Lime Sludge Kiln Operation

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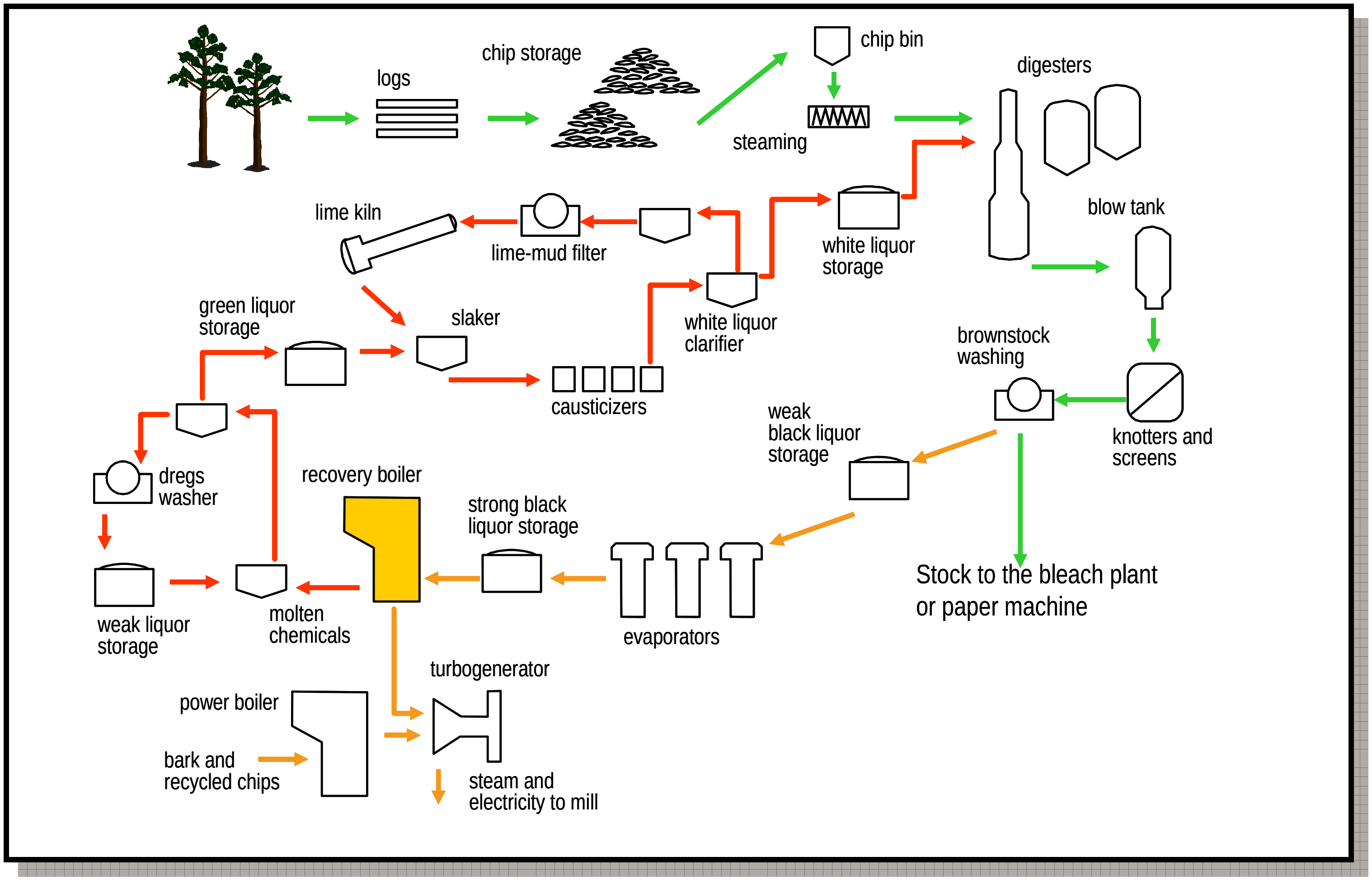
Schematic Diagram of Pulp & Paper Mill



Function of Lime Kiln

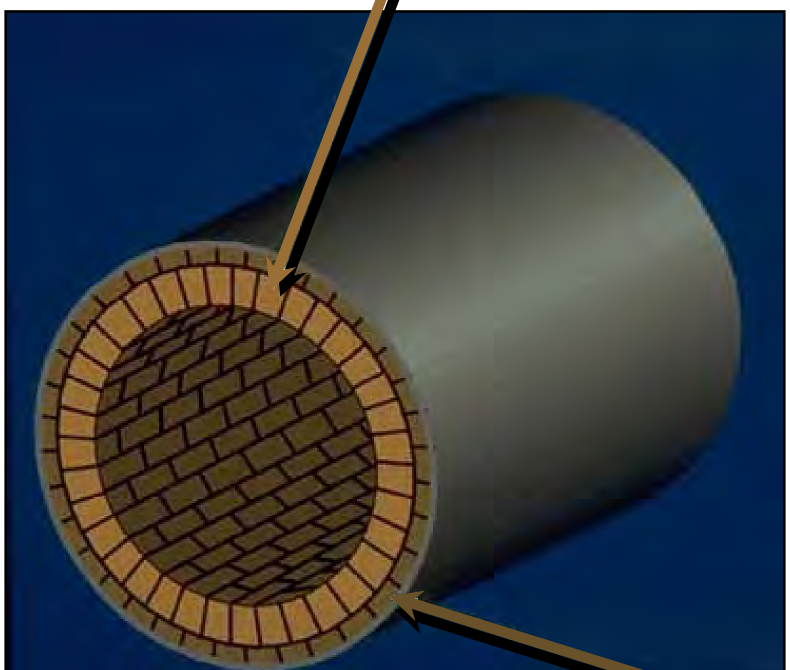
- The causticizing process that produces white liquor from green liquor consumes lime (CaO) and produces lime mud ($CaCO_3$) as a by-product.
- The function of the lime kiln is to convert $CaCO_3$ back to CaO for reuse in the causticizing process.

$$CaCO_3 \leftrightarrow CaO + CO_2$$

Everett Lime Kiln

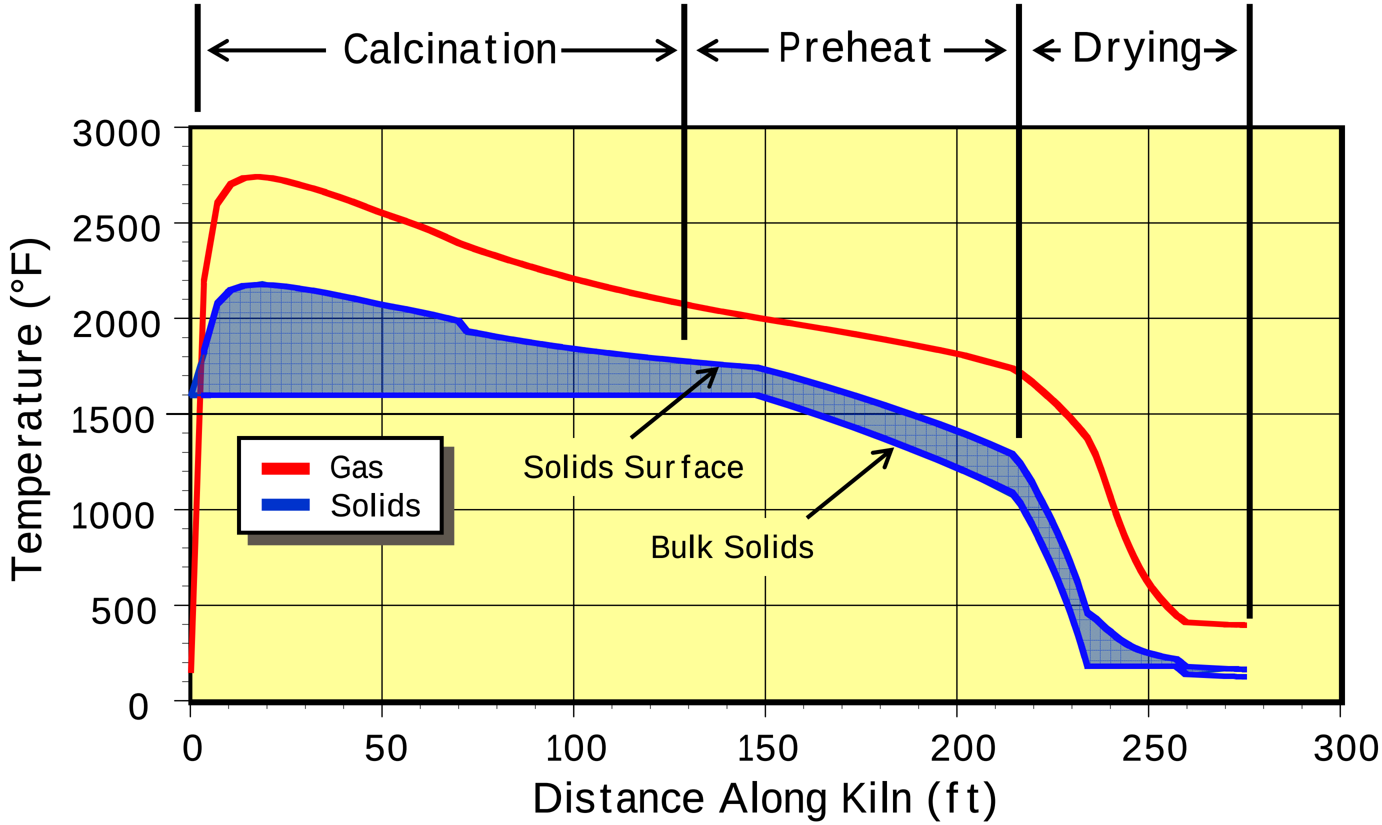
Refractory Layout

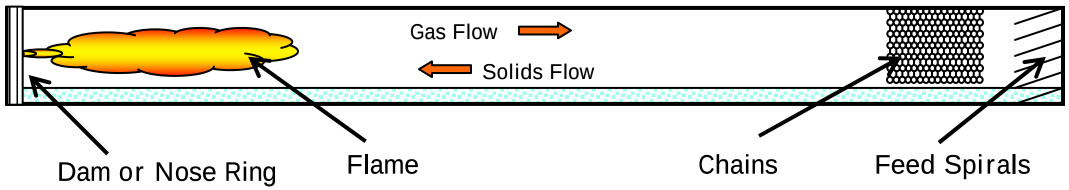
150-200mm High Alumina Brick



40-60mm Insulating Brick

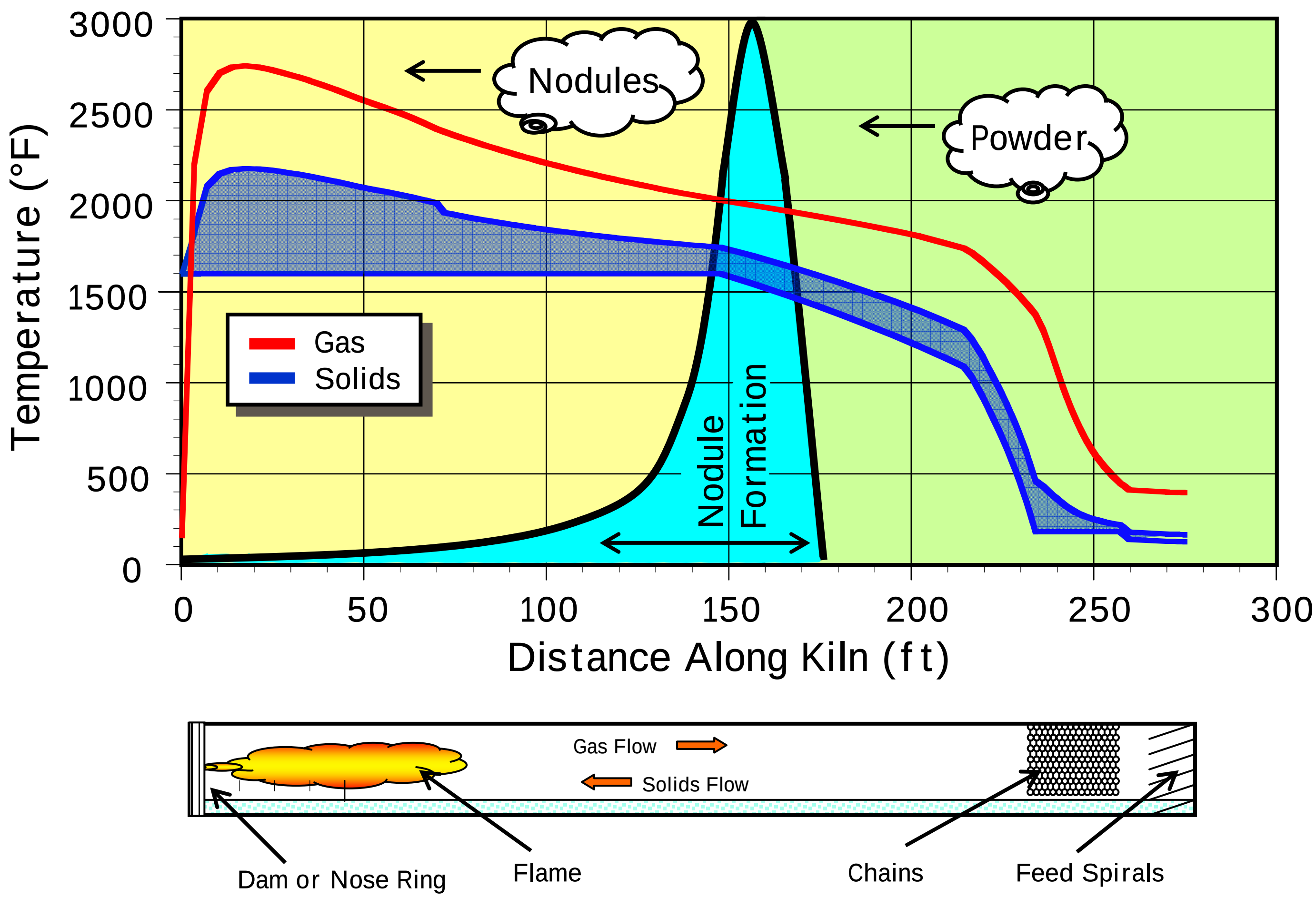
Lime Kiln Zones





The zones in the kiln are easy to distinguish using the bulk solids temperature profile. The drying zone is the region where the bulk solids temperature is constant, at a value of about 175°F. The bulk solids temperature in the calcining zone is constant at 1600°F, though the surface temperature of the solids can be as much as 500°F higher. The peak flame temperature is near 2800°F, with an exit gas temperature around 400°F.

Lime Nodule Formation

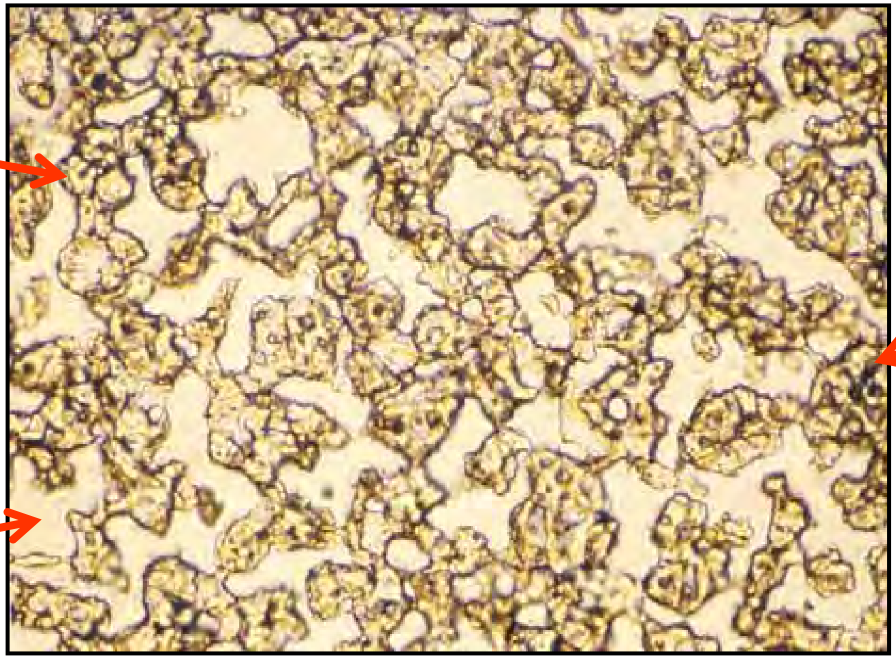


In order to produce a usable product, the kiln must not only dry and calcine the mud, but also agglomerate the dry mud (powder) into nodules so it can be handled by the system. Typically, the lime nodules vary in size from 0.5 to 2 inches in diameter. Sodium compounds play a key role in forming the nodules.

Structure of Lime Nodule

Polished Thin Section of Lime Nodule
(approximately 15 microns thick)

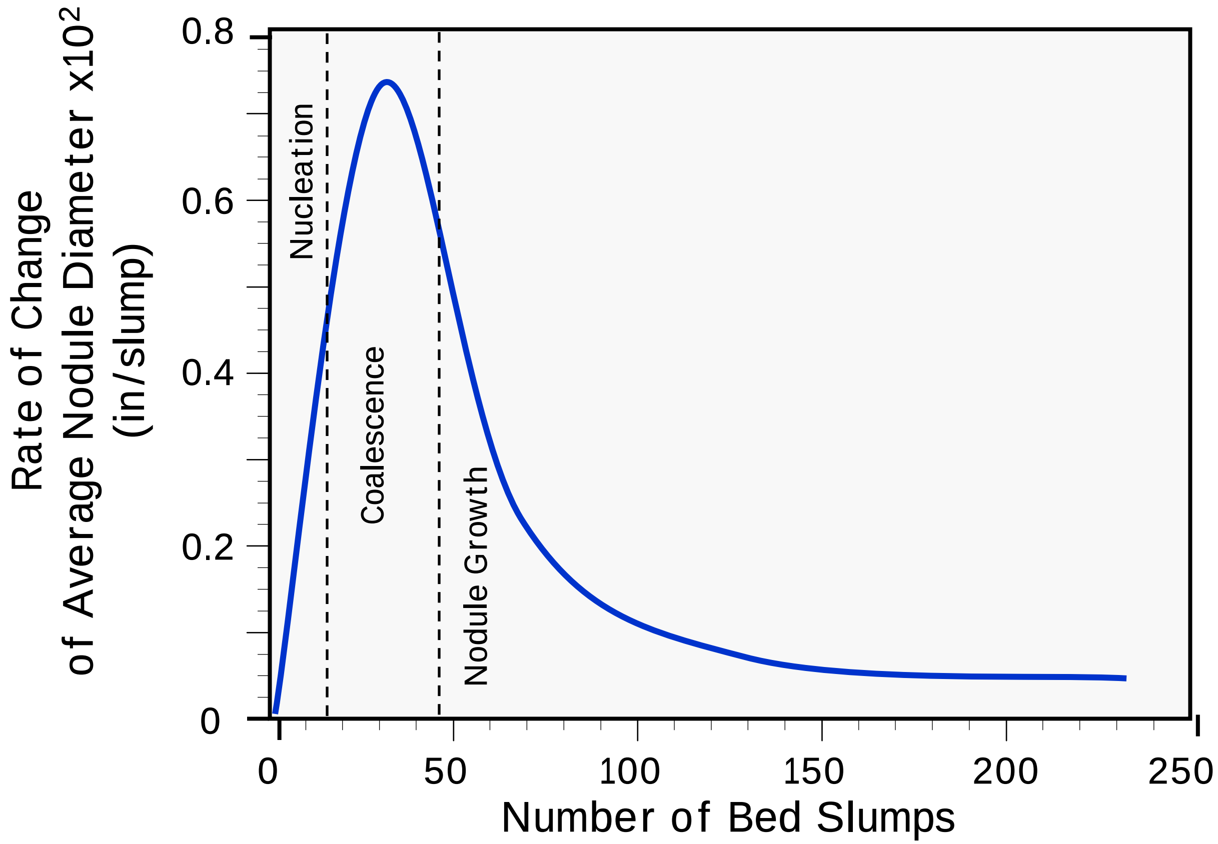
Lime
Particles



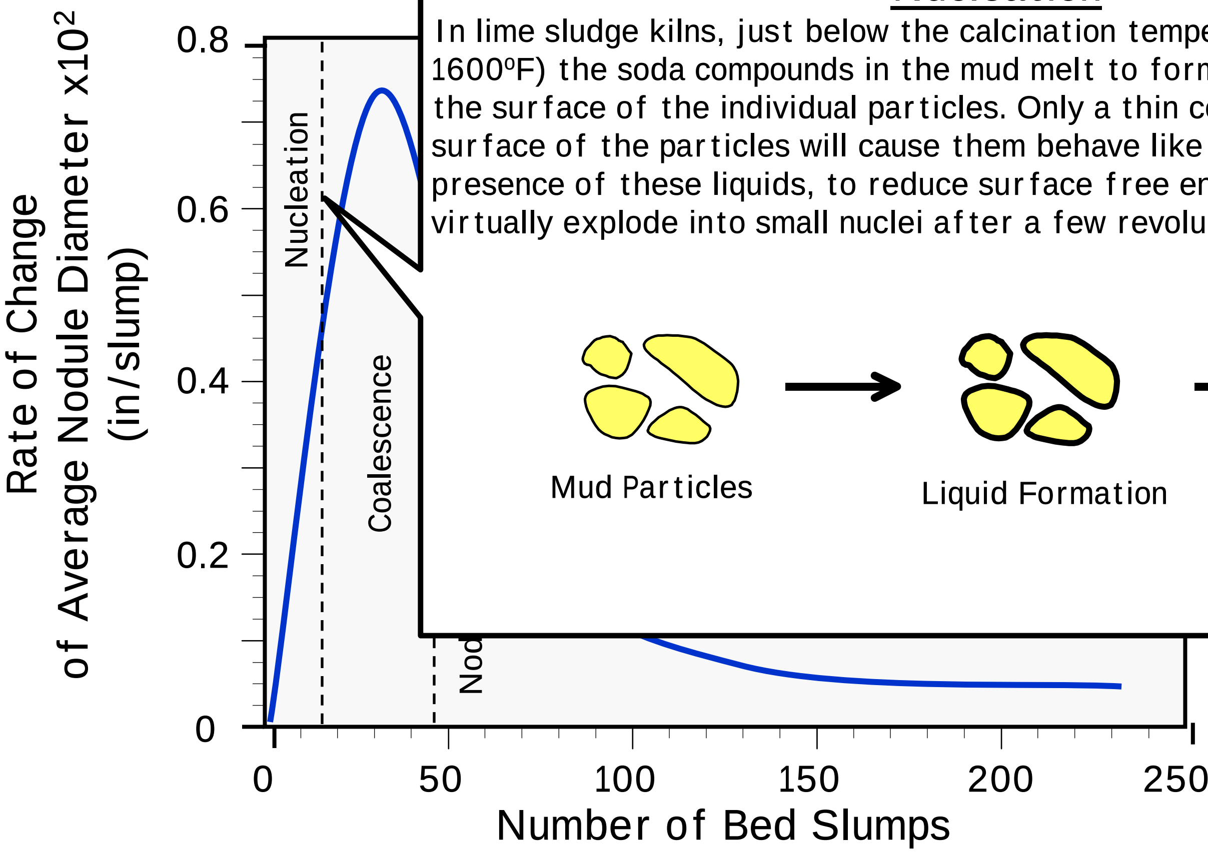
Dark Matrix
Phase Coating
Lime Particles
(rich in Fe,Al,Si,Na)

