PP TYPE CHARCOAL BRICK KILNS: CONSTRUCTION AND OPERATIONAL RESULTS

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Abstract. *Brazil is the world's largest charcoal producer, producing 9.7 millions of metric tons (40 millions m3), 25% of world's total production. This huge charcoal quantity is the consequence of a large steel making parks, that consumes 80% of this charcoal. For this intensive use of charcoal, it has been necessary to develop a modern industrial production technology. The charcoal brick kilns are a technology very well adapted to the Brazilian reality. The construction cost is low, the gravimetric efficiency is similar to the best continuous charcoal kilns and have easy operation, what is the reason that its use is spread in all country. The "rabo-quente" type (hot tail) is the type most spread in Brazil, and more than 70% of Brazilian charcoal production is made in these kilns. The rabo-quente is a semi-spherical brick kiln. It don't have stacks, and the air inlet is obtained by 8 holes in the wall at the floor level (tatus), and the output of carbonization gases by other 21 holes in the kiln wall at higher level (ventaneiras e baianas). Due the direct draft and the high number of input air /output gas holes, the control of this kiln is difficult, with combustion of large quantity of wood. The PP type charcoal brick kiln is the new type presently undergoing development with a stach with reverse (descending) draft, that permits a better carbonization control, and produces a charcoal with good quality and high gravimetric eficiency.*

Keywords: *Charcoal, biomass, carbonization, charcoal kiln, charcoal brick kiln*

1. INTRODUCTION

The charcoal is the result of the biomass thermal decomposition in air absence at temperatures over 300°C (pyrolysis). All biomass types can be used to charcoal production, but the wood is the most used biomass. The charcoal heat value and reactivity is higher than wood, but the carbonization process have low energetic efficiency, and the global efficiency of a process that uses the charcoal is lower than other that uses biomass directly.

Table 1. Brazilian Charcoal Production and Consumption (10^3 metric ton).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PRODUCTION	10016	8784	8066	8489	8593	7909	7292	7013	6387	7.054	7.713	7.031	7.364	8.657	10085	9.893
IMPORTS	0	0	0	2	6	16	8	11	11	10	11	18	12	25	52	90
EXPORTS	0	0	0	-18	-11	-10	0	-5	-10	-9	-8	-9	-7	-13	-28	-15
LOSSES and ADJUSMENTS	-512	-418	-384	-334	-330	-304	-247	-237	-216	-239	-261	-212	-222	-261	-275	-297
CONSUMPTION																
RESIDENTIAL	990	950	863	823	797	672	611	613	589	586	634	647	674	763	779	801
COMMERCIAL	82	85	93	90	90	87	92	95	93	95	98	95	90	98	102	104
PUBLIC	5	5	5	4	4	3	2	0	0	0	0	0	0	0	0	0
AGROPECULTURE	18	20	14	12	9	11	12	10	9	8	7	7	7	8	9	9
INDUSTRIAL	8409	7306	6707	7210	7358	6838	6336	6064	5481	6.127	6.716	6.079	6.376	7.540	8.944	8.757
CEMENT	542	387	318	353	401	438	565	373	315	303	361	327	320	382	440	385
PIG-IRON and STEEL	6760	5700	5314	5825	6012	5517	4786	5012	4597	5.249	5.668	5.325	5.515	6.280	7.588	7.436
FERRO-ALLOYS	560	755	640	775	677	590	895	600	503	559	666	408	518	823	864	883
MINING/PELLETIZATION	53	55	48	5	4	0	0	0	0	0	0	0	0	0	0	0
NON-FERROUS/OTHERS METALS	394	316	318	175	190	226	48	40	34	4	9	9	12	12	12	12
CHEMICAL	50	45	41	44	46	37	20	10	8	0	0	0	0	29	25	26
TEXTILES	5	5	3	3	2	1	2	2	2	0	0	0	0	0	0	0
CERAMIC	20	18	11	13	8	9	12	15	0	0	0	0	0	0	0	0
OTHERS	25	25	14	17	18	20	8	12	22	12	12	10	11	14	15	15
TOTAL FINAL CONSUMPTION	9504	8366	7682	8139	8258	7611	7053	6782	6172	6.816	7.455	6.828	7.147	8.409	9.834	9.671

Source: Balanço Energético Nacional (2006). Ministério de Minas e Energia.

