Low Cost Incinerator: Construction Guide

Reference: GFD11-Do03

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Author: Andrew Russell

Contents

Revision	Date	Author	Comment/Change

Construction Guide for the Low Cost Incinerator

1. Introduction

These notes are intended as a guide for the construction of a low cost incinerator (LCI) and should be used in conjunction with the following general arrangement drawings and the parts list.

GFD02-101 sheets 1/3, 2/3 & 3/3 - GA Combustion chamber
GFD02-102 - GA External ducting
GFD02-103 - GA Outer wall
GFD02-004 - Heat exchanger arrangement
GFD02-005 - Feed chute layout
GFD02-006 – Agitator layout

GFD09-Pa001 – Parts List

These notes are based on experience gained, by the authors, during the design, construction and operation of the prototype LCI. Throughout the construction of the refractory brick it will be necessary to build-in steel work such as combustion air plenums and ductwork. Therefore these notes are broken down into a series of sections, or steps, which highlight important aspects of the construction process. Each section gives the general arrange (GA) drawing number after the heading. Individual components identified, where appropriate, by a reference number that appears both on the GA and in the parts list (PL) and is shown in the text in parenthesis as (GA/PL ref: #).

1.1 General description

The low cost incinerator (LCI) is a simple two-chamber unit designed to operate at temperatures in excess of 850^{0}C with a residence time of 2 seconds. The design consists of an inner refractory brick built incinerator surrounded by an outer protective wall made from ordinary building brick or concrete blocks. There is a gap of approximately 300mm between the inner and outer constructions. The incinerator is a two-chamber design with vertical sidewalls and a low sprung arched-roof. The outer wall is a simple vertical wall, without a roof, that follows the contour of the incinerator.

The low arched-roof of the incinerator is supported by buck-stays, located within the gap between the incinerator and the outer wall, and tensioned using tie bars. Sheet steel is braced between the buck stays and the gap produced between the sheet steel and the incinerator wall is then backfilled with fine sand to provide a seal helping to reduce the likelihood of air ingress into the combustion chamber.

2 General notes (please read carefully before ordering materials for construction)

2.1 Materials

The LCI has been designed for construction on site using refractory bricks and mortars, and ordinary building blocks or bricks using standard building techniques. The steel components are designed for manufacture by small fabrication workshops that have access to steel welding, bending and rolling equipment.

Refractory materials: The combustion zones of the LCI is designed to operate at temperatures in excess of 850^{O}C with occasional temperatures above 1100^{O}C. At these temperatures ordinary building bricks and mortar could disintegrate. Therefore it is very important that refractory bricks and fire-cement are used to construct the primary and secondary combustion chambers. The parts of the primary combustion chamber that are outside of the combustions zones (i.e. areas below the grates) can be built using ordinary brick and cement.

A standard high alumni (45%) clay refractory brick capable of withstanding temperature of at least 1300^{0}C will be suitable for the LCI combustion chamber. Fire-cement is composed of high alumni refractory cement and refractory granules.

Standard masonry materials: For masonry requirements other than the combustion chamber (i.e. foundations, outer wall etc) standard bricks, cement, and cement blocks can be used depending on what is locally available.

Steel components: All steel components have been designed using standard sections and gauges. Mild steel corrodes readily especially at elevated temperature and when exposed to the combustion environment likely to be generated in the LCI. Therefore it is recommended that the specified material thickness for components used within the combustion zones is not reduced.

For all other steel components it is possible to vary or make changes to the material specified provided that the material chosen is not significantly weaker than that specified. For example if a U section is specified but none is available it is feasible to weld two lengths of angle to form a U section of approximately the same dimensions as specified.

2.2 Dimensions

2.2.1 Combustion chamber: The internal dimension of both the primary and secondary chamber has been carefully calculated and tested and so it is **<u>very important</u>** that all internal dimensions are observed. The external dimensions of the combustion chamber are less important and can be altered to some degree to take account of variations in brick size and mortar thickness.

2.2.2 Outer wall: The main purpose of the outer wall is to prevent the operators and/or other working on or near the LCI from touching the hot surfaces of the combustion chamber walls. Therefore the dimensional accuracy of this wall is nor very important and can be altered to suit brick size and mortar thickness.

2.2.3 Steel work: The dimensional accuracy of the steel work, especially the ducting and the components that are built into the LCI during construction are important. Therefore all dimensions of individual components should be within ± 1mm unless stated otherwise on the drawing.

