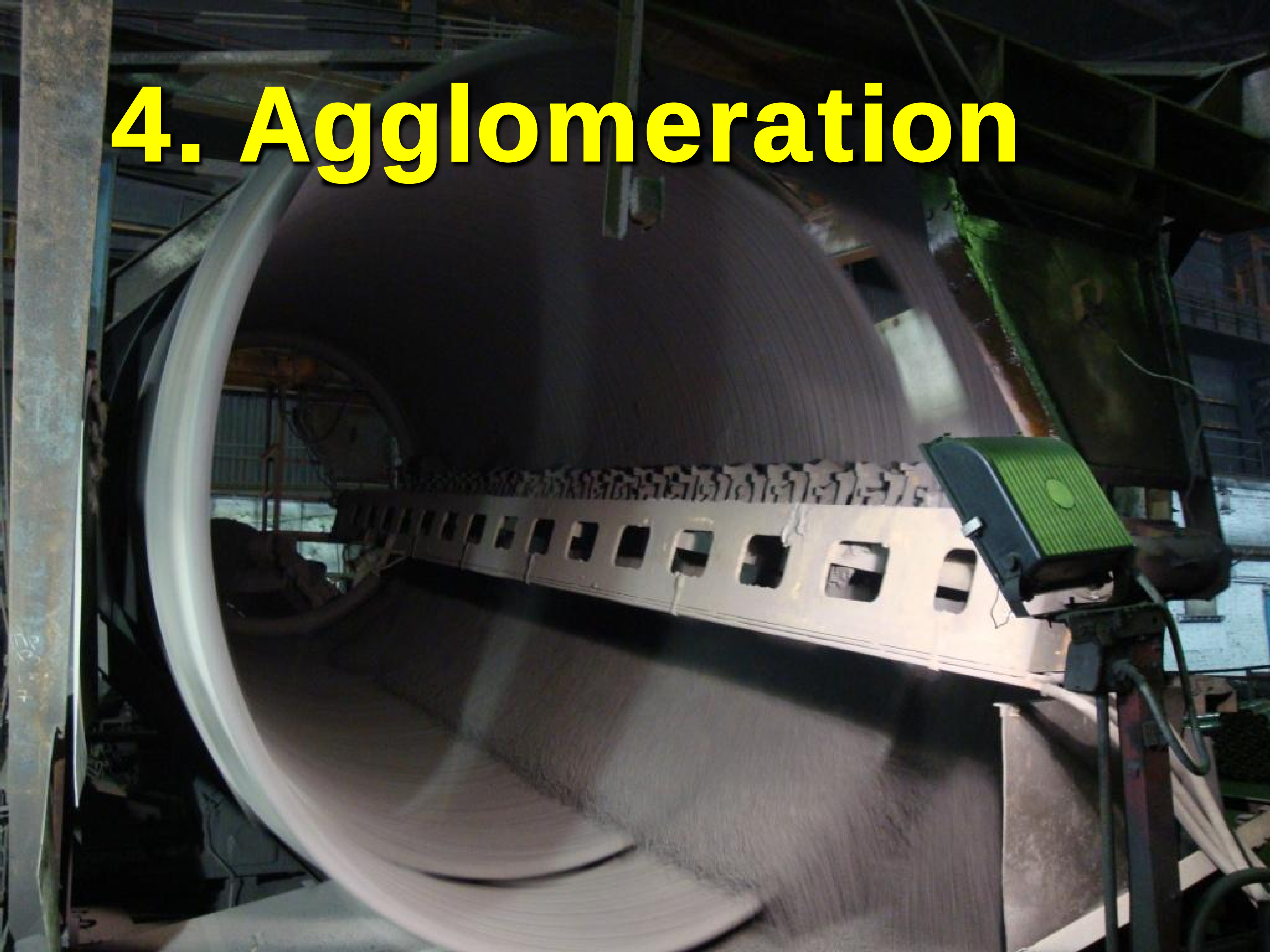
4. Agglomeration



Contents

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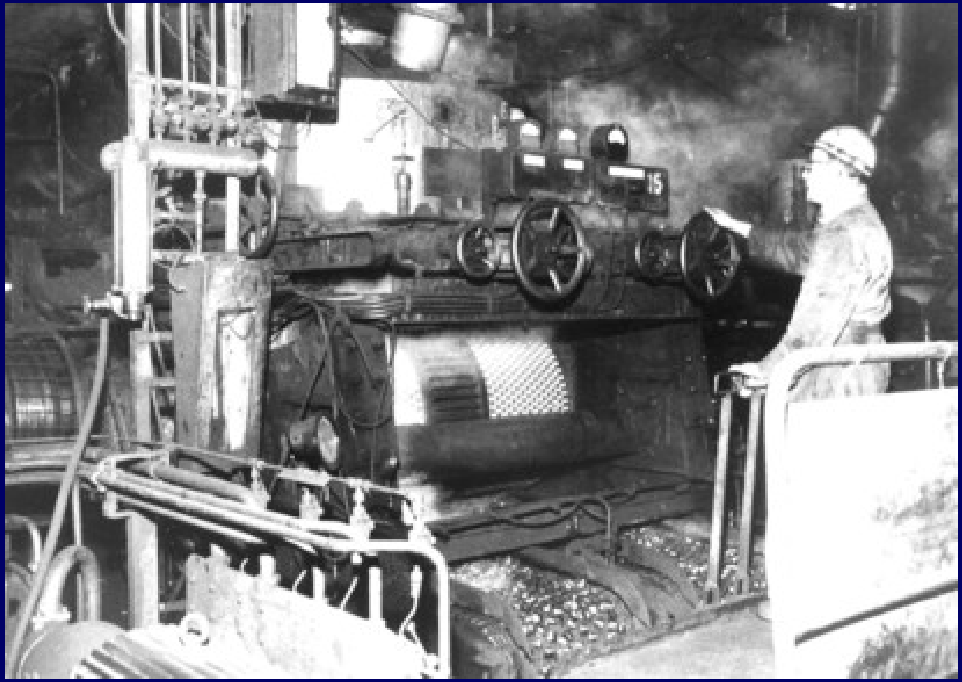
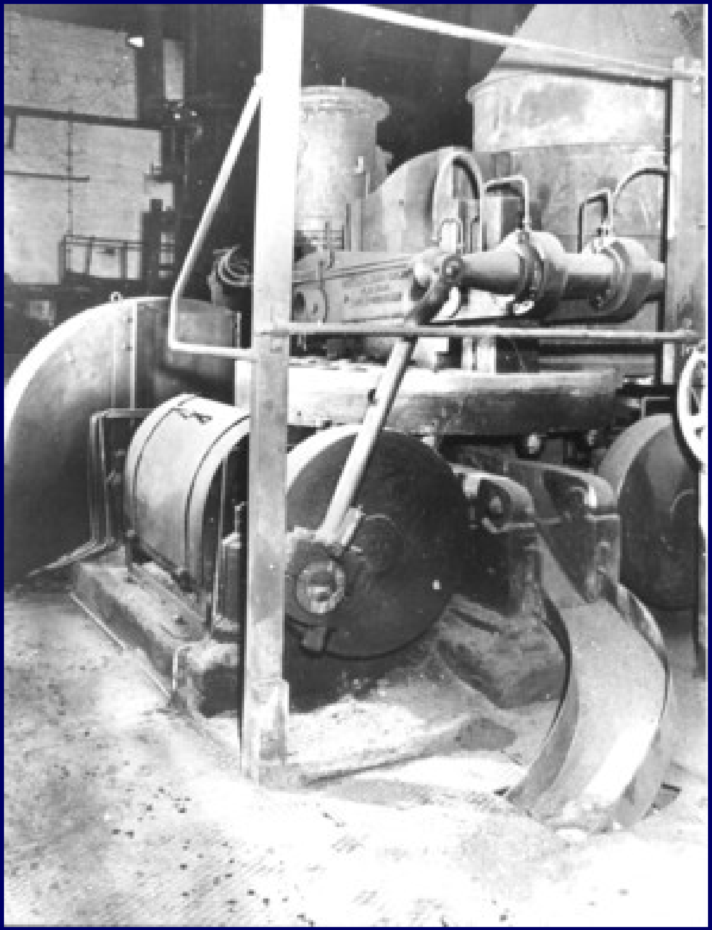
1. What is agglomeration ?

