Casing Solutions in High or Very High Temperature Geothermal Environment

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ArGeo – Kigali – October, 31st 2018
Geothermal Hotspots and Power Generation in East Africa

Geothermal Well Design
- Environment
- Economics

OCTG Solutions
- Material Selection
- Connection Selection
- Connection qualification and protocols – Standard framework

Recent projects around the world
Geothermal Hotspots and Power Generation in East Africa
Geothermal Hotspots

VALLOUREC has manufacturing facilities to serve every region.
Geothermal Power Generation is Growing

Geothermal power generation and cumulative capacity by region 2016 – 2022

<table>
<thead>
<tr>
<th>Region</th>
<th>2014 Installed Capacity (MW)</th>
<th>2020 Planned Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>7.3</td>
<td>1189</td>
</tr>
<tr>
<td>Djibouti</td>
<td>500</td>
<td>1189</td>
</tr>
<tr>
<td>Kenya</td>
<td>120</td>
<td>256</td>
</tr>
</tbody>
</table>

Growth rate % (CAGR)

- Africa: +8.6%
- Europe: +3.3%
- Lat Am: +12.2%
- APAC: +6.7%
- Africa: +8.6%
- APAC: +6.7%
- Europe: +3.3%
- Lat Am: +12.2%

Focus on East Africa

Global geothermal power capacity expected to be 17 GW by 2021 (+30% since 2016)
Main Challenges for Geothermal Applications

Geothermal Well Design involves finding the right balance between the reservoir environment & economics to optimize the Total Cost of Ownership.
Geothermal Well: Typical Well Design

Main Challenges for Tubulars’ Performance

- Temperature Cycles
- Local Erosion/Corrosion in the string
- Collapse Loads
- Corrosion (H2S, CO2, ...)

*If the upper blue part is a liner it will not be perforated*
OCTG Solutions
Material Selection
Material Selection Guide
Material Selection Guide

- **Derating Ratio** of pipe body mechanical strength

<table>
<thead>
<tr>
<th>Temperature derating</th>
<th>Yield strength</th>
<th>Ultimate Tensile strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>deg F</td>
<td>deg C</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>212</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>302</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>392</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>482</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Reduction coefficient</td>
<td>1 0.95 0.91 0.88 0.89</td>
<td>1 0.95 0.93 0.94 0.98</td>
</tr>
</tbody>
</table>

- **Extreme Mechanical Load** on tubulars (high external pressure loads for instance)
- **Gradient of Temperature** on different part of the string will generate Tension and Compression
- **High Compression** due to thermal expansion with cemented casings (Compressive Yielding)
- **Thermal Cycles**
Definitions: Connections Comparison

**API Buttress & 8-Round**
- No smooth ID
- No shoulder
- Thread seal/

**Semi-Premium Connection**
- Pin to pin connection (less jump in)
- Internal shoulder connection (increase of torque and compression)
- Quick run connection (3TPI instead of 5TPI)

**Premium Connection**
- Smooth ID
- Shoulder
- Improved thread profile
- Metal to Metal seal/

Buttress Thread

Internal Shoulder

J area
# Connection Definition

<table>
<thead>
<tr>
<th>Production string</th>
<th>API</th>
<th>Semi-Premium</th>
<th>Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealability</td>
<td>Liquid sealability limited pressure</td>
<td>Liquid fluid sealability with limited pressure</td>
<td>Gas tight metal to metal seal</td>
</tr>
<tr>
<td>Torque capacity</td>
<td>Low torque (triangle)</td>
<td>High torque for drilling with casing application</td>
<td>High torque capacity with scalability</td>
</tr>
<tr>
<td>Joint efficiency</td>
<td>Limited for compression</td>
<td>Higher than BTC in compression</td>
<td>100% joint efficiencies for T&amp;C design</td>
</tr>
<tr>
<td>Fluid flow capability</td>
<td>Have turbulence in J area</td>
<td>Some design can give better flow than BTC</td>
<td>Flush ID to prevent any turbulence</td>
</tr>
<tr>
<td>Connection design</td>
<td>Limited as per API 5CT</td>
<td>Some design has shoulder and some has pin to pin</td>
<td>Various design available: T&amp;C, better clearance (SC, semi flush, flush)</td>
</tr>
<tr>
<td>Design features</td>
<td>Buttress T&amp;C</td>
<td></td>
<td>Qualified per main standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Competitive solution</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fast make-up</td>
</tr>
</tbody>
</table>
OCTG Solutions
Connection Qualification and Protocols – Standard Framework
Geothermal Wells: Challenges and Protocols

• In case of **high temperature and flow rate**, more robust connections (semi-premium or premium) should be considered while designing a geothermal well.

• Need of **connection tightness** under Geothermal loads.

  Most basic connections cannot withstand such conditions.
# Geothermal Wells: Challenges and Protocols

**VALLOUREC SOLUTIONS:** A wide range of connections for every environment

- **Standard** connections
- **Semi-premium** connections
- **Premium** connections
  - As-strong-as the pipe connections with **100% PBYS in Compression Resistance**
  - Extensively tested in combined loads and under large **thermal cycles (up to 350°C/ 662F) / ISO 13679 CAL IV protocol**
  - Compliance with most stringent qualification guidelines: **TWCCEP**
  - Under development: **Fit-for-purpose geothermal testing protocol**

### ISO 13679:2002 testing protocols

<table>
<thead>
<tr>
<th>CAL</th>
<th># of samples</th>
<th>Pressure envelope</th>
<th>Internal Pressure</th>
<th>Series A IP / IP + T/C</th>
<th>Series B IP + T/C, bending</th>
<th>Series C Thermal Cycles IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3</td>
<td>Liquid</td>
<td>No</td>
<td>YES Bending optional</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>4</td>
<td>Gas</td>
<td>No</td>
<td>YES Bending optional</td>
<td>YES 135°C</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>6</td>
<td>Gas</td>
<td>YES</td>
<td>YES Bending optional</td>
<td>YES 135°C</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>8</td>
<td>Gas</td>
<td>YES</td>
<td>YES Bending required</td>
<td>YES 180°C</td>
<td></td>
</tr>
</tbody>
</table>

![VAM 21 Envelope](image)

**VAM 21 Envelope**

ISO 13679:2002 testing protocols
Recent Projects

- **Fonroche Géothermie, Alsace, France**
  - Depth: 5,408m first production well
  - Downhole reservoir temperature: 185°C
  - Products: 1500 tons of OCTG Premium Connections, VAM® 21
  - VAM Field Service to supervise on-site descent
  - Well design: material selection to allow exploitation for 60 years minimum

- **Holzkirchen, Bavaria, Germany**
  - Depth: up to 5,000m
  - Downhole reservoir temperature: 180°C
  - Severe External Pressure: up to 743 bar
  - VAM® Premium Connections, VAM® 21
  - Geothermal energy will soon represent a major share of the Munich energy supply

- **CFE, Los Azufres III, Mexico**
  - Depth: 1,100m
  - Downhole reservoir temperature: 320°C
  - VAM® Premium Connections
  - 25 MW project to come on line in 2018

- **Java Island, Indonesia**
  - Depth up to 2,200m
  - Downhole reservoir temperature: 250°C
  - VAM® Premium Connections, VAM® 21
  - 30MW project contributing to the strong incentive of Indonesia government to develop Geothermal energy

- **Lake Assal, Djibouti**
  - Depth: 2,200m
  - Downhole reservoir temperature: 360°C
  - VAM® Premium Connections, VAM® 21
  - Power plant: initial capacity of 15MW rising to 50MW following completion in 2025
Thank you

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