Epoxy
Resin

Theoretical Growth Rate Curve for Lime Nodules



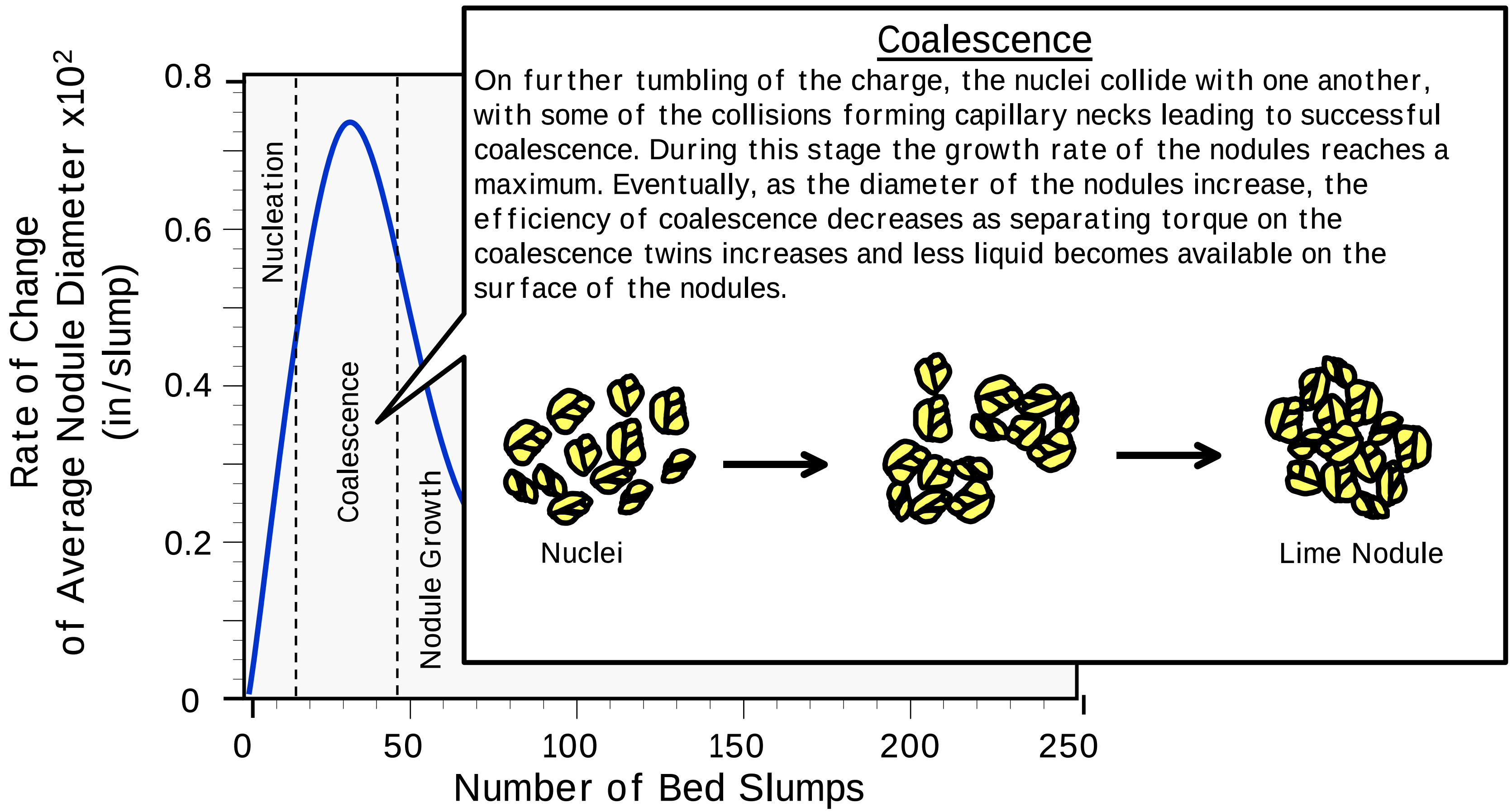
Nuclei Formation



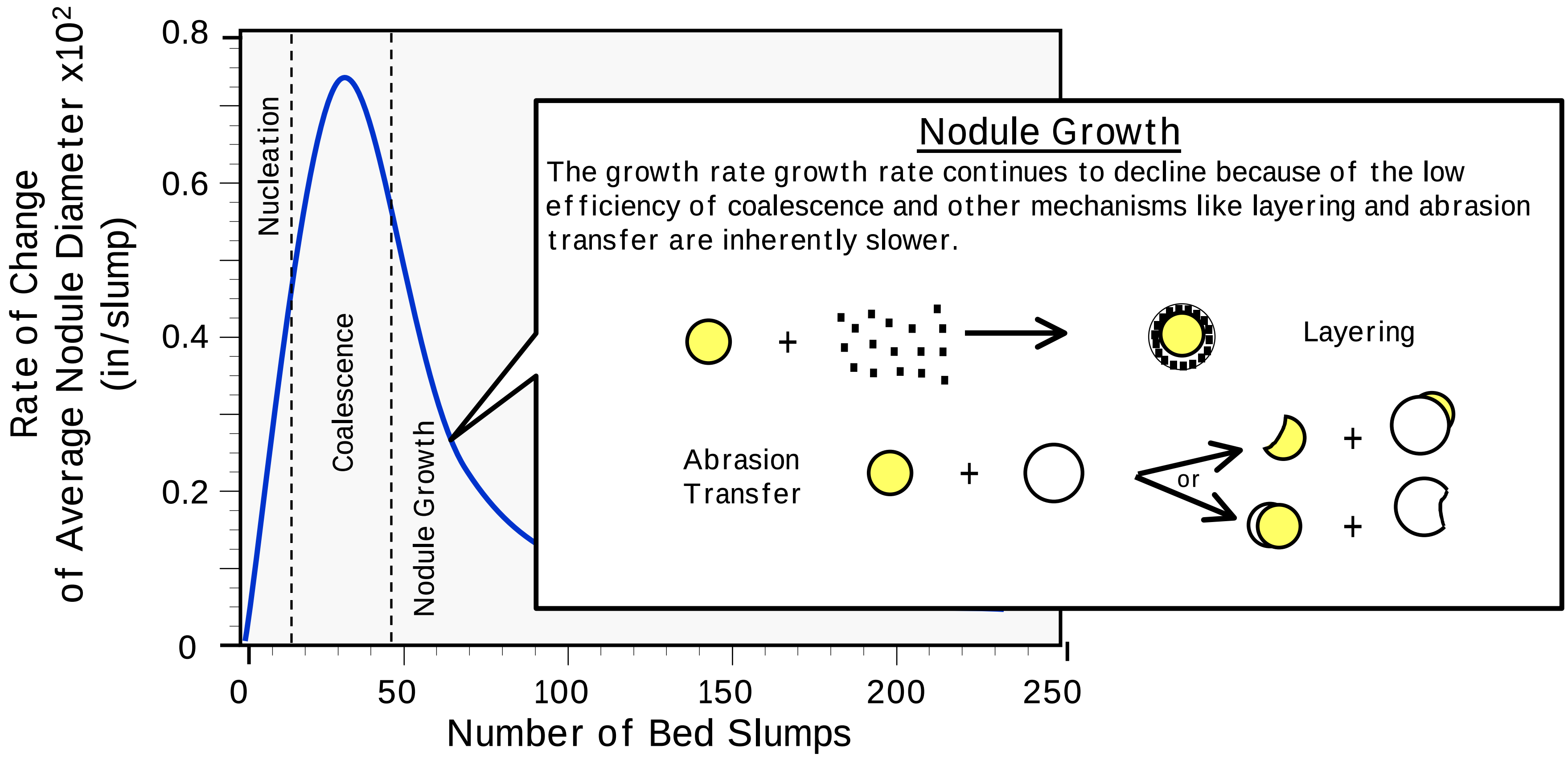
Nucleation

In lime sludge kilns, just below the calcination temperature (~1500 to 1600ºF) the soda compounds in the mud melt to form a layer of liquid on the surface of the individual particles. Only a thin coating of liquid on the surface of the particles will cause them behave like a bulk liquid. In the presence of these liquids, to reduce surface free energy, the mud particles virtually explode into small nuclei after a few revolutions of the kiln.

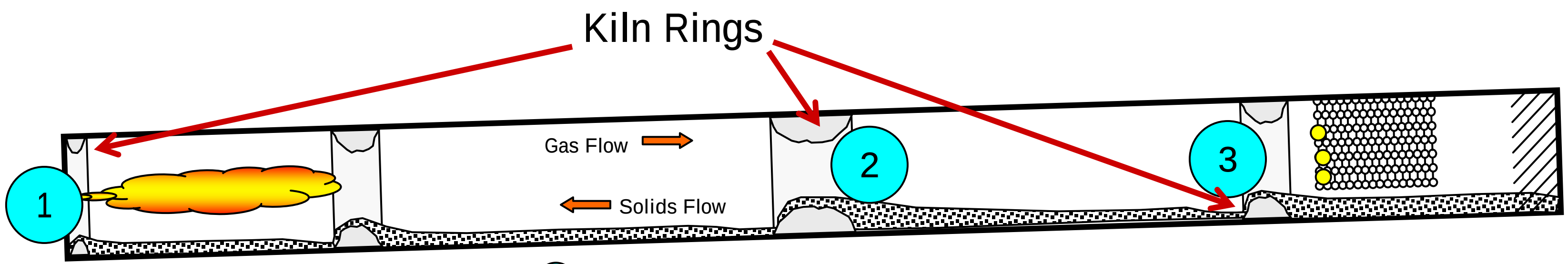
Nuclei Coalescence



Nodule Growth



Location of Kiln Rings

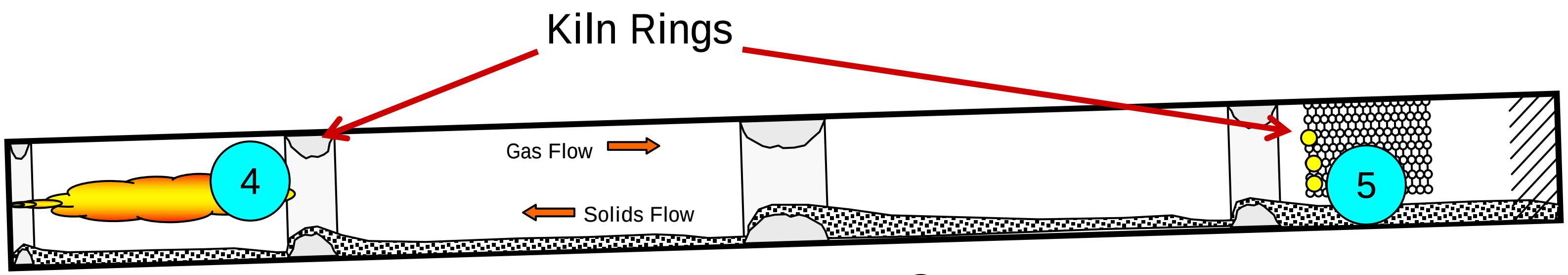


1. Dust Rings: Dust rings occasionally form during startups. Dust is picked up by the secondary air as it moves through firing hood or coolers and deposited on the nose ring or discharge dam. The exact mechanism of formation is not completely understood. These rings are not strong enough to support their weight and normally fallout shortly after startup. They do not pose a threat to production.

2. Mid-Kiln Rings (commonly referred to as "100 foot rings"): Sodium compounds form liquids as the mud approaches the calcination temperature (~1500 to 1600°F). The formation of these liquids on the surface of the mud particles in combination with the the rolling action of the bed causes them to agglomerate into nodules. At the same, rather than sticking to each other, some of the particles may stick to the wall forming a ring. Initially, the ring is soft and contains both $CaCO_3$ and CaO. Later, as the ring thickens or as operating conditions change, the ring cools and the CaO reacts with CO_2 to reform $CaCO_3$. As recarbonation occurs, the ring strengthens and will no longer fall out under its own weight. All lime sludge kilns have this ring. The size of the ring is dependent on the sodium content of the mud and the variability of the kiln operation.

3. Mud Rings: The moisture level of the mud leaving the chain section should be less than 5%. Excessively wet mud, greater than 15%, downhill from the chain section can stick to the wall forming rings. Typically, these rings form in the first few hours following a sheet drop and manual washing of the drum filter. The rings are very soft. and eventually, they dry and fall out. Pieces of the ring will show up at the front end of the kiln as balls and/or slabs. The installation of new more efficient mud filters and continuous cleaning systems have greatly reduced the occurrence of these rings.

Location of Kiln Rings (continued)

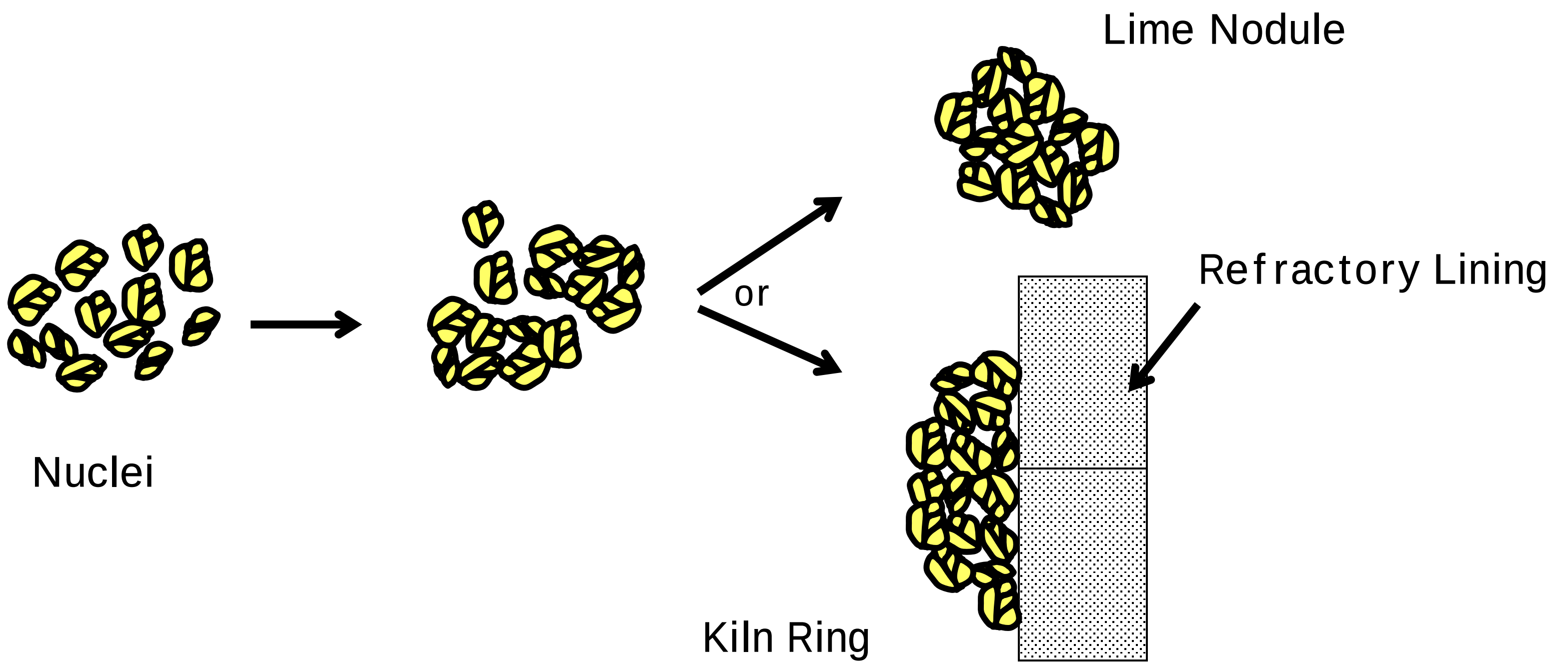


4. Burning Zone Rings: Rings are sometimes found near the end of the flame. The appearance of these is more common in lime kilns fired with oil or petroleum coke. The exact mechanism causing these rings is not well understood. The ash content of the fuel may play a key role. While no single chemical species can be pinpointed, fuels with low ash contents or fuels with very high ash melting temperatures are preferred. The flame shape (aerodynamics) and dust levels in the front of the kiln play key roles in forming these rings.

5. Soda Balls: The dust level in the freeboard above the bed is high. Up to 25% of the dry solids entering the kiln is lost as dust with the exist gases. The temperatures of the dust particles in the freeboard equilibrate with the gas temperatures. As is the case for particles in the bed, the sodium compounds form liquids when the dust particles traveling in the gas reach 1500°F. If the gas temperature distributions along the kiln are such that the sodium in the dust particles form liquids as they pass through the chain section, they may stick to the surface of the chain. Overtime, the deposits grow and due to the rolling action of the bed form ball like structures that hang on the chains. The extra weight from these deposits eventually overload the chains causing them to break. Improved chain system designs have greatly reduced the occurrence of these deposits.

Mechanism for Mid-Kiln Ring Formation

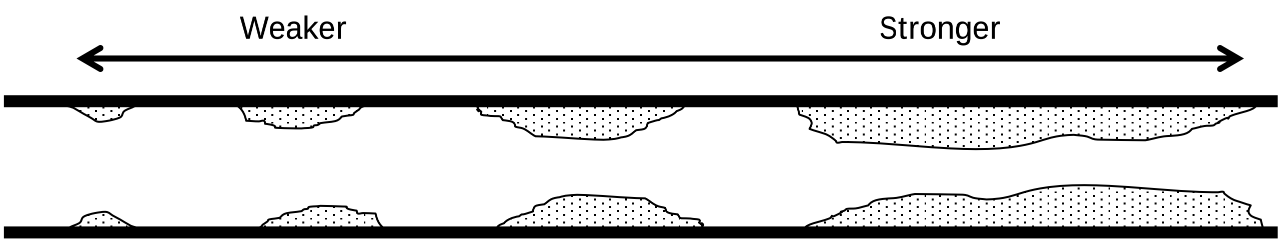
- The same mechanisms that form nodules cause mid-kiln rings to form on the refractory lining.
- The nuclei may stick to one another **or** the refractory lining forming a ring.



