Comparison of various ship unloading equipment for bulk materials concerning their specific energy consumption per ton

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Dipl.-Ing. Christoph Tilke

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Agenda

- The role of coal in global energy supply
- Topic of the study
- Measurement technique
- Measurements at unloading installations
- Final results & conclusion
The role of coal in global energy supply

World primary energy demand today

**Global energy mix 2008**

[16 billion t of coal equivalent (tce)]

- **35%** Oil
- **23%** Natural Gas
- **28%** Coal
- **8%** Nuclear energy
- **6%** Hydro and other Renewables

Source: IEA, World Energy Outlook 2009
The role of coal in global energy supply

World primary energy future demand

![Graph: World Energy Demand by Fuel Type, 1980-2030](Image)

Source: IEA, World Energy Outlook 2008
World primary Energy Consumption by Source and Sector, 2006 (Quad Btu)

Supply Sources

- Petroleum 36.6%
- Coal 27.0%
- Natural Gas 22.7%
- Hydro and other Renewables 7.8%
- Nuclear Energy 5.9%

Demand Sectors

- Residential & Com. 10.2%
- Transportation 19.2%
- Industrial 31.5%
- Electric Power 39.1%

Electricity-Related Losses 0.69%

Total 472.4 Quadrillion Btu ≈ 16 billion tce

Source: IEA, World Energy Outlook 2007
The role of coal in global energy supply

World primary energy demand

Coal Consumption in Selected World Regions, 1980-2030

Source: IEA, Coal Information, Paris 2009
The role of coal in global energy supply

Coal production by country

Top Producing Countries, 2007

- China: 2549 million metric tons
- United States: 981 million metric tons
- India: 452 million metric tons
- Australia: 323 million metric tons
- South Africa: 244 million metric tons
- Russia: 241 million metric tons
- Indonesia: 231 million metric tons
- Poland: 90 million metric tons
- Kazakhstan: 83 million metric tons
- Colombia: 72 million metric tons
- Others: 277 million metric tons

Source: World Coal Institute, Coal Facts 2008 Edition
The role of coal in global energy supply

Coal consumption by country

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>45.5 %</td>
</tr>
<tr>
<td>USA</td>
<td>18.6 %</td>
</tr>
<tr>
<td>India</td>
<td>9.7 %</td>
</tr>
<tr>
<td>Russia</td>
<td>3.9 %</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.8 %</td>
</tr>
<tr>
<td>Japan</td>
<td>3.4 %</td>
</tr>
<tr>
<td>Poland</td>
<td>2.5 %</td>
</tr>
<tr>
<td>Germany</td>
<td>4.6 %</td>
</tr>
<tr>
<td>South Africa</td>
<td>3.3 %</td>
</tr>
<tr>
<td>Australia</td>
<td>2.8 %</td>
</tr>
<tr>
<td>Others</td>
<td>3.9 %</td>
</tr>
</tbody>
</table>

Source: World Coal Institute, Coal Facts 2008 Edition
The role of coal in global energy supply

Coal seaborne trade

**World hard coal output and maritime trade, 2008**

- **Hard coal output**: 5850 Mt
- **85.7%**: Hard coal other [Mt]
- **10.8%**: World trade (maritime) steam coal [Mt]
- **3.5%**: World trade (maritime) coking coal [Mt]

Source: VDKI, Hamburg 2009
The role of coal in global energy supply

Coal output-seaborne trade ratio

Output and maritime exports of hard coal, 2008

Source: IEA, Coal information, Paris 2009 (output) and VDKI, Hamburg 2009 (exports)
The role of coal in global energy supply

Hard Coal Imports

Imports of hard coal, 2008

- Poland: 9 Mt
- France: 19 Mt
- Canada: 23 Mt
- Italy: 26 Mt
- Russia: 28 Mt
- United States: 31 Mt
- Spain: 33 Mt
- China: 41 Mt
- Germany: 46 Mt
- Great Britain: 48 Mt
- India: 54 Mt
- Taiwan: 65 Mt
- South Korea: 96 Mt
- Japan: 190 Mt

Source: VDKI, Annual Report 2009
The role of coal in global energy supply

Coal seaborne trade

Seaborne Hard Coal Transport 2008: 839 Million Tonnes

Seaborne trade: 839 Mill. t
incl. 632 Mt steam coal
207 Mt coking coal

Global hard coal production: 5.85 Bt

Source: VDKI, Annual Report 2009
The role of coal in global energy supply

Coal production, reserves and resources

![Diagram showing coal production, reserves, and resources with percentages and total energy in exajoules (EJ).]