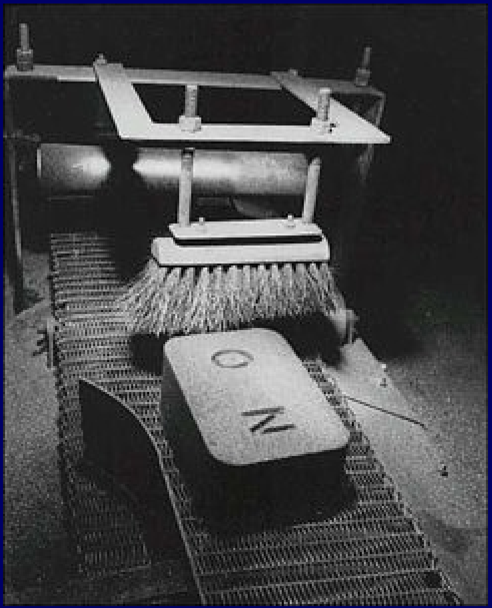
- Making uniform shapes from fine, incoherent particles
- Examples:
    - Coal briquettes
    - Briquettes from scrap metal turnings
    - Iron ore pellets
    - Iron ore sinter
    - Cement nodules
- Objectives:
    - Better transport and storage
    - Avoid dust
    - Better properties end use (e.g. porosity of ore bed)
    - Immobilization of certain components
    - Including components/elements (mill scale/fluxes)

Coal briquettes (1925 – 1975)



Block briquettes “Oranje Nassau”





2. Briquetting

- Most common agglomeration method
- Applications
  - Coal
  - Coke
  - Charcoal (BBQ!)
  - Quicklime
  - Phosphate ore
  - Iron ore
  - Mill scale
  - Refuse derived fuel (RDF)
  - Flue dust
  - Sponge metals
  - Turnings
  - Salt
  - Animal food
  - Washing powder
  - ... ...

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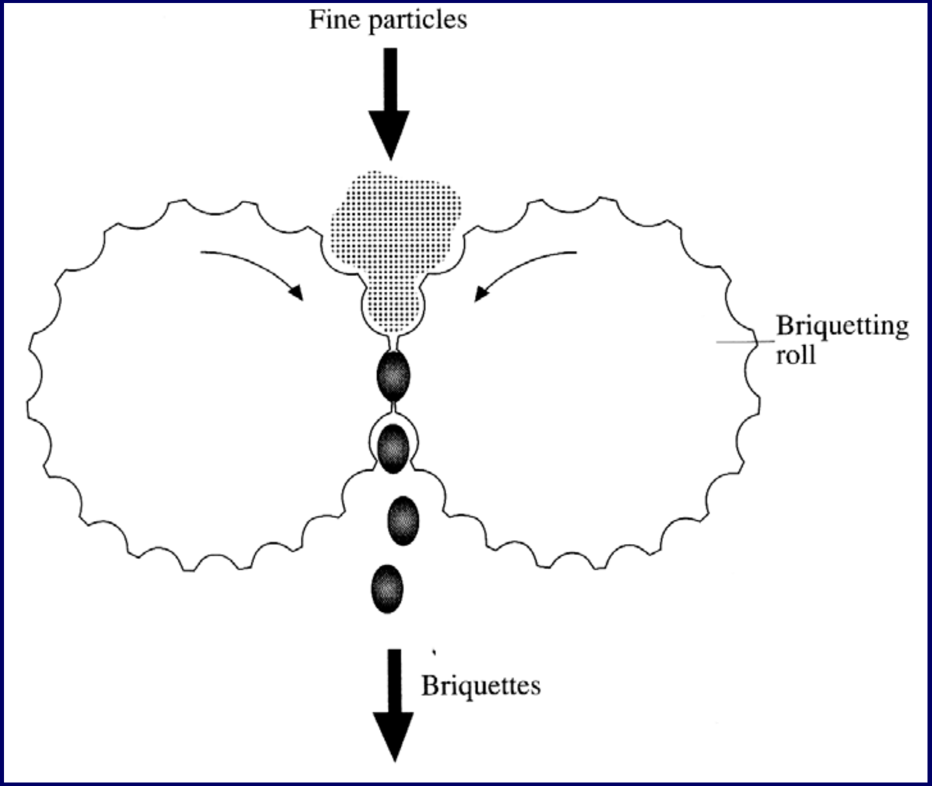
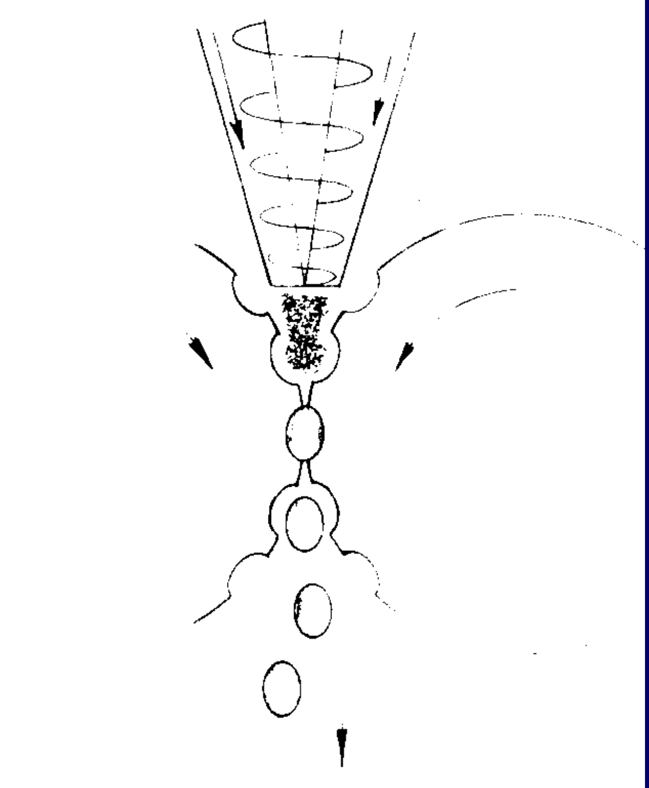
Roll briquetting

- Geometrically shaped pieces
- Gravity fed, screw fed





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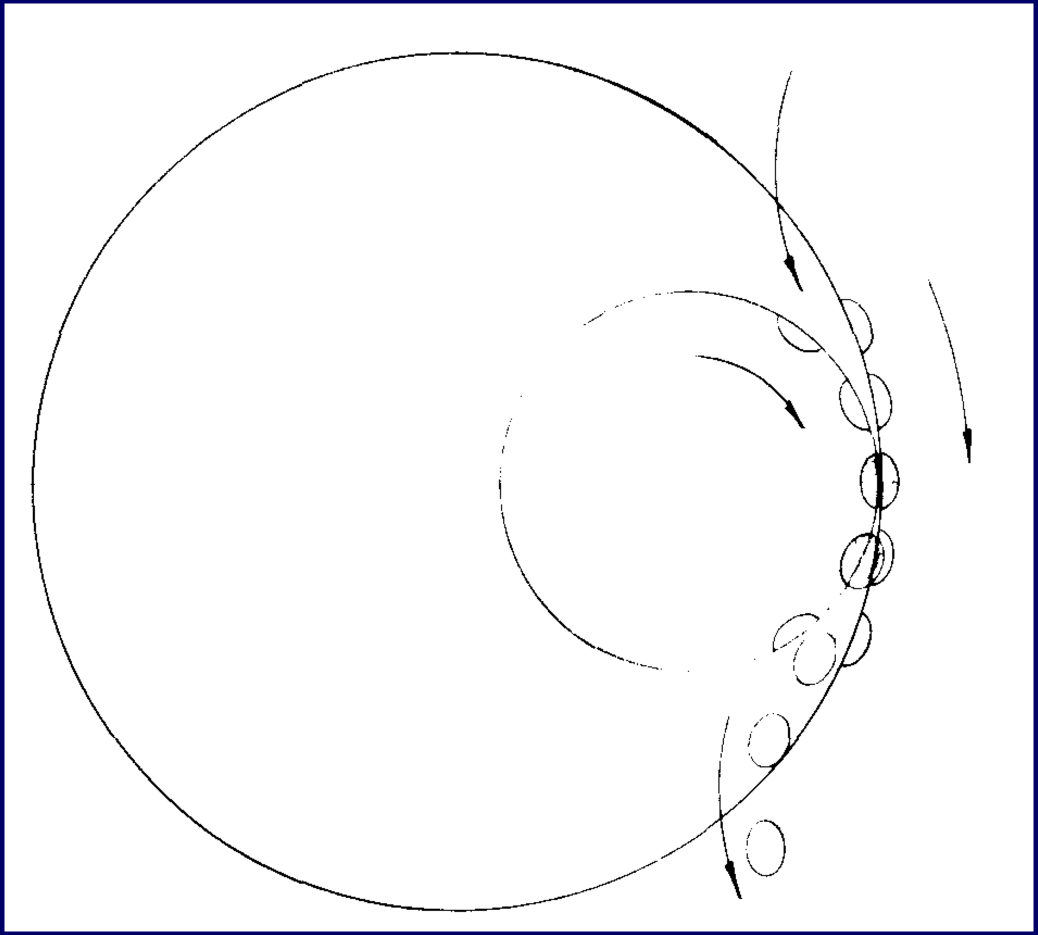
Ring roll press



