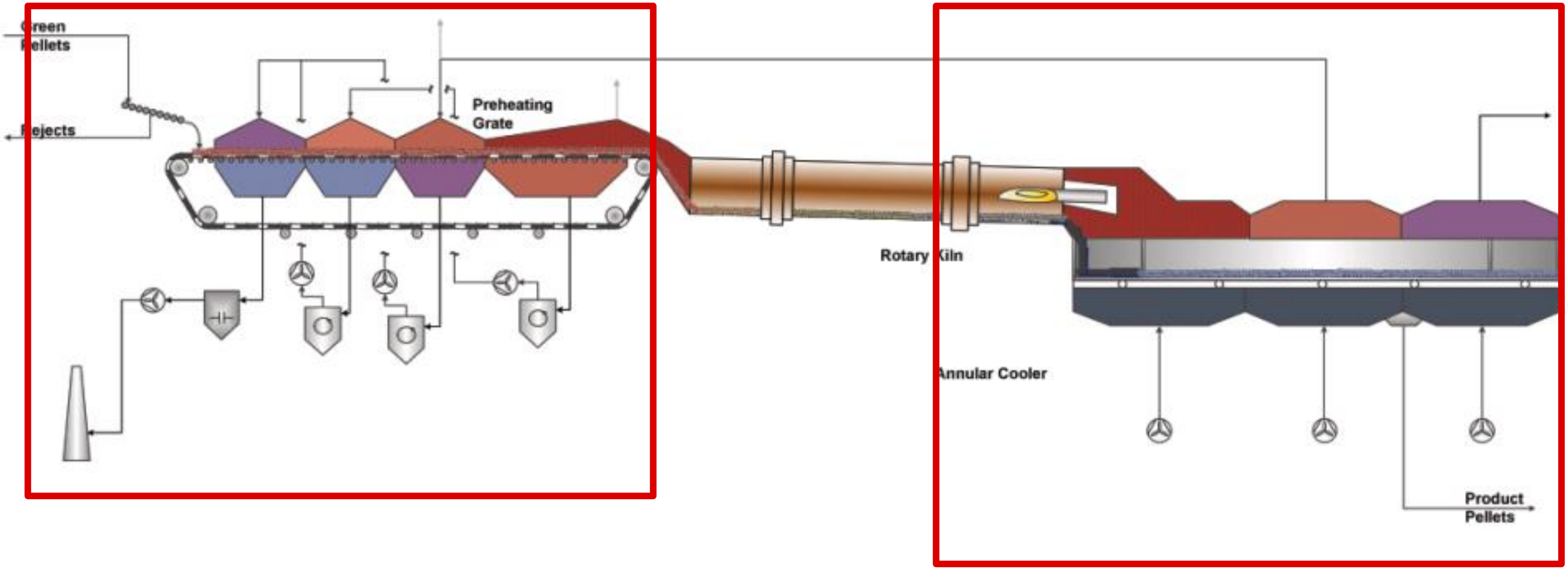
			
Fines Generation	Higher inside the kiln due to tumbling of pellet charge	Higher in the downstream product handling due to stationary bed on travelling grate	
Heat Transfer	Predominantly radiation	Predominantly convection	
Flexibility in Process Adjustments	Three equipment with different residence times	Preheating and firing profile adjustments and temperatures through multiple burners	

2c) Process Principles: Grate/Kiln for Hematite

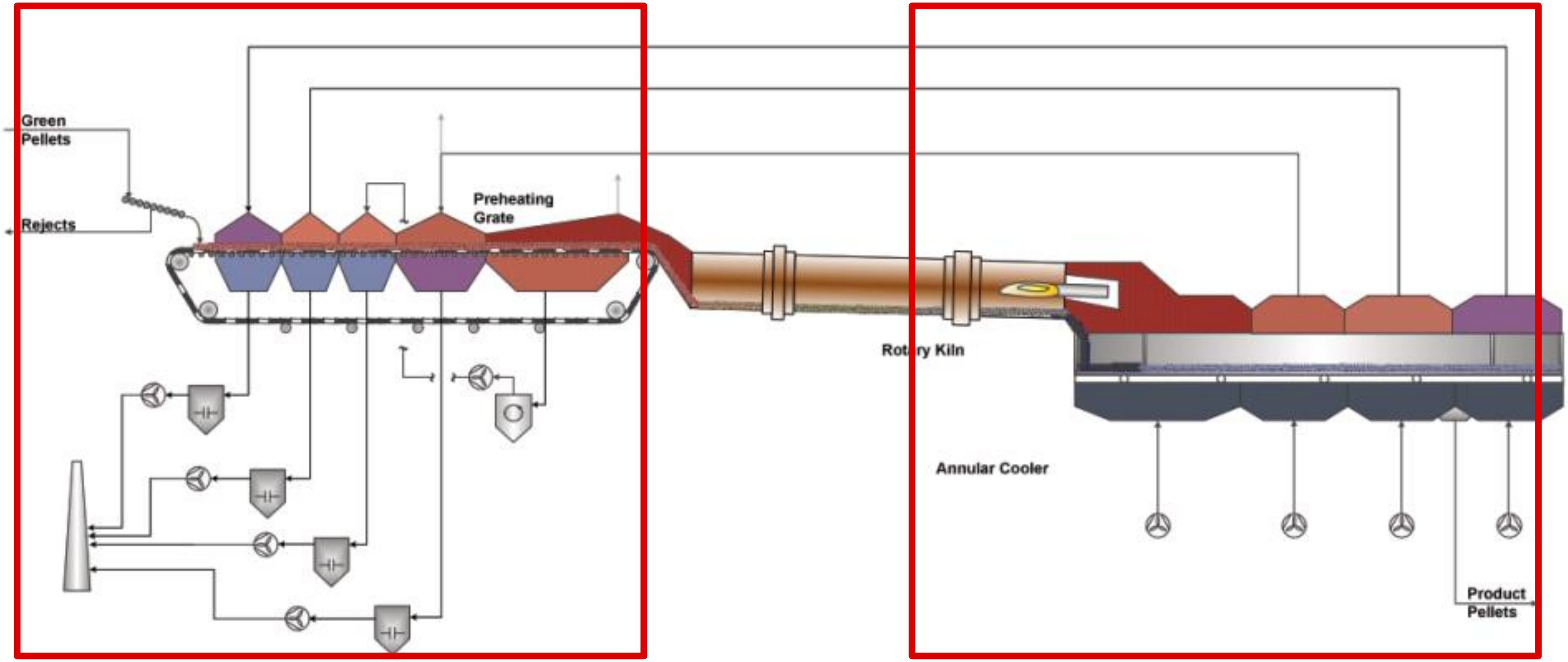


1) Four-stage Preheat Grate with two internal recycles
2) Four-stage cooler with external off-gas use in grinding

2c) Process Principles: Grate/Kiln "Kobe Pelletizing System"

