Pulverized Coal Injection Systems
Coal Preparation and Pulverized Coal Injection

Equipment in Main Structure
Grinding and Drying of Coal in Inert Conditions

Blast Furnace Gas Based Drying

Drying energy supply based on blast furnace gas combustion.

Inert conditions produced by closed loop circulation of waste drying gas as a dilution gas for drying gas temperature control (self inertizing process).

High dew point in drying gas due to waste drying gas recirculation.

Blast Furnace Gas Based Drying, Dilution Air

Drying energy supply based on blast furnace gas combustion.

Inert conditions produced by closed loop circulation of waste drying gas as a dilution gas for drying gas temperature control (self inertizing process).

Dew point in drying gas lowered by means of cold dilution air injection up to the oxygen limit value for inert conditions.
Drying energy supply based on blast furnace gas combustion.

Inert conditions produced by closed loop circulation of waste drying gas as a dilution gas for drying gas temperature control (self inertizing process).

Dew point in drying gas lowered by means of water vapor condensation in a spray cooler.

Drying energy supply based on inert stove waste gas, complementary on blast furnace gas combustion.

Low dew point due to stove waste gas and little or no waste drying gas recirculation.
Unit Operations of Pulverized Coal Injection
The pulverized coal injection technology is based on a combination of several unit operations. Main unit operations include:

**Inward Transfer**

Hot blast backpressure as well as pressure drops in pneumatic conveying lines and flow rate control devices require a pressurizing of pulverized coal from atmosphere pressure level to overpressure level.

After pressurizing, pulverized coal is transferred into a Distribution Device. Transfer may be:
- by gravity or
- by pneumatic conveying.

**Distribution**

Global flow rate to be injected has to be split up onto the hot blast tuyeres by means of a Distribution Device. Distribution Device may contain:
- a pulverized coal buffer volume (Hopper type Distribution Device) or
- no pulverized coal buffer volume (Splitter type Distribution Device).

**Metering**

Global pulverized flow supplied to the Blast Furnace as well as individual flows supplied to the hot blast tuyeres shall be controlled. Flow rate control may be of:
- closed loop type or
- static type (only for individual flows).

**Pneumatic Conveying**

Pneumatic transfer of pulverized coal into the Distribution Device as well as conveying of individual flows from the Distribution Device into the hot blast tuyeres are performed by means of pneumatic conveying.

Pneumatic conveying may be of:
- the dense phase type or
- the dilute phase type.
**Basic Combinations of Inward Transfer and Distribution**

**Transfer without Pressurizing Gas Recovery**

**Transfer by Gravity**

**Transfer by Pneumatic Conveying**

Continuous transfer into a Splitter type Distribution Device

Discontinuous transfer into a Hopper type Distribution Device

Continuous transfer into a Hopper type Distribution Device
Transfer with Pressurizing Gas Recovery by means of Pressure Equalizing between parallel Hoppers

Transfer by Gravity

Continuous transfer into a Splitter type Distribution Device

Discontinuous transfer into a Hopper type Distribution Device

Transfer by Pneumatic Conveying

Continuous transfer into a Hopper type Distribution Device
Sequences of Parallel Conveying Hoppers

Sequences of two Conveying Hoppers, operated without pressurizing gas recovery

Sequences linked by
• continuous transfer of pulverized coal to the Distribution Device

Sequences of three Conveying Hoppers, operated with pressurizing gas recovery.

Sequences linked by
• continuous transfer of pulverized coal to the Distribution Device
• pressure balancing between Conveying Hoppers for pressurizing gas recovery.

Sequences of three Conveying Hoppers, operated without pressurizing gas recovery.

Sequences linked by
• continuous transfer of pulverized coal to the Distribution Device.
**Transfer by Gravity - Advantages**
- Larger transfer flow rates obtainable.
- Lower operating and design pressure levels.
- Less process gas requirement.
- No pneumatic conveying equipment required.

**Transfer by Gravity - Disadvantages**
- Transfer flow rate strongly conditioned by flowability of pressurized pulverized coal.
- Larger height of equipment arrangement.
- More equipment installed close to Blast Furnace.

