Low emission charcoal kiln with steel retort based on a 30 m³ molasses tank

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Introduction

Measurements of kiln emissions carried out in the early 1990's suggest that the global warming impact of charcoal production may be much greater than the benefits of charcoal in replacing fossil fuels. Charcoal kilns produce methane, other greenhouse gases and particulate matter. Charcoal produced in poorly operated kilns is the worst energy source in terms of global warming (Kammen et al. 2005).

Traditional kilns are thus not a sustainable option. Retort kilns burn the gases from the carbonization processes and reduce the air pollution and its effect on global warming.

It was possible in 2013 to build a brick retort kiln at the Levas Flor site (near Condue, Sofala province, Mozambique).

This kiln was damaged during the first tests of making charcoal from waste wood of the sawmill.

A steel retort can cope better by bending stresses caused by the wood load and eventual over pressurization during the pyrolysis process. Round retorts are sturdier than those build from flat plates.

During the civil war a molasses tank wagon derailed at Condue near the Levas Flor site. The tank has been sitting there since then. The tank wagon was purchased by Levas Flor and the tank was cut loose from the carriage and has been transported to the sawmill site. It will turn waste wood from the saw mill into charcoal. In discussions with PUM senior consultants and the Levas Flor manager a simple low cost design has been developed.

Parts

Retort

The walls of the tank are approximately 10 mm thick. An area at the bottom of the front side was corroded and in one place a hole has been formed. This area has been patched with a new plate. A design with only one furnace opening has been adopted. The flames will then touch only the "good" part of the bottom of the tank.

The tank was factory reinforced with 10 mm steel at the junction with the curved stern plate. The stern has been cut loose and forms now the door. The thickness of the steel at the stern side of the tank is 30 mm at the bottom 120 ^{o} and 20 mm everywhere else. The door is reinforced at the workshop with three layers of 6 * 60 mm steel. In this way a rim of 28 * 60 mm was formed.

The vertical surface of the tank rim has been ground smooth. There is a gap of a few millimeters between the door and the tank. This gap needs to be filled with a paste of clay and water or a high temperature seal for operation of the kiln.

Furnace

The soil is, at the location chosen for the kilns, very hard at the end of the dry season. The soil has a paste like structure soaked with 65 mm of rain in 24 h.

The furnace is a trench .6 * .6 m dug in the soil after the loose top layer has been removed. The trench is 10 m long, in order that fire wood can be entered at one end. At the end of the furnace a side exit is provided, that connects the furnace to the chimney.

Chimney

The chimney has a diameter of 300 mm and a height of 2 500 mm. It is constructed from a 3 * 1 240 * 900 mm plate point welded to form a tube and an existing chimney of the earlier project made of 2 mm plate. The chimney trench is covered by a 6 * 1 250 * 1 250 mm steel plate in which a hole is cut for the chimney. The chimney is welded to this plate.

Tank support

A trench of 65 * 65 * 1 000 cm was dug to form the furnace. A bed for the tank at both sides was prepared using bricks, salvaged from the earlier project and soil. The tank was rolled onto this bed.

Frames

A square frame 120 * 2 250 * 2 250 mm outside and 120 * 2 100 * 2 100 inside dimensions was made of 60 * 120 * 2 250 mm H-profiles, welded together, to support the hinges of the door. The frame is placed flush to the end of the tank. The hinges for the door and the clamp to fix the door in the closed position are attached to this frame. Hinges and clamp were taken from the scrap yard.

Due to sagging of the tank, with a frame in place, a second frame was installed at 50 mm from the first frame with outside dimensions of 60 * 2 320 * 2320 mm and inside dimensions of 60 * 2 320 * 2 320 mm. The frame was made of 60 * 120 * 2 320 mm H-profiles, welded together.

This frame was further reinforced by four braces cut at an angle of 45 ^{o}, with the short length of 600 mm and a long length of 840 mm.

Door

The curved end plate is made into a door. The door was reinforced at the workshop with three layers of 6 * 60 mm steel. In this way a rim of 30 * 60 mm is formed. Plates, connecting with the hinges and clamp, are welded onto the outer surface of the door.

Door track

A door track is formed by two 5 * 750 * 1 900 mm plates. One of these is welded to the lower profile of the frame. The other is welded to the first, so that the door is supported by the plates when it swings open.

Hinges, lock and clamp

Hinges and the lock were taken from the junk yard. They were welded onto the first frame. The moving arms were then welded to the door, when the door was in the closed position.