2.3 General notes on refractory brick work

2.3.1 Types of bonds

The type of bond used for the refractory brick work is very important to ensure structural stability and integrity. All vertical walls are constructed using the so-called English garden wall bond, which consists of alternating headers and stretchers on each course (see figure 2.1).

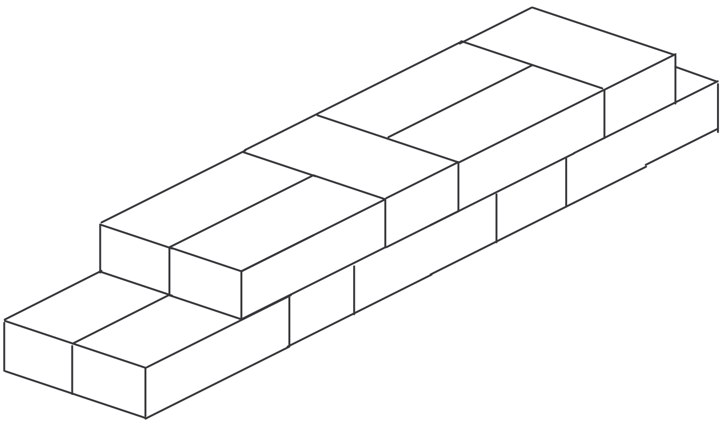


Figure 2.1 English garden wall bond

The primary and secondary chamber sprung arched-roof should be built using a bonded arch construction as shown in figure 2.2 (a).

a: bonded arch b: ring arc

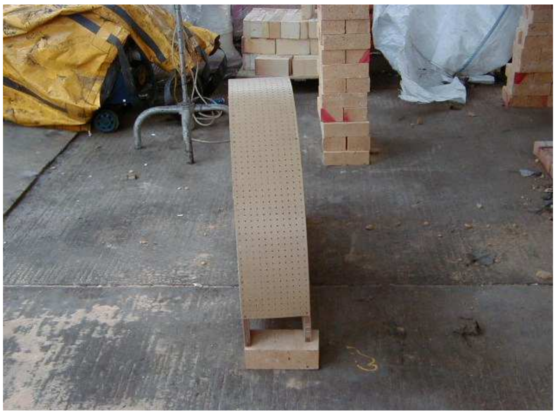
Figure 2.2: Arch construction

The access arches in the primary chamber (ash-end), secondary chamber (stack-end) and connection arch between the downward and upward section of the secondary chamber should be of the ring arch construction as shown in figure 2.2 (b).

***Important note*: Refractory cement should used sparingly as it shrinks and is libel to crack if spread too thickly. It is recommend that the cement thickness be no more than 3mm**

2.3.2 Arch forms

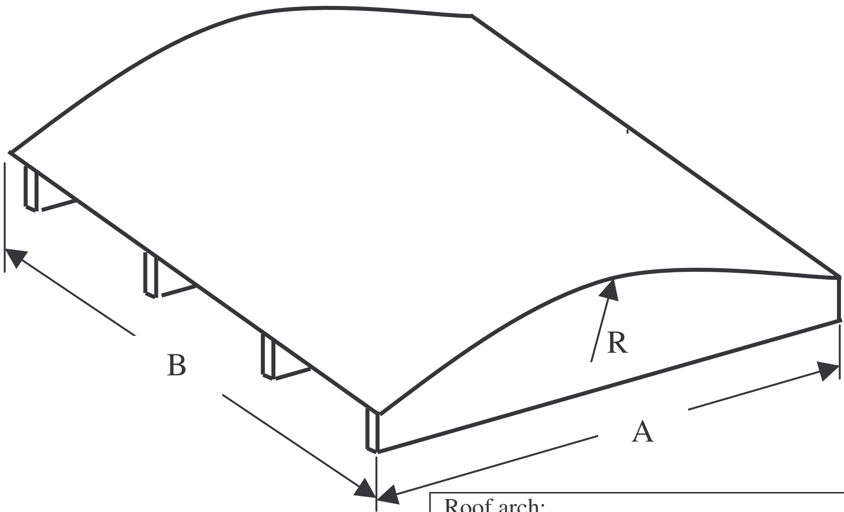
Each arch (access and combustion chamber roofs) will require a form to support the arch bricks during construction. These forms should be made on site to fit inside the chamber with a small amount of clearance, of approximately 5mm, all round. The top of the arch-former should have the same radius as the arch. The form should be a simple construction made from wood to make it easy to break up for removal after the arch is built or, if necessary, burnt out if it cannot be removed. Figures 2.3 a and b show the general design for the access and figure 2.4 for the roof arches.



