MACRO*burn*

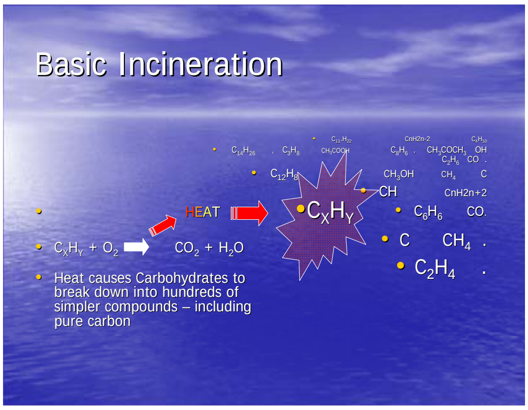
The Finest Incinerators in the World

EMISSION CONTROL SYSTEM

Potential obnoxious emissions from incinerator chimneys can be divided into three main groups:

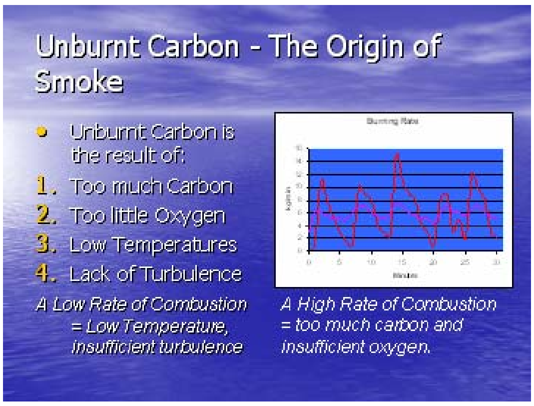
1. CARBONACEOUS MATTER

Includes hydrocarbons (many are malodorous and/or acidic), carbon monoxide and pure carbon. Very fine particles of carbon constitute black smoke. Carbonaceous pollutants can be eliminated by complete combustion. Combustion breaks down hydrocarbons into harmless carbon dioxide and water.



Requirements for complete combustion are :

i) **Oxygen** (air). Insufficient oxygen results in unburnt carbon (smoke) and malodorous hydrocarbons. If the waste burns too fast, there will be insufficient oxygen. Carbonaceous emissions due to a shortage of oxygen can be eliminated, if the **Rate of Combustion** (burning rate) is kept under control



ii) **Time** Combustion is a chemical reaction (oxidisation) requiring time for completion. Large combustion chambers retain the gases for sufficient time. If the waste burns too fast the gases (the volatiles) are pushed through too quickly. Control of the **Rate of Combustion** prevents this.

iii) **Turbulence**. Air, volatiles and heat must be thoroughly mixed. The flame port, mixing chamber and heated refractory screens are designed to produce turbulence. Optimum mixing is dependant on gas velocities, not obtained if the velocities are too high or too low. Control of the **Rate of Combustion** ensures correct gas velocities and optimum mixing.

iv) **Temperature**. High temperatures are needed in the secondary chambers to burn the carbon and hydrocarbons. Conversely, reduced temperatures are essential in the primary chamber and on the hearth to reduce and to trap the chemically formed compounds (see below) and to inhibit the rate of volatilisation (burning rate). Temperatures have a direct effect on the **Rate of Combustion** and the **Rate of Combustion** has a direct effect on the temperatures.

2. ENTRAINED ASH

Fine particles or flakes of incombustible material usually light in colour, are entrained in gas stream. Visible flakes are called fly ash. Fine dust is called white smoke. They cannot be eliminated by combustion.

Entrainment is reduced by controlling the volume and speed of volatiles leaving the fire bed. Entrained dust is removed from the gas stream in very large tertiary (settling) chambers, which also benefit from control of the speed and volume of the volatiles. The speed and volume of the volatiles is controlled by the **Rate of Combustion**.