Pyrolysis gas ducts

At the rear side of the manhole three holes are cut into the rim and three 75 mm tubes are fitted to the openings. These tubes run along the top of the tank for 2 500 mm, 2 425 mm and 2 350 mm respectively. The tubes then run 1 275 mmm, 1 200 mm and 1 125 mm horizontally sideways, down 2 350 mm and finally 825 mm horizontally so that the ends reach the furnace.

Isolation

During the building of the kiln it was decided to use a soil/sand/sawdust mixture as isolation. Thermal shields from the old project can be used for the front and rear side of the tank.

Construction

The tank was towed to a position about 1. 5 m sideways from its final position. Then the trench was dug out.

The tank was rolled in place. Further at the front of the tank an area of 10 * 30 * 235 cm was dug out of which 15 cm are under the tank so as to be able to place the frame.

At the same time the curved end plate of the tank was cut off.

The end plate is converted into a door by welding a rim at the outside. Hinges and a lock were welded to the curved end plate.

H-profiles of 60 * 120 mm were cut to a length of 2 250 mm. The ends were cut to a 45 ° so that the short side are 2 100 mm. They were welded to a frame with 2 250 * 2 250 mm outside dimensions.

At the tank site the frame is slid underneath the tank with the front side of the profile flush with the tank end. One plate of the door track is welded to the lower profile. The other plate of the door track is welded to the first plate.

Later the second frame was welded together and the braces were installed. For this some digging was done to slide the lower beam underneath the tank.

The trench for the chimney (60 * 60 * 140 cm) was then dug out and the
6 * 1200 * 1 250 mm plate laid over it adjacent to the frame.

Economics

The estimated investment is given in table I. The investment includes material that was available from the earlier project. Material from the scrap yard is not included. Labor from Levas flor workers is also not included.

Table I Investment

Item	Required number	€
Tank	1	3.200
Thick plates	2	300
Welding/grinding material		500
Design and supervision		700
Total		4.700
The prices of the plates is that of the Netherlands		

In the rainy season (December; 220 mm rain, January; 300 mm rain, February 280; mm rain and March; 250 mm rain) the kiln can not be operated. Twelve batches can be treated n the remaining 35 weeks of the year (One week offloading/loading, one week firing and one week cooling down).

- The firing of the small kiln in 2013 showed that about 100 kg/ m^3 charcoal from small offcuts per retort volume could be produced. With larger off-cuts this will be morel likely 65 kg/m^3. The production would be 25 000 kg/a.
  Depreciation is 0.06 €/kg of charcoal, with a write off period of three years for the kiln.
- In the earlier project manpower costs were estimated to be 0.08 €/kg. However 0.05 €/kg seems to be more appropriate.
- Transport costs are 0.03 €/kg to Beira.
- Distribution costs are set at 20 % of the retail costs. Transport and distribution costs are at present .07 €/kg, based on the price difference between Beira (300 MZN per bag) and Condue (120 MZN per bag); corrected for the tax on charcoal.
- Taxes 70 MZN per bag of 40 kg.

Charcoal is sold in Beira at 0.19 €/kg (300 MZN per bag of 40 kg). This is lower than the price calculated for the kiln at the saw mill site.

Charcoal production with the tank is viable, when a premium price can obtained by selling charcoal in smaller closed paper bags in supermarkets and gas stations.

Table II Price components

	€/kg
Depreciation	0,06
Manpower	0,05
Transport	0,03
Distribution	0,04
Tax	0,05
Total	0,23

Table III parts list

Part lists		Thickness	Width	Length	Number
Rims	New	6 mm	60 mm	2,200 mm	9
Pyrolysis gases ducts					
Tube (round)	Existing	1 mm	75 mm	2,500 mm	1
Tube (round)	Existing	1 mm	75 mm	2,425 mm	1
Tube (round)	Existing	1 mm	75 mm	2,350 mm	3
Tube (round)	Existing	1 mm	75 mm	1,275 mm	1
Tube (round)	Existing	1 mm	75 mm	1,200 mm	1
Tube (round)	Existing	1 mm	75 mm	1,125 mm	1
Tube (round)	Existing	1 mm	75 mm	825 mm	3
Frame and door track					
H-profile beams	Existing	60 mm	120 mm	2,320 mm	4
H-profile beams	Existing	60 mm	120 mm	2,250 mm	4
H-profile beams	Existing	60 mm	120 mm	840 mm	4
Plates	Existing	6 mm	750 mm	1,900 mm	2
Chimney					
Chimney	Existing	2 mm	300 mm	1,300 mm	1
Foil	Existing	3 mm	1,240 mm	1,1240 mm	1
Plate	Existing	6 mm	1,250 mm	2,500 mm	1
Other material					
Welding material					Not known
Grinding material					Not known

Experiences

Tank

The tank was supported on only two 1 500 * 150 mm reinforcement plates in the middle of the tank after it was rolled into its final position, demonstrating the strength of the soil in dry conditions. Heat resistant bricks, available from the old project, had to be used to fill the space between the tank and ground level.

