MEDECINS SANS FRONTIERES

INCINERATION IN HEALTH STRUCTURES OF LOW-INCOME COUNTRIES

CONSTRUCTION & OPERATION OF THE DE MONTFORT INCINERATOR

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INTRODUCTION

Incineration is an ultimate treatment method using fire to convert certain wastes “completely” into gasses and incombustible solid residues (ash) that should be as harmless as possible. The product gasses are released into the atmosphere, with or without gas cleaning, and the solid residues can normally be buried without any major risk.

The product gasses consist mainly of carbon dioxide (CO2), water vapour and excess air. According to the composition of the waste, noxious halogen acids, sulphur, nitrogen and phosphorus oxides, vaporised metal oxides, and traces of un-burnt waste and organic by-products can be found back in the gasses as well.

When the conditions aren’t adequate, traces of new organic compounds may also be released in the gasses. Great care must be taken to reduce the formation of these new compounds, because they can be more hazardous than the parent compound. An example of this is the incineration of all kinds of halogens (e.g. chlorine containing products) at relatively low temperatures, because dioxins are formed as by-products. These compounds are extremely toxic, and therefore more severe incineration conditions have to be maintained to minimize their toxic emissions.

The solids left behind in the incinerator comprise ash, metal oxides and material that is incombustible. These solids are generally sufficiently “sterile” to be safely buried. However, attention should be paid to some heavy metals that could be contained in the residues. Therefore, it is recommended not to incinerate material containing heavy metals.

Properly managed, incineration is still one of the best options for the elimination of certain medical waste in low-income countries because it brings a significant reduction in their weight and volume, leaving a “sterile” solid residue behind. It is recommended to incinerate mainly soft (i.e. burnable) waste in purpose-build facilities which are preferably located on the Health Structures compound itself. Organic waste should only be incinerated if sufficient fuel is available for prolonged periods, which will become very expensive in the long run. For hazardous waste such as pharmaceutical waste and laboratory chemicals, suitable adapted existing high-temperature process plants such as cement or limekilns, blast furnaces or high ovens can be an alternative.

FIRE

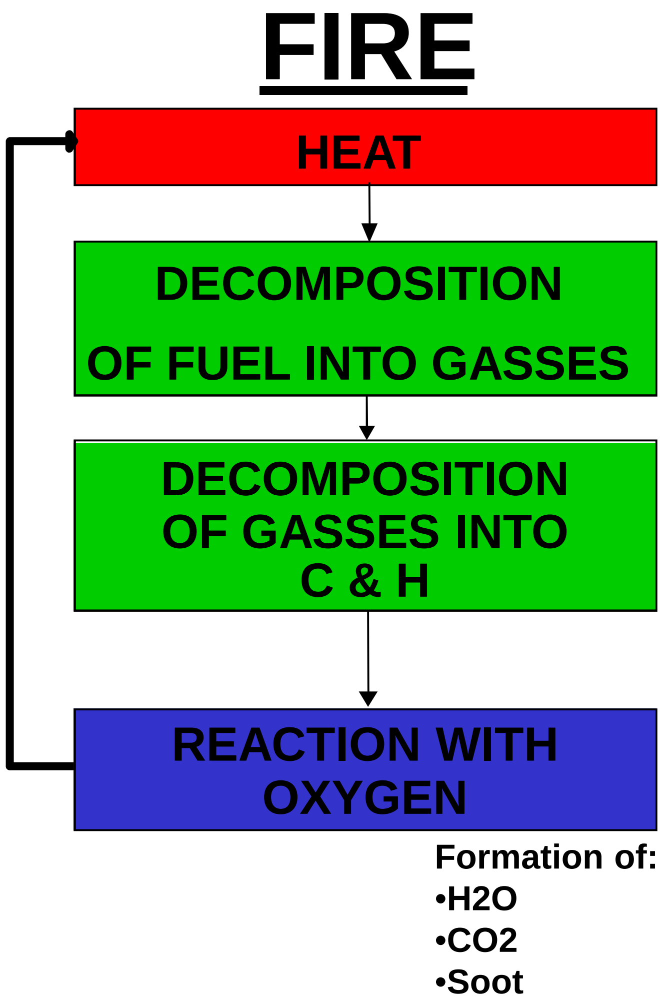
Fire is a thermal oxidation of material in the presence of oxygen from the air. The three important factors of fire / combustion are:

- Fuel / Combustible material
- Heat / Temperature
- Oxygen

The combustion process is a chain reaction of different chemical processes:

- When heat (e.g. burning match) is brought to fuel / combustible material, it will start to decompose into combustible (flammable) gasses.
- These gasses will decompose into molecules of different elements, mainly hydrogen (H) and carbon (C). In addition, the gasses may also contain oxygen (O), halogens, nitrogen, phosphorus, sulphur and/or a variety of metals.
- The combustible elements (H & C) will react strongly with the oxygen available in the air, which results in a flame and thus heat production, which keeps the chain reaction going. The higher the H and C content, the better the material will burn, as long as it isn't containing too many liquids. There will also be the formation of water (H_2O), carbon dioxide (CO_2), soot and potentially other (harmful) by-products (depending on the waste composition and the combustion temperature).

Unfortunately, the decomposition often goes faster than the combustion itself, resulting in combustible gasses that escape via the chimney without being burnt. This results in temperature loss and a higher amount of harmful gasses. Therefore, it's important to understand the combustion process, in order to operate an incinerator correctly.



FACTORS OF FIRE & INCINERATION

The basic factors of a combustion process

- fuel / combustible material
- heat / temperature
- oxygen

are often represented as the fire triangle; every side of the triangle being one factor.

In construction, a triangle is known to be a stable structure, but if one or more of its sides are lacking, it will collapse. This representation is also valid for the fire triangle; if one or more of the factors lack, the fire will die out. Fire extinguishing is based on this principle:

- Take the fuel / combustible material away.
- Drop the temperature (e.g. by adding water to the fire).
- Blocking off the oxygen supply (e.g. fire extinguishers with CO_2 gas or foam, closing doors and windows).

In absence of oxygen, it is still possible to decompose material into combustible gasses, as long as sufficient heat (> 400 °C) is present. This is called pyrolysis and is also a method of waste elimination. An external continuous heat source is necessary however because there aren't any flames that generate heat, due to the lack of oxygen. The formed combustible gasses should be “cleaned and made harmless” before being released.

Attention: Some pyrolysis will appear in the De Montfort incinerator, and the moment oxygen comes in contact with the hot combustible gasses generated during pyrolysis, they will flare off immediately, potentially leading to a violent flame shooting out via the opened loading door.

In order to have good incineration, two additional factors are required besides the fire triangle:

- Turbulence of the air needed for a good mixture of its oxygen and the combustible gasses.
- Time that the waste and the combustible / combusted gasses are kept at high temperature (residence time).

FUEL / COMBUSTIBLE MATERIAL

In principle, all products containing enough hydrogen and carbon, thus having a high heating value, burn rather well in the presence of oxygen, as long as they have a low liquid content (low moisture percentage). The heating value of different products can be expressed in Btu/lb (as can be seen in the table).

Some wastes have enough heating value (> 7000 Btu/lb) to support their own combustion (auto-combustion), and additional “commercial” fuel (e.g. wood, kerosene) is potentially only needed for their initial ignition. Other wastes’ heating value is so low (< 7000 Btu/lb) that additional fuel must be added to keep them burning.

Notice that wood doesn’t have a very high heating value, but as its residues keep glowing, it helps buffering the temperature variations when the loading door of a auto-combustible batch incinerator is opened for reloading, and thus heat gets lost. Also, un-burnt waste falling on the hot wood residues in the ashtray will flare off anyway. Thus wood is a good combustible for pre-heating an auto-combustion incinerator.

For low-income countries, it is preferred to use as much as possible auto-combustion incinerators in order to reduce the operational costs.

Besides the heating value and the moisture, the composition of the waste itself is important as well. Wastes containing halogens, phosphorus, sulphur or nitrogen can generate noxious by-products when burnt, thus they require a more sophisticated technology than wastes with just carbon, hydrogen and oxygen. As such, the choice of incinerator and its potential gas cleaning system will depend on the waste itself.

Some wastes aren’t suitable at all for incineration, such as (highly) explosive and/or radioactive materials.

	Btu value/lb	Content by weight	
Waste	(as fired)	Ash (%)	Moisture (%)
Carbon	14093	0	0
Hydrogen	61000	0	0
Kerosene	18900	0.5	0
Wax paraffin	18621	0	0
Methyl alcohol	10250	0	0
Ethyl alcohol	13325	0	0
Wood sawdust	7800 - 9600	3	10
Wood bark	8000 - 9500	3	10
Corn cobs	8000	3	5
Newspaper	7975	1.5	6
Brown paper	7250	1.0	6
Magazines	5250	22.5	5
Corrugated paper	7040	5.0	5
Plastic coated paper	7340	2.6	5
Polyethylene	20000	0	0
Polyurethane	13000	0	0
Latex	10000	0	0
Rubber waste	9000 - 11000	20 - 30	
Rags (linen or cotton)	7200	2	5
Citrus rinds	1700	0.75	75

Adapted from: Incinerator Institute of America, N.Y

Btu values only approximative

N.B. 1 Btu/lb = 2.3241 kJ/kg

HEAT / TEMPERATURE

The higher the temperature the waste is being burnt at, the more complete its elimination will be, and the less likelihood there is that any un-burnt waste will be released, or traces of by-products will be formed. To reduce the risk of toxic fumes, continuous temperatures of at least 850 °C have to be reached within the incinerator. For waste containing elements that are considered noxious (e.g. halogens), 1200 °C is the minimum temperature to be rendered “harmless”. Gas cleaning facilities should be added to eliminate the risks of toxic fumes, but it is doubtful that these facilities will be found in low-income countries, let alone properly maintained. To ensure the complete elimination of thermo-resistant pathogens within the incinerator, the minimum temperatures in the primary and secondary combustion chambers (see later) should be maintained at no less than 760 °C and 870 °C respectively.

In order to reach and to maintain as much as possible these high temperatures, and to obtain a long lifespan of the incinerator, the combustion chambers should be lined with refractory material. This refractory material (most often bricks) have the following advantages:

- Heat resistant: where normal bricks will resist temperatures up to 300 °C before they crack eventually, refractory bricks can stand temperatures up to 1200 °C and well above (depending on the type of bricks). Experience shows that incinerators that are built without refractory bricks have a life expectancy of few months only when used intensively.
- Higher combustion temperature inside : the refractory bricks normally have good isolating characteristics, thus the heat is kept inside the incinerator, which helps obtaining the required high temperatures for a good combustion.
- Heat buffer effect: the refractory bricks accumulate heat, so when the loading door is closed again after introducing new waste (batch loading for small incinerators in low-income countries), the temperature inside the incinerator will reach quickly again its operational temperature.

Preheating the incinerator is another important factor to reduce as much as possible the formation of toxic by-products and the release of thermo-resistant pathogens, certainly at the beginning of the incineration cycle.

HEAT / TEMPERATURE

Refractory bricks:

Different types of refractory bricks exist; some are:

- rich in alumina (Al_2O_3): they are most resistant against temperature variations (which are common during batch incineration), and against aggressive gasses generated during the combustion of medical (soft) waste.
- containing siliceous-alumina: they aren't resistant against temperature variations, thus they are only appropriate for ovens that stay for weeks or even months at the same high temperature (so not for batch volume reducers / incinerators).
- rich in magnesium (Mg): they resist well against extreme heat, but not against water and humidity, so they're not recommended for medical (soft) waste that can be wet, or for incinerators standing outside as is often the case in low-income countries.

The ideal composition of refractory bricks for batch incineration of medical (soft) waste should contain an alumina concentration of about 60% or above, an as low as possible iron (oxide) concentration and a high density. If refractory bricks are bought in the field, their composition should be as close as possible to the concentrations of the following example:

- Al_2O_3 60%
- TiO_2 1.8%
- Fe_2O_3 1.8%
- SiO_2 35%
- K_2O 1.5%
- Na_2O + CaO traces

The manufacturer might give the Pyrometric Cone Equivalent (P.C.E.) of their refractory bricks. This American coefficient indicates the temperature limits against which the refractory material resists. The table with the coefficients and their corresponding temperature limit can be found in the annexes.

Typical dimensions of refractory bricks are 230 mm x 114 mm x 65 mm or 230 mm x 114 mm x 74 mm. As such, the dimensions of the bricks don't play that much role (except if prefabricated metal works are used; see further); their composition, their P.C.E. and their density are more important.

HEAT / TEMPERATURE

Refractory cement / mortar:

Refractory bricks should be jointed together with refractory mortar, as mortar made with normal cement (e.g. Portland) can eventually only resist temperatures up to 300 °C. Refractory cement resists to high temperatures and as it should contain a high concentration of alumina (Al_2O_3), it should also resist to temperature variations.

Refractory mortar needs besides the refractory cement also certain aggregates. All the needed components are available in prepared refractory mixtures, which only require clean non-salty water to be added before use. These mixtures are preferred, even if they seem expensive. They are easier to use and have the right composition from the start, and only a fairly little amount is needed (50 kg for the De Montfort incinerator). The mixture that is recommended is Surebond 50 DAE in bags of 25 kg (previously Aludrite 50). Often, the (local) supplier of refractory cement / mortar can't give its composition, so the manufacturer might have to be contacted. Be aware that refractory cement can be aggressive, thus Personal Protective Equipment has to be worn during the construction of an incinerator.

The joints, even if they are made with suitable refractory mortar, don't have the same (heat) resistance as the refractory bricks. Therefore, the incinerator must have joints that are as narrow as possible; in practice only 2 – 3 mm thick. Professionals apply the refractory mortar directly on the bricks, like smearing chocolate paste on a sandwich and trimming the layer under 45° at all its edges (instead of putting fresh mortar on the erected walls as is usually done in construction of brick buildings).

The refractory bricks shouldn't be too warm at the time the refractory mortar is applied, being just before the bricks are put in place. Otherwise, the humidity of the mortar might evaporate (next to some absorption by the bricks), leading to a bad adhesion in between the refractory bricks and the mortar. Humidifying and thus cooling down the refractory bricks by plunging them at least some minutes in water is controversial as solution, and should certainly be avoided for those containing Mg. Overall, it is better to keep the bricks as cool as possible in the shade, to avoid that they accumulate heat from the sun! Only if it would be noticed that the adhesion of the refractory mortar would be unsatisfactory, the refractory bricks can be dipped very shortly in some clean non-salty water.

HEAT / TEMPERATURE

Vermiculite:

An incinerator should have an external hull / wall covering the refractory bricks to protect them and even more importantly the refractory mortar from the elements. If not protected, the refractory mortar will erode away, shortening considerably the lifespan of the incinerator.

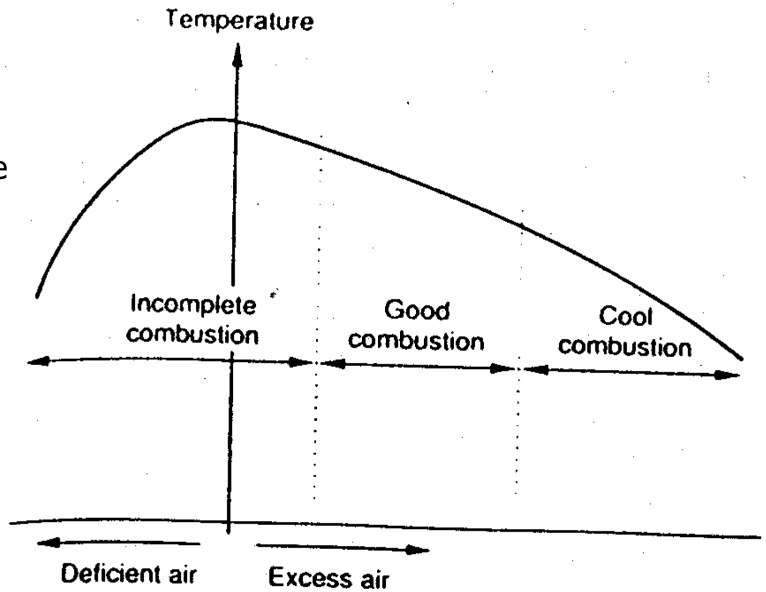
A layer of Vermiculite concrete is recommended in between the refractory bricks and the external hull / wall to increase the isolation in order to keep the heat as much as possible inside the combustion chambers, and also to stabilise the incinerator even more. Attention should be paid to local purchase of Vermiculite as some brands might be contaminated with asbestos!

The Vermiculite should preferably be mixed with Lafarge Fondu cement as it can resist high temperatures. In case this kind of cement isn’t available, Portland cement can do, as the temperature on the outside of the refractory bricks stays reasonable.

OXYGEN

A good combustion means a good thermal oxidation of carbon (C) and hydrogen (H). To achieve this, the air that contains only 21% of oxygen (O) by volume, must be thoroughly mixed with the vaporised carbon and hydrogen elements of the fuel / waste. Theoretically, a stochiometric mixture of the three elements should be reached, meaning that all the oxygen available is consumed, as this would result in very high combustion temperatures (see graph).

The amount of oxygen plays an important role in the degree of generating (toxic) by-products and the effectiveness of waste elimination. Its availability should always be sufficient; not just to satisfy the theoretical demand of the combustion process, but also a little in excess. Varying factors such as the waste containing a lot of elements other than C and H, make that it is impossible to reach the ideal stochiometric mixture anyway. Deficient air / oxygen amounts lead to incomplete combustion at lower temperatures, and result in the generation of very toxic carbon monoxide (CO) gas. Therefore, a slight excess in air (oxygen) is required, even if this gives a slightly cooler combustion. Way too much air would lead to a cool combustion, which isn't desired either, even if this avoids the CO formation completely.



Source: Incinerator Institute of America, N.Y.

The important factors for a correct oxygen supply are the:

- air inlets: they should have the right size and location to allow a good mixture of the air (oxygen) with the waste (gasses).
- draught of the chimney:
  - diameter: the "bigger", the more draught.
  - length: the "longer", the more draught.
  - away from obstacles like buildings, trees.
- maintenance: ashes and other residues block the free passage of air (oxygen) and can thus have a negative influence on the combustion process. These residues should be removed after each cycle.

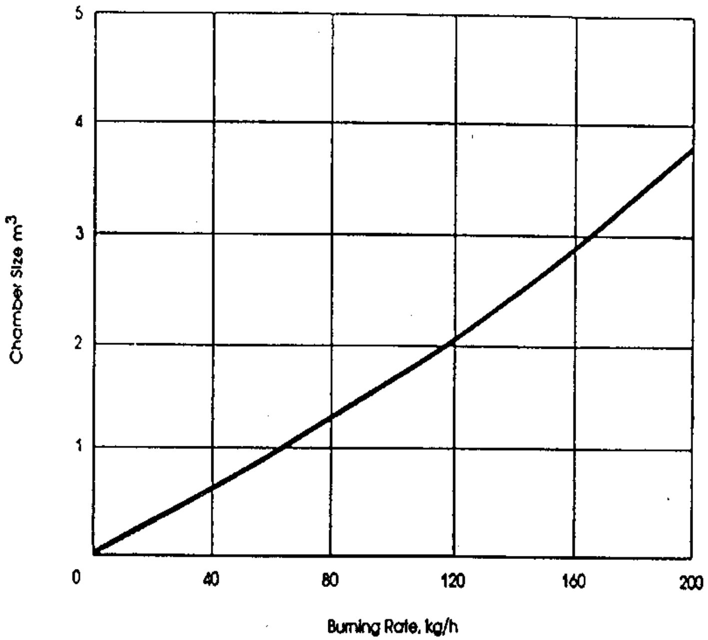
TURBULENCE / TIME

Whereas the temperature and the excess oxygen can potentially be controlled during operation, the turbulence and the residence time are generally fixed, within narrow limits, by the design of the incinerator.

The turbulence relates to the degree of mixing in between the oxygen of the air and the waste (gasses), and the absence of temperature gradients (differences) within the incinerator. A greater turbulence provides better control, better access to air and thus a completer elimination of the waste. A maximum turbulence and thus mixing can be achieved in the combustion chamber by proper location of fans. However, fans are often not appropriate on small incinerators for low-income countries because they need electricity. The form and the size of the combustion chamber will also have their influence on the turbulence.

The residence time of the waste in its gas phase is also of particular importance. The longer the waste gasses are held at high temperature, the greater the elimination degree of thermo-resistant pathogens, and the less toxic the by-products will become. So the bigger the combustion chamber of an incinerator is, the longer the residence time. However, a bigger combustion chamber also means more (pre-)heating and often a less concentrated heat within the furnace, thus the need for more additional fuel. To obtain a good turbulence inside a big combustion chamber, fans will be needed to obtain a correct mixture.