3. CHEMICALLY FORMED COMPOUNDS

Obnoxious, incombustible vapours and gases are sometimes liberated or formed. Many are completely invisible. Others condense to a visible plume on leaving the chimney. They cannot be completely eliminated by combustion. However, in most cases, the formation or liberation can be reduced by optimising combustion conditions.

The most common chemically formed emissions are:

i) **NOx** formed at very high flame temperatures. Such high temperatures are prevented by control of the **Rate of Combustion**

ii) **Halogens** include chlorine, fluorine, bromine and iodine. PVC and PTFE plastics are common sources of halogen. Fortunately, these are NOT the most common form of plastic. Many plastics, called "PVC" by the man in the street, are not halogenated. Ashes produced by wastes such as wood, paper and bones contain basic oxides. These oxides combine readily with halogens to form salts (chlorides, bromides etc). The salts are trapped in the ash. This process is most effective with a controlled **Rate of Combustion**

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iii) Dioxins and Furans. The incomplete break down of complex hydrocarbons can result in the production of benzene C_6H_6.

A pair of benzene atoms may be linked by a single oxygen atom to form a FURAN or by a pair of oxygen atoms to form a DIOXIN.

Hydrogen atoms occupy the free corners of the dioxin and furan molecules. The positions occupied by the hydrogen atoms are numbered as shown in the illustration at right Halogens, chlorine and fluorine, can displace any one, or more of the hydrogen atoms.

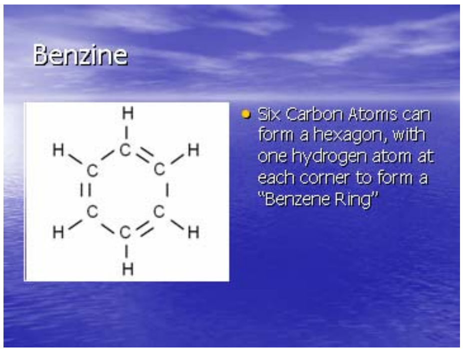
Any dioxin that has either **Chlorine or Fluorine** in positions **2, 3, 7 and 8** is **POTENTIALLY CYTOTOXIC**. In large doses it may cause cancer in human beings.

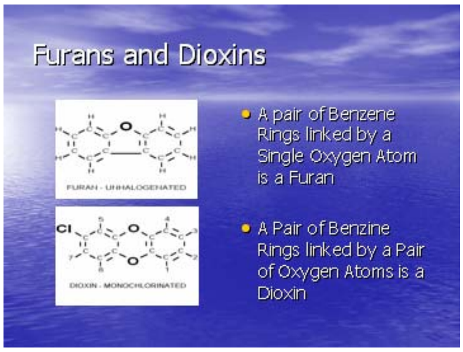
If any one, or more of the above four positions is **NOT occupied by a halogen**, the dioxin is **NOT CYTOTOXIC.**

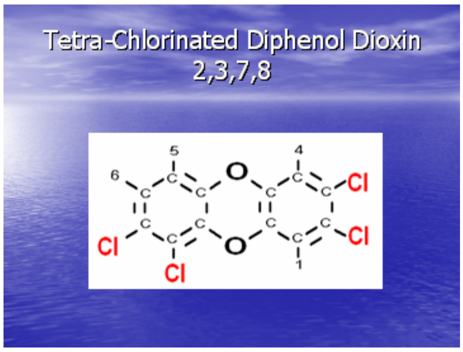
iv) Sulphur burns to form SOx. SOx is neutralized by the same process that neutralizes the halogens. Typical domestic and hospital wastes and fuels have relatively low sulphur contents so sulphur emissions from incinerators rarely cause concern.

v) Heavy Metals Small amounts of lead, silver, chrome and cadmium may be oxidised and entrained. Oxidisation is drastically reduced or completely eliminated by controlled temperature and control of the **Rate of Combustion.**

Mercury and chlorine react violently – so rapidly as to be almost explosive. Mercury-chloride salt is formed before the chlorine is neutralized. It is trapped in the ash from the incinerator and from the filter. This salt is insoluble in water and in weak acids. It can be safely deposited in a municipal tip with risk of contaminating ground water.







