Low Cost Incinerator: Operating manual

Reference: Close-Do-01a

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Contents:

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FDa	22.11.00	RV	1st Outline
FDb	July 01	RV	2nd Draft for comment EMC
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Operating Manual for Low Cost Incineration (LCI)

1 Introduction

1.1 General Remarks

This manual is aimed at the operators of the Low Cost Incinerator (LCI) who have built the installation according to the construction manual. The description covers the operations from waste reception to disposal of residues. It includes commissioning activities and essential maintenance activities. Health and safety aspects are worked into this manual. In order to successfully operate the installation potential operators must read and understand this manual. A copy must be available in the control room for reference.

As this technology is not widely tested, and as circumstances (such as waste composition, available materials and skills) differ from place to place we expect that during the operations new relevant aspects and changes to procedures will be discovered. These changes must be recorded in the logbook. The operator must then insure that the operating manual is updated accordingly. Contact details for the ITC project team ca be found at the end of this manual.

1.2 Overview of Operations and Plant

The Low Cost Incinerator (LCI) has been designed for use in developing economies. It provides a means of disposing of pre-sorted household waste on a semi-continuous basis at a maximum of 425 kg per hour by combustion. For start-up the incinerator is fired with wood waste or other biomass (depending on local availability) and then only fed with pre-sorted household waste, once the required temperatures for full combustion have been reached. In the text below this auxiliary fuel will be referred to as biomass.

Primary combustion takes place in a primary chamber, fed with natural draft primary air via dampers, and is followed by secondary combustion in a secondary chamber with forced draft air from a fan. The combustion air is controlled via dampers according to combustion conditions. Primary and secondary air can be pre-heated, depending on waste composition and CV. Once burnt out (again using biomass as auxiliary fuel, to maintain good combustion) the incinerator is allowed to cool to warm-keeping conditions. To end one combustion cycle the ashes are raked out (in the morning) before starting up again.

Note to Front and Back End Operations:
The process also requires front and back end operations (waste sorting and ash handling/disposal). However these aspects of operations need to be tailored to local circumstances as MSW composition, historic/traditional waste management arrangement, geographical circumstances, etc. have a large impact. Specifications and other information on front and back end operations are contained in the next chapter to assist the appointed design engineers with the planning and implementation of the overall process.

Although a simple design, combustion is still designed to meet the current European/UK requirement of 850 °C / 2 seconds residence, for good combustion. These conditions are achieved by following a combination of feed stock control and 2-stage combustion (air-starved primary and fan assisted mixing in secondary combustion).

All operations are manual with the exception of the combustion air fan, which is driven by an electric motor.

It is expected that 3-4 operators are required during the burning phase to transport, feed, stoke and control the operations.

2 Waste reception, pre-sorting and ash handling

Waste reception, pre-sorting and storage as well as the nature of the biomass used as auxiliary fuel differ from country to country, from site to site, depending on circumstances such as collection vehicle types, collection patterns, site circumstances, MSW composition, traditional and historic waste separation patterns, etc.

Similarly, ash disposal depends on availability of land filling sites and associated planning permits.

It is therefore that this section is written in terms of specifications, dimensioning and other, general considerations. The detailed planning and execution of the front and back end operations must be carried out by qualified civil engineers with experience in the fields of waste management and recycling. The following description is based on a design example for the overall lay-out of the LCI, the drawing for which is contained in section 9.2.

However, it must be stressed here that the success of the overall processes depends on good quality pre-sorting and efficient ash handling. In particular it is noted that the combustion unit is not designed to combust un-pre-selected MSW.

2.1 Reception

<u>*Dimensioning*</u>

– Biomass for start-up/shut-down; 3 hours worth ⇒ 1,000 kg minimum 3-5 m^3

– MSW say for running max 10 hours with waste 10 x 500 (it is assumed that per cycle of 4250 kg sorted MSW 750 kg of glass, tin & undesirables (~18%) are removed) = 5000 kg ~16 m^3

  If this is delivered in one go we will need to store the 5000 kg in the reception area. 1 m deep ⇒ 3 x 6 m (18 m^3 maximum space). Needs walls on 3 sides (plywood).

Construction Details

- The delivery area is not suitable for storage – it should always be swept clean at the end of the workday.

- Slope is towards sorting area.

- Quality of surface:
  Hardstanding, smooth, preferably with impermeable membrane incorporated with a sump to catch any liquid effluents.

Work Process:

The refuse collection vehicle (RCV) backs onto the reception platform and deposits the waste onto the hard standing. In order for the whole load to be deposited it may be necessary to 'shovel back' between dumping phases. Two operators, while ensuring that any danger of crushing or other form of injury from the RCV is averted, are required to do this.

Once a load is dumped the sorting operation starts.

Sorting of waste consist of the transfer of waste with carts to the sorting area, bag ripping, separation and transfer of components to their designated storage places. The sorted waste is loaded into the carts and deposited in the storage area. Metals, glass and undesirables are shoveled into their respective containers. This operation is carried out by 3 persons.

Sorted MSW is simply transported through to the fuel storage area with the carts or wheelbarrows.

All deliveries and disposal operations have to be logged correctly on forms by the operators.

Number and qualifications (reception & storage): 3 labourers able to carry out this work conscientiously following written and verbal instructions. In particular it is important to recognise waste fractions for recycling and also undesirable objects containing PVC and heavy metals as well as oversized objects (→ create reference guide for material recognition).}

i) Waste reception: 3,500 kg per cycle (one or several loads depending on access and delivery vehicle).
– tipped on surface stacked against side & back walls
– taken in cart through gate to sorting area
ii) Start-up/shut-down biomass is dumped (1,000 kg/cycle) and taken through directly to biomass storage area through 2 gates.

Other notes:

- Ideally with roof
- Clean after sorting

2.2 Sorting

<u>Dimensioning</u>

- 2 m x 5 m area
- Only maximum 200 kg there at one time

- MSW is brought in from reception in a wheeled cart and dumped at Point a (refer to drawing). Metal, glass and undesirables are sorted manually (bag breaking then push in direction of containers b, c & d. Sorted waste is loaded in a second cart and dumped in (3) Storage MSW.

<u>Construction Details</u>

- Hardstanding, smooth preferably with impermeable membrane, draining towards a sump (Point e on drawing).

- Not suitable for waste storage – always swept clean at end of working day.

- All sides walled to 1 m (ply).

- Bins b, c & d are containers for undesirables, glass and metals respectively.

<u>Work process:</u>

Waste sorting of 3500 kg of MSW per cycle (maximum 5000kg).

- Use forks/shovels for loading carts 50 – 100 kg/load.
- Sorting: break bags and flick materials in 4 directions with tools (fork, rake): sorted waste, undesirables (b), glass (c) and metals (d). Use shovels to periodically load these materials into wheelie bins. Assume up to 5% / 7% / 5% of waste undesirables /glass/ metal: bin capacity 150 / 210 / 150 kg respectively.
- Sorted waste is loaded into cart 2 and dumped in the MSW storage area.
- Containers b, c & d are removed by way of the reception area.

<u>Other notes:</u>

- Ideally with roof.
- Clean after sorting.

2.3 Storage

<u>Dimensioning</u>

- MSW storage: 3.5 m x 3.0 m stacked to 1.5m. Average this is ~ 15 m^3 of sorted waste (lowest possible density: 250 kg/m^3). This correpsponds to 3.75 tonnes storage.

- Biomass storage: 3 m x 1.5 m = 4.5 m^2 to store about 1,000 kg (check this).

Construction Details

– Back and division wall up to roof (2.50 m).

– All other walls and openings in wire mesh to stop vermin.

– Hardstanding, smooth, preferable with membrane draining towards sorting area.

– Roofed area.

Work process:

i)

– MSW from sorting is stacked against back and dividing walls up to 1.5 m height.

– When burning it is loaded into carts and moved over the ramp to the feed hopper area where a 1 hour storage is arranged.

– The passage through the biomass storage area is initially blocked. But with stoking up at least 50% of the biomass will go.

– No MSW should be stored for longer than 2 weeks (normally – if exceeded, risk analysis).

ii)

– Biomass is brought through directly from reception and stacked up to 2 m in wood storage area (preferable before MSW is brought in). MSW may block the passageway.