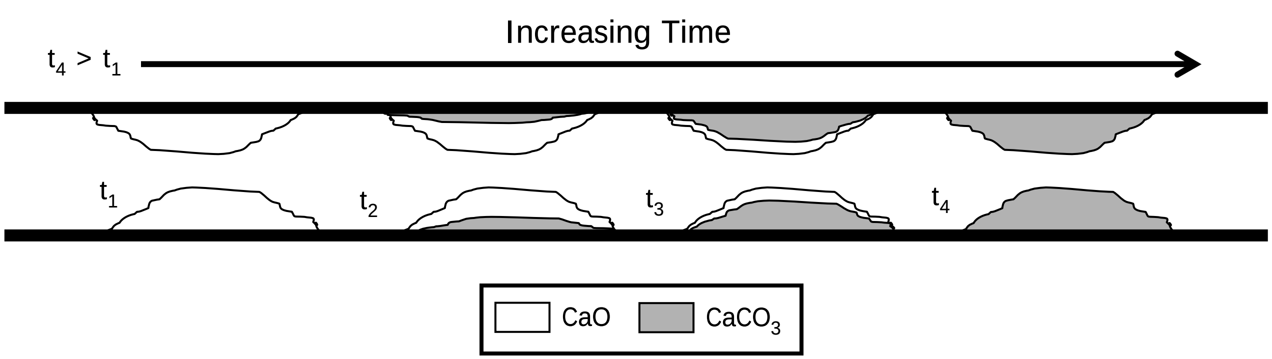
Strength of Mid-Kiln Ring

The strength of mid-kiln rings increases with:

⌘ Size - Thicker longer rings are much stronger and harder to remove



⌘ Recarbonization ($CaO + CO_2 \rightarrow CaCO_3$) - Reforming $CaCO_3$ from CaO in the ring strengthens it to the point it will not fall out



Mud Compositions (early 1990's)

Mill Location	Al (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)	Na (ppm)	P (ppm)	Si (ppm)	S(total) (%)
Mill #1	742	691	2350	81	**5800**	827	1300	0.12
Mill #2	1010	795	5470	98	**6200**	2230	990	0.17
Mill #3	92	120	1760	158	**7200**	1070	<200†	0.06
Mill #4	807	506	2870	43	**7800**	5000	910	0.09
Mill #5	376	1040	5410	305	**7800**	7440	1100	0.18
Mill #6	1560	1450	5430	81	**7860**	8340	741	0.15
Mill #7	726	753	3710	117	**8500**	3000	860	0.18
Mill #8	763	1310	2700	260	**11000**	2460	1000	0.31
Average	**760**	**833**	**3713**	**143**	**7770**	**3796**	**986**	**0.16**

† Below limit of detection

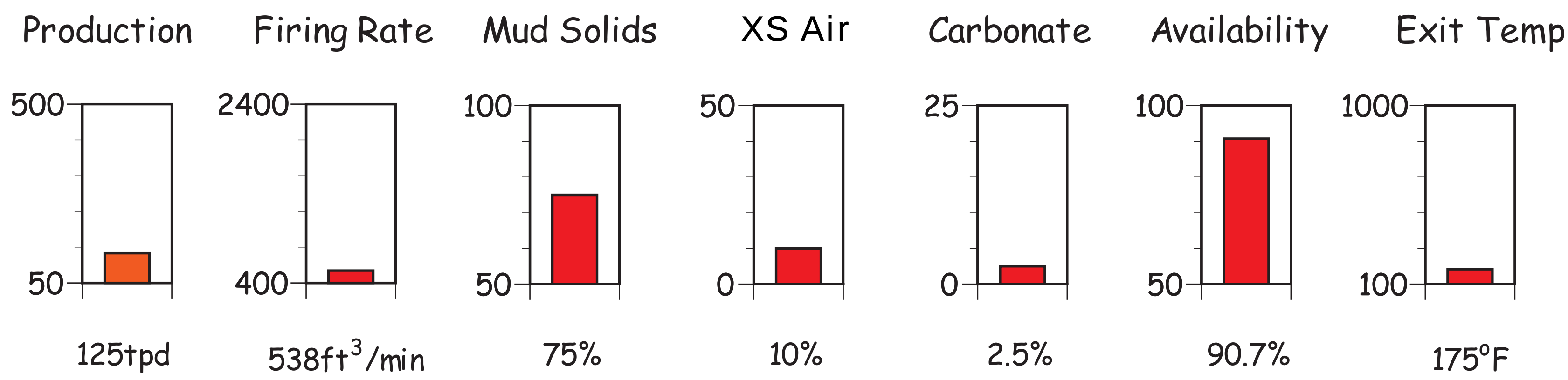
- Occasional Problems with Rings (grey)
- Moderate Problems with Rings (white)
- Severe Problems with Rings (yellow)

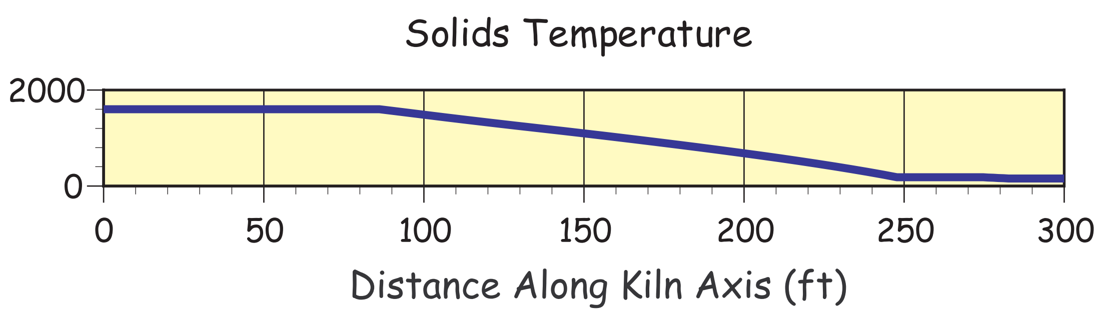
Factors Impacting High Temperature Agglomeration

- Chemical composition and amount of matrix phase
- Particle size distribution of mud
- Lime purge rates
- Sources of fresh lime
- Impurities in wood chips
- Handling of dust recycle
- Ash composition of fuel
- Composition of refractory lining
- Chemicals used for make up

Impact of Production on Ring Formation

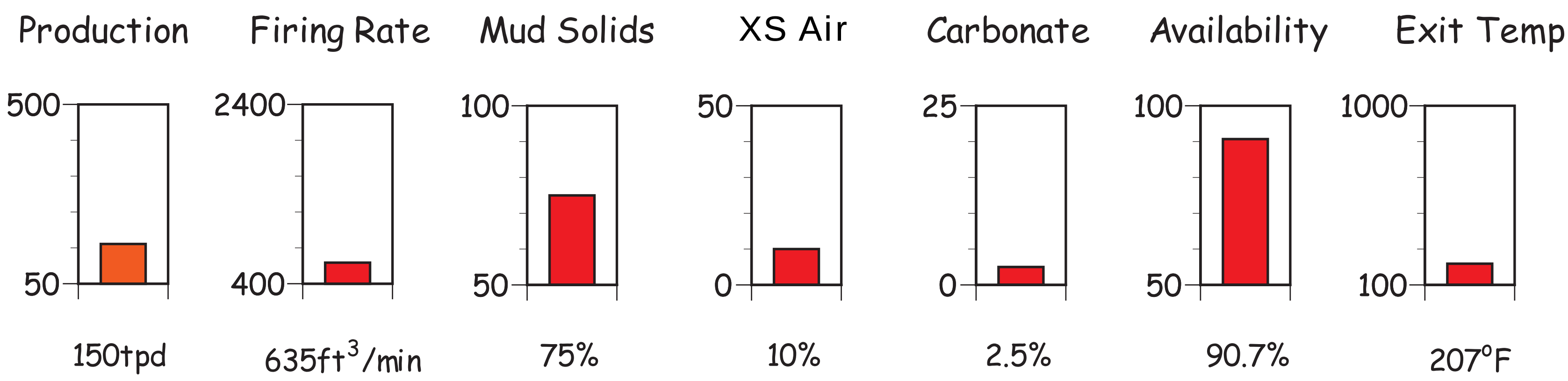
125 tpd


Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
125tpd
538ft^3/min
75%
10%
2.5%
90.7%
175°F

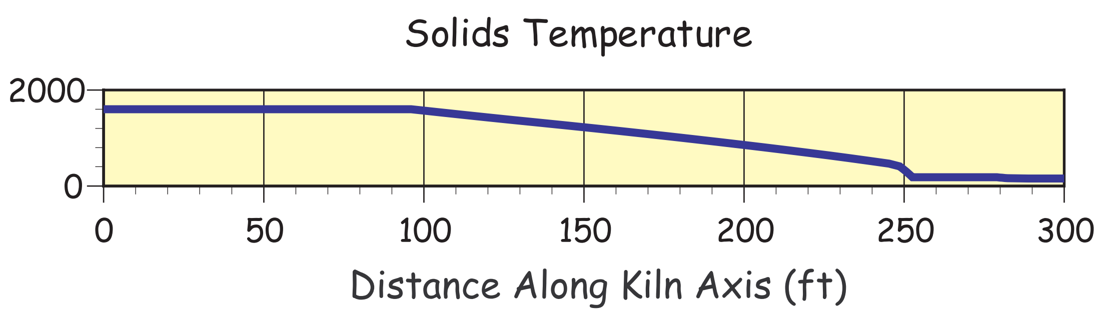

Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)


Gas Flow
Solids Flow

150 tpd



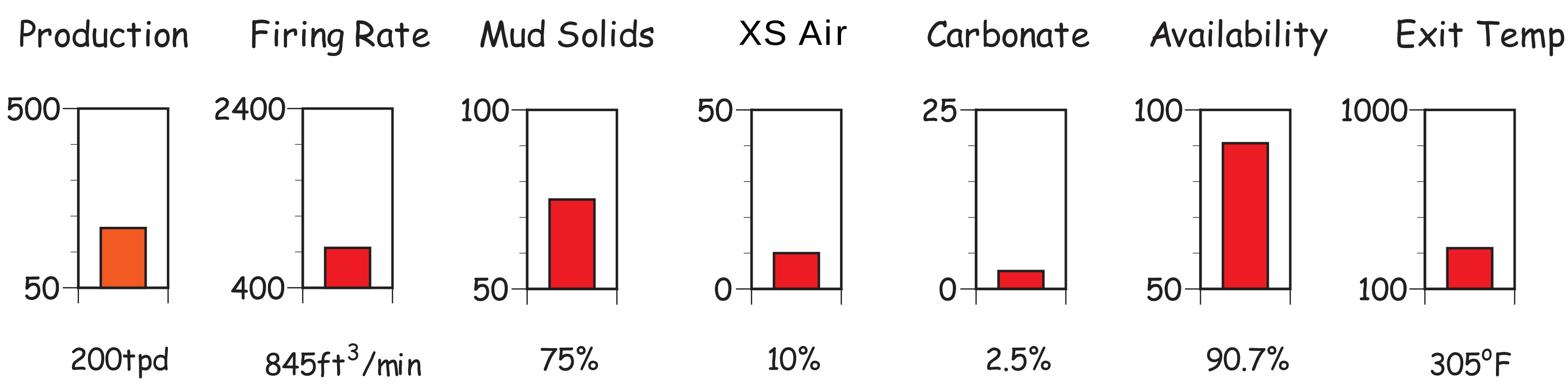
Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
150tpd
635ft3/min
75%
10%
2.5%
90.7%
207°F



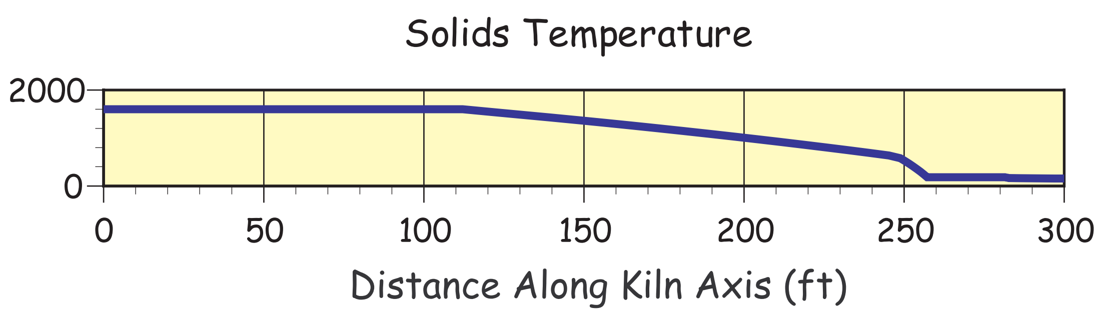
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

Gas Flow
Solids Flow

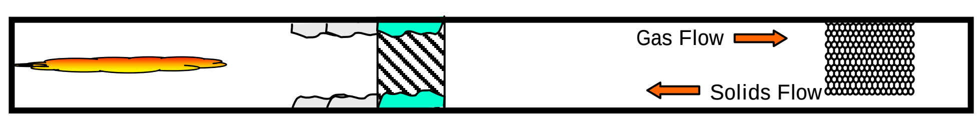
200 tpd



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
200tpd
845ft3/min
75%
10%
2.5%
90.7%
305°F

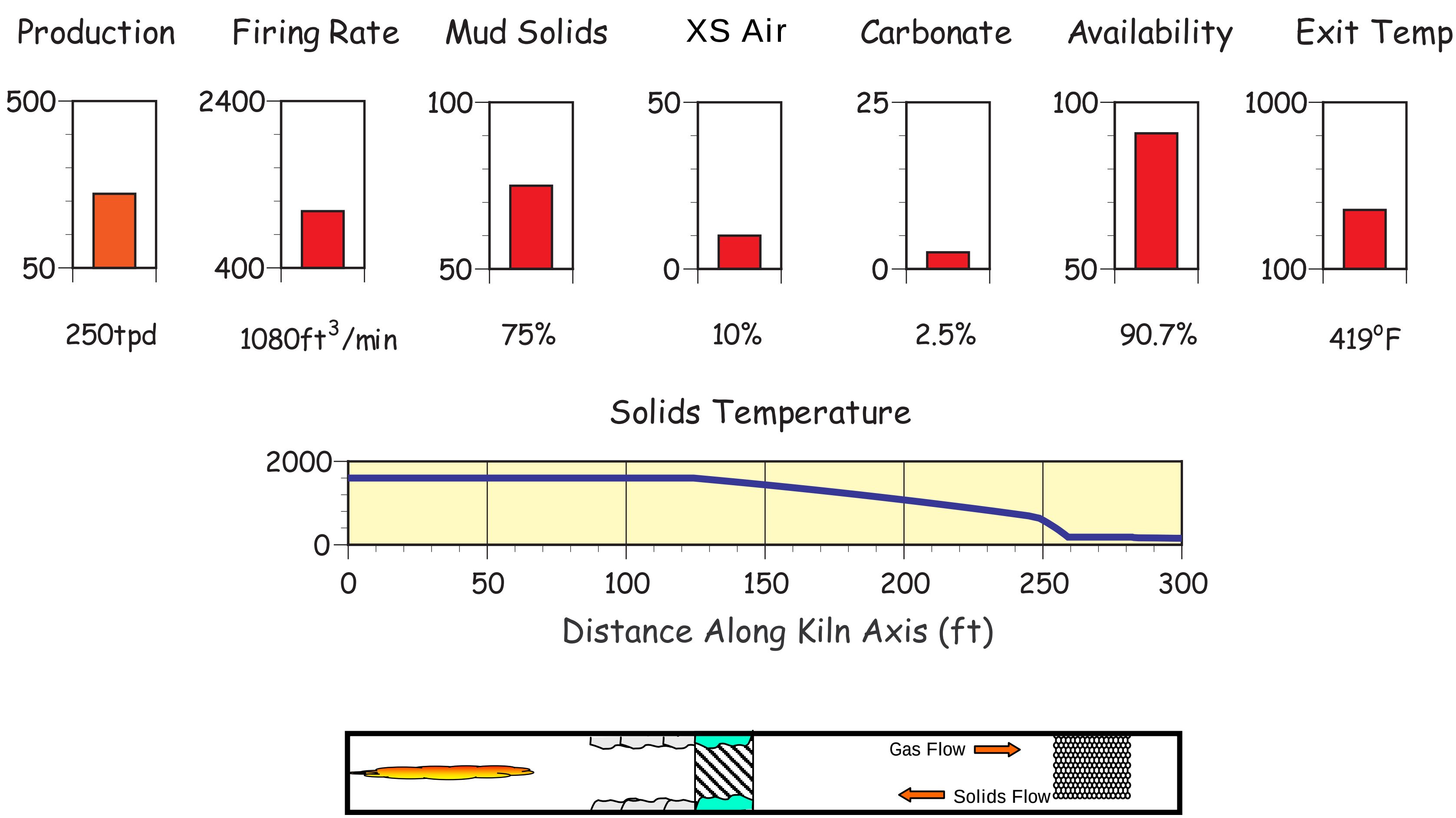


Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)



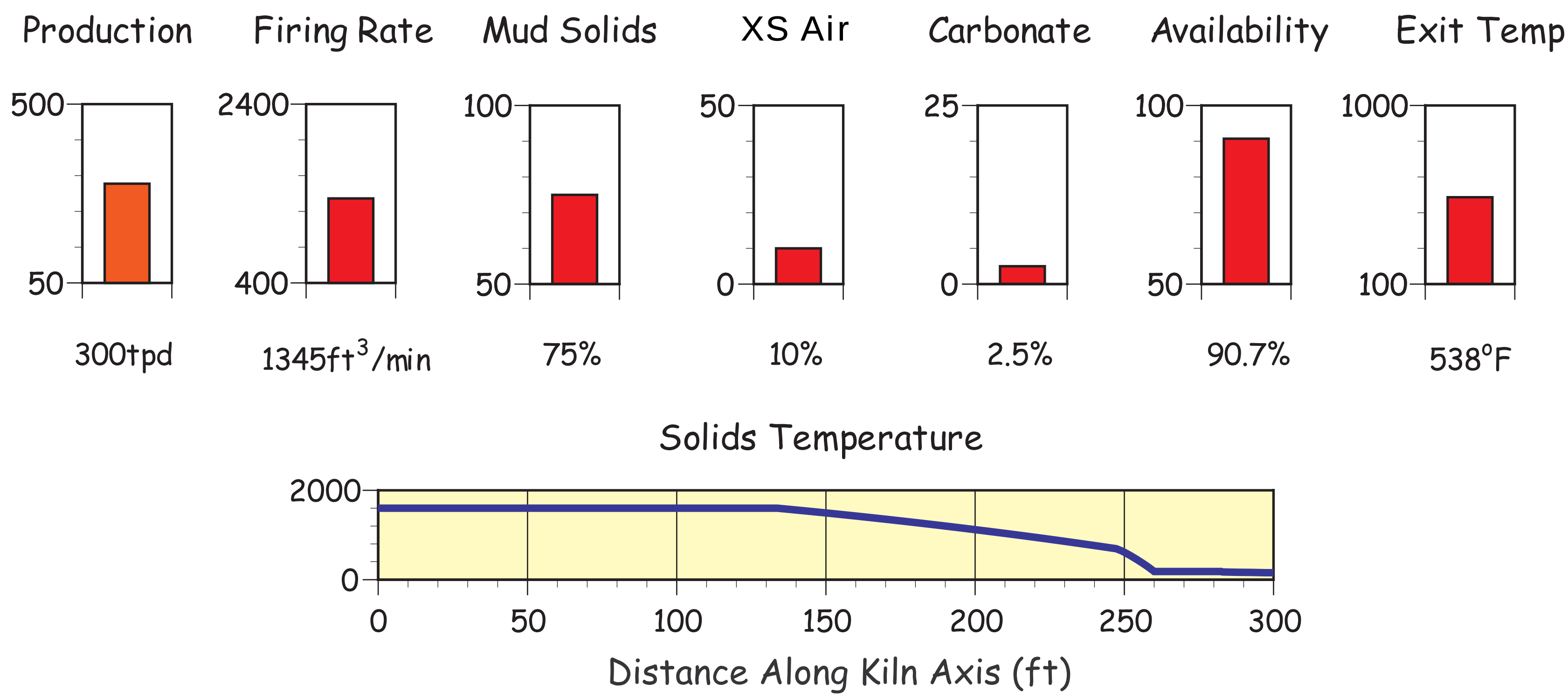
Gas Flow
Solids Flow

250 tpd

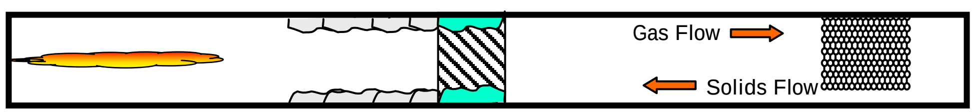


Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
250tpd
1080ft3/min
75%
10%
2.5%
90.7%
419°F
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)
Gas Flow
Solids Flow

300 tpd

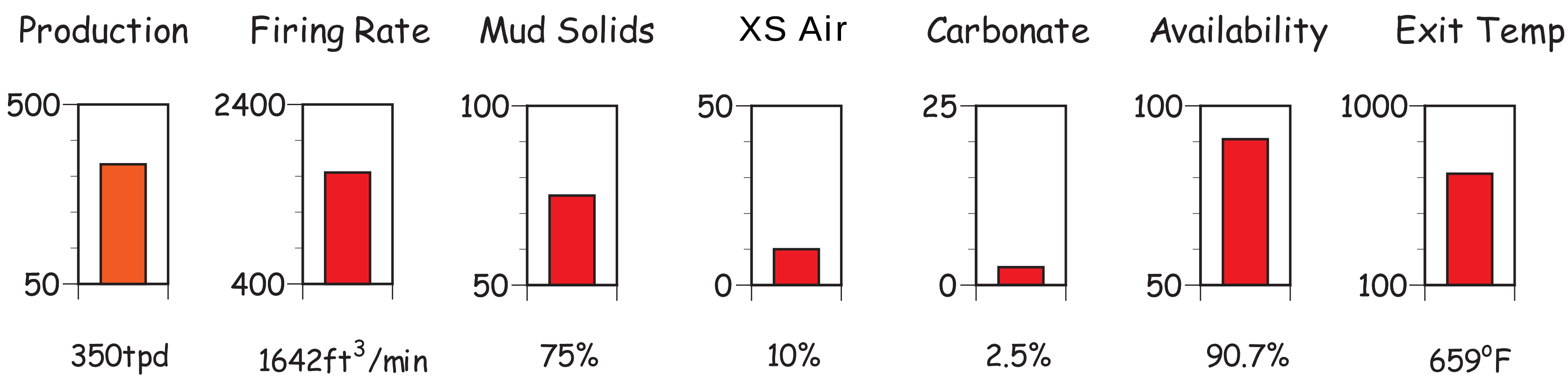


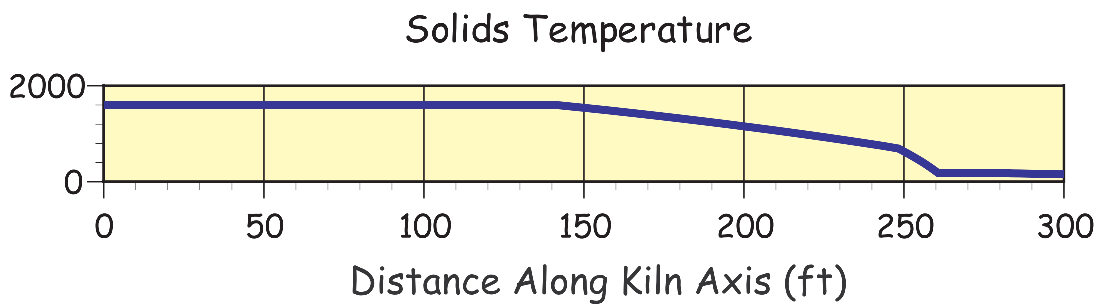
Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1345ft3/min
75%
10%
2.5%
90.7%
538°F
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