The original idea was to reinforce the tank on the outside with 24 mm of steel before the curved end plate was cut off.

During inspection of the inside of the tank is was felt that the outer ends of the tank were sufficiently reinforced, so that when the curved end plate was cut no large deformation of the round tank would take place. This proved not to be the case as the tank sagged. This sagging was further enhanced by the cutting off of two tension panels, factory installed inside the tank, to prevent the sagging. After the tank was in its final position it was oval with a cord of 2 000 mm in the vertical direction and 2 130 mm in the horizontal direction.

A round shape (outer diameter 2 080 mm) was obtained with a jack in the end of the tank and the frame was installed and welded to the tank. Unfortunately the profiles of the frame were cut and assembled in such a fashion that not the maximum strength of the frame was obtained. The tank remained oval with the vertical dimension 2 050 mm and the horizontal dimension 2080 mm.

A second frame with braces was then aded and the tank was round with a diameter of 2 080 mm

The welding of the outer rim of the door went very fast.

A better sequence of installing the kiln would have been.

- Dig the furnace and provide some extra space for the support plates on the tank.
- Prepare the retort bed
- Roll the tank in place
- Weld two 6 * 60 * 240 mm strips on the top 270 ^{o} flush to the end plate.
- Install the frames with braces
- Separate the curved endplate and the tension panels from the tank.

Door track, hinges, door lock and clamp

The door track was very efficient. The 200 kg door could be moved with three man. The hinges are over-dimensioned as they are only needed to hold the door in the upright position. The door can however swing un-supported by the door track.

A factory made clamp was needed to reduce the space between the door and tank to 3 mm as the door was free to move a few millimeters in the hinges and door lock.

Pyrolysis gas duct

Existing tubes were used for the pyrolysis gas duct. The area of these tubes is rather small (12 500 mm$^{2)}$ compared to the area between the door and the tank (18 000 mm^2). The area is sufficient should the paste of clay with water put into the space between the door and the tank be effective as a high temperature seal.

A larger duct (140 000 mm^2) could have been made from 3 * 1 240 * 2 430 mm plates that were available from the earlier project. Experience with the chimney showed that these plates can be hammered into a tube. These tubes can have their entrance from the manhole. The present solution has the advantage that the manhole acts as opening for light and fresh air when the cover has been taken off.

Literature

Ann. no date “Making charcoal: the retort method” Volunteers in Technical Assistance, Mt. Rainier, Maryland 20822 USA

Kammen D.M. and Lew D.J. (2005), Review of Technologies for the Production and Use of Charcoal. Renewable and Appropriate Energy Laboratory Report. University of California, Berkeley, USA,

Hello Mr. Willem,

I hope you´re fine,

From our side it´s going on.

I would like to inform you that regarding to the furnace for charcoal production, we made some slight modifications to it, where instead of having only the back of the oven for placing the fire, we increased the dimensions (width and depth) of the fire channel (70x70cm), with a continuity opening this channel so that it extends to the front door, and as a result, we put in the middle zone and left side of the oven, the chimney, which means that the fire is made both in the front as well as behind of the oven to ensure that the process is effective. With this, temperature of the furnace body is now high to 200 ° C, while the chimney, can achieve the required 500 ° C, which was utterly impossible before the modification.

Further, we reinforced the door with a plate which covers the edge of the door, allowing the reduction of the possibility of air coming inside of the oven.

However, we have a small problem related to cracking of the metal body of the charcoal kiln, which reaches up the bottom of the furnace, especially in that welded place, after removal of the tubes that were part of the tank-wagon. Nevertheless, with the aforementioned changes, we are having acceptable results, where even we got the charcoal in three experiments that we did after the modifications. which means we can categorically say that LevasFlor has as improved charcoal kiln and produces charcoal from residues from logging, especially those from the sawmill.

It should be noted that at this time, we are doing some analysis in terms of oven income as well as analysis of the properties of charcoal produced based on this process.

In addition, you can view the images attached that illustrate some of the changes we made, as well as the product obtained in the experiments.

And because it constitutes a source of pride for us in LevasFlor, I really want to thank you for this wise experience that gave to us in the construction of improved furnace for the charcoal production, and we think that this is one of the few experiences in our country, I guess.