**Transfer by Pneumatic Conveying - Advantages**
- Transfer flow rate less conditioned by flowability of pressurized pulverized coal.
- Direct Global Flow Rate Control possible in case of continuous transfer.
- Lower height of equipment arrangement.
- Less equipment installed close to Blast Furnace.

**Transfer by Pneumatic Conveying - Disadvantages**
- Transfer flow rates basically smaller.
- Higher operating and design pressure levels.
- Larger process gas requirement.
**Distribution**

**Splitter Type Distribution Device**

- **Advantages**
  - Direct global flow rate control possible in the upstream Conveying Line.
  - Reduced space requirement for equipment.
  - Reduced scope of equipment.

- **Disadvantages**
  - Individual flow rate control in downstream individual Injection Lines less efficient.
  - Larger conveying gas input into blast furnace.

▲ Distribution Splitter at ArcelorMittal Gijón BF ‘A’ & ‘B’

▲ Distribution structure at Cockerill Sambre Seraing BF ‘6’
Hopper Type Distribution Device

Hopper Type Distribution Device - Advantages

• No mutual disturbing of operation of downstream individual Injection Lines.
• Maximum accuracy of individual flow rate control in downstream individual Injection Lines.
• Minimum conveying gas input into blast furnace.

Hopper Type Distribution Device - Disadvantages

• Efficient direct global flow rate control difficult.
• Slightly increased process gas requirement, caused by second fluidizing of pulverized coal at the inlets of the downstream individual Injection Lines.
• Larger space requirement for equipment.
• Larger scope of equipment.
Pulverized Coal Injection

Metering

Determining of Pulverized Coal Flow Rate

By Means of Weighing System of Lock or Distribution Hopper:

- Indirect flow rate determining based on weight differences divided by time interval durations.
- Gives absolute values [kg/s].
- Quicker response reduces accuracy and vice-versa.
- Only gives value of total flow rate supplied by Hopper.

By Means of Correlative Flow Rate Measurement Device in Coal Conveying Line:

- Direct determining of relative flow rate value in coal conveying line.
- Gives relative values [mA].
- Requires second level weighing system for turning relative values [mA] into absolute values [kg/s].
- Quicker response than weighing system based flow rate determining.
- Gives individual flow rate values in multiple parallel lines.
Factors Determining Pulverized Coal Flow Rate in Line

**Fixed Value Factors, may be used in Static Flow Rate Control:**

- Length, routing of line.
- Inner diameter of line.
- Single static flow resistance (e.g. orifice, tuyere with sub-critical expansion).
- Critical expansion device (tuyere with critical expansion).

**Variable Value Factors, may be used in Closed Loop Flow Rate Control:**

- Line inlet pressure level.
- Line outlet pressure level.
- Conveying gas flow rate.
- Single variable flow resistance (mechanical flow control valve).
- External flow rate determining device (e.g. variable speed rotary valve).
## Pulverized Coal Injection

### Metering

#### Static Flow Rate Control

Means of Static Flow Rate Control

<table>
<thead>
<tr>
<th>FLOW RATE CONTROL METHOD</th>
<th>DISTRIBUTION PATTERN</th>
<th>PRESSURE LOSS DUE TO CONTROL</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diameter balanced flow resistances of Lines</td>
<td>Uniform, fixed</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>2. Equalized flow resistance of Lines (length, bends)</td>
<td>Uniform, fixed</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>3. Equalized flow resistance plus Subcritical Tuyeres</td>
<td>Uniform, fixed</td>
<td>About 1 - 2 bar</td>
<td></td>
</tr>
<tr>
<td>4. Critical Expansion Tuyeres in (arbitrary) Lines</td>
<td>Arbitrary, may be changed</td>
<td>( P_{in} &lt; P_{out} \times 1.65 )</td>
<td>4%</td>
</tr>
</tbody>
</table>

**Diagram:**

1. **Equal Distribution by Diameter Balanced Lines:**
   - Diameter Increase

2. **Equal Distribution by Length Balanced Lines:**
   - Balanced Line Length

3. **Equal Distribution by Length Balanced Lines and Subcritical Tuyeres:**
   - Subcritical Expansion Tuyere

4. **Flow Control by Critical Expansion Tuyeres:**
   - Critical Expansion Tuyere
Static Flow Rate Control by Critical Expansion Tuyeres

Acceleration requires gas pressure decrease and causes gas density decrease. Decreases in convergent nozzle are limited to critical values. In critical conditions, flow rate is only determined by pressure and density upstream of nozzle and by nozzle minimum cross section area.