Cytotoxic dioxins and furans are not equally toxic. Furans are all significantly less toxic than dioxins – (about half). Dioxins with four chlorines atoms in positions 2, 3, 7, 8 are the most toxic. They are called 2378 tetra-chlorinated biphenol dioxin. Dioxins with more than four halogens are progressively less toxic as the number of halogens increases.- Octa-chlorinated dioxins have positions 2, 3, 7, and 8 occupied by halogens but they are only 0.001 times as toxic as 2378 tetra-chlorinated dioxin.

The Toxicity of a Dioxin, expressed as a decimal fraction of the toxicity of 2378 TCDD is called the TEF (Toxicity Equivalent Factor). The Mass of a dioxin present multiplied by the TEF is the TEQ (Toxicity Equivalent Quotient. The TEQ is used to specify the amount of dioxin emitted from a chimney.

DIOXIN	TEF
MONO, DI, TRI – CDD	0
2,3,7,8 Tetra CDD	1
Other Tetra CDD's	0
2,3,7,8 Penta CDD's	0.5
2,3,7,8 Hexa CDD's	0.1
2,3,7,8,Hepta CDD's	0.01
The only Octa CDD	0.001

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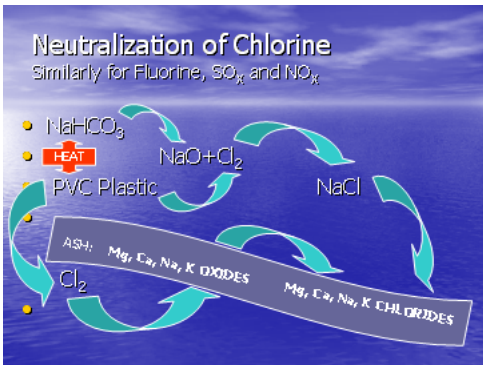
THE MACROburn ANSWERS TO EMISSIONS

MACROBURN INCINERATORS use multiple techniques for the elimination of dioxins and furans. Paragraph ii) on page 1 has already described how some halogens are trapped in the ash.



Further reduction of halogens is achieved by the addition of a neutralizing agent (NaHCO3 or CaO). MACROtech have developed a system that makes the neutralizing agent effective as soon as the waste enters the primary chamber. This ensures that most of the halogen is neutralized BEFORE it has time to form dioxin or furan. This is in marked contrast with other designs that can only apply the neutralizer after the gases leave the incinerator.

If any halogen escapes the neutralization and some dioxin or furan is formed, MACROburn destroys the dioxins and furans by high temperature combustion combined with massive excess air, turbulence for mixing and long retention time. The high temperature destruction releases the halogens that were not neutralized in the primary chamber. These are neutralised by excess neutralizing agent in the flue gases and the filter.

More than 1050

MACRO*burn* INCINERATORS ELIMINATE EMISSIONS AT SOURCE

They achieve through a very sophisticated system to

CONTROL OF THE RATE OF COMBUSTION.

Four Elements of Combustion Control

1. Heat, air and hot gases in the primary chamber move in a vortex with horizontal axis. Temperature differential and the release of volatiles from the fire-bed interrupt the vortex and deflect the heat and air into the second chamber. This provides **A MODULATED SUPPLY OF HEAT AND AIR** to the fire-bed and controls the **Rate of Combustion**.

2. A portion of the primary air is induced by negative pressure (draught) in the primary chamber. Excessive burning causes a pressure build-up and reduces the amount of air induced. The **Rate of Combustion** is reduced accordingly.

3. Air for secondary combustion is induced by **VENTURI ACTION**. An increase in the volume and velocity of the gas stream increases, the venturi effect and the volume of secondary air. This automatically compensates for the reduction in primary air mentioned in the previous paragraph.