Brazil is the greater world charcoal producer, produced 9,7 million of metric tons (40 million m^3) in 2005, approximately 25% of all world production. The wood of reforestation is used in 75% of the Brazilian charcoal production [AMS], and eucalyptus is used in 47% of the Brazilian planted forests. Near than 90% of charcoal produced in Brazil, it is used in the industrial sector in the pig-iron and steel production (7,4Mton), ferro-alloys (0,88Mton) and cement (0,38Mton). The residential sector uses only 8% and the commercial sector (pizza and barbecue restaurants, bakeries) 1%. Brazil is the only country in the world with a iron and steel industry charcoal based, producing high quality pig-iron and steel, due the charcoal low level impurities. The charcoal is used in 33% of pig-iron and 98% of ferro-alloy Brazilian production.

The charcoal is a porous and fragile material, with apparent density between 160 and 400 kg/m^3. Its low heat value is near 30,8 MJ/kg, similar to a high quality coal, and the sulfur and phosphorus content lower than 0.1%.

2. CHARCOAL BRICK KILNS

The charcoal brick kilns are a technology very well adapted to the Brazilian reality. The construction cost is low, the gravimetric efficiency is similar to the best continuous charcoal kilns and have easy operation, what is the reason that its use is spread in all country. They are constructed with brick without holes, and these bricks are assembled with mixture argillaceous and arenaceous land adobe, without the cement necessity. Many times the bricks are manufactured just in time, in same place of the charcoal plant. The heat necessary for the carbonization process is obtained by the combustion of some wood inside the kiln (partial burning).

There are several charcoal brick kilns types, with different forms, dimensions, stacks numbers etc. The rabo-quente type (hot tail) is the type most spread in Brazil, and more than 70% of Brazilian charcoal production is made in these kilns. The rabo-quente is a semi-spherical brick kiln, constructed with burned bricks and assembled with mud. It has one input door, where is charged the wood and discharged the charcoal. It don't have stacks, and the air inlet is obtained by 8 holes in the wall at the floor level (tatus), and the output of carbonization gases by other 21 holes in the kiln wall at higher level (ventaneiras e baianas). Theses kilns have 2.90 to 3.80 m base diameter, and near 2.30 m maximum height, with 8 wood stereos (m^3) capacity, and 3,8 m^3 charcoal production by cycle. The kiln charge is handmade, and the wood is cuted in 1.0 to 1.8 m long and 3 to 30 cm diameter logs. A typical charcoal plant has 6 to 120 kilns constructed in the same line. Some time, don't exists a charcoal plant, and the kilns are spread in all the forest.

Closing the holes of air inlets (tatus) and the gas outputs (baianas and ventaneiras) carries the rabo-quente kiln operation control. The color and smell of smoke leaving the holes evaluate the progress of the carbonization process. The duration of all carbonization cycle (charge, carbonization, natural cooling and discharge) is 5 to 7 days. A kiln with 8 to 9 stereos (m^3) wood capacity can produce 3 to 4 charcoal metric tons per month (12-16 m^3/month).

Although it's great diffusion and use, the rabo-quente kiln had 2 great problems:

1) The half-spherical geometry, although to be structurally well-sustainable, to make the charge of the kiln need many hours of hard work, therefore the wood must be cut with different sizes and the worker spends much time to choose the good log size to each position inside the kiln.