Compaction

- Flakes or sheets from compressed fines
- Flakes are broken to desired size
- Fragments are larger as the input material

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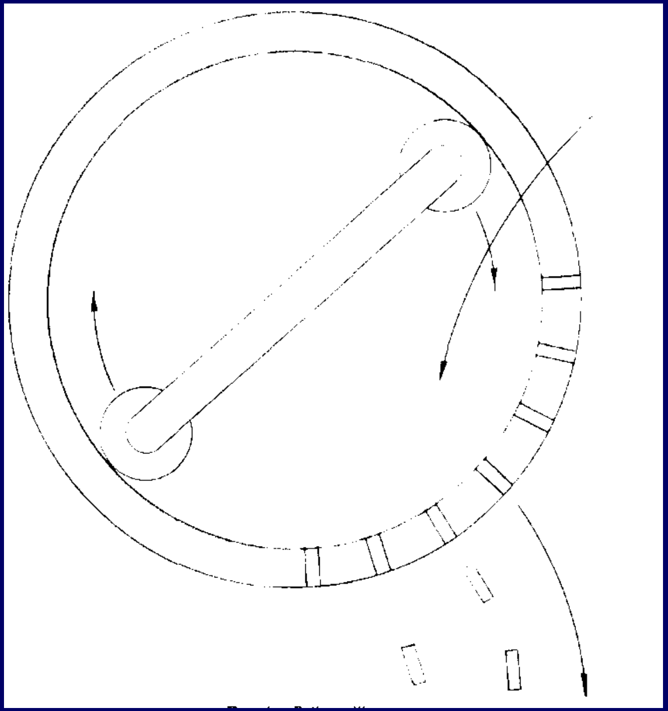
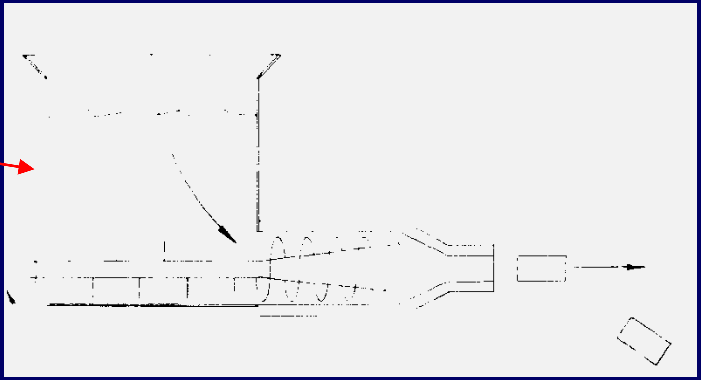
Extrusion

- Forcing presses solids through a cylindrical die
- Typically 10 mm diameter, 10 – 20 mm length



- Larger sizes made by a single press



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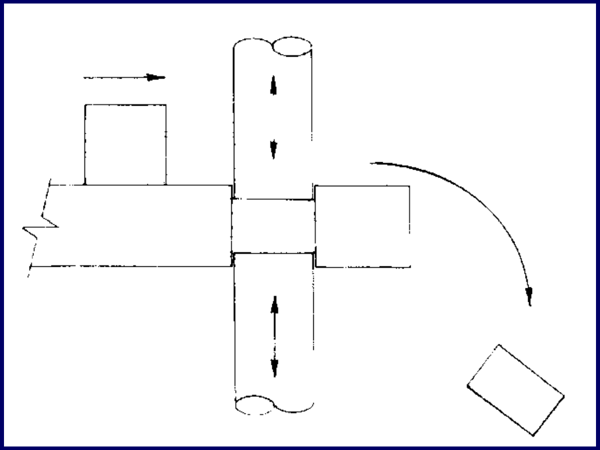
Tabletting

- Complex machines
- Chemical and pharmaceutical industry



Briquetting mechanisms

- Feed must be free flowing
- Add lubricants (0.5% – 2%)
    - Water, stearic acid, Ca, Mg stearate, parrafin waxes, mineral oil, starch, graphite, MbS_2
- Binders
    - Adhesive
    - Surface tension
    - Hardening binders (briquettes develop strength after pressing)

Binderless briquetting

- Higher pressures
- Solids “welding”
- Example: salt, metal turnings
- Metal turnings should be:
  - Clean, no oil on it
  - Not weathered (no oxidized surfaces)

Roll press action

- Exact pressure cannot be measured. Estimation:
- Roll force / Projected area of 1 row of briquettes
- Shear stresses cause close packing

- Angle of nip: see discussion on roll mill
- Roll spread 1.5 – 10 mm, fluctuates during operation
- Clean discharge:
  - Pockets not too deep
  - Not too much binder
  - Pressure not too high or low

Briquette machine performance

- Power:
  - Mixing (where binders and/or lubricants are used): 1.5 to 7.5 kW/t feed
  - Feeding: 0.4 to 4 kW/t feed
  - Briquetting: 1.5 to 20 kW/t feed
- Roll life 400 – 30.000 hours depending on abrasiveness
- Capacity Q in kg/min: $Q = \pi DWTN\rho$

Briquette machine performance

- Power:
  - Mixing (where binders and/or lubricants are used): 1.5 to 7.5 kW/t feed
  - Feeding: 0.4 to 4 kW/t feed
  - Briquett … d
- Roll life 4… urs depending on abrasiveness
- Capacity Q in kg/min: $Q = \pi DWTN\rho$

Roll diameter

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Briquette machine performance

- Power:
  - Mixing (where binders and/or lubricants are used): 1.5 to 7.5 kW/t feed
  - Feeding: 0.4 to 4 kW/t feed
  - Briquett… …d
- Roll life 4… …urs dep… …n abrasiveness
- Capacity Q in kg/min: $Q = \pi DWTN\rho$

Roll diameter

Roll width

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Briquette machine performance

- Power:
  - Mixing (where binders and/or lubricants are used): 1.5 to 7.5 kW/t feed
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  - Briquett… …d
- Roll life 4… …urs dep… …n abrasiveness
- Capacity Q in kg/min: $Q = \pi DWTN\rho$

Roll diameter

Roll width

Briquette thickness

Briquette machine performance

- Power:
  - Mixing (where binders and/or lubricants are used): 1.5 to 7.5 kW/t feed
  - Feeding: 0.4 to 4 kW/t feed
  - Briquett… …d
- Roll life 4… …urs dep… …n abrasiveness
- Capacity Q in kg/min: *$Q = \pi DWTN\rho$*

Roll diameter

Roll width

Briquette thickness

Rotation speed /min

Briquette machine performance

- Power:
  - Mixing (where binders and/or lubricants are used): 1.5 to 7.5 kW/t feed
  - Feeding: 0.4 to 4 kW/t feed
  - Briquett… d
- Roll life 4… urs dep… n abrasiveness
- Capacity Q in kg/min: $Q = \pi DWTN\rho$

Roll diameter
Roll width
Briquette thickness
Rotation speed /min
Density

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Performance example

Roll diameter (mm)	Effective roll width (mm)	Maximum force between rolls (tons)	Appr. Capacity* (t/hr)
130	50	10	0.15
305	76	25	1.2
380	102	50	2.5
457	152	100	5.5
610	203	150	12.5

*For salt, with briquette density of 2165 kg/m^3, roll speed is 25 rpm, and D/T = 60.