2.4 Feeding Platform

Dimensioning

– The feeding platform is an integral part of the combustion unit. It is linked to the storage area by a 3 m long 33% inclination ramp. This leads to a 1 x 3 m platform, which extends from the combustion unit. The platform and the first meter of furnace roof form a 2 m x 3 m feed hopper area with storage against the sidewalls and back wall and the feeding slide leading down into the combustion chamber.

– Platform 1 x 3 m in thick ply.

Construction Details

– Furnace roof 1 x 3 m smooth rendering finish.

– Sidewalls 1 m tapering off in direction of storage with hands rails except ramp access.

– Install fire-fighting equipment.

Work Process:

– Wood and MSW is pushed up the ramp in carts and dumped against the walls and fed into the feedchute as and when required.

– At all times there should be 1 hours of feedstock in reserve in this area.

2.5 Ash Storage

Dimensioning

– 3 m x 2 m hardstanding area linked by a hardstanding walkway to the combustion unit door. (3 m x 2 m x 1 m = 6 m^3 @ 1,000 kg/m^3 this corresponds to 6 tons of storage ~ several burn cycles).
– This area must be fully enclosed to avoid wind blown contamination

– Vehicle access to remove ashes is on one side of the storage area.

– Max Quantity of ash per cycle:
15 % of 5,000 kg = 637 kg (less than 1 m^3)

– Quality of surface:
  – Hardstanding, smooth, impermeable membrane, drain towards sump.
  – Roofed over, sides with wire mesh (against vermin), front closable.

Work Process:

– At end of burning /cooling cycle ash is removed with a wheelbarrow from the lower combustion chamber and dumped in the ash storage area.

– Removal of ashes onto suitable vehicle directly from storage area.

2.6 General Considerations

– Mass balance:
  – Weigh incoming wood and MSW
  – Weigh wheelie bins b, c and d
  – Weigh ash out

Quantity list (just as an example)

i)	Hardstanding floor area	~ 50 m^2
ii)	Foundations for LCI	15 m length by 0.65 m width
iii)	Vehicle access points	2
iv)	1 m sidewalls	22 m length
v)	1 m gates	1
vi)	3 m gates	2 (MSW del./ash removal)
vii)	High side walls	8 m length
viii)	Wire mesh (MSW storage)	8 – 10 m^2

ix)	Roof covering	21 m^2 min, 40 m^2 max
x)	Perimeter fencing	62 m length + 2 x 3 m vehicle access doors
xi)	Hand tools	Shovels, forks
xii)	2 carts; 1 wheelbarrow	

<u>*Other notes:*</u>

– In case MSW cannot be treated within 14 days of receipt the stored MSW is loaded back onto vehicles through the reception area.

– Smell nuisance, vermin must be considered by site designers

3. Plant & Process Description

3.1 General

The combustion operations consist of a waste storage area, auxiliary fuel (biomass) storage, the LCI structure and the ash storage area.

Approximately 500-1000 kg of pre-sorted MSW are stored as a feed stock buffer in the designated waste storage area on a concrete covered and walled floor. This storage area is continually restocked over the day from the pre-sorting operations.

The biomass storage area allows for the storage of approximately 1000 kg of biomass, which is used as auxiliary fuel.

The LCI structure consists of a feeding ramp and intermediate storage for MSW and auxiliary fuel, a primary combustion chamber, a secondary combustion arrangement, a tertiary chamber and a connection duct leading to the adjacent brick stack.

The P & ID schematic GFD04-Dr01a and associated Lists provide a schematic representation of the LCI (see section 9.3)

The ramp is a steel construction allowing the operators to transfer the MSW and auxiliary fuel from the storage area to the feed chute intermediate storage.

The feed chute is a slot of the dimension of 1.2 m x 0.3 m approximately leading in an incline of approximately 30° on to the drying grate (grate 1). A feed ram allows the controlled dosing of MSW onto the grate.

A sand-sealed cover is provided for emergency situations and for the burn down phase. It provides an airtight seal in the absence of a MSW ‘stopper’. In addition a spray valve arrangement allows the dowsing of any fires occurring in the feed chute.

The **primary combustion** chamber is a double walled, refractory lined box of approximately 1.2 m x 2.9 m. It incorporates the feed chute inlet onto grate 1 (drying grate), the main combustion grates (all with an incline of 20°) and an ash chamber, where a day’s production of ashes is stored until de-ashing.

The sidewalls are constructed in three layers designed to reduce heat losses and avoid ingress air. Refractory brick, sand, steel sheet, air gap (with steel structure) and outer brick wall.

The roof of the chamber consists of a refractory brick arch, with an opening approximately above grate 2 where gases exit into the secondary combustion chamber. The roof is covered in a layer of sand to control heat losses and ingress air.

At the ash chamber end of the primary chamber a de-ashing door and viewing port are arranged and a temperature sensor (CT010) is arranged above grate 2 in the primary chamber

Primary air is supplied into the primary chamber via primary air ducting (and flow monitoring), through the steel plenums under grate 1, 2 & 3 and introduced through holes in the grate bricks and on the right hand sidewall. Total airflow rate is controlled with a butterfly valve (AA102) in the primary air ducting.

Primary air pre-heating is achieved by mixing ambient air with hot air, drawn from a brick heat exchanger in the dividing wall between primary and secondary chamber. Temperature control is achieved by using butterfly valve AA101 and observing temperature sensor CT110.

The distribution between grate 1, 2 and 3 and under grate and side wall is controlled with the aid of butterfly valves. (In normal operations the pre-set values of these valves are only changed to correct the fire position on the grate.) Ash is removed via ash doors at the bottom of the plenums. Through the gap in the roof arch the gases pass into the S-shaped **secondary chamber** arrangement. Secondary air nozzles are arranged in the vertical walls dorsally and frontally in a way to achieve maximum penetration of the gases and good burnout. Secondary air is provided from the secondary and cooling air fan with flow rate control from butterfly valve AA200. After the valve the secondary air is pre-heated in the heat exchanger AP21, which extracts heat from the gases in the tertiary chamber. In order to ensure that the heat exchanger is cooled at all times a pressure relief valve allows air to vent to ambient just after the heat exchanger (AA201). The secondary air temperature is monitored on temperature sensor CT120. Secondary airflow is monitored by venturi CF020. On the combustion side of the process, after two changes of direction the flue gases pass vertically upwards into the tertiary or cooling chamber. Outlet temperatures are measured by temperature sensor CT021a & b. Also on the outlet of the secondary there is a sampling port for exhaust gas monitoring.

Principles of construction of the secondary chamber are of a similar multi-layer design (refractory – sand – steel sheet – air – brick) as the primary.

An ash door at the base of the third pass allows for ash removal from the secondary chamber. The walls of the secondary ash plenum are at a steep angle to discourage ash accumulating.

The **tertiary chamber** incorporates tertiary air nozzles designed to cool down the gases instantaneously from the 700-850 °C (exit secondary) to approximately 350 °C. A heat exchanger in the tertiary chamber reduces the exhaust gas temperatures further to below 300°C. A transition from the refractory constructed secondary joins up to the steel construction of the tertiary chamber, which in turn connects to the brick stack via a connector and flange. All steel sheet hot ducting are lagged with suitable mineral wool insulation material to avoid heat losses and for safety reasons.

Tertiary or cooling air is provided via ducting from the secondary and cooling air fan and controlled with the butterfly valve AA300.

The exit temperature of the flue gas at the outlet of the tertiary chamber is monitored by T-sensor CT030 and opacity by cross channel analyser CQ04. Tertiary airflow is not continuously monitored, but controlled by adjusting the exit temperature.

3.2 Process Description

Waste/auxiliary fuel feeding is done from the intermediate waste storage next to the feed chute by shovel. With a rake like tool the feedstock is pushed down the vertical chute. A manually operated ram arrangement (2connected rams) allows the feedstock to be fed onto grate 1 in well-defined strokes.

At the start up combustion of auxiliary fuel (biomass) only is the rule until conditions in the secondary chamber allow MSW feed.

The fire is started by introducing a (lit) oily rag onto grate 1 and feeding biomass onto it.

While firing with auxiliary fuel the combustion conditions in primary and secondary are with excess air (see tables 1 in section 9.5, combustion parameters).

The basic operating parameters, which must be obtained, are presented in Table 1 – Basic Operating Parameters. Corrective action is presented in Table 2, also in section 9.5.

