CalPortland Invests for energy efficiency

Cement Kiln Clinker Cooler modernization for reliability and energy efficiency

DOE track J WEEC 2017

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Chief Energy Engineer

CalPortland Company

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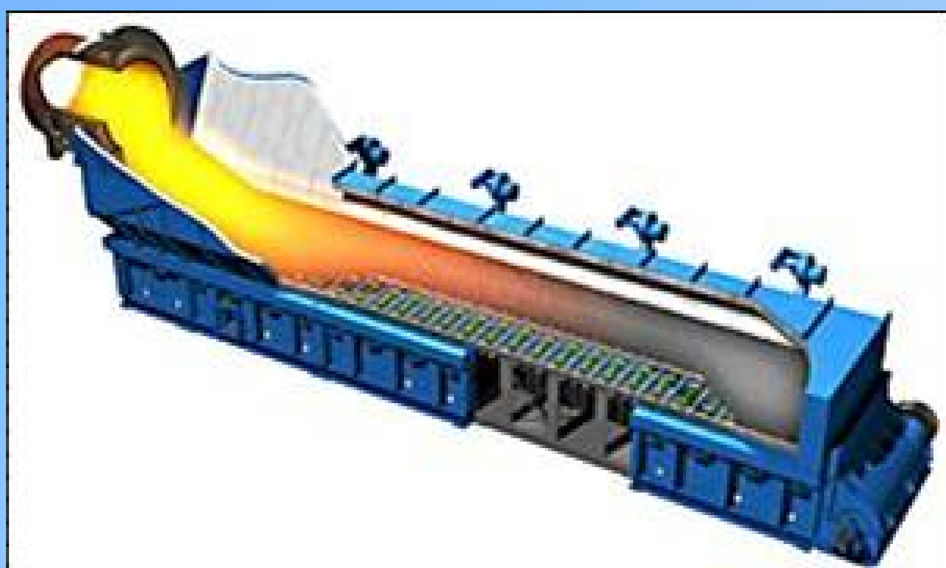
Company Information

- 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

energy ENERGY STAR AWARD 2017
PARTNER OF THE YEAR
Sustained Excellence



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Portland Cement 101

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

This is a Ready Mix Concrete truck not a "cement truck"

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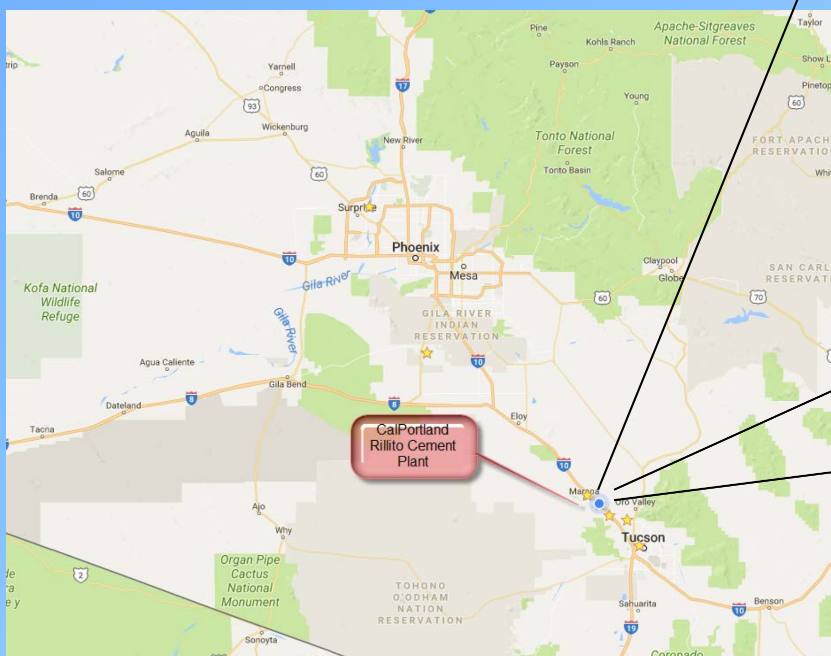
Rillito Cement Plant Clinker Cooler replacement

- 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



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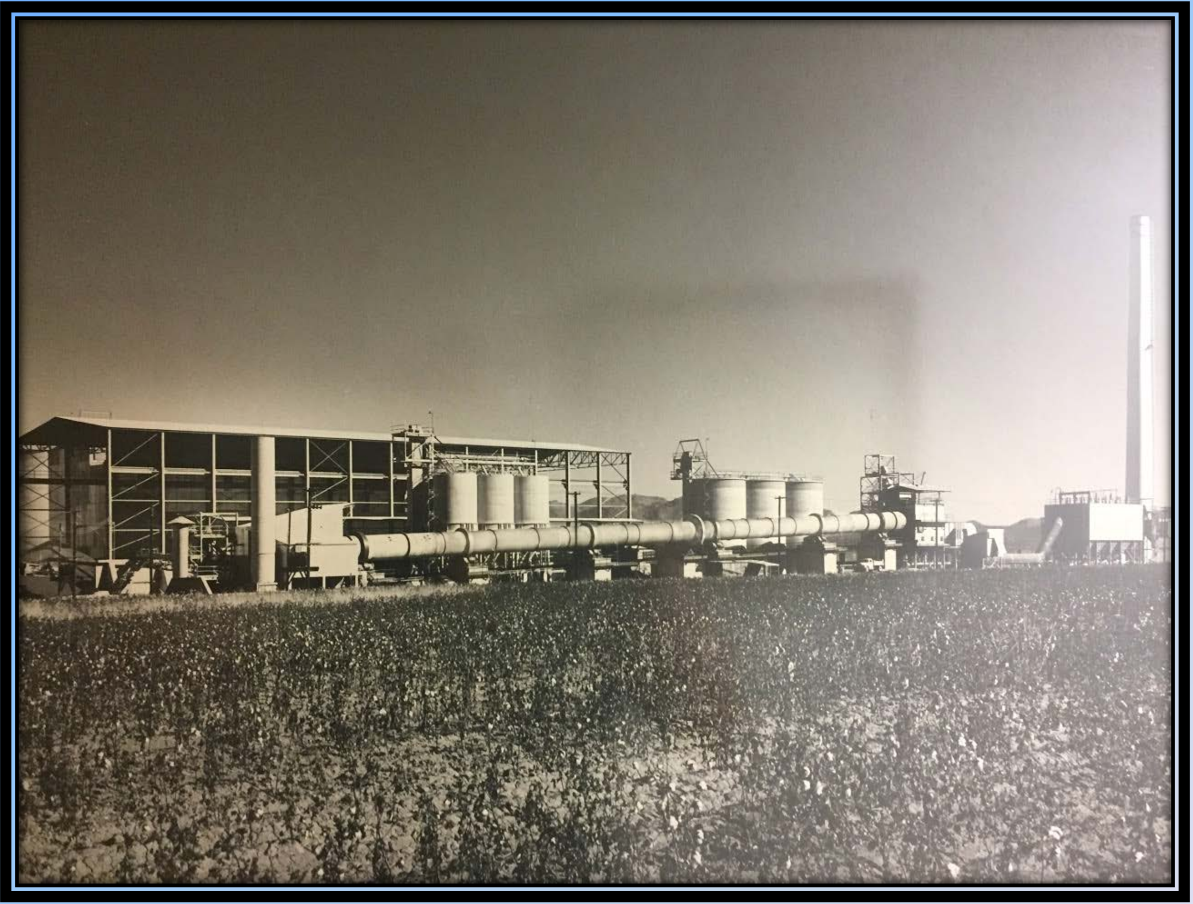
Plant Modernization History