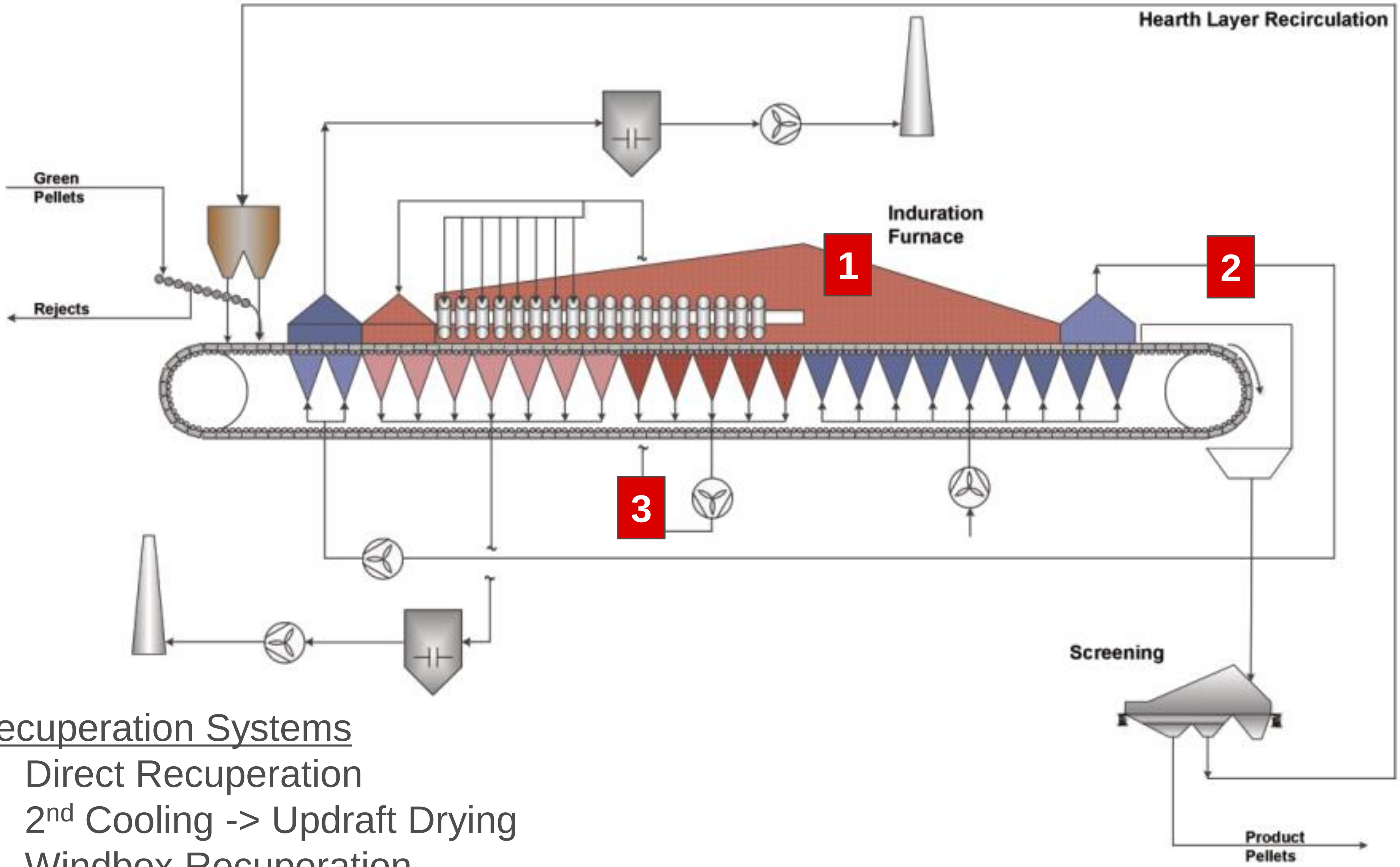


1) Four-stage Preheat Grate with three internal recycles
2) Three-stage cooler



1) Five-stage Preheat Grate with one internal and three cooler recycles
2) Four-stage cooler without no waste gas

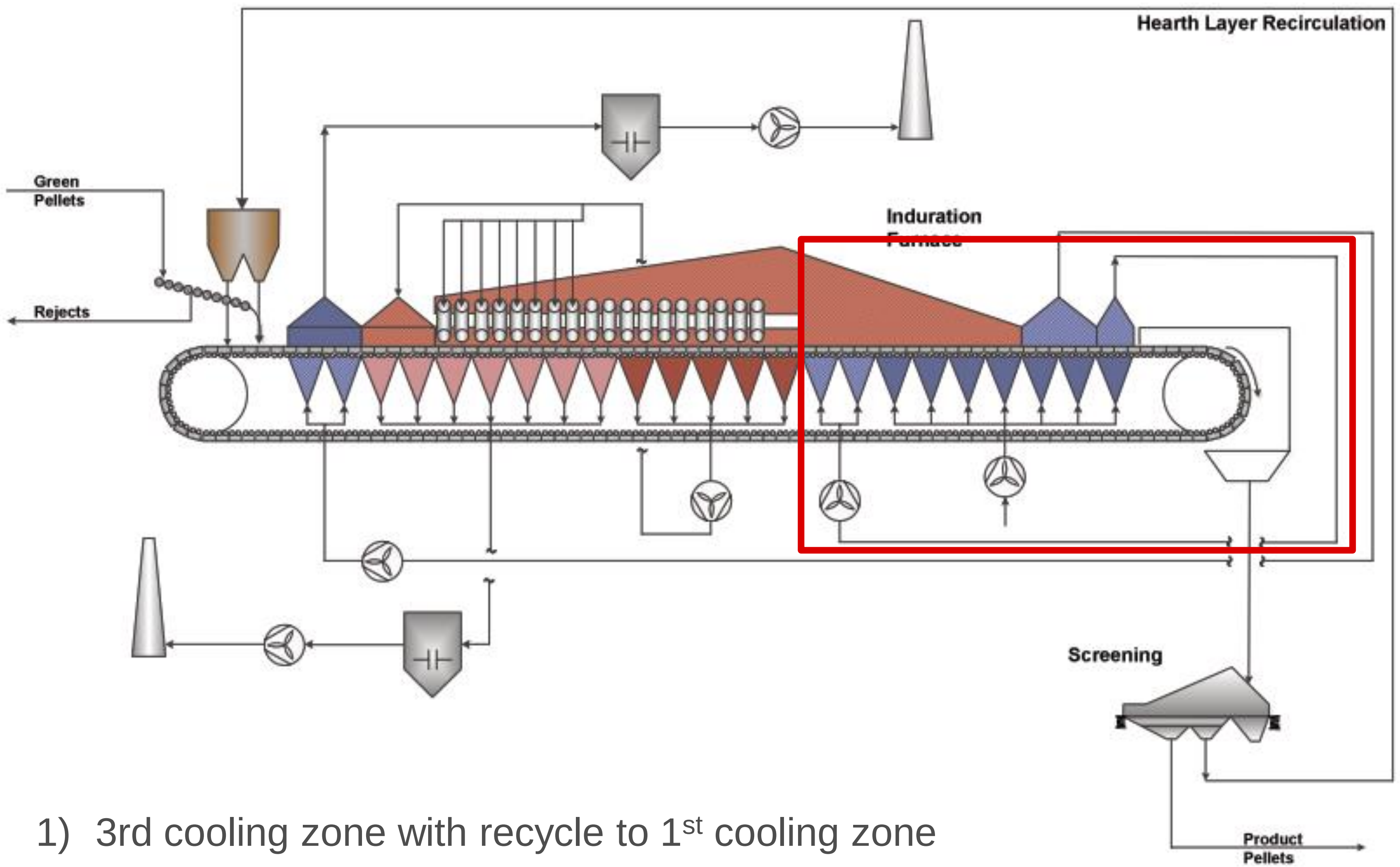
2c) Process Principles: Travelling Grate Standard Gas Flow