Briquetting processes

- Low pressure (< 1 t/cm^3)
  - Earthy ore, oil shale, laterite, coal/pitch, clayey bauxite, phosphate
  - 1 to 5 kWh/t
- Medium pressure (1 to 4 t/cm^3)
  - 5 to 15 kWh/t
  - Salts, Calcium, magnesium oxides
- High pressure (> 4 t/cm^3)
  - 15 to 30 kWh/t
  - Metal turnings, powders, sponge, steel mill dust
  - Temperature up to 1000 ^oC

3. Partial fusion

- Sintering
  - Iron ore
  - Base metal ore
- Straight grate sinter machine

- Nodulizing
  - Cement clinker, waste dusts and sludges
  - Rotary kiln

Straight grade sinter machine

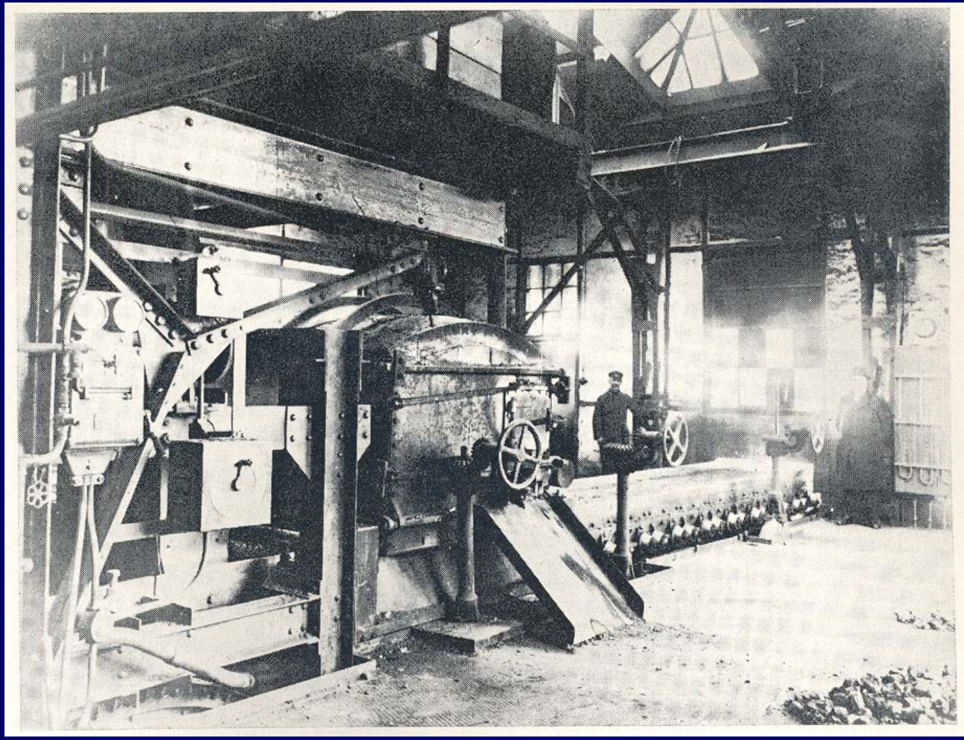
Introduction

Purposes of iron ore sintering = Preparation of ´möller´ for the BF

- Prepare the ore fines
- Change particle size (distribution)
- Improve reducibility
- Prevent disintegration
- Prevent LOI
- Dose fluxes
- Use of in plant reverts
- Less materials to the BF

Sintering is old technology

First priciple	1897
First industrial application	1911
´Large scale´ (75 m^2)	’30
IJmuiden sinter strands	’56/’60/’63