- 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



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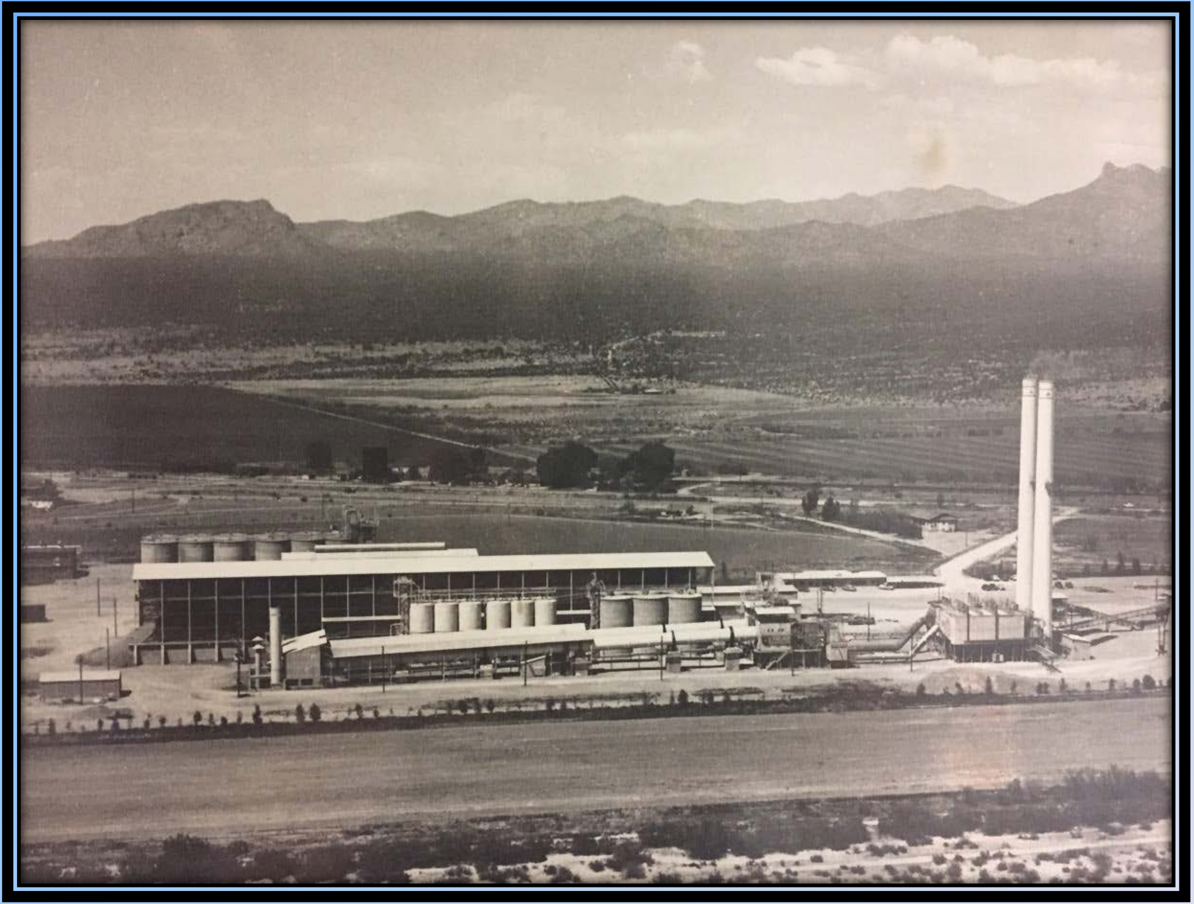
Rillito Cement Plant expaned to two kilns in 1952



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Rillito Cement Plant 3 kilns by 1955

