"PETROLEUM COKE UTILIZATION FOR CEMENT KILN FIRING"

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Abstract

Pulverized delayed petroleum coke imported from the U.S.A is the prime energy source for both 5000 MTPD modern dry process clinker lines operating in the company's Ramla plant.
Both the first line – RDL-1 – operating since 1995 and the second one – RDL-2 – operating since 1999, were designed and guaranteed for firing of eighty percent of energy as pet.coke, the rest being bunker C heavy fuel oil.
The article will discuss the different points being taken care of at the design phase and will outline the parameters of the actual operating mode under which both lines practically fire hundred percent of energy as pet.coke.

What is pet.coke and why is it considered "hard to burn"?

The solid black material is produced when subjecting a very heavy liquid fraction – asphalt – to conditions aimed at extracting out of it maximum possible distillates. The reaction is taking place in a coker and the pet.coke is formed as a hard black cake which is cut out, mostly by water jets.
The typical ultimate and proximate analysis of pet.coke is given in annex A. The main points to be mentioned here are the relative high net energy content – around 33500 kj/kg (14500 Btu/lb) – the low volatile matter content in the range of 8-12 percent only, and the normally high sulphur content of between 4 to 7 percent depending on the crude oil used.
The low volatile matter content is the reason for two negative aspects which are slow ignition and production of relatively high NOx. Technological answers do exist in order to overcome these two major disadvantages.

What is the significance of the TOT principle?

TOT stands for:
Temperature
Oxygen
Time
All three of which should be considered when designing a pyroprocessing system for firing "hard to burn" type of fuel taking in account the fineness of fuel powder available expressed in terms of weight percents retained on 170 mesh (90 micron) sieve. TOT is of utmost importance especially for the sake of firing pet.coke in the precalciner.
Let us now review each of the parameters separately:
TEMPERATURE plays an important role in the kinetics of the burning reactions of pulverized pet.coke. In the range of temperatures existing in a preclaciner an increase by 100 centigrades (180^{0}F) will double the rate of burning reaction and therefore one should seriously consider this point in the design phase.
OXYGEN concentration in the burning gas is also an important factor and using combustion air (21 percent oxygen) is preferable in this sense upon the use of a mixture of air and kiln's combustion flue gas which is having a lower oxygen content. This point should not be ignored when specifying the pyroprocessing technology.
TIME is the dimension that should be long enough to enable a complete burning process to prevail. This depends on the temperature and oxygen available as well as on the fineness of the pulverized pet.coke.

How was the TOT principle taken in account at the design phase of each of the two Ramla plant lines?

We should focus on RDL-1 and the year 1992 as RDL-2 passed a much simpler and shorter design phase in 1997 after almost two years of operation of RDL-1, and therefore with RDL-2 we saved much of the doubts and debating process which we had to go through during 1992.

From annexes B1 and B2 one can see that the precalciners are up-draft vessels getting the combustion air from below and the flow pattern is an upward flow.

For the sake of maintaining highest possible temperature we chose to withdraw the combustion air directly from the kiln hood and not from the cooler's roof and thus ensuring a tertiary air temperature of above 1000^0C (1832^0F).
We also asked the equipment supplier to allow for split feed of raw meal powder into the precalciner so not all powder will be fed at the down part of the vessel causing flame cool down due to the endothermic character of the calcination reaction. Supplier was in doubt as to the necessity of such a split. However it has been decided to leave it as an option if we find it necessary after operation start up.

For maintaining maximum possible oxygen we chose a separate calciner upon an in-line one so that the combustion air is having its 21 percent oxygen.

As for maintaining long enough retention time we decided to have a long kiln with traditional length to diameter ratio (this is also due to equipping our pyroprocessing with a small by-pass of maximum 15 percent in view of future possible use of chlorinated materials) and to install a bigger than normal precalciner vessel (around 980 cubic meters volume) that will have a four seconds retention time while the normal one is shorter than three seconds.

