The history and Development of Dense Medium Cyclones
David Woodruff
• 1.0 Development Dutch State Mines 1940 - 1960
• 2.0 Alternative Centrifugal Separation Technologies
• 3.0 The Demise of DSM and development of the Modern Dense Medium Cyclone
• 4.0 Large Diameter DMC’s Advantages and disadvantages
• 5.0 Conclusions
There have been many advances in Coal Preparation since the end of WW2. We have seen the introduction of computers, instrumentation, development of Synthetic Reagents for Flocculation and Flotation, and a massive scaling up of unit equipment, and plant capacities.

However, the Dense Medium Cyclone which was invented over 75 years ago, remains the last step change in Coal Preparation Technology.
The DSM Process 1938 with Shale Medium
# DSM Cyclone Capacity Chart for Coal

<table>
<thead>
<tr>
<th>Diameter of the cyclone</th>
<th>Pulp capacity (medium + product) in m³/h</th>
<th>Feed head H in m liquid for the given capacities</th>
<th>Max. product feed in m³/h</th>
<th>Max. underflow product in m³/h (solids)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>inches</td>
<td>H = 9 x D</td>
<td>H = 9 x D</td>
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<tr>
<td>200</td>
<td>8&quot;</td>
<td>16</td>
<td>1.8</td>
<td>5</td>
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<tr>
<td>350</td>
<td>14&quot;</td>
<td>56</td>
<td>3.15</td>
<td>15</td>
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<tr>
<td>400</td>
<td>16&quot;</td>
<td>77</td>
<td>3.6</td>
<td>23</td>
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<tr>
<td>500</td>
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<td>125</td>
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<td>560</td>
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<td>155</td>
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<tr>
<td>600</td>
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<td>190</td>
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<tr>
<td>660</td>
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<td>225</td>
<td>5.95</td>
<td>65</td>
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<tr>
<td>700</td>
<td>28&quot;</td>
<td>265</td>
<td>6.3</td>
<td>77</td>
</tr>
<tr>
<td>750</td>
<td>29½&quot;</td>
<td>300</td>
<td>6.75</td>
<td>87</td>
</tr>
<tr>
<td>Dimensions in mm</td>
<td>Dimensions in inches</td>
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<tr>
<td>200-40-85-60 Ø-20°-120</td>
<td>8&quot; - 1(\frac{9}{16})&quot; - 3(\frac{5}{16})&quot; - 2(\frac{5}{16})&quot; Ø - 20° - 4(\frac{3}{4})&quot;</td>
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<tr>
<td>350-70-150-100 Ø-20°-230</td>
<td>14&quot; - 2(\frac{3}{4})&quot; - 6&quot; - 4&quot; Ø - 20° - 9(\frac{1}{16})&quot;</td>
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<tr>
<td>400-80-170-130 Ø-20°-250</td>
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<td>500-100-215-150 Ø-20°-295</td>
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<tr>
<td>560-110-235-160 Ø-20°-330</td>
<td>22&quot; - 4(\frac{5}{16})&quot; - 9(\frac{1}{16})&quot; - 6(\frac{5}{16})&quot; Ø - 20° - 13&quot;</td>
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<tr>
<td>600-120-260-180 Ø-20°-355</td>
<td>24&quot; - 4(\frac{3}{4})&quot; - 10(\frac{1}{4})&quot; - 7(\frac{1}{4})&quot; Ø - 20° - 14&quot;</td>
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<td>660-130-280-190 Ø-20°-385</td>
<td>26&quot; - 5(\frac{1}{8})&quot; - 11&quot; - 7(\frac{1}{2}&quot; - 15(\frac{3}{16})&quot;</td>
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<td>700-140-300-210 Ø-20°-395</td>
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<tr>
<td>750-150-320-250 Ø-20°-440</td>
<td>29(\frac{1}{2}&quot; - 5(\frac{7}{8}&quot; - 12(\frac{5}{8}&quot; - 9(\frac{13}{16}&quot; Ø - 20° - 17(\frac{5}{16})&quot;</td>
<td></td>
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</tbody>
</table>
• Feed Inlet: Tangential
• Cone Angle: 20 Degrees
• Feed Entry: 0.2 x Cyclone Diameter, (D)
• Vortex Finder Diameter: 0.4 x D
• Underflow Orifice: 0.3 x D
• Cyclone Feed Head 9 x D in Metres Head
• Maximum Feed Particle Size 1/3 x Feed Opening
• Raw Solids to Medium Volumetric Ratio: 1:2.8
Original DSM Cyclone Flowsheet 1945
First UK installation Nine Mile Point Colliery 1955
• Dense Medium Drums and Cyclones used
• For Cyclones Feed Head 15 – 25 x Cyclone Diameter. S.G. of Separation 2.0 – 4.0
• Pump Feed to Cyclones very high wear rates
• Mixtures of Ferrosilicon and Magnetite required to achieve higher S.G’s of Separation.
• DSM Monopoly of Centrifugal Separation was not liked by the market
• Royalty payments to DSM charged through it’s licensees were unpopular
• 700 Dutch Guilders per TPH Feed to the Cyclone
• By 1960’s new Centrifugal Technologies under development to circumvent patents
• Dyna-whirlpool, (American Zinc Co, USA), Vorsyl, (NCB, UK), Swirl Cyclone, (Tagawa), Japan
Fig 8 – The Dynawhirlpool
Gravity Feed Arrangement Dynawhirlpool Versus DSM Cyclone
The Vorsyl Separator
Swirl Cyclone
From the late 1950’s most of the Dutch State Coal Mines began to close

DSM was refocusing on Chemicals

The DSM Cyclone Technology was moved to the DSM licensing arm Stamicarbon BV

In 1970 all the Patents expired

Several New Cyclone manufacturers entered the market

Revenues from license fees declined

Stamicarbon Minerals division was closed in 1992
• Coincided with the rise of the new Coal industries in RSA and Australia.