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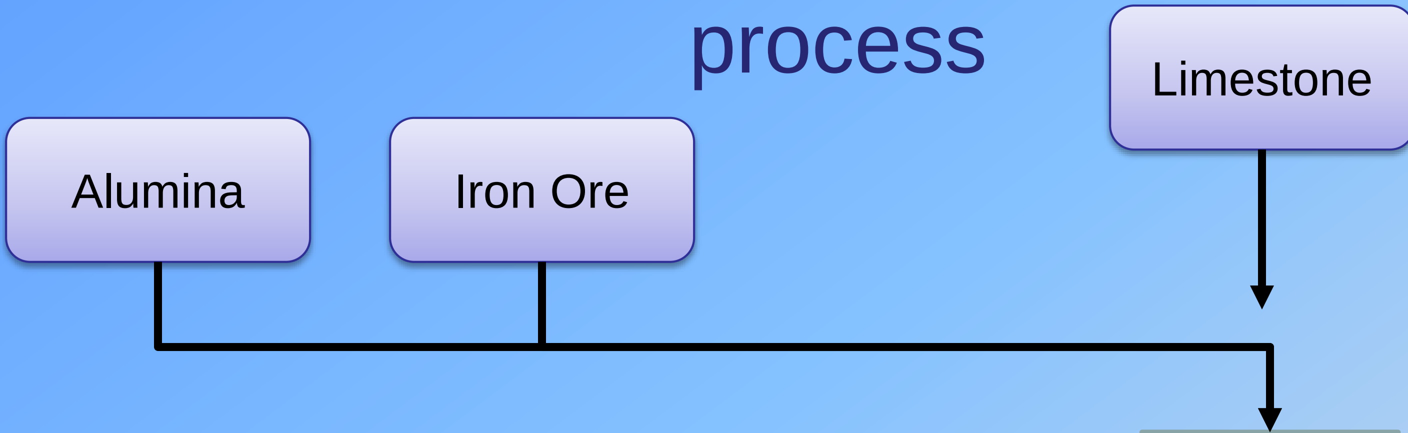
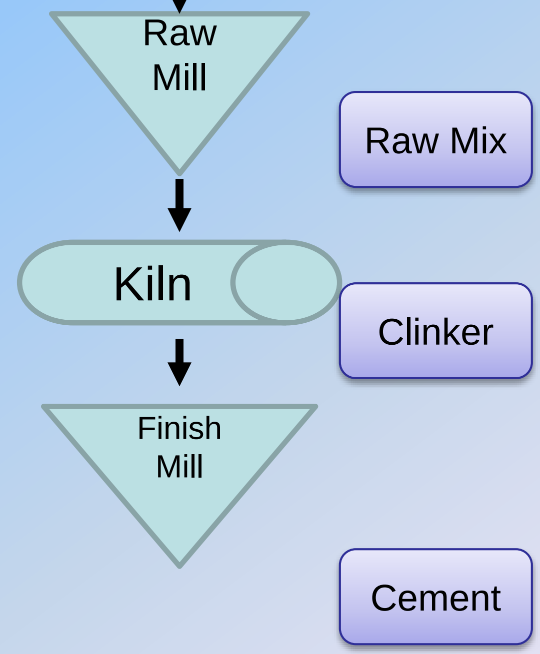
Rillito cement plant underwent major modernization adding a kiln with preheater tower in 1972

Basic Portland Cement Manufacturing process



- 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



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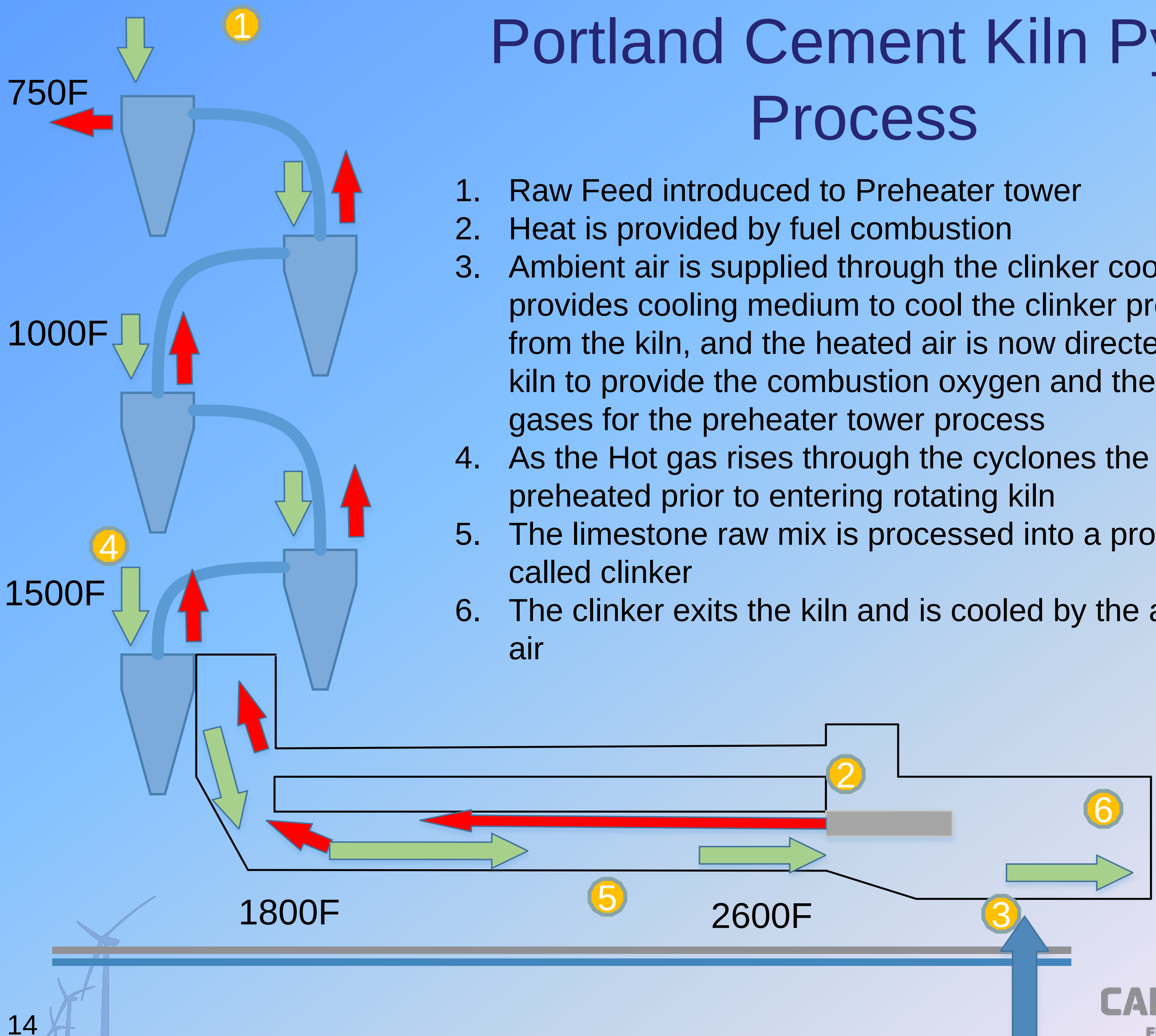
Chemistry
Limestone to Cement