What did we discover during RDL-1 running–in period?

Starting on pet.coke fineness of max. five weight percent retained on 170 mesh (90 micron) sieve (this was a supplier's prerequisite for guarantying firing of 80 percent energy as pet.coke) and operating a modern efficient main burner we faced no difficulty to cross the line of 80 percent pet.coke in the main burner. However, we were not able to cross the line of 50 percent of pet.coke in the precalciner. It became evident that we should implement the option of split the raw meal powder feed into the precalciner so that only part of the raw meal will be fed at the normal lower feed point.
Following the implementation of the split option we were able to cross the former barrier of 50 percent pet.coke and operate on a level of 70 percent pet.coke.

What was the next target and what difficulties did we have to overcome in order to match it?

We decided to examine the system's ability to operate on hundred percent pet.coke. System's description appears on annexes C1 and C2. For succeeding to achieve this target we had to improve our operation in the following three aspects:

1. Improve the main burner operation in order to reduce the kiln back-end temperature. This was done by replacing the primary air fan to a somewhat bigger one and at the same time lowering the injection speed of the pet.coke particles from the main burner tip into the kiln.

2. Maintain good stability of the pet.coke feed rate to both main burner and precalciner burners. Annexes D1 and D2 describe the pet.coke system, the last link of which is the gravimetric feed of the fuel powder to the burners performed by weighing roto scales. These feeders were originally getting the fuel powder supply directly from a 200 metric ton silo above them. Unfortunately there were hiccoughs from time to time in the pet.coke feeding to the burners resulting with temporary increase of carbon monoxide concentration in the flue gas. In order to avoid such malfunction we introduced an interim small bin between the 200 mertic ton silo and the roto scale. This change managed to solve the problem completely.

3. Find the mode of operation that will enable us bleeding most of the sulphur through the clinker without too much disturbances by heavy coating in the riser duct area. Our system is having a high sulphur to alkali ratio. In annex E the typical chemical composition of raw meal powder, by-pass dust and clinker are presented. Experimentally it has been found that we should avoid exceeding SO_3 concentration of 2.0 percent in the "hot raw meal" entering the kiln from preheater bottom cyclone. In order to keep sulphur volatilization in the kiln as low as possible and at the same time maintain high clinker production capacity of 5600 metric ton per day with a specific energy consumption of 2926 kj per kg clinker (2.52 million Btu per short ton of clinker) with 7.5 percent by-pass operation, we are overdrafting our system so that oxygen

content in kiln’s combustion gas outlet to riser duct is over 3.5 percent and on preheater top is in the range of 5-6 percent.
Under these operating conditions we can run with 100 percent pet.coke so long as sulphur concentration in pet.coke is not exceeding 4.7 percent on dry basis. This is assuming that sulphur concentration in raw meal powder is negligible. Annex F describes the division of sulphur among clinker, by-pass dust, by-pass stack flue gas and main stack flue gas.

<u>What is the normal day-by-day practice of operation?</u>

Annex G outlines the normal process parameters.

Experience proved that keeping pet.coke fineness at 5 percent residue over 170 mesh sieve is of no real importance and presently the solid fuel is prepared to a fineness of 9-12 weight percent retained on such 90 micron sieve.

As to NOx emission, the E.L.V (Emission Limit Value) for 100 percent pet.coke firing is 1300 milligrams per normal cubic meter dry air and the emission from both RDL-1 and RDL-2 is at a level of 1000 milligrams of NOx per normal cubic meter dry air normalized to ten percent oxygen in the flue gas. This emission level can be further reduced by adopting one of a few existing options which are presently under study.