• DSM could no longer hold back development of larger diameter, higher capacity DMC’s

• The newer cyclones with features developed from grinding circuit Hydro-Cyclones, began their entry to the market
• Involute Feed entry, allowing much higher Coal to Medium solids Volumetric Throughput

• Much larger Vortex finder diameter

• Flexible Geometry, tailored to Raw Coal Washability Characteristics

• Sophisticated Lining systems offering very long life

• Larger Diameters offer vastly increased capacities per unit.
Cyclone Geometry and other Parameter Comparison

**DSM**
- Feed entry 0.2 x Cyclone Diameter
- Tangential feed entry
- Underflow opening 0.3 x Cyclone Diameter
- Vortex Finder 0.4 x Cyclone Diameter
- Raw Coal Solids to Medium ratio 1:2.8

**Modern DMC**
- Feed Entry 0.4 x Cyclone Diameter
- Involute Feed entry
- Underflow opening 0.3 x Cyclone Diameter
- Vortex Finder 0.6 x Cyclone Diameter
- Raw Coal Solids to Medium ratio 1:3 – 1:6
The influence of Cyclone diameter on Centrifugal acceleration and fine particle (-3mm) Epm
Original “Centre Tube” DMC Pump Feed System (DSM 1945)

Modern “Wing Tank” DMC Pump Feed System (DSM 1950)
### KREBS Heavy Media Cyclones - Typical Operating Parameters (Metric Units)

<table>
<thead>
<tr>
<th>Krebs Model Designation</th>
<th>Feed Particle Maximum Size</th>
<th>Dry Feed Capacity* (mtph)</th>
<th>Pulp Flowrate Range (m³/h)</th>
<th>Head Equivalent (meters)</th>
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<tbody>
<tr>
<td>D20LSB</td>
<td>19mm</td>
<td>77</td>
<td>238</td>
<td>4.6</td>
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<tr>
<td>D26B</td>
<td>38mm</td>
<td>136</td>
<td>434</td>
<td>6.1</td>
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<tr>
<td>CoalMAX26</td>
<td>38mm</td>
<td>145</td>
<td>464</td>
<td>6.1</td>
</tr>
<tr>
<td>D263B</td>
<td>38mm</td>
<td>150</td>
<td>469</td>
<td>6.0</td>
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<tr>
<td>D30B</td>
<td>51mm</td>
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<td>643</td>
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<td>D33T154</td>
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<td>264</td>
<td>829</td>
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<td>D33T214</td>
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<td>D40B</td>
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<tr>
<td>D44B-A</td>
<td>76mm</td>
<td>432</td>
<td>1348</td>
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<tr>
<td>D44B-U</td>
<td>76mm</td>
<td>527</td>
<td>1653</td>
<td>10.1</td>
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<tr>
<td>D48B</td>
<td>89mm</td>
<td>659</td>
<td>2066</td>
<td>11.0</td>
</tr>
<tr>
<td>D55B</td>
<td>102mm</td>
<td>895</td>
<td>2792</td>
<td>12.6</td>
</tr>
</tbody>
</table>

* Based on a 4:1 media-to-coal ratio

* These capacities represent maximums for units fitted with the largest inlet and vortex finder
4.0) Large Diameter DMC’s Advantages and disadvantages
Versus the original smaller diameter DSM Cyclone

**Advantages**
- No distributors
- Reduced number of moving parts
- Increased top size of Feed ~70 mm
- Bottom size feed 1.0 mm, easier de-sliming, and reduced medium consumption

**Disadvantages**
- Reduced efficiency on minus 3 mm fraction
- Massive increase in medium circulation capacity
- Reduced efficiency in 1mm x 0.5mm fraction
**DSM**
- 750mm Diameter
- Max Feed Solids: 139 TPH*
- Pulp Capacity: 300M3/Hr
- Sinks Capacity: 59 TPH^(~40%)

* Mean S.G. = 1.6

**Modern Cyclone**
- 750mm Diameter
- Max Feed Solids: 205 TPH*
- Pulp Capacity: 643M3/Hr
- Sinks Capacity: 59 TPH , (~30%)

^ Mean S.G = 1.9
• The Dense Medium Cyclone is now the world's most commonly used Coal Preparation Separation Process
• DMC’s are also being increasingly being used on Mineral Applications
• Large Diameter High Capacity Units are now the Norm
• There is renewed interest in Fine Coal Dense Medium Separation to produce high value products.
• Charles Corbidge Colliery Engineering/Head Wrightson / Davy
• Wilfred Gordon Wade Colliery Engineering/Head Wrightson / Davy
• Herbert Driessen DSM / Stamicarbon BV
• Josef Mengelers DSM / Stamicarbon BV
• Albert Basten DSM / Stamicarbon BV