a: side view

b: front view

Figure 2.3: Form for access arch



Roof arch:	A mm	B mm	R mm
Primary combustion chamber – feed end	1190	800	1655
Primary combustion chamber – ash end	1190	1200	1655
Secondary cross connector	680	2500	1350

Figure 2.3 showing roof arch former

2.4 Tools and equipment

The LCI and its components have been designed to be as simple as possible to build and/or manufacture. The brickwork is undertaken on site using tools that are normally used by builders. The majority of steel components are manufactured off-site by fabrication workshops using a range of basic tools and equipment. Tables 2.1 and 2.2 list both tools and equipment that are necessary to build the LCI and those that would be useful if available.

Table 2.1 Tools for brickwork

Necessary	Useful
Bolster and/or masonry chisels	Disc cutter
Hammer	
Plumb-line	
Shovel and buckets	
Spirit level	
Square	
Trowel	

Table 2.2 Fabrication workshop tools and equipment

Necessary	Useful
Arc welder	Angle grinder
Chisels	Disc cutter
Electric drill	Jig saw
Folding/bending machine	MIG/TIG welder
Gas welder/cuter	Pan break
Hacksaw	Pedestal drill
Hammer	Power saw
Rolling machine	
Sheet steel snips/cutter	

3 Construction notes

3.1 Foundation and LCI floor

A concrete foundation is required and should be substantially larger than the footprint of the outer wall. Although the LCI is 'T' shaped it may be more practical to make a rectangular or square foundation providing additional hard standing.

The footprint is set out as shown in figure 3.1 below. The reference terms shown, indicating which end is which, will be used throughout this manual. It may be useful to use this or similar terminology when setting out and building an LCI to ensure that every one involved knows which end is which.