At the time, please accept our warm greetings and best wishes

Milton Chaúque
LevasFlor

Dear Milton,

Thank you I am fine, having some nice time at our vacation home.
I am really glad that you started to operated the charcoal kiln.

I would like to have a picture of the cracking of the bottom of the kiln, to see the nature of the damage.

The modifications you made are very good.

Could you provide with the time sequence

- time required for loading
- time required for heating up
- time required for cooling down
- time required for off-loading and bagging.

I had the fire only on one side as I was thought that the door needed a support on the bottom. The hinges are however that sturdy that this is not necessary.

I gather from the pictures that you pack the wood quite regularly.

- this requires extra work (costs)
- The gases in the retort can not circulate properly and the heat transfer is reduced. This means that the heating up and cooling down require more time than when the wood is just thrown into the retort.

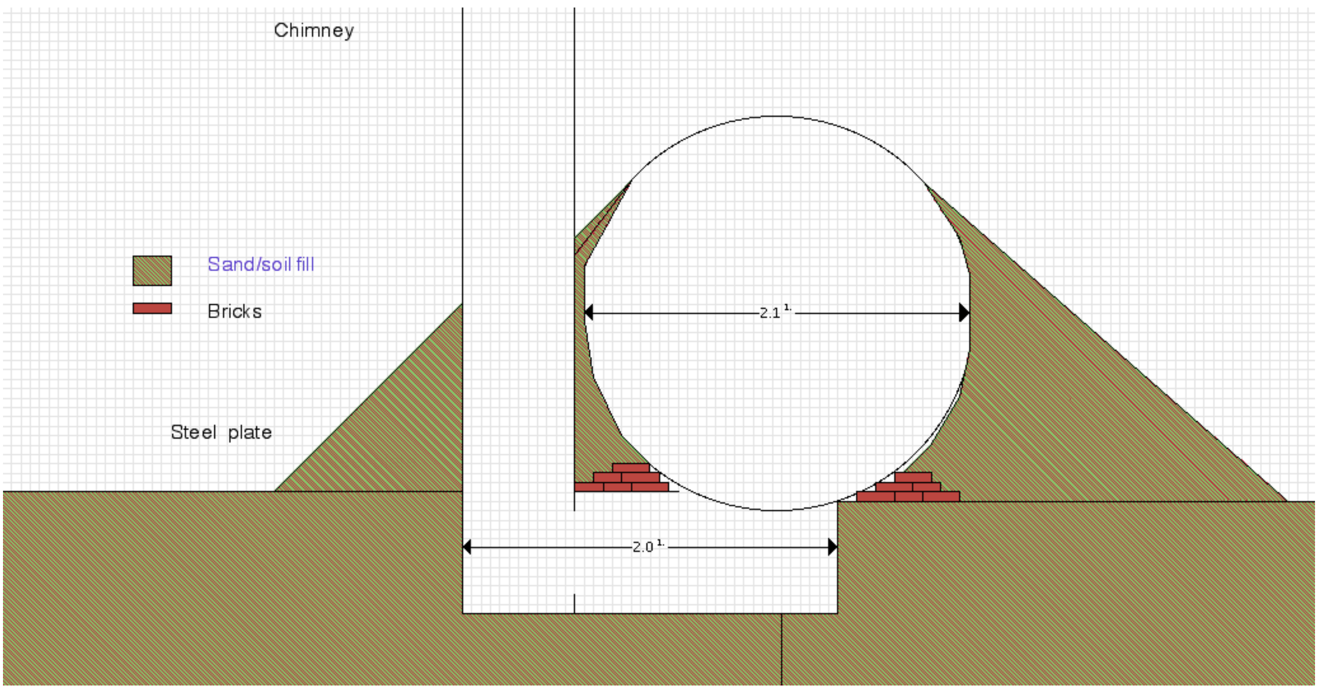
In my report to Erik Swerup I proposed:

Test should be performed to load the small off-cuts from the sawing benches into oil barrels, that have been cut into half, with handles attached to them. These barrels could then be transported into the retort and left there during charring.The barrels could also be used to unload the charcoal from the retort and to transport it to the site, where the charcoal is bagged.