- **Reserves**:
  - Hard coal 46.3%
  - Conv. natural gas 18.3%
  - Conv. oil 17.2%
  - Non-conv. oil 5.6%
  - Lignite 7.9%
  - Uranium 1.9%
  - Thorium 2.3%
  - Total reserves: 38,946 EJ

- **Production**:
  - Hard coal 31.2%
  - Lignite 2.2%
  - Uranium 1.8%
  - Conv. oil 35.9%
  - Natural gas 26.6%
  - Non-conv. oil 2.4%
  - Conv. natural gas 1.7%
  - Total production: 453 EJ

- **Resources**:
  - Hard coal 72.4%
  - Lignite 9.2%
  - Uranium 1.1%
  - Conv. oil 0.7%
  - Non-conv. oil 2.4%
  - Conv. natural gas 1.7%
  - Non-conv. natural gas 19.4%
  - Total resources: 571,368 EJ
Agenda

- The role of coal in global energy supply
- Topic of the study
- Measurement technique
- Measurements at unloading installations
- Final results & conclusion
Topic of the Study

Considered Types of Ship Unloaders

- Ship Unloader
  - Grab-Type Unloader
    - Gantry Crane
    - Level Luffing Crane
  - Continuous Unloader
    - Vertical Screw
    - Bucket Elevator
    - Pneumatic Conveyor
    - En-Masse Conveyor
    - Bucket Wheel
Considered Types of Ship Unloaders

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Agenda

The role of coal in global energy supply

Topic of the study

Measurement technique

Measurements at unloading installations

Final results & conclusion
Measurement technique

Theorie and equipment for power measuring

- **The three wattmeter method:**
  - measures the power in each single phase
  - very accurate even with unbalanced loads
  - e.g. for complete unloaders
  - calculation formula:
    
    \[ p(t) = u_{1N} \cdot i_1 + u_{2N} \cdot i_2 + u_{3N} \cdot i_3 \]

    \[ W = \int p(t) \, dt, \]

- **The single wattmeter method:**
  - suitable for balanced loads
  - e.g. for driving motors
  - calculation formula:
    
    \[ p(t) = 3 \cdot u_1 \cdot i_1 \cdot \cos \varphi \]
Agenda

1. The role of coal in global energy supply
2. Topic of the study
3. Measurement technique
4. Measurements at unloading installations
5. Final results & conclusion
Measurements at unloading installations

Grab-Type Unloader - Gantry Crane

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Krupp</td>
</tr>
<tr>
<td>Year of construction</td>
<td>1979</td>
</tr>
<tr>
<td>Lifting capacity</td>
<td>35 t</td>
</tr>
<tr>
<td>Grab weight</td>
<td>12 t (19 m³)</td>
</tr>
<tr>
<td>Lift above pear</td>
<td>ca. 20 m</td>
</tr>
<tr>
<td>Horizont. driveway</td>
<td>ca. 25 m</td>
</tr>
<tr>
<td>Flow rate max.</td>
<td>ca. 1,200 t/h</td>
</tr>
<tr>
<td>Flow rate avg.</td>
<td>ca. 1,000 t/h</td>
</tr>
<tr>
<td>Installed power</td>
<td>ca. 1.7 MW</td>
</tr>
<tr>
<td>Bulk material</td>
<td>Steam coal</td>
</tr>
<tr>
<td>Personnel placement</td>
<td>2+2</td>
</tr>
<tr>
<td>Self-weight</td>
<td>ca. 1,000 t</td>
</tr>
</tbody>
</table>
Measurements at unloading installations

Grab-Type Unloader - Gantry Crane

![Graph showing godet unit with time and kW/kWh axes]
Measurements at unloading installations

Grab-Type Unloader - Gantry Crane

closure unit

-100 100 200 300 400 500 600
-200

kW/kWh

time

kW

kWh

12/01/29 12/02/29 12/03/29 12/04/29 12/05/29 12/06/29 12/07/29 12/08/29 12/09/29 12/10/29 12/11/29 12/12/29 12/13/29 12/14/29 12/15/29 12/16/29 12/17/29 12/18/29 12/19/29 12/20/29 12/21/29 12/22/29 12/23/29 12/24/29 12/25/29 12/26/29 12/27/29 12/28/29 12/29/29 12/30/29 12/31/29 01/01/30 01/02/30 01/03/30 01/04/30 01/05/30 01/06/30 01/07/30 01/08/30 01/09/30 01/10/30 01/11/30 01/12/30 01/13/30 01/14/30 01/15/30 01/16/30 01/17/30 01/18/30 01/19/30 01/20/30 01/21/30 01/22/30 01/23/30 01/24/30 01/25/30 01/26/30 01/27/30 01/28/30 01/29/30 01/30/30
Measurements at unloading installations

Grab-Type Unloader - Gantry Crane

![Graph showing trolley drive unit with data from 12-00-09 to 12-31-09 with measurements in kW and kWh over time.]