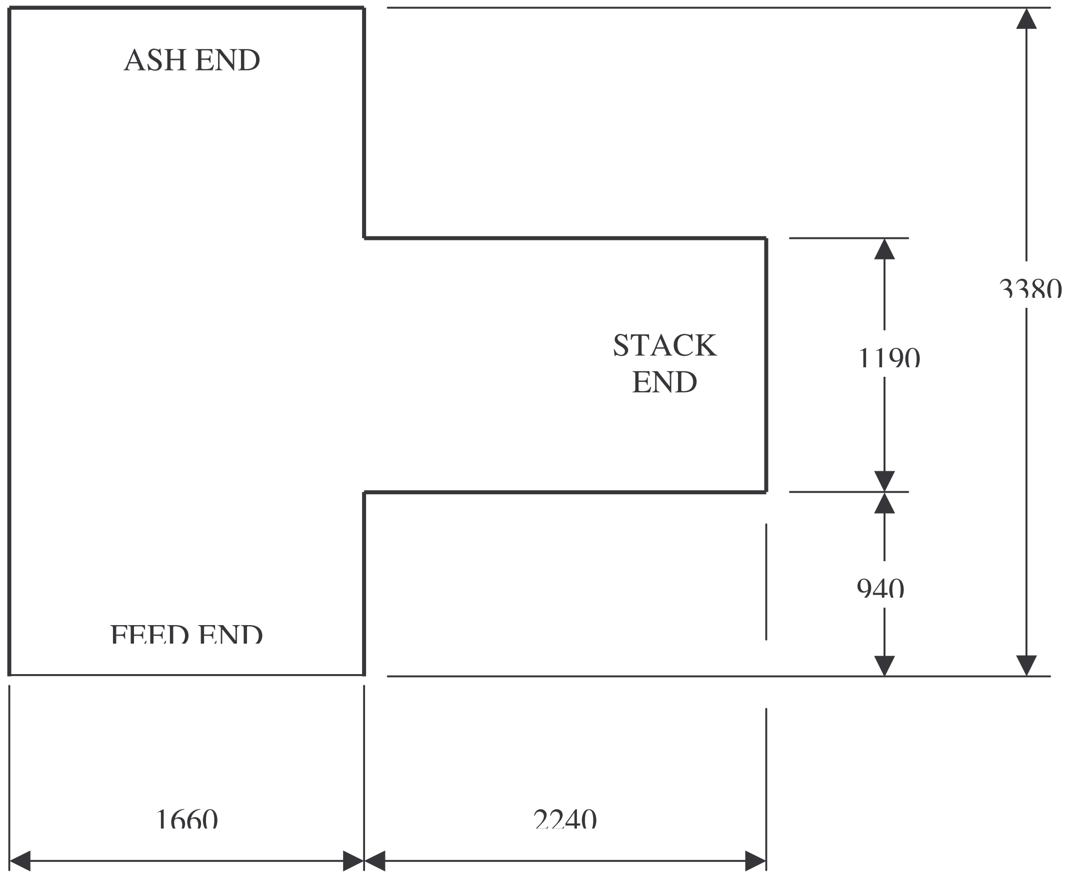


Figure 3.1: LCI footprint

NOTES:

- ***See drawing GFD02-101 sheet 1/3 to confirm footprint dimensions***
- ***It is the internal dimensions that are important and the footprint shown in figure 3.1 assumes a wall thickness 225mm. If the refractory bricks being used are a different size then it will be necessary to modify the dimensions of the footprint to suit the size of the bricks being used. For example the internal width of the LCI at the feed end is 1200mm and therefore if the bricks being used are 215mm long then the 1660 dimension shown in figure 3.1 will become 1630mm. For details of internal dimensions see general arrangement drawing FD02-Dr101 sheets 2/3 & 3/3.***

Once the footprint has been set out then a single course of common bricks can be laid to make the floor for the LCI. These bricks need be bedded in mortar and set level (see figure 3.2 below)

Figure 3.2: Laying LCI floor

3.2 Primary and secondary chambers

(GA GFD02-Dr101 sheets 2/3 & 3/3)

Figure 3.3: Laying refractory bricks (from stack end)

The primary and secondary chambers, including roof and access arches, are constructed from refractory brick and fire cement. Starting from the stack end (see figure 3.3) the vertical walls can be laid keeping the inside face of the LCI, the most important in terms of finish, as smooth as possible. Any irregularities due to variation in brick dimensions or mortar joint thickness should appear on the outside face.

The right hand wall (from the feed end) of the main primary combustion chamber can also be built up and the plenum/grates (GA/PL ref: 1), ash boxes (GA/PL ref: 6 & 7) and air ducting (GA/PL ref: 9) can be placed in position (see figure 1.6 and section 1.5 for details). The stack end walls should be built up to the height level with bottom of the arch between the downward and upward section of the secondary chamber (see GA FD02-DR101 sheet 1/3 &2/3) and primary chamber right hand wall up to a height level with the bottom of the primary chamber access arch.

Figure 3.4: Building primary chamber right hand position
(Note: Plenum/grate shown is the prototype design and differs from current design)

3.3 Primary chamber grates and air ducts

GA Drawing GFD02-Dr101 sheet 2/3

The grate support legs (GA/PL ref: 2,3,4 & 5) should be attached to the plenum/grates (GA/PL ref: 1) and the complete assembly placed in position on the LCI floor as shown in the assembly drawing. Next the ash box for grates 3 (GA/PL ref: 6) and grate 2 (GA/PL ref: 7) should be placed in position under the plenum/grates with the outlets passing through the left wall of the primary chamber.

The height of the plenum/grates is correct when the ash boxes are sitting on the floor. The legs are then adjusted to ensure that the grate bars are level and that the great/plenum is stable. There is no need to bolt the plenum/grates assembly to the floor of the LCI.

The primary under-air ducts (GA/PL ref: 9) are then attached to the plenum/gates. The ends of the ducts will required a simple (wood or metal) support to prevent buckling until the combustion chamber and outer wall brickwork can be built up around them.

***Note**: The flange joints between the air inlet ducts, ash boxes and the plenum/grates should be sealed with a gasket or sealing tape to ensure that the joints air tight. The thread of the bolts or nuts, used to join the ducting and plenum together, should be greased using a heat resistant grease to facilitate future maintenance*.

The surface of the grate is made from perforated refractory brick size 230 x 114 x 50mm thick (GA/PL ref: 109). These bricks should not be laid until the primary chamber sidewalls have been built up above the height of the grates.