Pressure drops due to critical expansion are minimized in an “optimum” tuyere, the variable minimum cross section fitting exactly with any flow rate requested. Actually, flow rate range is split into few subranges, each having a tuyere exactly fitting with the lowest flow rate in the subrange.
Pulverized Coal Injection

Metering

Static Flow Rate Control

Static Flow Rate Control by means of Injection Lines with equalized flow resistance plus pulverized coal tuyeres with subcritical expansion. Only produces uniform distribution.

Static Flow Rate Control by means of pulverized coal tuyeres with critical expansion installed in Injection Lines with various line length. May produce uniform distribution as well as arbitrary distribution patterns.
## Closed Loop Flow Rate Control

Means of Closed Loop Flow Rate Control

<table>
<thead>
<tr>
<th>FLOW RATE CONTROL METHOD</th>
<th>FLOW RATE DETERMINING</th>
<th>PRESSURE LOSS DUE TO CONTROL</th>
<th>ACCURACY (approximately)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Variation in Hopper (Global Flow only)</td>
<td>Weighing System on Hopper</td>
<td>none</td>
<td>2 - 4 %</td>
</tr>
<tr>
<td>Pressure Variation in Hopper (Global Flow only)</td>
<td>Flow Rate Measurement Device in Line</td>
<td>none</td>
<td>2 - 4 %</td>
</tr>
<tr>
<td>Dilution Gas Injection into Conveying Line</td>
<td>Weighing System on Hopper</td>
<td>none</td>
<td>2 - 3 %</td>
</tr>
<tr>
<td>Dilution Gas Injection into Conveying or Injection Line</td>
<td>Flow Rate Measurement Device in Line</td>
<td>none</td>
<td>1 - 2 %</td>
</tr>
<tr>
<td>Coal Flow Rate Control Valve in Conveying Line</td>
<td>Weighing System on Hopper</td>
<td>1 - 2 bar</td>
<td>2 - 3 %</td>
</tr>
<tr>
<td>Coal Flow Rate Control Valve in Conveying or Injection Line</td>
<td>Flow Rate Measurement Device in Line</td>
<td>1 - 2 bar</td>
<td>1 - 2 % (Conv.) or 0.5 - 1 % (Injec.)</td>
</tr>
</tbody>
</table>

### Notes:
- **Depressurizing control valve used in hopper pressure control**
- **Coal Flow Rate Control Valve for Conveying Line (Global Flow Rate Control)**
Pulverized Coal Injection

Metering
Closed Loop Flow Rate Control

- Coal Flow Rate Measurement Devices in Injection Lines, downstream of Coal Flow Rate Control Valves installed beneath the Distribution Hopper at ArcelorMittal Gijón BF ‘A’ & ‘B’

- Coal Flow Rate Control Valves installed beneath the Distribution Hopper at Rogesa Dillingen BF ‘5’

- Coal Flow Rate Control Valves installed downstream of Splitter type Distribution Device at ArcelorMittal Gijón BF ‘A’ & ‘B’
Closed Loop Flow Rate Control

- PULVERIZED COAL STORAGE BIN
- LOCK AND WEIGHING HOPPER
- PRESSURIZING GAS VESSELS
- DISTRIBUTION HOPPER
- COAL FLOW RATE CONTROL VALVES
- COAL FLOW RATE MEASUREMENT DEVICES
- INJECTION LINES

*Injection Structure at Rogesa Dillingen BF '5'*
Pulverized coal has outstanding fluidizability and gas retaining characteristics. These are the basis for dense phase pneumatic conveying of pulverized coal in fluidized state.