2) The rabo-quente kiln has direct (ascending) draft system: The air inlets are placed at the kiln floor (tatus) and the gases go out by the holes at higher position (baianas e ventaneiras). Higher is the temperature inside the kiln, higher is the draft force, that increase the air inlet, in this way increases the combustion process, that increases the temperature inside the kiln. For this reason, the control becomes unstable, and the kiln must be continuously supervised. Without supervision, in few hours all the wood inside the kiln must burn. In general way, the kiln is not continuously supervised, mainly in night time. By the way, in usual charcoal plant exists an important wood burning, and the efficiency of carbonization process is low

3. THE PP TYPE CHARCOAL BRICK KILN

The PP type Charcoal Brick kiln was developed to aiming use the tail-hot kiln good aspects (low cost, appropriate technology to rural place, use rural worker handwork), and to minimize its negative aspects (half-spherical geometry and direct draft). The PP type charcoal brick kiln is a cylindrical kiln with one parabolic roof, constructed with bricks assembled with a land-water mixture, with one door, one stack and only one air input (tatu). The inner diameter at the base is 3.20m and the maximum height 2.30m. The charge of the kiln is handmade, and the wood must be cutting in 1,2 to 1,5 m lengths and 3 to 30 cm diameter logs. This geometry allows charge more wood inside the kiln and makes more ease the carbonization control. A kiln (14 m^3) produces 22 m^3 charcoal/month and one charcoal worker can operate 12 kilns at same time, with a 6 days carbonization cycle.

The wood to be carbonized firewood is charge inside the kiln. When the kill is full charged, the door space is closed with bricks and covered with mud (barrelada), leaving an only a small air input (tatu). The ignition is conducted by 4 small outputs situated in the roof (pegadeiras), that they are closed when the carbonization running. The carbonization control is carried through action simultaneously (or alternatively) in the air inlet (tatu) or in the stack damper (smoke output). With a high air input has an increase of combustion process, burning more wood and lowing the carbonization efficiency. With a small air input has a diminution of the kiln temperature, that can be stop the carbonization process. The carbonization progress is evaluated by the gas temperature and color leaving the stack and the gas temperature inside the kiln (near the roof).

How that the air inlet (tatu) and the stack (gas output) are situated in the same level at the kiln, the PP kiln has a reverse draft system. The reverse draft system produces some kiln operation self-control. If the combustion increases, the high smoke volume produced return to air inlet (tatu) direction, stopping the air input and lowers the combustion. If the combustion lower, produces a depression inside the kiln and higher the air input. Moreover, as the smoke produced flow cross the charge and pyrolysis inside kiln before the output, its are partially cracked and carbonized, high the carbonization efficiency.

The construction technology is simple and its construction cost is about US$250.00 (R$500,00 in MG Northwest region). The low cost allows that the construction of this charcoal plant may follows the forest harvest. Most important construction cost is the 3,000 bricks and men work (16 men/hour). The kiln lifetime is about 4 years, and the bricks can be reutilize in the construction of a new kiln. The stack permits the carbonization gases and vapors caption, and also follows the process by the temperature measurement or gases analysis.

4. MATERIALS AND METHODS

In order to study the kilns PP operation, to develop operational methodologies, to analyze the thermal losses and the gases emissions (mainly greenhouse effect gases), was constructed an experimental thermogravimetric installation at the Plantar farm in Curvelo MG (figure 1), composed of:

One truck size scale. The scale has a 4.0 x 4.0m base, and was mounted over an inspection basement. The scale base is supported by 4 Alpha load cells model M10T (Dual Shear Beam), with 10 tons capacity each. Over the scale base was placed a 60 cm compact land layer (for thermal insulation), and over the land layer are constructed a real size 3.2 m diameter PP kiln, (experimental kiln). After the kiln was constructed and burned some time, the scale was calibrated in all its range, with 1.0 kg resolution and 5.0 kg precision.

At scale left side, at ground, was constructed another PP kiln, identical to the first one, in order to compare and validate the results obtained in the experimental scale kiln.