The perforated bricks are laid along the sloping face of the plenum/grate supported by the angle cross members ensuring that the holes are uppermost (see figure 3.5). The refractory bricks should be cemented in position (using fire cement or clay) and then covered with a sheet of wood to protect them while the rest of the LCI is built.

Figure 3.5: Perforated refractory bricks being laid on plenum/grates

To ensure an airtight seal mineral wool insulation (or similar) or a gasket material should be placed between the side of the plenum/grate and primary chamber sidewalls. Similar gasket material should be placed under the ash boxes (GA/PL ref: 6 & 7) at the point where they exit the primary chamber wall and also on all sides of the duct as the vertical wall is built around it. This material will act both as a seal and also as an expansion joint between metal and masonry materials.

3.4 Primary chamber access arch

Drawing: GFD02-101 sheet 2/3 -

The primary chamber access arch is a full arch made from refractory brick (see figure 3.6) and an arch form will be required to support the arch while it is being constructed. The arch is made up from a series of tapered (along the stretcher face) refractory brick segments. Bricks with two different tapers are used to make the single arch ring: 18 bricks 230 x 114 x 76/57 taper (GA/PL ref: 106) and 16 bricks 230 x 114 x 76/52 taper (GA/PL ref: 107). As the arch is double thickness then two rings are required. Starting with a 76/57 taper brick at its base the arch should be built up from both sides at the same time alternating the taper on each layer (i.e. first course 76/57 and the second course 76/52 and so on). The last brick in place should be key brick at the top of the arch.

Figure 3.6: Primary chamber access arch construction (with former in place) from the Ash End

3.5 Secondary chamber arches

GA drawing: GFD02-Dr101 sheet 3/3

They are two arches in the 'S' section of the one connecting the downward and upward section of the chamber (see GA FD02-DR101) and the second providing access into the bottom of the 'S' section of the chamber. Both are full section double thickness arches of the same size and so only one form will be required. A single arch ring is made up from 18 tapered bricks of the same dimensions – 230 x 114 x 76/45 taper (GA/PL ref: 108). Figure 3.7 shows the secondary chamber arches in position.

The secondary chamber walls (side wall, 'S' section dividing wall and end wall) can now be built up to the height of the primary chamber wall.

a: Connecting arch b: Access arch

Figure 3.7: Secondary chamber arches

3.6 Completion of vertical walls

GA drawing: GFD02-101 sheets 2/3 - Combustion chamber

A corbelled wall is built at the Ash End of the primary chamber starting one course above the primary chamber access arch. The corbelled wall is on the inside only with the outside face remaining vertical (see figure 3.8).

Figure 3.8: Corbelled wall above access arch on Ash End wall of the primary chamber

3.7 Primary chamber side air

GA drawing: GA drawing: GFD02-101 sheets 2/3 - Combustion chamber

Primary side-air is delivered through the left hand wall to the lower and middle grates only. The side air inlet ducts (GA/PL ref: 16) do not pass directly into the primary chamber but only extend halfway through the left hand wall into a plenum constructed from perforated refractory brick. This design enables the side air to be more evenly distributed across the whole grate and helps to reduce problems with ash, char and other solids blocking the air inlet jets.

The perforated bricks are the same as those used for the grates (GA/PL ref: 109) with each brick containing ten 13mm diameter holes in the stretcher face. Each brick has the same length (225mm) and width (115mm) as standard refectory bricks but are only 50mm thick compared to 76mm for standard bricks. The perforated bricks are fitted as vertical headers set flush with the inside face of the primary chamber wall leaving a gap of 26mm between the end of the air inlet jets and the perforated bricks. Standard refractory bricks are then placed as headers across the width of the wall to complete the side air plenum (see figure 3.9).

Figure 3.9: Building side air plenum

Ensure that the side air inlet ducts (GA/Pl ref: 16) are sealed onto the stubs on the lower and upper primary side-air manifold (GA/PL ref: 10 & 11) using fire cement at the joint and then covered with sealing tape.

3.8 Sight glass box

GA drawing: GFD02-101 sheets 2/3 - Combustion chamber

The sight glass box (GA/PL ref: 77) is located in the primary chamber one course above the ash-end arch. Looking through the sight glass box and adjusting it so that the best possible view of both the lower and middle grate is found should determine the exact position. The sight box will need a temporary support (at the glass end) until the outer wall has been built. Care is required to ensure that the sight box is fully sealed in position.