An incinerator with a secondary combustion chamber doesn't require a big hearth (primary combustion chamber), whilst it potentially creates a better natural turbulence and increases the retention time of the gasses (ideally at least 2 seconds). A secondary chamber provides also an after-burner section for the combustible gasses that weren't flared off yet in the primary chamber.



Source: Incinerator Institute of America, N.Y.

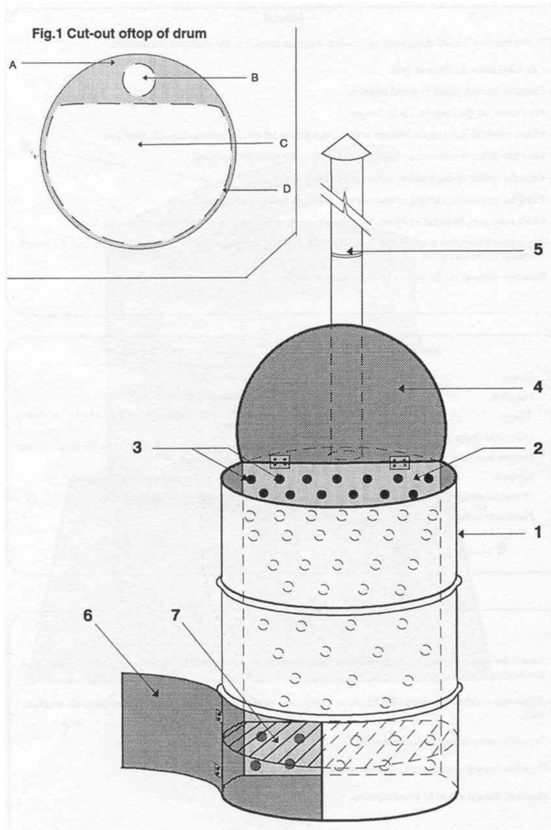
The volume of the (primary) combustion chamber should still be sufficient to receive the physical bulk of the waste, and provide adequate gas residence time. However, for simple incinerators without burners and fans, it's better to have 2 small units than 1 big one, or to increase the length of the cycles by splitting the waste up in smaller batches.

BURNING / VOLUME REDUCTION

The intention of burning certain wastes is mainly to reduce their volume by thermal oxidation. To a certain extent, the fire will also render the waste non-reusable.

When waste is burnt in a big pile on the ground or in a pit, there will be a lack of oxygen inside the heap, resulting in a bad combustion with a high smoke production. Although this smoke looks to be harmless as it is often white, it contains a lot of thermo-resistant pathogens and toxic components. Therefore, open burning should be prohibited.

An alternative is to burn waste in specially made volume reducers, still functioning on the burning principle. Volume reducers only have one combustion chamber, so a lot of flammable gasses escape without being burnt, resulting in lower combustion temperatures, and less elimination of thermo-resistant pathogens and toxic by-products.



With the temperatures reached in volume reducers, it is impossible to melt needles and other sharp metallic objects. However, the generated heat is enough to explode glass objects like ampoules and vials, which can lead to serious injuries. Thus all these sharps should generally not be burnt (except certain sharps with specific burning equipment). Waste such as placentas, organs, blood, amputated limbs and food residues (also called organic waste) should not be burnt either, as their high liquid content will reduce the combustion temperature even more. Chemicals should certainly not be burnt as this will generate a lot of toxic fumes. Volume reducers are generally to be used for soft wastes that burn easily, with a minor hazard for the environment and public health.

As the combustion process doesn't perform optimally in a volume reducer, burning of soft waste should be limited to emergencies and small rural health centres only. Emergencies require rapid solutions which are often temporary, thus the investments should be limited. Therefore, the typical emergency solution for burning soft waste is a volume reducer made out of a drum. For longer term solutions in small health centres, a special refractory brick volume reducer has been designed.

For further information: Medical Waste Management in Low-Income Countries, MSF

INCINERATION

The solution for (soft) waste in stabilised situations lies more in incinerators with double combustion chambers. As such, the residence time of the (flammable) gasses will be increased and a better turbulence will be obtained within the hearth, thus creating a better mixture with the available oxygen, which finally leads to a better combustion. Incinerators made with refractory bricks reach higher temperatures in comparison with metal waste reducers / incinerators and their lifespan will also increase enormously.

The double combustion, leading to higher temperatures and longer residence time, results in more decontaminated and unrecognisable solid residues (ash), and less toxic smoke that contains also less thermo-resistant pathogens.

In order to limit the running costs for low-income countries, it's often preferable to choose for auto-combustion incinerators. Auto-combustion means that the (soft) waste itself is the fuel to run the incinerator and that no other additional fuel is needed, except during the pre-heating phase or when the (soft) waste is extremely wet.

Although the temperatures that can be reached in a small (auto-combustion) incinerator are higher than in a volume reducer, it still won't melt metallic sharps. Again, the liquids in the organic waste will reduce considerably the temperatures of the (auto-)combustion, requiring lots of additional fuel which are often too expensive for health structures in low-income countries. The temperatures and retention times obtained in small (auto-combustion) incinerators are definitely not enough to destroy hazardous wastes like laboratory chemicals and expired drugs.

A recommended small auto-combustion incinerator is the De Montfort 8a model with external wall, which is relatively cheap and easy to build, and has a good performance when well managed.

De Montfort 8a incinerator with external wall

Be aware however that the De Montfort incinerator is only a tool to deal with (soft) waste amongst other technical solutions, and that Medical Waste Management also includes Human Related Aspects ("Software component").

For further information: Medical Waste Management in Low-Income Countries, MSF

DE MONTFORT INCINERATOR

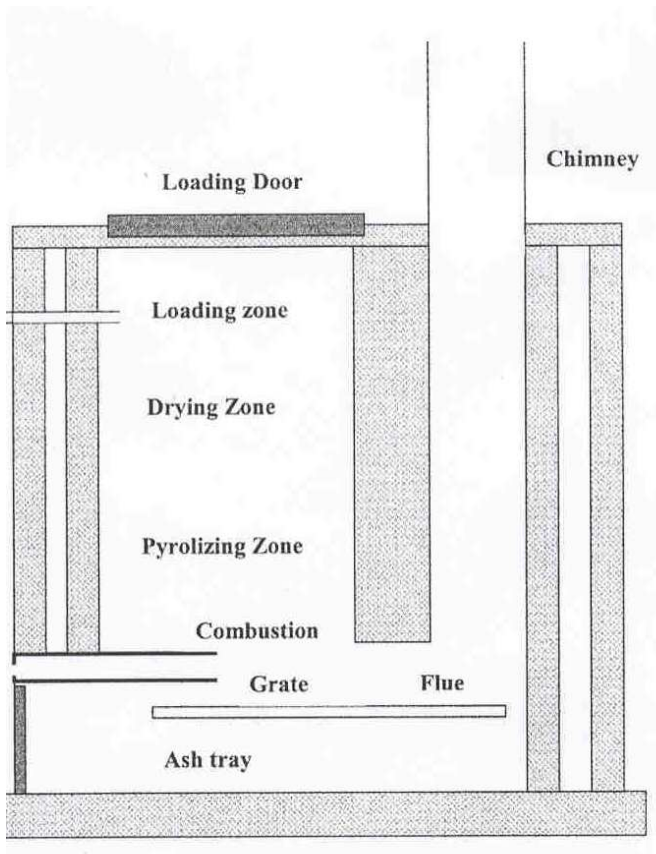
The De Montfort incinerator is composed of two combustion chambers; the primary and the secondary.

The primary combustion chamber has different zones:

- Ash tray zone: collection of the incinerated residues.
- Combustion zone: place where the primary combustion takes place because the three factors of the fire triangle are present: fuel / combustible waste, heat generated by the flames and oxygen.
- Pyrolyzing zone: only two factors of the fire triangle are present: fuel / combustible waste and heat. The heat will still decompose the waste into combustible gasses, but due to the lack of oxygen, they can't ignite (so no fire in this zone). When the loading door is opened however, oxygen can get in contact with the hot combustible gasses which can ignite suddenly, potentially creating a high flame.
- Drying zone: the heat at this point isn't high enough anymore to decompose the waste into combustible gasses, but it still dries the (soft) waste that is wet.
- Loading zone: place where new batches of (soft) waste are introduced in the incinerator.

The secondary combustion chamber consist mainly of the flue where the flammable gasses of the primary combustion chamber that haven't burnt yet are drawn into. As these gasses pick up oxygen and heat when passing through the flames of the primary combustion chamber again, they ignite in the flue, creating a lot of heat. This helps to burn different components in the fumes, which reduces the toxic output of the exhaust a bit more, and thermo-resistant pathogens that might have survived the primary combustion will be eliminated as well.

Although that the chimney isn't part of the secondary combustion chamber as such, flames are often noticed there as well. This can lead to an accelerated corrosion of the chimney, needing a more frequent replacement.



Source: De Montfort University

INCINERATION IN EXISTING INDUSTRIAL FACILITIES

It is recommended to do the incineration as much as possible on-site to avoid accidents and potential fraud. However in certain situations, it will be impossible to do the incineration on-site (e.g. urban and peri-urban zones). Incineration in existing industrial facilities can be an alternative. Also for certain **hazardous wastes** (e.g. some laboratory chemicals and pharmaceutical waste), existing industrial facilities that reach very high temperatures with long retention times can be a very good solution.

Several industrial processes can provide temperatures and residence times similar to those of special (hazardous) medical waste incinerators in high-income countries, and thus have the potential to recover the heating value of the waste, to remove halogens (e.g. chlorides), and to provide an equivalent destruction and removal efficiency (DRE). Potential industrial alternatives in low-income countries are cement, lime and aggregate kilns, and blaze furnaces, although they often lack the washers and scrubbers as found on (hazardous) medical waste incinerators of high-income countries.

The most common industrial solution in low-income countries is most probably the kilns of cement factories. They obtain temperatures of at least 1400 °C up to 2000 °C for the combustion gasses, and have retention times of several seconds. Thus cement factories are suitable for the destruction of certain (hazardous) wastes. Some of these (hazardous) wastes even have a heating value that will support the combustion. But it might also be that they will have to be removed from their packaging and even grinded in order not to block the feeding mechanisms of the hearth. Hazardous waste and/or their packaging that can explode shouldn't be incinerated at all (e.g. aerosols). It will be up to the kiln's responsible to decide if ampoules and vials can be incinerated, as they often give small explosions when the glass pops due to the heat, and therefore can cause damages to the kiln.

As usual, it should be checked if the national legislation permits the destruction of (hazardous) medical waste in these existing industrial facilities. It's recommended to have an official authorisation letter of the concerned authorities for the destruction of (hazardous) waste, before starting the whole negotiation procedure with the industry. Make sure to have the list with (hazardous) waste ready before the first meeting with the industrials takes place. Once an agreement is reached and a price determined, a contract will have to be made to ensure that the (hazardous) waste that is brought to the factory is effectively destroyed by incineration. This contract needs to be signed by both parties, and potentially as well by the concerned authorities. If possible, it is recommended to be present during the destruction of the (hazardous) waste, to make sure that it doesn't get another destination. After the incineration, a certificate of destruction should be asked for (part of the contract) as proof of the correct elimination of the (hazardous) waste.

For further information: Hazardous Waste Manual, MSF

CONSTRUCTION OF THE DE MONTFORT MARK 8A INCINERATOR

Concept of: D.J. Picken

In collaboration with: Médecins Sans Frontières

WARNING!

Maintain the following rules because they will:

- increase the lifespan of the De Montfort incinerator.
- reduce the risks during the construction of the De Montfort incinerator.

- Read this chapter completely before constructing the De Montfort incinerator.
- Purchase good quality material.
- Hire skilled people and train them for the specificity of constructing a De Montfort incinerator.
- Choose the right site within the waste zone to construct the incinerator, so that it doesn't cause nuisances nor fire hazards inside the health structure, nor to the surroundings. Make also sure that the incinerator will be away from trees, buildings or other objects that could hinder the correct functioning of its chimney.
- Follow the construction instructions precisely.
- Do not change the form and size of the incinerator as this can lead to serious consequences on its performance.

REQUIRED MATERIAL LIST

- **Foundation**
  - Concrete (300 kg/m³) and reinforcement bars
- **Incinerator body**
  - Refractory bricks with high Al_2O_3 content: 160 + 5 % reserve
  - Refractory cement (pre-mix): 50 kg
- **Insulation and outer wall**
  - Vermiculite granularity 1: 300 l
  - Vermiculite granularity 3: 300 l
  - Lafarge Fondu cement: 100 kg
  - Normal bricks or cement blocks
  - Portland cement
- **Metal works** (see appropriate pages below; all dimensions in mm)
  - Top frame with loading door and chimney spigot: (stainless) steel
  - Ash door / tray with grate: (stainless) steel
- **Chimney**
  - Steel pipes Ø 120 – 150 mm, min. 2 mm thick, total length at least 4 m
  - Chimney cap
  - Cables, tensioning devices and accessories
- **Tools**
  - Mason’s and Metal worker’s tools
  - Heavy and Soft (rubber or plastic) hammers
  - Flat chisel
  - Welding machine and accessories, tools and protective equipment

FOUNDATION

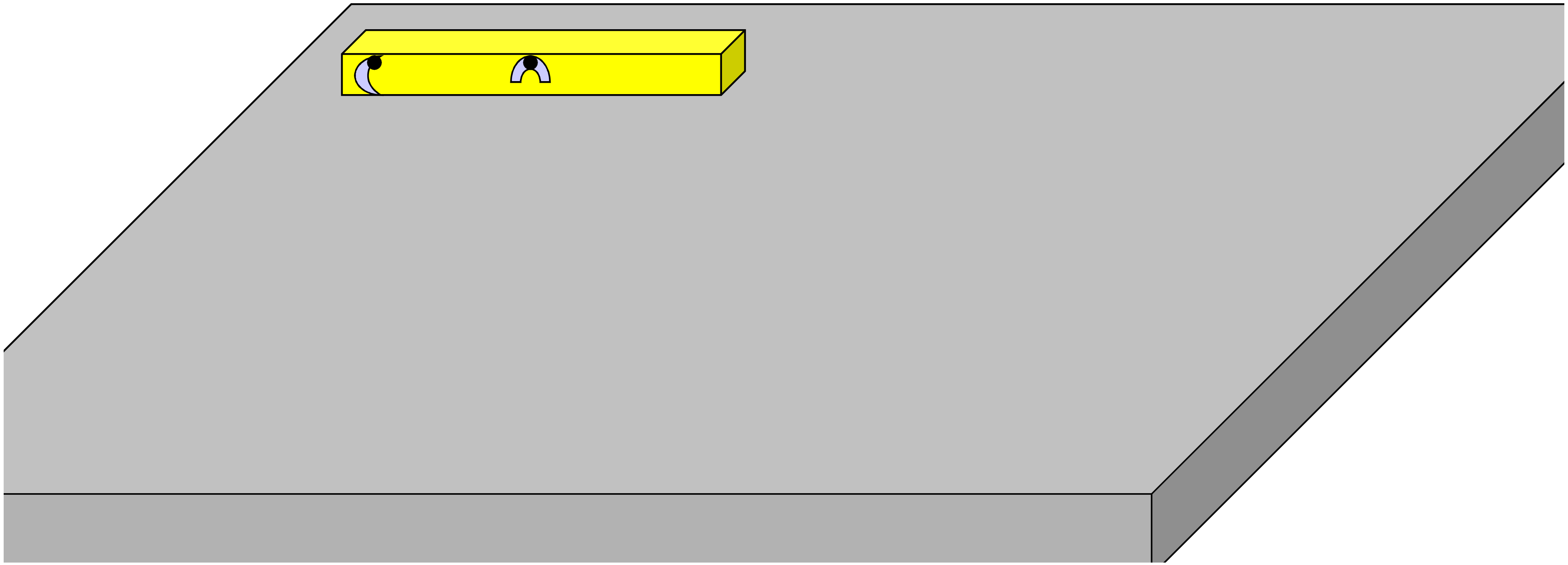
- Cast a solid reinforced concrete foundation (300 kg/m³) that can resist the final weight of the incinerator (about 1000 kg).

-Its dimensions should be at least: 2 m x 2 m x 0.15 m, which includes immediately a small temporary storage area for the soft waste bins. For big health structures, a bigger platform should be foreseen.

-The foundation should be level in its length and width.

- Mark out where the incinerator has to be positioned exactly.

The foundation shouldn't be too rough at the place where the incinerator will be constructed, to keep the refractory mortar layer in between the concrete and the first layer of refractory bricks as thin as possible (2 to 3 mm thick).



PREPARATORY WORKS

During the curing of the foundation, which should last for at least a week, the preparatory works for the construction of the De Montfort incinerator can be done.

•Bring in all the material and equipment, and store them safely under a shelter.

-This is to avoid theft, but also to protect them against damages and adverse weather conditions (e.g. sun, rain).

-The refractory cement should be stored on pallets in a dry location where temperatures can be kept between 5 and 30 °C. Warm storage is recommended in extreme cold conditions. If the pallets are covered with plastic sheeting or tarps, ventilation is required in order to prevent condensation.

-The refractory bricks should also be stored on pallets.

•Keep the refractory bricks at all times in the shade in order to avoid that they get warm!

This should be done for all the refractory bricks used for the incinerator, even during the construction itself.

•Provide some kind of temporary shelter over the manufacturing area to protect the incinerator against the rain or sun during its construction.

Exposure to rainwater as well as the heat of the sun during the construction phase could have a negative impact on the lifespan of the incinerator.

PREPARATORY WORKS

Before the actual construction starts, it’s recommended to try out already the refractory cement according to the manufacturer’s instructions. For Surebond 50 DAE mixture, proceed as follows:

•Verify the refractory cement.

In case lumps have been formed due to the pressure and settlement during its storage, it should still be possible to break them down by hand. Don’t use the refractory cement when the lumps can’t readily be broken down by hand.

•Make sure all mixing equipment is clean and dry.

Contaminants, such as Portland cement, can adversely affect the physical and bonding characteristics of Surebond 50 DAE mortar.

•Use only clean, non-salty water with a pH between 6 and 8.

Warm mixing water, with a temperature between 25 and 30 °C is preferred. Mixing water should accurately be weighed or measured. Refer to the chart provided below for water requirements (but don’t mix a full bag at once).

Consistency	Bag size kg	Water addition Wt %	Water/bag Volume in litres	Water/bag Weight in kg
Brick setting	25	23	5.8	5.8

•Mix until the mortar is uniform.

The total mixing time should not exceed three to five minutes.

LAYER 1

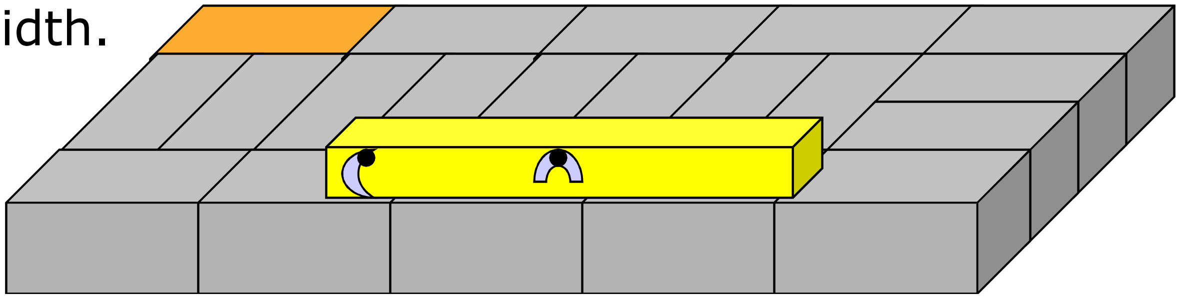
•Prepare the refractory mortar according the manufacturer's instructions.
-To be used as quickly as possible (max. 30'), therefore make several batches!
-Refractory cement / mortar might be aggressive, so do wear protective clothing.

•Apply a thin layer (max. 2 – 3 mm thick) of the refractory mortar directly on the bottom of the 1^{st} brick, like smearing chocolate paste on a sandwich, and trim the layer under 45° at all its edges.
The picture indicates how the layer is applied.

•Position the prepared brick (indicated in orange) in the corner of the foundation's markings.

