Modern Steam Plant

Hugh Kennedy
06/11/2012
<table>
<thead>
<tr>
<th>Agenda</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Boiler Features</td>
<td>2</td>
</tr>
<tr>
<td>Steam Turbine Features</td>
<td>16</td>
</tr>
<tr>
<td>Challenges and Trends</td>
<td>20</td>
</tr>
<tr>
<td>Potential Solutions for South Africa</td>
<td>30</td>
</tr>
<tr>
<td>Conclusions</td>
<td>35</td>
</tr>
</tbody>
</table>
Boiler Product Types
Current Portfolio

**Tower**
- Minimum footprint
- Drainable heating surface
- Lower ash carry over
- Minimized erosion potential
- Ease of maintenance

**Two Pass**
- Minimum height
- Pendant surface
  - Simple support/sealing
  - Fewer uncooled attachments
- Optimised backpass heating surfaces
- Spiral or vertical furnace wall

**CFB**
- Broad fuel flexibility
- Simple fuel preparation
- Inherent emission control
  - Low NO\(_x\) / SO\(_2\) from furnace
  - Simple equipment for additional reduction

Proven solutions for all fuels
Alstom fuel expertise

Specialist experience

- Fiddlers’ Ferry*
- Drax*
- Patnow II
- Maritza East
- Belchatow II
- Neurath F/G

World Class Products

- Waigaoqiao II and III
- RDK 8
- Westfalen D/E
- Comanche 3
- Pee Dee

- Shoaiba
- Chalk Point 3
- Ravenswood 3
- Pittsburgh 7
- LaSpezia 4

Specialist experience

- Tamuin
- Mailiao
- Tonghae, Luohuang

- *Biomass Co-firing

Expertise & world class products for a broad fuel spectrum

- Biomass
- Lignite
- Bituminous
- Sub-bituminous
- Oil*
- Anthracite
- Petcoke

- Pulverized Coal
- Circulating Fluidized Bed

*Oil-fired boiler
Boiler Key Features
Tower & Two Pass

Tangential firing system
- Excellent fuel/air mixing for tolerance to fuel variation
- Low slagging tendency:
  - Reduced cleaning
  - Maximised efficiency

Tilting burners
- Reheat steam temperature control without spray attemperation
- High efficiency over full load range

Spiral or Vertical walls
- Optimum solution for every fuel

Thermal & operational flexibility with improved performance
SPSC Boiler Arrangement

Two types of arrangements are offered for once-through technology

Two Pass, Pendant Arrangement

88m (288 ft)

Tower Boiler Arrangement

+ 114.5m (376 ft.)
## Technology Selection Criteria

<table>
<thead>
<tr>
<th>Tower</th>
<th>2-Pass</th>
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<tbody>
<tr>
<td></td>
<td>Cost</td>
</tr>
<tr>
<td></td>
<td>Performance</td>
</tr>
<tr>
<td></td>
<td>Operability</td>
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<tr>
<td></td>
<td>Footprint</td>
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<tr>
<td></td>
<td>Height</td>
</tr>
<tr>
<td></td>
<td>Drainability</td>
</tr>
<tr>
<td></td>
<td>Economizer Upflow*</td>
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<tr>
<td></td>
<td>Erosion Potential</td>
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<td></td>
<td>Pressure Part Attachments</td>
</tr>
<tr>
<td></td>
<td>Maintainability</td>
</tr>
</tbody>
</table>

*Generally only applicable to lignite firing*
Furnace Wall Designs

Spiral Wall Configuration

Vertical Wall Configuration
Spiral tube furnace walls

Spiral to Vertical Transition Area - Load Transfer

Support Fingers

SPIRAL WALL SUPPORT
Vertical tube furnace walls

- LSW
- FW
- RSW
- RW

Burner zone

Distribution orifices

Ring header

Heat flux

115
100
75

1 1/4" (31.8 mm) O.D. Tubing

1 1/8" (28.5 mm) O.D. Tubing

POWER SYSTEMS | ALSTOM
Vertical tube furnace walls

- Heat flux varies across furnace walls
- Orifices match fluid flow to heat flux
- Proper tube metal temperatures maintained