Annex A

Pet.coke characteristics

Ultimate analysis (percent dry basis)

C	-	87
H	-	3.8
N	-	1.5
S	-	5
O	-	1.7

Proximate analysis (percent)

Fixed carbon	-	88
Volatile matter	-	11
Ash	-	0.5

HGI (Hardgrove Grindability Index)

Mostly between 40 and 80

Annex C2: Equipment Description

A: kilns

		RDL1		RDL2	
Nominal capacity mt/day		5000		5000	
		Kiln string	Calciner string	Kiln string	Calciner string
Cyclon Diameter (meters)	stage 1	5.0	2 x 4.6	5.4	2 x 4.8
	Stage 2	5.0	6.3	5.4	6.6
	Stage 3	5.4	6.6	5.7	6.9
	Stage 4	5.4	6.6	5.7	6.9
	Stage 5	5.4	6.6	5.7	6.9
Calciner diameter x height		5.25 x 39.1 meter		7.2 x 25 meter	
Calciner volume		972 cubic meter		984 cubic meter	
Kiln Diameter x length		4.88 x 73.15 meter		4.88 x 73.15 meter	
Bypass design		15%		15%	

B: Solid fuel mills

Number of mills: 2
Capacity: 25 mt/h each.
Type: vertical roller mill 20.20D
Table: diameter 2 meters, 4.68 rpm
Rollers: 2 rollers diameter 1.6 meters
Mill motor power: 400 KW
Separator: type LKS 28D, motor 30 KW
Hot gas generator: 16.72×10^6 KJ/h
Bag filter: 78000 Am3/h
I.D fan: 80000 Am3/h, 80 ^oC

Annex E: Material composition [percents]

bypass dust	clinker	hot raw meal	raw meal	
59.50	65.54	63.00	43.76	CaO
17.76	21.26	20.70	13.30	SiO2
5.31	5.75	5.64	3.70	Al2O3
2.87	3.44	3.35	0.82	Fe2O3
1.14	1.26	1.22	0.82	MgO
0.42	0.46	0.45	0.29	TiO2
2.18	0.42	0.88	0.30	K2O
0.41	0.24	0.28	0.15	Na2O
6.25	0.86	2.16	0.07	SO3
0.27	0.27	0.27	0.21	P2O5
0.249	0.003	0.268	0.022	Cl-
32.44	0.28	40.2		FL
3.64	0.07	1.96	34.96	LOI

102.84	96.61	94.32	101.67	LSF
2.17	2.31	2.3	2.25	SiM
1.85	1.67	1.68	1.67	AlM

Annex F: Sulphur input/output

Material	Flowrate	Sulphur Metric ton/hour		%
Pet.coke	20.4 metric ton/hour	0.8854	input	100.00
Clinker	235 metric ton/hour	0.8082	output	91.30
Bypass dust	2.23 metric ton/hour	0.0557	output	6.30
Main stack gas	741400 st.cu. meters/hour	0.0213	output	2.40
Bypass stack gas	57100 st.cu. meters/hour	0.0002	output	0
	Total output	0.8854		100.00

Annex G: RDL1 process parameters

average	units	
402.5	Ton/h	Total feed
5650	Ton/day	Clinker production
2976	kJ/kg clinker	Total energy
8785	Kg/h	Kiln pet coke
11625	Kg/h	Calciner pet coke
1038.7	^0C	Kiln back end temp
4.1	%	Kiln back end O_2
1100	ppm	Kiln back end NO_x
2000	ppm	Kiln back end SO_2
308.4	^0C	Kiln string exit temp
- 876.1	mmWG	Kiln string exit pressure
5.2	%	Kiln string exit O_2
889.0	^0C	Calciner exit temp
4.5	%	Calciner exit O_2
1100	ppm	Calciner exit NO_x
314.3	^0C	Calciner string exit temp
- 943.4	mmWG	Calciner string pressure
4.9	%	Calciner string exit O_2
12.6	%	Main stack O_2
376	ppm	Main stack NO_x
20	ppm	Main stack SO_2
1100	^0C	Secondary air temp
1020	^0C	Tertiary air temp