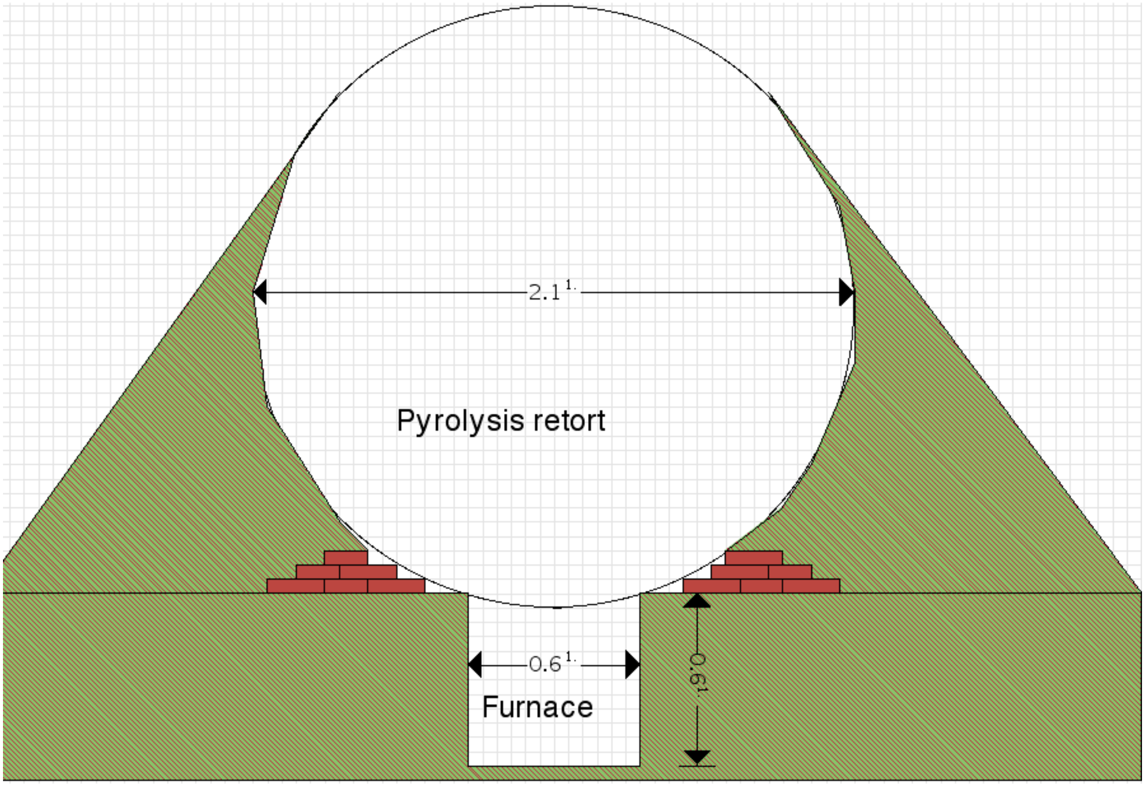
Dear Milton,

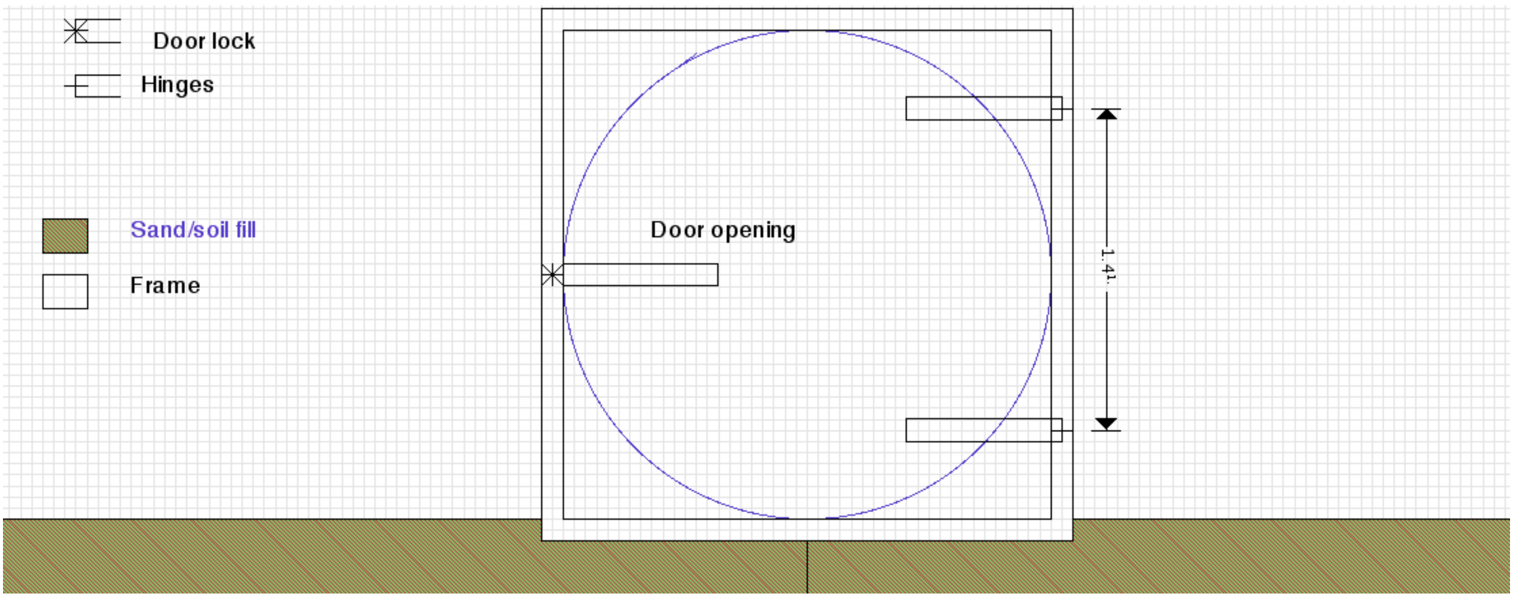
From the pictures I would suggest that the tank should be covered with a insulation layer of sand/charcoal fines/sawdust that is at least 20 cm thick.