$$CACO_3 + Heat \rightarrow CaO + CO_2$$

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

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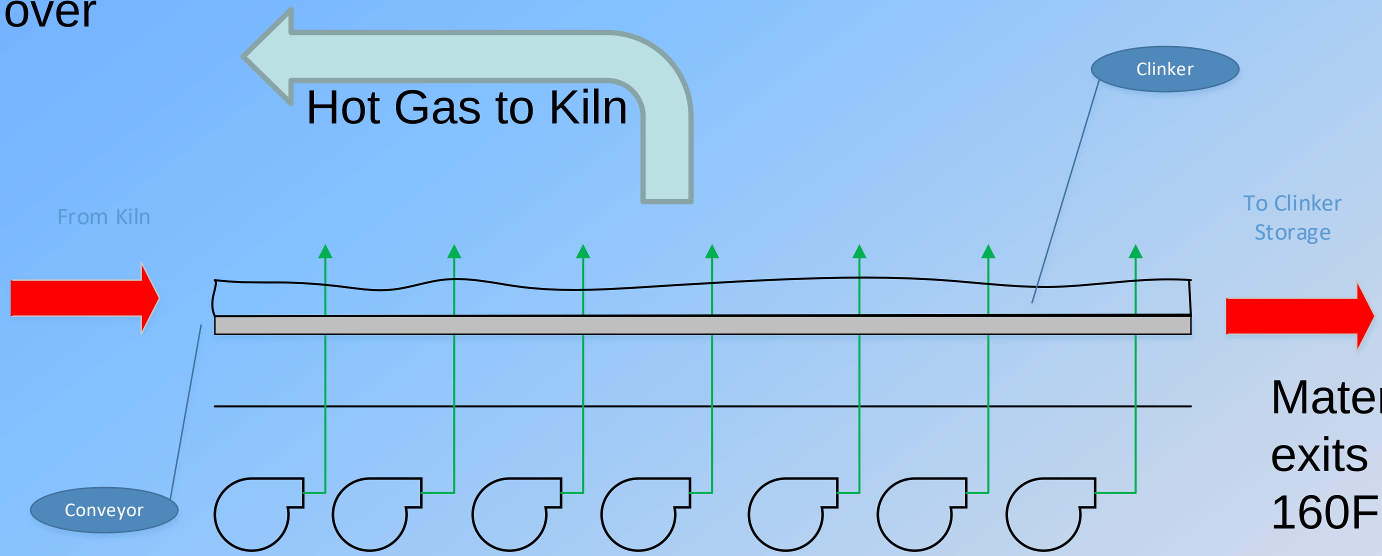
Heat Exchange in Clinker Cooler

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

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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

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Heat Balance Existing Cooler

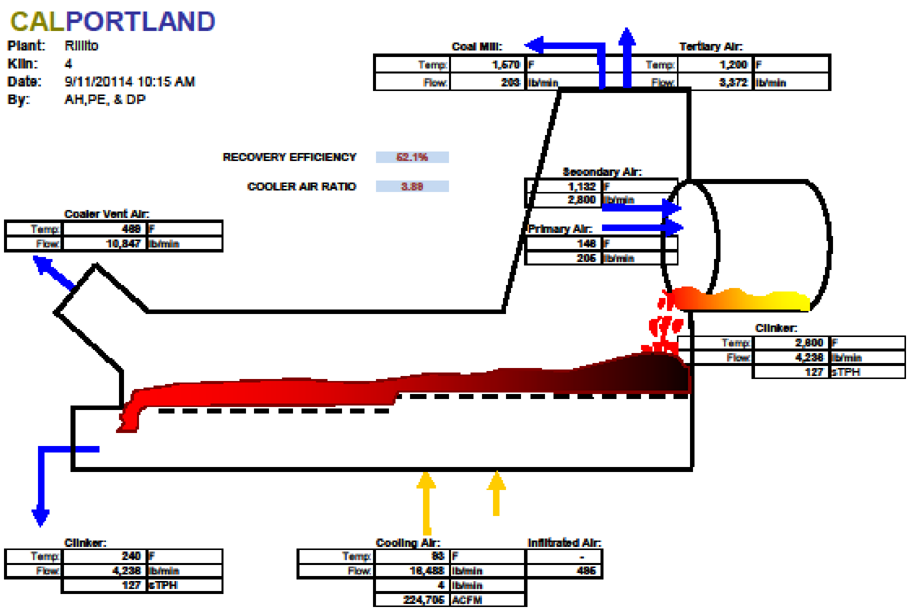

TABLE 3: MASS BALANCE

	lb/lb clk	
IN		
Cooler Fan Air	3.89	
Infiltrated air	0.12	
		3.96
OUT		
Secondary Air(w/infil)	0.60	
Tertiary Air & Coal Mill	0.80	
Vent Air	2.56	
		3.96