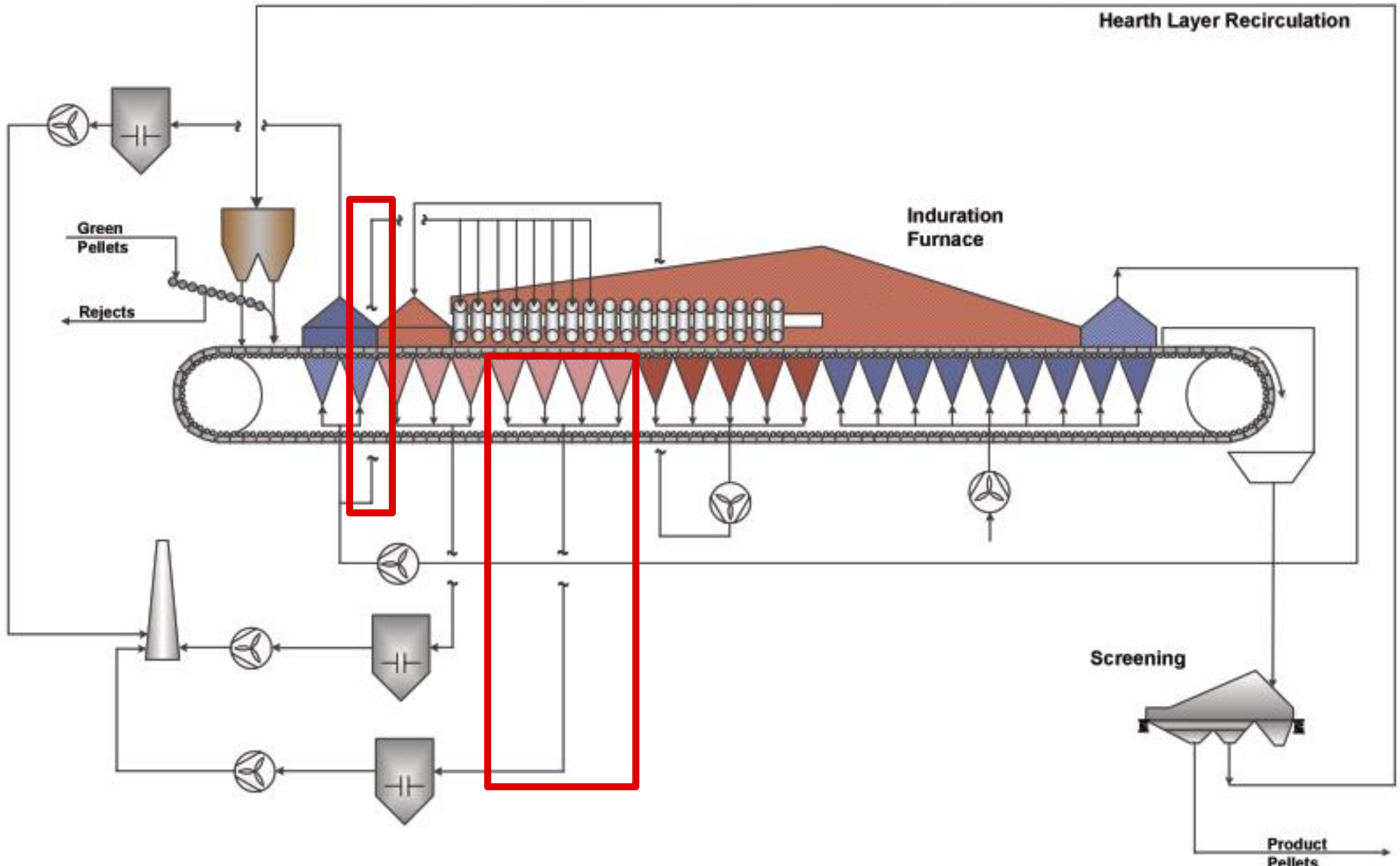
Recuperation Systems

1. Direct Recuperation
2. 2nd Cooling -> Updraft Drying
3. Windbox Recuperation

2c) Process Principles: Travelling Grate with Staged Cooling

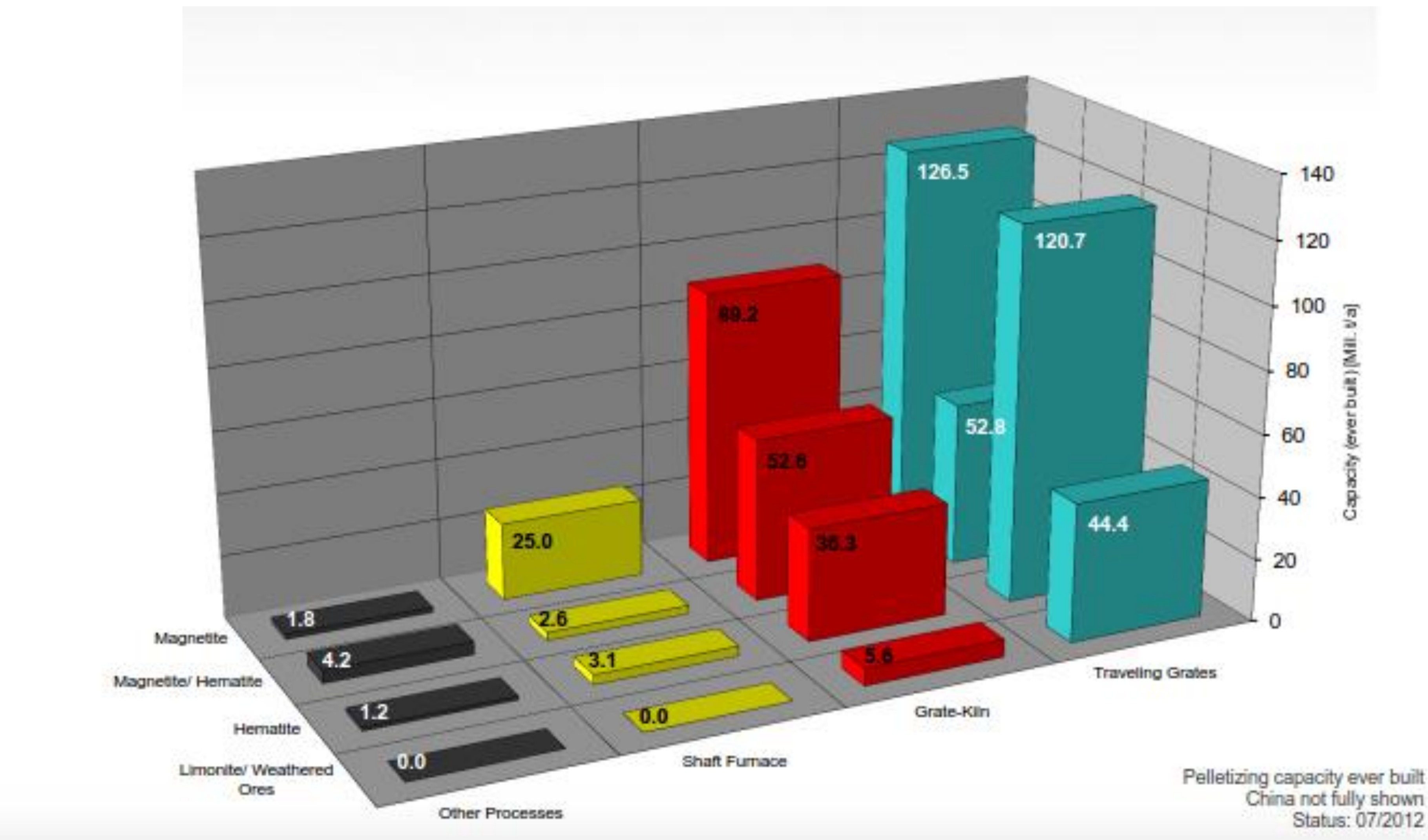


1) 3rd cooling zone with recycle to 1st cooling zone



1) Preheating fed from 2nd cooling and not from WB-recup
2) Two waste gas systems, 2nd one intended for DeSOx

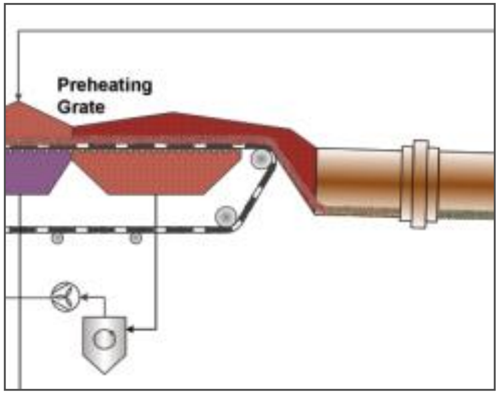
2d) Raw Materials

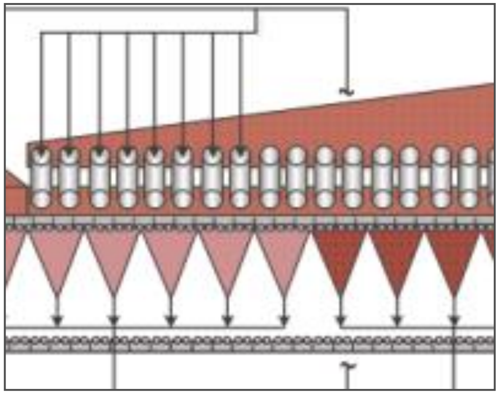


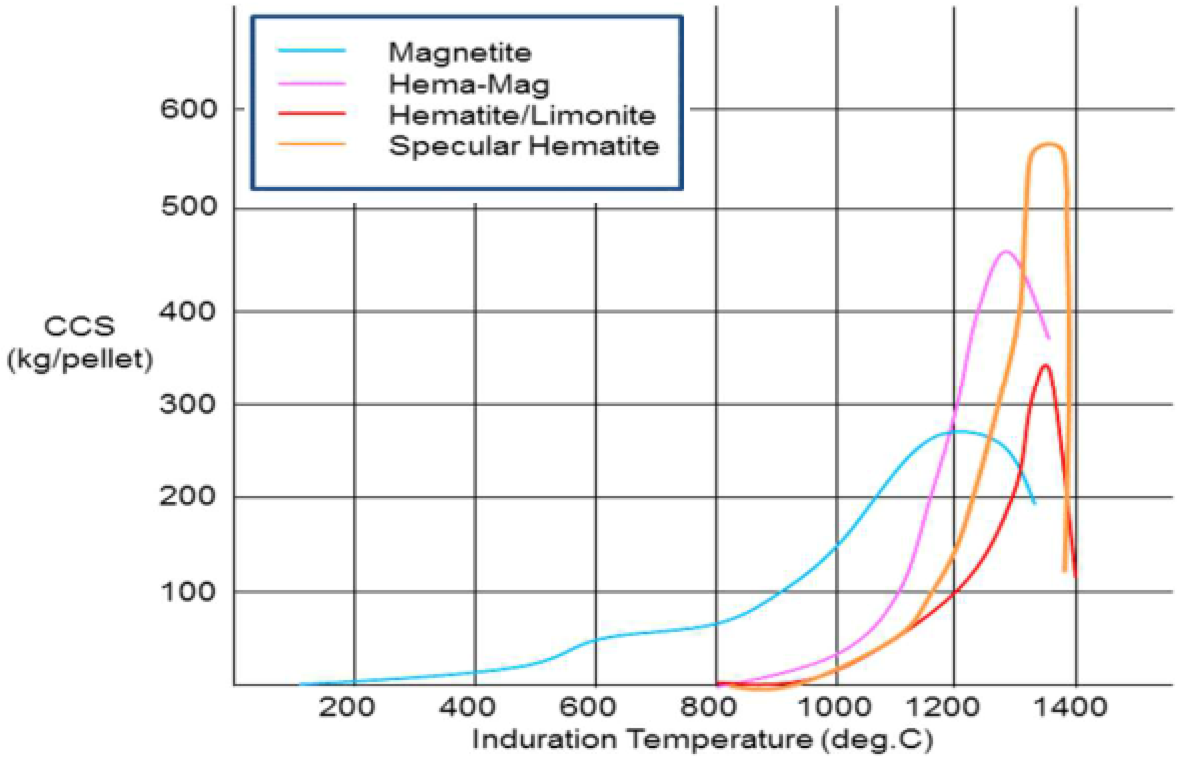
Schwalm (Outotec).: Recent Advancements in High Capacity Pellet Plants, 3[rd] COREM Iron Ore Pelletizing Symposium, 10.2013, Quebec City

2d) Raw Materials: Magnetite vs. Hematite

Transfer Preheating -> Firing





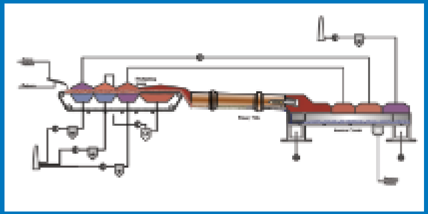
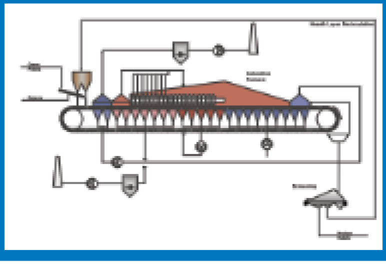


Nomura (Kobelco).: Latest and Future Prospects on Pelletizing Technology, 4th Metal Bulletin DRI- and Pellet Conference 04.2016, Dubai

Grate Kiln: increase of preheat temperature by additional burners, requirement for additional cooling

Travelling Grate: stationary pellet bed carried by pallet cars through the furnace

