Falling-Film Evaporator Plant for a Cane Sugar Factory
Concept and Operating Results

Brahim, F.1, Lehnberger, A.1, Mallikarjun, S. S.2

1 BMA, Germany
2 Indian Cane Power Ltd., India

Without verbal explanation the information on this document is incomplete.
Falling-Film Evaporator Plant for a Cane Sugar Factory: Concept and Operating Results

- Introduction
- New FFE evaporation plant (2012)
- Operating figures (season 2012/13)
- Scaling / Cleaning
- New Configuration of FFE evaporation plant (2013)
- Operating figures (season 2013/14)
- Summary
- New FFE project in Pakistan – JDW Unit III (GSM)
Introduction

- Cane sugar factory Indian Cane Power Ltd. (ICPL) / India feeds electrical power to local grid with considerable economic benefits

- Objective: to increase of power yield by minimising specific steam consumption

- ICPL is attempting to increase their co-generation proceeds by employing new technologies in sugar production and gaining surplus electricity from bagasse.
New FFE evaporation plant (Season 2012/13)

- **ICPL’s original proven concept:**
  - evaporation plant with Robert and falling film evaporators
  - continuously operating vacuum pans for B- and C-product

- **New 5-effect falling film evaporation plant: Capacity improvement**
  - designed for 7,000 TCD
  - FFE1 – 4000 m²
  - FFE2 – 4000 m²
  - FFE3 – 4000 m²
  - FFE4 – 1000 m²
  - FFE5 – 1000 m²
  - additional equipments like pumps, tanks, heat exchangers

- **3rd (and 2nd) vapour used for crystallisation**
OPERATING FIGURES OF ICPL (SEASON 2012/13)
Operating figures (Season 2012/13)

**Typical operating conditions:**
- Crushing rate 7,000 tcd
- Juice Brix from 15 % to 65 %
- Temperature vapour 1: 116 °C
- Temperature vapour 5: 75 °C
- Steam requirement: 33 % o. c. at 2.1 bar abs.
Operating figures (Season 2012/13)

Daily crushing capacity from start of campaign

Design daily crushing capacity = 7,000 TCD
Operating figures (Season 2012/13)

- **Daily crushing capacity from start of campaign and specific steam consumption**

![Graph showing daily crushing capacity and steam consumption](image)

- **Design daily crushing capacity = 7,000 TCD**
- **Design steam consumption = 33 %o.c.**

Passion for Progress
Operating figures (Season 2012/13)

**Begin of operation**

- crushing capacity 10% over design capacity
- specific steam consumption 10% less than design figure
- heating surfaces are clean

**After 18 days of operation**

- crushing capacity remains slightly below design capacity
- specific steam consumption raises above design figure
- heating surface became scaled

**Cleaning of evaporator plant after 21 days**
Scaling

- Scaling takes place during operation of the evaporation plant.
- Scale hampers heat flow by solid layer with low heat conductivity.
- At constant evaporation rate, the temperature gradient rises due to scale formation on heating surfaces.
- Specific temperature gradient is a good measure for scale development.

After 21 days, the specific temperature gradient becomes twice than the beginning of operation.
## Analysis of scales from heating tubes (Feb 2012)

<table>
<thead>
<tr>
<th>Effect</th>
<th>FFE 1</th>
<th>FFE 2</th>
<th>FFE 3</th>
<th>FFE 4</th>
<th>FFE 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>2.8 %</td>
<td>3.1 %</td>
<td>&lt; 0.1 %</td>
<td>1.5 %</td>
<td>2.9 %</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>42.8 %</td>
<td>6.6 %</td>
<td>3.5 %</td>
<td>3.0 %</td>
<td>1.4 %</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>11.2 %</td>
<td>19.7 %</td>
<td>32.3 %</td>
<td>31.8 %</td>
<td>27.5 %</td>
</tr>
<tr>
<td>Calcium sulphite</td>
<td>0.1 %</td>
<td>14.4 %</td>
<td>&lt; 0.1 %</td>
<td>1.8 %</td>
<td>&lt; 0.1 %</td>
</tr>
<tr>
<td>Silicate</td>
<td>0.4 %</td>
<td>9.3 %</td>
<td>21.1 %</td>
<td>34.9 %</td>
<td>31.8 %</td>
</tr>
</tbody>
</table>

Scale samples

Scale structure

- Soft, thin layer. Can easily be scraped off.
- Soft, thin layer. Can easily be scraped off.
- Hard, thick layer. Difficult to remove mechanically.
- Very hard, thin layer. Very difficult to remove mechanically.
- Very hard and compact, thick layer. Very difficult to remove mechanically.
Scaling