•Apply a thin layer of refractory mortar in a similar way on the bottom of a 2^{nd} brick (max. 2 – 3 mm thick) and its side (1 – 2 mm thick) that will be in contact with the 1^{st} brick, and position the brick as required.
A rubber hammer can be used to ease the exact positioning.

•Keep on doing this until all 20 bricks of the 1^{st} layer are in place according to the drawing, and verify if the whole is level in its length and width.



LAYER 2

•Apply a thin layer (max. 2 – 3 mm) of the refractory mortar on the bottom of the 1st brick and trim the layer under 45° at all its edges.

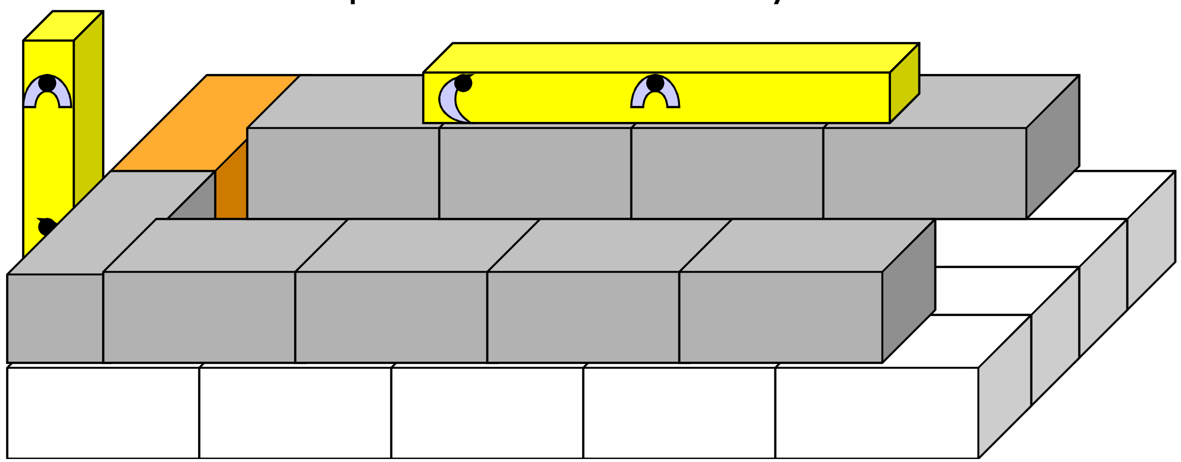
•Position the prepared brick at the back corner of the incinerator.

•Prepare in a similar way a 2nd brick with a thin layer of refractory mortar on its bottom and its side that will be in contact with the 1st brick.

•Position the prepared brick next the 1st one.
A rubber hammer can be used to ease the exact positioning.

•Keep on doing this until all the bricks of the 2nd layer are in place according to the drawing.

•Verify at different places on all sides if the 2nd layer is level in its length, width and height.
This should be repeated for all the layers!



LAYER 3

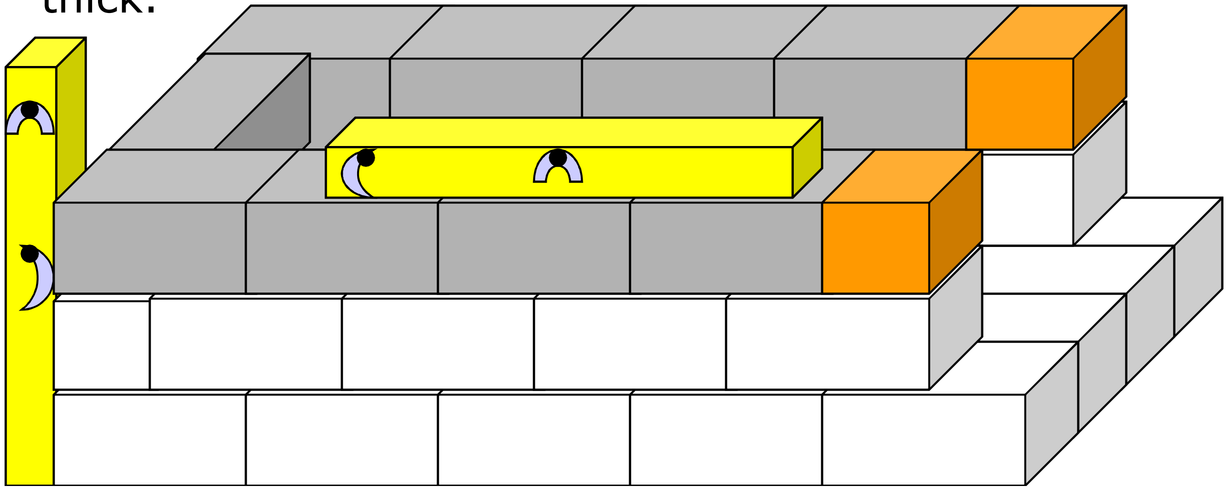
- Cut 1 refractory brick in half.

A small V-shaped cut must be made all around the middle of the brick by means of a flat chisel and a heavy hammer. Once the V-cut is made, a heavy blow with the hammer on the flat chisel inside the V-cut should be sufficient to break the brick in two.

<u>Attention:</u>
Protective goggles are important because small pieces of the brick can be projected!

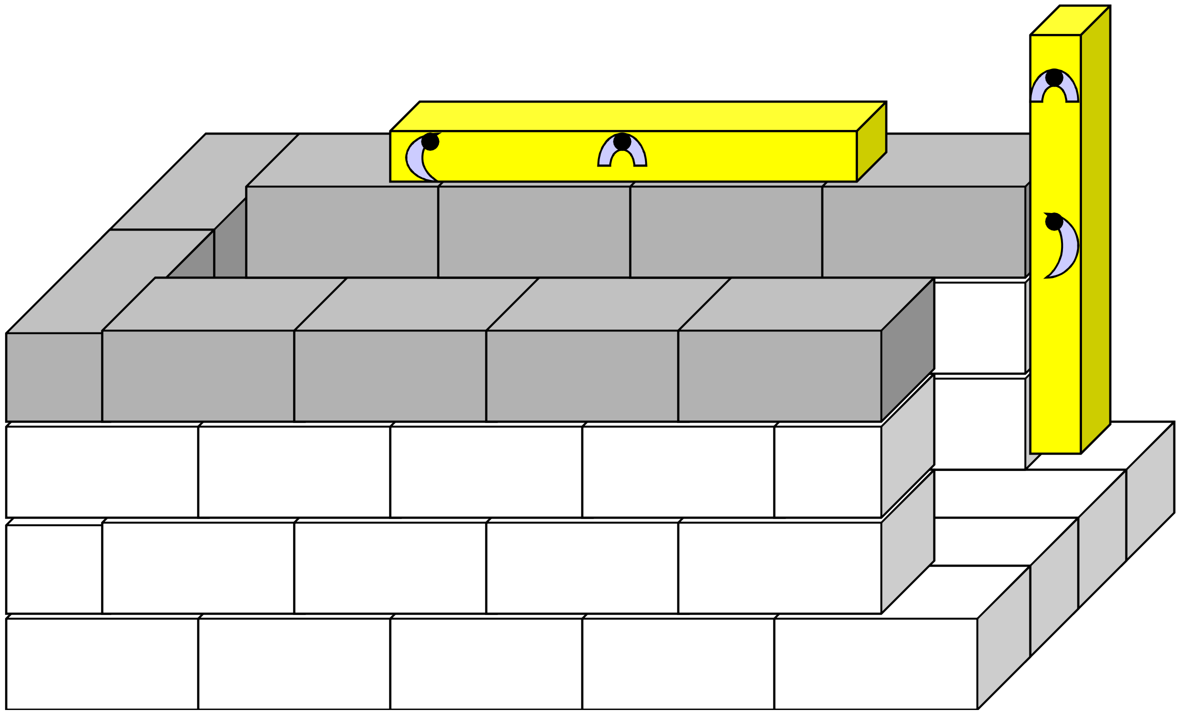
- Build the 3rd layer as described before and according to the drawing, making sure both rough faces of the cut brick are facing outwards.

The latter is to avoid that the mortar layers in between the bricks become too thick.



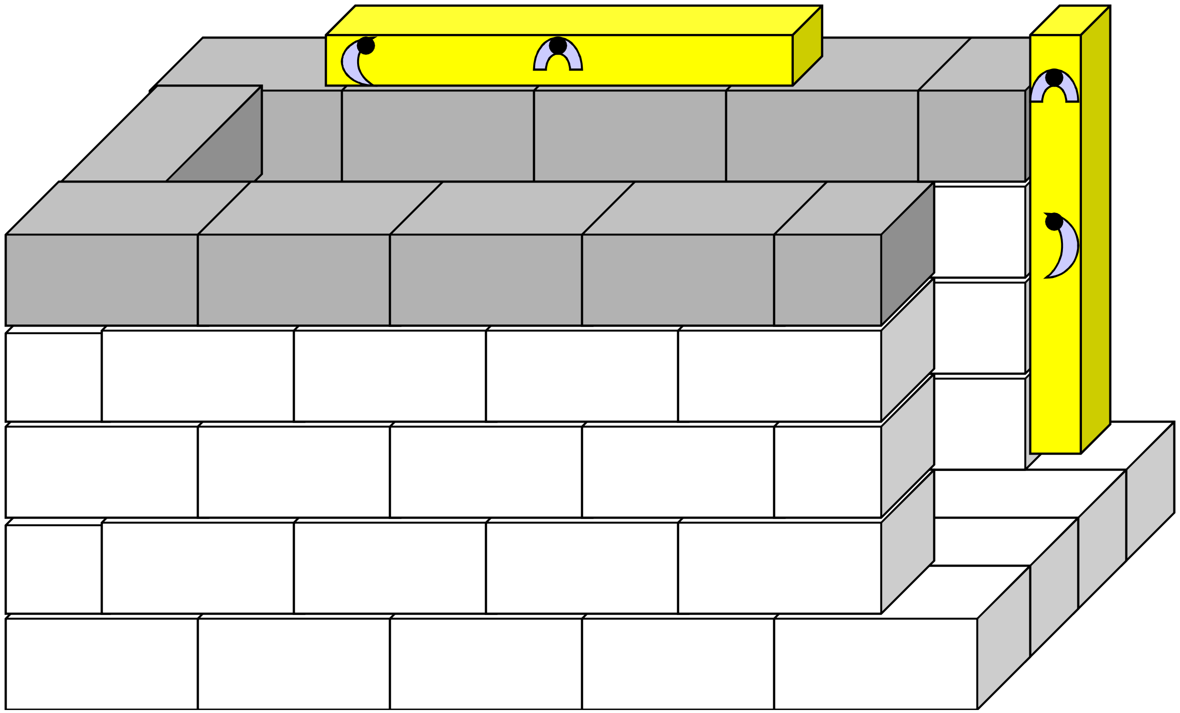
LAYER 4

- Build the 4th layer as described before and according to the drawing.



LAYER 5

- Cut 1 refractory brick in half as described before.
- Build the 5th layer as described before and according to the drawing, making sure both rough faces of the cut brick are facing outwards.



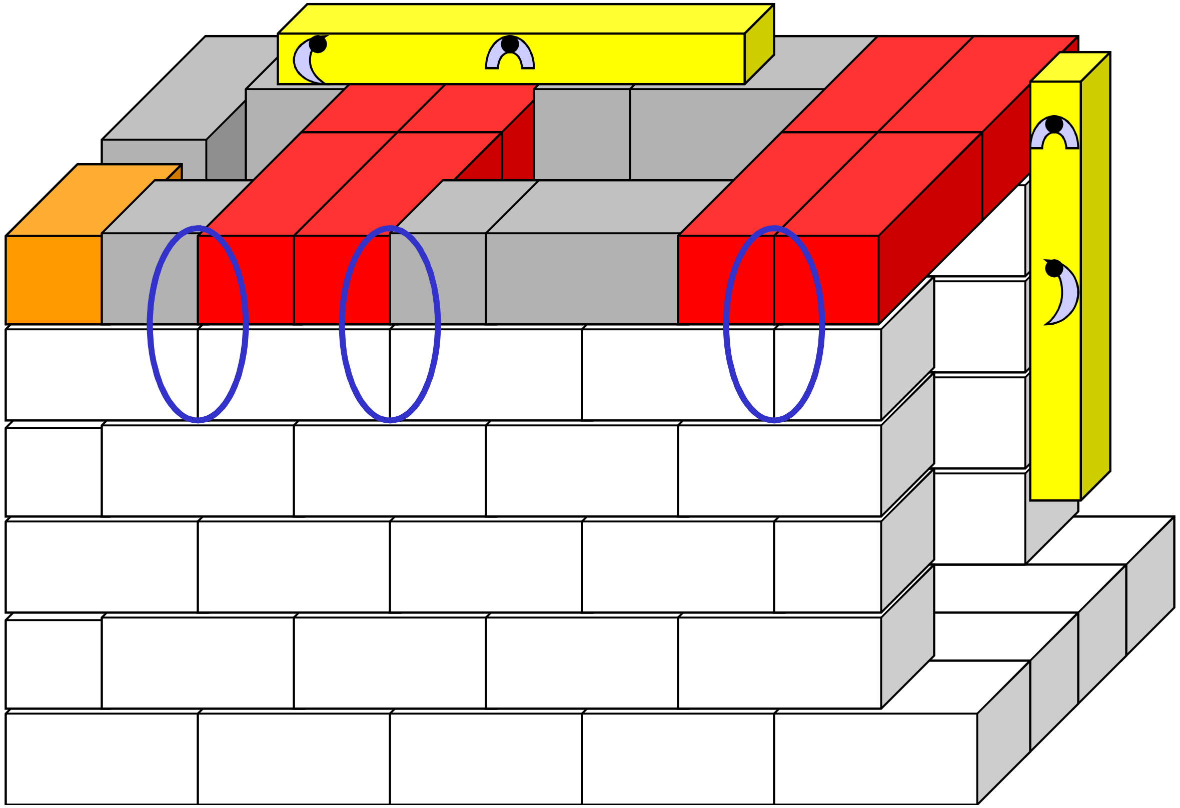
LAYER 6

•Cut 2 refractory bricks in half, and 1 to ¾ of its length.

•Build the 6th layer as described before and according to the drawing, inserting the ¾ brick at the back of the incinerator and making sure all rough faces of the ½ cut bricks are facing outwards.

-The opening created at the back of the incinerator is a peephole to monitor the secondary combustion (see the operation chapter further in this manual).

-For the brick bridges (indicated in red) to stay in place as the cement dries, provide a support in bricks or wood underneath.

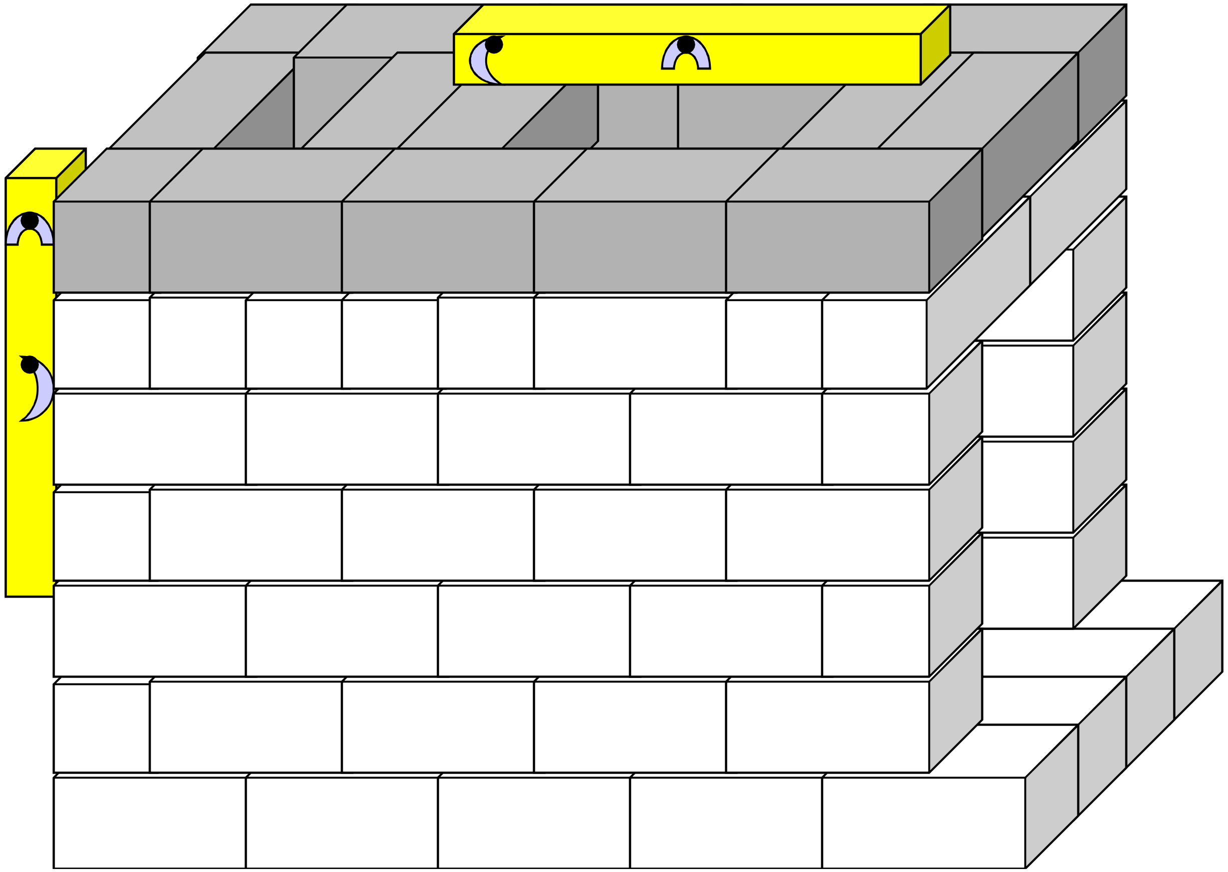


From layer 6 onwards, superposing joints are to be noticed. From a constructor's point of view, this isn't ideal. But as these aren't structural walls, and the failures seen on existing De Montfort incinerators were more related to bad curing (see below), it has been opted to ease the construction, instead of following strict building rules.

LAYER 7

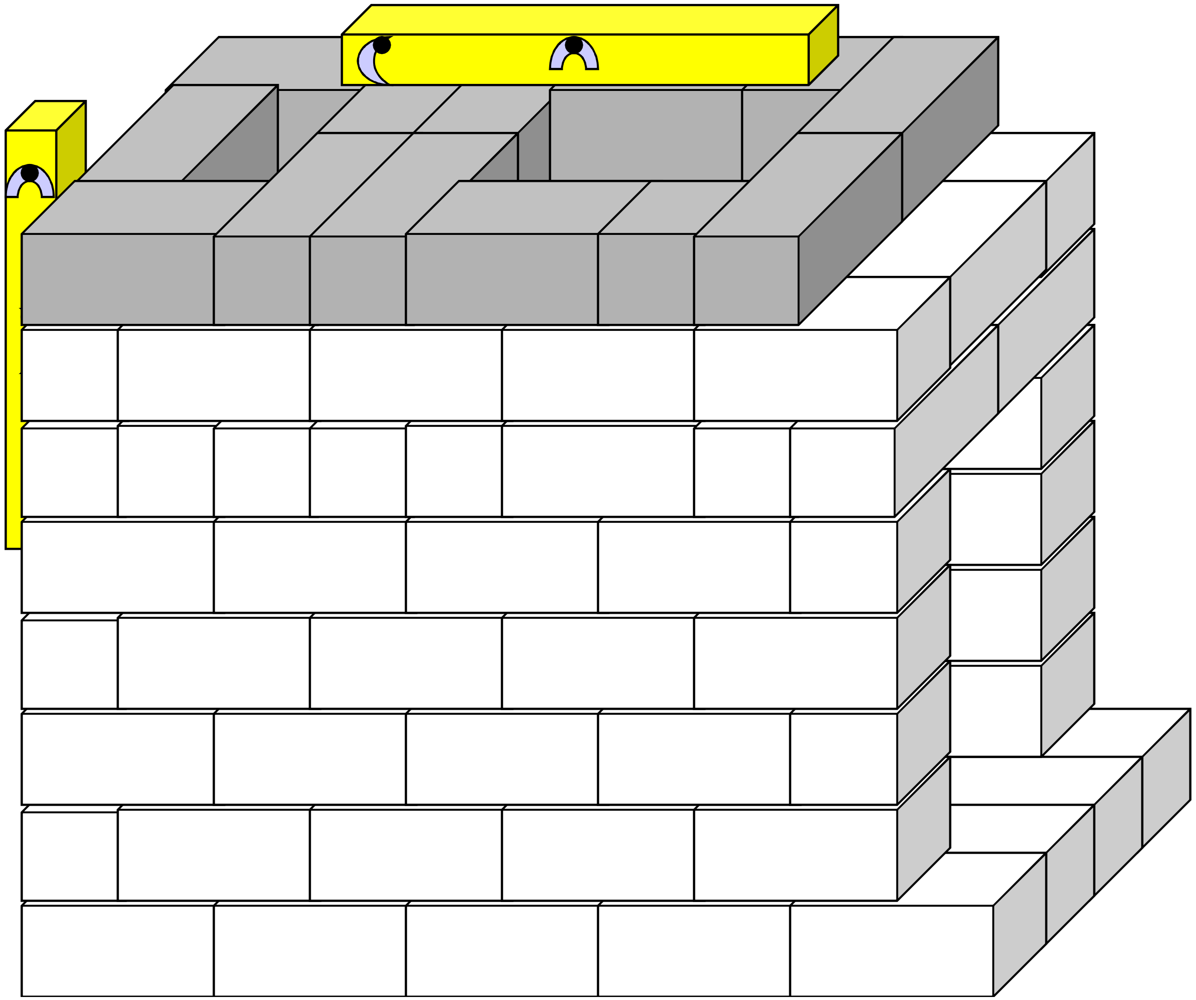
•Cut 1 refractory brick in half as described before.