TABLE 4: ENERGY BALANCE

	Mbtu/t clk	
IN		
Clinker	1.37	
Cooler Fan Air	0.17	
Infiltrated air	0.01	
		1.55
OUT		
Vent Air	0.34	
Clinker	0.09	
Wall Losses(Assumed)	0.03	
Tertiary Air & Coal Mill	0.47	
Secondary Air by diff.	0.58	
		1.55

Multiple heat balance analysis were performed to determine appropriate design and calculate savings

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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

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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

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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"

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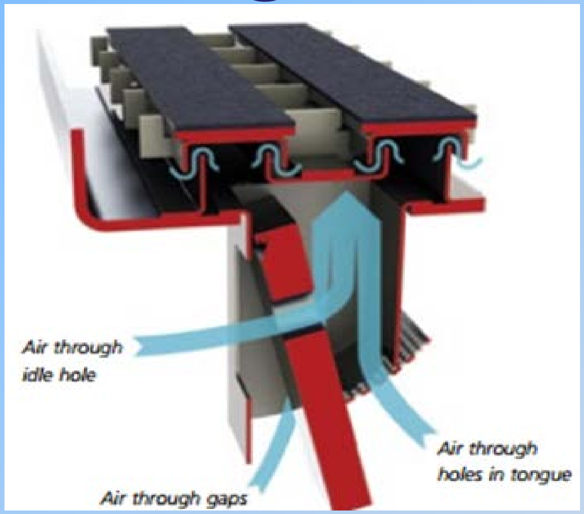
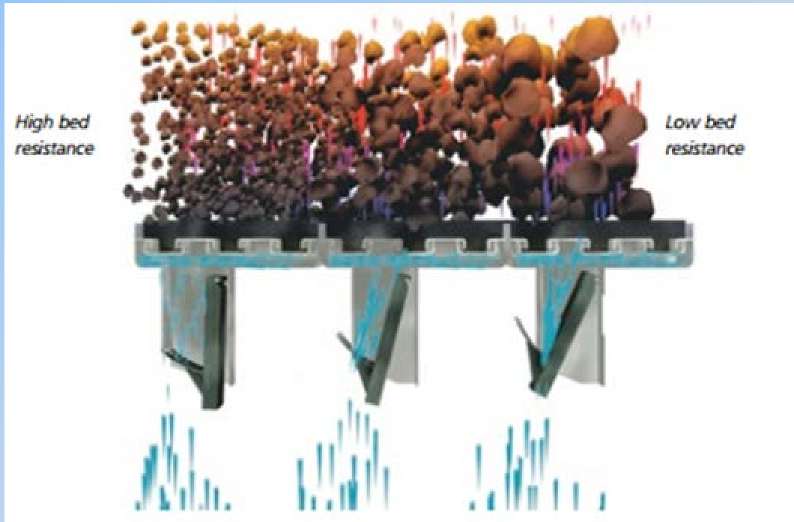
Mechanical Air Flow Regulator "MFR"



- 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



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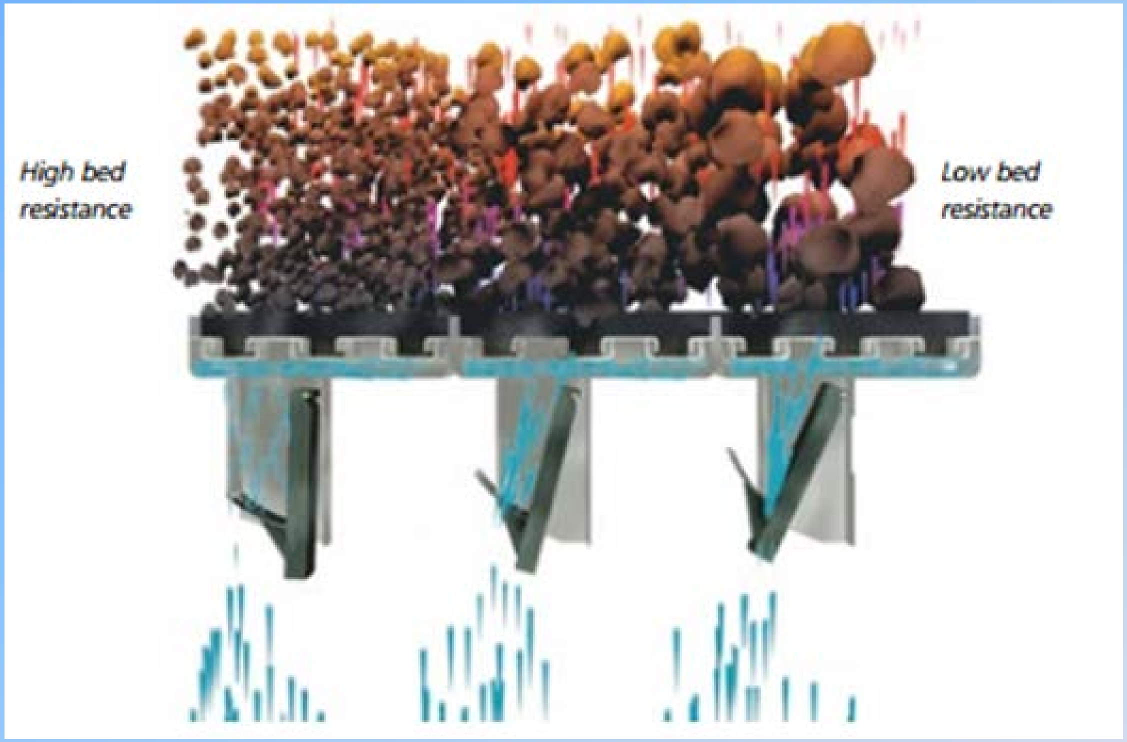
MFR in operation



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

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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

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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