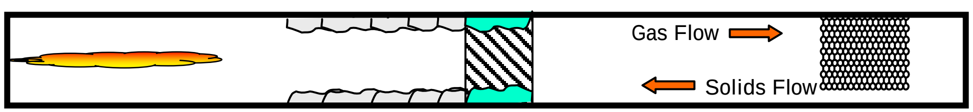


Gas Flow
Solids Flow

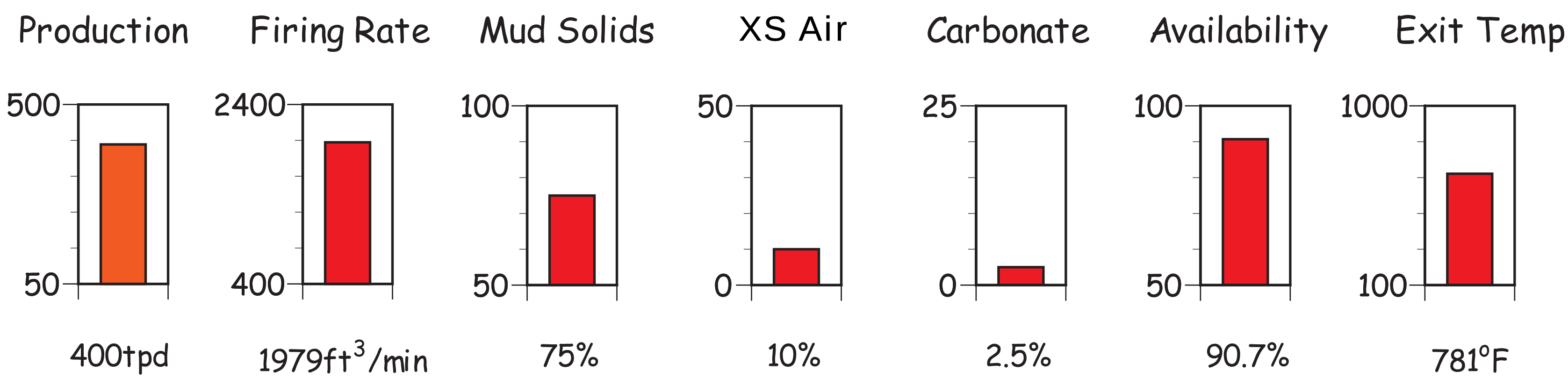
350 tpd

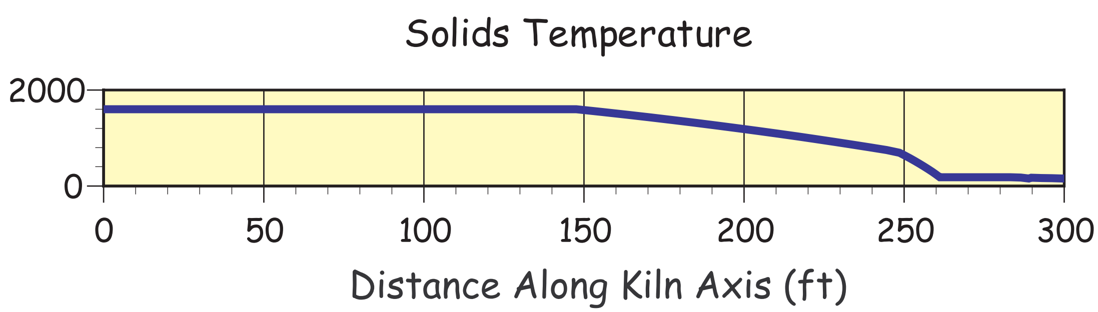

Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
350tpd
1642ft3/min
75%
10%
2.5%
90.7%
659°F

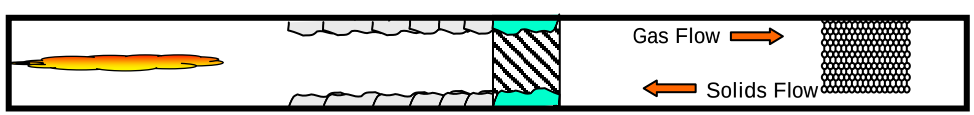

Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)


Gas Flow
Solids Flow

400 tpd

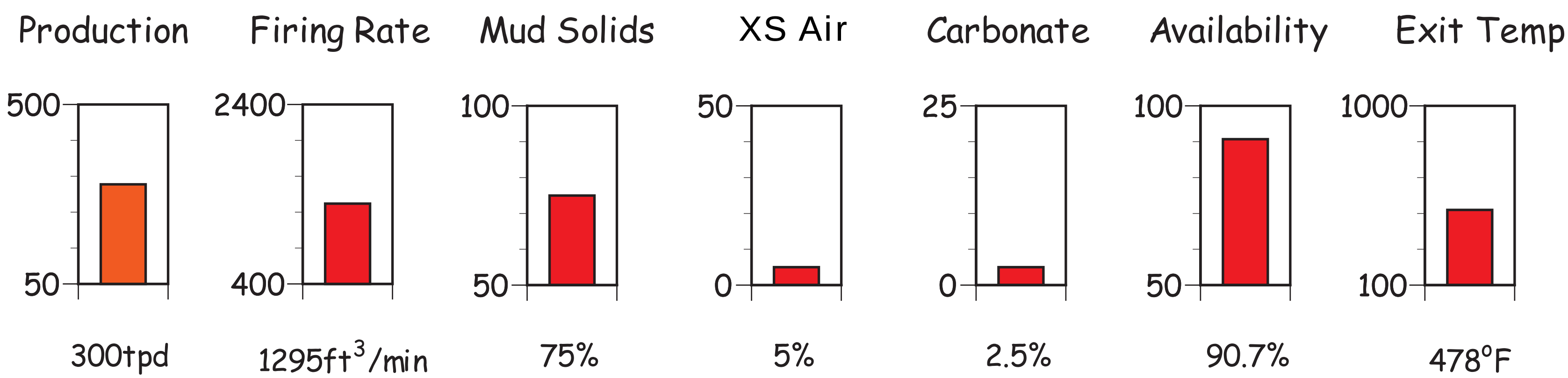

Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
400tpd
1979ft3/min
75%
10%
2.5%
90.7%
781°F

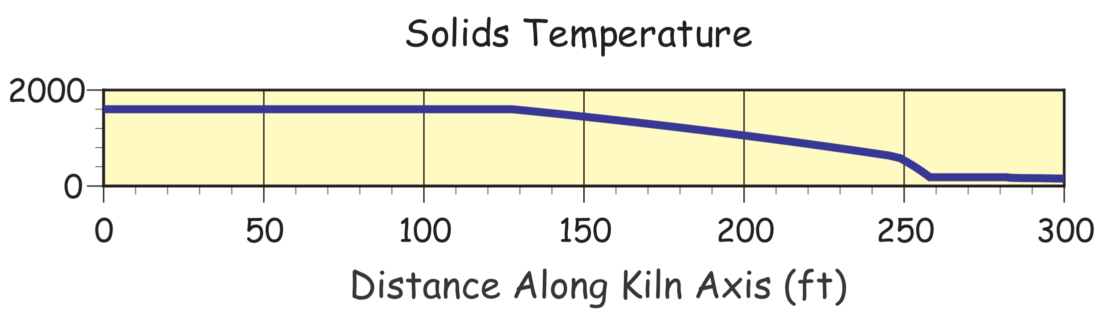

Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

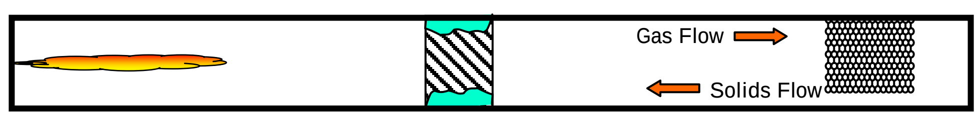

Gas Flow
Solids Flow

Impact of Mud Solids on Ring Formation

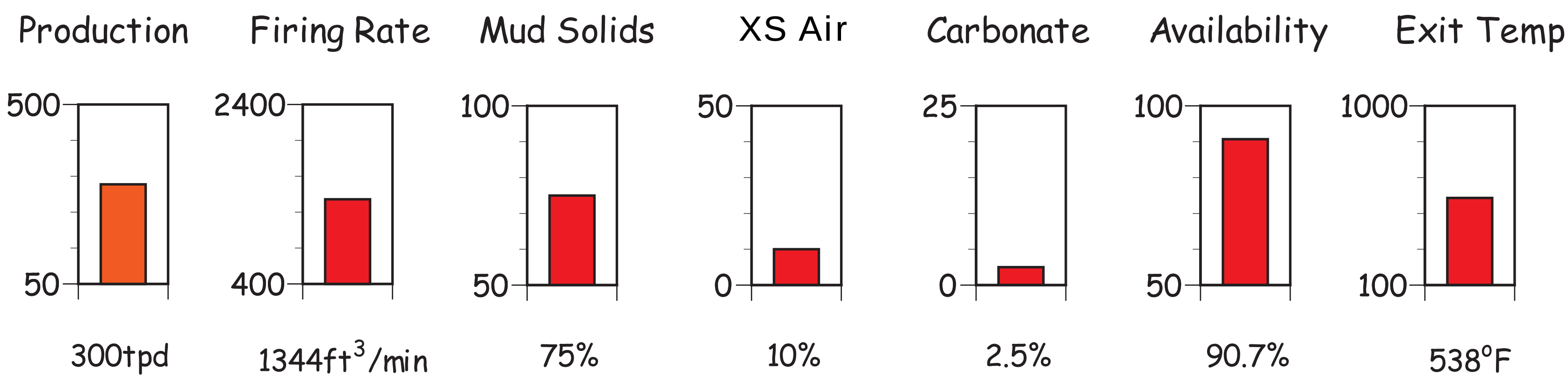
5% XS Air


Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1295ft3/min
75%
5%
2.5%
90.7%
478°F

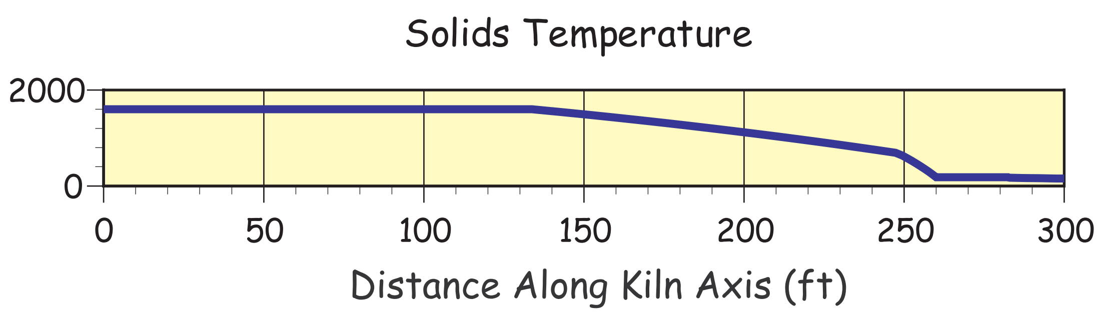

Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)


Gas Flow
Solids Flow

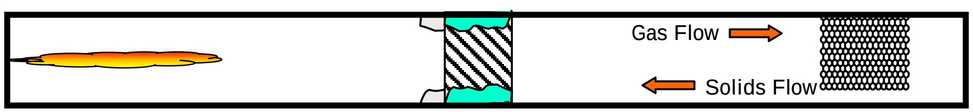
10% XS Air



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1344ft3/min
75%
10%
2.5%
90.7%
538°F

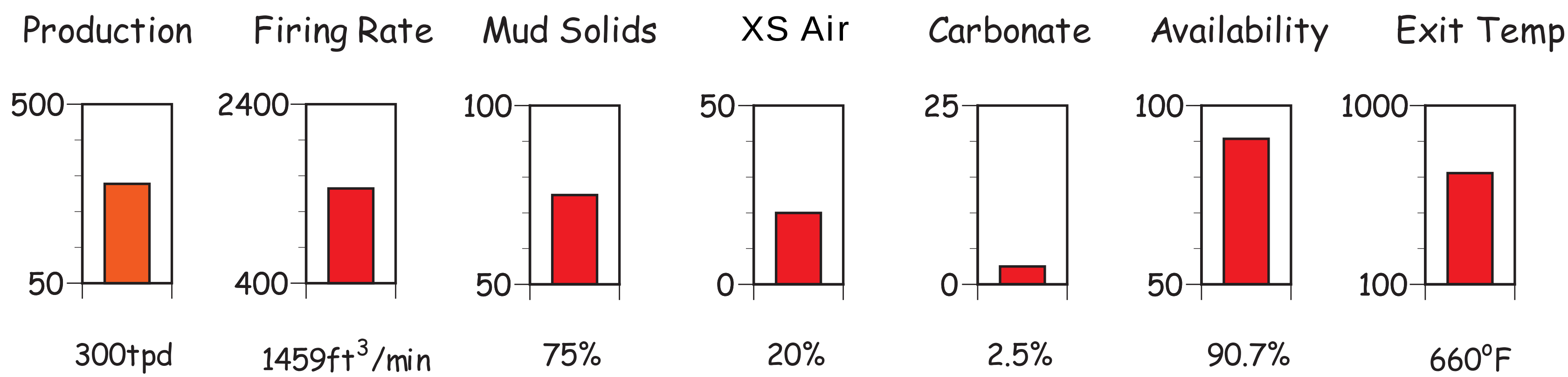


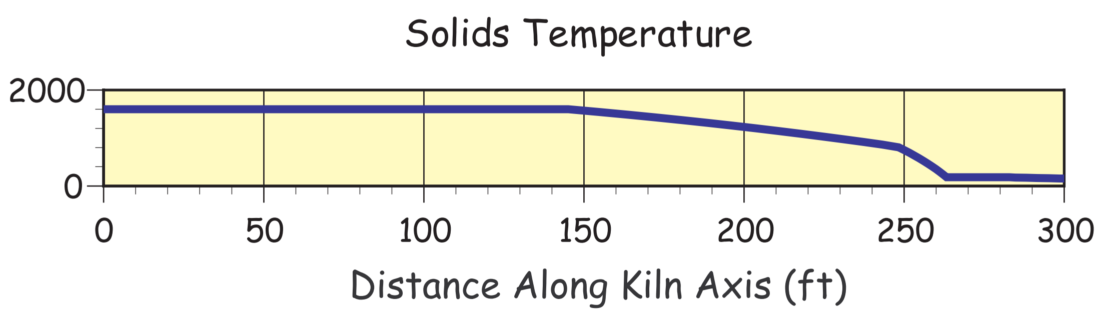
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

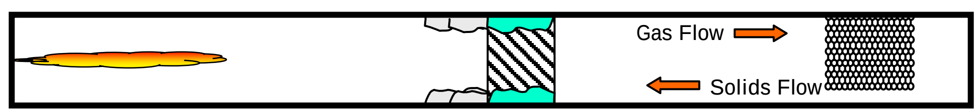


Gas Flow
Solids Flow

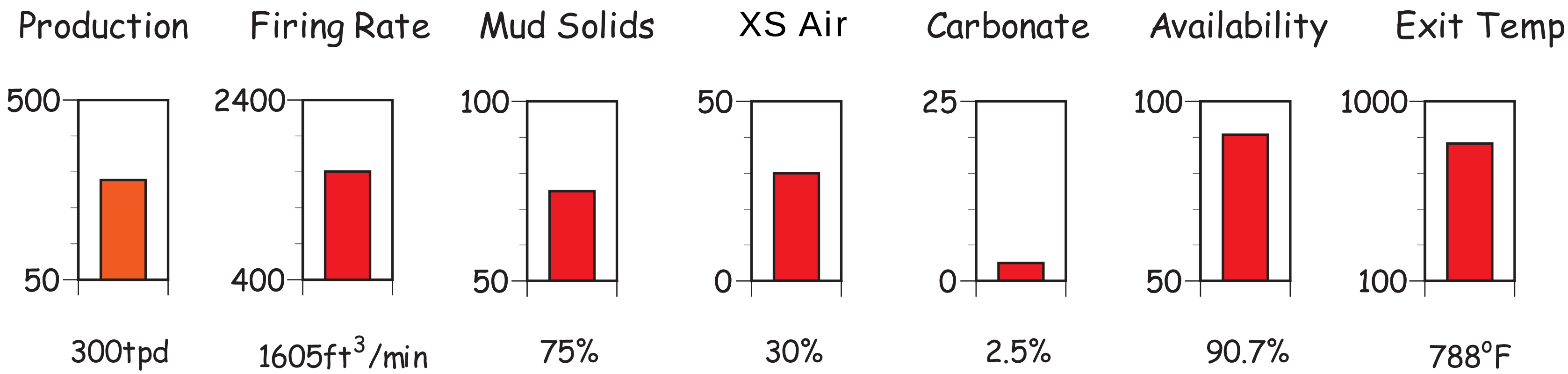
20% XS Air


Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1459ft³/min
75%
20%
2.5%
90.7%
660°F

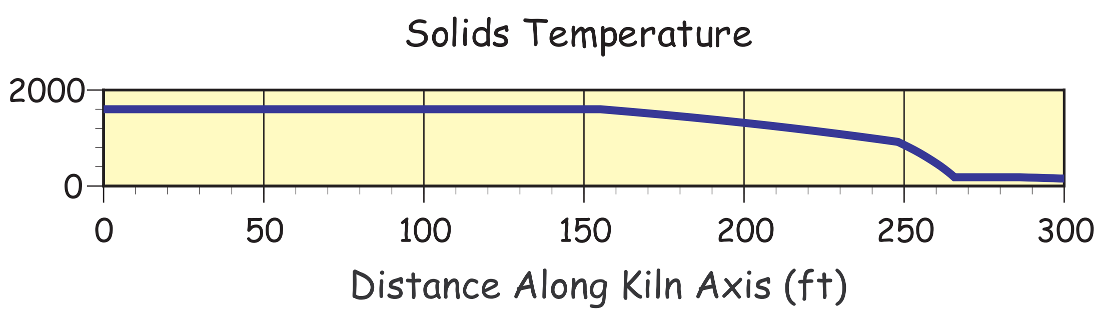

Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)


Gas Flow
Solids Flow

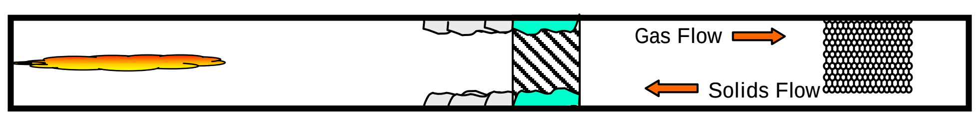
30% XS Air



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1605ft3/min
75%
30%
2.5%
90.7%
788°F

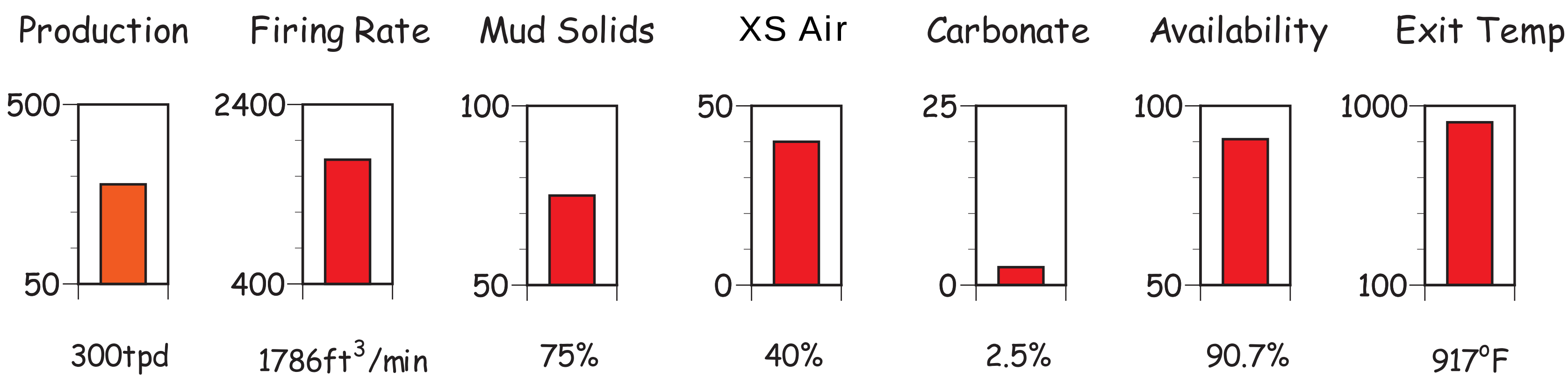


Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

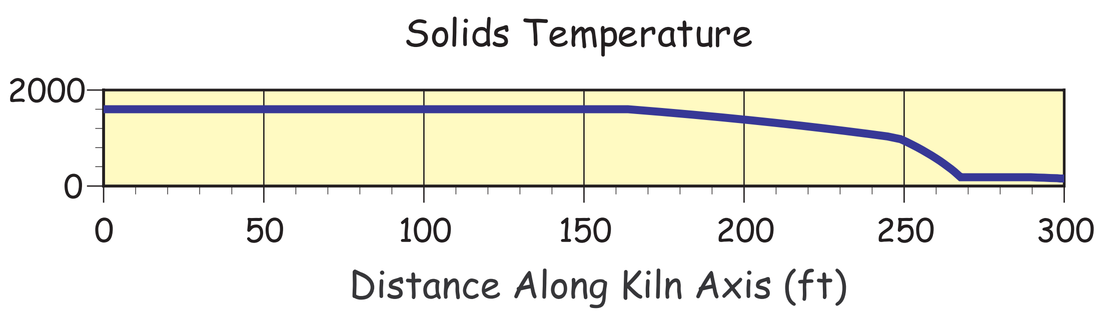


Gas Flow
Solids Flow

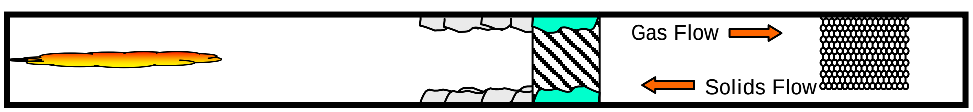
40% XS Air



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1786ft³/min
75%
40%
2.5%
90.7%
917°F