•Build the 7th layer as described before and according to the drawing, making sure both rough faces of the cut brick are facing outwards.



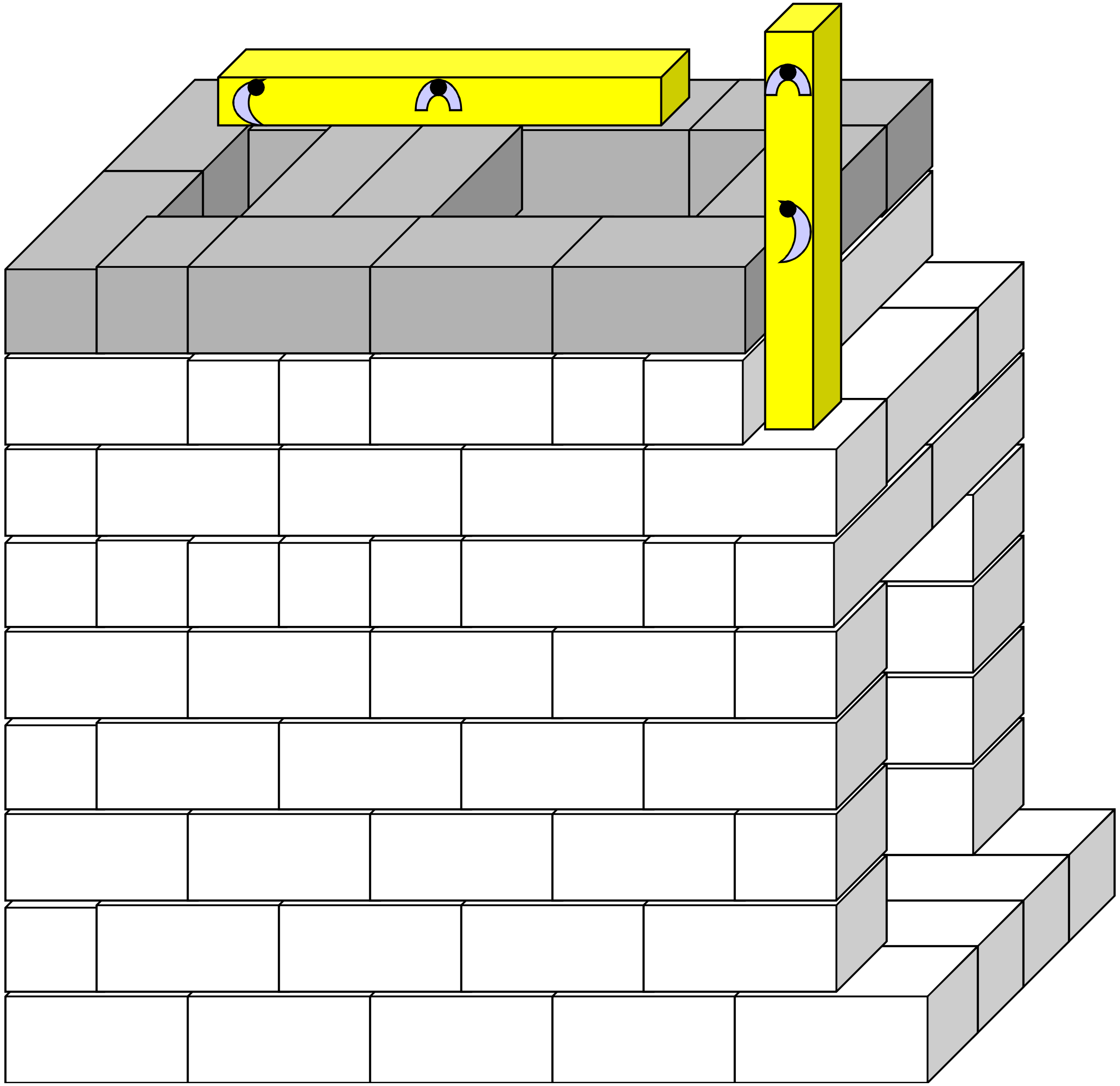
LAYER 8

- Cut 1 refractory brick in half as described before.
- Build the 8th layer as described before and according to the drawing, making sure both rough faces of the cut brick are facing outwards.



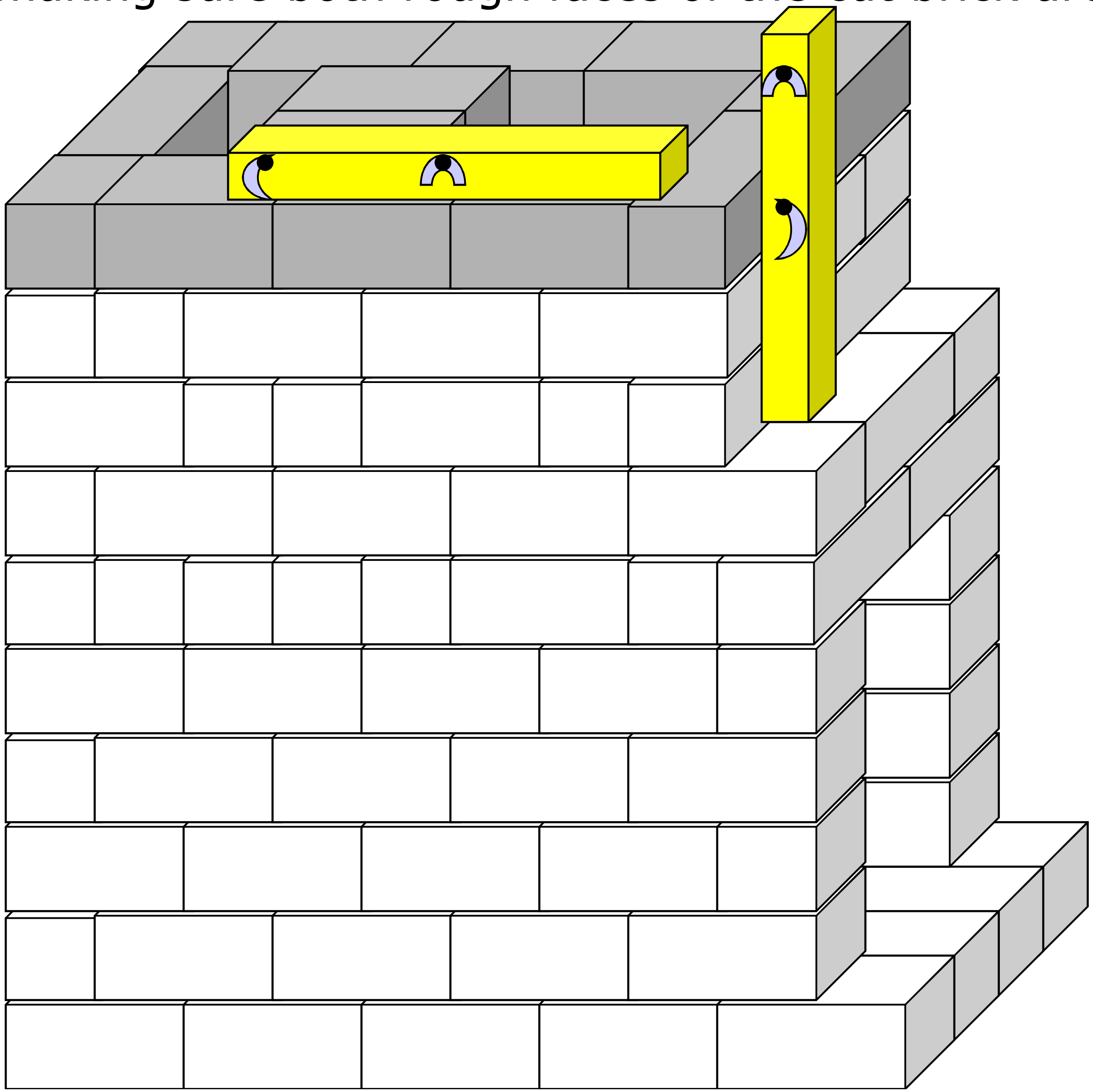
LAYER 9

- Cut 1 refractory brick in half as described before.
- Build the 9th layer as described before and according to the drawing, making sure both rough faces of the cut brick are facing outwards.



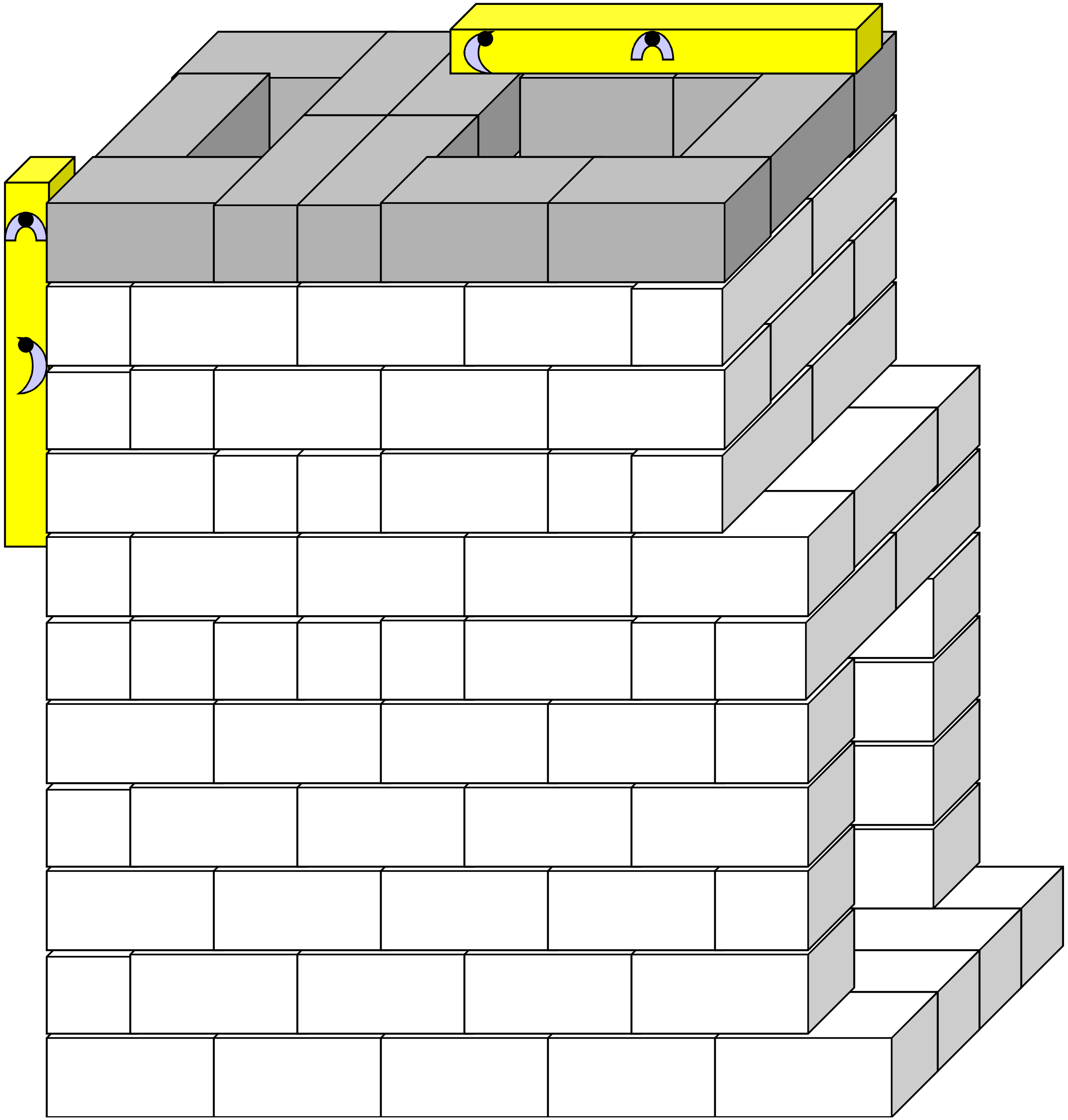
LAYER 10

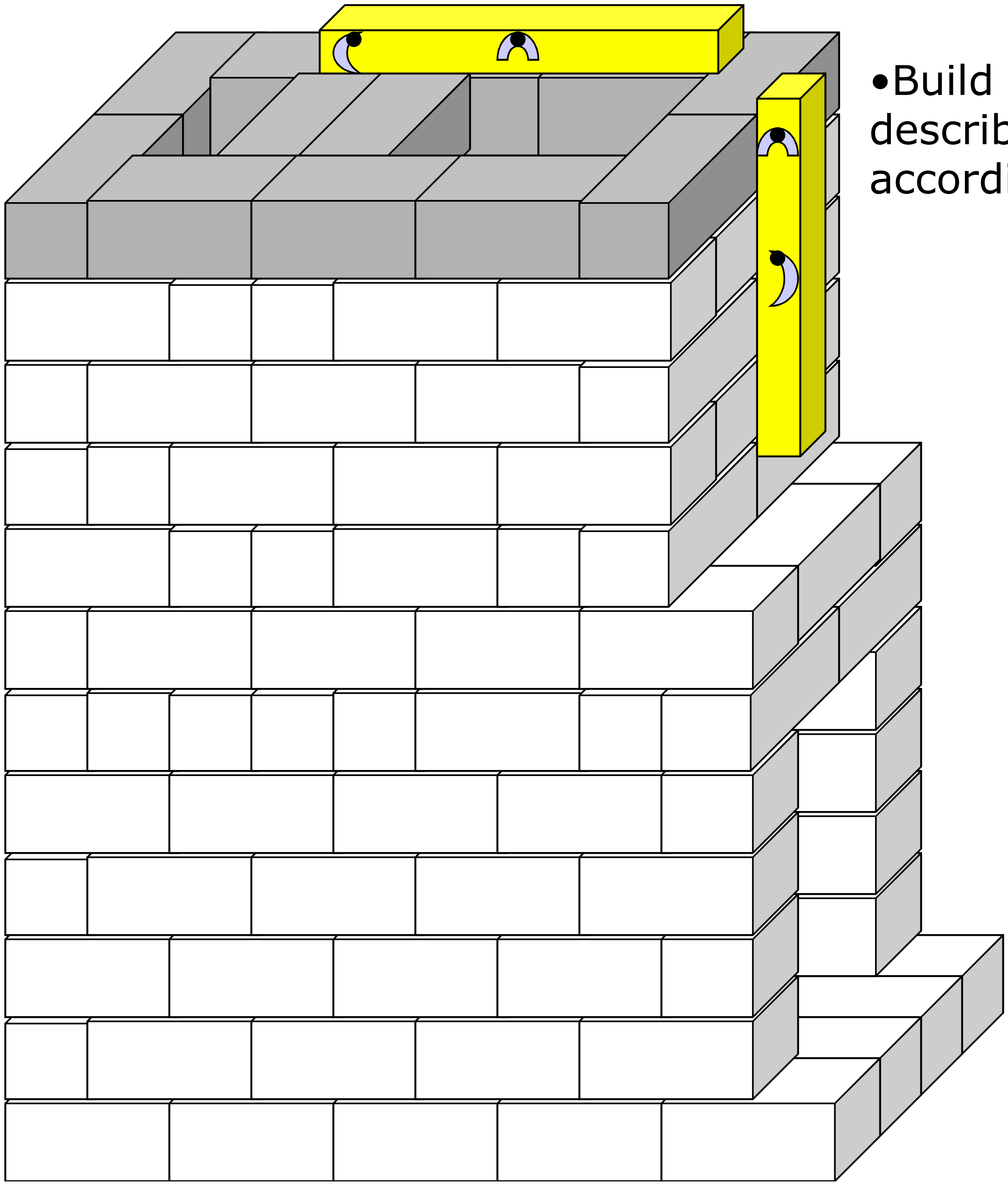
- Cut 1 refractory brick in half as described before.
- Build the 10th layer as described before and according to the drawing, making sure both rough faces of the cut brick are facing outwards.



LAYER 11

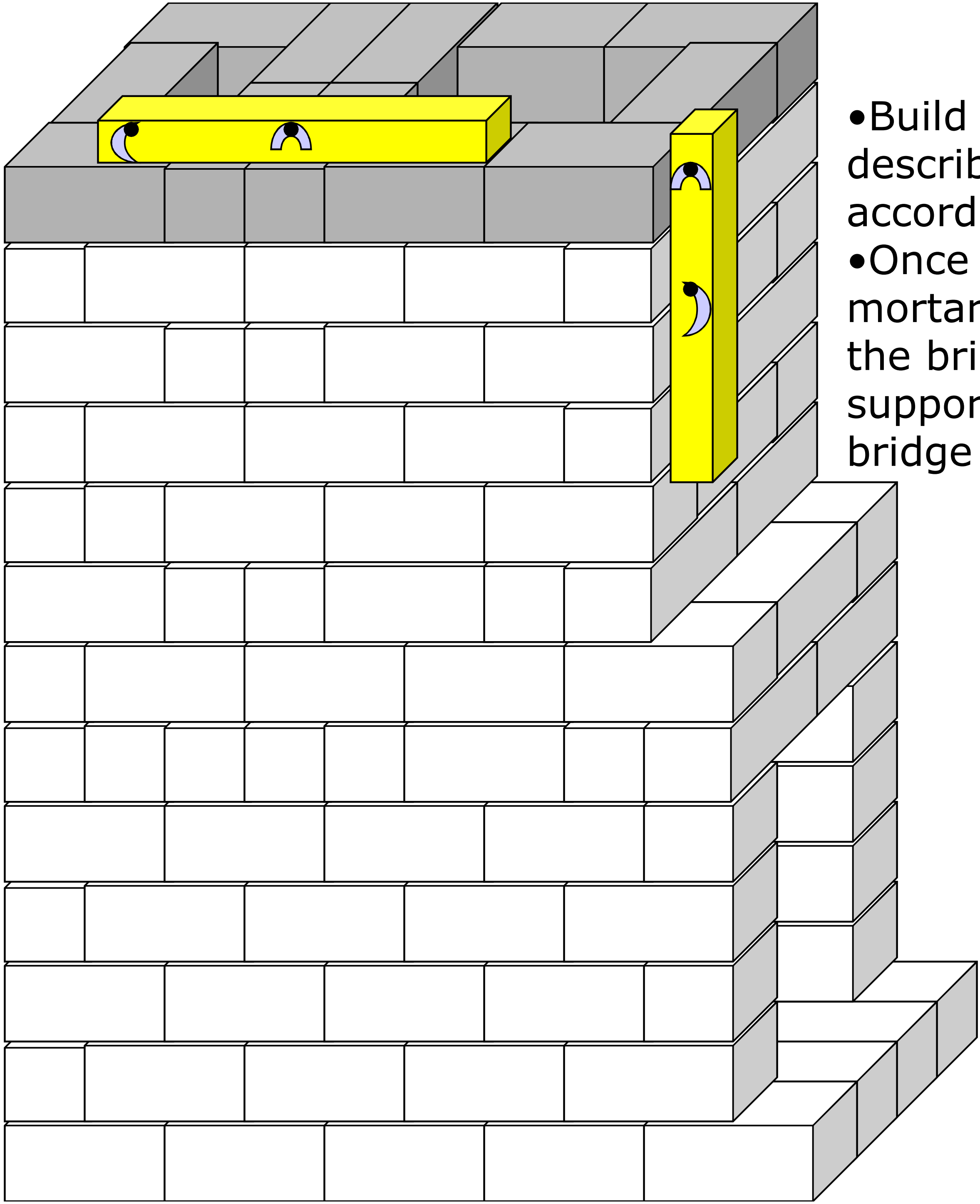
- Build the 11th layer as described before and according to the drawing.