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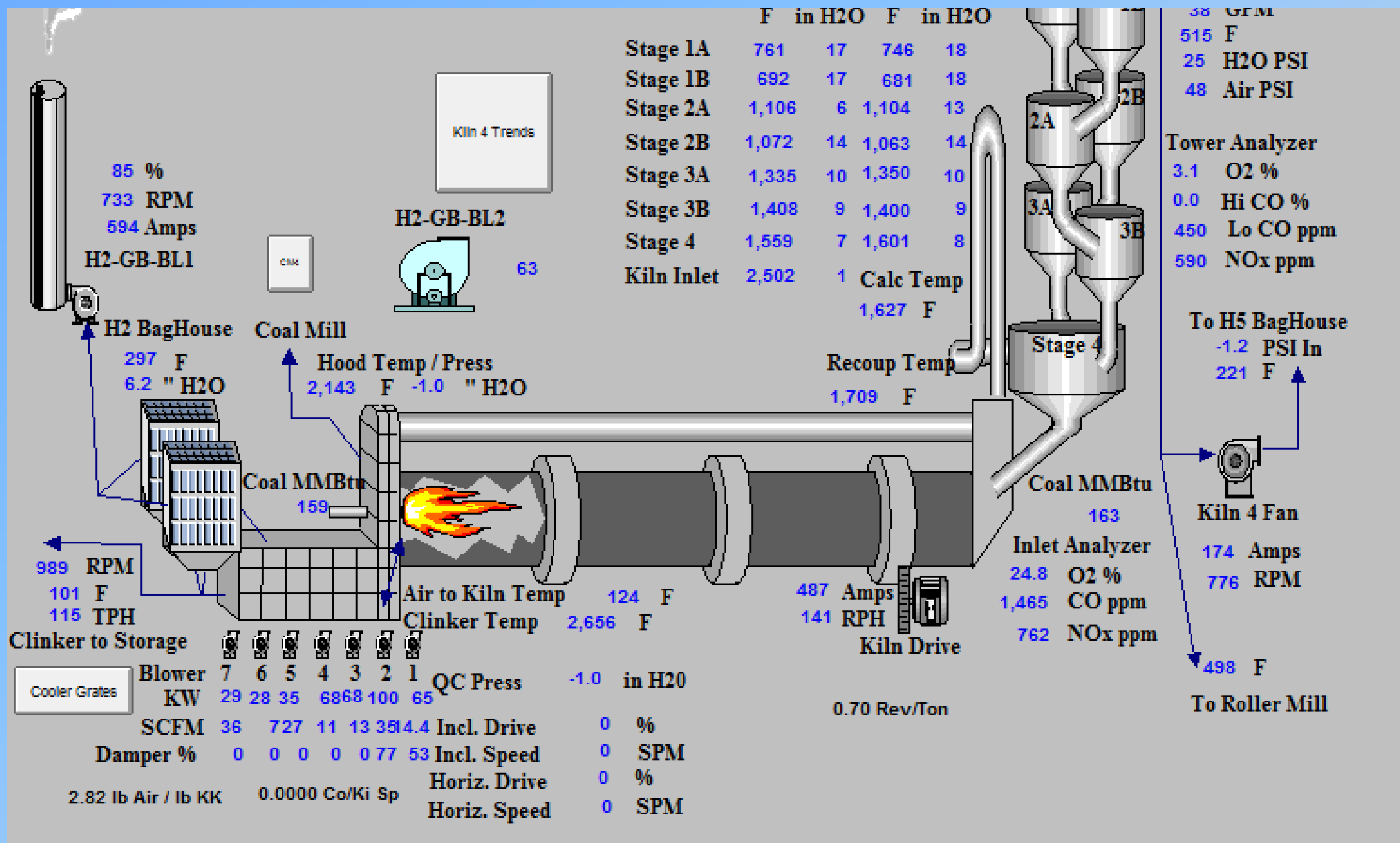

F in H2O F in H2O
Stage 1A 761 17 746 18
Stage 1B 692 17 681 18
Stage 2A 1,106 6 1,104 13
Stage 2B 1,072 14 1,063 14
Stage 3A 1,335 10 1,350 10
Stage 3B 1,408 9 1,400 9
Stage 4 1,559 7 1,601 8
Kiln Inlet 2,502 1
Calc Temp
1,627 F
515 F
25 H2O PSI
48 Air PSI
Tower Analyzer
3.1 O2 %
0.0 Hi CO %
450 Lo CO ppm
590 NOx ppm
2A
2B
3A
3B
Stage 4
To H5 BagHouse
-1.2 PSI In
221 F
Kiln 4 Trends
85 %
733 RPM
594 Amps
H2-GB-BL1
H2-GB-BL2
63
H2 BagHouse
297 F
6.2 " H2O
Coal Mill
Hood Temp / Press
2,143 F -1.0 " H2O
Recoup Temp
1,709 F
Coal MMBtu
159
Coal MMBtu
163
Kiln 4 Fan
174 Amps
776 RPM
Inlet Analyzer
24.8 O2 %
1,465 CO ppm
762 NOx ppm
989 RPM
101 F
115 TPH
Clinker to Storage
Air to Kiln Temp 124 F
Clinker Temp 2,656 F
487 Amps
141 RPH
Kiln Drive
498 F
To Roller Mill
Cooler Grates
Blower 7 6 5 4 3 2 1
KW 29 28 35 68 68 100 65
SCFM 36 727 11 13 35 14.4
Damper % 0 0 0 0 0 77 53
QC Press -1.0 in H20
Incl. Drive 0 %
Incl. Speed 0 SPM
Horiz. Drive 0 %
Horiz. Speed 0 SPM
0.70 Rev/Ton
2.82 lb Air / lb KK
0.0000 Co/Ki Sp