By controlling feed, primary air, secondary air, PA and SA pre-heat and stoking the required combustion conditions must be obtained.

The secondary and cooling air fan must be switched on as soon as secondary/cooling air is required. This is the case during start-up when temperatures in the tertiary chamber exceed 150ºC.

Once 850 °C is obtained in the secondary chamber using biomass, MSW is added to the feedstock and primary and secondary airflow rates are increased gradually until operating parameters for normal MSW operations listed in Table 1, section 9.5, are reached.

In the combustion chamber the feedstock is dried and degassed on grate 1 (little primary air input). On grate 2 the main combustion under slightly sub-stochiometric (70%) conditions takes place and on grate 3 combustion of the fixed carbon is achieved. Grates 2 and 3 receive primary air from under the grate and the right wall. Grate 1 receives a mixture of pyrolisis products from grate 2 and primary air. Partial combustion under grate 1 and in the wall channels above are designed to accelerate the drying process on this grate.

The transport of feedstock from grate 1 to 3 is achieved by a combination of 3 factors and must be tightly controlled at all times. (1) The feed rams push the feedstock into the combustion zone and down the grate. (2) The grate inclination encourages transport by way of gravity. (3) Stoking arrangements on grate 2 and 3 allow active agitation of the feedstock resulting in a downward movement (in addition to the stoking effect this has).

Combustion products and products of partial combustion (12.9% CO by volume) exit the primary chamber under normal operating conditions and travel along the three-pass secondary chamber arrangement.

At the inlet of the secondary chamber secondary air is injected through nozzles in the dorsal and frontal wall of the secondary. The nozzles on either side are offset so that the projection of one nozzle hits the opposite wall between 2 opposite nozzles. This is designed to allow for good mixing of the gases and hence complete gas burn out. As secondary air is pre-heated, the quenching effect of injecting cold air is greatly reduced.

At the exit of the secondary chamber gas burnout should be complete and the temperature not less than between 700 and 850 °C.

The gases are then conducted into the tertiary or cooling chamber, where they are cooled down from 700 - 850 °C to approximately 350 °C by way of injecting tertiary air through opposing nozzles. The gases are cooled further in the secondary air heat exchanger.

Gases are conducted into the brick stack via an inclined connector. The buoyancy of the hot gases supports the flow of primary air into and combustion gases through the ducts and chambers.

4 Health & Safety Overview

4.1 General Remarks

The aim of our H&S overview is to identify risks and the mitigation of risks and ultimately to ensure that the test rig operations can be conducted without accidents or any other harm to the persons directly involved in operations and also third persons.. The aim is a zero accident record.

Health and Safety (H&S) risks in this project (building, operating and decommissioning of the pilot plant) are associated to standard H&S issues of building and demolition work on the one hand and the operation of combustion equipment on the other. Here we will focus on the specific risks deriving from the operation (waste handling/combustion) aspect of the project.

A Hazop study was conducted during the test rig phase, relating to the test rig operations. The Hazop panel was formed from EMC and ITC members. Any findings from this study were integrated into the present H&S procedure and the operating manual.

Below we present the risks and mitigation/protection measures for each part of the processes as well as the proposed implementation program.

4.2 H&S Risks and Associated Mitigation/Protection

Building and Decommissioning Phase

Risks and mitigation/protection during these phases are associated with those of general building work. Therefore standard procedures will be adopted here. Subcontractors will be asked to observe the H&S guidelines as part of their subcontract. They will also be aware of and comply with site-specific H&S regulations.

Operating the LCI

Waste Reception:

Risks: Crushing from vehicles reversing, hydraulics, waste discharge; splashing; inhaling of dust and bio-aerosol; risks associated with initial handling (shoveling into initial storage area, removal of initial undesirables)
Mitigation /protection: Crushing: waste delivery protocol (to be drawn up with delivery organisation); splashing, inhaling, handling: mandatory wearing of overalls and steel capped shoes/boots, mandatory use of protective gloves when handling waste, dust masks and protective goggles on the man/women to be worn in case of relevant risks arising. Further measures to mitigate splashing and dust are the provision on site absorbent and water hose (spray abatement of dust)

Waste Handling/Sorting:

Risks: splashing; inhaling of dust and bio-aerosol; risks associated with handling and sorting of recyclables/undesirables (shoveling into initial storage area, removal of initial undesirables), Crushing from handling and dispatch of recyclables/undesirables.
Mitigation /protection: Crushing: waste dispatch protocol (to be drawn up with waste disposal organisation); splashing, inhaling, handling: mandatory wearing of overalls and steel capped shoes/boots, mandatory use of protective gloves when handling waste, dust masks and protective goggles on the man/women to be worn in case of relevant risks arising. No direct contact with the waste is made; sorting is done by way of hand tools (shovels, forks, brooms), small sharps are part of the waste stream to be combusted and are not to be picked up by hand but by shovel.

Waste Storage

Risks: Fire hazard, methane generation
Mitigation /protection: Waste is not stored for longer than 7 days in the specified storage area. Due to the sorting activity this waste is tightly controlled so that no glowing embers or other ignition sources are allowed into this area. If storage of more than one day takes place a daily check of the waste takes place (hot spots, steam). Any methane build up is discouraged due to dispersion to ambient air.
To extinguish small fires a hose with town's water is available.
(See also fire procedures).

Operating and Maintaining the Combustion Unit

Risks: Risks associated with enclosed spaces, inhalation of combustion gases and dust, risks associated with hand feeding/stoking, back burning (chute), explosion (in combustion chamber), falls from structure, burns from hot surfaces and incandescent material. Also specific risks from conveyor unit such as crushing or cutting.
Mitigation/protection: Enclosed spaces: check that no (combustion) gases are present (21% O2 on emission monitoring), open feed chute, ash door and stack to ensure draft, use buddy system plus rope, personal protection as required (overall, face mask, hard hat, steel capped boots, gloves and goggles mandatory);
Risks feeding/stoking: gloves and goggles mandatory; back burning: wet sand at ready, feed chute cover; in sever cases of backburning use water spray
Explosion: waste control will largely exclude potential risk of explosion, with respect to build up (potentially explosive pyrolysis gases in the primary chamber, the instructions demand auxiliary fuel input at lower than 600° C ; blow out doors are fitted in both de-ashing openings providing pressure relieve in case of high internal pressures; before de-ashing a purge cycle must be observed
Falls from structure: all operating areas are guarded according to the regulations in force
Burns from hot surfaces: all surfaces within reach of normal operations will not exceed 50° C
Burns from incandescent material: avoid situation with blow back risks, if not avoidable use adequate protection (full face protection, gloves, protective cloths)
Risks from conveyor: all persons to stand back from moving conveyor, stop machine and isolate in case of danger or incident

General Site Access

Risks: General risks relating to third persons and vermin control can include unauthorised access and risks during unauthorised access (fire, accidents, etc.) danger to domestic animals and wild life.
Mitigation/protection: The site is surrounded by a perimeter fence and guarded. A vermin proof chain link fence surrounds the storage area. Signs on the fence warn of the general dangers on site and a list of mandatory personal protection required when entering the site. In addition a fire alarm and fire procedures are provided (needs doing in accordance with Gambian law).
There is a designated First Aid Officer and a First Aid Kit is kept in the main site building.

→ *Procedures in Case of Fire*

In general the local fire procedures apply. The nearest fire alarm is situated *(place to be indicated)*. Small fire may be fought with fire extinguishers and water hose. In case of bigger incidents the Fire alarm must be raised.

4.3 H&S Procedures Implementation, Training and Dissemination

Subcontractors (building and other) will be issued with the H&S procedures with an obligation to train their staff and acknowledge awareness of these.

At all times of operation there will be an operations manager on site who is also the designated person responsible for H&S (responsible: *name*, deputy: *name*).

Operators and any other person entering the site are to be made aware of the H&S procedures and go through an appropriate training process in respect to these.

A copy of the H&S/operating procedures is available in the control centre on site (H&S procedures are integral part of the operating manual)

5 Operating Instructions

5.1 First Commissioning

Before running a number of biofuel (wood chips) runs the refractory is dried using wood chips. Drying consists of slowly heating up to 120-140° and holding this temperature for up to 24 h. At this moment or during the subsequent biofuel runs the accuracy of primary air monitor can be checked since this cannot be done with the cold system (prim. air flow depends on thermo-syphon effect).