To the side of the scale, on ground firm, another identical kiln PP was constructed the first one, in order to serve of comparison and witness of the assays carried through in the experimental kiln.

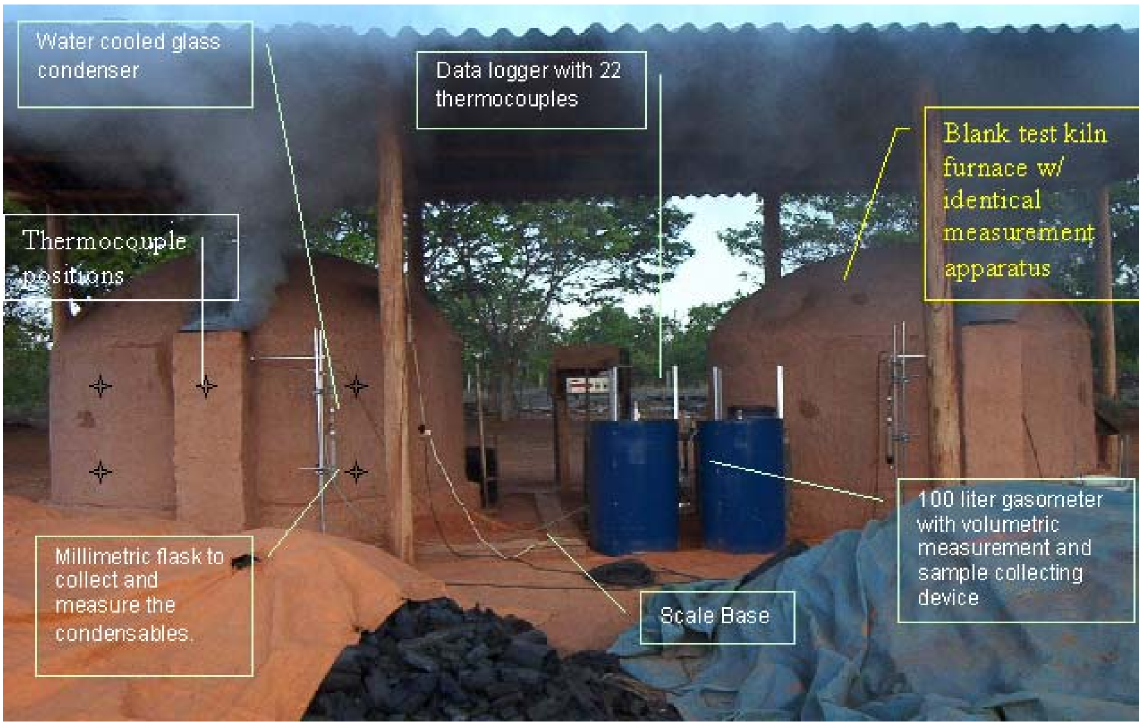

Figure 2. Experimental apparatus. Scale located at the base of the Kiln on the left.

The two kilns had been instrumented with 12 K type thermocouples each one. The thermocouples had been placed in the roof, stack, floor and several other places in the lateral kiln wall connected to a data acquisition system. A roof had protected the 2 kilns in order to prevent rains over the kilns and the scale.

In the stack of each kiln had been installed a carbonization gas sampling system. Each system have one peristaltic pump, one glass condenser and one 100 liters tank metallic for gas stock. During all carbonization test, the pump work for 5 minutes each hour, stocking about 15 liters of gases. At each 6 hours, were measured the gas volume inside the tank, the condensed vapors volume, and take gases and condensed vapors samples for analysis. The gas samples had been collected in glass bottles and send to a certified laboratory to be analyzed by gas chromatography (CO_2, CO, CH_4,

N_2 and O_2). A second gas sample was retained, if was necessary make a new gas analysis. The gas inside tank was also analyzed by an Orsat gas analyzer (CO_2, O_2 and CO), and the Orsat results compared with the chromatography result. After take off the samples and analysis the gases, the gas tank was purged, starting a new carbonization gas sampling cycle.

