CalPortland Invests for energy efficiency
Cement Kiln Clinker Cooler modernization for reliability and energy efficiency
DOE track J WEEC 2017

William Jerald, CEM,
Chief Energy Engineer
CalPortland Company
Company Information

• Founded in 1891 in California
• Producer of Cement, Concrete, Concrete Products, Aggregates and Asphalt
• 145 Facilities in Western U.S. & Canada
• 2000 Employees
• Received the U.S. Environmental Protection Agency (EPA) ENERGY STAR Award 13 years in a row
Portland Cement 101

- Portland Cement is the binding agent used in making concrete
- Concrete is the combination of Portland Cement, water and a sand and gravel mixture

This is a Ready Mix Concrete truck not a “cement truck”
Rillito Cement Plant Clinker Cooler replacement

• This is an overview of the process of choosing, designing and building a new clinker cooler for a Portland cement plant
• The project reduced fuel consumption and electrical consumption
• The cooler also replaced various electrical equipment including installing 7 new variable frequency drives
• An impact crusher was replaced with a roll crusher
• The new cooler design allowed for an increased thermal efficiency, and improved conveyor technology to reduce down time
CalPortland Rillito Cement Plant

The Rillito Cement Plant is located Northwest of Tucson, AZ. The limestone quarry is 5 miles southwest of the plant.
Plant Modernization History

• The Rillito cement plant was built in 1948 with one long dry kiln.
• The plant expanded to three long dry kilns.
• In 1972 the Kiln #4 line was installed, which utilized a pre heater tower.
• Over the next 40 years various parts of the plant experienced modifications and improvements, but the cooler essentially maintained its original design.
Rillito Cement Plant Built with one Cement Kiln in 1949
Rillito Cement Plant expanded to two kilns in 1952
Rillito Cement Plant 3 kilns by 1955
Rillito cement plant underwent major modernization adding a kiln with preheater tower in 1972
Portland cement is manufactured by mining Limestone, and adding Iron and Alumina to the mixture.

The material is ground to a fine powder and introduced to a pyro process in the rotary kiln.

The kiln will raise the temperature of the mixture in order to perform the chemical transition to create clinker.

Clinker is mixed with gypsum and ground to a fine product that becomes the final product of Portland Cement.
Chemistry
Limestone to Cement

\[ CaCO_3 + \text{Heat} \rightarrow CaO + CO_2 \]
Portland Cement Kiln Pyro Process

1. Raw Feed introduced to Preheater tower
2. Heat is provided by fuel combustion
3. Ambient air is supplied through the clinker cooler, air provides cooling medium to cool the clinker produced from the kiln, and the heated air is now directed to the kiln to provide the combustion oxygen and the heating gases for the preheater tower process
4. As the Hot gas rises through the cyclones the raw mix is preheated prior to entering rotating kiln
5. The limestone raw mix is processed into a product called clinker
6. The clinker exits the kiln and is cooled by the ambient air
Heat Exchange in Clinker Cooler

From Kiln to Clinker Storage

- Hot gas to kiln exiting at over 2000F
- Material enters at 2500F
- Material exits at 160F
- Ambient Air entering cooler (Arizona Summer tops at 120F)
Choice of rebuilding existing cooler or replacing

Option 1: Replace the cooler with a new modern cooler

- Capital Cost $9 million
- Four Cooler Suppliers considered: FLS, IKN, Polysius & Claudius Peters
- Reduced Energy Cost $1,200,000
- Reduced Cooler Maintenance Cost $426,000
- 50 year expected lifetime

Option 2: Rebuild Existing Cooler

- Capital Cost $1.106 million
- Increased Baghouse Maintenance Cost of $97,000 to meet NESHAP
Energy analysis of cooler

- Fuel reduction due to increased heat transfer, kiln uses 2-3 Million MMBTU annually
- Electrical savings from fan VFD
- Electrical savings from removal of drag line
- Electrical savings from cooler exhaust air
- Finish grind electrical savings due to better quality clinker for grinding process

The plant uses approximately 100 Million kWh annually at an average cost of $.08 per kWh
Multiple heat balance analysis were performed to determine appropriate design and calculate savings.
Previous Clinker Cooler

- The Cooler air supply uses 7 constant speed fans with damper controls for controlling mass flow of the input air.
- The “Conveyor” uses a pair of ac motors driving a gear and reciprocating drive.
- The exiting clinker passes through a hammer mill for breaking up larger clinker sizes.
- Below the cooler a drag conveyor is used for collecting remnant particles.
- Tipping valves utilizing compressed air cylinders convey the remnant particles to the drag conveyor.
Original Clinker Cooler
New Cooler installation

The kiln was taken down for 40 days, the old cooler was completely removed, and the new cooler built in its place.
New clinker cooler