4. Natural draught chimneys on MACROburn incinerators provide an automatic increase in draught as the chimney temperature increases.

- The four control elements are fully modulating.
- Control is achieved without the use of moving parts.
- The system is simple and effective and will not wear out.
- Burners mounted on the primary chamber perform both primary and secondary functions.
- Almost instantaneous diversion of heat and air from primary to secondary provides correspondingly rapid adjustment of the conditions required for optimal combustion.

The control elements outlined above are complimented by conventional controls such as pyrometers, to switch burners and fans on and off according to heat demand.

Other features contribute to effective emission control. A **HEATED REFRACTORY SCREEN** burns the carbon out of fly ash flakes and creates vigorous turbulence for mixing. A massive tertiary chamber ensures long retention times and settles fly ash. A door operated draught limitter reduces the inrush of air and entrainment if the manual loading door is opened.

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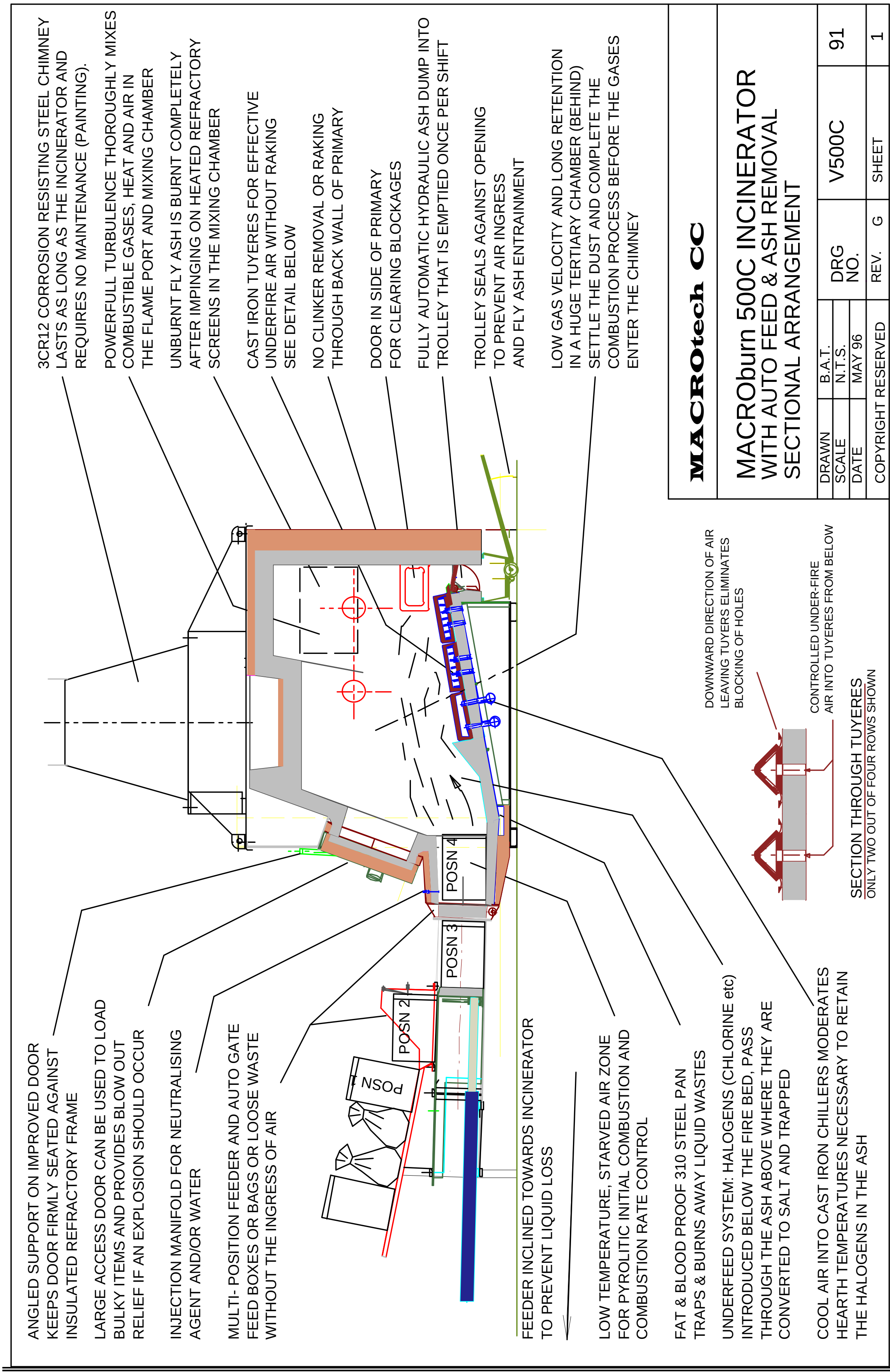