2e) Product Quality

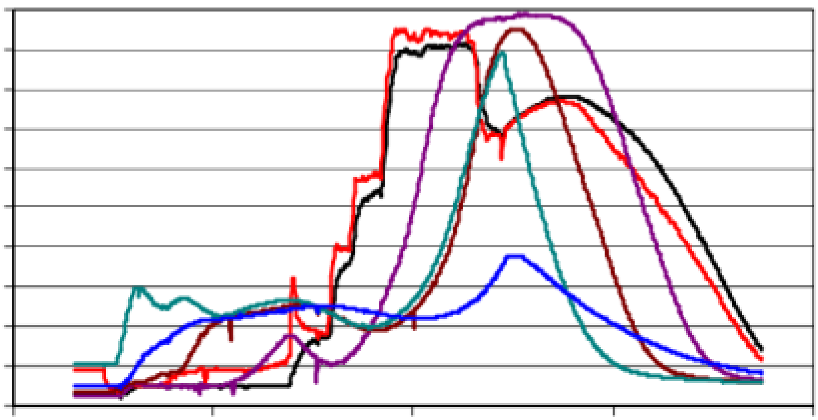
		
Cold Compression Strength	Average values >250 kg Standard deviation lower	Average values >250kg Standard deviation higher
Tumble Index, Abrasion	Better due to tumbling movement in kin	Worse due to stationary bed
Porosity	Lower due to compaction in kiln	Higher due to stationary bed

Improvement areas:

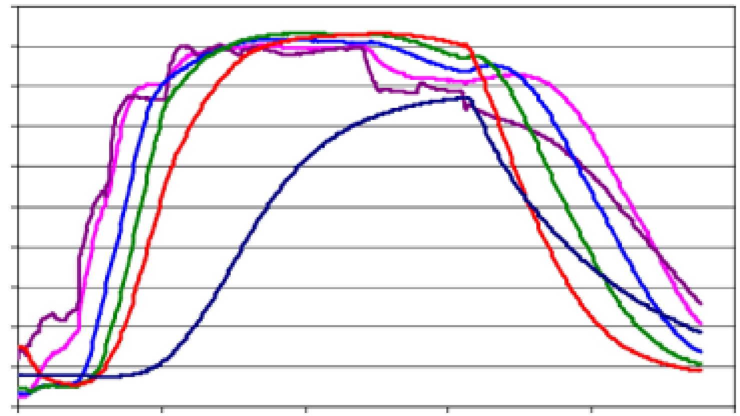
- Dedicated after-firing zone to avoid overheating of top layers
- Close control of pellet feed fineness
- Accurate addition of carbon carrier (if applicable) and fluxes
- Application of adequate heat patterns to ensure all reactions to complete

2e) Product Quality

Travelling Grate



Grate Kiln



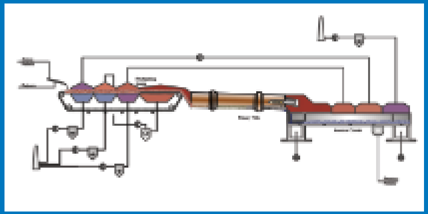
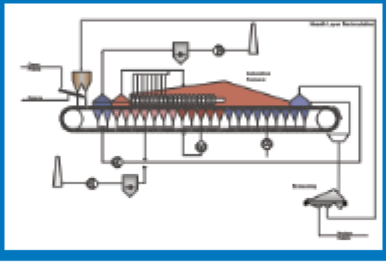
Process Zone	Travelling Grate	Grate Kiln
Preheating	Typically 5 – 10 min	Typically 2 - 5 min
Firing	About 10 min	About 20 min

Reactions:

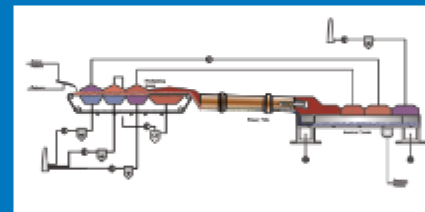
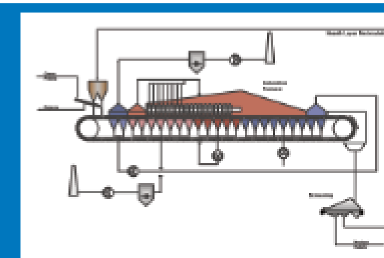
- Magnetite oxidation begins at about 500 ºC
- Carbonate decomposition begins at 800 ºC
- Carbon combustion begins at 600 ºC
- Sulfur combustion begins at 500 ºC but effective removal is at about in 800 ºC
- Porosity decrease: significantly above 1000 ºC
- Sintering begins at 1000 ºC

Charts courtesy of University of Minnesota, NRRI

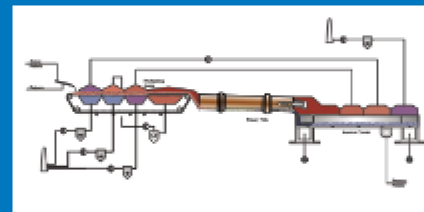
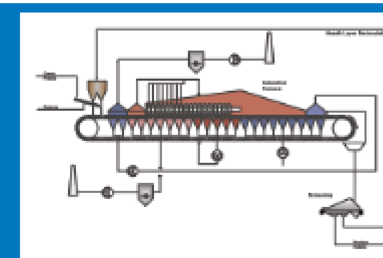
2f) Maintenance

		
Refractory concept	Kiln: direct contact of pellets with refractory Cooler: high wear on charging area	Refractory lined hoods are distant from product, highest wear in burning chambers
Campaign life	Up to 5 years for kilns, 2 years for grates and up to one year for cooler	Typically cold shutdowns every two years, in experienced operation >5 years

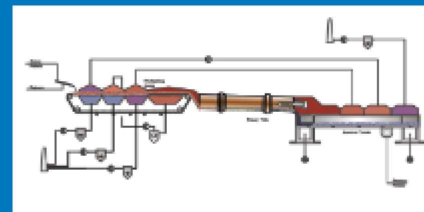
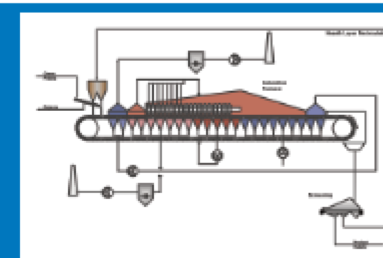
2f) Maintenance

		
Dust Generation	High on grate->kiln transition (drop height and “grate scraper”) High in kiln due to tumbling movement	Liberation in last zones, and at transfer points, higher dust generation by hearth layer
Dust Impact on Operation	Formation of chunks in: 1.grate->kiln: Pellet flow deviation 2.at kiln: ring formation 3. kiln -> cooler: chunk at primary hot grizzly high risk of inefficient cooling	Risk of accumulation in DR-main, slagging in burning chambers

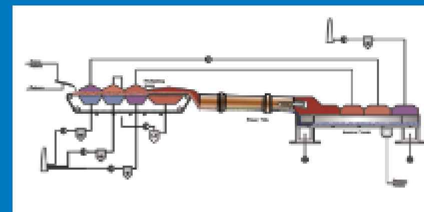
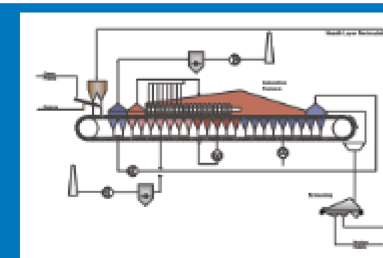
2f) Maintenance

		
Pellet accumulation in windboxes, process gas ducts	By worn grate plates in preheat grate with higher risk in hematite processing, minor in cooler, none in kiln	By improper grate bar arrangement and insufficient pallet chain tensioning
Grate/Pallet Car Maintenance	For safety compliance only during shutdown	Pallet car exchange systems and pallet car service off-line, short daily stoppage for exchange
Burners	One central kiln burner, in general low maintenance	Multiple burners (big plants up to 50) with maintenance-prone fuel distribution