Electrical data M&V for utility rebate

	A	B	C	D	L	M	N	O	P	Q	R	S	T	Z	AC	AD
1																
2		Date	H4BS1FT	Clinker Production TPH)	H2GBBLSCR	H2GBBL-RPM	H2GBBL-Volts	H2GBAM	H2GBKW	Calc HP	H2MCC3/4 kW	H2GBBL2	H2GBBL2 kW	H2DR1 kW	H2QC4 Total kW	July 16 KW/TON
3		7/1/2016 0:00	199.0842438	119.45	80.01	680.06	400.04	510.31	204.14	273.65	531.13	82.53	58.32	16.79	693.74	5.81
4		7/1/2016 1:00	199.08	119.45	80.21	681.75	401.03	509.24	204.22	273.75	534.46	82.36	58.20	16.79	697.26	5.84
5		7/1/2016 2:00	199.08	119.45	78.71	669.07	393.57	483.50	190.29	255.08	533.01	64.75	45.76	16.79	694.33	5.81
6		7/1/2016 3:00	199.08	119.45	77.65	660.05	388.27	492.19	191.10	256.17	523.42	64.08	45.28	16.79	686.02	5.74
7		7/1/2016 4:00	199.08	119.45	79.66	677.12	398.31	497.17	198.02	265.45	535.12	63.85	45.12	16.79	704.81	5.90
8		7/1/2016 5:00	199.08	119.45	75.19	639.10	375.94	446.68	167.93	225.10	514.62	57.40	40.57	16.79	658.77	5.51
9		7/1/2016 6:00	199.08	119.45	76.09	646.74	380.44	463.54	176.35	236.39	512.96	57.01	40.29	16.79	665.80	5.57
10		7/1/2016 7:00	199.08	119.45	77.00	654.48	384.99	485.98	187.10	250.80	504.82	57.33	40.51	16.79	668.19	5.59
11		7/1/2016 8:00	199.08	119.45	75.79	644.25	378.97	479.10	181.56	243.38	510.21	57.52	40.65	16.79	667.91	5.59
12		7/1/2016 9:00	199.10	119.46	76.15	647.31	380.77	467.12	177.87	238.43	510.54	57.60	40.71	16.79	664.48	5.56
13		7/1/2016 10:00	200.18	120.11	75.88	644.98	379.40	456.40	173.16	232.12	513.31	57.08	40.33	16.79	662.92	5.52
14		7/1/2016 11:00	200.18	120.11	74.96	637.18	374.81	456.19	170.99	229.20	515.41	57.31	40.50	16.79	662.68	5.52
15		7/1/2016 12:00	200.18	120.11	76.48	650.11	382.42	479.12	183.22	245.61	524.37	57.44	40.59	16.79	683.78	5.69
16		7/1/2016 13:00	200.18	120.11	75.62	642.75	378.09	450.79	170.44	228.47	516.32	57.41	40.57	16.79	662.97	5.52
17		7/1/2016 14:00	200.18	120.11	74.33	631.81	371.66	441.21	163.98	219.81	521.47	56.35	39.82	16.79	662.41	5.52
18		7/1/2016 15:00	200.18	120.11	73.20	622.21	366.01	449.00	164.34	220.29	518.81	57.25	40.45	16.79	659.47	5.49
19		7/1/2016 16:00	200.18	120.11	75.34	640.35	376.68	451.01	169.89	227.73	513.49	56.97	40.26	16.79	659.90	5.49
20		7/1/2016 17:00	200.18	120.11	79.80	678.29	398.99	503.32	200.82	269.20	524.84	56.78	40.12	16.79	702.32	5.85

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

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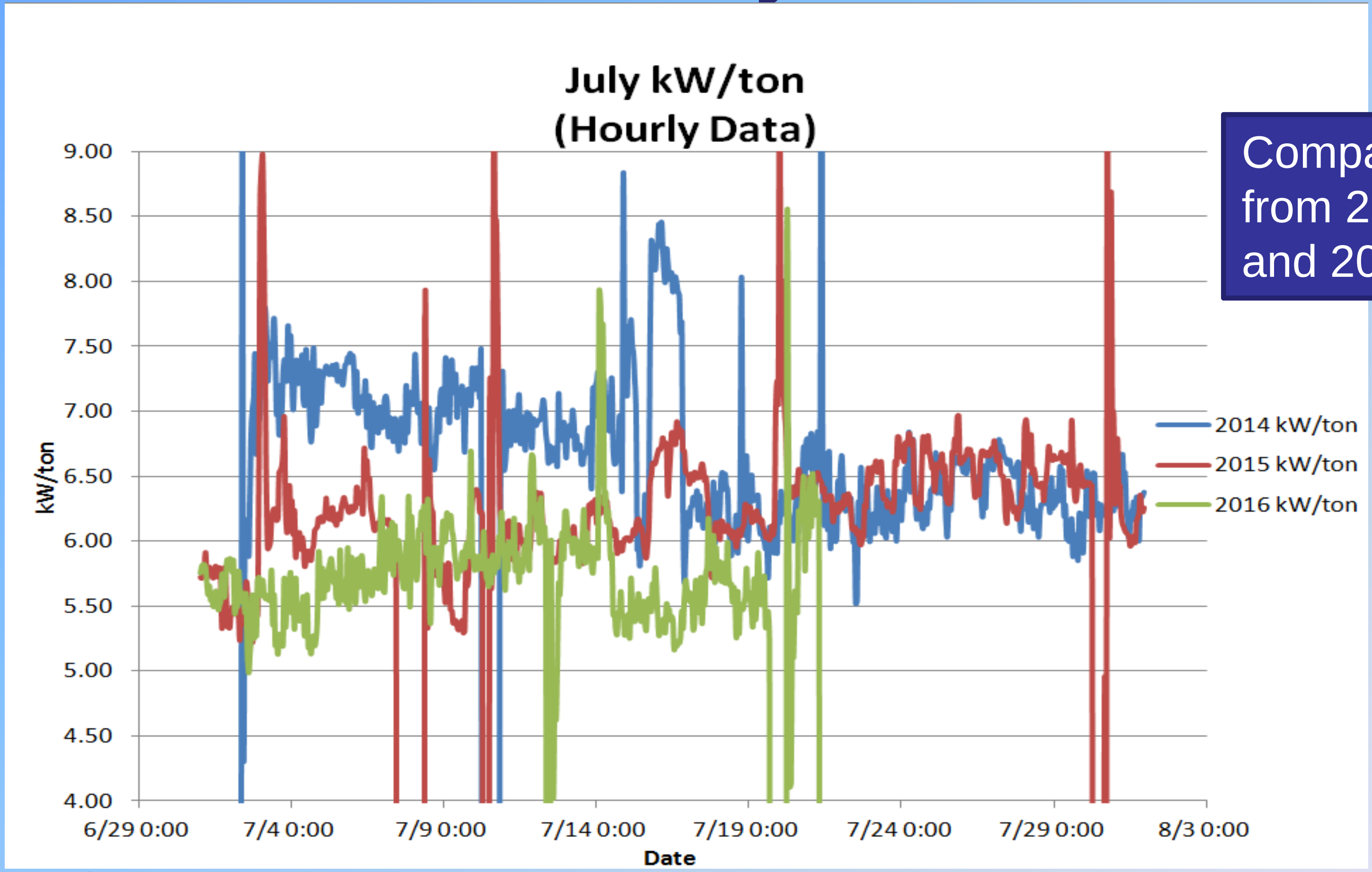
Electrical Energy intensity study for utility rebate