After the kilns were built a series of six carbonization cycles were required to guarantee the complete kiln "cooking". These tests realized during the "cooking" cycles had allowed a better understand the kiln operation, the instrumentation test, the training of operators team and developing the condensed collection system, gas analysis methodology and the experiment methodology.

After the "cooking" cycles had been carried the carbonization tests, some aiming to obtaining high efficiencies and others aiming to obtaining low efficiencies (high temperatures in the kiln and combustion of some wood charge). The kiln operation in these tests was carried through by charcoal operators with high experience, using his usual operational procedures. The kilns were charged with the wood, the doors closed with bricks (tecer a porta) and covered with mud (barreladas). The wood charge in the 2 kilns was attempted to be identical quite possible. The 2 kilns ignition was simultaneous. After the ignition, during all the carbonization cycle, the kilns was continuously monitored, had being registered each hour all the temperatures in the 2 kilns and the mass in the scale kiln, and each 6 hours carried a gases sampling and analysis. After finished the carbonization, the kiln was closed for natural cooling. With the cold kiln, the produced charcoal was take off, the volume measured (mdc) and make the proximate and granulometric analysis.

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5. RESULTS

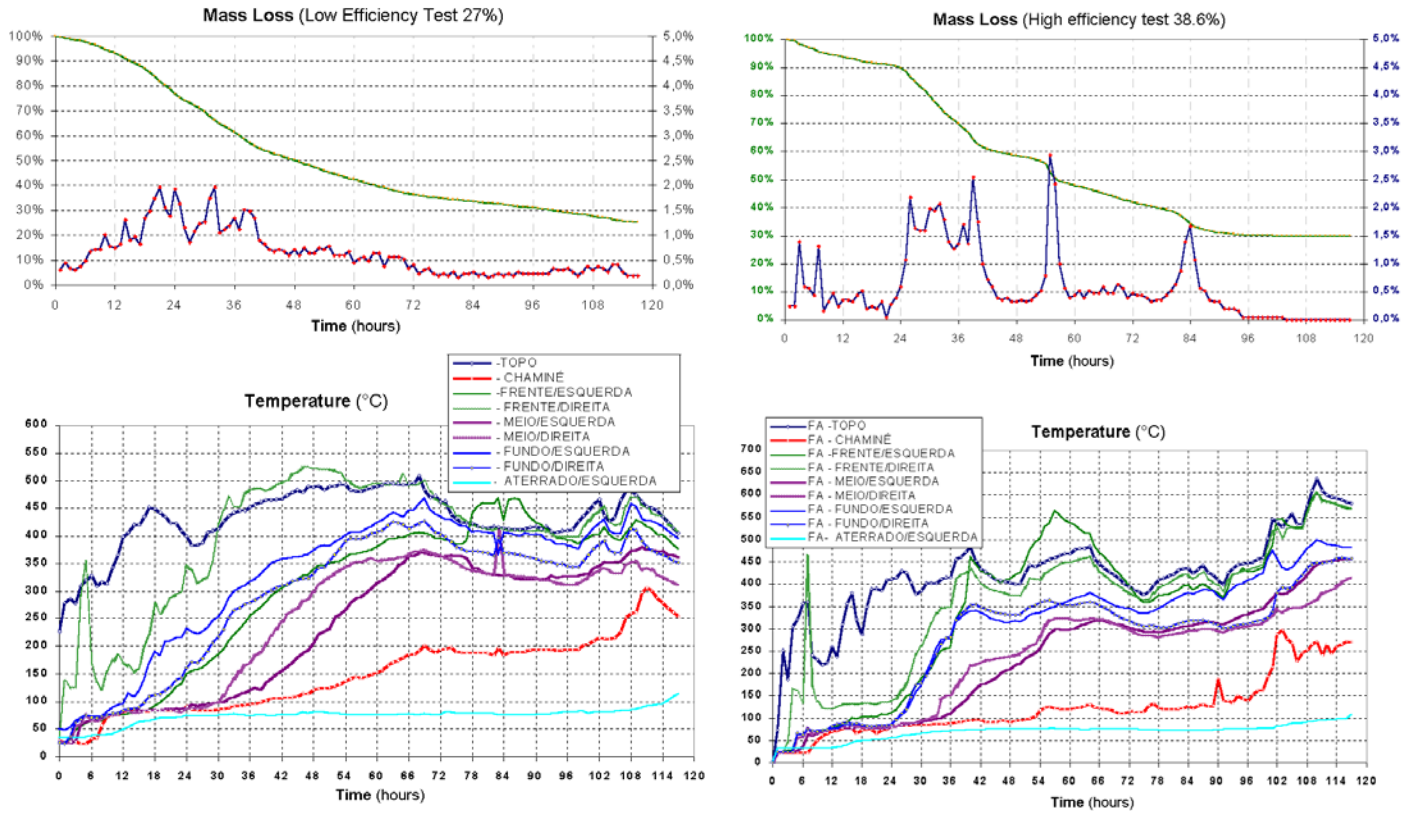

Figure 3. Experimental Results.

Figure 3 shows 2 typical experimental results obtained in the experimental termogravimetric installation. The two tests had been carried through with 6 years Eucaliptus Camaldulensis, with approximately 90 days natural drying. The humidity content (dry base) had been respectively 30.8% and 29.1% and the carbonization efficiency 36,8 and 26.4% (kg of charcoal/kg dry wood). It can be show that the high efficiencies had been obtained with lower carbonization temperatures and with longer carbonization time.

From these experimental results had been carried the mass and energy balances of all carbonization cycle of this kiln.

6. CONCLUSIONS

High temperatures of carbonization lower the carbonization gravimetric efficiency due to a bigger biomass thermal decomposition, due a higher effluent gases and kiln walls thermal loss and due the burning of some wood charge.