<u>Note</u>: The site glass is made from Pyrex or similar heat resistant glass suitable for use with combustors. This type of glass is expensive and so it is recommended that the it is not fitted into sight box (other than to check that it fits correctly) until all construction work has been completed. The glass should be fitted with seals on both sides.

3.9 Primary chamber roof-arch

GA drawing: GFD02-101 sheets 1/3, 2/3 & 3/3 - Combustion chamber

The primary chamber roof is a low sprung arch comprising two sections one either side of the outlet to the secondary chamber. The arches are the same width and radius the section of roof on the ash-side of the secondary chamber outlet is slightly longer. Formwork is required to enable the arches to be built. Buckstays and tie-bars are required to support and keep the arch in tension.

Figure 3.10: Skew-brick and skew-brick rails in position.

The buckstay uprights (GA/PL ref: 51) and skew-brick support rails (GA/PL ref: 52, 53, 54, & 55) should be assembled and placed in position as shown in the drawing GFD02-101. The tie-bars (GA/PL ref: 56) and tie-bar plates (GA/PL ref: 57) can be fitted but do not tighten.

The buckstay uprights can now be bolted to the floor using rag-bolts (GA/PL ref: 134). The buckstay uprights should be vertical and so, if necessary, place shims or washers under the foot of the buckstay to achieve this. Tighten the tie bars (hand tight) until the buckstays are under tension.

Adjust the skew-brick support rails so that the bottom rail is level with the top of the combustion chamber walls and secure in position. Span the gap between the skew-brick rails and the primary chamber wall with a refractory brick making sure that it is hard up against buckstay rail. Fit a skew-brick between this and the inside face of the primary chamber. The Skew bricks can be made by cutting one end of a refractory brick at an angle of 45^0 (see figure 3.10). Place a second course of refractory brick on top the skew brick and lower the top skew brick support rails into position.

Two arch-form of the same radius and width, but slightly different length, are required for the primary chamber roof (see GA GFD02-101 sheet 2/3 and section 2.3.2 for sizing and design details). The arch formers are supported from underneath using wooden posts wedge against the plenum/grate (see figure 3.11).

Figure 3.11: Arch form supported by wooden posts

Once the form is in place the arch can be constructed. To turn the arch bricks with two different tapers are required as follows: 230 x114 x 76/73 (GA/PL ref: 104) and 230 x 114 x 76/70 (GA/PL ref: 105). The bricks are laid in the bonded arch configuration as shown in figure 2.2a on page 5.

<u>Note</u>: It is recommend that a dry test be carried out by laying out two or three courses of the bricks, on the arch former, without mortar. This will familiarise the builder with the bond and help determine the order in which the different tapered bricks are laid to turn the arch effectively.

Figure 3.12: Primary chamber arch under construction.

3.10 Secondary chamber cross-connector

GA drawing: GFD02-101 sheets 1/3, 2/3 & 3/3 - Combustion chamber

There are three important features that require special consideration when building the cross connector. First of all the connector is built on top of, and supported by, the primary chamber arched-roof and spans across the downward section of the secondary chamber. Secondly the left hand wall (from the feed end) of the connector is corbelled (see GA GFD02-101 sheet 2/3) and finally the secondary-air inlet tubes (GA/PL ref: 29), five each side, are built into the vertical walls (see figure 3.13).

To enable the secondary-air ducts to be positioned correctly it will be necessity to assembly the duct on the inlet manifold (GA/PL ref: 30) and support the manifold in position while the walls are built up. It may be necessary to temporarily assembly all the secondary air ducting to achieve this.

Once the vertical walls of the secondary chamber are built to the correct height the backstays, skew brick supports and tie bars can be fitted. The design of the secondary chamber backstays differ from those used on the primary chamber and consists of a simple frame comprising of two pillars (GA/PL ref: 58) connected together by the buckstay support rail (GA/PL ref: 59). This frame spans across the primary chamber and along the length of the secondary chamber. The buckstay uprights (GA/PL ref: 61) are then bolted to the support rail. The skew brick support trail (GA/PL ref: 60) is then attached to the buckstay uprights (see figure 3.15)

Figure 3.13: Cross connector built on top of primary chamber roof-arch - showing corbelled wall under construction and secondary-air tubes (view from ash end)

Figure 3.14: Building up the vertical walls of the cross chamber from the corbelled end

Figure 3.15: Secondary chamber buckstay frame and backstays in position

3.11 Secondary chamber roof-arch

Figure 3.16: Secondary chamber roof-arch under construction – showing arch former and backstays in position

The secondary chamber roof-arch is constructed in the same manor as the roof-arch for the secondary chamber (see section 3.10 for details). However, please note that the radius of the secondary chamber roof-arch is different to that of the primary chamber and so a new arch form will be required (see GFD02-101 sheet 2/3 and section 2.3.2 for design guidance).