5.2 General Operating Principles and Operator Numbers and Qualifications

The operations of the LCI consist of waste and fuel reception, storage, feeding, combustion and de-ashing. All these activities are carried out manually, with the help of hand tools. The only electrical drive (apart from small econsumers in the monitoring equipment) is the secondary and cooling air fan. The combustion side of operations is led by a shift engineer with suitable mechanical and combustion engineering qualifications. The 2-3 feeders and stokers must have some experience with mechanical and combustion equipment.

5.3 Waste and Fuel Reception, Storage and Transport

After sorting the MSW is conveyed via handcarts to the intermediate feedstock storage area immediately adjacent to the feed hopper. A record is kept of the amount and weight of each load and the approximate volume conveyed to the feedstock storage.

Biomass is stored in a separate storage area on delivery. It is transported to the intermediate storage area via handcarts, like the MSW. A record of the total weight in storage and the approximate volume conveyed to the intermediate storage (feed platform) must be kept.

A water hose is kept near to the storage areas for MSW and biomass.

5.4 Plant operation and de-ashing

Preparation for Start-up

Before de-ashing it is necessary to blow secondary air through the system at a rate of 1500m3/h for 10 minutes to purge the system. The O2 and CO level must also be checked before proceeding to de-ash (if monitoring is available).

At the start of a shift (morning) de-ashing of the lower primary chamber takes place through the ash door. De-ashing is carried out with hand tools (like a wide hoe) from the outside onto a small hardstanding. From here ash is shovelled into a wheelbarrow and dumped into the enclosed ash storage area.

In order to suppress dust blowing the ash may be wetted down (attention: ash may heat on contact with water). Operators must wear appropriate protection (dust masks, goggles).

After de-ashing the ash door is closed and secured. A checklist is used to ensure that the plant is ready for start-up to check readiness, start-up sub-systems etc. (See checklist section 9.7). The mass of ash removed must be recorded on the corresponding record sheet.

Biomass is used for start-up and lit either from the feed chute or from the ash door. Biomass/ MSW is stockpiled in an intermediate feedstock area next to the chute (~ 0.5 hours worth).

Until the required conditions in the secondary chamber are reached (850° C) firing with biomass only continues. After reaching these conditions (pre-sorted) waste is added to the feed. During switching from biomass to MSW the proportion of waste is determined by the temperature achieved in the secondary combustion chamber (≥ 850° C).

Start-up

Once a burning rag is placed on grate 1 biomass is piled on top in order to stoke up the fire.

The secondary and tertiary air fan is switched on as soon as the fire is lit. Guide values for biomass feed, primary and secondary air are given in Section 9.5, Table 1, Main Combustion Parameters. It is necessary to calibrate the feed ram during commissioning in order to control the feed.

Values for primary and secondary air can be read from the instrumentation and adjusted according to the Section 9.5, table 2. Secondary air may be further adjusted according to the required O_2 (wet) values given in Table 1 (if O_2 monitoring is available).
During firing up with biomass the primary chamber remains in excess air conditions. Flames should be vivid and temperature of the primary should be above 650 °C after initial start-up. Even during start-up the feed chute should be kept full of feedstock in order to avoid ingress air and back burning. If this is not possible a cover should be placed on the chute between feeding intervals.

The heat exchange in the tertiary chamber (AP21) preheats the secondary air. As soon as the temperature in the tertiary chamber exceeds 150˚C the secondary and tertiary air fan needs to be started and the heat exchanges cooled. If no secondary air is required the secondary air heat exchange cooling damper needs to be opened until PA is required in the process. This is done to protect the heat exchanger from temperatures in excess of 150˚C.

When 850 °C are reached consistently at the secondary outlet, MSW can be fed while simultaneously reducing biomass feed. Quantitative guidance for biomass and waste feed as well as for primary and secondary air are given in Table 1, section 9.5. Primary air and secondary air pre-heat is also adjusted according to table 2.

During the change over from wood chips to MSW feed the conditions in the primary will change from excess air to sub-stoichiometric conditions. The sub-stoichiometric regime produces combustible gases, which may react explosively with oxygen if allowed to accumulate in the absence of a flame. It is therefore important, that vivid flames and high temperatures are always present in the primary chamber to ensure that any combustible gas mixture is lit before explosion conditions arise.

During this start-up tertiary air is controlled to keep the temperature in the tertiary at below 300 °C.

Start-Up Checklist

- ❑ Check ash build-up primary air and secondary reversal chamber
- ❑ Primary air access clear of ash under grate and side walls etc.
- ❑ All ash doors closed (Front door, secondary door)
- ❑ Primary and secondary air ducting ready, main air dampers in closed position
- ❑ Biomass and rag ready for lighting
- ❑ Everything ready to follow-up with MSW feed (MSW & biomass for whole run in storage area)
- ❑ Monitoring instruments operational and recording
- ❑ Check specially opacity meter for dust. Also ensure purge air for viewing port.
- ❑ Water pressure available at fire hose and spray in chute
- ❑ Water tank full check; water flow visual check
- ❑ Wet sand ready
- ❑ Electricity for fan, alarms and lighting available
- ❑ Alarm test OK (alarm should be operated as a test)
- ❑ Round of waste storage, feed chute and stack are done – visual inspection OK

Checked by: Date/time:
(name)……………………….. ………………………..

<u>*Normal Operations*</u>

The feedstock is shovelled into the feed hopper and pushed via the feed ram onto the first grate using carefully controlled feed strokes.

The feed hopper is kept full of feed stock at all times as this provides the gas seal stopping hot gases escaping or cold air to be drawn in.

In case of "backburning" a cover over the feed chute is available which when lowered sits in a sand seal; in extreme cases wet sand can be used (ready stockpile stored near feed chute). In very severe cases of back burning a water spray in the feed chute can be operated.

Records are taken of waste and biomass feed (in terms of approximate volumes dumped at the stockpile location and feed ram strokes) as well as instrument readings and damper settings. In addition a logbook is used to enter any comments or important actions by the staff. Primary air (undergrate) is controlled with a damper as a function of the primary chamber temperature. A record sheet is included in section 9.7, showing all records, which need to be taken.

Secondary air is fed as a function of temperature and/or O_2 in the secondary combustion chamber (if available).

Stoking is done by agitating two sets of stoking arrangements, which have handles on CR side of the primary chamber.

Stoking must be carried out in such a way as not to cause excessive suspension of fly ash in the gases.

A regular inspection (every 15 minutes) of the grate and fire should be carried out through the viewing port.

Levels of CO and particulates have to be kept within the recommended levels. Under no circumstances is the temperature in the primary to fall below 600° C (danger of explosion).

<u>*Normal Shut Down*</u>

At the end of a waste burning-cycle biomass is fed into the primary combustion chamber until all waste has burnt out on the grate (see Graph 1 for guidance). This is undertaken to ensure that secondary combustion temperature is kept ≥ 850° C.

As soon as biomass feeding has stopped the feed chute cover should be lowered.

When all active combustion on the grate has stopped there will be a purge stage after which the secondary and cooling fan air is stopped and the primary air damper is closed.

Before complete shut down and leaving the site a checklist is used to verify the plant is safe (see shutdown checklist, section 9.7).

Emergency Shut Down

Controlled shutdown

If at all possible feedstock on the grate should be burnt out. Such a fast shut down would include immediate feedstock cut off and the placing of the cover on the feed chute.

Combustion parameters to be like normal shut down, however the 850° C and 2 seconds cannot be respected as no more feed is allowed.

Emergency stop

However if the situation does not allow for any delays the sequence of events is as follows:

- Closing of all combustion air dampers and stopping of fan
- Placing of cover on feed chute after wet sand is fed down the chute
- Check for ingress air and monitor situation especially for accumulation of pyrolysis gases

Note:
These procedures must be trained during commissioning!

Shutdown Security Checklist *(before leaving plant)*

- ❑ Combustion process is stopped (view through port, O_2 reading 21%; CO near zero)
- ❑ The feeding stock pile near the chute is cleared of MSW and wood chips
- ❑ Air dampers are all closed, the MCC of the fan is locked out
- ❑ All water valves are closed (fire hose, spray valve in feed chute)
- ❑ MSW and wood chips feed stock areas are tidy and secure
- ❑ Data recording and finishing of paper work done
- ❑ Monitoring instruments are switched off and stored securely
- ❑ A round of the installation (waste storage, LCI structure, stack) shows nothing of concern)

Checked by: *(name)*………………………..   Date/time: ………………………..