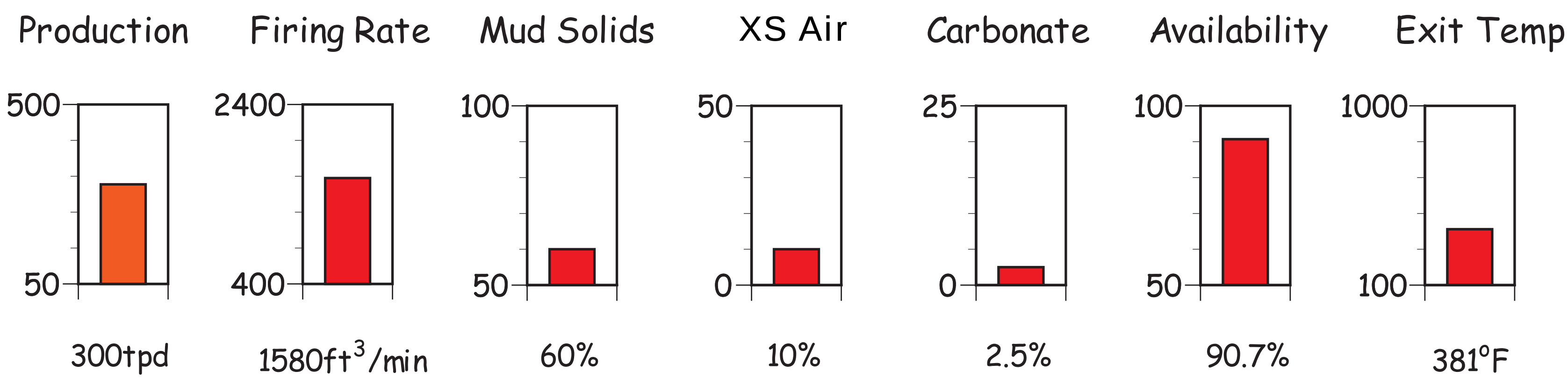
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

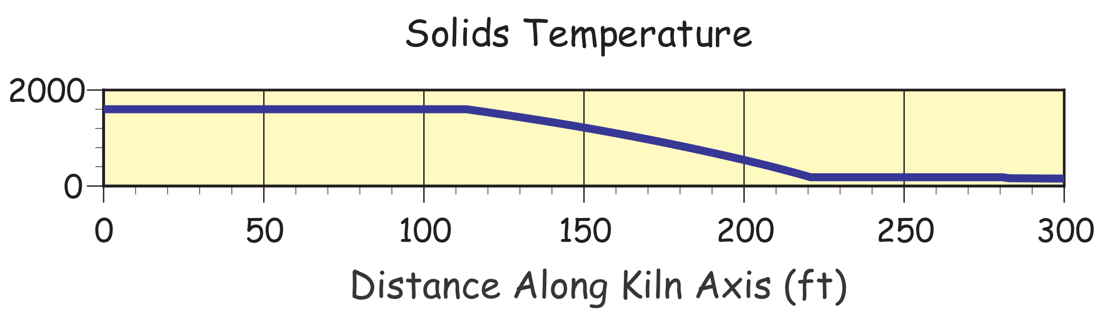


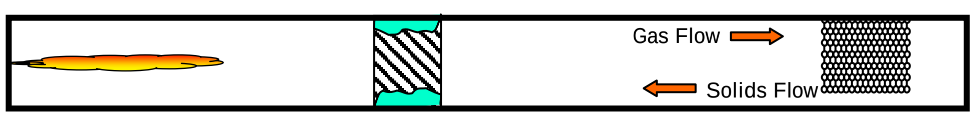
Gas Flow
Solids Flow

Impact of Mud Solids on Ring Formation

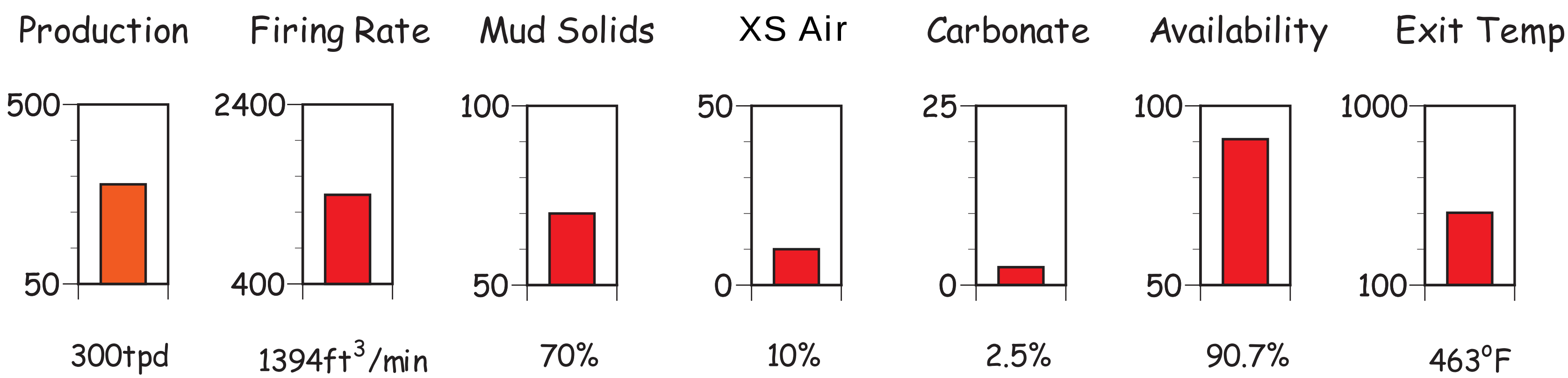
60% Mud Solids

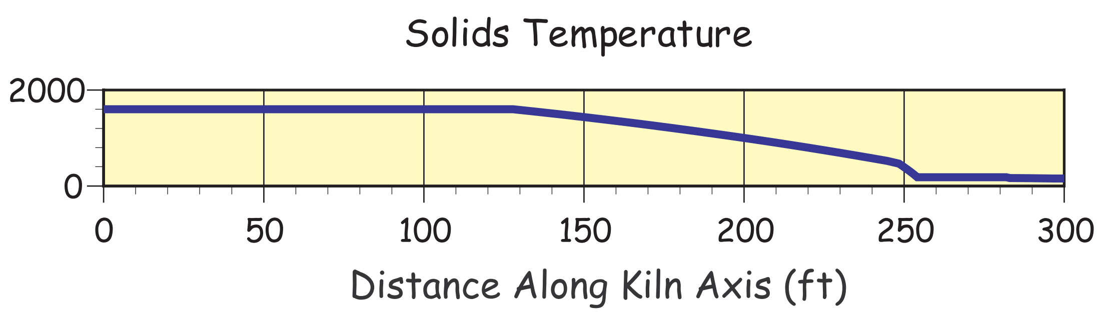


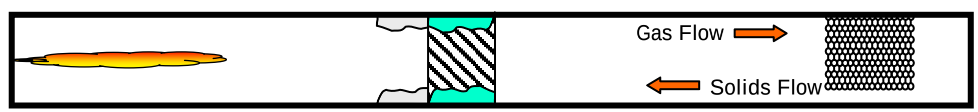




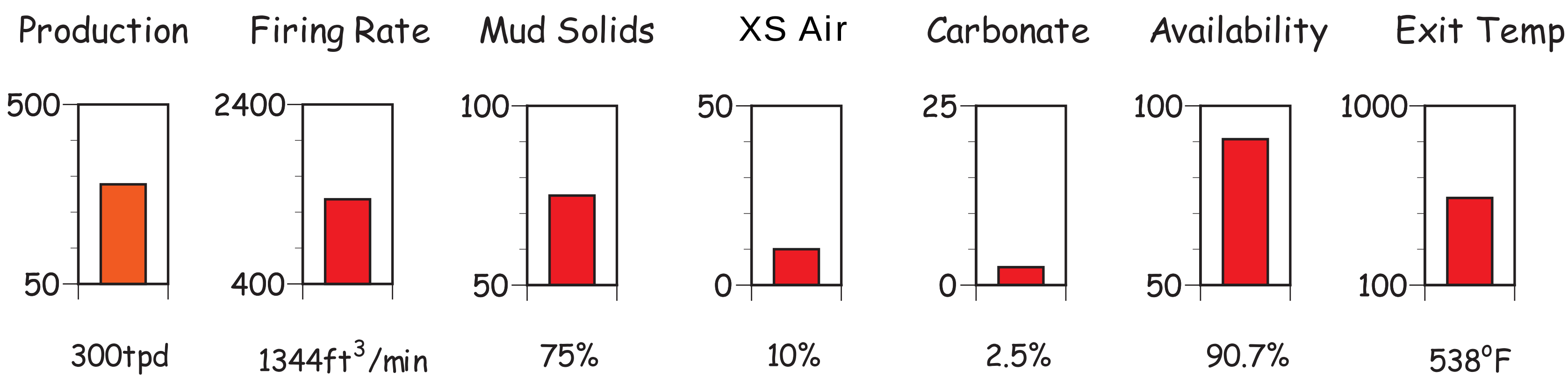
70% Mud Solids

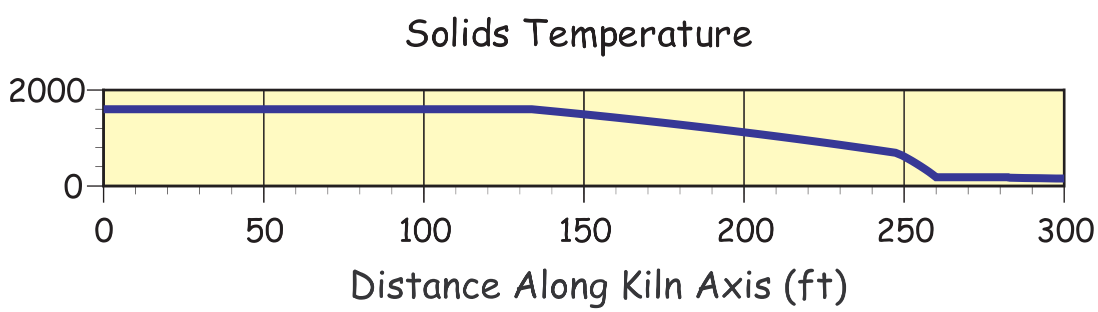


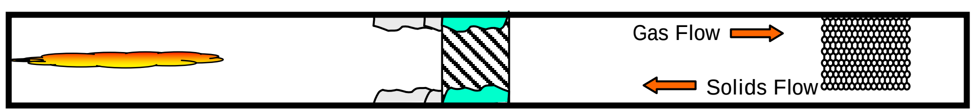




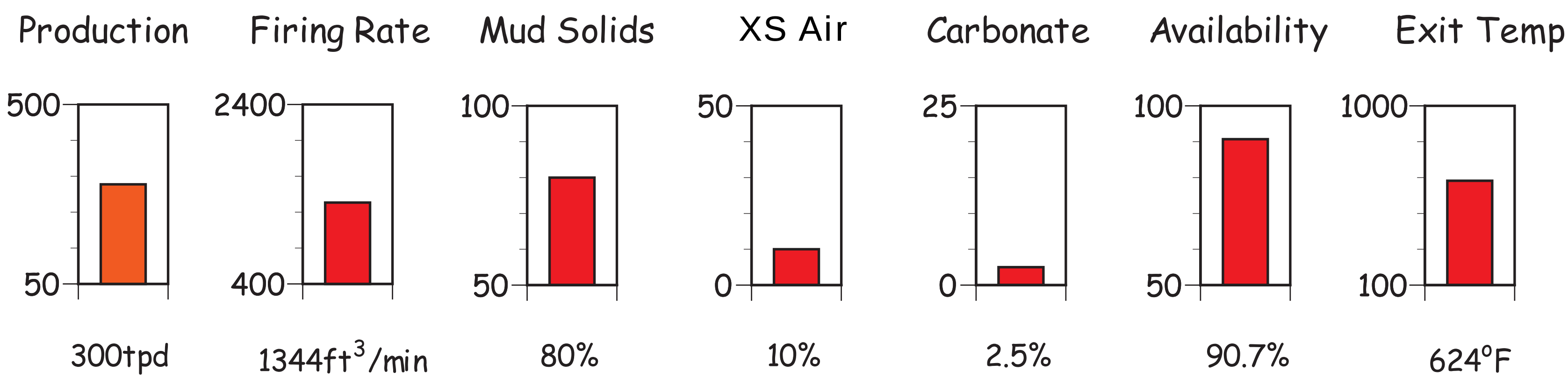
75% Mud Solids

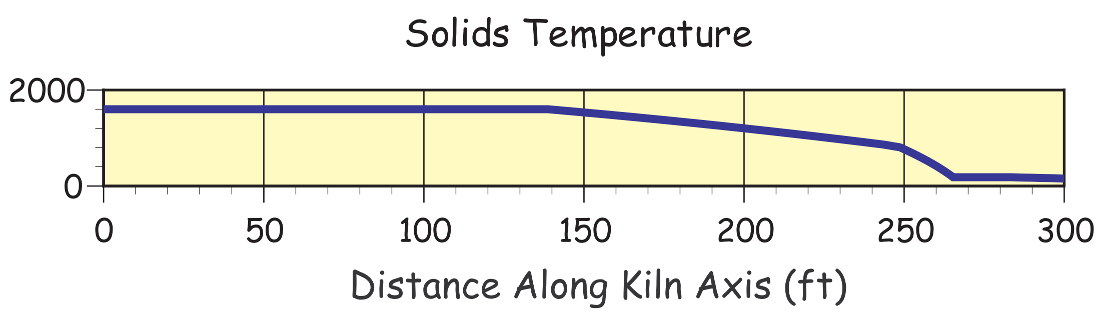


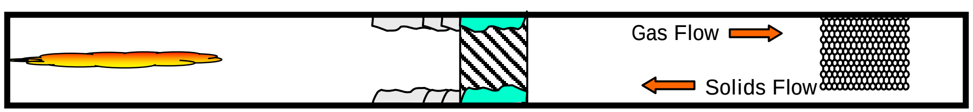




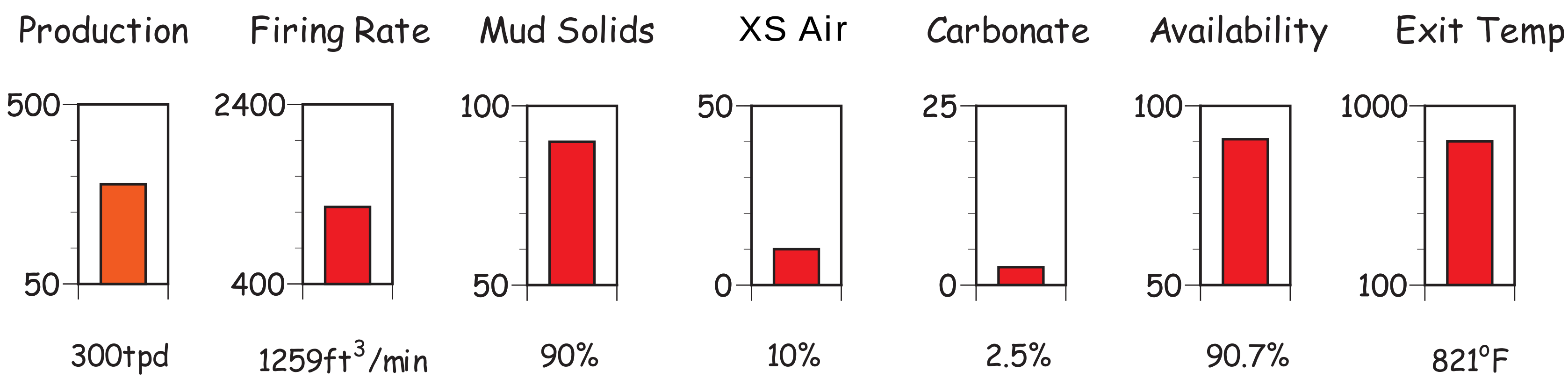
80% Mud Solids

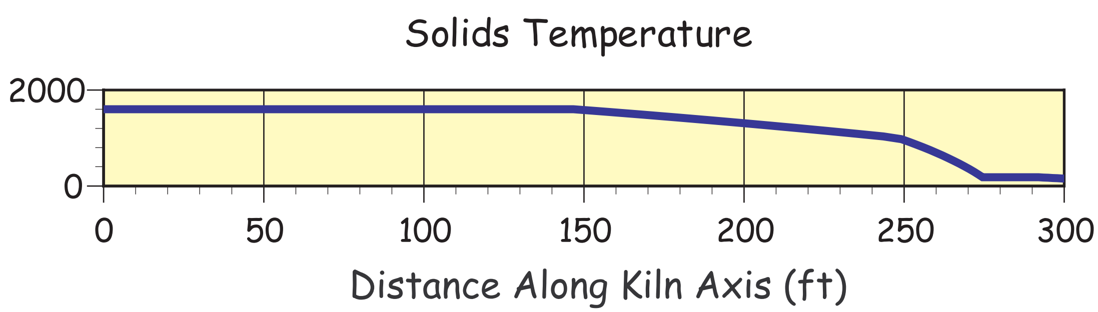


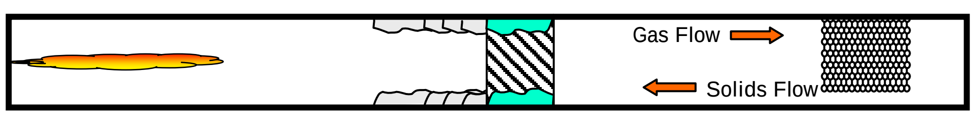




90% Mud Solids

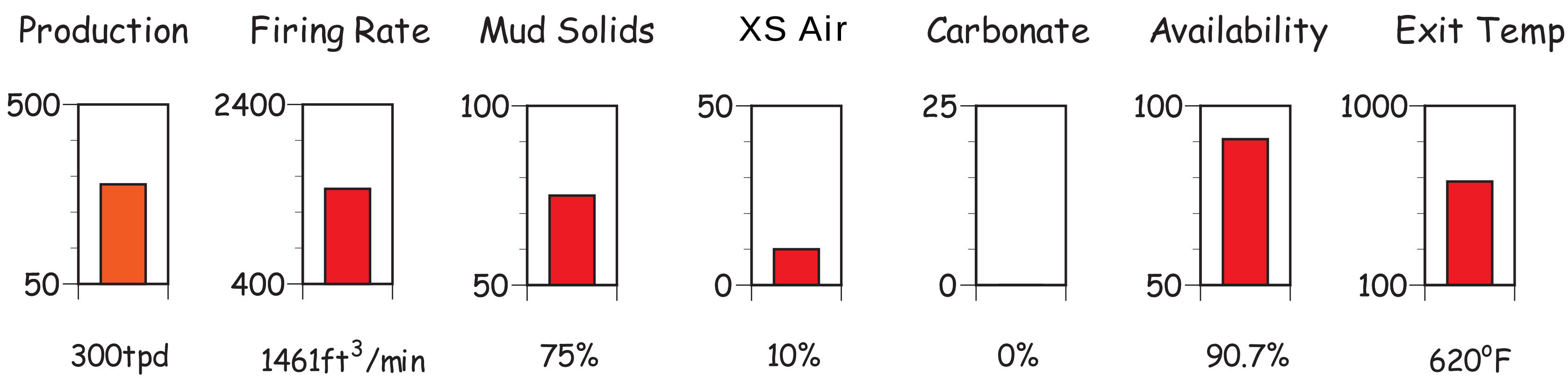




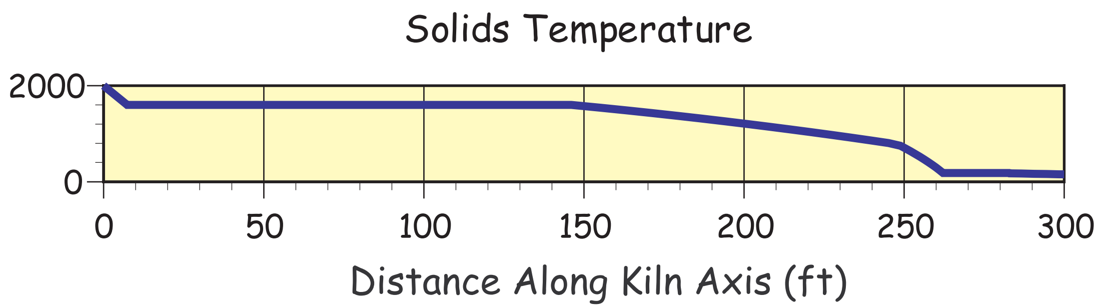


Impact of Firing Rate on Ring Formation

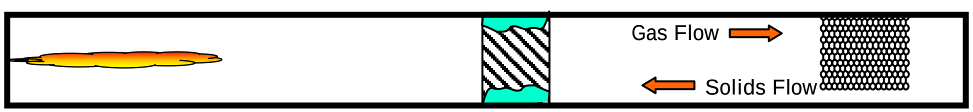
1461 ft^3/min



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1461ft3/min
75%
10%
0%
90.7%
620°F