Dwight-Lloyd sinter machine 1914

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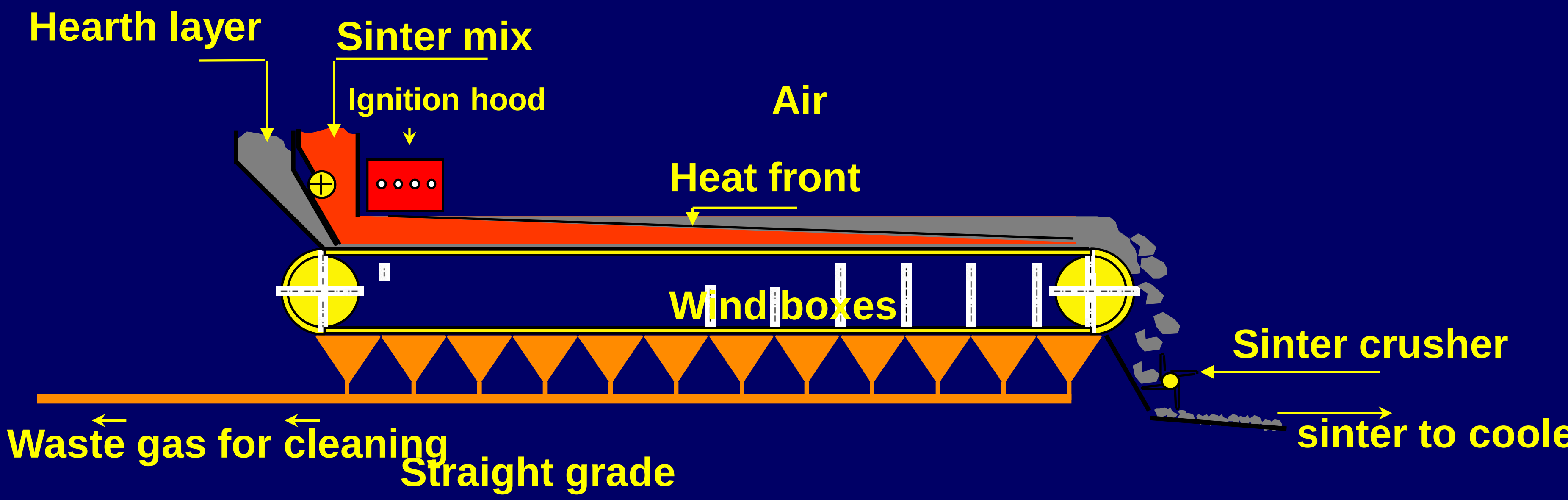
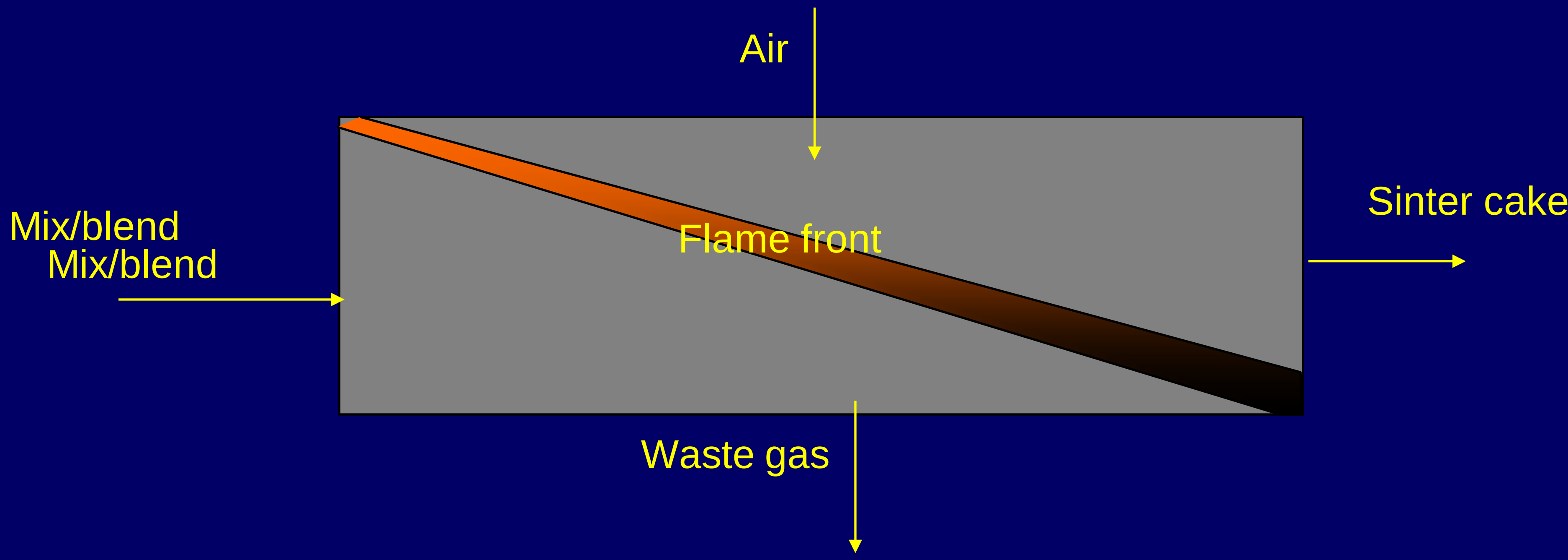
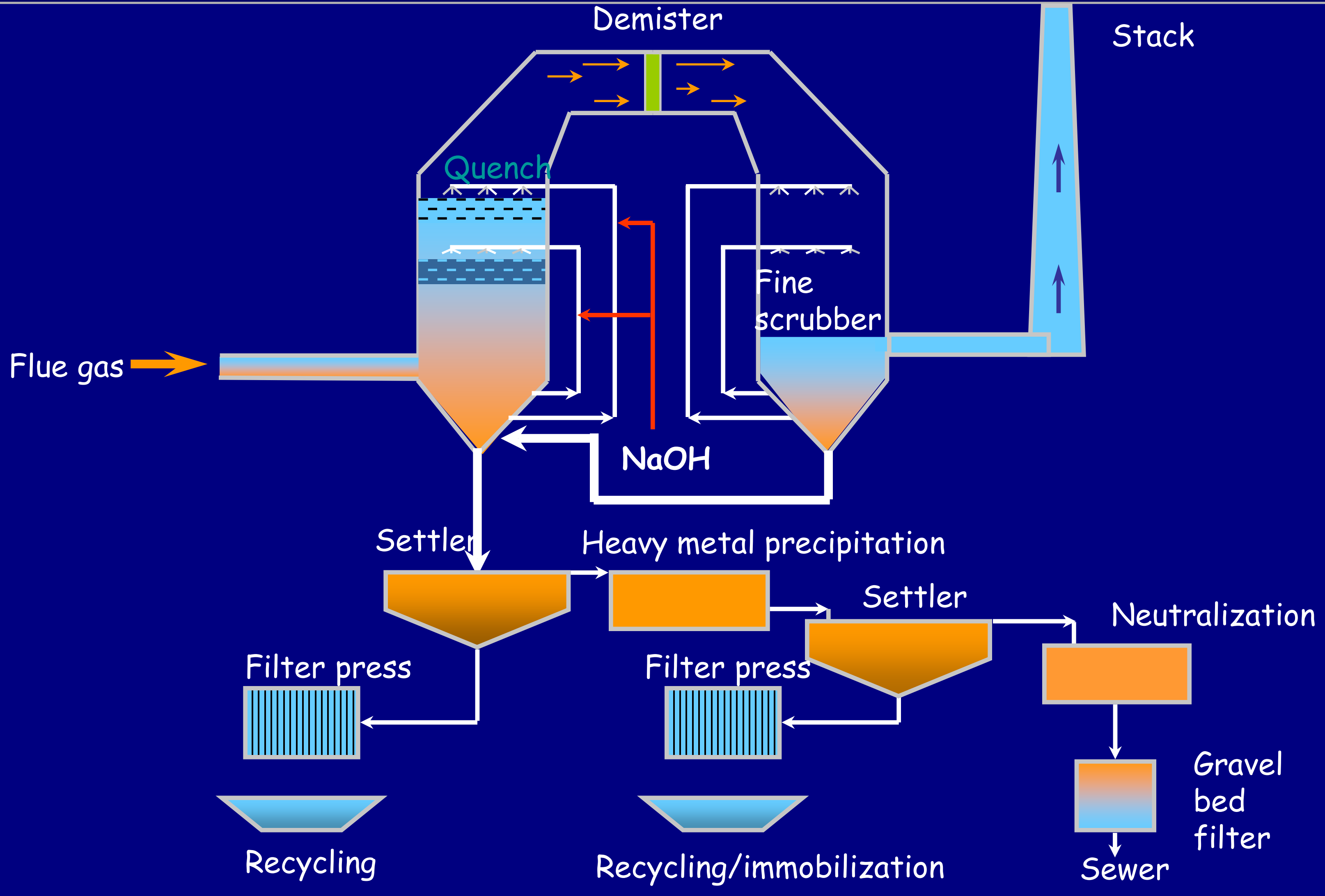
Sinter machine



Sintering principle



Do not forget the environment!
Gas cleaning at Corus IJmuiden



4. Pelletizing

- 230 Mtpa (1976) increased to 400 Mtpa (2009 est)
- Fine ground, damp, ore is rolled into ´green´ balls and heat hardened

Add value to the abundant fines ores and concentrates by agglomeration at location into an agglomerate transportable to integrated steel works

Transport

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Introduction

Technology developped in Sweden, Germany and USA

• First patent	1913
• First pilot plant	1930
• First shaft furnace	1943
• First Travelling Grate	1950’s
• IJmuiden pellet plant	1970

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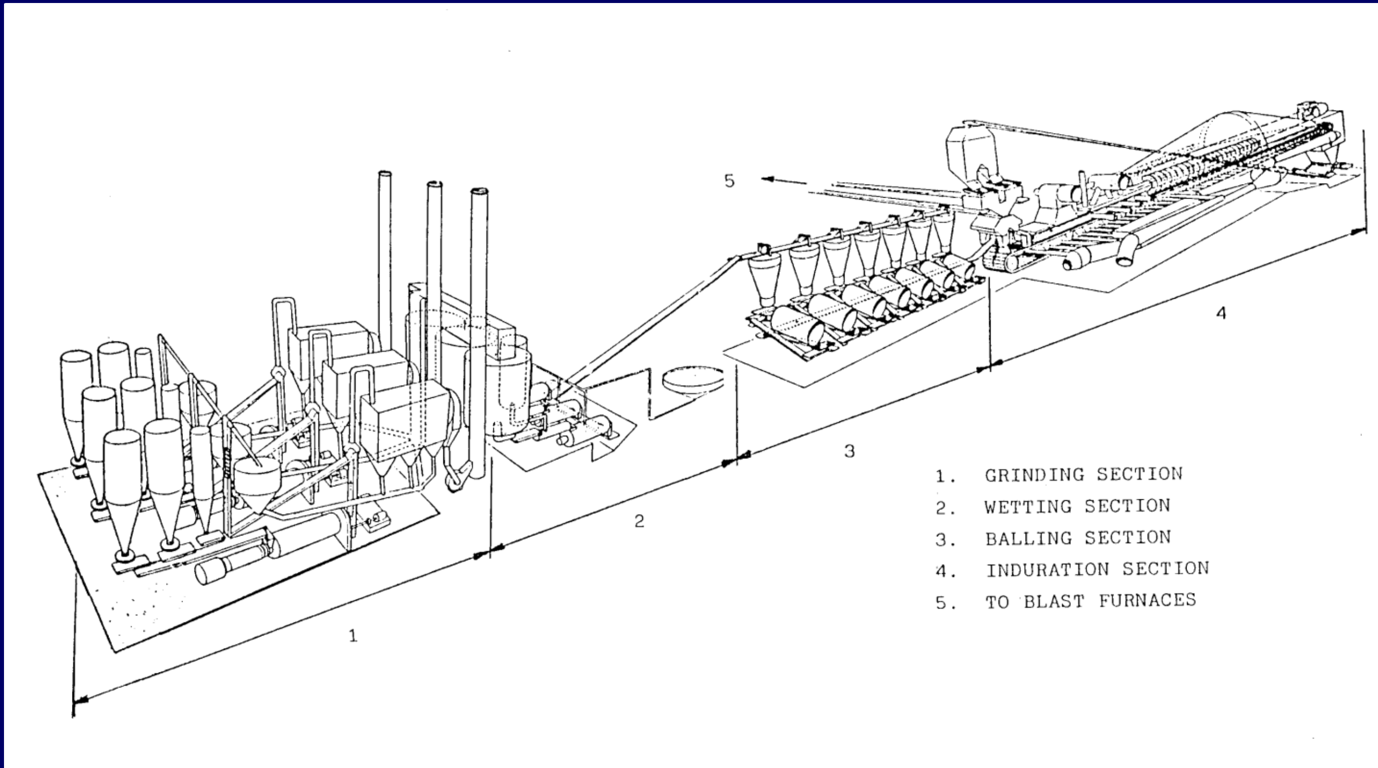
Corus Strip Products IJmuiden