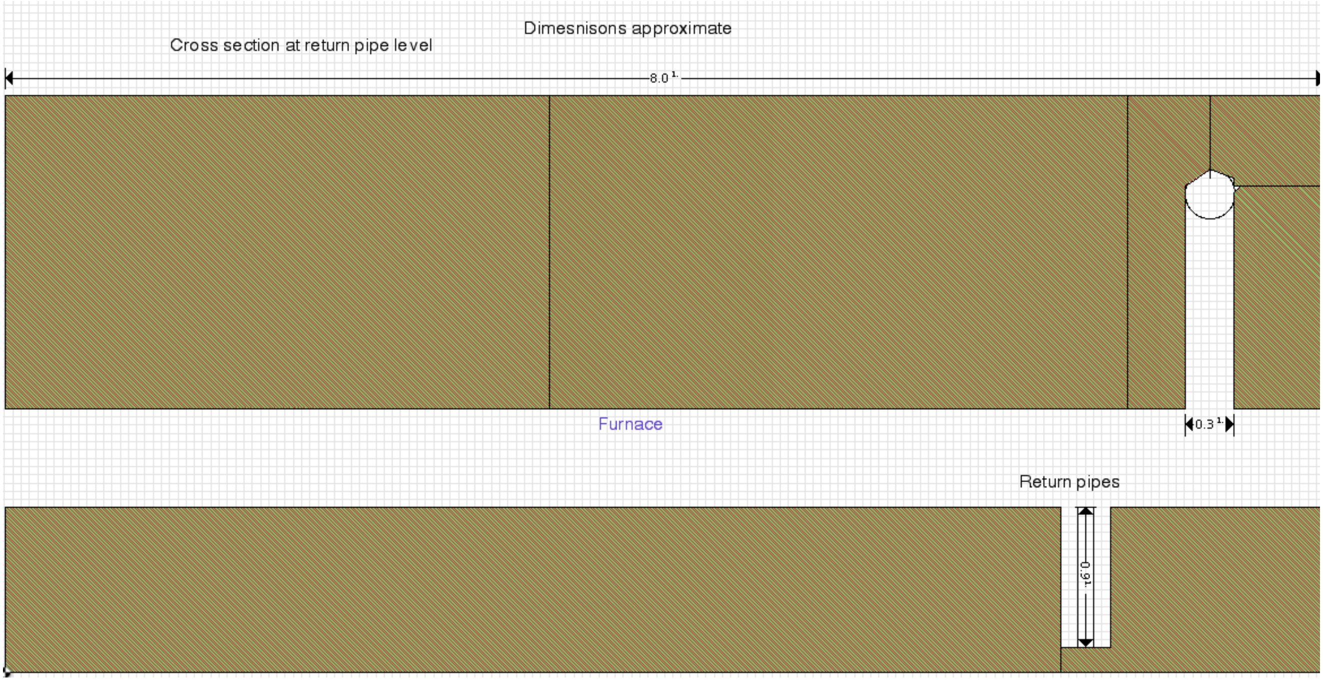
Look at the pictures in my report



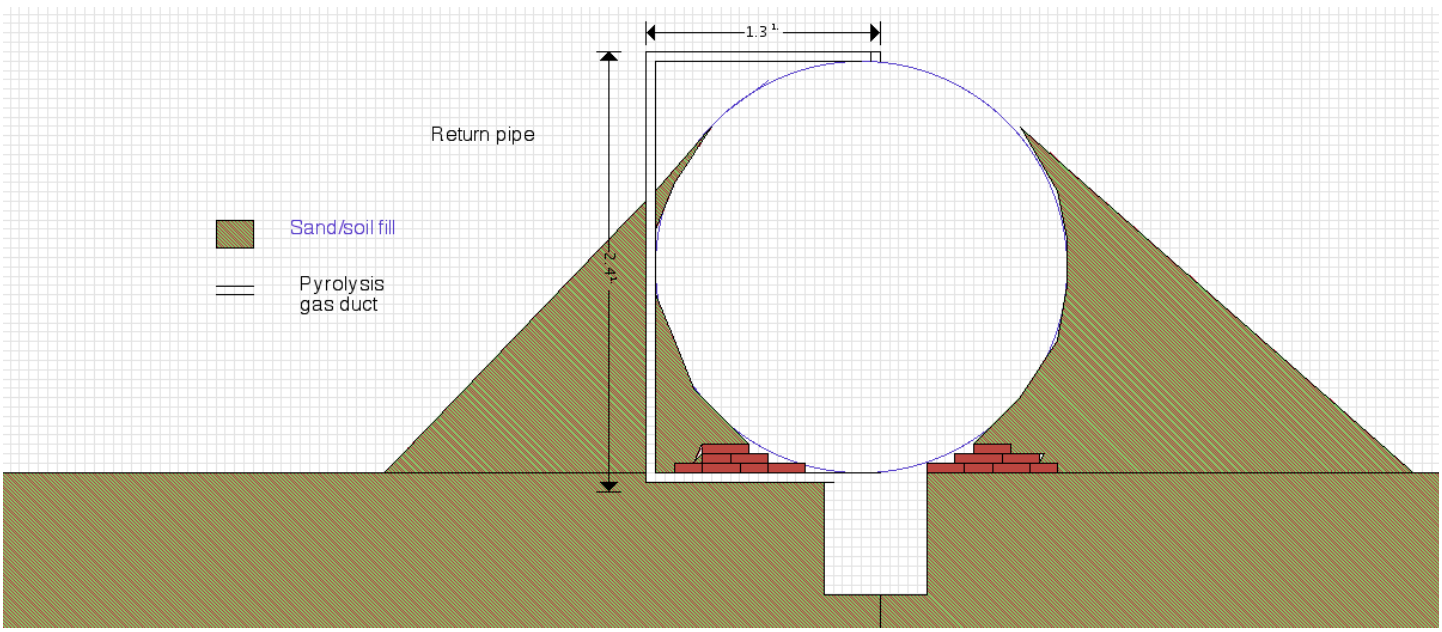
Chimney
Sand/soil fill
Bricks
2.1
Steel plate
2.0