2f) Maintenance

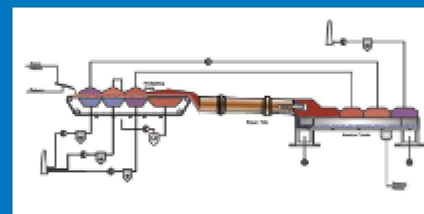
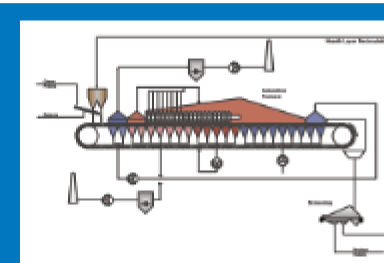
		
Process Fans	7-11 smaller fans	5 (in bigger plants 6) fans of bigger capacity
Auxilliary Fans	Combustion Air TG Combustion Air Kiln Cooling Baffle Walls TG Cooling Baffle Walls Cooler Cooling Hot Grizzly Sealing Air Kiln	Combustion Air Hood Sealing

2f) Maintenance

		
Typical frequency of - Pallet Car Exchange - Hot Shutdowns - Cold Shutdowns	no 12-24h/2-3months 10-20 days/1 year	5-15min/day..1h/week 12-24h/2-3 months 10-20 days/2 years
Plant Availability	Design basis up to 330 dpy	Typical design basis 330 dpy Operated up to 352 dpy

2g) Consumption Figures – Electrical Energy

- To be considered without grinding, dewatering, mixing and green pelletizing, witch is independent from chosen furnace technology

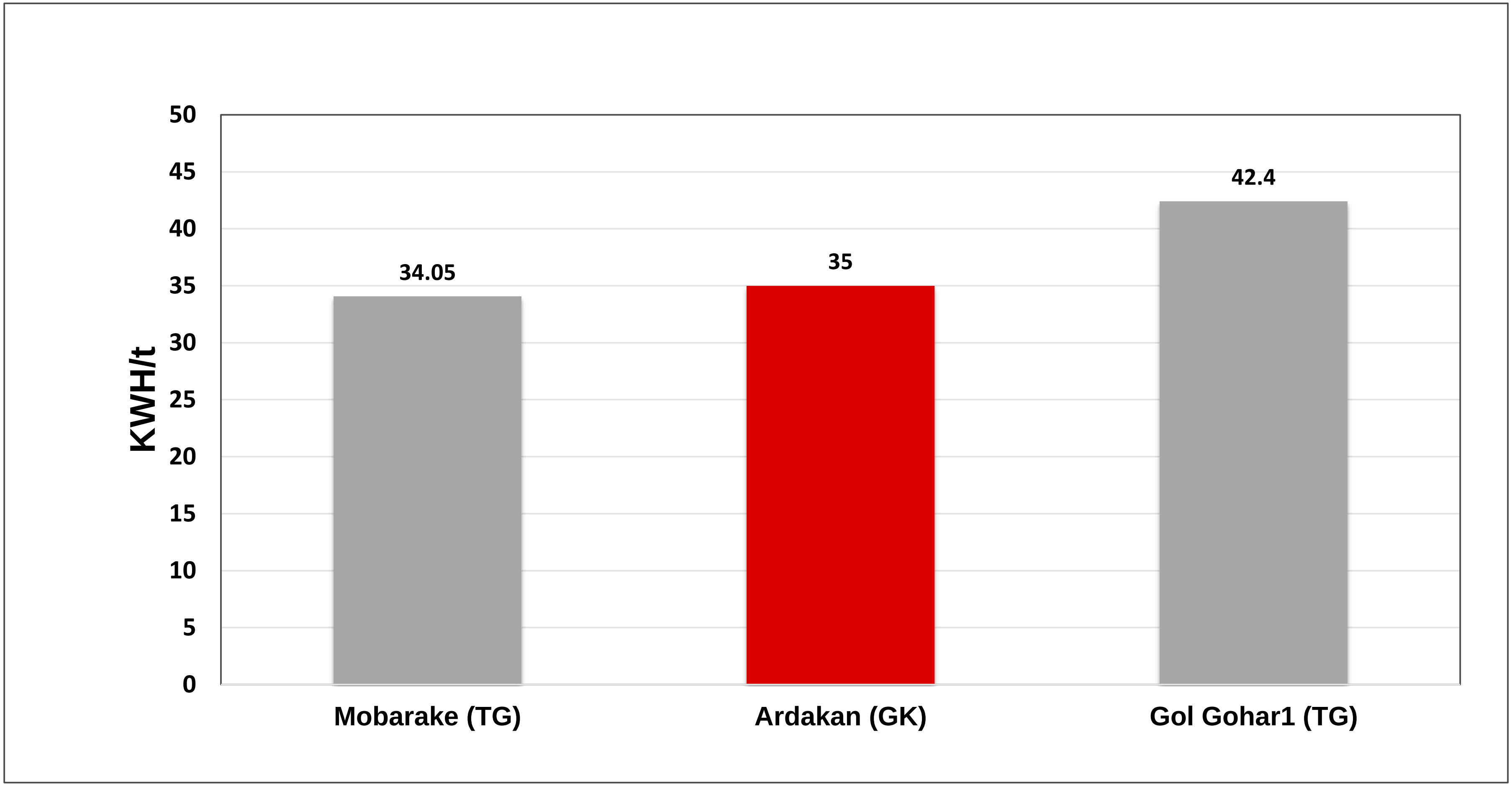
		
Bed Height	12-23cm on preheat grate 60-100cm on cooler	41-50cm on travelling grate
Recuperation Systems	1) Kiln -> Preheating 2) Cooler -> TPH 3) Cooler -> Drying 4) Preheating -> Drying	1) Direct Recuperation 2) 2nd Cooling -> Updraft 3) Windbox Recuperation 4) 3rd -> 1st Cooling

Result

Electrical energy consumption in grate kiln tends to be lower than in travelling grate

2g) Consumption Figures – Electrical Energy

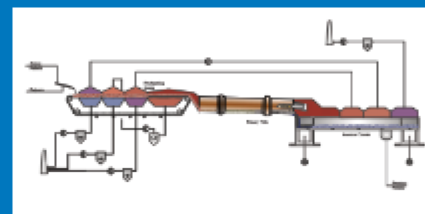
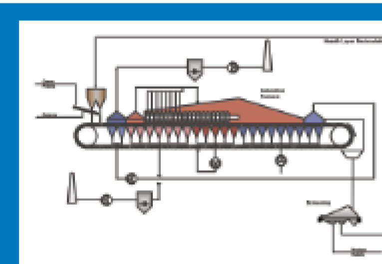
- Examples from Iranian Operation



Various Sources

2g) Consumption Figures – Thermal Energy

- To be considered under the same process conditions, i.e. pellet feed moisture, chemical composition, type of pellet quality produced