Pellet Plant



- Lurgi straight grate, suction surface area ± 430 m^2
- Maximum pellet production: 5 Mtpa
- Flue gas scrubbers with water treatment plant

Feed preparation

- Proper size range! 65% < 80 μm
- Blaine 1100 – 2500 cm^2/g
- Optimum moisture 8.5% for iron ore
  - Higher for a finer smaller feed
- Bentonite as binder and flux additives are common

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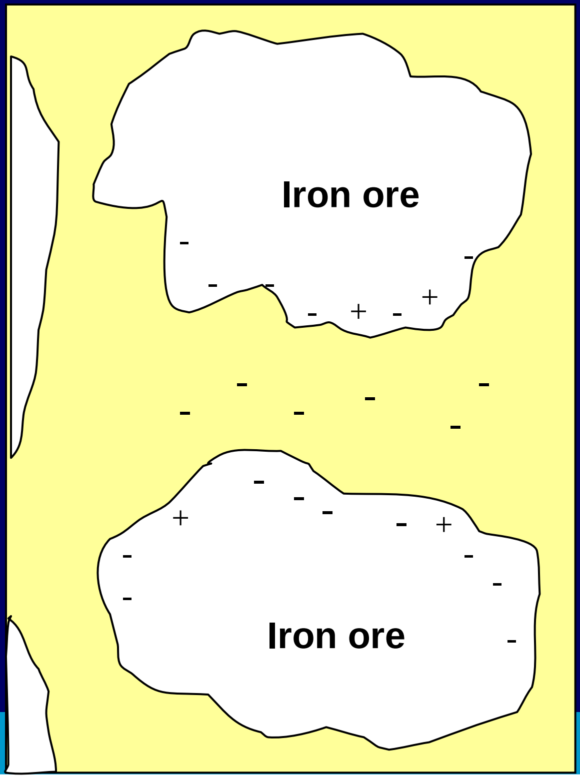
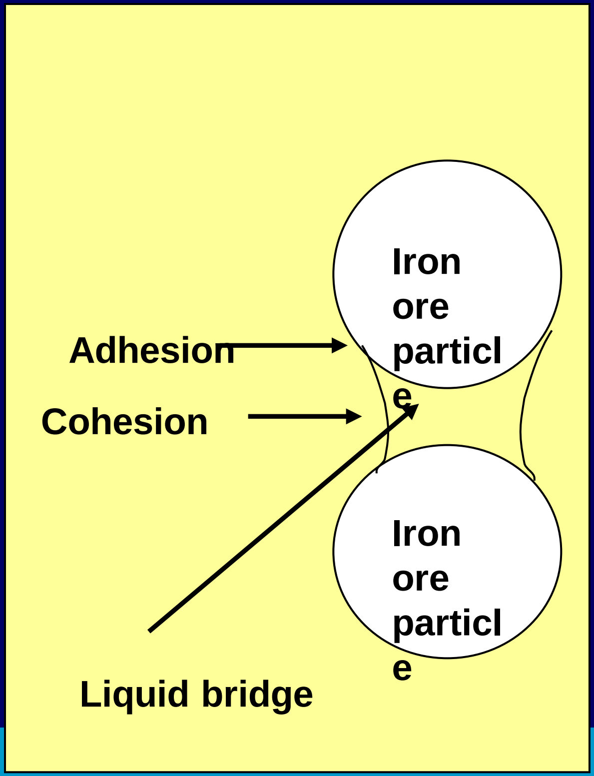
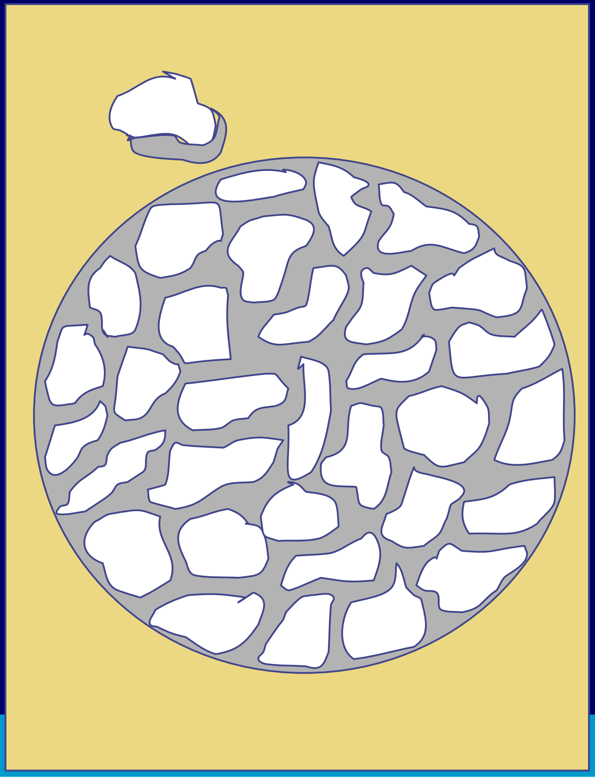
Balling principles

- Forces that bind green balls:
  - capillary forces in the liquid film
  - adhesion and cohesion forces
  - attraction between solid particles by van der Waal and electrostatic forces
  - mechanical interlocking of the granular particles
- Binders:
  - soluble salts,
  - bentonite,
  - inorganic chemicals,
  - organic materials.