2.1 1.
Pyrolysis retort
0.6 1.
Furnace
0.6 1

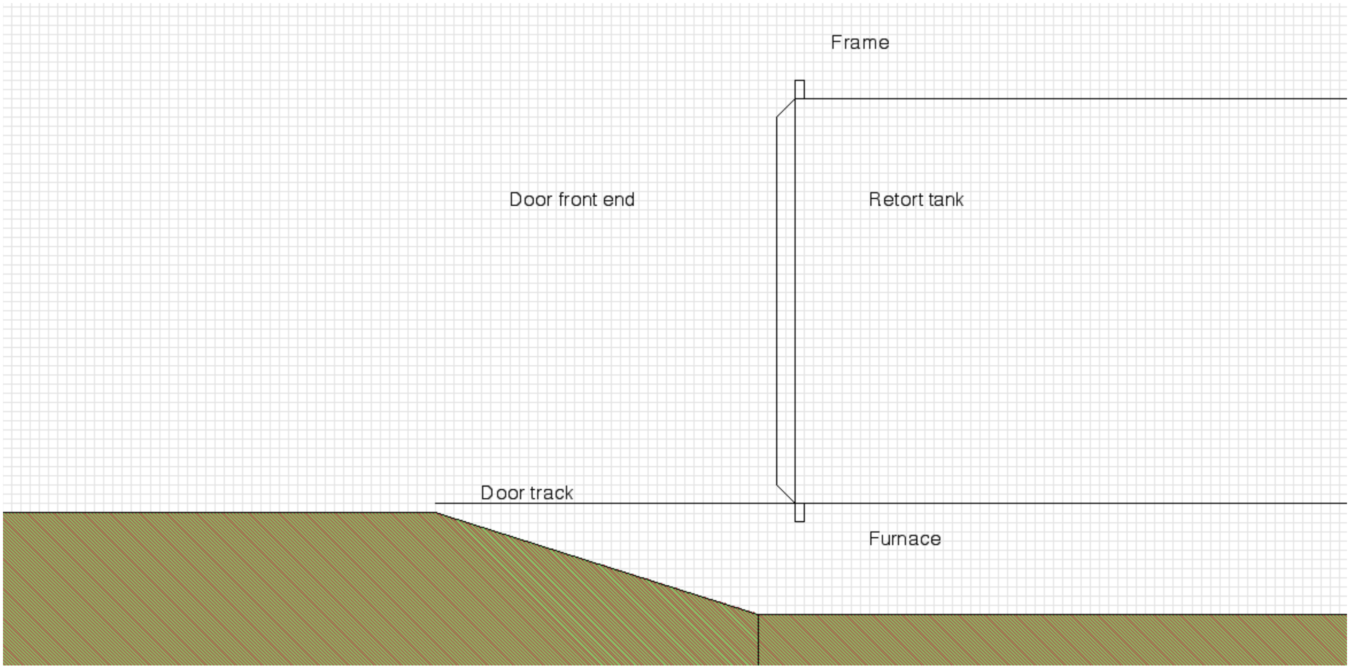

Door lock
Hinges
Sand/soil fill
Frame
Door opening
1.4 1.

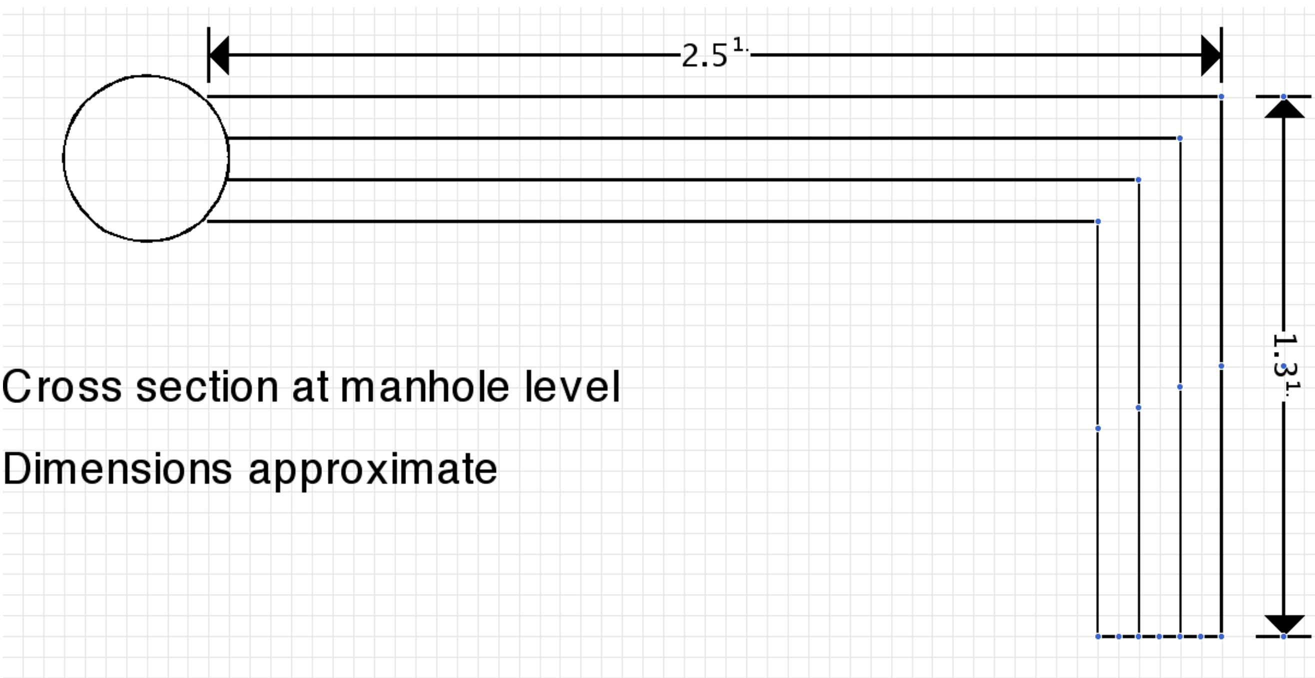


Dimesnisons approximate
Cross section at return pipe level
8.0
Furnace
0.3
Return pipes
0.9



1.3
Return pipe
2.4
Sand/soil fill
Pyrolysis gas duct





Cross section at manhole level

Dimensions approximate