LAYER 12

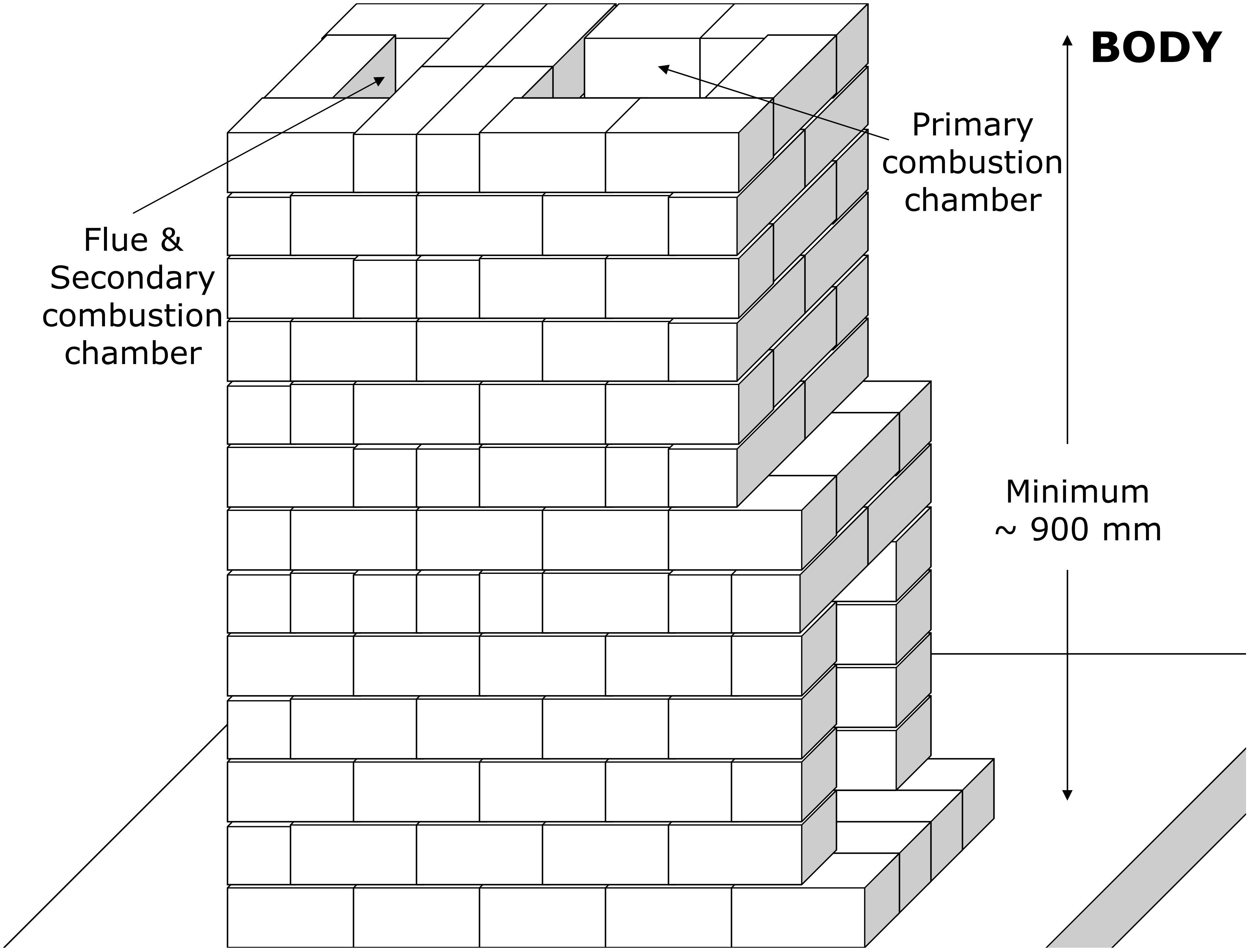
- Build the 12th layer as described before and according to the drawing.



LAYER 13

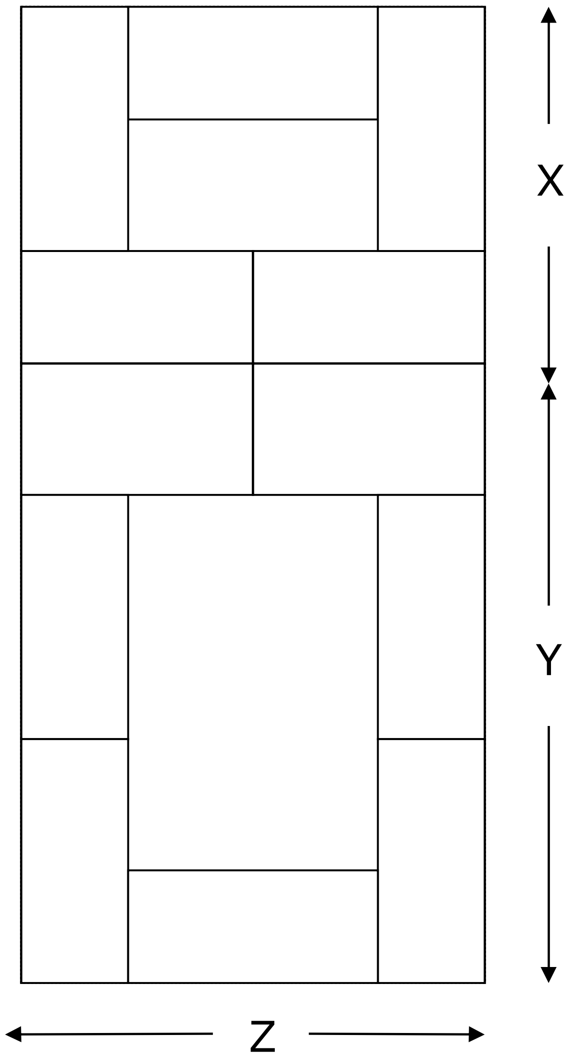
- Build the 13th layer as described before and according to the drawing.
- Once the refractory mortar has dried enough, the brick or wooden support underneath the bridge can be removed.

BODY


Primary combustion chamber
Flue & Secondary combustion chamber
Minimum ~ 900 mm

TOP FRAME

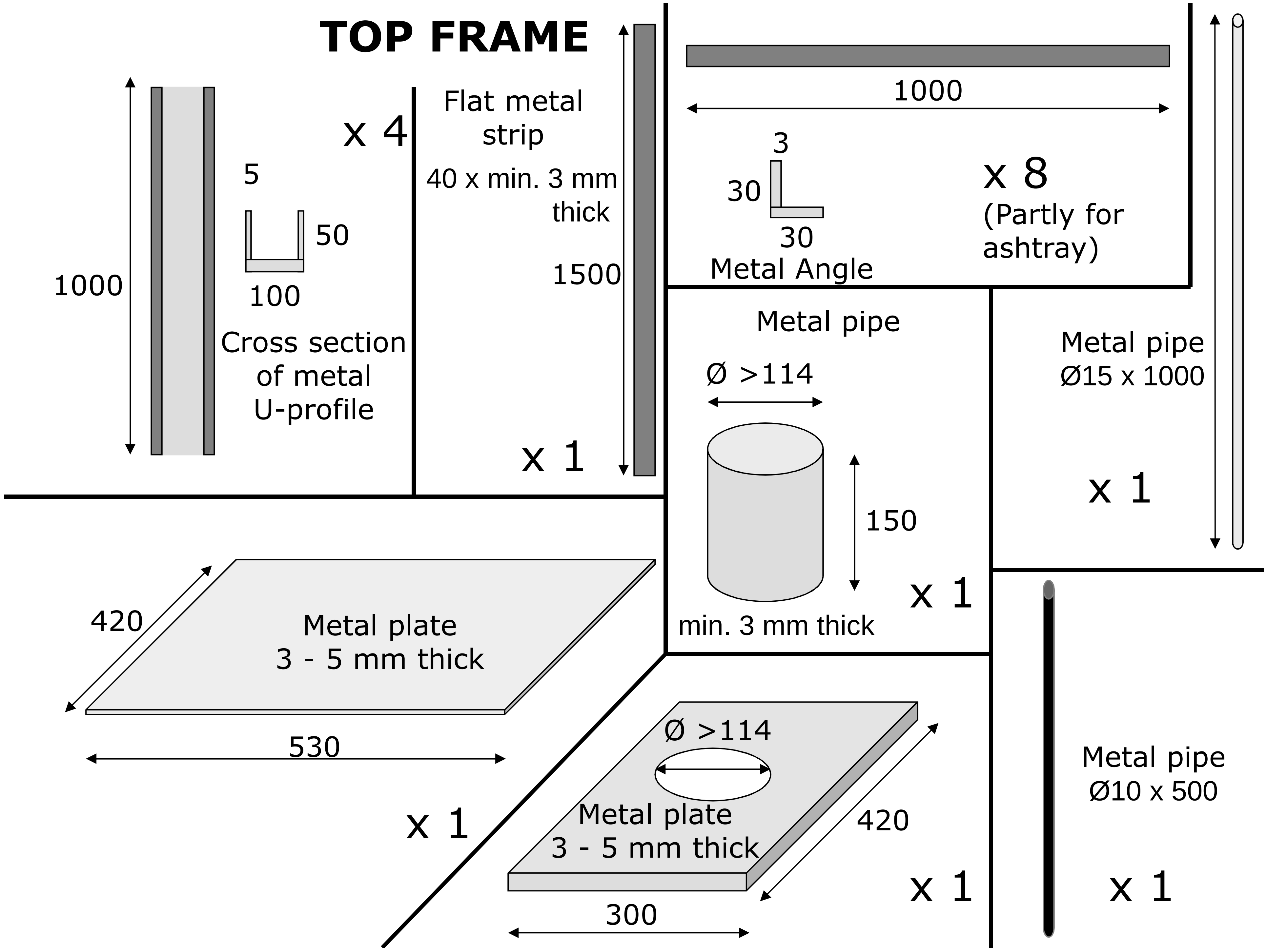
- Measure the exact external top dimensions of the refractory construction (body of the incinerator).



The list concerning the material needed for the metal works of the top frame with loading door and chimney spigot are to be found on the next page.

The dimensions (in mm) given on the material list for the top frame are for an incinerator made with the standard refractory bricks of 230 mm length x 114 mm width, and might have to be adapted if non-standardized bricks are used!

TOP FRAME


1000
5
50
100
Cross section of metal U-profile
x 4
Flat metal strip
40 x min. 3 mm thick
1500
x 1
1000
3
30
30
Metal Angle
x 8
(Partly for ashtray)
Metal pipe
Ø >114
150
min. 3 mm thick
x 1
Metal pipe
Ø15 x 1000
x 1
420
Metal plate
3 - 5 mm thick
530
x 1
Ø >114
Metal plate
3 - 5 mm thick
420
300
x 1
Metal pipe
Ø10 x 500
x 1

TOP FRAME

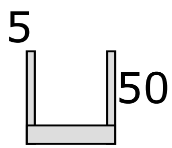
•Cut the metal U-profile at the needed external lengths (X, Y, Z) under 45°.
-If U-profile isn't available, metal angles can be welded together to form a U-shape, but this complicates things enormously.

-An alternative is to order module 3: Metal Works (see annexes) at your HQ.

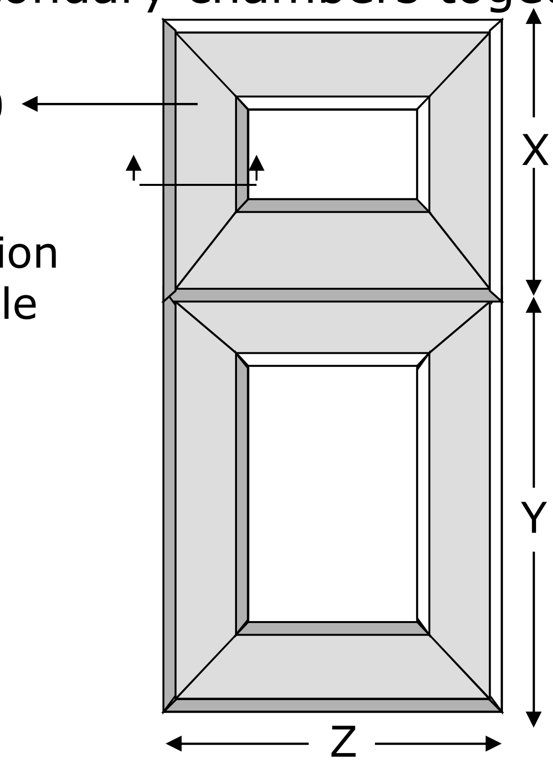
•Remove all sharp edges that could cause injury.

•Weld the profiles together, so that they become two frames. Be aware that some deformation will occur during the welding. Therefore, hire a skilled welder who knows how to deal with this phenomenon (by tacking).

•Weld the frames of the primary and secondary chambers together.

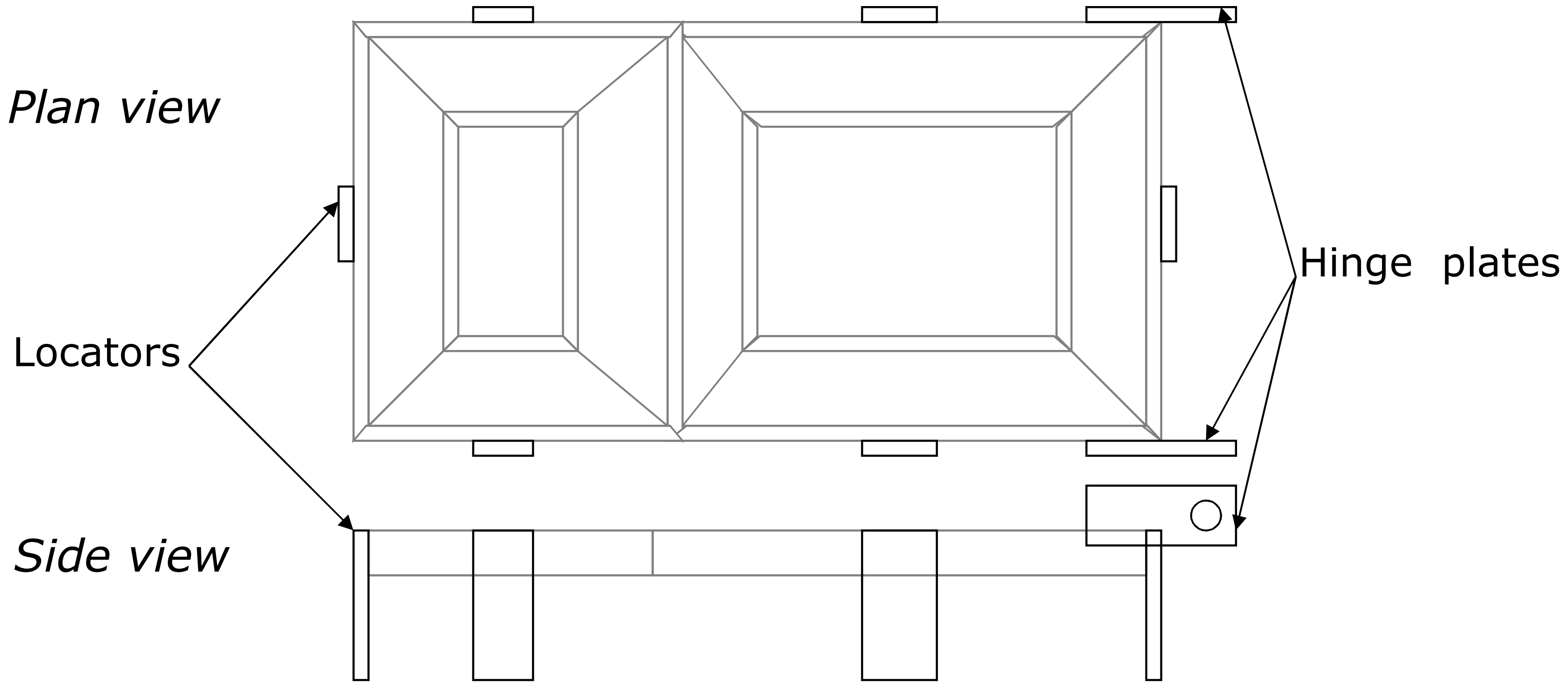


Cross section of U-profile



TOP FRAME

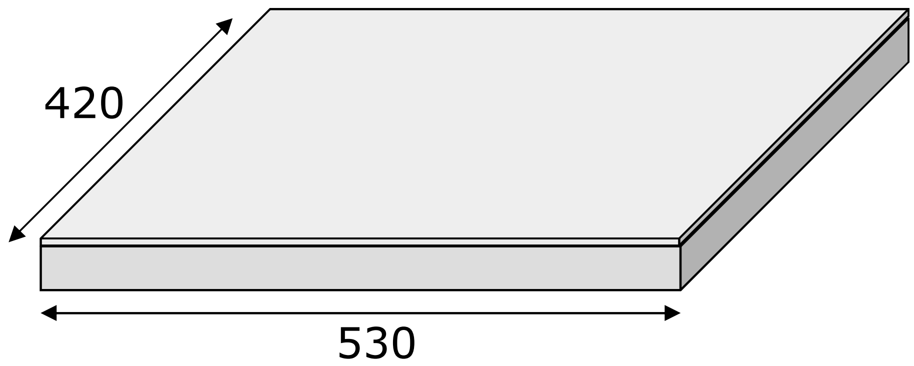
- Cut 8 pieces of flat metal strip (min. 3 mm thick) to a length of 150 mm.
- Remove all sharp edges that could cause injury.
- Weld 6 of them to the centres of the combined top frames (as indicated on the drawing), where they'll function as locators.
- Provide holes to the 2 remaining strips (hinge plates) with a (slightly bigger diameter) as the hinge bar / bolts (Ø 10 mm; see further).
- Weld the 2 hinge plates to the top frame as indicated on the drawing.
- Verify if the top plate fits on the body of the incinerator.

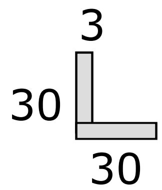


LOADING DOOR

- Cut the metal angles under 45° to the lengths indicated on the drawing.
- Cut a 3 – 5 mm thick metal plate to the size indicated on the drawing.
- Remove all sharp edges that could cause injury.
- Weld the metal angle lengths together with the metal plate to form the loading door.

Underside



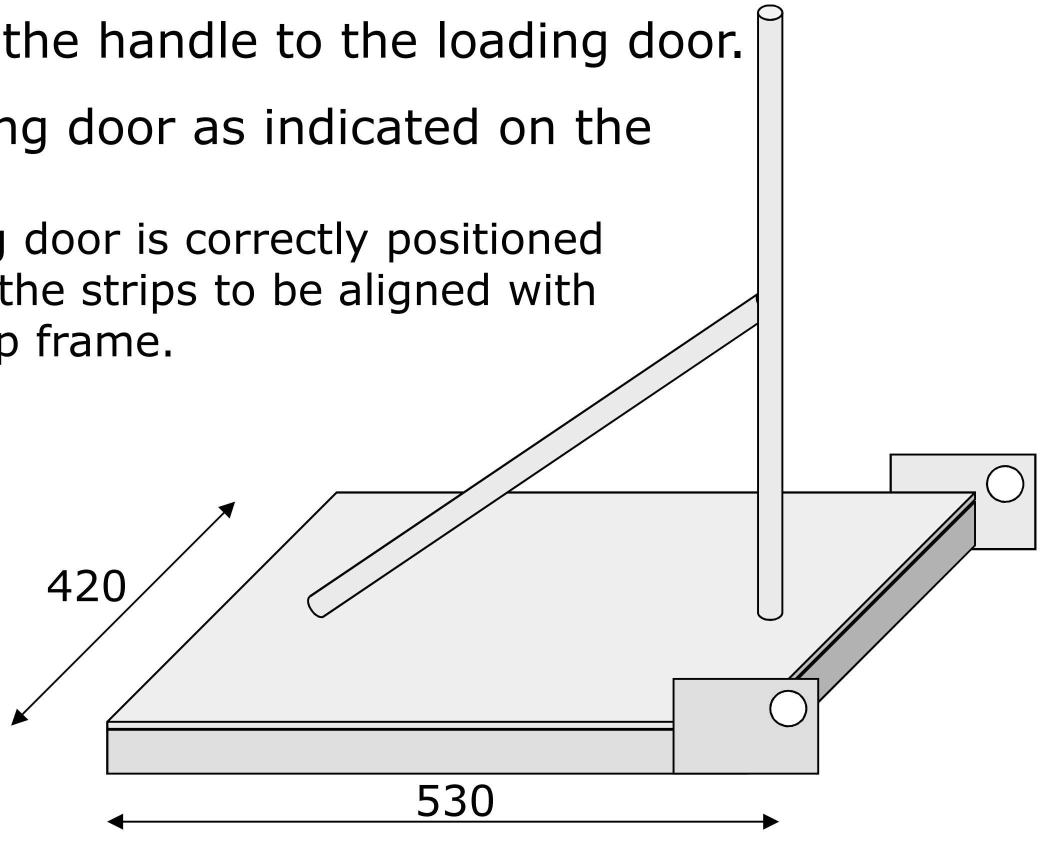


Metal Angle

LOADING DOOR

- Cut 2 pieces of flat metal strip (min. 3 mm thick) to a length of 150 mm.
- Drill holes in the 2 strips with the same diameter as the hinge bar / bolts (Ø 10 mm).
- Cut 2 pieces of metal pipe (at least Ø 15 mm) to the desired length.
- Remove all sharp edges that could cause injury.
- Weld the pipes that will form the handle to the loading door.
- Weld the 2 strips to the loading door as indicated on the drawing.