- The H2-QC4 clinker cooler was replaced in May of 2016, the new cooler has both thermal and electrical efficiency savings
- The new cooler is a FLS cross bar cooler
- The existing 7 cooler fans were constant speed fans using damper controls for flow control
- The new installation uses 7 cooler fans with Toshiba Variable speed drives, the variable speed drives are used for air flow control versus the previous damper control. Controlling fan speed is a more energy efficient method of air flow control.
- The previous clinker crusher was an impact crusher and was replaced by a set of roll crushers with 3 variable speed drives
- The older cooler drive was a mechanical reciprocating drive, replaced by a hydraulic drive system
- Due to the increased thermal efficiency of the cooler it is expected that the exhaust air will be a lower temperature allowing the H2-GB-BL fan to require less power consumption
Cooler Control Graphic
Clinker bed depth control

The molten clinker lays across the cooler bed, ambient air blows from underneath and passes through the clinker to cool it. If the bed becomes dense and thick the air flow will tend to adjust to a less resistant path and eventually not pass through the denser section. A method of controlling the air flow to cause more air over denser portions was needed, this was answered by installing mechanical flow regulators “MFR”
Mechanical Air Flow Regulator “MFR”

- Fan air is supplied through multiple points.
- Differential pressure created by material loading causes movement of MFR.
- Automatically regulates air flow to distribute flow across entire cooler area.
MFR in operation
Clinker roll crusher

When clinker exits the cooler, larger “chunks” of clinker must be broken up to a more manageable size. The previous “chunk breaker” was a hammer mill which fractured the clinker, the fracturing caused many small particle “fines”. These fines become difficult to manage in the finish mill process hydraulic roll press. The new roll crusher, breaks apart the clinker in a crushing process which reduces the number of fines, and allows more efficient finish mill production, and improved quality.
Direct Drive fans replaced with VFD controlled fans

The previous cooler utilized 4 4160Volt and 3 480Volt fans with louver control for controller the amount of air flow directed into the cooler.

The new cooler replaced those fans with 7 variable frequency drives which allows for energy savings by reducing fan speed in order to control air flow.
New crossbar cooler

New inlet designed for better flow and reduced material buildup

Hydraulic cylinders located below the crossbars actuate repeatedly to push the layer of clinker downstream
Cooler baghouse and exhaust fan

• The air leaving the cooler is pulled through a filtration unit by a 600HP fan
• The reduced air temperature increases the filtration unit bag life
• The reduced air temperature allows for higher density air which lowers the fan speed required to move the air, which then reduces power requirement
Power consumption is recorded in a data historian and we tabulated it to create an energy intensity value of kw per ton of product produced.
Electrical Energy intensity study for utility rebate

Comparing data from 2014, 2015 and 2016

kW/ton data by hour for the month of July
Based on the Average kWh/ton for the month of July, the annual kWh usage for the respective year was calculated with the assumed production of 1,000,000 tons.
Tucson Electric Power rebate

TEP EasySave Plus
Custom Incentive Worksheet

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Rillito Clinker Cooler Modification</th>
<th>TEP Account No.:</th>
<th>232700051</th>
</tr>
</thead>
</table>

Please attach supporting documents as described in the specifications. Do not use this form for projects where a custom worksheet is available (custom lighting, heat exchangers, packaged dx energy management systems, etc). Applications using this form where specific worksheets exist will require a resubmittal using the applicable worksheet.

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Description</th>
<th>Rebate: $0.10 /kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>The Rillito Cement Plant Clinker Cooler for Kiln #4 is being replaced with a new energy efficient Clinker Cooler. The Clinker Cooler is a complex grouping of many pieces of equipment that in combination provide ambient air to cool and transport the clinker being discharged from Kiln #4. The new cooler brings increases in fuels efficiency for the kiln. There are 7 existing cooler fans with air flow controlled by dampers, that are now being replaced with VFD's. The existing hammermill will be replaced with 3 VFD controlled roll crushers</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual kWh Savings</th>
<th>Rebate Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>968,000</td>
<td>$96,800.00</td>
</tr>
<tr>
<td>kW Savings</td>
<td></td>
</tr>
<tr>
<td>110.5</td>
<td></td>
</tr>
<tr>
<td>Annual Oper. Hrs</td>
<td></td>
</tr>
<tr>
<td>7,884</td>
<td></td>
</tr>
<tr>
<td>Measure Cost</td>
<td>$8,900,000.00</td>
</tr>
</tbody>
</table>

Enter Operating Schedule and Days Closed Below

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Start Time</th>
<th>End Time</th>
<th>Total Hours</th>
<th>Days Closed per Year</th>
<th>Weeks Closed per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Tuesday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Wednesday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Thursday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Friday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Saturday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Sunday</td>
<td>12:00 AM</td>
<td>12:00 AM</td>
<td>24.00</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

TEP made conservative calculation and reduced rebate to $70,000
Project results

- Clinker temperature reduction – 96F
- Fuel consumption reduction 7.1%
- Electrical Power consumption 10-20%
- Product quality improvement 4%
- Tertiary air temperature increase 259F
- $70,000 utility rebate for the electrical portion of the project
Summary

The CalPortland Engineering team investigated every cost aspect of the installed cooler and the impact of installing a new design cooler. The focus we maintain on energy allowed us to make a decision to invest in a large capital project with the knowledge that future energy cost reduction would be realized.