Orifices ensure adequate cooling by matching flow to heat flux
Circulating Fluidized Bed Boilers

**Dual Grate**
- 350 MWe subcritical
- Scalable up to 600MWe ultra-supercritical

**Single Grate**
- Single cyclone
  - 100 MWe
  - Non-reheat
- Dual-cyclone
  - 135 – 150 MWe
  - Reheat
- Tri-cyclone
  - Up to 350 MWe
  - Reheat

Leading CFB technology for outstanding fuel flexibility
CFB Boilers
Narva, Estonia

2 x 300 MW CFB Turnkey Plant

Customer
• Narva Elektrijaamad AS (subsidiary of Eesti Energia)

Product
• 2 x 300 MW CFB for local oil shale & biomass

Scope
• Full turnkey steam power plant

Benefits
• Burning local oil shale containing 46% ash and 12% moisture
• Co-firing of retort gas up to 10%
• Biomass co-firing up to 50%

Fuel Flexibility and Low Emissions
CFB Boilers
Emile Huchet, France

1 x 125 MW CFB Turnkey Plant

Customer:
• SODELIF, France

Fuel:
• Coal washing waste
• Ultra fine product: d50% =150 microns, d99% < 2 mm
• Slurry:
  30% ash content,
  33% moisture,
  LHV, Kcal/Kg 2500
• Schlamms:
  8% moisture,
  LHV 5000 Kcal/kg

Steam Conditions:
• 367 t/h; 155 bar/545°C/540°C

Emission levels (mg/Nm³ @ 6%O₂ DG):
• SO₂: 330
• NOₓ: 300
### CFB boilers
Seward, USA

- **Emission levels**
  - **SO₂**
    - mg/Nm³ @ 6 % O₂: 780
    - or sulphur removal: 95%
  - **NOₓ**
    - mg/Nm³ @ 6 % O₂: 130
  - **Particulates**
    - mg/Nm³ @ 6 % O₂: 40

- **Energy levels**
  - **Heating Value**
    - MJ/kg: 12.8 (11.6-14)
    - Kcal/kg: 3050

---

### 2 x 260 MW CFB Turnkey Plant

**Customer:**
- Reliant Resources, USA

**Commissioned:**
- 2004

**Steam Conditions:**
- 2 x 872 t/h
- 174 bar/541°C/541°C

**Fuel**
- 2 million tonnes waste coal on site
- 100 million more within 80 km

<table>
<thead>
<tr>
<th></th>
<th>% wt</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>29.32 (25-35)</td>
<td></td>
</tr>
<tr>
<td>Volatile matter</td>
<td>11 (9-30)</td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>2.75 (2 – 4.25)</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>51 (25-58)</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>8.7 (7 – 12)</td>
<td></td>
</tr>
<tr>
<td>Heating Value</td>
<td>12.8 (11.6-14)</td>
<td></td>
</tr>
<tr>
<td>Kcal/kg</td>
<td>3050</td>
<td></td>
</tr>
</tbody>
</table>

**Emission levels**
- **SO₂**
  - mg/Nm³ @ 6 % O₂: 780
  - or sulphur removal: 95%
- **NOₓ**
  - mg/Nm³ @ 6 % O₂: 130
- **Particulates**
  - mg/Nm³ @ 6 % O₂: 40

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Clean and efficient disposal of coal residue

Modern Steam Plant - H Kennedy - 05/11/2012  - P 15

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Welded Rotor Design
Superior design – in use since 1930

- Optimal material selection
- Lower stress levels enable faster start-up and load cycling
- Small forgings easier and faster to obtain on the market

Best fit to (ultra-)supercritical conditions
Shrink ring design

- Thin-walled rotationally symmetric inner casing with unique shrink ring design
- Double shell design with thin-walled outer casing and small flange
- Eliminates casing distortions, maintains clearances & efficiency
- Enables faster start-ups and load cycling
- Ensures long-term reliability and operational flexibility
- Proven since 1960

**Best thermal flexibility and sustained efficiency**
Alstom Steam Turbines
Lateral Exhaust for ACC

Savings in civil engineering and exhaust ducts to the ACC

Crane height: 14.5 m
Shaft center line: 8 m
Floor level: 7 m
Exhaust center line: 6 m
Agenda