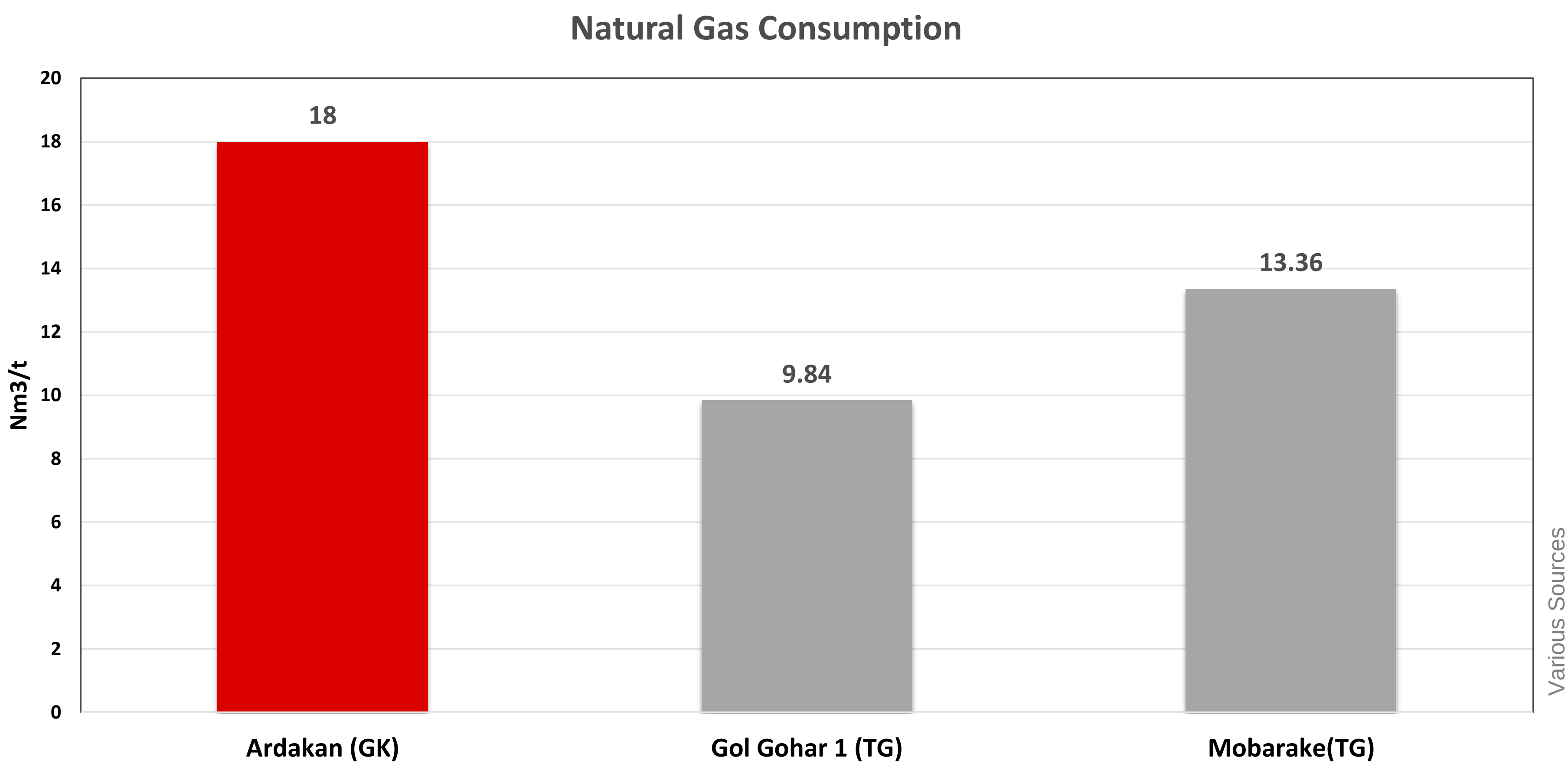
		
Recuperation Systems	1) Kiln -> Preheating 2) Cooler -> TPH 3) Cooler -> Drying 4) Preheating -> Drying	1) Direct Recuperation 2) 2nd Cooling -> Updraft 3) Windbox Recuperation 4) 3rd -> 1st Cooling
Type of Fuel	High flexibility: oil, gas coal	Limited to liquid or gaseous fuels, in hematite plants up to 40% thermal energy is generated from admixed carbon

Result

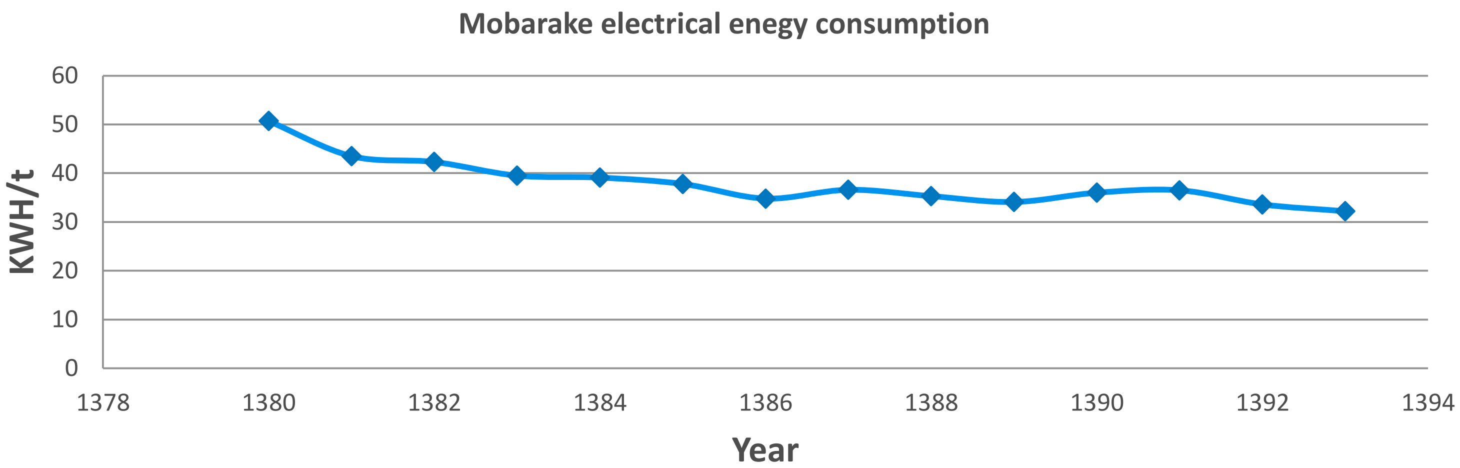
Thermal energy consumption in travelling grate tends to be lower than in grate kiln