Remarks:
…………………………………………………………………………………

6 Unsafe operating conditions and how to rectify them.

Temperature Primary Chamber Low

Problem

If the temperature in the primary chamber falls below 600 °C the accumulation of a mixture of combustible gases and air may take place and ignite explosively.

Proposed Action

- Reinstate excess air conditions by allowing more primary air into the chamber
- Feed of biomass to increase calorific value of feed stock

Temperature Primary Chamber High

Problem

The temperature in the primary rises above 900 °C. The structure is not designed for high temperature conditions. There is also a risk of over feeding.

Proposed Action

- Check primary air flow with respect to Graph 1
- Check feed rate of MSW/biomass. The feed stock might have excessive calorific value
- By reducing feed and primary air and avoiding stoking the temperature is reduced

Back Burning from Feed Chute

Problem

Back burning through feed chute

Proposed Action

- Cover with sand sealed feed chute cover; if no improvement, apply wet sand to feed chute. In extreme cases dump one load of 20 l of water by operating the header tank valve.
- If the problem persists the shift responsible has to decide if running down the operations is the correct action.

Temperature Secondary Chamber High

Problem

The temperature in the secondary chamber outlet rises above 900 °C. The structure is not designed for high temperature conditions

Proposed Action

- Check if primary is not over fed, excessive CV
- Secondary air input may be too low; check against Graph 1 and required O_2 values
- Rectify situation to reduce temperature by adjusting the above mentioned parameters

Temperature Secondary Chamber Low

Problem

Insufficient gas phase burn out occurs with low secondary temperature

Proposed Action

- Check if secondary air regime is in accordance with other operational parameters (see Graph 1). If too much secondary air is injected, reduce damper setting until temperature and O_2 values are within the recommended range
- Check if the primary chamber is run correctly and remediate by adjusting above mentioned parameters if necessary

Note:

During start-up and shut down, when operating with biomass secondary chamber temperatures are lower than 850 °C even under normal operating conditions.

Low O_2 in Secondary Chamber (Only if O_2 monitor available)

Problem

In order to ensure good gas-phase burn out the O_2 value in the secondary chamber should never fall below 6% O_2

Proposed Action

- Check if sufficient air is fed into the secondary chamber (fan, ducting, dampers) and remediate accordingly (i.e. increase air flow if necessary)
- Check if primary chamber is not over fed with combustible material and remediate accordingly (i.e. reduce feed, stop stoking, etc.)

Temperature Tertiary Chamber High

Problem

The construction of the secondary chamber (and the optical particulate monitor) are not designed for temperatures in excess of 400 °C

Proposed Action

- Check if sufficient air is fed into the tertiary chamber (fan, ducting, dampers) and take remedial action if necessary (i.e. increase tertiary air flow rate)

- The plant may run on thermal overload – check feed rate and take corrective action if necessary (see primary, secondary chamber excess temperature measures).

7 Operating Tools / Equipment and Maintenance

Tools

2	large volume SHOVELS; for filling chute with pre-sorted waste
1	FEEDING TOOL (short); for waste pushing in chute
1	STOKING TOOL (long); for agitating fire process through chute
2	ASH RAKES; cleaning device for morning cleanout operation in ash chamber of furnace and secondary chamber

N.B. the tools may be adapted and locally fabricated for use on site.

Health & Safety (min. requirement)

- Personal safety equipment
- 1st aid kit
- Fire hose
- CO2 Fire extinguishers (for small fires)

Maintenance

Weekly maintenance:

- Clean out grate and under grate and air holes to allow free PA passage, re-stuff mineral wool joints, check stoking and feed ram and repair if necessary.
- Clean SA injection ensuring proper SA injection (remove fused ash, etc.)
- Dampers and ducting: check, clean and grease, ensuring PA, SA and cooling air is delivered efficiently
- Instrumentation: Check T-sensors, flow monitoring and other monitoring instruments
- Fan: Check and clean impeller and intake screen, lubricate according to manufacturers instructions(attention use lock out procedures to ensure the fan cannot be started during maintenance work).
- H&S: Check functionality of fire hose and alarm

Yearly overhaul:

- Overhaul of grate, combustion chamber and secondary: repair refractory bricks, re-stuff expansion joints with mineral wool, clean off fused ash and replace grate bricks, overhaul stoking and feed ram systems.
- Overhaul of ash plenums, air ducting and dampers
- Overhaul and lubrication of fan and fan drive

Please add to this list as other activities become necessary

8 Instrumentation Concept

Instruments are essential for a safe and controlled operation. The following comments are included to familiarise the operators with the concept. All displays are situated in a dedicated area labelled as the control room.

The P & ID Schematic and Instrument List (see section 9.3) gives an overview of the instruments included in the project.

Temperature sensors for the primary, secondary and tertiary chamber are displayed on a multi-channel display, where they are given positions Channel 1, 2 and Channel 3. In addition the exit temperature of the secondary chamber is duplicated on Channel 6 of the multi-channel display. Other channels are used to monitor PA and SA temperature

Secondary air (SA) is measured via a venturi arrangement with a display a dP in a U-tube. Calibration will be by Pitot tube and a look-up table is produced during commissioning relating pressure reading (in mm water column) to airflow (Nm^3/h)

Due to low air velocity **primary air** (PA) is measured with low cost air resistance anemometer and calibrated with the hot bulb anemometer during commissioning. The dial should give a direct reading in Nm^3/h.

Flue gas analysis with respect to CO, CO2 and O_2 (wet) is achieved with low cost analysis equipment (Anglonordic or similar). Samples are extracted from the exit of the secondary chamber. Alternatively more sophisticated instruments may be used.

Opacity monitoring may be done by means of cross-channel opacity monitor (for example the PCME DV420). The monitor can only work under temperatures below 400 C and is therefore positioned in the stack. The display unit is situated in the control room. Units are dimensionless and may be correlated to mg/Nm3 once extractive stack monitoring is done. It is important to check the cleanliness of the lenses, air purge and other operational parameters according to the manufacturers specification.

Ambient temperature is recorded from a alcohol thermometer in the CR.

9 Technical Documentation (Summary)

9.1 Specifications LCI

9.2 Example of possible front/back end layout (see section 2) LCI – Working Plan and Site Layout (CD05-001b)

9.3 P & ID Schematic and Lists

9.4 Combustion Diagram

9.5 Tables of Basic Operating Parameters and corrective action (Tables 1 and 2)

9.6 Documentation for Commissioning

9.7 Log sheets and check list forms

a. Start-up checklist
b. Shutdown checklist
c. Recording log sheets

9.1 Specifications LCI

Outline Design Specifications for Test-Rig

1. Waste Properties/Throughput

- Waste composition (Municipal Solid Waste): Gambia composition
- Waste CV_{net} 6800 - 9800 kJ/kg
- Waste throughput 213-425 kg/h

2. Front End Operation

- Fe/non Fe metal removal
- Glass removal
- PVC removal

Also removal of oversized and other potential problem (hazardous/harmful) elements, and storage of at least 1.5 h of ready feedstock.

