INTERMEDIATE TECHNOLOGY CONSULTANTS

# Evaluation of Hoffmann Kiln Technology

Low Cost Solid Waste Incinerator

Project No. 2C98028

Work Package Number

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Roger Sharp -Technical Services Manger, Hanson Brick Co. Ltd

Geoff Bowler - Consultant and ex. Manager of Technical and Environmental Division of Hanson Brick. And,

# 1. INTRODUCTION AND BACKGROUND

As a result of the South Africa visit, the project team were able to identify a number of designs for MSW incineration dealing with quantities of up to ten tons per day. It was established that one such existing plant with "acceptable" emission standards has been constructed for somewhere in the region of £80,000. Whilst this price can be argued to be affordable in relative terms (when compared to cost of engineered landfill, or other waste disposal plant) it has been recognised that for practical wide- scale uptake of the plant in developing countries, a lower cost technology (but one that still meets agreed minimum emission standards) is needed.

As a result a study visit was undertaken to view some Hoffmann Kilns in use at Stewartby Brick Works, elements of which could contribute to the design of a 'no-frills' incinerator with a lower capital cost. It was thought that the low support fuel requirement and minimum number of moving parts as well as the high combustion temperatures achieved via the Hoffmann Kiln could contain useful elements for the low cost solid-waste incinerator project.

It is in this context that a study visit was organised to investigate the design and operation of a Hoffmann brick kiln. The objective was to assess whether there are aspects of the design and operation that could be incorporated into the design of a low cost solid waste incinerator.

The visit was to Hanson Brick's Stewartby brick works in Bedfordshire where there are two Hoffmann-type kilns in operation. An initial meeting was held between the study team (Andrew Russell and Roberto Vogel) and Roger Sharp of Hanson Brick and Geoff Bowler (ex. Hanson Brick) followed by a tour of an operational Hoffman Kiln. The visit concluded with a second meeting to discuss design and operational aspects of the Hoffmann Kiln and their relevance to solid waste incinerator design.

# 2. DESCRIPTION OF THE HOFFMANN KILN TECHNOLOGY (see photographs in Annex)

The kiln investigated at Stewartby is a natural draught multi-chamber transverse-arch Hoffmann Kiln designed for producing Fletton bricks in a continuous process. The Kiln is a large permanent structure built entirely from ordinary building brick, inside and out, with a number of simple cast iron and steel non-structural components. The Kiln consists of a central chimney, approximately 70m (200ft) high, connected to a main flue running the length of the Kiln. On either side of the main flue there are seventeen barrel-arched firing chambers, each linked to the main flue via damper controlled underfloor 'steam-flues' (see figure 1 in Annex)

The chambers are connected via a number of small tunnels, known as fire trace holes, through the dividing walls just above ground level. A number of offtake flues in the chamber walls carry drying and combustion gases down into the 'steam-flues', which are under draught as soon as the damper controls to the main flue are lifted. Each chamber is also connected to a hot air flue, situated around the top of the kiln, which enables hot air, via damper controls, to be recirculated from one chamber to another. Support fuel can be added to each chamber through small openings in the roof. Larger openings allow the control of temperature (reduction) by introducing ingress air.

## 3. PRINCIPLES OF OPERATION

The kiln is operated 24 hours a day (3 shifts) 365 days per year, producing 1.25 million bricks per week. Two fires 'chase' each other around the kiln, moving progressively from one chamber to another with the bricks undergoing drying, pre-heating, firing and cooling in turn. Once lit the kiln is not allowed go out and the whole process is controlled manually by manipulating dampers and sliders, which requires skill and experience. To assist the operator in controlling the process, chamber temperatures are monitored using a number of thermocouples linked to a PC.

The clay used for making the Fletton bricks is unusual in that it contains about 5% by weight of an organic lignite-like material which contributes significantly to the firing of the bricks and minimises the amount of support fuel needed. This organic material is formed from algae, spores, pollen, bacteria and other plant and animal cells.

Newly made 'green' bricks are set in a chamber and the entrance is bricked up and then sealed using an ash and clay based skim to prevent the ingress of air. Hot air conveyed from cooling bricks in one chamber is used to dry and pre-heat bricks in another. Drying is carried out relatively slowly to ensure that all the moisture is driven out of the bricks uniformly and that distortion does not occur. Once the bricks are dry then it is important to raise their temperature rapidly in order to maintain reducing conditions in the chamber. The organic material in the clays helps with this process.

Once the required temperature has been reached, caps over the openings in the roof are opened permitting 'easing' of bricks by allowing cold air into the chamber. Coal is subsequently fed through openings in order to achieve the necessary soaking time (30 hours at 930-960$^{o}$C). After firing the bricks are allowed to cool in the chamber before they are removed. This cooling process provides the heat to drive the drying process of the next batch. New 'green bricks' are then placed in the chamber and the process cycle starts again. Each cycle takes 10 days to complete.

The kiln operates by natural draught with the buoyancy of the exhaust gases providing the motive force, with maximum exhaust temperatures at 150$^{o}$C. The draught has to be sufficient to overcome the pressure drop through the kiln and to ensure that the chambers are always under negative pressure. The driving pressure in the chimney is maintained at around 25mm water gauge.

The brick making process attempts to minimise the use of fuel. Therefore the mass throughput of gases through the flue system is kept to a minimum which ensures removal of the drying effluents and the combustion products used to maintain the required temperature. Gas velocities in the chambers are low and not conducive to high turbulence.