This is best done when the loading door is correctly positioned on the top frame, for the holes of the strips to be aligned with those of the hinge plates of the top frame.



LOADING DOOR

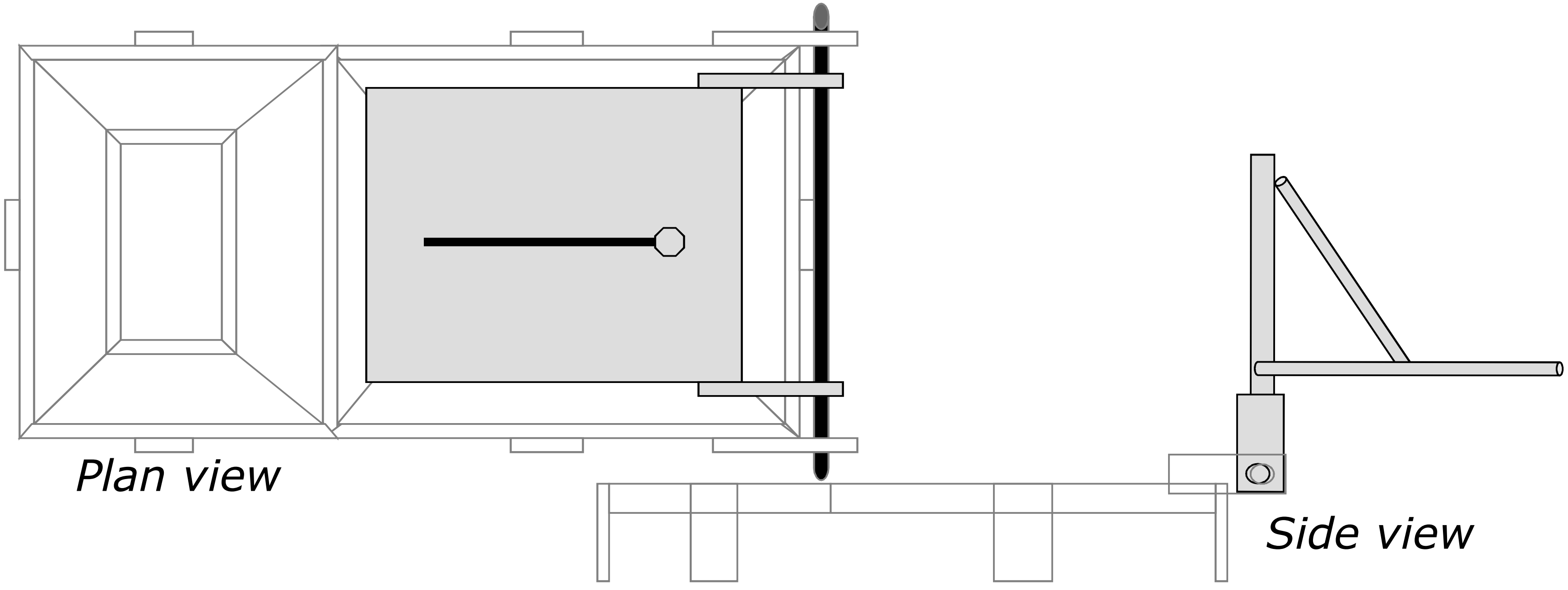
•Cut the metal hinge bar to length and remove all sharp edges.

•Place the loading door on the top frame.

•Slide the metal hinge bar trough the holes of all the hinge plates.

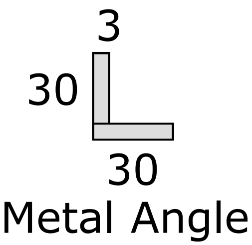
•Weld the hinge bar to the strips of the loading door, and preferably fix this assembly to the top frame.
-To fix the assembly, drill a perpendicular hole in the hinge bar on both its extremities and install on each side a pin.
-In case a hinge bar isn’t available, replace it with big bolts and nuts.

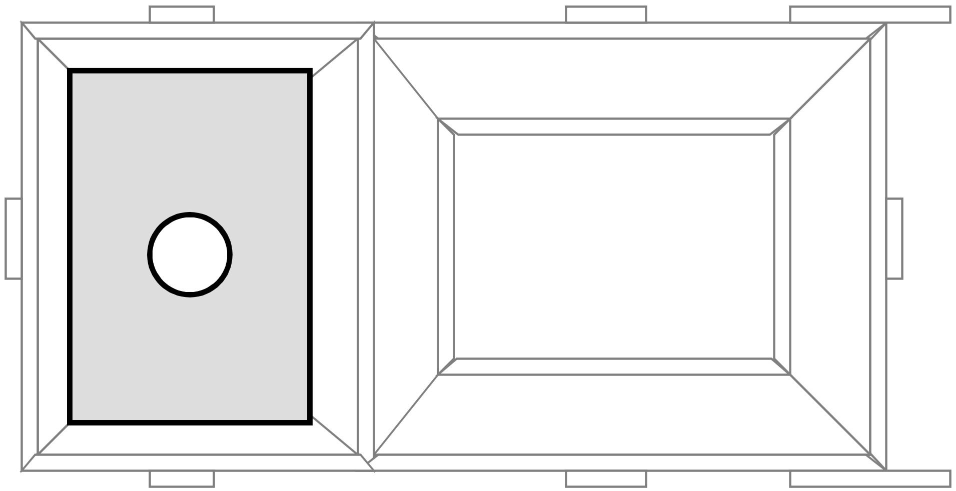
•Verify if the loading door opens easily.
Use grease if necessary and/or un-tighten the nuts if bolts are used.

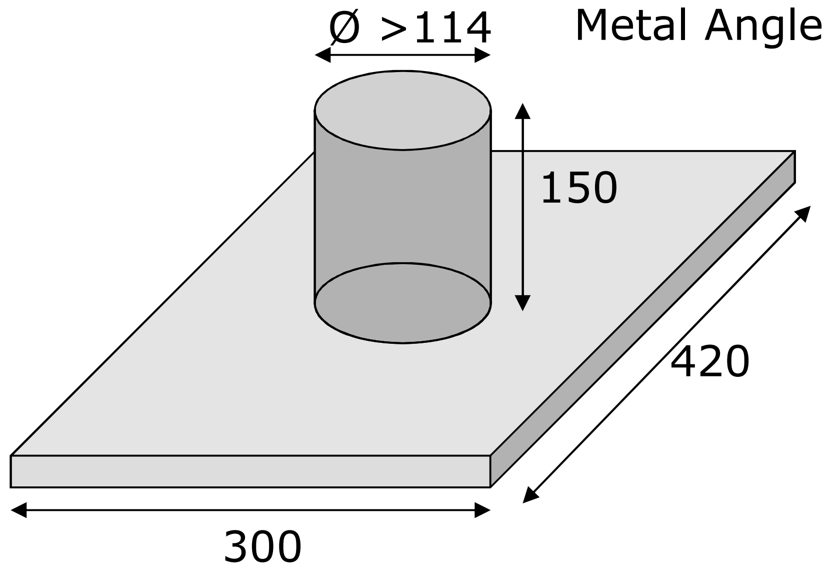


CHIMNEY SPIGOT

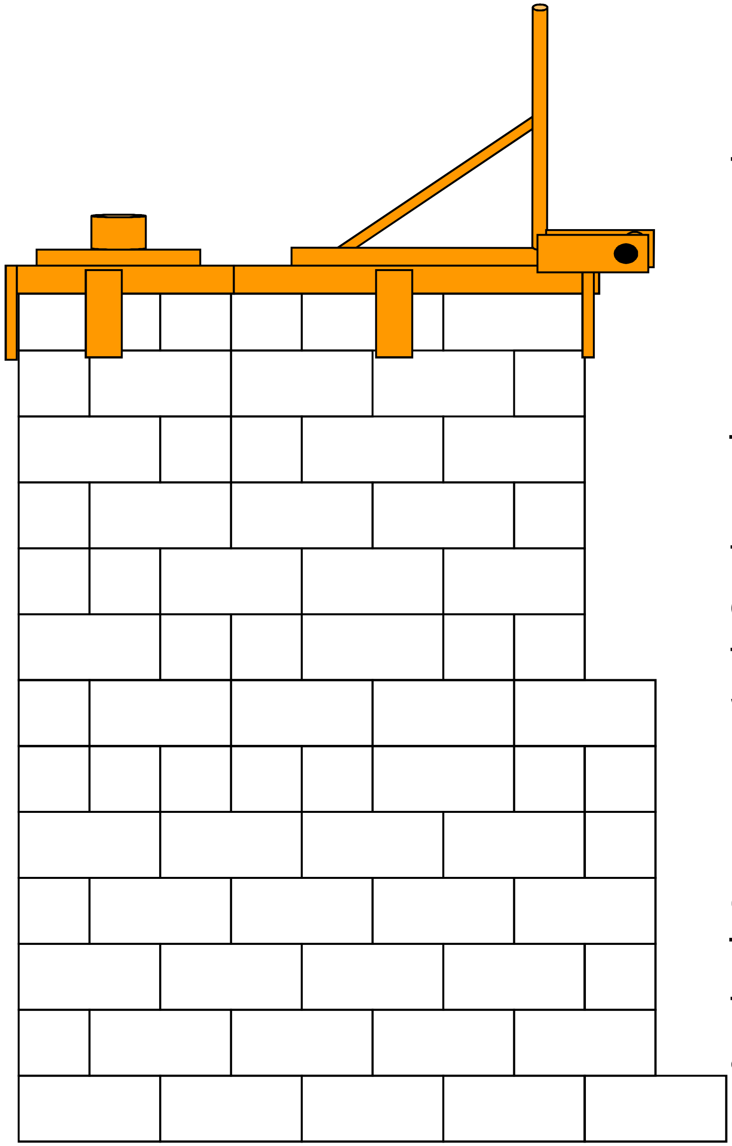
- Cut the metal angles under 45° to the lengths indicated on the drawing.
- Cut a 3 - 5 mm thick metal plate to the size indicated on the drawing.
- Cut the steel pipe (with min. 3 mm thickness) to a length of 150 mm.
- Cut a hole with the inner diameter of the pipe in the centre of the plate.
- Remove all sharp edges that could cause injury.
- Weld the metal angle lengths together, and the metal plate to form the chimney spigot.
- Weld the tube to the chimney spigot in a straight angle.
- Position the chimney spigot on the top frame to verify if it fits.







FITTING THE TOP FRAME



•Paint the top frame assembly with heat-resistant paint to inhibit corrosion.

•Verify once again if the top frame assembly fits on the body of the incinerator.

•Remove the top frame from the body.

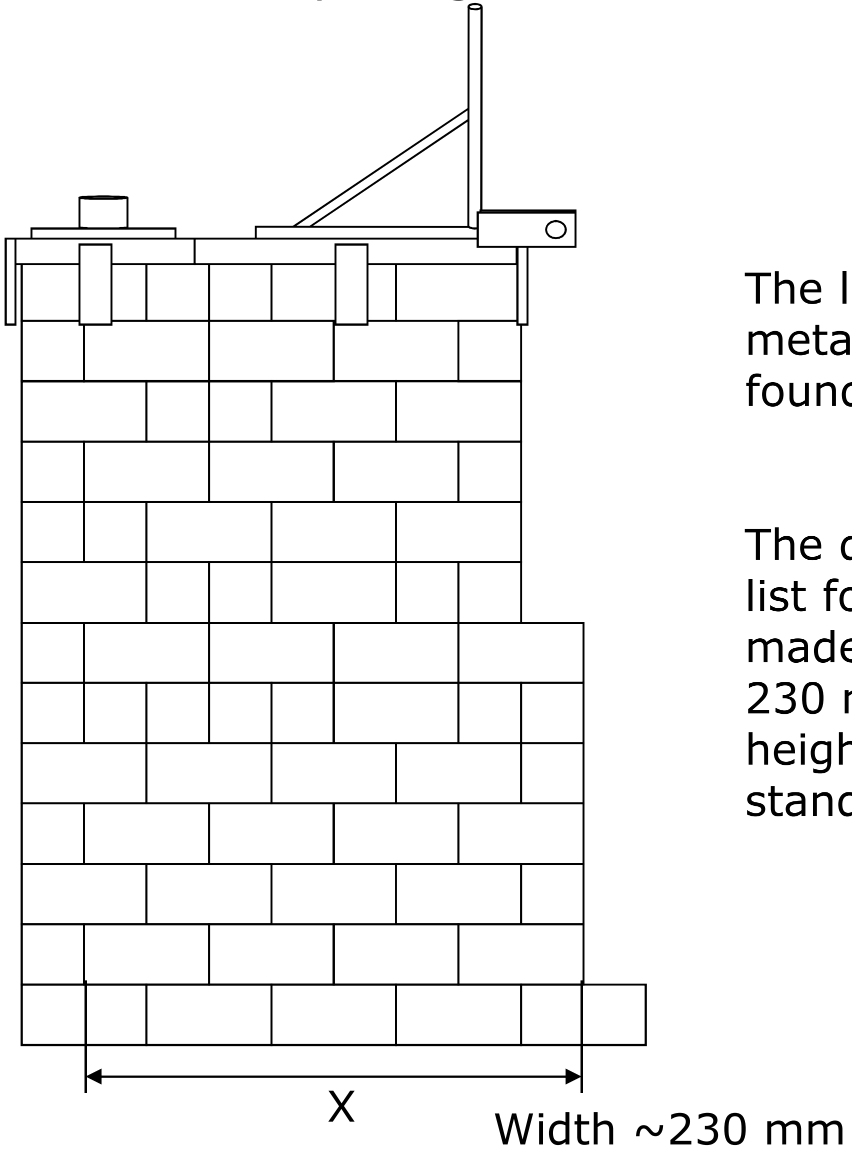
•Smear a layer of (old) engine oil on the bottom of the top frame.
This oil avoids that the top frame will stick to the refractory mortar once installed, which could lead to serious cracks of the refractory mortar and even the refractory bricks due to deformation of the top frame once the incinerator is lit. The oil will disappear gradually when the incinerator will be in use.

•Apply a thin coating of refractory mortar on the top layer of the refractory bricks.
The coating should be just thick enough to close the gaps in between the body of the incinerator and the top frame once installed.

•Install the top frame assembly on the body of the incinerator.

ASH TRAY / DOOR

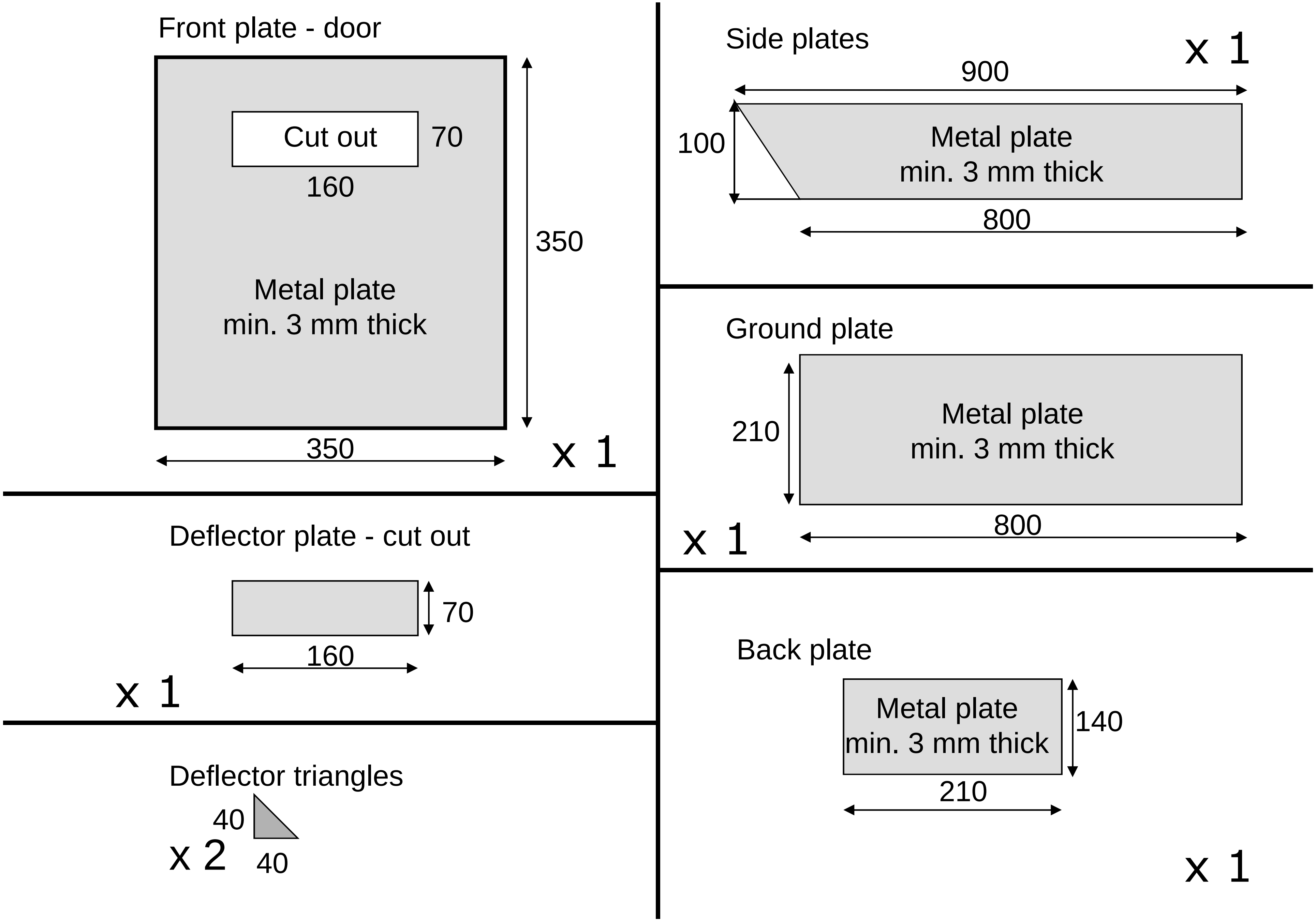
•Measure the total depth of the incinerator (X), the width and the height of the ash opening.