3. Loading, Ash Handling

- Side loading: through hopper, push with rake type instrument
- De-ashing: manually through ash doors (furnace + sec. chamber) at end of operating cycle (morning)

4. Combustion

- Semi-pyrolytic primary chamber (λ=0.7)
- Secondary combustion: 2 sec. at 850 °C and secondary air injection (with fan) (with CV net of 7000 kJ/kg), air excess 6-11% O2 (wet gas)
- Pre-heating of secondary air by heat exchanger from flue gases (optional, not done on test rig)
- Auxiliary fuel: solid auxiliary fuel (wood chips) through feed chute for start up/shut down and insufficient secondary temperature
- Refractory lined primary and secondary chambers (brick)
- Max skin temperatures: 1.Accessible 50 C, 2. Non-accessible 100 C

5. Gas Cooling and Gas Cleaning

- Passive (low gas velocity in PC < 0.3m/s) stops entrainment of suspended solids
- Gas cooling option: heat exchanger to secondary air (not done on test rig)
- Flue gas transport; thermo siphon (updraft from stack)
- Gas cooling at exit of secondary by mixing with cold tertiary air through nozzles

6. Releases to the Environment

- Releases to air should comply with PG5/4 (as far as possible-see environmental specs)
- Continuous monitoring of gases: O2, CO, CO2, Particulate

- Monitoring of process conditions: Temperature primary/secondary, tertiary chamber, primary, secondary, secondary & tertiary air flow
- Ash loss on ignition <5%
- No releases to water: Waste storage and handling areas covered, no surface water run off

7. Operation, H&S, Maintenance (see also H&S and operating specs)

- Plant failsafe, no dangerous operations required
- Emergency shut down procedures drawn up and operators trained
- Include training and personal protection for front end sorting and ash handling
- Keep operation and maintenance simple
- Operators & maintainers to be trained on-site
- Manual controls
- Monitoring instrumentation to be kept as simple as possible
- Operating effective: 2 persons combustion, 3 person front end

8. Assembly, general construction guidance

- Keep Assembly simple
- No special tools
- Manual controls
- Lubricants and spares to be locally available
- Include fire fighting and emergency escape provisions
- Low visual impact

9. Options for Retrofit to be Considered

- Heat recovery
- Further gas cleaning

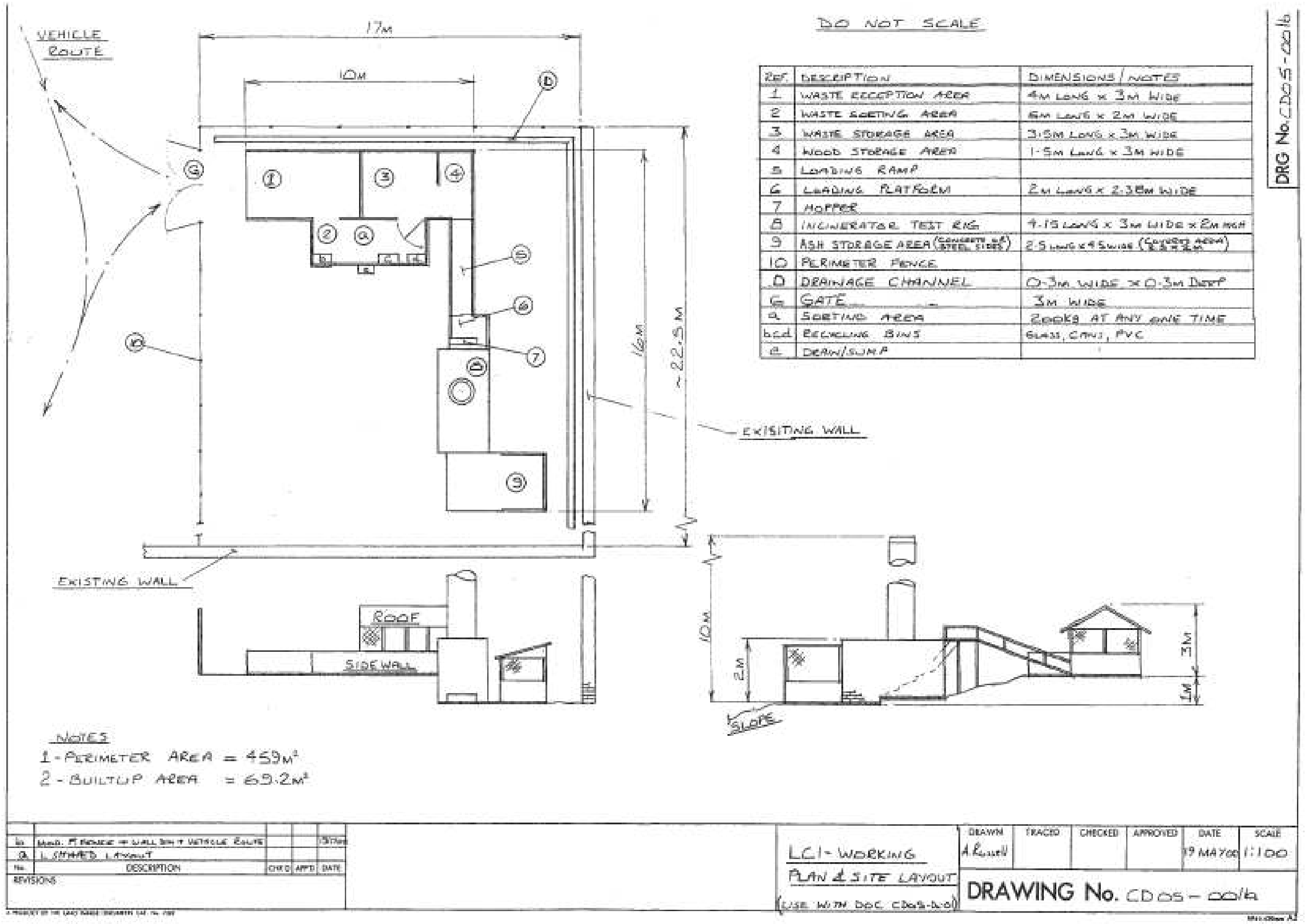
Note to Specifications

These specifications are not intended to be restrictive in the sense that practicable and cost efficient alternatives are encouraged. The specifications are intended to focus the mind and narrow down the number of alternative designs. In particular it is noted that the aim of achieving the daily throughput may be realised with more than one unit.

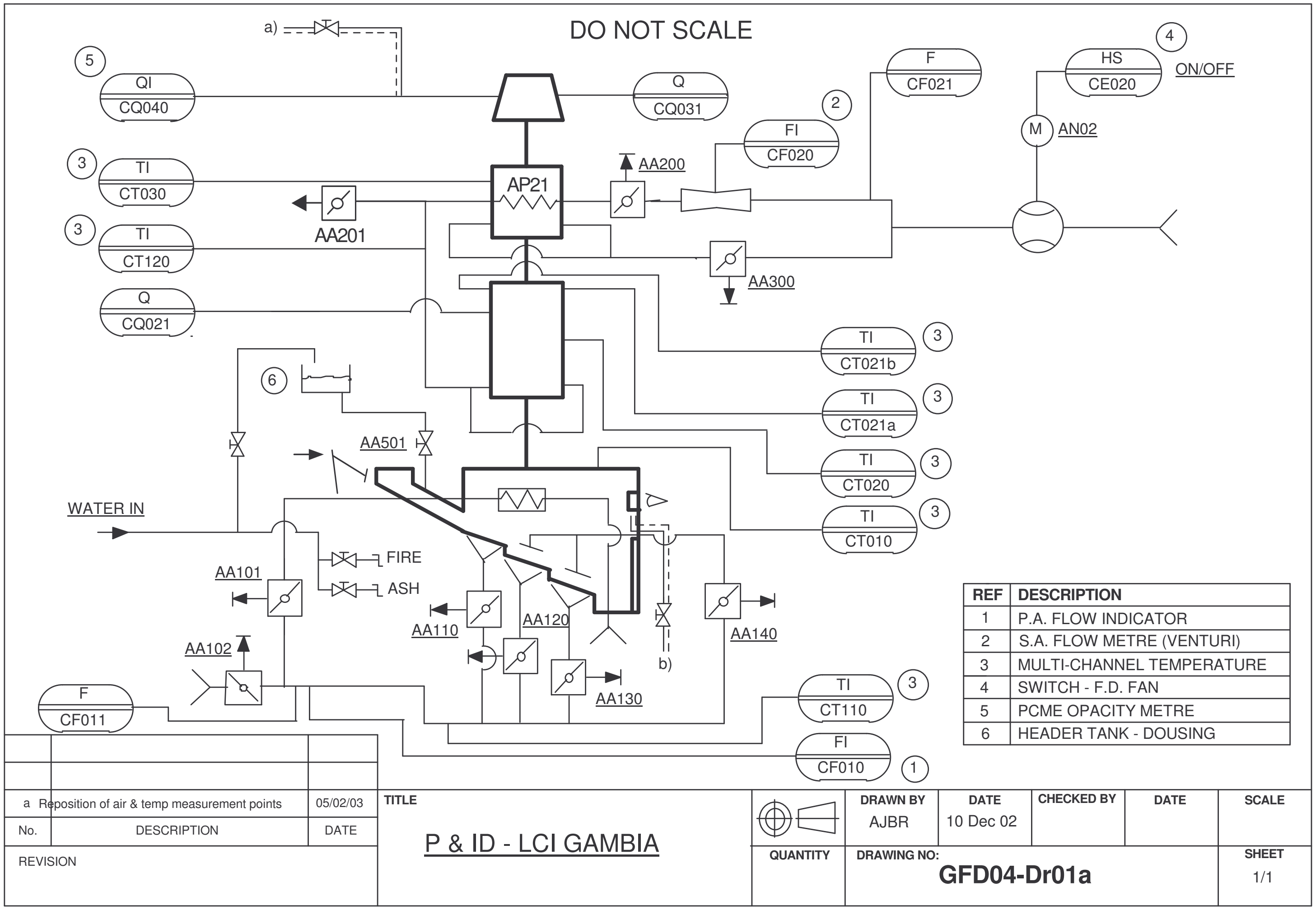
The aim is to design, build and operate a simple and reliable Municipal Solid Waste combustion device for the use of lesser-developed countries at a moderate cost and causing a minimum of hazardous emissions and nuisance. Residuals should be of low hazard and biologically inert (i.e. good burnout).