# 4. EMISSIONS

The following typical releases to air are produced in this process:

| | | |
|---|---|---|
| Particulates: | 60 - 70 mg/Nm$^3$ | (18% $O_2$ dry) |
| CO: | 100 mg/Nm$^3$ | (18% $O_2$ dry) |

Concrete emission data was not available at the time of the visit and a formal request for this information has been made in writing to Geoff Bowler.

From observation, the chimney emitted a white exhaust for most of the time. However, most of this will be air and water vapour (generated during the drying process) and is not due to poor combustion within the kiln. The organic content of the clay as well as the coal (support fuel) have a high sulphur content and so it is assumed that $SO_2$ and $SO_3$ will be the main gases emitted.

Products of incomplete combustion including some odourless compounds are emitted specifically from the 'Coming Hot' and 'Main Drier' phase of the process.

Once the temperature in the chamber has reached soaking temperature (960°C approximately) the combustion of the organic content in the clay and of the support fuel (coal) is thought to be complete, giving rise to no significant releases of products of incomplete combustion.

It is important to note that the emission characteristics of the Stewartby kiln are directly related to the brick material and firing regime and do not necessarily reflect the performance of a comparable design used to incinerate MSW.

# 5. HOFFMANN KILN CONCEPT IN RELATION TO THE LCI PROJECT

Although designed for a different purpose the Hoffmann Kiln does have a number of operating features and design characteristics that could be incorporated into a low-cost incinerator design as follows:

- Brick built structure with some simple steel and cast iron components means that the design will be easy to transfer elsewhere. Refractory brick may be needed to line the chambers, as waste incineration temperatures may exceed that experienced in a brick kiln. In addition, refractory bricks are more able to withstand fouling, abrasion and impact, which may occur when feeding and stoking solid waste (the bricks are not in contact with the chamber walls when being fired).

- Hoffmann Kilns are used in a number of Asian and African countries and so the knowledge and skills required to build this type of technology may already exist.
- The large thermal mass when up to working temperature helps to maintain good combustion conditions and to smooth over variations in fuel calorific value.
- The down-draught operation means that low density feed-stock, such as paper and plastic bags, would have less tendency to be volatilised when top fed.
- Labour intensive operation requires skills and experience rather than electronic control devices.
- Brick built chimney tall enough to help create sufficient draught to ensure negative pressure and velocities to create turbulence in the combustion chamber.
- Multi-chamber design with heat recirculation may have relevance to municipal solid waste incineration as the heat from incineration could be used to pre-dry waste.

Having noted positive aspects of the Hoffmann design the following aspects have to be treated with caution:

- Combustion in the chamber takes place at low gas velocities not conducive to the turbulence required for full gas burn out.
- The brick structure of the chamber is dry wall from a height of 1 metre from the floor. This is permeable to air even with the cover of ballast applied on top of the dry brick barrel vault. If pyrolitic conditions are to be maintained in the chamber for the combustion of waste, better impermeability to air needs to be achieved.
- While the mass throughput of fuel is minimised in the brick making process, in waste combustion the waste throughput must be maximised. With high throughput conditions the chamber will not satisfy the need for full burn out of the gases and a secondary chamber will have to be added to the design.

# 6. CONCLUSIONS AND RECOMMENDATIONS

- Some features of the Hoffmann Kiln design and operating principles (such as simplicity, low cost, high thermal mass, multi-chamber design and heat re-cycling) could be incorporated in a low cost 'no-frills' incinerator design which could be designed to meet minimum acceptable emission standards.

- Caution is recommended with the high permeability, dry brick barrel vault and other aspects of the design.
- Geoff Bowler, who has extensive experience with the construction and operating principles of Hoffmann Kilns, could bring his expertise into the project. Possible areas of expertise include:
  - Design of low cost brick structures for combustion chamber and stack
  - Brick technology and mortar technology
  - Technical review services
- It is therefore recommended that we:
- Draw up guidelines for the design and operation a low cost MSW incinerator according to Section 11 of the South Africa Report.
- Organise a multi-stakeholder workshop in the chosen partner country to ensure that the operating standard is acceptable and appropriate.
- Design and build a test-rig for a low cost incinerator combining appropriate aspects of the South African incinerators (see S.A. Study Visit Report) with low cost features from the Hoffmann Kiln.
  - The following aspects can be taken from the South Africa Report:
    - Basic design of pyrolitic combustion chamber and secondary combustion chamber
    - Pre-treatment of MSW and removal of pollutants
    - Use of used engine oil as a support fuel
    - Manual stoking
  - The following aspects can be brought in from Hoffmann Kiln design:
    - Brick based structures (including the stack)
    - Simple design possibly including down-draft and top-feeding
    - Multi-cell design
    - High thermal mass
    - Manual operation
    - A minimum of moving parts
- Assess the performance (including releases to air from this design) in the light of the guidelines agreed and confirmed at the multi-stakeholder workshop.

# Annex

1 General view of Stewartby brick works

2 Chamber about to be “set” with green bricks.

3 Chamber dividing wall showing
- off-take flue
- fire chase hole (right)

4 Hot air vent on arch of chamber roof

5 Loading of green bricks into chamber

6 Loaded tunnel chambers being bricked up ready for drying and firing.

7 View of barrel-arch chambers

8 Roof of the Hoffmann Kiln showing chimney and small piles of coal and caps over fuel inlet holes.

9 Support fuel loading holes.

10 Air inlet opening

11 Thermocouple connection point.

12 General view of roof of kiln

13 General view of chimney stack with single storey buildings in foreground.