Fluidizing of pulverized coal is performed in fluidizing compartments connected to the coal outlet nozzles of the Conveying Hoppers or Distribution Hopper.

Pulverized coal may also be conveyed in conventional dilute phase conveying.
Load in pneumatic dense phase conveying (ratio of solid flow rate to gas flow rate) is conditioned by the pressure level existing in the fluidizing device upstream of the coal conveying line.
Pulverized Coal Injection

Pneumatic Conveying

Dilute Phase Conveying versus Dense Phase Conveying

**DILUTE PHASE CONVEYING**

High solid material velocity, requiring

- abrasion protection in bends.

Low ratio of solid material flow rate to conveying gas flow rate in coal conveying line, meaning

- higher conveying gas requirement (conditioned by void).

More pneumatic energy in conveying gas per solid material unit mass, meaning

- lower pressure drop in coal conveying line

- lower pressure level, less pressurizing gas and less pressure maintaining gas required in Conveying Hopper.

Design criteria: solid material velocity > minimum velocity, meaning

- conveying gas flow rate constant when solid material flow rate is decreasing

- specific conveying gas requirement is increasing with decreasing solid material flow rate

- turn-down ratio of conveying flow rate is unlimited.

Transportability is based on action of gas turbulence on individual solid particle, meaning

- conveying is less conditioned by bulk solid material properties

- conveying is less sensitive.

**DENSE PHASE CONVEYING**

Low solid material velocity, requiring

- no abrasion protection in bends.

High ratio of solid material flow rate to conveying gas flow rate in coal conveying line, meaning

- lower conveying gas requirement (conditioned by line inlet pressure).

Less pneumatic energy in conveying gas per solid material unit mass, meaning

- higher pressure drop in coal conveying line

- higher pressure level, more pressurizing gas and more pressure maintaining gas required in Conveying Hopper.

Design criteria: conveying time duration (traveling time) < maximum possible duration, meaning

- conveying gas flow rate is decreasing with solid material flow rate

- specific conveying gas requirement is nearly constant, independently of solid material flow rate

- conveying distance and turn-down ratio of conveying flow rate are limited.

Transportability is based on fluidizing of bulk solid material, meaning

- conveying is more conditioned by bulk solid material properties (fluidizability, flowability, gas retaining capacity)

- conveying is more sensitive.
Main Structure of PCI-System at Cockerill Sambre Charleroi BF ‘4’ and BF ‘5’

Conveying of pulverized coal from the PCI-System Main Structure to Cockerill Sambre Charleroi BF ‘4’, total conveying distance about 1000 m
Preheating of Pulverized Coal

Preheating and Injection Equipment Arrangement

Preheating and Degassing of Pulverized Coal

Pulverized coal is pre-heated in the Conveying Line upstream of the Distri- bution Hopper.

Residual moisture is separated in the Distribution Hopper.

Preheating of Pulverized Coal

Pulverized coal is pre-heated in the Conveying Line upstream of the Splitter type Distribution Device.

Closed loop individual injection flow rate control is performed down- stream of the Splitter type Distribution Device.

Preheating of Pulverized Coal

Pulverized coal is pre-heated in the Conveying Line upstream of the Splitter type Distribution Device.

Static individual flow rate control is performed down stream of the Splitter type Distribution Device.
The Paul Wurth Group is today one of the world leaders in the design and supply of complete plants, systems and processes as well as specialised mechanical equipment for:

**the iron & steel industry:**
- Blast Furnaces & Auxiliary Plants
- Coke Making Plants
- Agglomeration Plants
- Direct Reduction Plants
- Environmental Protection, Recycling & Energy-Saving Technologies

**other industries:**
- Systems & Equipment for Non-Ferrous Pyrometallurgy, Electrometallurgy & Residue Treatment
- Intralogistics Solutions for Heavy Loads
- Engineering & Project Management for Civil Construction and Infrastructure Projects