The application of very large piston diaphragm pumps in the oil sand industry
What is a piston diaphragm pump
What is a piston diaphragm pump

A piston diaphragm pump is:
- A piston pump where the main pumping parts are separated from the slurry by means of a rubber diaphragm.
What is a piston diaphragm pump

Piston diaphragm pump operating principle

- **diaphragm**
- **hydraulic oil**
- **slurry**
- **piston**
What is a piston diaphragm pump

A piston diaphragm pump is:

- A piston pump where the main pumping parts are separated from the slurry by means of a rubber diaphragm
- Only wearing parts are suction and discharge valves
  - Lower parts costs
  - No leakages over piston
  - Maintain high pressure capability
  - Higher availability
- Depending on abrasivity of slurry, extra costs for diaphragm configuration are amortized within short period of time
What is a piston diaphragm pump

Piston diaphragm pump performance range

Pressure rating (bar)

Capacity (m³/hr)
What is a piston diaphragm pump

Piston diaphragm pump: 1000 m³/hr @ 85 bar
The application of very large piston diaphragm pumps in the oil sand industry

What are piston diaphragm pumps used for
Applications in the mining and metallurgical industry

Underground mine dewatering : pumping dirty mine water from underground to surface in one stage

Pressure vessel feed : autoclaves, digesters

Slurry concentrate transfer : pipeline transfer of copper, iron, gold, etc to metallurgical plant of port (500 km)

Slurry tailings transfer : pipeline transfer of copper, iron, gold tailings to TSF (6,000 m³/hr @ 100 bar)

Piston diaphragm pumps are used as an alternative to multistage centrifugal pumps
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Differences with centrifugal pumps
Differences with centrifugal pumps

Centrifugal pumps for high pressure slurry transfer

- Large particle handling capability
- Low pressure capability
- Multiple pumps in series required
- Complicated gland water system required
- Low mechanical efficiency (+/- 70%)
- High wear part consumption
- Capacity is pressure dependent
Differences with centrifugal pumps

**Piston diaphragm pumps for high pressure slurry transfer**

- No large particle handling capability (< 10 mm)
- High pressure capability
- Single pump required
- No gland water system required
- High mechanical efficiency (+/- 88%)
- Low wear part consumption
- Capacity is pressure independent
Differences with centrifugal pumps

Tailing slurry pipelines from refinery to TSF

- Centrifugal: multi station, multiple pumps in series
- Piston diaphragm: single station, multiple pumps in parallel
Differences with centrifugal pumps

**Centrifugal pumps**

- Capacity is pressure dependent:
- If pressure increases
- Pump follows curve
- Capacity decreases
- Slurry velocity decreases
- Risk of plug increases
Differences with centrifugal pumps

**Piston diaphragm**

- Capacity is pressure independent:
  - If pressure increases
  - Pump follows curve
  - Capacity remains the same
  - Slurry velocity remains the same
  - No risk of plug increases
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Case description
# Case description

## Basic operating data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline flow rate</td>
<td>5,000 m³/hr</td>
</tr>
<tr>
<td>Required discharge pressure</td>
<td>50 bar</td>
</tr>
<tr>
<td>Number of operating hours</td>
<td>8,500</td>
</tr>
<tr>
<td>Type of slurry</td>
<td>oil sand tailings</td>
</tr>
<tr>
<td>Abrasivity</td>
<td>high (Miller number &gt; 100)</td>
</tr>
<tr>
<td>Price of power/kWhr</td>
<td>C$ 0,10</td>
</tr>
</tbody>
</table>
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Pump options
Pump options

Options:

Centrifugal pumps
- Capacity : > 8,000 m³/hr
- Pressure : < 6 bar

Piston diaphragm pumps
- Capacity : 1,000 m³/hr
- Pressure : > 400 bar
**Pump options**

**Centrifugal pumps**

- **Pumping capacity:**
  - 5,000 m³/hr
  - Qty of pumps: 1

- **Pumping pressure:**
  - 4 to 6 bar max.
  - Qty of pumps in series: 10

- **Pump casing pressure**
  - Maximum pressure: < 40 bar
  - Number of pump stations: 2
  - Number of pumps per station: 5 (train)