3.12 External steel work and sand seal

GA drawings: GFD02-101 sheets 1/3, 2/3 & 3/3 – combustion chamber; GFD02-004 – Duct work; GFD02-005 – Feed chute assembly

Once the refractory brickwork has been completed the external ductwork and the feed chute mechanism can be assembled. It is important that the Venturi duct (GA/PL ref: 21) is fitted correctly before the heat exchanger.

Once the ductwork is in position then sheet steel (1.5mm thick max) should be fixed to the buckstay uprights to form a retaining wall around the combustion chamber (see figure 3.17). The gap between the retaining wall and the combustion chamber wall should be approximately 200mm. The top of the retaining wall should be level with the top of the refractory brickwork. Make sure that there is access through the retaining wall to the ash-end and stack-end access doors. Also the retaining wall will need to be cut around air inlet duct and other steel work that passes through the combustion chamber walls (see figure 3.18).

Figure 3.17: Sheet steel retaining wall under construction

Once the retaining wall has been built it is backfilled with sand to provide an air seal minimising the ingress of air through cracks that may occur in the mortar and brickwork over time.

3.13 Outer wall

GA drawing: GA drawing: GFD02-101 sheets 1/3, 2/3 & 3/3 - Combustion chamber

An outer wall, made from ordinary building brick or concrete block, surrounds the LCI. The purpose of this wall is to prevent people from touching the hot surfaces of the combustion chamber or the sand-seal retaining wall. The outer wall follows the profile of the combustion chamber at a distance of approximately 300mm and a height of at least 2500mm. There is no roof on this wall. All buckstay uprights should be inside the wall (see figure 3.18).

Figure 3.18: Outer wall construction

It is important that an access tunnel between the outer wall to the ash-end and stack-end access arches is built (see figures 3.19).

Figure 3.19: Access tunnel from outer wall to combustion chamber access arch (ash-end)

When in operation a dry wall of refractory bricks should built up in the tunnel to block the access arch. Rockwool should also be placed against these bricks and a simple door bolted over the whole of the tunnel opening. The door can be a simple angle steel frame with sheet steel cladding. A simple explosion door should be installed in the door such as a hinged flap.

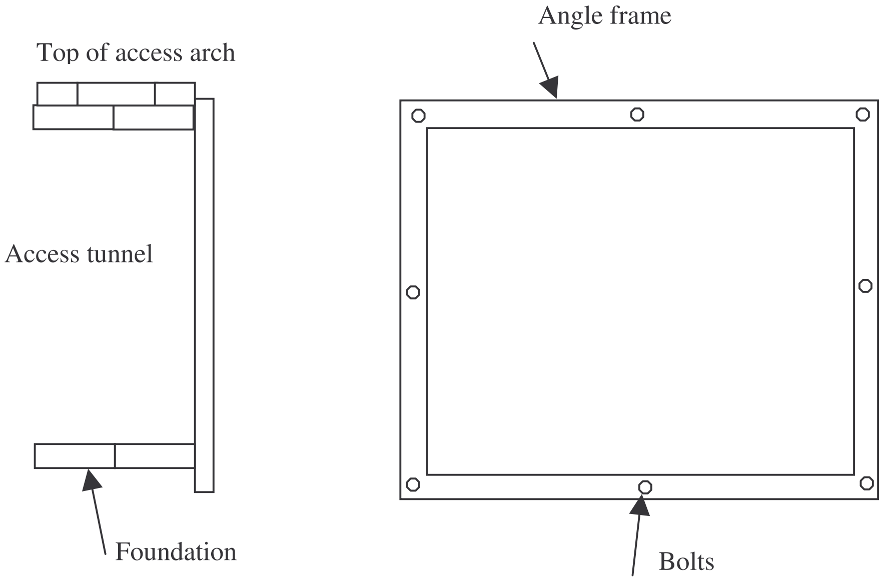


Figure 3.20: Door for access tunnels