Comparing data from 2014, 2015 and 2016

kW/ton data by hour for the month of July

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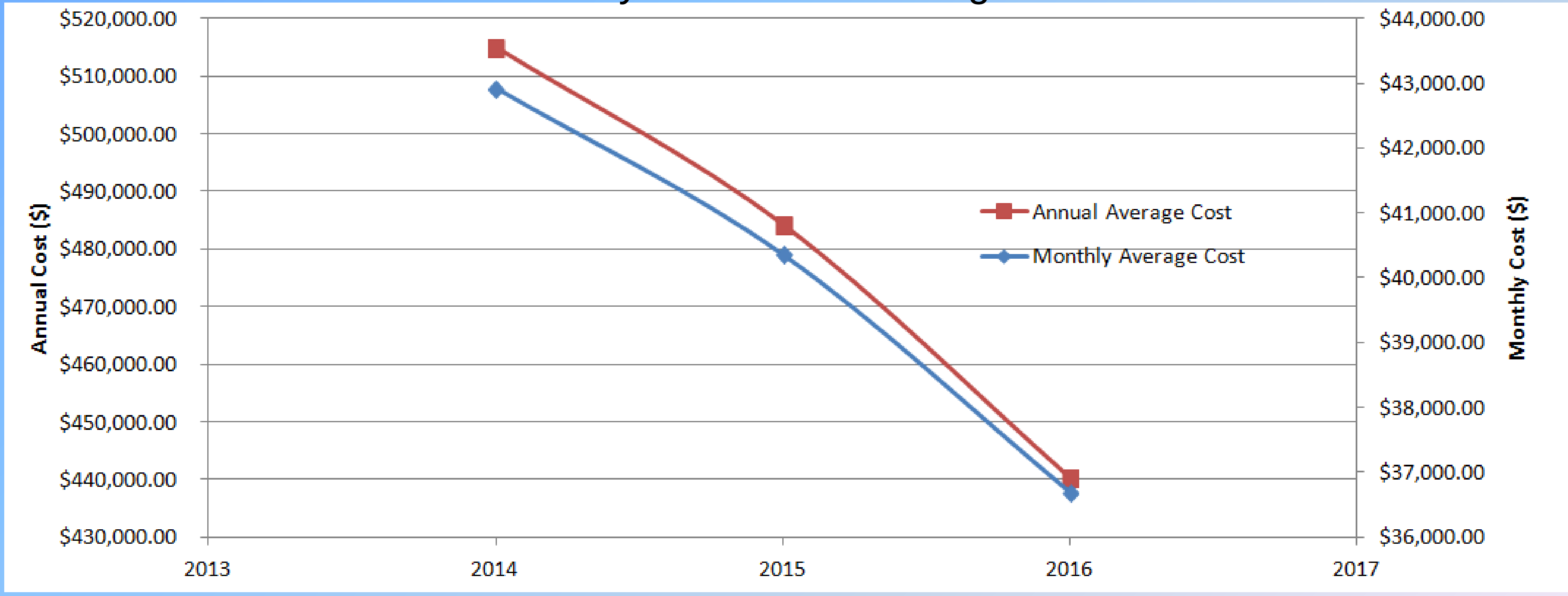
2014 annual kwh	6,688,477.62		
2016 annual kwh estimate	5,719,902.82	968,574.80	annual kwh savings

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.

Monthly and Annual Savings



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Tucson Electric Power rebate

TEP EasySave Plus

Custom Incentive Worksheet

Project Name:	Rillito Clinker Cooler Modification	TEP Account No:	232700051

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.

Item 1	**Description**	**Rebate: $0.10 /kWh**	
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		**Annual kWh Savings**	**Rebate Subtotal**
		968,000	$96,800.00
		kW Savings	
		110.5	
		Annual Oper. Hrs	
		7,884	
		Measure Cost	
		$8,900,000.00	

Enter Operating Schedule and Days Closed Below

Day of Week	Start Time	End Time	Total Hours		
Monday	12:00 AM	12:00 AM	24.00	**0**	Days Closed per Year
Tuesday	12:00 AM	12:00 AM	24.00	0.00	Weeks Closed per Year
Wednesday	12:00 AM	12:00 AM	24.00		
Thursday	12:00 AM	12:00 AM	24.00	Weeks/Year	**52.14**
Friday	12:00 AM	12:00 AM	24.00	Hours/Week	**168.00**
Saturday	12:00 AM	12:00 AM	24.00	Calculated Hours/Year	**8760.02**
Sunday	12:00 AM	12:00 AM	24.00		

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

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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

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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.