The waste quality/quantity compositions are an approximation of the wastes that can be expected in an as yet unidentified lesser-developed country. The operations are intended to be 1-shift, with a daily throughput of 5 t/day, so heat conservation during daily downtime should be considered (warm keeping).

9.2 Example of possible front/back end layout (see section 2) LCI – Working Plan and Site Layout CD05-001b



9.3. P & ID Schematic and Lists



REF	DESCRIPTION
1	P.A. FLOW INDICATOR
2	S.A. FLOW METRE (VENTURI)
3	MULTI-CHANNEL TEMPERATURE
4	SWITCH - F.D. FAN
5	PCME OPACITY METRE
6	HEADER TANK - DOUSING

Instrumentation List - To be used in conjunction with P&ID schematic

PID No	Title	PIN	Functn	Name	Field Instr	Units	MIN	NORM	MAX	Position display/controls
GFD04-Dr01	LCI Gambia	CF010	FI	PRIMARY AIR FLOW	SIMPLE PA FLOW METER	m3/h	0	803	2000	Dedicated design based on resistance to air flow in paddle shape
GFD04-Dr01	LCI Gambia	CF020	FI	SECONDARY AIR FLOW	VENTURI	m3/h	0	1400	4000	Display as U-tube with look-up table
GFD04-Dr01	LCI Gambia	CF011	F	PRIMARY AIR FLOW	ACCESS PORT	m3/h				For calibration purposes
GFD04-Dr01	LCI Gambia	CF021	F	SECONDARY AIR FLOW	ACCESS PORT	m3/h				For calibration purposes
GFD04-Dr01	LCI Gambia	CT010	TI	T PRIMARY CHAMBER	K TYPE	°C	0	900	1200	Channel 1 on multi-channel display
GFD04-Dr01	LCI Gambia	CT021	TI	T HALFWAY SECONDARY CHAMBER	K TYPE	°C	0	850	1200	(Channel 2 on multi-channel display)
GFD04-Dr01	LCI Gambia	CT020a	TI	T EXIT SECONDARY CHAMBER	K TYPE	°C	0	850	1200	Channel 2 on multi-channel display
GFD04-Dr01	LCI Gambia	CT020b	TI	T EXIT SECONDARY CHAMBER	K TYPE	°C	0	850	1200	Channel 6 on multi-channel display
GFD04-Dr01	LCI Gambia	CT030	TI	T TERTIARY AFTER MIXING	K TYPE	°C	0	300	350	Channel 3 on multi-channel display
GFD04-Dr01	LCI Gambia	CT110	TI	T PRIMARY AIR	K TYPE	°C	0	100	150	Channel 4 on multi-channel display
GFD04-Dr01	LCI Gambia	CT120	TI	T SECONDARY AIR	K TYPE	°C	0	100	150	Channel 5 on multi-channel display
GFD04-Dr01	LCI Gambia	CE020	HS	SWITCH SA FAN		ON/OFF				In Control room
GFD04-Dr01	LCI Gambia	CQ021	Q	SAMPLING PORT SECONDARY						For extractive gas sampling
GFD04-Dr01	LCI Gambia	CQ031	Q	SAMPLING PORT TERTIARY						For extractive gas sampling
GFD04-Dr01	LCI Gambia	CQ040	QI	PARTICULATE MONITOR TERTIARY/STACK	PCME	%, mg/Nm3	0			Display in dedicated display
GFD04-Dr01	LCI Gambia	1	Display	Airflow Display PA	Dedicated dial (see design)					On site
GFD04-Dr01	LCI Gambia	2	Display	Airflow Display SA	U-tube					In Control room
GFD04-Dr01	LCI Gambia	3	Switch	Fan switch						In Control room
GFD04-Dr01	LCI Gambia	4	Display	Display for all K-type T monitors						In Control room
GFD04-Dr01	LCI Gambia	5	Display	PCME						In Control room

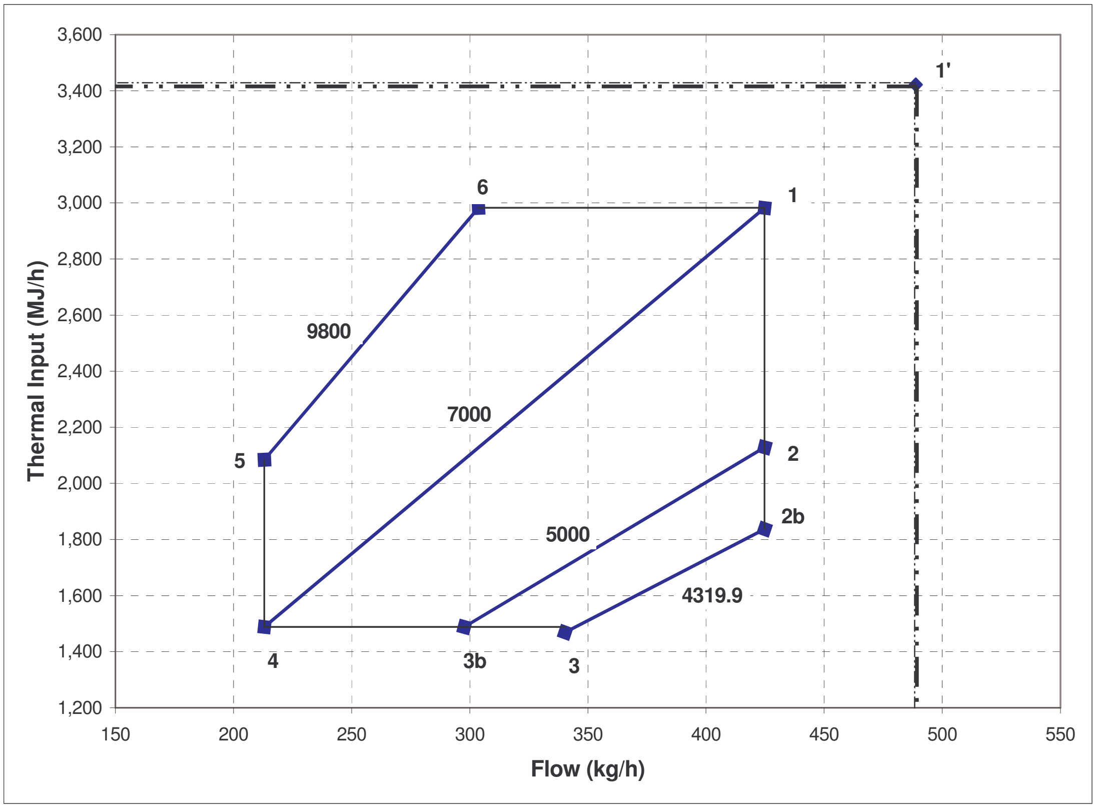
Valve List- To be used in conjunction with P&ID schematic