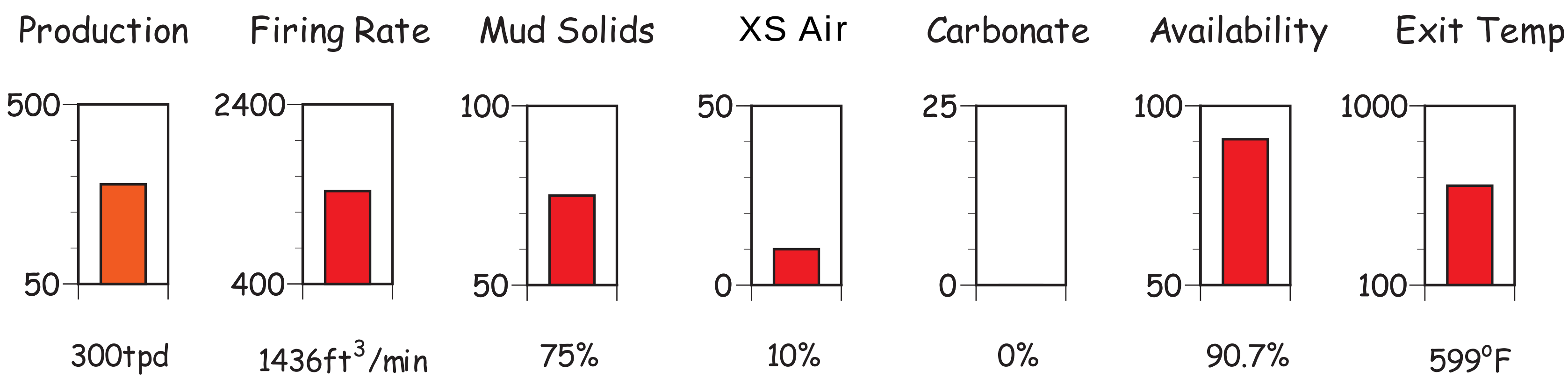


Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

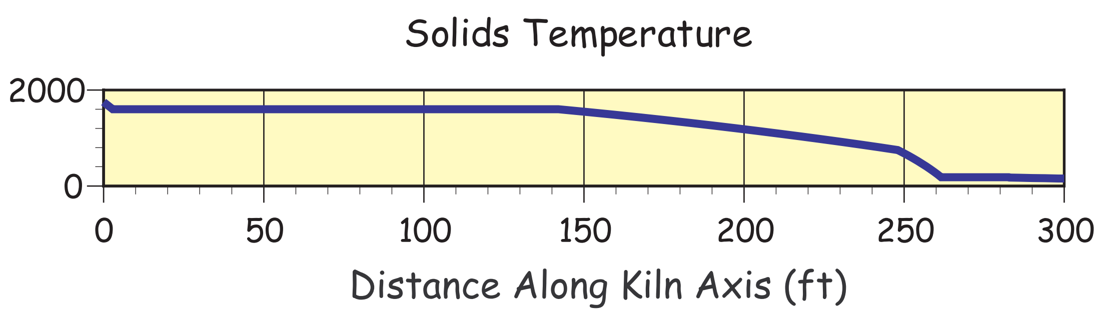


Gas Flow
Solids Flow

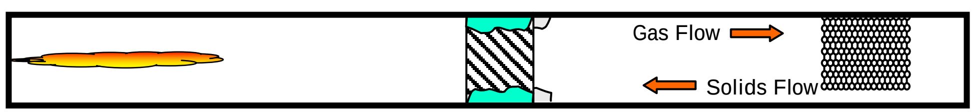
1436 ft³/min



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1436ft³/min
75%
10%
0%
90.7%
599°F

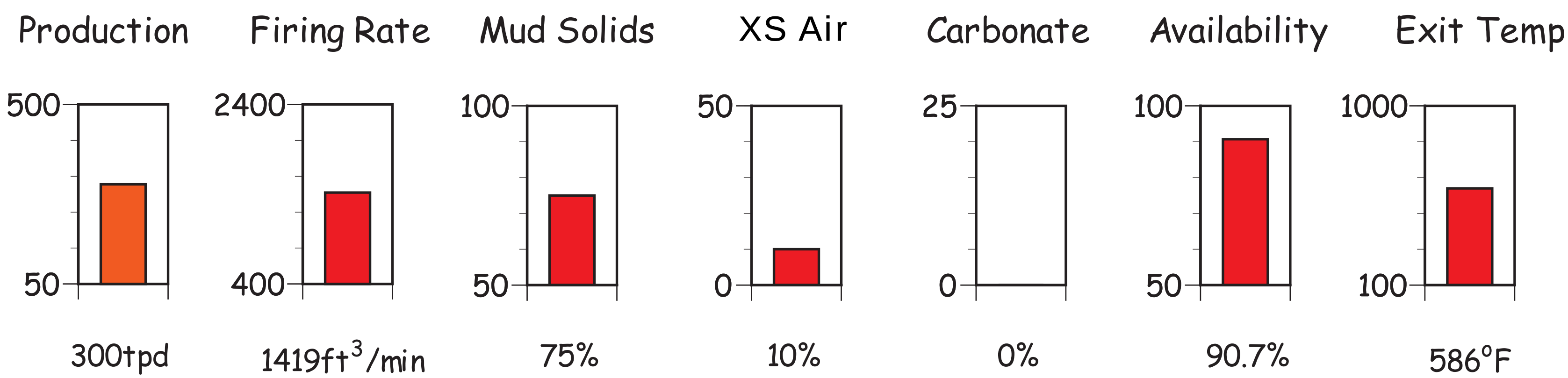


Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

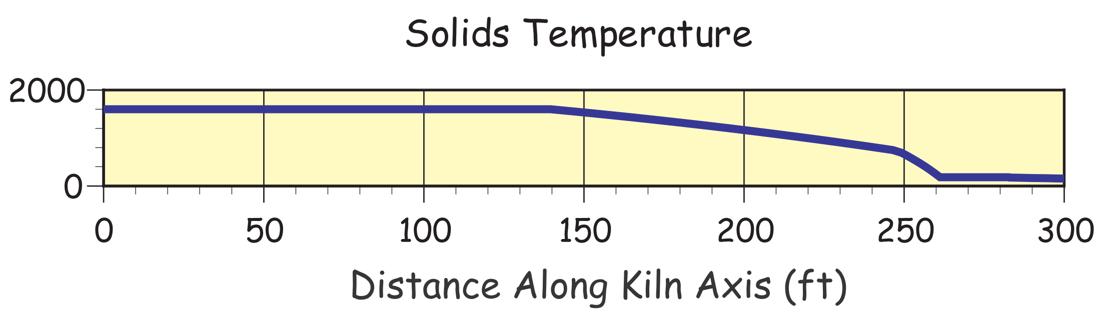


Gas Flow
Solids Flow

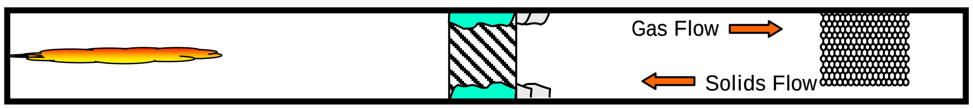
1419 ft^3/min



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1419ft3/min
75%
10%
0%
90.7%
586°F

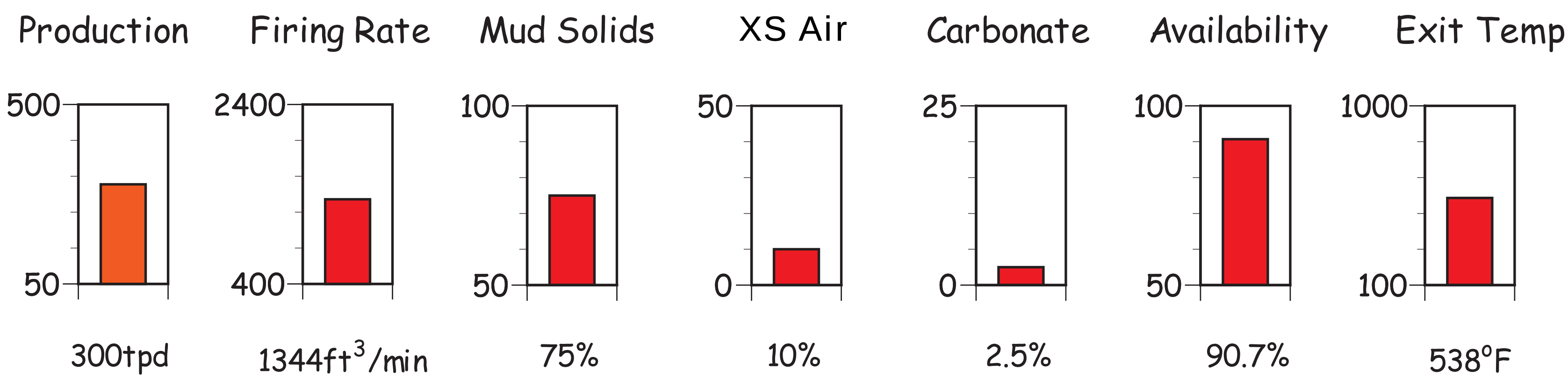


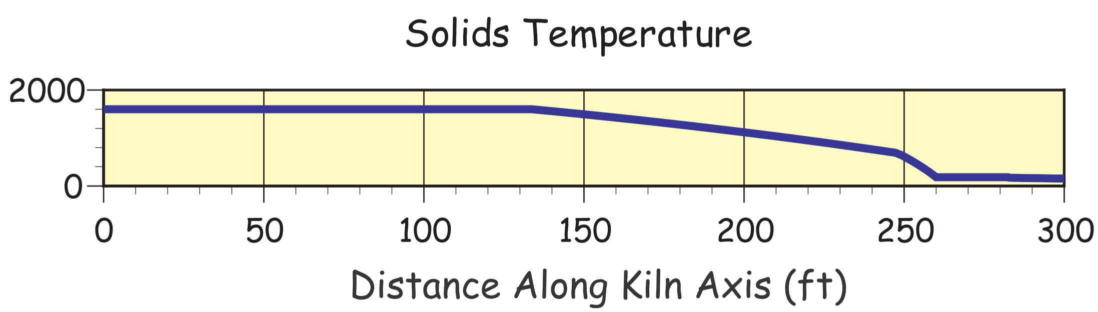
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)

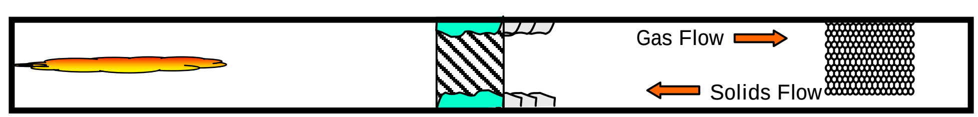


Gas Flow
Solids Flow

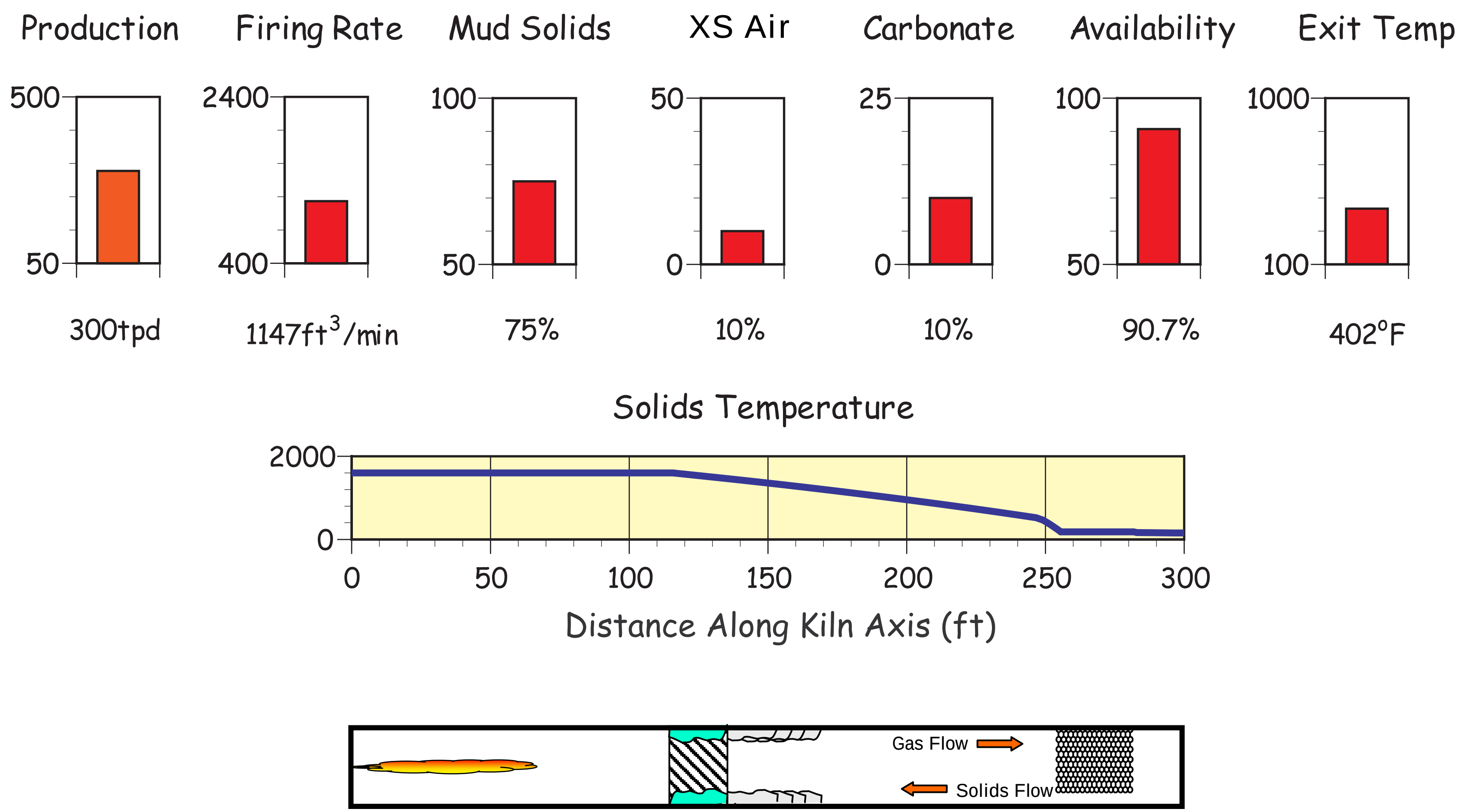
1344 ft^3/min


Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1344ft3/min
75%
10%
2.5%
90.7%
538°F

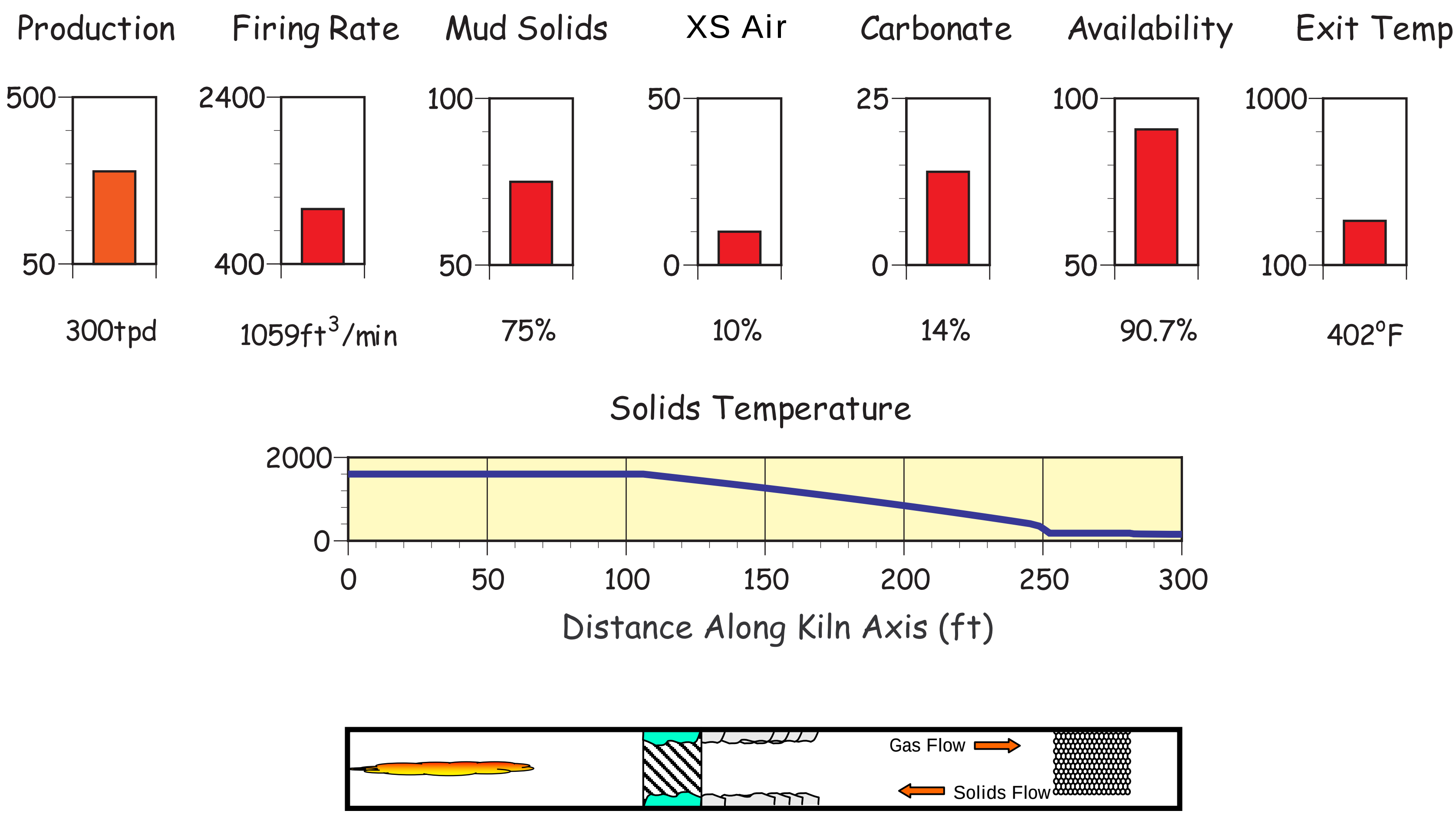

Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)


Gas Flow
Solids Flow

1147 ft^3/min

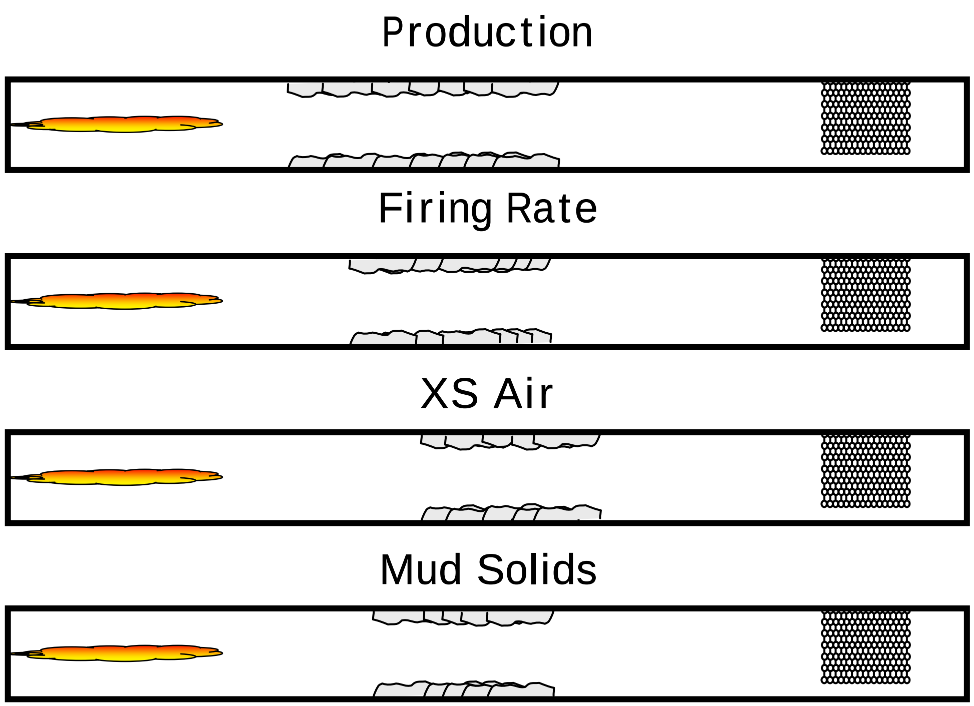

Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1147ft^3/min
75%
10%
10%
90.7%
402°F
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)
Gas Flow
Solids Flow

1059 ft^3/min



Production
Firing Rate
Mud Solids
XS Air
Carbonate
Availability
Exit Temp
500
50
2400
400
100
50
50
0
25
0
100
50
1000
100
300tpd
1059ft3/min
75%
10%
14%
90.7%
402°F
Solids Temperature
2000
0
0
50
100
150
200
250
300
Distance Along Kiln Axis (ft)
Gas Flow
Solids Flow

Ranking of the Impact of Kiln Upsets on Ring Formation



Production >> Firing Rate > XS Air ≈ Mud Solids

Ring Formation

- As long as lime sludge kiln are required to produce nodules, rings will never go away, you can only minimize their impact on operation
- To control ring growth
  - Maintain total level of sodium below 0.75% (balance between mud washing and lime purge)
  - Minimize changes to production rate (every mill should develop a rate/surge strategy)
  - Maintain consistent product quality (constant level of residual carbonate)

Stability… Stability… Stability…

Lime Kiln Capacity Constraints

- There is no fixed upper limit to the capacity of the lime kiln itself. The production is limited by constraints on the peripheral equipment.
- There are nine major constraints on the production rate of a lime sludge kiln are:
  - ✓ Mud flow into the kiln - mud filter, conveyors and feed screws
  - ✓ Product flow out of the kiln - lump crusher, drag conveyors, bucket elevator and kiln drive
  - ✓ Gas flow out of the kiln - ID fan
  - ✓ Fuel flow into the kiln - fuel valve train, primary air fan and burner
  - ✓ Air flow into the kiln - firing hood and coolers
  - ✓ Materials temperature limits - metal shell, refractory surface, chains, ID fan and precipitator
  - ✓ Environmental emissions - particulate, NO_x and TRS
  - ✓ Structural design - kiln shell, trunnions, tires and foundations
  - ✓ Operational problems - mud balls, poor nodulization and ring formation
- Ultimately the material temperature limits and operation problems play the most significant role in determining the maximum capacity for most kilns.