Principle of balling





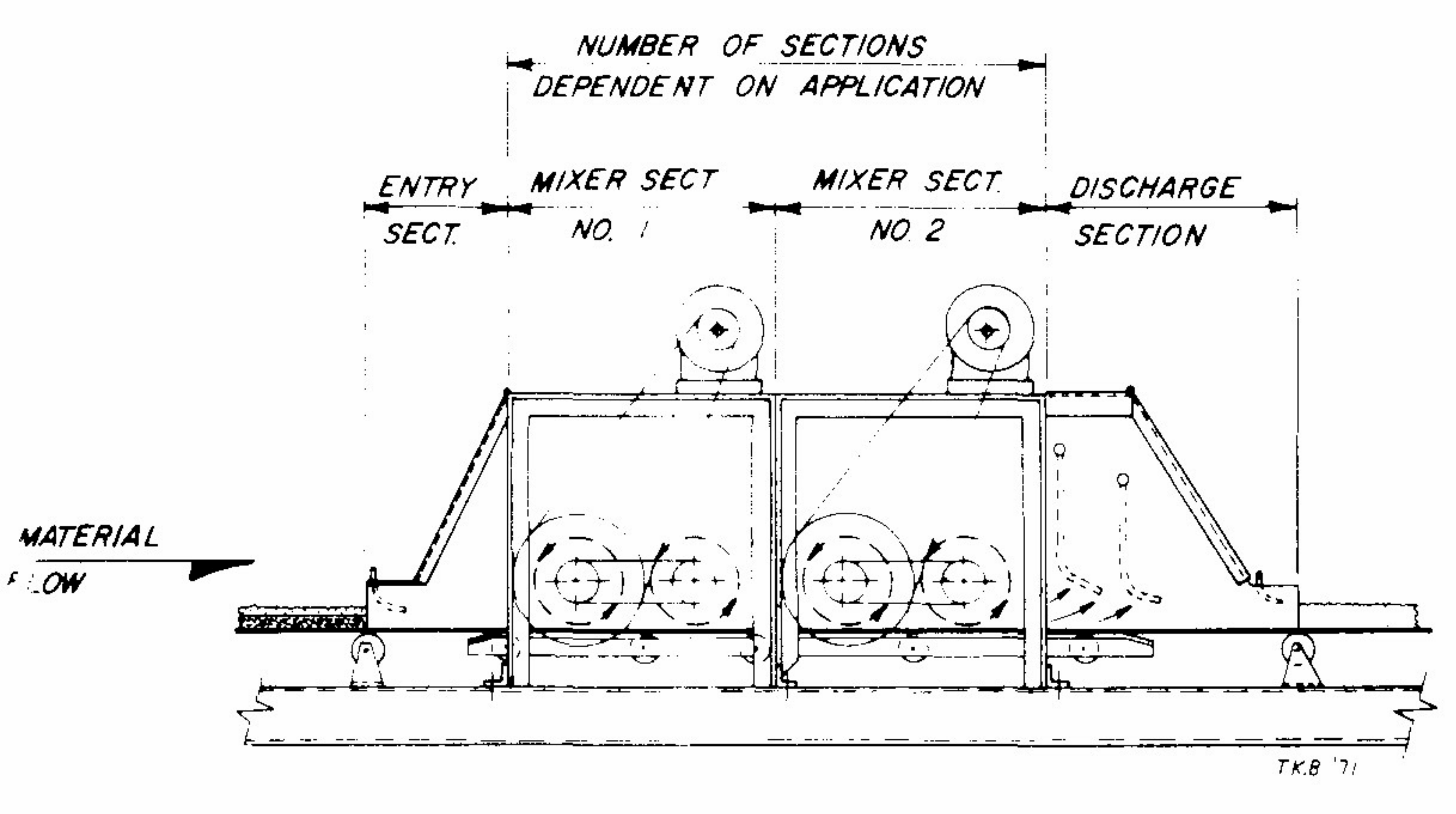


Important

- uniform size distribution of feed,
- uniform balling feed mixture,
- uniform addition of additives,
- good mixing of additives,
- maintaining clean screening surfaces

Feed mixing

Belt mixer

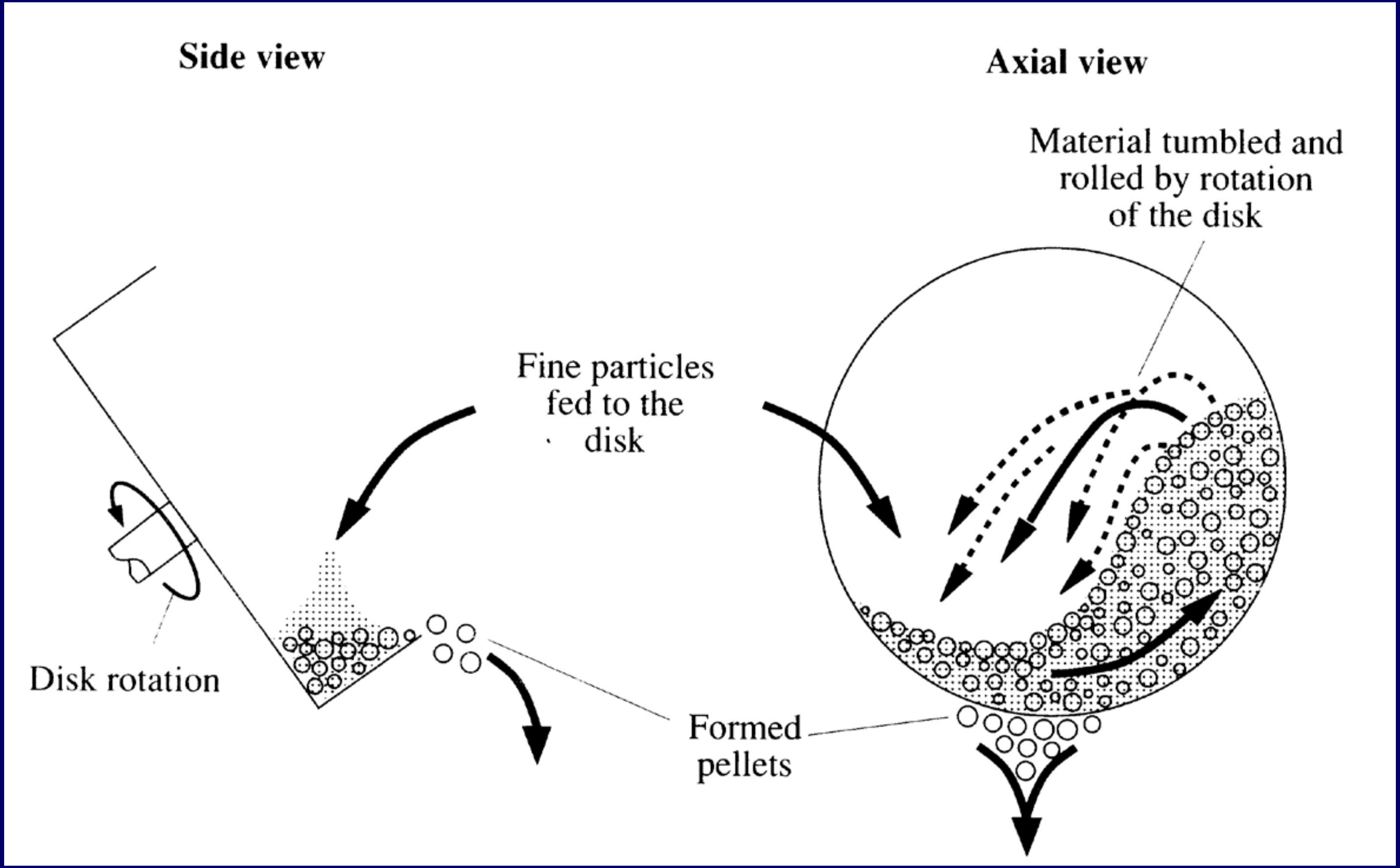


Balling disc

- Natural size classification

Balling disc with roller screen

Balling pan principle



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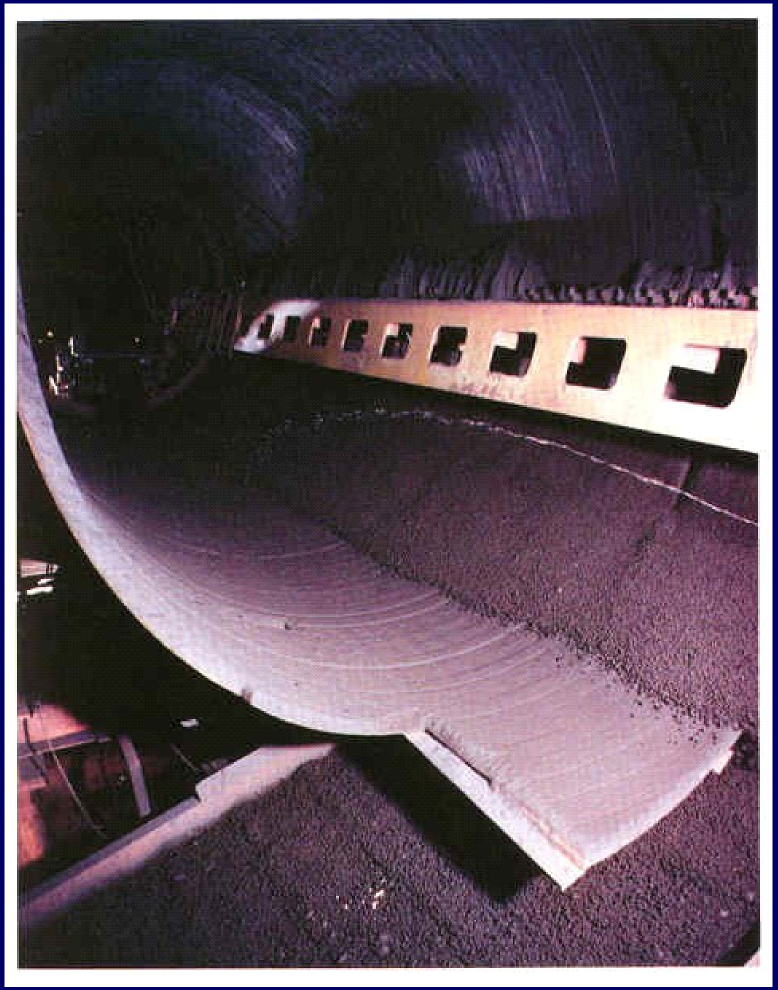
Balling pan data