Steam Boiler Features | Page 2
Steam Turbine Features | Page 16
Challenges and Trends | Page 20
Potential Solutions for South Africa | Page 30
Conclusions | Page 35
Challenges for Today's Steam Plants

- Emissions
- Efficiency
- Flexibility
- Water Impact
The need for high efficiency

Efficiency increase key to reduced fuel burn and emissions
Overview of Steam Cycle Developments

<table>
<thead>
<tr>
<th>Year</th>
<th>Subcritical</th>
<th>Supercritical</th>
<th>Ultrasupercritical (USC)</th>
<th>Advanced USC (AUSC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>270/580/600</td>
<td>280/600/620</td>
<td>Medupi Kusile</td>
<td>R&amp;D Europe: AD700 project COMTES 700 NRW PP 700 (Ni-base)</td>
</tr>
<tr>
<td>2020</td>
<td>350/730/760</td>
<td>350/730/760</td>
<td>Advanced USC (AUSC)</td>
<td></td>
</tr>
</tbody>
</table>

* Based on LHV and open cycle cooling at 13°C

Net efficiency: 50%

Steam Conditions (bar/LS°C/RHS°C): Subcritical, Supercritical, Ultrasupercritical (USC), Advanced USC (AUSC)
Ultra-Supercritical plant
RDK8, Germany 912 MW

Customer
• EnBW Kraftwerke AG

Product
• 1 x 912 MW coal-fired Ultra-supercritical power plant
• 275bar/600°C/620°C

Scope
• Turnkey Power Block, including Plant Engineering, Procurement, Erection and Commissioning

Benefits
• Overall net plant efficiency of >46% (>58% with district heating)
• Considerable reduction in emissions:
  • CO₂ < 740 g/kWh
  • CO & NOₓ < 100 mg/Nm³

One of the most efficient steam power plants in the world
Water Consumption

- Dry cooling saves ~30 000 m³/day/unit
- Regulations require desulphurisation
- FGD consumption (Kusile ~ 6 600 m³/day/unit)
- Two mitigation solutions

- Semi-dry FGD
  - 45% less water

- Circulating Fluidised Bed (CFB) combustion
  - No water for desulphurisation
  - No coal washing
Economies of Scale drive selection of larger unit sizes

- EPRI estimates a 0.7 economy of scale (EOS) factor for coal units
- The curve is not linear, but will have step changes – based on unique size ranges of major equipment

Example: For an EOS factor of 0.7, compared with a 800MW unit, a 1000MW unit would cost approximately:

Larger units bring capital and operating cost benefits
Unit Size
e.g. Manjung 4, Malaysia

1080 MW USC Plant

Customer
- Tenaga Nasional Bhd (TNB)

Product
- 1x 1080 MWe Supercritical coal-fired power plant

Scope
- Turnkey EPC contract with China Machinery Import & Export Corporation consortium partner

Benefits
- Additional capacity to meet strong demand in fast-growing economy
- Reduced coal consumption and CO₂ emissions
- Large size reduces specific capital and operating costs

South East Asia’s largest and most efficient unit
Unit Size

e.g. Neurath F&G, Germany

2x 1100 MW USC Lignite Plant

Customer
- RWE Power AG

Product
- 2 x 1100 MW lignite-fired Ultra-Supercritical power plant (260bar/595°C/604°C)

Scope
- Plant Engineering
- Turnkey steam turbine islands
  - 49” last stage blades
- Lignite boilers in consortium
  - 170m high

Benefits
- Large size reduces specific capital and operating costs
- A proven technology for clean, efficient lignite-based power production
- Advanced technology resulting in high efficiency and reduced CO₂ emissions

World’s largest lignite-fired power plant
**Dynamic response**

- Load jump capability 0.5 Hz frequency dip
  - Primary Frequency Response:
    - + 10% of MCR in 10s sustained for 20s
  - Secondary Frequency response
    - + 10% of MCR in 30s sustained for 30 min

- Load jump capability restored 20 min after initial load jump

- Load profile for 0.5 Hz frequency drop
  - 10% load jump: 65% to 80% load
  - Reducing to 2.5% at 95% load