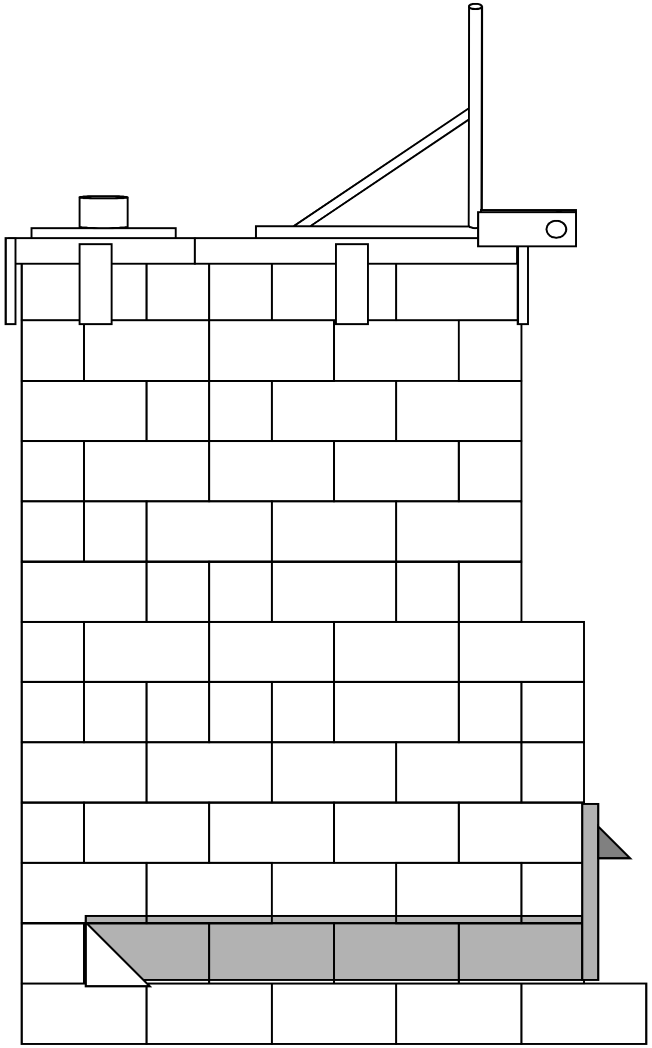
The list concerning the material needed for the metal works of the ashtray / door are to be found on the next page.

The dimensions (in mm) given on the material list for the ash tray / door are for an incinerator made with the standard refractory bricks of 230 mm length x 114 mm width x 74 mm height, and might have to be adapted if non-standardized bricks are used!

ASH TRAY / DOOR



ASH TRAY / DOOR



•Cut the metal plates (min. 3 mm thick) as depicted on the previous page:
- 2 side plates
- 1 ground plate
- 1 back plate
- 1 front plate for the door
- 2 triangular plates for the deflector

The dimensions of the different plates as depicted might have to be adapted if non-standardized refractory bricks are used. The front plate should be at least bigger than the ash removal opening.

•Cut an opening of 160 x 70 mm in the front plate.

This little cut out together with the two little triangular plates will serve as a deflector against potential projections caused by unexpected explosions.

•Remove all sharp edges that could cause injury.

•Weld all the plates together to form the ashtray.

All big plates should be welded perpendicular to each other. The ashtray can be reinforced with metal angles at its corners.

ASHTRAY GRATE

•Cut 8 to 10 metal angles (30 x 30 x 3 mm) with a length equal to the width of the ashtray.

•Cut 2 metal angles (30 x 30 x 3 mm) with a length equal to the upper length of the ashtray.

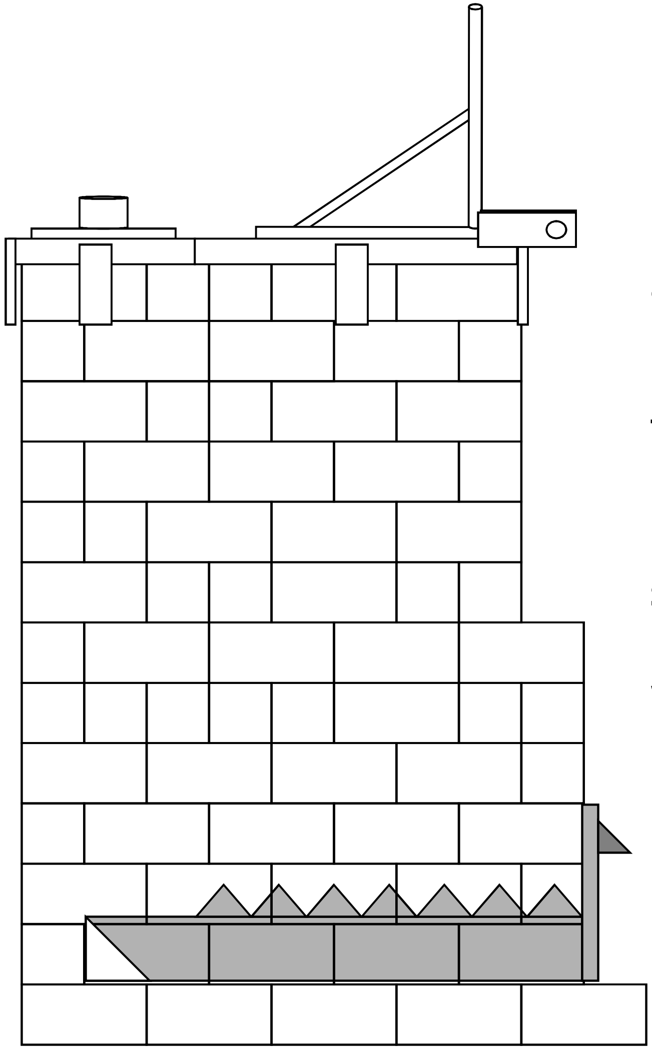
•Remove all sharp edges that could cause injury.

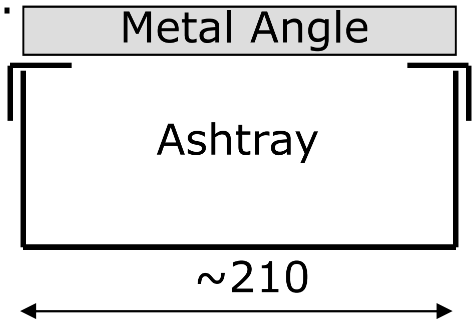
•Lay the long metal angles inverted along the ashtray as indicated on the drawing.

•Weld the short metal angles perpendicular to the long metal angles, spaced out by 20 mm in between two angles as seen on the picture.

-There is no real need for a grate underneath the secondary combustion chamber. -

-To avoid that the grate would fall into the ash pit when being emptied, block the grate on the ashtray by means of little bolts and nuts on both sides, or with a hook.

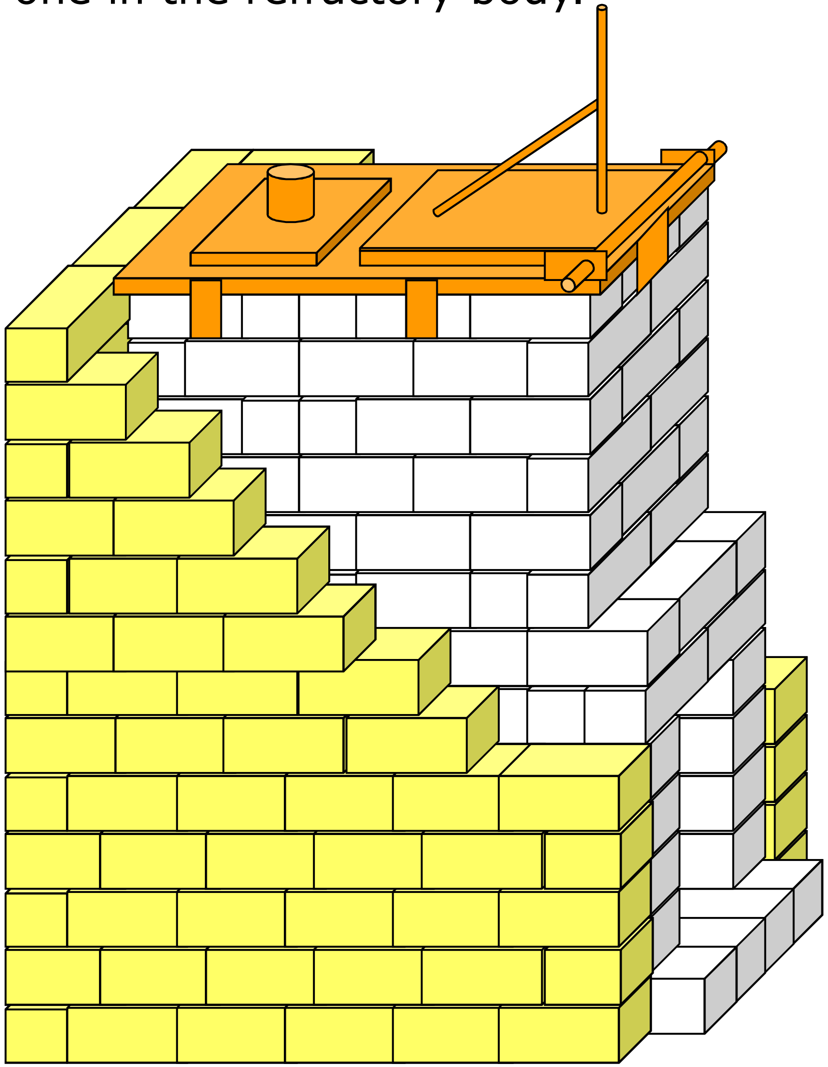


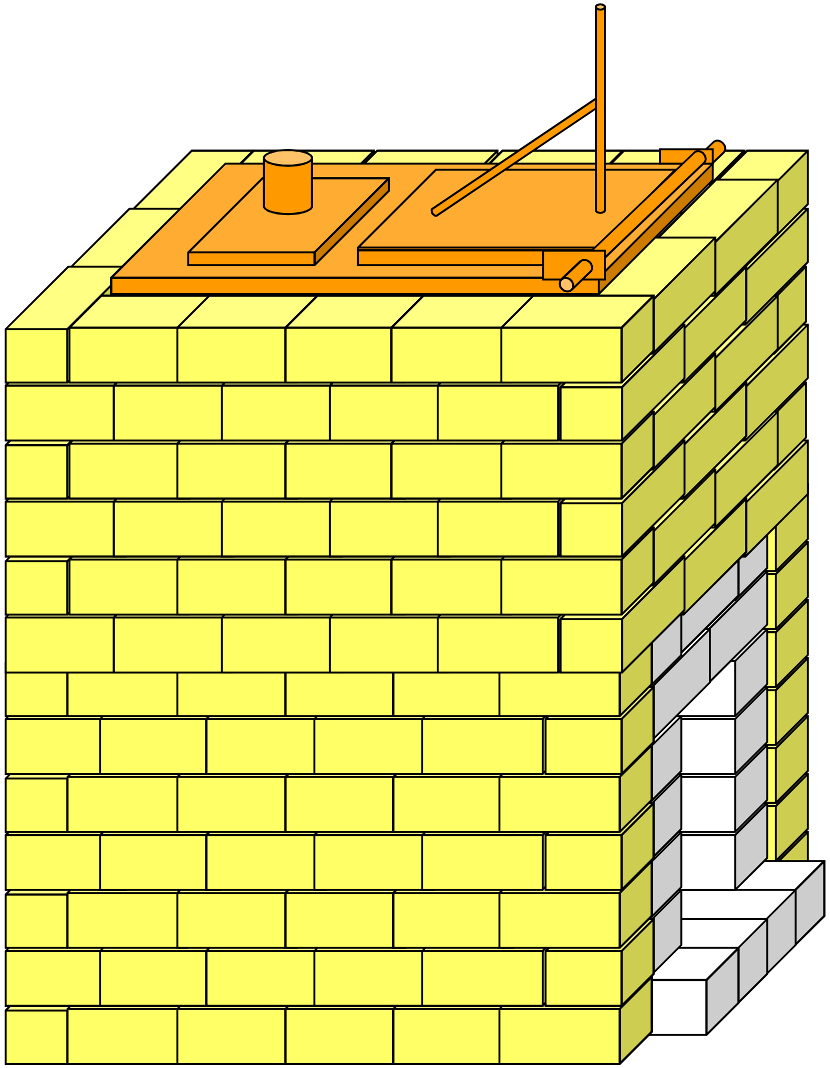


OUTER WALL

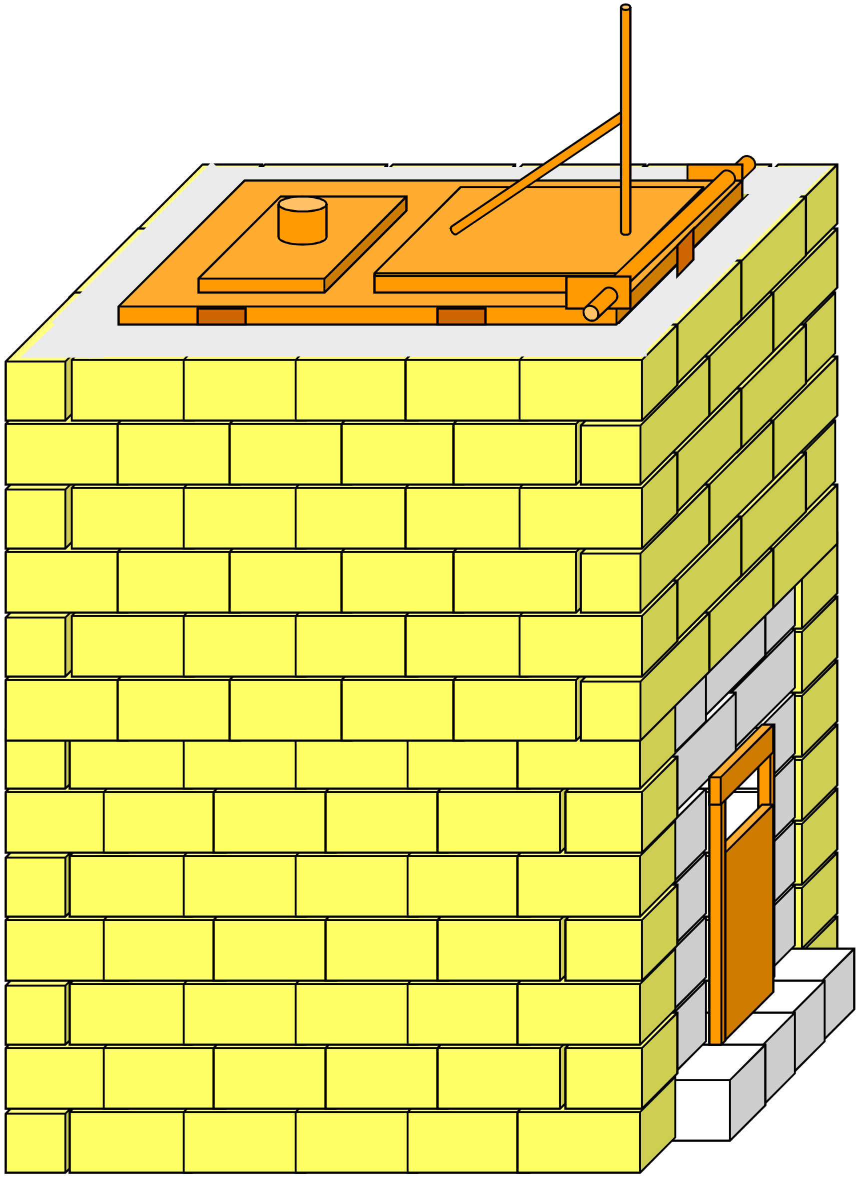
- Build an outer wall around the incinerator's body with normal bricks and (Portland) cement as indicated on the drawings.

The distance in between the body and the outer wall should be about 115 mm (except at the front). Don't forget to foresee a peephole that is aligned with the one in the refractory body.





STABILIZE THE INCINERATOR



•Paint the ash tray / door with heat-resistant paint to inhibit corrosion.

•Mix thoroughly:
1 volume of Lafarge Fondu cement,
3 ½ volumes of Vermiculite N°1,
3 ½ volumes of Vermiculite N°3
and add some water to humidify.
The mixture shouldn’t be liquid, just humid enough to link the Vermiculite together. It’s recommended to make the mixture in different batches.

•Pour each mixture batch in between the body of the incinerator and the outer wall, until the upper edge.
Putting Vermiculite concrete in between the incinerators body and the outer wall solidifies the refractory bricks more, which increases the lifespan of the incinerator. It also improves the isolation. Don’t block the peephole at the back with the Vermiculite concrete however.

•Finish the top layer of Vermiculite concrete with some refractory mortar.

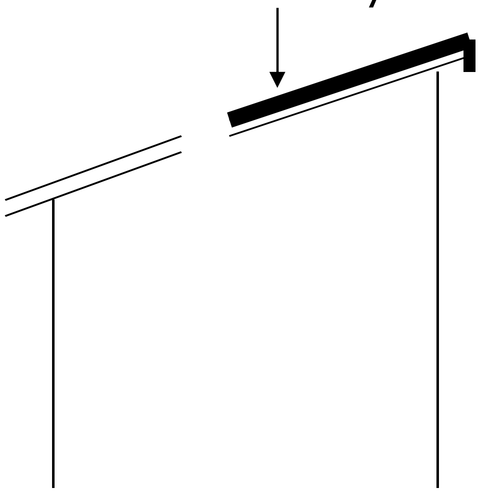
SHELTER

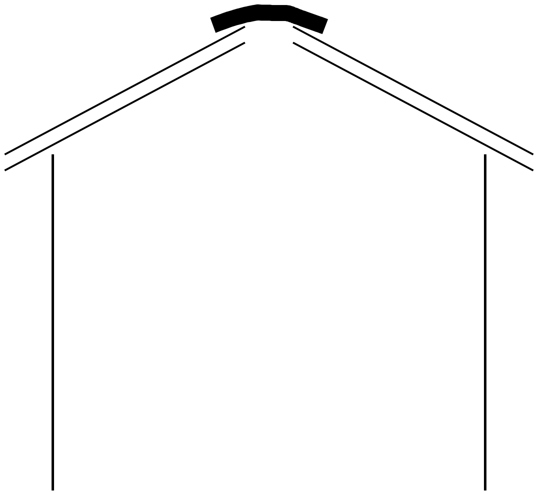
•Construct a real roof over the incinerator and the temporary storage area for the soft waste bins.

-The roof can be single or double sloped, although the former is easier to build and drains rainwater away from the waste zone. Whatever the form, the shelter should be well ventilated.

- Use non-combustible materials, such as iron sheeting and poles. Part of the fence around the waste zone can be used as support for the roof (e.g. honeycombed wall).
- Anchor the vertical poles into concrete for solidity.
- The shelter should be high enough for the operator to be able to walk all around the incinerator without having to duck, and wide enough to avoid rain coming in contact with the incinerator and the soft waste bins, even with heavy side winds.

Plate to divert rain away from the chimney





•Provide a protective plate to divert the rainwater away from the chimney.

Rainwater that flows down the future chimney will enhance its corrosion, certainly at its hottest part.

•Foresee a rainwater collection system on the roof (optional).

The collected rainwater can be used to clean and disinfect the waste bins before being put back into circulation.

SAND SEALS

- Open the loading door and remove the spigot.
- Pour white construction sand in the U-profiles of the top frame as indicated by the drawing.

The sand will function as a seal to avoid gasses escaping via the top frame.

- Close the loading door and replace the spigot.