Composition is typical of evaporators in the cane sugar industry

<table>
<thead>
<tr>
<th>Effect</th>
<th>FFE 1</th>
<th>FFE 2</th>
<th>FFE 3</th>
<th>FFE 4</th>
<th>FFE 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>2.8 %</td>
<td>3.1 %</td>
<td>&lt; 0.1 %</td>
<td>1.5 %</td>
<td>2.9 %</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>42.8 %</td>
<td>6.6 %</td>
<td>3.5 %</td>
<td>3.0 %</td>
<td>1.4 %</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>11.2 %</td>
<td>19.7 %</td>
<td>32.3 %</td>
<td>31.8 %</td>
<td>27.5 %</td>
</tr>
<tr>
<td>Calcium sulphite</td>
<td>0.1 %</td>
<td>14.4 %</td>
<td>&lt; 0.1 %</td>
<td>1.8 %</td>
<td>&lt; 0.1 %</td>
</tr>
<tr>
<td>Silicate</td>
<td>0.4 %</td>
<td>9.3 %</td>
<td>21.1 %</td>
<td>34.9 %</td>
<td>31.8 %</td>
</tr>
</tbody>
</table>

Juice purification: phospho-defecation with clear juice sulfitation
- High calcium phosphate content in first effects: soft scale
- High calcium sulfite content in the second effect
- High calcium sulfate content in last effects: hard scale
- High content of silicate in last effects: very hard scale
Cleaning

- **Standard chemical cleaning at ICPL after 21 days of operation**
  - Alkaline cleaning (10 % caustic soda + sodium carbonate) at 100 °C for 8 h
  - Acid cleaning (6 % formic acid) at 95 °C for 8 h

- **Result**
  - FFE1: very good cleaning, clean heating surfaces
  - FFE2: very good cleaning, clean heating surfaces
  - FFE3: good cleaning, heating surfaces largely clean
  - FFE4: poor cleaning, heating tubes still covered
  - FFE5: poor cleaning, heating tubes still covered

- **Measures**
  - FFE1, FFE2, FFE3: chemical cleaning after 30 days
  - FFE4, FFE5: alternating chemical cleaning and high pressure water cleaning with shorter operating time
<table>
<thead>
<tr>
<th>Effect</th>
<th>Before cleaning</th>
<th>After cleaning</th>
<th>Cleaning effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFE 1</td>
<td></td>
<td><img src="https://example.com/image1.png" alt="Image" /></td>
<td>Very good. Heating tubes are clean.</td>
</tr>
<tr>
<td>FFE 2</td>
<td></td>
<td><img src="https://example.com/image2.png" alt="Image" /></td>
<td>Very good. Heating tubes are clean.</td>
</tr>
<tr>
<td>FFE 3</td>
<td></td>
<td><img src="https://example.com/image3.png" alt="Image" /></td>
<td>Good. Heating tubes are largely clean.</td>
</tr>
</tbody>
</table>
# Cleaning

<table>
<thead>
<tr>
<th>Effect</th>
<th>Before cleaning</th>
<th>After cleaning</th>
<th>Cleaning effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFE 4</td>
<td><img src="image1" alt="Before" /></td>
<td><img src="image2" alt="After" /></td>
<td>Poor. Heating tubes still covered with considerable encrustations.</td>
</tr>
<tr>
<td>FFE 5</td>
<td><img src="image3" alt="Before" /></td>
<td><img src="image4" alt="After" /></td>
<td>Poor. Heating tubes still covered with considerable encrustations.</td>
</tr>
</tbody>
</table>
OPERATING FIGURES OF ICPL
(SEASON 2012/13)
New Configuration Season 2013/14

- **Two new BMA falling film evaporators were added before season 2013/14**
  - 2 x 4000 m²

- **Updated 5-effect falling film evaporation plant**
  - FFE1 – 4000 m²
  - FFE2 – 4000 m²
  - FFE3 – 4000 m²
  - **FFE4 – 4000 m²**
  - FFE5 – 1000 m²

  - Spare bodies for cleaning
    - 1x 4000 m²: FFE3 and FFE4
    - 1x 1000 m²: FFE5 (former FFE4)
Operating figures (Season 2013/14)

Season 2013/14

- Cane crushing (average without stoppages) 9200 tcd
Operating figures (Season 2013/14)

- **Season 2013/14**

  - Cane crushing (average without stoppages) **9200 tcd**
  - Steam consumption (average without stoppages) **28.1 % o.c.**
    - (with clean heating surfaces of evaporators down to **27 % o.c.**)

![Graph showing the trend of cane crushed and steam consumption over months from December 2013 to April 2014. The graph indicates a fluctuating pattern in cane crushing but a relatively stable steam consumption. The data is available in the PDF provided by BMA.]
Operating figures (Season 2013/14)

**Season 2013/14**
- Cane crushing (average without stoppages) 9200 tcd
- Steam consumption (average without stoppages) 28.1 % o.c.