The PP kiln PP is a carbonization kiln with reverse draft, what it allows inside some range carbonization process self-control. However, due the complexity of the all factors that influence the carbonization process, is not yet possible to write a standard operation procedure that allows a complete carbonization control.

Some developments can improve the PP kiln operation and ease the operation supervision and control:

- The PP Kiln has one only air intake (tatu), placed in the door. In several plants surveillance was found air intakes of sizes from 15 x 14 to 6 x 6 cm, and these air intake dimensions it's only a choice of the charcoal operator. The air inlet control in the PP kiln is carried by closing partially the air intake with a brick piece. In this way, each kiln operates at different conditions, and was impossible a standardized operation. The installation of mechanical damper in the stack allows a better draft control, and by consequence the control of the air inlet. It was verified that with the use of mechanical damper, when the carbonization is controlled it remains steady during long time of the carbonization cycle.

- Double Brick Wall. A thicker wall kiln can lower the environment thermal loss, increasing the carbonization efficiency (kg charcoal/kg dry wood). However, it also increases the cooling time, diminishing the kiln productivity (ton charcoal/month).

- Roof. During the rain weather, the outside kiln surface gets wet, cooling the kiln, consequently increasing the thermal losses and lowing the gravimetric efficiency. A roof over the kiln minimizes these losses.

- Charcoal plant organization. A new organization of the charcoal plant can allow to synchronized kilns operation, lowing the operator work, allowing optimum wood supply and charcoal production control and improving the carbonization process control and the man work management.

- Kiln temperature measurement. The inside kiln top temperature is the locus where the carbonization process is better represented. The gas stack temperature also can be used to aid the kiln control. For this reason, the installation of a temperature sensor in each kiln, can aid the carbonization process control, producing a measure control parameter.

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