*Image of graph showing trolley drive unit with data from 12-00-09 to 12-31-09 with measurements in kW and kWh over time.*
Measurements at unloading installations

Grab-Type Unloader - Gantry Crane

Grab Gantry Crane unloader 35t
Energy consumption without recovery 0.27 kWh/t
Possible energy recovery 0.04 kWh/t

- godet unit: 33%
- closure unit: 27%
- trolley unit: 5%
- other (carriage, belt conveyor, lights,...): 35%
**Continuous Unloader - Bucket Elevator**

<table>
<thead>
<tr>
<th><strong>Manufacturer</strong></th>
<th>PWH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year of construction</strong></td>
<td>1988</td>
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<tr>
<td><strong>Lift above pear</strong></td>
<td>7.4 m</td>
</tr>
<tr>
<td><strong>Flow rate max.</strong></td>
<td>ca. 1,200 t/h</td>
</tr>
<tr>
<td><strong>Flow rate avg.</strong></td>
<td>ca. 800 t/h</td>
</tr>
<tr>
<td><strong>Installed power</strong></td>
<td>ca. 565 kW</td>
</tr>
<tr>
<td><strong>Bulk material</strong></td>
<td>Coking coal</td>
</tr>
<tr>
<td><strong>Personnel placement</strong></td>
<td>1+1</td>
</tr>
<tr>
<td><strong>Self-weight</strong></td>
<td>ca. 516 t</td>
</tr>
</tbody>
</table>
Measurements at unloading installations

Continuous Unloader - Bucket Elevator

*driving motor bucket elevator*

![Graph showing energy consumption over time for a continuous unloader bucket elevator](image)

- **kw**
- **kWh**

**time**

- 18:00:00 to 18:40:00
Measurements at unloading installations

Continuous Unloader - Bucket Elevator

carriage motors

kw/kWh

kW
kWh

time


FML – Institute for Materials Handling Material Flow Logistics · Prof. Dr.-Ing. Dipl.-Wi.-Ing. W. A. Günther · Technische Universität München
Continuous Unloader - Bucket Elevator

Bucket elevator (1200 t/h)
Energy consumption 0.24 kWh/t

- 73% bucket elevator
- 11% carriage
- 9% belt conveyor
- 7% other (lights, heating, ...)

Measurements at unloading installations
Measurements at unloading installations

**Continuous Unloader - Vertical Screw**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Siwertell</td>
</tr>
<tr>
<td>Year of construction</td>
<td>1988</td>
</tr>
<tr>
<td>Length vertical screw</td>
<td>ca. 15 m</td>
</tr>
<tr>
<td>Length horiz. screw</td>
<td>ca. 16.5 m</td>
</tr>
<tr>
<td>Flow rate max.</td>
<td>ca. 600 t/h</td>
</tr>
<tr>
<td>Flow rate avg.</td>
<td>ca. 400 t/h</td>
</tr>
<tr>
<td>Installed power</td>
<td>ca. 600 kW</td>
</tr>
<tr>
<td>Bulk material</td>
<td>Steam coal</td>
</tr>
<tr>
<td>Personnel placement</td>
<td>1+1</td>
</tr>
<tr>
<td>Self-weight</td>
<td>ca. 136 t</td>
</tr>
</tbody>
</table>
Measurements at unloading installations

Continuous Unloader - Vertical Screw

vertical screw

kw/kWh

kWh

time

kW

kWh
Measurements at unloading installations

Continuous Unloader - Vertical Screw
Measurements at unloading installations

Continuous Unloader - Vertical Screw

Screw unloader 600 t/h
Energy consumption 0,53 kWh/t (Coal)

- Vertical screw: 52%
- Horizontal screw: 8%
- Other (lights, carriage, ...): 40%
Agenda

The role of coal in global energy supply

Topic of the study

Measurement technique

Measurements at unloading installations

Final results & conclusion
Final results & conclusion

Specific energy consumption of ship unloaders

- Screw
- Grab with energy recovery
- Grab without energy recovery
- Bucket elevator

Nominal unloader capacity [t/h]

Specific energy consumption [kWh/t]
Thank you for your attention!