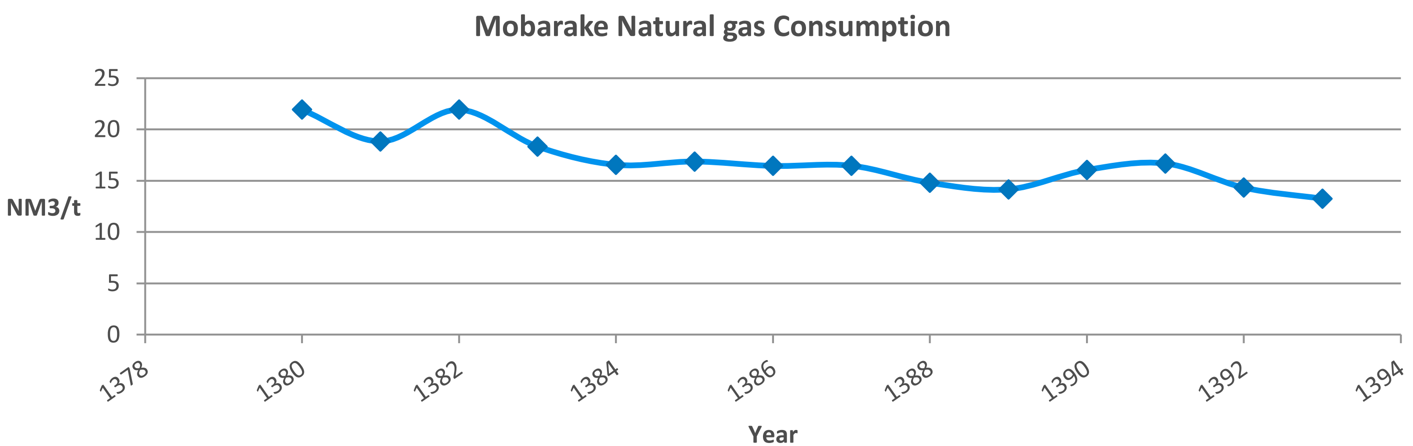
2g) Consumption Figures – Thermal Energy

- Examples from Iranian Operation



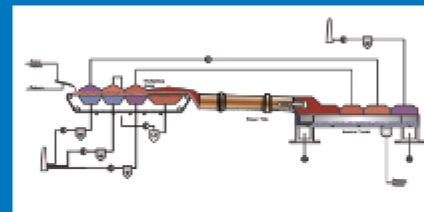
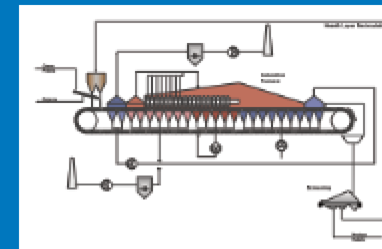
2g) Consumption Figures



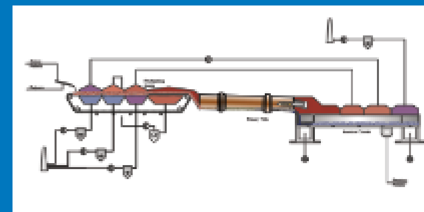
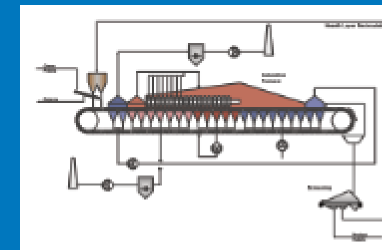


Mobarakeh Annual Report, 1394

2f) Environmental Aspects

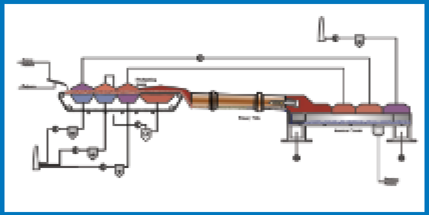
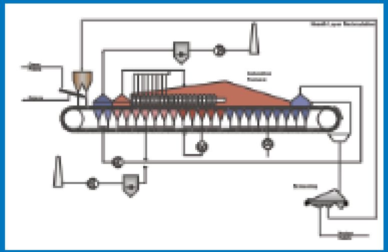
		
Dust	Stack emission depends on dust cleaning equipment (ESP's, bag houses, scrubbers, multiclones/cyclones); Working level dust concentration depends on efficiency of dust capturing and belt cleaning system	
SO_x	Depending on quality of raw material and fuel, on operation and pellet quality	
CO_2	Goes along with the (thermal) energy consumption and tends to be lower in the travelling grate (LKAB: Δ15-20%), also influenced by type and quantity of additives	
NO_x	Depending on fuel type ("fuel NO_x), burner design and operation and firing zone design, "primary abatement measures" at the source (Vale Sohar, Magnetation), "secondary abatement measures" end of pipe (LKAB KK4) easier in grate kiln, since off gas temperatures are higher	

3a) Investment Costs

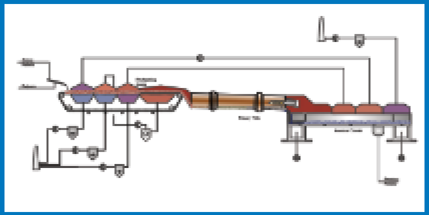
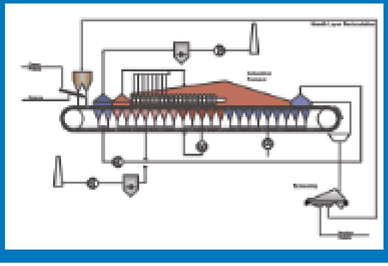
		
Footprint	Slightly smaller due to wider preheat grate, typically circular cooler	Slightly bigger due to maximum travelling grate width 4m
Building Heights	Substantially higher due to 3 internal transfer points: 1. Balling->Preheat Grate 2. Preheat Grate->Kiln 3. Kiln->Cooler	Substantially lower due to 1 internal transfer point: 1. Balling->Travelling Grate
Equipment Costs	High price items • Kiln/Cooler • Refractory • Process Fans	High price items • Pallet Cars • Refractory • Process Fans

Result: Under similar condition, grate kiln tends to be up to 10% more expensive than travelling grate, but significant influence by financing costs, local cost levels, supply split

3b) Operating Costs

		
Iron Ore	Similar, depending on ore chemistry, fines and chips losses	
Binders	Tends to be slightly lower in travelling grate, since pellets rest on the grate and there is no need for a minimum intermediate strength, often more influences by pellet feed quality (fineness, moisture)	
Additives	Identical, only depending on pellet feed and product pellet quality	
Thermal Energy	Tends to be lower in the travelling grate (more recuperation)	
Electrical Energy	Tends to be lower in the grate kiln (lower bed height, less recuperation)	
Water	Process water depending pellet feed quality and type of grinding (dry or wet), marginal differences in cooling water	

3b) Operating Costs

		
Refractory	Lower in the travelling grate, since refractory is not in touch with the product	
Other consumables and wear parts	Similar and depending on detailed machine design, plant operation and consumables quality	
Labour	Similar	

4) Summary and Conclusion

- **Capacity and Aailability**
  - Travelling Grate builds bigger units, but needs hearth layer
  - Grate Kiln with lower availability
- **Raw Material Flexibility**
  - On iron ores: travelling grate more flexible
  - On fuels: grate kiln more flexible
- **Energy Consumption**
  - Grate Kiln lower in electrical energy consumption
  - Travelling grate lower in thermal energy consumption
- **Maintenance**
  - Grate Kiln with higher refractory consumption
  - Travelling Grate with sophisticated burner system
- **Product Quality**
  - Easier to achieve even (mechanical) quality in grate kiln
  - Porosity and metallurgical qualities better in travelling grate
- **Environmental Impact**
  - Travelling grate lower in CO_2-emission

4) Summary and Conclusion

- Project success depends on
  - Adequate technology selection
  - Excellence in plant design
  - Excellence in plant operation and maintenance

With Special Thanks to Mr. Bakhtiari Ghale

Thank you for your attention