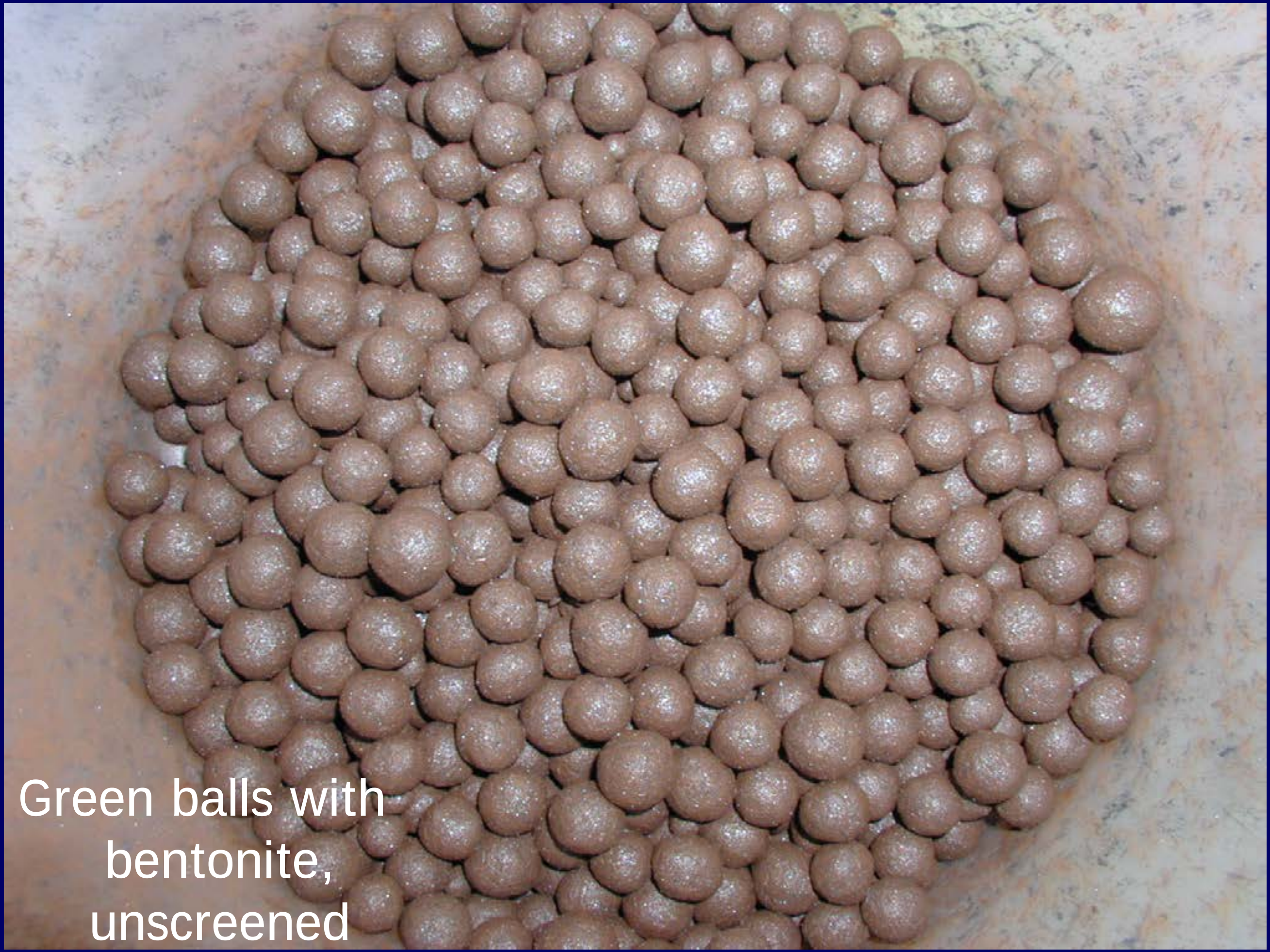
Size: inner diam. (m)	*Rotation speed (rpm)*	*Output (t/h magnetite)*
4.5	9.0	60
6.3	7.5	80
7.59	6.2	120

Balling drum

- Operated in closed circuit
- Easier to control



Green balls



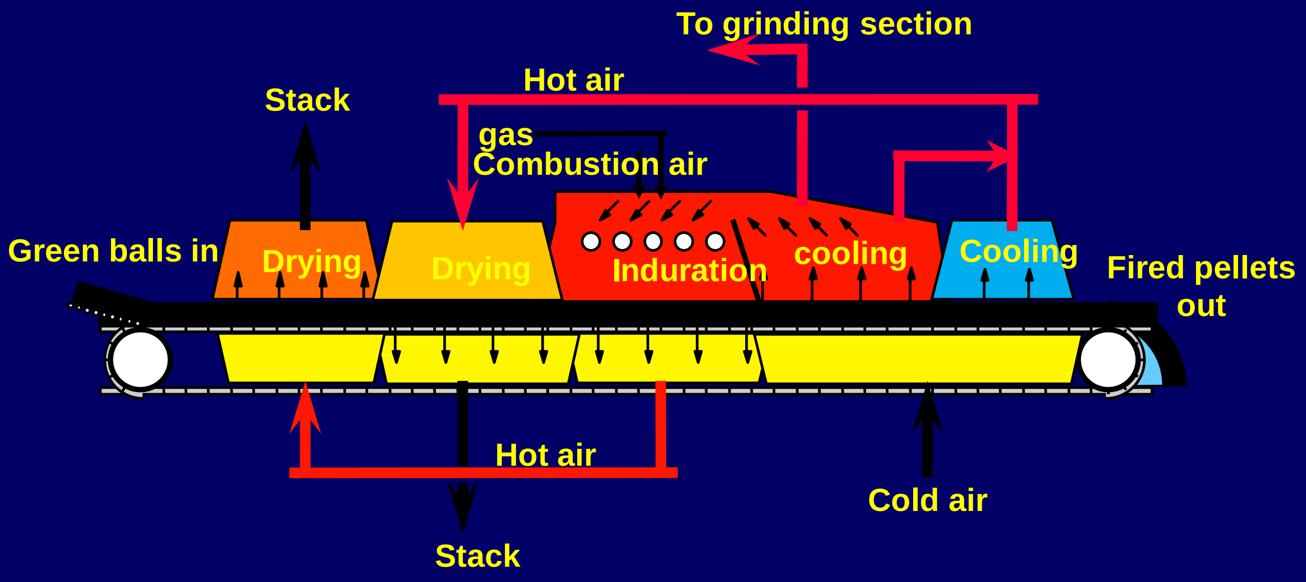
Green balls with bentonite, unscreened

Balling drum data

Size: diam. x length (m)	*Rotation speed (rpm)*	*Output (t/h magnetite)*
2.7 x 9.3	12.0	60
3.0 x 9.6	11.2	80
3.6 x 9.9	9.3	120

Straight grate induration machine: principle

$430\ m^2 = 30\ t/m^2\ 24\ hr$



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Grate kiln

Induration Process

Bed permeability

The permeability or void fraction of a packed bed of pellets is a critical parameter for the productivity, energy efficiency and stable operation of:

- Induration furnaces
- Blast furnaces
- DR shafts

Induration Process

Bed permeability

Pressure drop across a packed bed of spheres

Ergun equation:

$$\Delta P = \left[\frac{150(1-\varepsilon)^2 \mu_g}{\Phi^2 d^2 \varepsilon^3 e_g} G + \frac{1.75(1-\varepsilon)}{\Phi d \varepsilon^3 e_g} G^2 \right] \Delta Z$$

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Induration Process

Bed permeability

Pressure drop across a packed bed of spheres

Ergun equation:

Everything else being constant, approximately:

$$\Delta P \propto \frac{1}{\varepsilon^3}$$

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Induration Process

Bed permeability

$$\Delta P \propto \frac{1}{\varepsilon^3}$$

ε = Void fraction = 0.37 to 0.43

If $\Delta\varepsilon$ = 0.02 $\Delta P \cong$ 15%

$\Delta G \cong$ 8% (productivity)

Induration Process

Bed permeability

$$\Delta P \propto \frac{1}{\varepsilon^3}$$

$\varepsilon \propto$ Green ball plasticity $\propto$ H_2O
Binder
Ore particle size

$\varepsilon \propto$ Bed Packing $\propto$ Ball size dist.
Sphericity
Feeding device