Examples of Lime Kiln Problem Solving

Original Pillard Burner at Longview

Pillard Burner

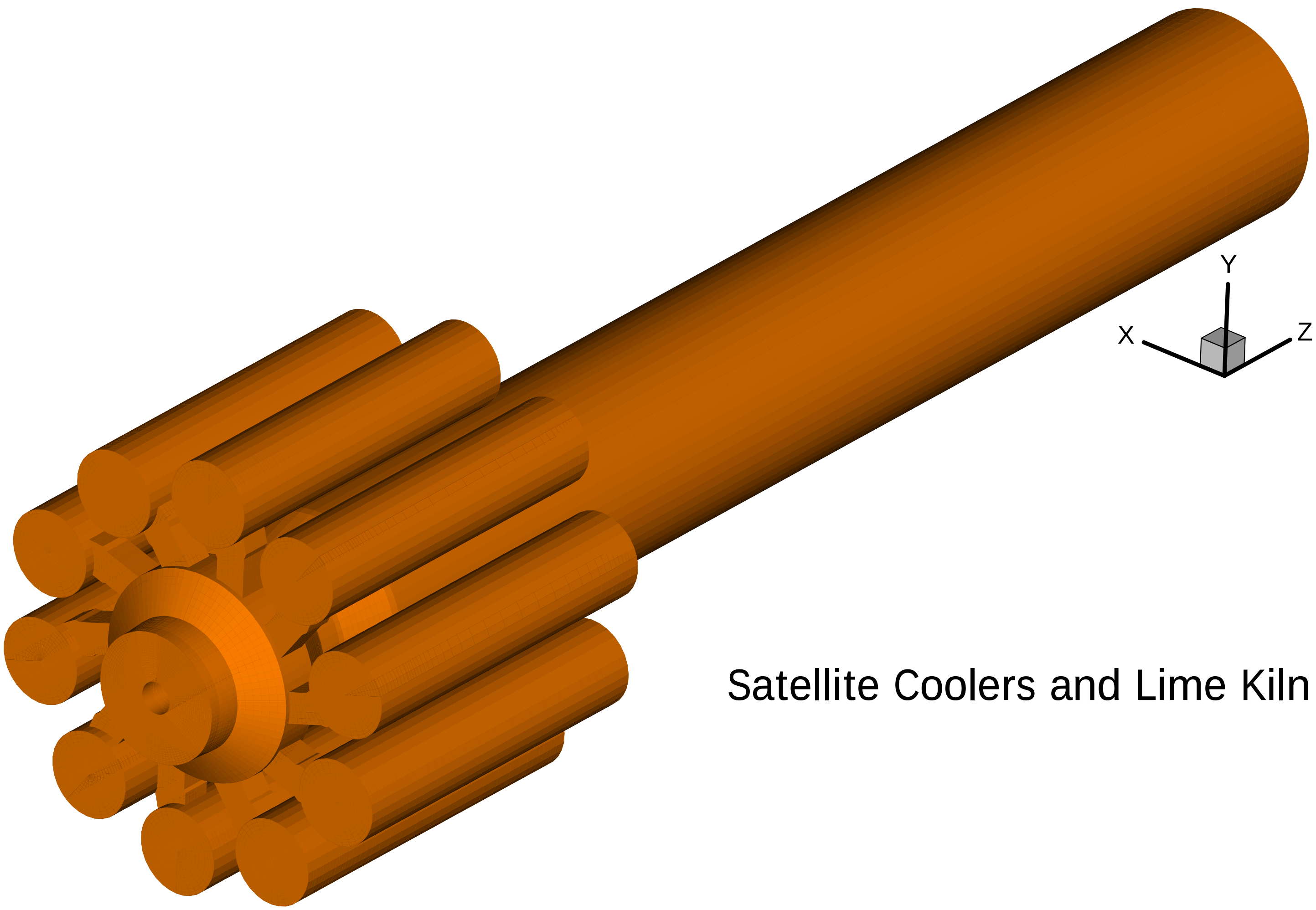
- High momentum burner (CC =6.65)
- Short flame slightly pushed to the left side of the kiln (looking from the front-end)
- Large amount of recirculation
- No impact from NCG stream
- Corrected flame length is 41 ft
- Recommend replacing Pillard burner

Optimized KFS OPTIMIX Burner

KFS Burner

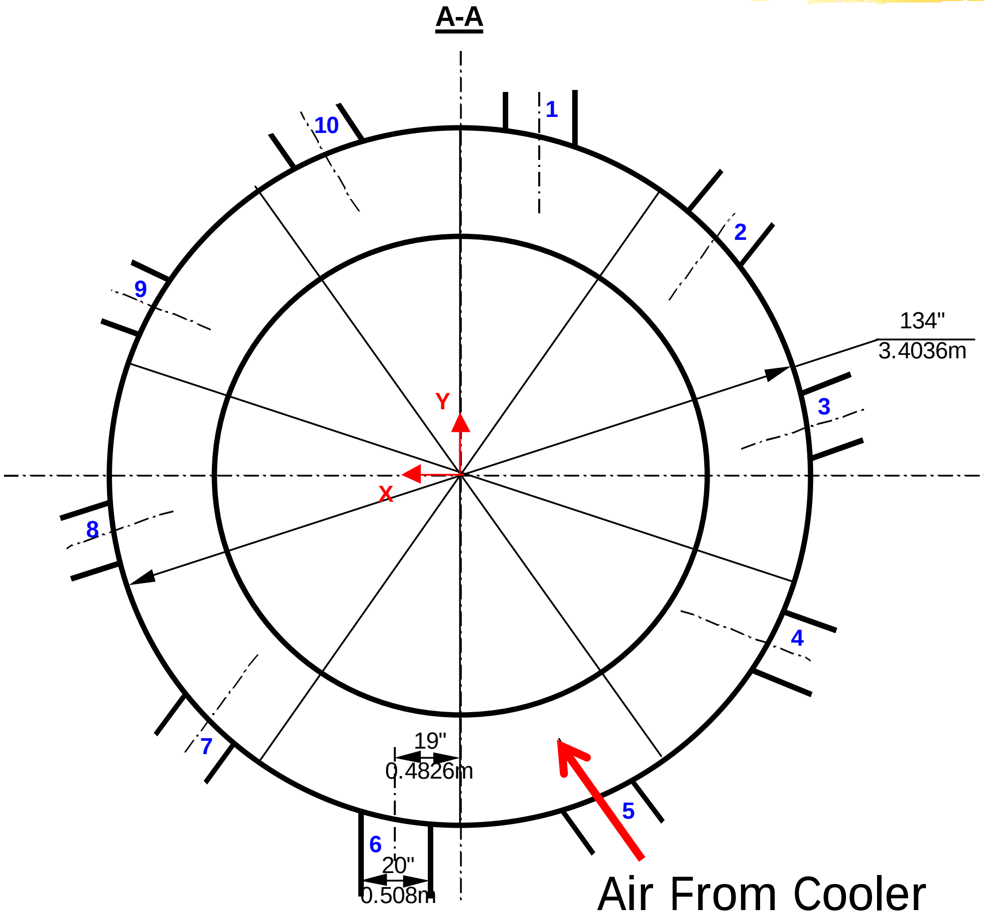
- Lower momentum burner (CC=2.5)
- More stable flame envelope
- No impact from NCG stream
- Good entrainment of NCG stream
- Corrected flame length is 64 ft

CFD Model of Longview Lime Kiln

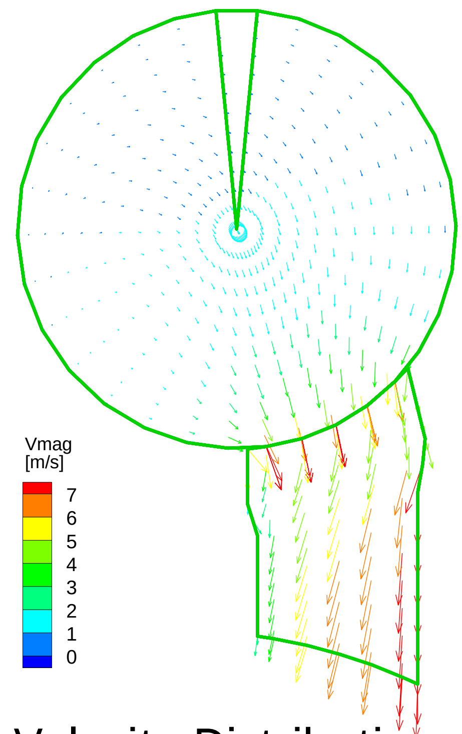


Satellite Coolers and Lime Kiln

Non-Uniform Flow From Cooler

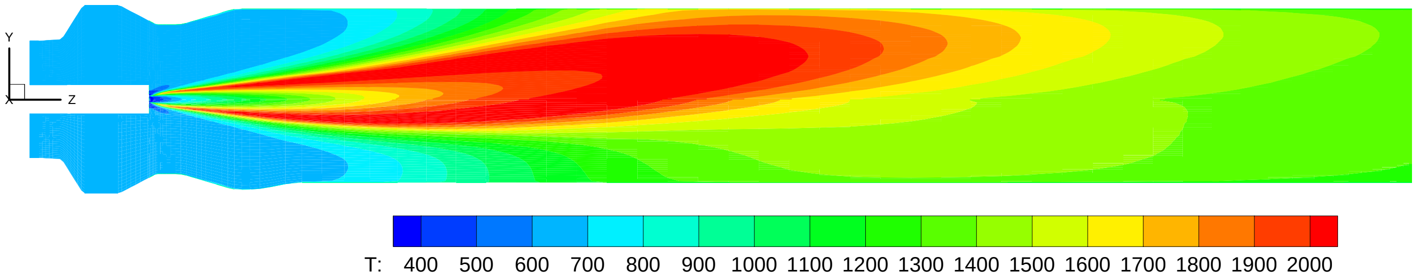


Air From Cooler

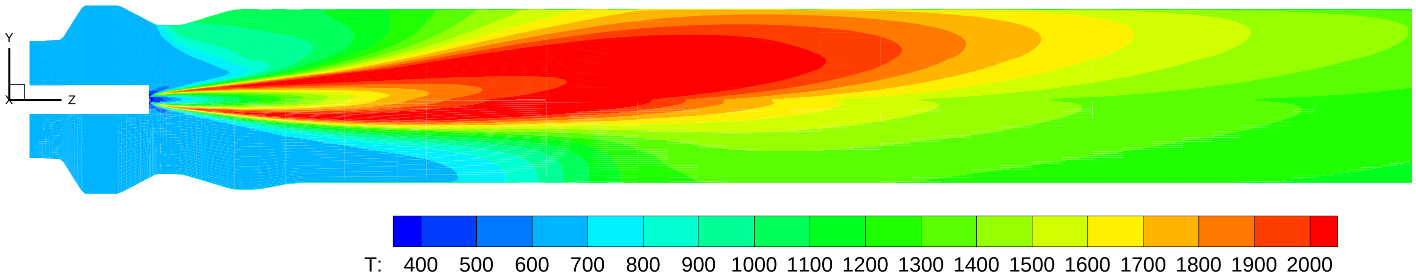


Velocity Distribution Across Cooler

Effect of Swirling Secondary Air



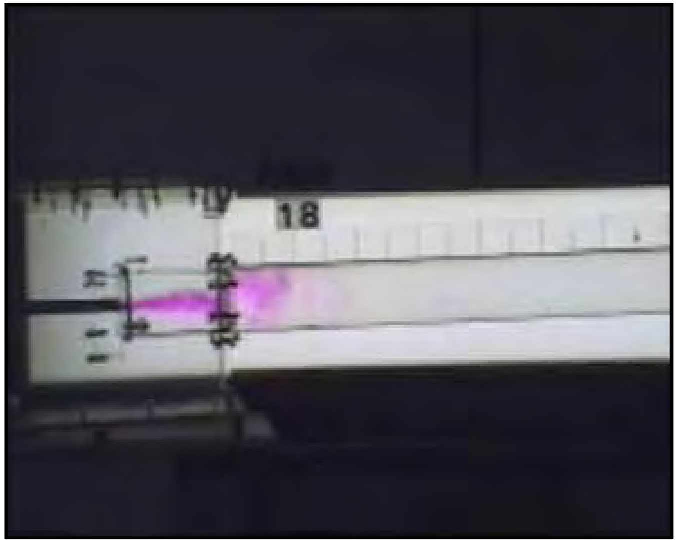
Swirling Secondary Air



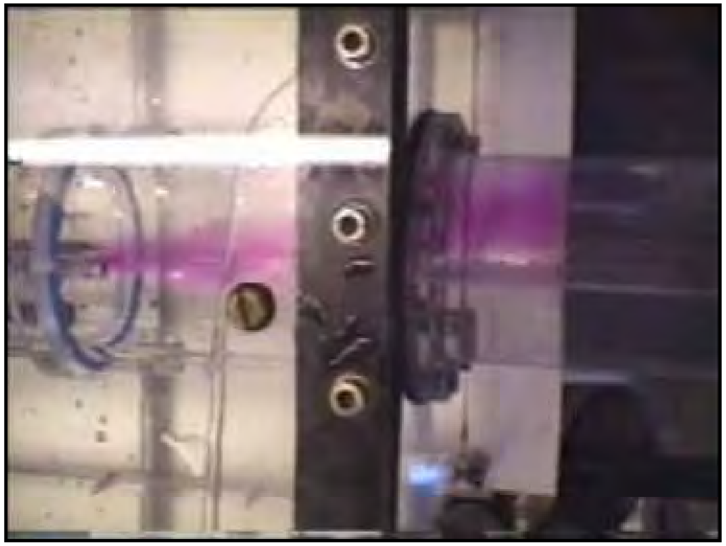
Non-Swirling Secondary Air

Pine Hill Acid/Alkali Modeling of Existing Burner

Side View

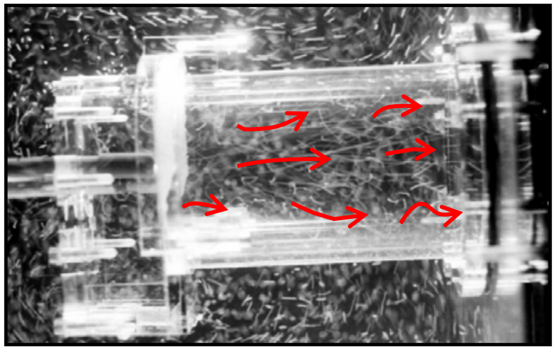


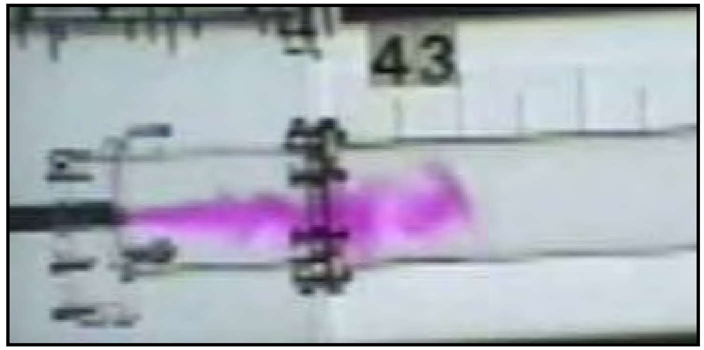
Plan View



- Natural gas firing
- Flame deflected toward the left and top of the kiln
- NCG has no effect on the flame View

Improved Kiln Hood Aerodynamics



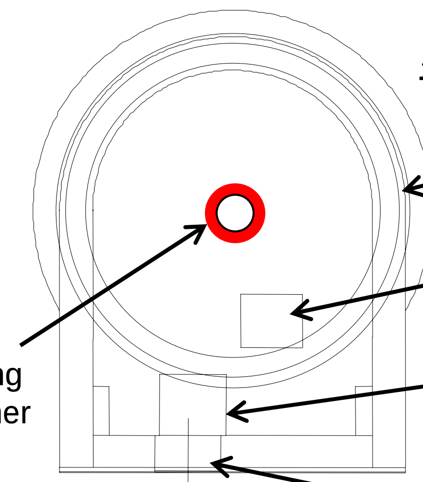


Design Parameters:

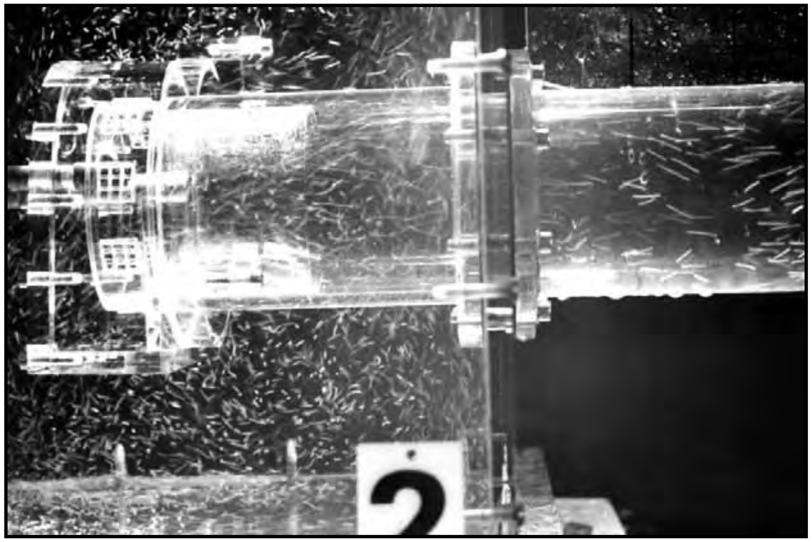
- Natural Gas
  - CC=2.65
  - FL=69 ft
- Oil:
  - CC=2.44
  - FL=63 ft

Hood Modifications:

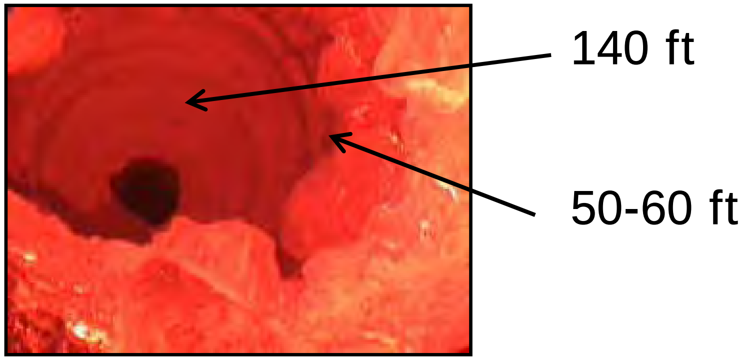
- Open rear kiln seals
- New opening around burner (8" gap)
- Top door closed
- Bottom door open
- Discharge chute closed



New Bern Acid/Alkali Modeling

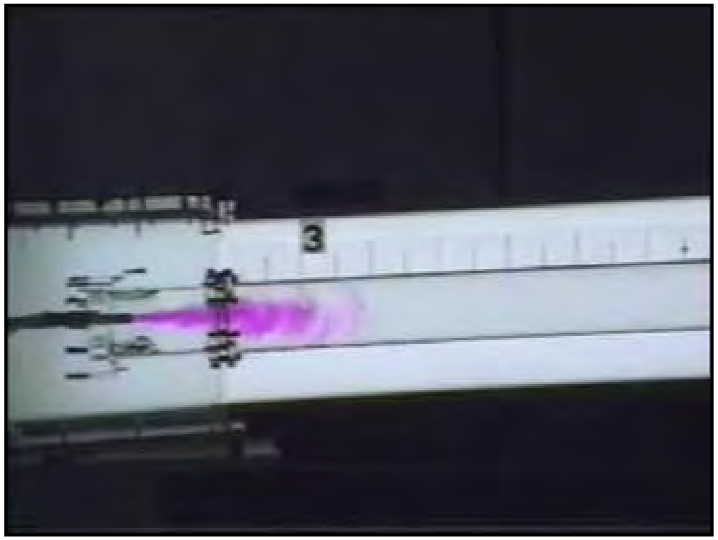


Existing Ring Formation

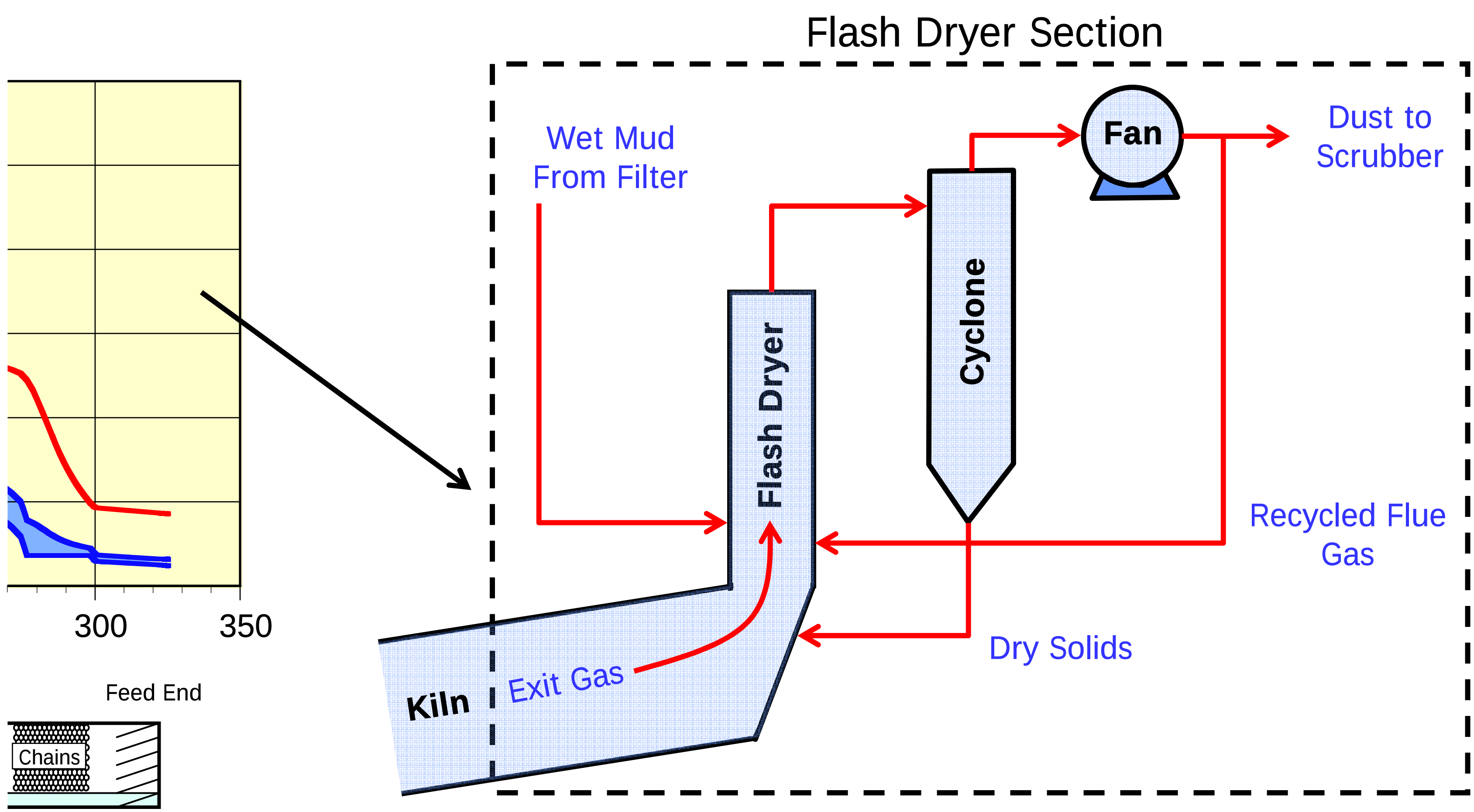


New KFS Burner

- CC=2.18
- Good flow patterns
- No flame impingement
- Corrected flame length = 65 ft