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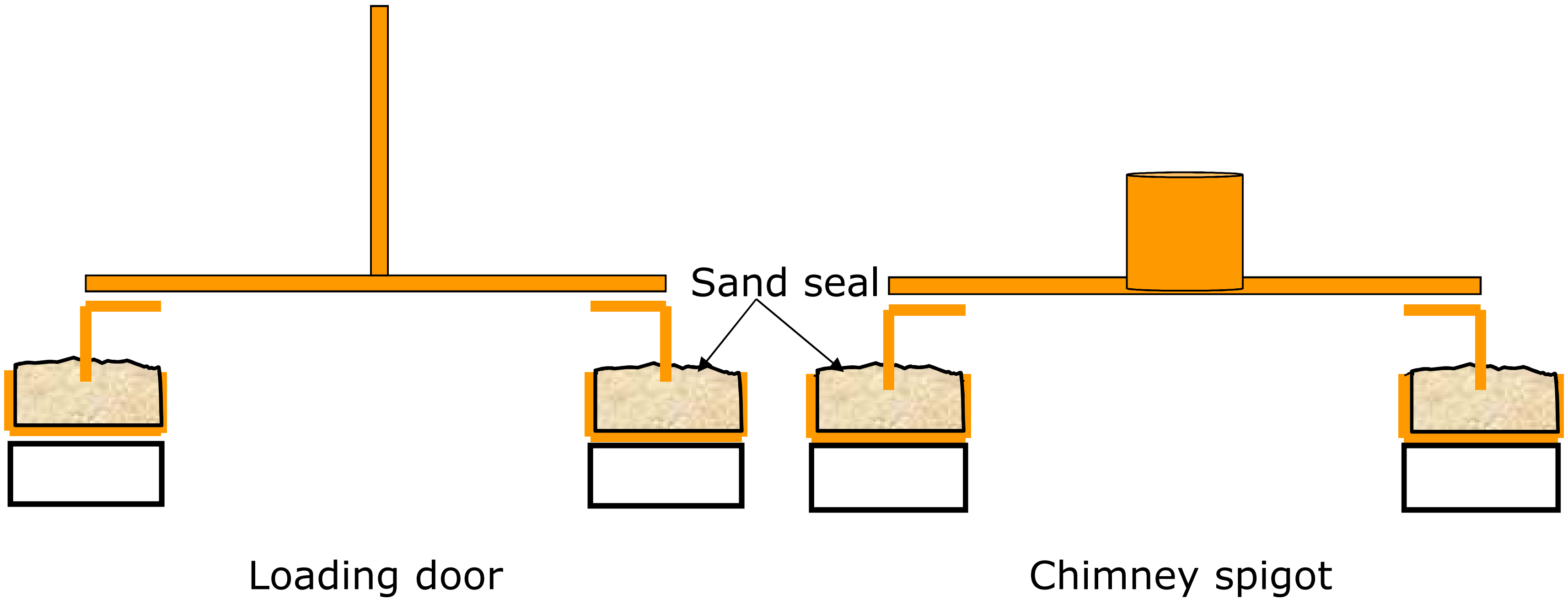
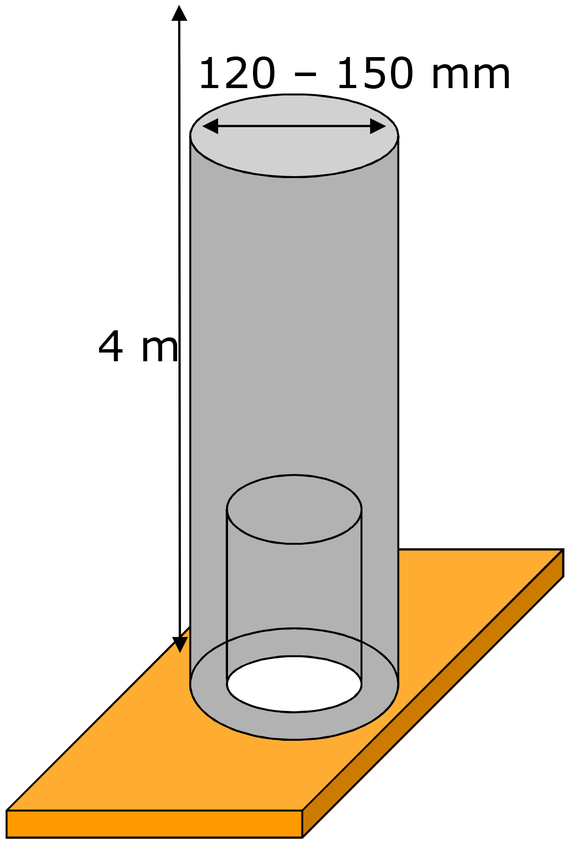


CHIMNEY



•Install a rain cap on the chimney.

•Slide the chimney through the roof and over the spigot without seals.
The chimney should be made of (stainless) steel pipe, at least 2 mm thick and 4 m long (it can be in several parts, preferably welded together).

•Anchor the chimney by means of the roof and/or steel cables.

- *Flexible stainless steel pipe is an alternative, but it needs poles to hold it up.*
- *A seal in between the chimney and the spigot / roof will most often melt or crack when the metal chimney expands due to the heat, thus it isn't recommended.*
- *The chimney is the most vulnerable metal part due to the corrosive gasses that pass through and the high temperatures that will be reached inside. Thus having spare chimney pipes in stock is highly recommended.*
- *The bottom part of the chimney can be protected by a screen to avoid burn injuries.*

Chimney guard for safety

CURING THE INCINERATOR

•Heat up charcoal until it is hot, outside of the incinerator.
In absence of charcoal, normal wood can be burnt as well until hot residues are obtained.

•Transfer the hot charcoal in the incinerator's ashtray.

•Slide the ashtray inside the incinerator to heat it up slowly.

•Remove the ashtray from the incinerator, once the charcoal has cooled down completely.

•Repeat this action several times, depending on the humidity of the incinerator.
Try having the charcoal a little hotter each time, until it is eventually red hot.

▪*The curing of the incinerator is essential. When the incinerator is put in function without this procedure, the humidity (water) inside its refractory bricks and mortar will expand rapidly, leading (rather) quickly to irreparable cracks. The curing procedure will permit the humidity to evaporate slowly, thus reducing the risk of these cracks.*

▪*Curing is always done for high-temperature ovens / incinerators made with refractory bricks. In high-income countries, the slow evaporation is reached by keeping the oven / incinerator during several days at a constant temperature of 150 °C with gas burners. As this might be difficult to implement in low-income countries, the above mentioned procedure is proposed.*

OPERATION OF THE
DE MONTFORT INCINERATOR

WARNING!

Maintain the following rules because they will:

- increase the lifespan of the De Montfort incinerator.
- reduce the risks during use of the De Montfort incinerator.

- Read this chapter completely before operating the De Montfort incinerator.
- Train motivated persons for their specific job, who will most probably be managing all the Medical Waste.
- Provide the operators with Personal Protective Equipment:
  - Overall (or long sleeve shirt and working trousers)
  - Leather apron (if available)
  - (Multipurpose) heavy-duty gloves (preferably heat, cut & chemical resistant, waterproof)
  - Safety boots
  - Respirator (preferably FFP2 / N95; or at least dust mask)
  - Face shield (or goggles)

  If this equipment can't be found locally, be aware that a Personal Protective Equipment module can be ordered from MSF.
- Follow the operation instructions precisely.

Step 1	
Open the residues (ash) pit.	
Step 2	
Remove the ashtray from the incinerator. Make sure the residues have cooled down enough to avoid injuries and not to damage the cleaning equipment.	

Step 3	
Empty the ashtray in the residues pit.	
Step 4	
Wipe the remaining ashes off the ashtray into the residues pit by means of a small brush.	

Step 5	
Clean the lower inner part of the incinerator by means of a brush and a dustpan.	
Step 6	
Empty the dustpan in the residues pit.	

Step 7

Close the residues pit.

Step 8

Put the ashtray back in the incinerator.

Don’t slide the ashtray completely to the back yet, as the fire will be lit via the ashtray opening.

Step 9

Open the loading door of the incinerator.

Step 10

Choose a waste bin with plenty of paper and cardboard (e.g. from the administration), and pour some via the loading door into the incinerator.

Load maximum up to half the height of the combustion chamber, without compacting.

Step 11

Add some dry firewood on top of the paper and cardboard.

The wood sticks should have a diameter of maximum 2 – 3 cm, and not be longer than the loading opening of the incinerator. Make sure the wood is really dry. Dried coconut shells or wood shavings can be used as well.

Step 12

Close the loading door.

It is recommended to make it a habit to always stand aside the air inlet, which is integrated within the ashtray door (see further).

Step 13

Light the paper and/or cardboard via the ashtray opening, and let the fire take.

Step 14

Close the ashtray door completely once the fire has taken off well.

Step 15

Verify after a while via the little peephole at the back of the incinerator if flames start to develop in the secondary combustion chamber.

This may take some minutes.

Step 16

Prepare for loading (soft) waste when high flames are visible in the secondary combustion chamber.

In case the fire in the primary combustion chamber starts to die out without having flames in the secondary combustion chamber, more dry firewood (or dried coconut shells / wood shavings) will have to be added.

Step 17

Open the loading door.

Always stand to the side of the incinerator and behind its loading door when the latter is opened. With the ongoing fire, a big flame might shoot out of the primary combustion chamber just after the loading door has been opened.

Step 18

Fill the incinerator via the loading door with (soft) waste or more dry firewood / coconut shells / wood shavings.

The additional combustibles are only necessary if no flames are visible in the secondary combustion chamber.

Step 19

Close the loading door immediately once the filling is completed in order to avoid that too much heat is lost.

Always stand to the side of the incinerator when closing the loading door as a flame might shoot out of the air intake at the bottom of the incinerator (integrated within the ashtray door). This is a risk when the loading door is closed too quickly.

Step 20

Verify shortly after via the little peephole at the back of the incinerator if flames are still visible in the secondary combustion chamber. If not, add plenty of dry wood.

High quantities of wet (soft) waste reduce the combustion temperature a lot (potential sizzling noise), thus the fire in the 2ndary chamber can't be sustained.

Step 21

Keep on repeating the filling procedure on a very regular basis until all the (soft) waste has been incinerated.

(steps 17 till 20).

Experience will learn when new batches of (soft) waste will have to be added. But be aware that once the incinerator is working properly, the combustion process goes very fast.

Step 22

Push the waste that has fallen beside the loading opening into the incinerator by means of a metal stick or a solid brush, after having added the last batch of (soft) waste.

Step 23

Close the loading door and let the last batch burn until the fire dies out naturally.

No extra attention should be given to the last batch, except when the fire would die out immediately due to a too high humidity content of the waste. If this is the case, additional combustibles should be added.

The ashes should only be removed after they have cooled down completely, so at the next incineration cycle (e.g. the next day).

Remarks:

- Be careful not to injure yourself by burns, cuts caused by exploding vials or ampoules, or needle stick injuries (all sharps which could accidentally have slipped into the soft waste). So always wear your protective equipment during incineration: overall with long legs and sleeves, heavy duty gloves, safety boots, respirator and face shield / goggles, leather apron if available.
- The removal of the (ash) residues before starting a new incineration cycle is important because they may hinder a good combustion (e.g. due to blockages of the air flow).
- The recommended additional combustibles (for preheating) are dry fire wood or dried coconut shells, because their glowing residues in the ashtray help to maintain a temperature buffer when the incinerator is opened to add a new batch of waste. Kerosene and (natural) gas have a higher heating value, but as they don’t leave glowing residues behind, they don’t have the temperature buffer effect. On top of that, special safety and operator’s measures will be required. Contact your technical referent for more information.
- A good combustion, which makes a roaring noice, will consume the soft waste very fast. Therefore, it is important to stay beside the incinerator to keep on charging new batches of (soft) waste. Once the last batch of soft waste has been added into the incinerator and a good fire is noticed as well in the primary as in the secondary combustion chambers, no particular actions have to be done anymore. This is because the fire will die out eventually once all combustible material has been incinerated.
- Once a waste bin is emptied, it can be moved towards the washing area of the waste zone for cleaning and disinfection!
- Hands should be washed with water and soap after the intervention.

ANNEXES

- Pyrometric Cone Equivalent (P.C.E.) table

- Kit De Montfort 8a

  In case that some or most of the building materials would be difficult or even impossible to find locally, or being of inferior quality, Médecins Sans Frontières proposes 4 construction modules that can be ordered separately as modules or all together as a complete kit.

  - Module 1: Refractory material
  - Module 2: Insulating stabilizer
  - Module 3: Metal works
  - Module 4: Chimney

PYROMETRIC CONE EQUIVALENT (P.C.E.) TABLE

N° of cone	T° limit °C	N° of cone	T° limit °C	N° of cone	T° limit °C
15	1435	26	1595	32 ½	1720
16	1465	27	1605	33	1745
17	1475	28	1615	34	1760
18	1490	29	1640	35	1785
19	1520	30	1650	36	1810
20	1530	31	1680	37	1820
23	1580	32	1700	38	1835

Example: a refractory brick with a PCE of 31 can be used until 1680 °C

MODULE 1: REFRACTORY MATERIAL

Building materials	Use	Quantity
Refractory bricks – with 60% Al_2O_3 and high density	Main structure (body) of the incinerator	168 pcs including 8 reserve bricks (packed on pallets of 42 pcs).
Refractory cement premix - Surebond 50 DAE	To be used as mortar for the refractory bricks	2 bags of 25 kg each.
Construction tools	To cut & position the refractory bricks	1 flat chisel 1 heavy hammer 1 soft hammer

The refractory materials are the most important components of the incinerator as they will determine its effectiveness and even more its lifespan. Therefore, enough attention should go to the purchase of these materials.

However, knowing that the refractory bricks are the most expensive and heavy components to build a De Montfort 8a, there is a tendency to purchase these items locally. It would be appreciated if information concerning the manufacturers and/or suppliers in low-income countries would be send to Médecins Sans Frontières, together with the composition of their refractory bricks, their P.C.E. and their density. This will allow MSF to extend the existing list of potential manufacturers and suppliers worldwide.

[redacted]

LY 60

Chemical analysis

	Al_2O_3	TiO_2	SiO_2	Fe_2O_3	K_2O	$Na_2O + CaO$
Value (%)	60	1,8	35	1,8	1,5	Trace
Standard deviation	2	0,2	3	0,2	0,1	

Physical properties

	Unit	Typical	Min value	Max value
Bulk density	g/cm³	2,55	2,5	2,6
Apparent porosity	%	19	18	20
Cold crushing strengh	N/mm²	60	45	70

Dimensional Tolerance

1% on thickness and height
Max 2 mm on length

Technical datas obtained by analysis on standard products
some low variations could appear on special shaped products

Téléphone-Administration/Direction : (065) 62 03 71 Usine : (065) 62 00 52 FAX : (065) 62 09 63
R.C.Mons 95219/95262/134378 TVA BE 624.519.256 GB 270-0375599-68 BBL 370-0108200-35

Surebond 50DAE

Product Information Sheet

Monolithic Refractory

An airset mortar supplied dry and used for laying firebrick where a strong bond is required over a wide range of temperature.

Service Temperature:	1650 °C	**Material Required:**	-
Typical Water Required:	23 %	**Maximum Grain Size:**	0.5 mm
Particle Size, -75 µm:	95 %	**Mortar required per 1000 Standard Bricks:**	250 kg

Chemical Analysis

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	$Na_2O + K_2O$	
38.4	1.9	53.3	2.1	0.7	0.6	2.7	

Typical Physical Properties

Tested in accordance with International and European Standards

Prefired to	Bulk Density	Cold Crushing Strength	Cold Modulus of Rupture	Permanent Linear Change
(°C)	(kg/m³)	(N/mm²)	(N/mm²)	(%)

Other Physical Properties

Tested in accordance with International and European Standards

Prefired to	Apparent Porosity	Thermal Conductivity	Hot Modulus of Rupture	Permanent Volume Change
(°C)	(%)	(W/m.K)	(N/mm²)	(%)

Formerly: Maksiccar 2; Aludrite 50

Product Number:	LEX10076 MX1E MOR	Revision :	E:00	MSDS Reference :	LEX10076
Drying & Firing :	N/A	Pumping :	N/A	Mixing / Installation :	N/A
Shotcreting :	N/A			Effective Date:	11/05/2006

VESUVIUS

MODULE 2: INSULATING STABILIZER

Building materials	**Use**	**Quantity**
Vermiculite (granularity n° 1)	To be mixed with Lafarge Fondu cement to obtain an insolating concrete	3 bags of 10 kg (100 l) each.
Vermiculite (granularity n° 3)	To be mixed with Lafarge Fondu cement to obtain an insolating concrete	3 bags of 10 kg (100 l) each.
Lafarge Fondu cement	To be mixed with Vermiculite to obtain an insolating concrete	4 bags of 25 kg each.

Although optional, this module is highly recommended as it helps stabilizing the refractory bricks and thus increases the lifespan of the incinerator. It also contributes to a better insulation of the incinerator, resulting in less heat loss.

Be careful with local purchase as some brands of Vermiculite might be contaminated with asbestos!

FICHE TECHNIQUE

DATE : 04/10/2003 **PRODUIT : VERMICULITE EXFOLIEE**

Vermiculite est le nom usuel d'un minéral hydrobiotite formé de lamelles de mica.
Il s'agit d'un silicate de magnésie et d'alumine.

Composition chimique :	SiO_2 : 39%	Fe_2O_3 : 8%
	Al_2O_3 : 11%	TiO_2 : 1%
	MgO : 25%	H_2O : 10%
	CaO : 3%	
	K_2O : 3%	

Imputrescible et stérile. Ph : +/- 7,5

Propriétés physiques :

- forme : accordéon
- densité : 0,085 à 0,115
- volume air : 93 %
- rétention en eau : 35 % volume
- conductivité thermique faible : 0,053
- combustibilité nulle

Granulométries disponibles :

Micron	0,0 à 1,0 mm	grade 0
Super Fine	0,2 à 1,5 mm	grade 1
Fine	0,5 à 2,5 mm	grade 2
Medium	1,0 à 5,0 mm	grade 3
Large	1,5 à 15,0 mm	grade 5

Conditionnements . Sacs plastique 100 litres / 33 sacs par palettes

Ciment Fondu Lafarge®

Fiche de Données de Sécurité

Référence SDS-110-FR 25/06/2002

1 Identification des produits et de la Société

• Nom du produit

Ciment Fondu Lafarge®

• Nom du Fournisseur

Lafarge Aluminates
28, Rue Emile Ménier
F-75782 Paris Cedex 16 ; FRANCE
Tél. +33 (0) 1 53 70 37 00
Fax +33 (0) 1 45 53 58 67

2 Composition / information sur les composants

• Nature Chimique

Substance obtenue à partir d'un clinker d'aluminates de calcium (plusieurs composés chimiques confinés dans une masse cristalline). Les éléments chimiques principaux sont Al_2O_3, CaO, SiO_2, Fe_2O_3. Ils apparaissent principalement dans les composés minéralogiques suivants :

- $CaO \cdot Al_2O_3$	- $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$
- $12CaO \cdot 7Al_2O_3$	- $2CaO \cdot SiO_2$

• Numéro CAS

(Chemical Abstracts Service)

Aluminates de calcium : 65997-16-2

• Numéro EINECS

(European Inventory of Existing Commercial Chemical Substances)

Aluminates de calcium : 266-045-5

• Composants contribuant aux dangers

Déclaration et classification des composants selon les Directives de la Commission de la Communauté Européenne 91/155/CEE et 93/21/CEE :

	Classification	Etiquetage
Aluminates de calcium	Aucune	Aucun

Ne contient pas de chaux libre ou de silice cristalline (tels que quartz, tridymite ou cristobalite) en quantité détectable.

3 Identification des dangers

• Principaux dangers

En présence d'eau, on obtient une solution alcaline (pH 11-11,5). Malgré le niveau de pH, l'alcalinité est limitée et le produit n'a pas été classifié comme un *irritant* selon les critères définis par les directives européennes (93/21/CEE).

En atmosphère confinée, la poussière peut devenir un problème. Elle est considérée comme poussière nuisible sans aucun effet spécifique connu sur la santé.

• Risques spécifiques

Les Aluminates de Calcium réagissent chimiquement et durcissent en présence d'eau. Cette réaction est exothermique ce qui entraîne une augmentation de la température. Lorsque la réaction

MODULE 3: METAL WORKS

Building materials	Use	Quantity
Top frame (U – profiles) with locator plates	To be mounted on the incinerator body, which is made of refractory bricks	1 complete double frame, covering the primary and secondary combustion chambers
Loading door with handle and hinge plates Hinge bar	Loading door mounted on the top frame and connected via the hinge bar	1 complete loading door (530 mm x 420 mm) 1 hinge bar
Chimney spigot	Mounted on the top frame	1 chimney spigot (420 mm x 300 mm)
Ashtray / door Ash grate	To slide through the ash removal opening To be installed on the ashtray	1 ashtray 1 ash grate

MODULE 4: CHIMNEY

Building materials	Use	Quantity
Chimney pipe	At least 4 overlapping pipes for the chimney	6 steel pipes (potentially 2 to be used as reserve); 1m length, 2 mm thickness, internal diam:150 mm
Chimney rain cap	Covering the top opening of the chimney	1 rain cap

The chimney should be cleaned regularly, preferably once every trimester. This is a good opportunity the check the condition of the chimney and replace parts if needed.

Due to the high temperatures that can be reached at the bottom part of the chimney and the aggressive gasses that pass through, it sustains a lot of corrosion. Hence, the chimney is the most vulnerable part of the incinerator.

For long-term use, it is highly recommended to have this module as a spare in stock, and to hand it over when the agency pulls out.

FURTHER READING

Durand M-C.
Incineration
Médecins Sans Frontières-Belgium, 1998

Lermusiaux F.
Matériaux Réfractaires
Médecins Sans Frontières-Belgium, 2001

Van Den Noortgate J.
Hazardous Waste Management in Health Structures of Low-Income Countries
Médecins Sans Frontières, 2012 (3rd edition)

Van Den Noortgate J. & Maes P.
Public Health Engineering in Precarious Situations (Chapter 6)
Médecins Sans Frontières, 2010

Van Den Noortgate J.
Safety Box Reducer: Construction & Operation Manual
Médecins Sans Frontières, 2012 (3rd edition)

Van Den Noortgate J.
Waste Zone Operators Manual
Médecins Sans Frontières, 2012 (3rd edition)