PID No	Title	PIN	Function	Name	Settings	Type	Manufacturer	Comments
GFD04-Dr01	LCI Gambia	AA101	HAND	PRE-HEAT PRIMARY AIR DAMPER	0 - 100%	Butterfly	Custom Made	
GFD04-Dr01	LCI Gambia	AA102	HAND	COLD PRIMARY AIR DAMPER	0 - 100%	Butterfly	Custom Made	
GFD04-Dr01	LCI Gambia	AA110	HAND	UNDERGRATE AIR ZONE 1	0 - 100%	Butterfly	Custom Made	Failsafe Open
GFD04-Dr01	LCI Gambia	AA120	HAND	UNDERGRATE AIR ZONE 2	0 - 100%	Butterfly	Custom Made	Failsafe Open
GFD04-Dr01	LCI Gambia	AA130	HAND	UNDERGRATE AIR ZONE 3	0 - 100%	Butterfly	Custom Made	Failsafe Open
GFD04-Dr01	LCI Gambia	AA140	HAND	WALL AIR ZONE 2 & 3	0 - 100%	Butterfly	Custom Made	Failsafe Open
GFD04-Dr01	LCI Gambia	AA200	HAND	SECONDARY AIR DAMPER	0 - 100%	Butterfly	Custom Made	Failsafe Open
GFD04-Dr01	LCI Gambia	AA201	HAND	SA HE COOLING DAMPER	0 - 100%	Butterfly	Custom Made	Failsafe Open
GFD04-Dr01	LCI Gambia	AA300	HAND	COOLING AIR DAMPER	0 - 100%	Butterfly	Custom Made	
GFD04-Dr01	LCI Gambia	AA501	HAND	WATER SPRAY FEED CHUTE	0 - 100%			

E Consumers List- To be used in conjunction with P&ID schematic

PID No	Title	PIN	Name	Nominal Power	Voltage	Make	Model	Comments
GFD04-Dr01	LCI	AN02	Secondary/Cooling Air Fan	15 KW	415 V/3 Phase	Furness Fans	HD56K3/DD	Controls in CR

9.4. Combustion Diagram



9.5. (1)Table of Basic Operating Parameters

TABLE 1 PARAMETER GUIDE STANDARD OPERATION

Time Hours	Time when starting at 9:30	Wood Chips kg/30 min**	Wood Chips shovels/30 min**	MSW kg/30 min	PA m3/h[1]	SA Pre-Heat Temperature Deg C	SA m3/h	Comment
0	9:30	70	28	0	0	n/a	0	This is the start-up. This is quicker if the boiler is in warm-keeping conditions
0.5	10:00	70	28	0	0	n/a	0	
1	10:30	80	32	0	240	n/a	0	
1.5	11:00	100	40	0	240	n/a	0	
2	11:30	120	48	0	240	100	150	
2.5	12:00	120	48	0	240	100	150	
3	12:30	0	0	150	300	100	400	
3.5	13:00	0	0	210	660	100	1000	These are the normal operating parameters after start-up. Combustion with these parameters can be sustained until filling the ash chamber
4	13:30	0	0	210	660	100	1000	
4.5	14:00	0	0	210	660	100	1000	
5	14:30	0	0	210	660	100	1000	
5.5	15:00	0	0	100	300	100	500	This is the start of shut-down
6	15:30	0	0	100	300	100	240	
6.5	16:00	0	0	100	300	100	240	
7	16:30	70	28	0	300	100	249	
7.5	17:00	70	28	0	300	100	120	
8	17:30	50	20	0	300	100	120	
8.5	18:00	0	0	0	150	n/a	0	
Totals		750	300	1290	0	n/a	0	

Notes
This guide assumes a CV of approximately 7500kJ/kg and waste throughput of 300 kg/h and wood chips as biomass (18% humidity)
These parameters are only approximate and need to be adapted to actual conditions
Primary Air (PA) pre-heat depends on MSW properties; wet MSW 90-120 Deg C, dry MSW no pre-heat

9.5. (2) Table of Basic Operating Parameters

TABLE 2 CORRECTIVE ACTIONS

These measures allow the correction of poor combustion conditions and apply in addition to table 1

Observation through viewing point:	CV estimate	PA Pre-heat ˚ C	Action Required				
			PRIM.AIR			SEC.AIR	SEC. AIR Preheat
			Zone1 Pos. damper [%] AA110	Zone2 Pos.damper [%] AA110	Zone3 Pos. damper [%] AA110	Pos. damper [%]	Pos damper [%]
Bright “white flame; dry waste	9800	Ambient	Decrease opening	Normal	Decrease opening	Increase opening	Increase opening
Yellow flame, dry waste	7000	50-70	Decrease opening	Normal	Normal	Normal	Normal
Orange flame; quite some organic material	5000	70-100	Increase opening	Increase opening	Normal	Normal	Decrease opening
Dark orange flame; wet waste, much organic material	4300	100-120	Increase opening	Increase opening	Increase opening	Decrease opening	Decrease opening

9.6 Notes for Commissioning

A mechanical engineer with some experience with combustion plants must carry out commissioning of the plant. The following notes only give some guidance on how to proceed at first commissioning, after the LCI construction is completed:

In order to avoid damages to the refractory construction, humidity has to be expelled slowly applying a low temperature drying process.

Further on all elements have to be checked to ensure safe and correct operation of the furnace.

In particular there are the following checks which need to be done before first regular hot operation:

- MECHANICAL CHECKS:

→ Gas path from primary chamber to the stack needs to be checked. The flue gas path needs to be free of foreign bodies, waste etc.

→ Combustion air ducting to be checked to ensure they are correctly mounted and clean; flaps need to move freely.

→ Fan casing is clean and impeller turns freely without chafing.

- ELECTRICAL:

→ Fan rotation control done and ok, current setting correct.

→ Indicators for temperature / flow / gas quality all connected correctly and voltage corresponding and calibrated/checked.

PROCESSS:

→ Calibration flow measured for primary air / secondary /tertiary air according to required flows. The dampers position indicators need to be labelled accordingly (0-100% open) marks made on the dampers

→ Calibration of shovels of biomass and feed ram feed strokes

SECURITY:

→ Personnel are fully instructed regarding operation and health and safety aspects.

→ Safety devices are working properly; cover plate for fed chute in place, water or sand available for emergency extinguishing, fire fighting hose is operational.

9.7 Log sheets and check list forms

9.7a

Start-Up Checklist

- ❑ Check ash build-up primary air and secondary reversal chamber
- ❑ Primary air access clear of ash under grate and side walls etc.
- ❑ All ash doors closed (Front door, secondary door)
- ❑ Primary and secondary air ducting ready, main air dampers in closed position
- ❑ Biomass and rag ready for lighting
- ❑ Everything ready to follow-up with MSW feed (MSW & biomass for whole run in storage area)
- ❑ Monitoring instruments operational and recording
- ❑ Check specially opacity meter for dust and switch-on rinsing air. Also open purge air for viewing port.
- ❑ Water pressure available at fire hose and spray in chute
- ❑ Water tank full check; water flow visual check
- ❑ Wet sand ready
- ❑ Electricity for fan, alarms and lighting available
- ❑ Alarm test OK (alarm should be operated as a test)
- ❑ Round of waste storage, feed chute and stack are done – visual inspection OK

Checked by: *(name)*……………………….. Date/time: ………………………..

9.7b

Shut-Down Checklist

- ❑ Combustion process is stopped (view through port, O_2 reading 21%; CO near zero) (Note: check this during commissioning)
- ❑ The feeding stock pile near the chute is cleared of MSW and wood chips
- ❑ Air dampers are all closed, the MCC of the fan is locked out (primary air fan is electrically disconnected)
- ❑ All water valves are closed (fire hose, spray valve in feed chute)
- ❑ MSW and wood chips feed stock areas are tidy and secure
- ❑ Data download and operational recording done
- ❑ Monitoring instruments are switched off and stored securely
- ❑ A round of the installation (waste storage, LCI structure, stack) shows nothing of concern)

Checked by: *(name)*………………………..   Date/time: ………………………..

Remarks:
………………………………………………………………………………………

9.7c Recording Log Sheet (Suggestion) LCI

Date: …………………..
Responsible: ………….

Time	Shovels Fed		PA Nm^3/h	SA Nm^3/h	Cooling Air Nm^3/h	T Primary °C	T Secondary °C	T Tertiary °C	O_2 Secondary	CO Secondary	Opacity % (Tertiary)	Ambient Temp °C	Comments
	MSW	Biomass											
08:00													
08:30													
09:00													
09:30													
10:00													
10:30													
11:00													
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