**Cleaning of evaporators in season 2013/14**
- 1st and 2nd effect: up to 40 days of operation
- 3rd and 4th effect: up to 20 days of operation
- 5th effect: each 10 days of operation

**Comparison to the season 2012/13**
- Steam production remaining at average 104 t/h (maximum 110 t/h)
- Increased steam efficiency from 30 to 33 % o.c. to 28.1 % o.c.
- Increased crushing capacity by approx. 30 %
- Surplus bagasse is used for power production during off-season

*Is it only due to the installation of 2 new evaporators?*
Why this low steam % o.c.?

- **Not only the installation of two new falling film evaporators, additional measures for boiling sugar were realised**

- **A-pans with powerful agitators**
  - Excellent circulation
  - High heat transfer
  - Working with 3rd vapour and even with 4th vapour possible

- **Separate syrup concentrator on 4th vapour**

- **Non-condensables from pans are directed to condenser**
  - Full steam/vapour system is operating under vacuum
  - Heating of continuous pans became more stable
  - Less water addition to boiling
Summary

- **5-effect falling film evaporator plant with vapour 3 for A-product crystallization shows reliable operation with 30to33\%o.c. steam demand** and helps maximising electric power generation.

- **Scale forms during several weeks of operating period between cleaning and limits crushing capacity.**

- **Composition of scale varies from first effect (mostly calcium phosphate) to last effect (calcium sulphate and silicate).**

- **Cleaning effort is low in first, second and third effect: only by chemical cleaning; in both last effects chemical cleaning is supported by high pressure water cleaning.**
Summary

- **Installing 2 standby evaporators (one for 3rd/4th effect + one for 5th effect)** and sugar boiling with 4th, 3rd and 2nd vapour shows reliable operation with **28% o.c. steam demand** (seasons average without stoppages) and helps maximising electric power generation.

- **High heating surface in 4th effect** is a mandatory to bleed a respectable quantity of vapour for sugar boiling.

- **Equipment of sugar boiling must be able to work at low heating temperatures**
  - Powerful agitator reduce necessary temperature difference
  - Tight steam and vapour system to work at vacuum (low quantity of non-condensable gases, NCGs conducted to condenser)
  - Increased syrup brix for feed to A-boiling (syrup concentrator)

- **Low 1st vapour temperature** reduces heating requirement for clear juice.
NEW FFE PROJECT IN PAKISTAN
JDW UNIT III (GSM)
Current situation: 11,800 TCD

- **Steam consumption for process** = 48,9 %c. (240 t/h)
- **Total steam production** = 49,4 %c. (243 t/h)
- **Electrical power production** = 13,4 MW (7,9 MW for own consumption + 5,5 MW for WAPDA Export)
- **Bagasse surplus** = 4,6 %c. = 22,8 t/h
- **Condenser losses** = 0,5 %c. = 2,3 t/h
Future situation: 13,000 TCD

- **Change in evaporation station**
  - Installing 2 new FFE’s (5,000 m² each) as new 1st effect
  - The current 1st effect will act as 2nd effect
  - The current 2nd effect will act as 3rd effect
  - The current 3rd effect will act as 4th effect

- **Heating A-CVP with VP 3 instead of VP 2**

- **Installation of new heaters to improve vapour bleeding**
Future situation: 13,000 TCD

New heating surface distribution in the evaporation station
(Red heating surfaces are standby)

- 1st effect: 5,000 m² + 5,000 m² + 3,500 m²
- 2nd effect: 3,500 m² + 3,000 m² + 2,500 m²
- 3rd effect: 2,500 m² + 2,100 m² + 1,800 m²
- 4th effect: 1,800 m² + 1,500 m²
- 5th effect: 900 m² + 900 m²
Future situation: 13,000 TCD

- Expected new results

- Total steam consumption = 41.9 %c. (227 t/h)

- Reduction of steam consumption of 7 %c.

- Electrical power production = 22.6 MW (8.7 MW for own consumption + 13.9 MW for WAPDA Export)
  (The electrical power production is calculated based on a specific steam consumption of the new turbines in the Cogeneration Plant of 5.5 kW.h/kg steam)

- Bagasse surplus = 8.7 %c. = 47 t/h

- Condenser losses = 0.12 %c. = 0.6 t/h
With special thanks to:

Mr. S.S. Mallikarjun and ICPL Staff – ICPL / India

Mr. Rana Nasim Ahmed and JDW Staff – JDW / Pakistan

Passion for Progress