- No efficiency penalty

**Patented solutions to support renewable integration**
Agenda

Steam Boiler Features Page 2

Steam Turbine Features Page 16

Challenges and Trends Page 20

Potential Solutions for South Africa Page 30

Conclusions Page 35
Power Block Optimisation

• Target: Maximum Net Present Value (NPV), balanced between:
  - Performance
  - Investment
  - Availability & Reliability
  - Construction, Operation & Maintenance
  - References
  - Flexibility
  - Land and water use

• Key areas to be studied:
  - Steam Parameters,
  - Unit size (MW),
  - Components & Systems selection,
  - Plant/turbine hall layout.
USC with ACC
Improvements on Medupi/Kusile

Medupi 241bar abs, 560/570°C → 275bar abs, 600/620°C

Superheater

Reheater

Pressure drop optimisation

HARP

No Throttling

Retain 2 x LPs

Feedwater 268°C -> 305°C

Top de superheater

2 → 3 HP heaters

Boiler Feed Water Pump

Hydraulic → VFD

Separator

Membrane wall

Economiser HP8 HF7 HP6

2 → 3 HP heaters

Feed Water Tank

3 → 4 LP heaters

USC adapted expansion line

Condensate Polishing Plant

Condensate Extraction Pump

Air Flow

Air Cooled Condenser

LP Bypass

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**Potential cycle improvements**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Medupi</th>
<th>USC Based on RDK8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Unit Output (TMCR)</td>
<td>794 MW</td>
<td>900 MW</td>
</tr>
<tr>
<td>Net Unit Output</td>
<td>723 MW</td>
<td>819 MW</td>
</tr>
<tr>
<td>Main Steam Pressure (Turbine Inlet)</td>
<td>241 bar abs</td>
<td>275 bar abs</td>
</tr>
<tr>
<td>Main Steam Temperature (Turbine Inlet)</td>
<td>560°C</td>
<td>600°C</td>
</tr>
<tr>
<td>Re-heat Steam Pressure (Turbine Inlet)</td>
<td>50.5 Bar abs</td>
<td>60.5 bar abs</td>
</tr>
<tr>
<td>Re-heat Steam Temperature (Turbine Inlet)</td>
<td>570°C</td>
<td>620°C</td>
</tr>
<tr>
<td>Final Feedwater temperature</td>
<td>268°C</td>
<td>305°C</td>
</tr>
<tr>
<td>Main Steam Flow at ST Inlet at TMCR</td>
<td>617 kg/s</td>
<td>693 kg/s</td>
</tr>
<tr>
<td>Condenser exhaust pressure</td>
<td>141 mbar</td>
<td>141 mbar</td>
</tr>
<tr>
<td>Estimated steam plant efficiency</td>
<td>40.13%</td>
<td>42.54%</td>
</tr>
</tbody>
</table>

+2.41%pts efficiency gain with optimised USC
USC Improvement Potential

- Applying the latest proven technology to South African conditions

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Medupi/Kusile</th>
<th>USC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated CO₂ emissions (tonnes/year)</td>
<td>29.1 million</td>
<td>27.5 million (-5.9%)</td>
</tr>
<tr>
<td>Estimated Coal Consumption (tonnes/year)</td>
<td>15.7 million</td>
<td>14.8 million (-5.9%)</td>
</tr>
</tbody>
</table>

- Units > 1 000 MW are feasible, based on similar and proven components

- Reduction in specific cost (R/kW):
  - 900 MW ~ -4.3%
  - 1000 MW ~ -7.7%

Significant gains from applying current technology
<table>
<thead>
<tr>
<th>Agenda</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Boiler Features</td>
<td>Page 2</td>
</tr>
<tr>
<td>Steam Turbine Features</td>
<td>Page 16</td>
</tr>
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<td>Page 30</td>
</tr>
<tr>
<td>Conclusions</td>
<td>Page 35</td>
</tr>
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Conclusions

• Steam plant remains the most important source of power generation globally (and in SA)

• Therefore, it must be:
  • Efficient
  • Economical
  • Flexible
  • Clean
  • Water friendly

• Alstom provides the full range of solutions to meet these demands