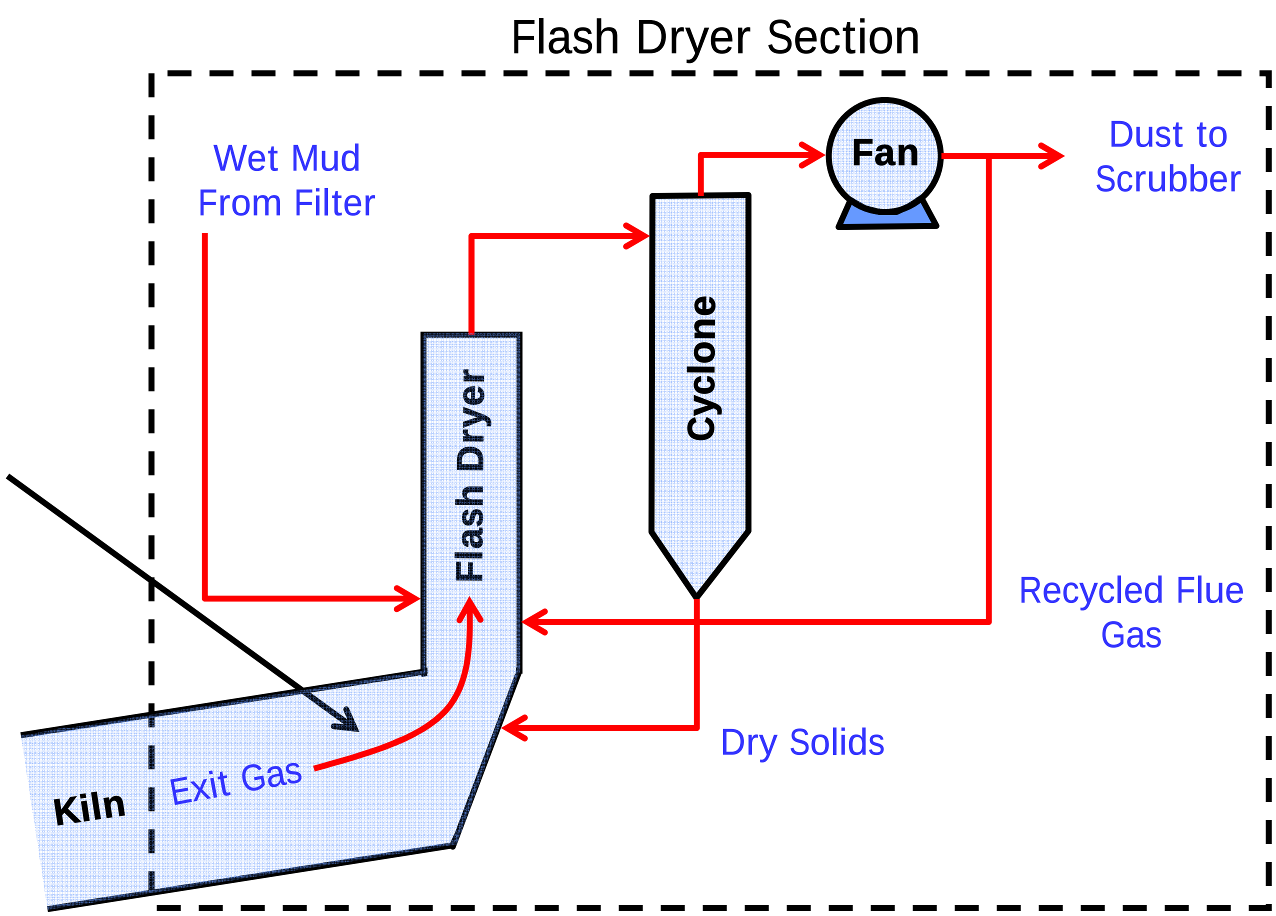


Flash Dryer Layout at Kamloops

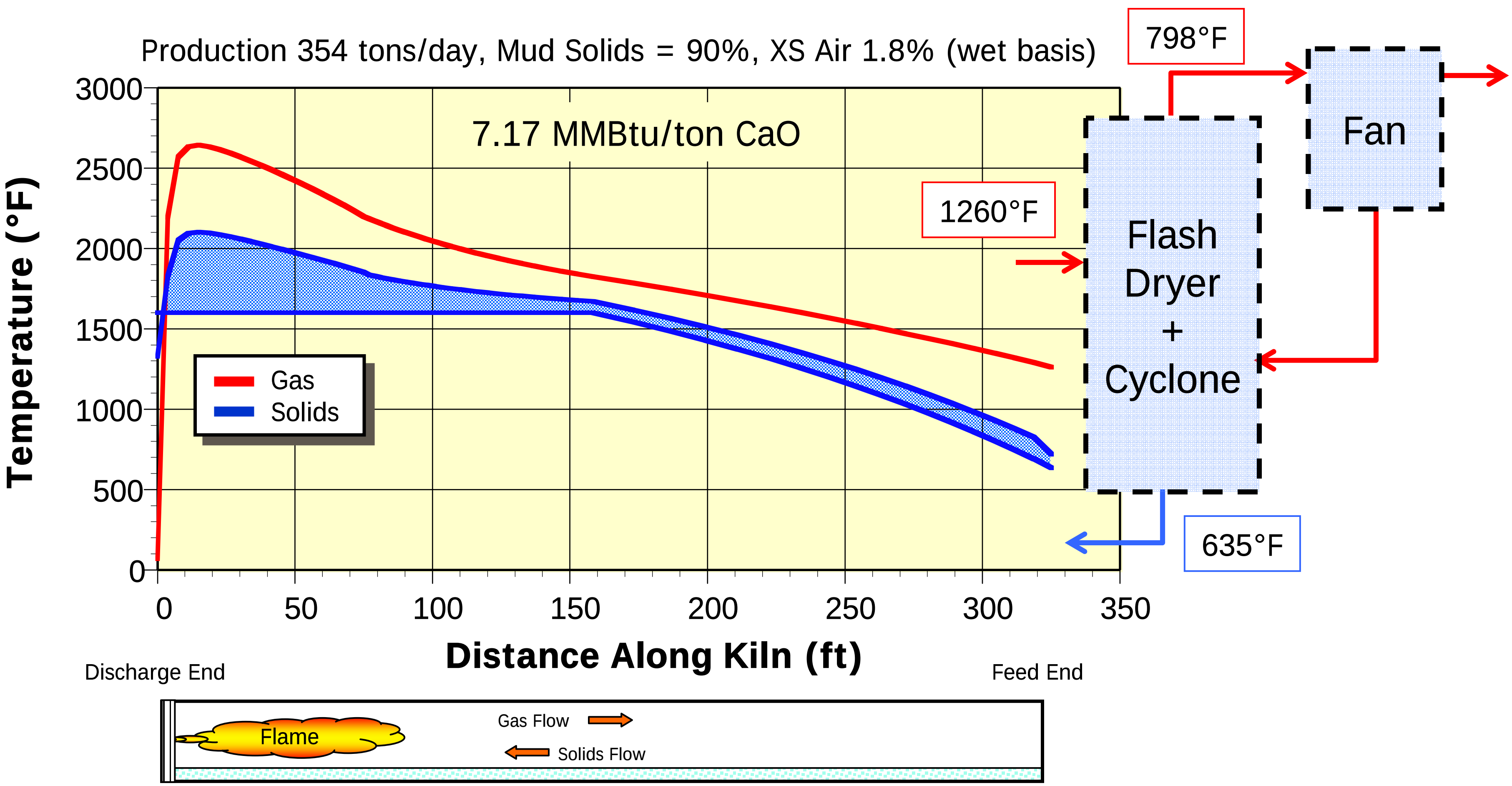


Flash Dryer Capacity Constraints

The capacity rating for flash dryers is set by the exit gas temperature from the kiln. Above 1200°F The sodium in the mud particles form liquids that stick to the walls of the kiln and flash dryer. At these temperatures the dryer can plug in a matter of hours forcing the kiln to be shutdown for cleaning. This mechanism is similar to the way soda balls form on kiln chain (ring type 5 in slide #17).



Current Operation at Kamloops Using FEE Minerals Flash Dryer



Validation of Computer Model - Measured vs. Predicted Heat Balances

	KFS Measured 9/11/2002	Weyerhaeuser Predicted 9/12/2003
Heat In:	(MMBtu/hr)	(MMBtu/hr)
Sensible in Mud Feed	0.56	0.79
Sensible in Combustion Air	0.50	
Sensible in Fuel	0.01	
Sensible in NCG's		
Sensible in NCG Purge	0.02	
Heat of Combustion*	100.56	97.63
Total	101.65	98.42
Heat Out:	(MMBtu/hr)	(MMBtu/hr)
Sensible in Kiln Product	8.89	9.82
Sensible in Exit Drier	21.90	22.71
Sensible in Dust	0.86	
Calcination	39.02	34.58
Drying	7.15	5.51
Hydrogen Loss	8.99	9.59
Shell Loss	15.64	16.21
Unaccounted	-0.80	
Total	101.65	98.42

* The heating value is given on a gross basis.

Validation of Computer Model - Measured vs. Predicted Mass Balance

	KFS Measured 9/11/2002	Weyerhaeuser Predicted 9/12/2003
Mass In:	(ton/hr)	(ton/hr)
Mud Feed	30.69	28.28
Combustion Air	42.10	40.67
Fuel	2.24	2.06
NCG's		
NCG Purge Air	1.87	
Total	76.90	71.01
Mass Out:	(ton/hr)	(ton/hr)
Kiln Product	14.75	14.75
Exit Gas from Drier	60.80	56.26
Kiln Dust	1.35	
Total	76.90	71.01

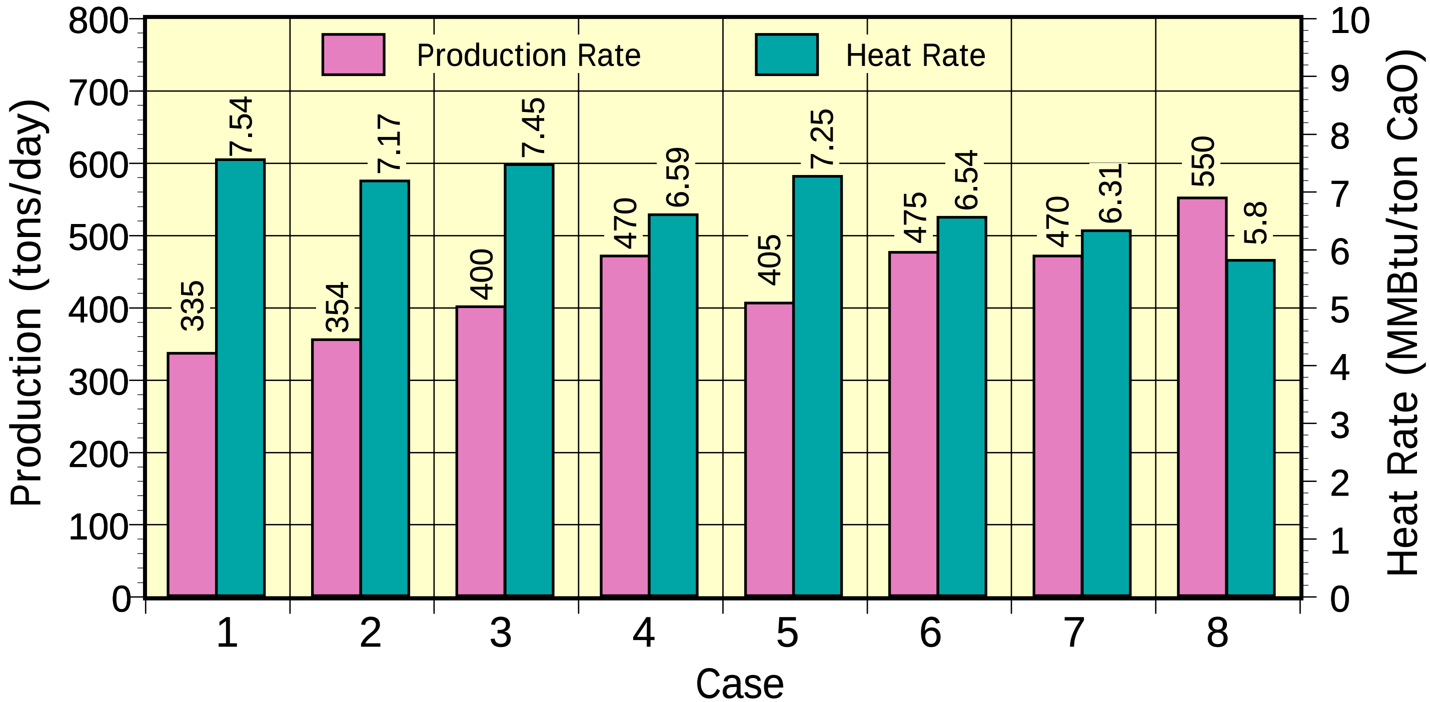
The computer predictions agree with the measurements made by KFS in September of 2002

Options Considered for Increasing the Capacity Rating of the Kamloops Kiln and Flash Dryer System

The following options were considered in this study:

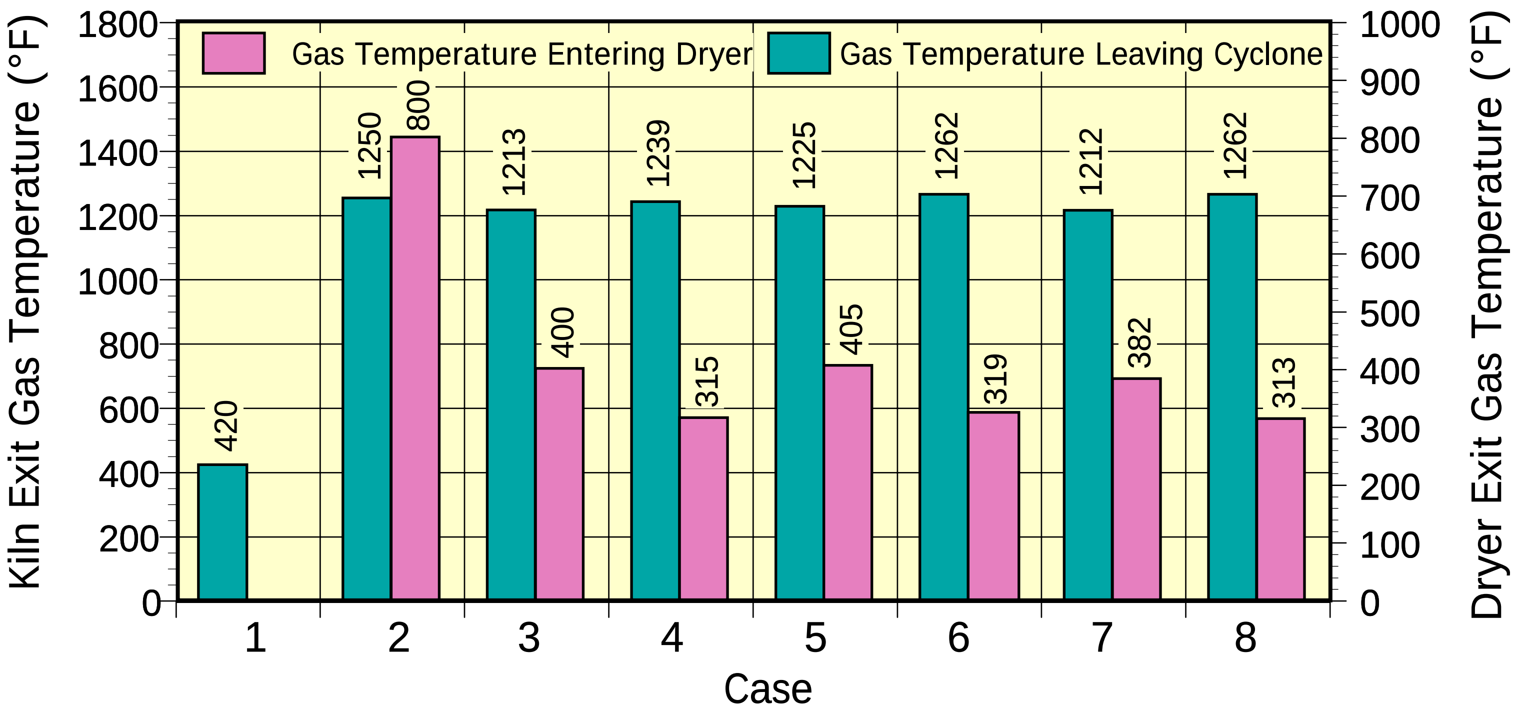
1. Original Kiln (No Dryer,70%Mud Solids,Natural Gas)
2. Flash Dryer (90%Mud Solids, Natural Gas)
3. Flash Dryer (70%Mud Solids, Natural Gas)
4. Flash dryer (70%Mud Solids,Oil)
5. Flash Dryer (70%Mud Solids, Natural Gas,Dam)
6. Flash Dryer (70%Mud Solids,Oil,Dam)
7. Flash Dryer (70%Mud Solids, Natural Gas,Dam,Coolers)
8. Flash Dryer (70%Mud Solids,Oil,Dam,Coolers)

Effect of Operating Conditions and Kiln Geometry on Kiln/Dryer Performance



1 Original Kiln (No Dryer,70%Mud Solids,Nat Gas)
2 Mud Dryer (90%Mud Solids,Nat Gas)
3 Mud Dryer (70%Mud Solids,Nat Gas)
4 Mud dryer (70%Mud Solids,Oil)
5 Mud Dryer (70%Mud Solids,Nat Gas,Dam)
6 Mud Dryer (70%Mud Solids,Oil,Dam)
7 Mud Dryer (70%Mud Solids,Nat Gas,Dam,Coolers)
8 Mud dryer (70%Mud Solids,Oil,Dam,Coolers)

Effect of Operating Conditions and Kiln Geometry on Exit Gas Temperatures



1 Original Kiln (No Dryer,70%Mud Solids,Nat Gas)	5 Mud Dryer (70%Mud Solids,Nat Gas,Dam)
2 Mud Dryer (90%Mud Solids,Nat Gas)	6 Mud Dryer (70%Mud Solids,Oil,Dam)
3 Mud Dryer (70%Mud Solids,Nat Gas)	7 Mud Dryer (70%Mud Solids,Nat Gas,Dam,Coolers)
4 Mud dryer (70%Mud Solids,Oil)	8 Mud dryer (70%Mud Solids,Oil,Dam,Coolers)

Ranking of Options Used to Increase the Capacity of the Kamloops Kiln and Flash Dryer System

- The original capacity rating for the Kamloops kiln was around 335 tons/day with a fuel consumption of 7.54 MMBtu/ton of CaO. Originally, the kiln was sized for a mud solids content of 70%. Around 7000ft^2 of chain would have used at the time the kiln was built.
- The capacity rating after removing the chain and installing the flash dyer was estimated by FFE Minerals to be around 560 tons/day. In their calculations they used a mud solids content of 70%.
- The mud solids content off the new filter is currently over 90%. As a result, the kiln and flash dryer system is only able to produce around 354 tons/day with a fuel consumption of 7.17 MMBtu/ton CaO. As previously described, the high temperatures entering the flash dryer and entering the ID fan constrain the capacity of the system. The addition of a flash dryer only increased the production of lime by 20 tons/day.
- Due to the sizing of the throat in the flash dryer, at the current production levels, a large amount of recycled flue gas is required to entrain all of the mud being fed to the kiln. The throat in the flash dryer is oversized.
- Decreasing the mud solids to 70% would increase lime production to 400 tons/day with a fuel consumption of 7.14 MMBtu/ton of CaO. This is a small energy penalty for increasing production.

Ranking of Options Used to Increase the Capacity of the Kamloops Kiln and Flash Dryer System (con't)

- Firing the kiln with oil at a mud solids content of 70% would further increase the lime production to 470 tons/day with a fuel consumption of 6.59 MMBtu/ton CaO. Oil is a better fuel than natural gas. The higher flame emissivities combined lower combustion air requirements reduces both the fuel consumption and exit gas temperatures. The lower temperatures leaving the kiln translate into increased lime production.
- Installing a discharge dam results in only a small increase the production rates for both natural gas and oil. The big advantages of a discharge dam are:
  - Lower refractory temperatures in the burning zone of the kiln
  - More consistent product quality
  - The large chunks will spend more time in the kiln giving them more chance to break apart
  - Allows for the installation of a rotating grizzly (installing a rotary grizzly with no other changes would most likely eliminate the need for shooting chucks inside the kiln and firing hood)
- Decreasing the mud solids content in combination with installing product coolers offers another large increase in lime production. For natural gas, retrofitting a product cooler would increase the lime production to 470 tons/day. For oil, the lime production would be increased to 550 tons/day. In both cases, installing product cooler decreases the exit gas temperature. The production levels with a cooler are very close to the capacity rating originally given by FFE Minerals.