- **Availability:**
  - Per pump: 96%
  - Per train of 5 pumps: 77%

- **Number of standby pumps:**
  - Per train: 5

- **Total qty pumps required:** 20
Pump options

Centrifugal pumps

Plant pump station:
- Pumps operating : 5
- Pumps standby : 5

Booster pump station:
- Pumps operating : 5
- Pumps standby : 5

Pump mechanical efficiency
- Average : +/- 70%

Unit price
- Per pump (+ motor, gearbox) : C$ 600.000
- Per pump (as above + VSD) : C$ 975.000 (only 1 per train)
- Average pump price in train of 5 : C$ 675.000

Multiplying factor (applied to pump CAPEX)
- For BOP (piping, cabling, civil, etc) : 2,5
Piston diaphragm pumps

Pumping capacity:
- Maximum capacity : 1,000 m³/hr
- Qty of pumps in parallel : 5

Pump pressure
- Maximum pressure : 85 bar
- Number of pumps stations : 1

Availability:
- Per pump : > 98%

Number of standby pumps
- Per station : 1

Total qty of pumps required : 6
Pump options

Piston diaphragm pumps

Plant pump station:
- Pumps operating : 5
- Pumps standby : 1

No booster station

Charge pumps:
- Pumps operating : 3
- Pumps standby : 2

Pump mechanical efficiency
- Average : +/- 88%

Unit price
- PD pump (+ motor, VSD, gearbox) : C$ 4,250,000
- Charge pump (+ motor, gearbox) : C$ 180,000

Multiplying factor (applied to pump CAPEX)
- for BOP (piping, cabling, civil, etc) : 1,0
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CAPEX of each option
# CAPEX comparison

<table>
<thead>
<tr>
<th></th>
<th>Centrifugal</th>
<th>Piston diaphragm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x (5 + 5)</td>
<td></td>
<td>5 + 1</td>
</tr>
<tr>
<td>5.000 m³/hr</td>
<td></td>
<td>1.000 m³/hr</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of required pump units</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Price per pump (average incl. gearbox, motor, VFD)</td>
<td>in C$</td>
<td>675.000</td>
</tr>
<tr>
<td>Nr. of operating pumps</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Nr. of standby pumps</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Nr. of charge pumps for PD pumps</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Nr. of standby charge pumps</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Price per charge pump</td>
<td>in C$</td>
<td></td>
</tr>
</tbody>
</table>

**Calculation**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total system pump CAPEX</td>
<td>in C$</td>
<td>13.500.000</td>
</tr>
<tr>
<td>CAPEX of BOP and pump station</td>
<td>in C$</td>
<td>33.750.000</td>
</tr>
<tr>
<td>Total direct cost</td>
<td>in C$</td>
<td>47.250.000</td>
</tr>
<tr>
<td>EPCM (12%)</td>
<td>in C$</td>
<td>5.670.000</td>
</tr>
<tr>
<td>Contingency (15%)</td>
<td>in C$</td>
<td>7.087.500</td>
</tr>
<tr>
<td>Total CAPEX pump station(s)</td>
<td>in C$</td>
<td>60.007.500</td>
</tr>
<tr>
<td>Difference in investment</td>
<td>in C$</td>
<td></td>
</tr>
</tbody>
</table>
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OPEX of each option
# OPEX comparison

## Power

<table>
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<th>Centrifugal</th>
<th>Piston diaphragm</th>
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<tbody>
<tr>
<td></td>
<td>2 x (5 + 5)</td>
<td>5 + 1</td>
</tr>
<tr>
<td></td>
<td>5,000 m³/hr</td>
<td>1,000 m³/hr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>bar</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Capacity</td>
<td>m³/hr</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Price per kW hr</td>
<td>in C$</td>
<td>0,10</td>
<td>0,10</td>
</tr>
<tr>
<td>Operating hours</td>
<td>Per yr</td>
<td>8,500</td>
<td>8,500</td>
</tr>
<tr>
<td>Assumed efficiency</td>
<td>in %</td>
<td>70</td>
<td>88</td>
</tr>
</tbody>
</table>

### Calculation

#### Absorbed power
- in kW: 9,921
- in C$: 992

#### Hourly power cost
- in C$: 8,432,540

#### Annual power cost
- in C$: 6,707,702

#### Difference in power consumption per year
- in C$: **1,724,838**
# OPEX comparison

## Wear part consumption

<table>
<thead>
<tr>
<th></th>
<th>Centrifugal</th>
<th>Piston diaphragm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 x (5 + 5)</td>
<td>5 + 1</td>
</tr>
<tr>
<td></td>
<td>5.000 m³/hr</td>
<td>1.000 m³/hr</td>
</tr>
</tbody>
</table>

### Parts consumption in % of purchase price*

<table>
<thead>
<tr>
<th></th>
<th>in %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>5</td>
</tr>
</tbody>
</table>

### Calculation

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual pump wear parts cost</td>
<td>4.218.750</td>
<td>630.000</td>
</tr>
<tr>
<td>Difference in wear parts costs per year</td>
<td>3.588.750</td>
<td></td>
</tr>
</tbody>
</table>

*Applied only to operating pumps, excluding drive
## OPEX comparison

### Summary CAPEX/OPEX

<table>
<thead>
<tr>
<th></th>
<th>Centrifugal 2 x (5 + 5) 5.000 m³/hr</th>
<th>Piston diaphragm 5 + 1 1.000 m³/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual power consumption</strong></td>
<td>in C$ 8.432.540</td>
<td>in C$ 6.707.702</td>
</tr>
<tr>
<td><strong>Annual wear parts costs</strong></td>
<td>in C$ 4.218.750</td>
<td>in C$ 630.000</td>
</tr>
<tr>
<td><strong>Annual labour costs</strong></td>
<td>in C$ 600.000</td>
<td>in C$ 150.000</td>
</tr>
<tr>
<td><strong>Annual gland water costs</strong></td>
<td>in C$ 60.563</td>
<td>in C$ 18.169</td>
</tr>
<tr>
<td><strong>Annual OPEX (sub-total)</strong></td>
<td>in C$ 13.311.852</td>
<td>in C$ 7.505.871</td>
</tr>
<tr>
<td><strong>Contingency (15%)</strong></td>
<td>in C$ 1.996.778</td>
<td>in C$ 1.125.881</td>
</tr>
<tr>
<td><strong>Total annual OPEX</strong></td>
<td>in C$ 15.308.630</td>
<td>in C$ 8.631.751</td>
</tr>
<tr>
<td><strong>Difference in OPEX per month</strong></td>
<td>in C$ 556.407</td>
<td></td>
</tr>
<tr>
<td><strong>Total CAPEX</strong></td>
<td>in C$ 60.007.500</td>
<td>in C$ 66.294.000</td>
</tr>
<tr>
<td><strong>Amortization period of difference in investment</strong></td>
<td>in years 0.9</td>
<td></td>
</tr>
</tbody>
</table>
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Sensitivity analyses
Sensitivity analyses

Variables

Calculation assumptions:
- Price of power per kWhr: C$ 0,10
- Parts consumption centrifugals: 100% of CAPEX

Sensitivity analyses:
- Price of power per kWhr: C$ 0,08 – 0,15
- Parts consumption centrifugals: 50 – 150% of CAPEX

Parts consumption of piston diaphragm pumps is proven to be approx 5%
- Only valve components are subject to wear (life time 3 to 4 months)
- Diaphragms have a life time of 2 years
Sensitivity analyses

Payback time centrifugal versus piston diaphragm pumps

Payback Period in years

Price of power in C$ cent/kWhr

Parts consumption in % of centrifugal pump price
The application of very large piston diaphragm pumps in the oil sand industry

Conclusions
Conclusions

Pipeline properties: Capacity 5,000 m³/hr @ 50 bar pressure

Centrifugal pumps:
- 20 pumps in 2 x 5 + 5 configuration required

Piston diaphragm pumps:
- 6 pumps in 5 + 1 configuration required

Payback time of piston diaphragm pumps when compared to centrifugal pumps:
- 1.6 to 0.6 years

Centrifugal pumps are prone to settling of solids and plugging of pipeline
Risk of plugging is minimal with PD pumps