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The Feed System

The Hydraulic Feed Ram is designed to handle waste with a very broad range of calorific values, shapes and densities. Compact design and limited cross section provide better control over the rate of feed and restrict excessive air ingress around the feed opening. Bulky components, too large to pass through the feed ram can be loaded through a manual loading door. Small to medium animal carcasses sharps containers and buckets can be loaded through the feed ram.

Automatic regulation of the feed rate provides long term control of the rate of combustion. However, modern medical waste is highly volatile. It burns very rapidly. In the short term, a single load of waste can burn so fast as to exceed the design capacity of the incinerator. The combustion rate is controlled by limiting the primary air and the amount of heat on the waste during the initial stages of volatilisation. To facilitate this control the ram operates as follows:

1. Up to five boxes or bags of waste or loose waste are loaded onto an inclined stainless steel chute or raised concrete platform. (A roller conveyor can be used in place of the chute if the waste is loaded in rigid boxes. The front box is marked position 1 in the illustration.
2. The front box drops over into the inlet chute on top of the ram in position 2. The ram is at rest in the position shown in the illustration.
3. When the incinerator is ready for loading (determined on a combined time and temperature function), the ram moves right back. The box in position 2 drops into the feeder ahead of the ram. The next box on the inclined chute then tips into the feeder inlet chute to lie on top the first box.
4. The ram moves forward, pushing the first box to position 3. Until this time, the gate is kept closed, preventing any blowback and the ingress of air.
5. The ram stops with the box in position 3 while the gate opens
6. The ram then pushes the box to position 4 before returning and allowing the gate to close.
7. The box in position 4 is shielded from direct heat by a refractory tunnel. Air from the primary chamber is also restricted. The initial rate of combustion is controlled and steady. Volatiles leaving the tunnel are forced to pass through the bed of burning waste. Halogens and fly ash are trapped in the ash.
8. As the following box is pushed in, the first box is pushed out onto the hearth, and exposed to the full heat and air supply.

IF THERE ARE
NO FREE HALOGENS PRESENT
,CYTOXIC DIOXINS CANNOT FORM

Liquids on the Hearth, in the Feeder and the Fat Pan

The hearth is inclined upwards away from the inlet. Because refractory and firebrick cannot be made impervious to liquids, the under side of the inclined refractory hearth is lined with stainless steel. Fat and liquids, penetrating the refractory, run down the stainless steel sheet into a stainless steel pan, located beneath the refractory at the tunnel outlet. On either side of the tunnel, the pan is exposed to the heat and gases of the chamber. Molten fats and liquids are burnt away in the pan.

The feed ram is slightly inclined towards the incinerator. Liquids spilt during the feed process run down into the tunnel. An inclined stainless steel sheet under the floor of the tunnel ensures that all liquids are conveyed to the fat pan for combustion.

Combustion on the Hearth

A semi-pyramidal shape on the hearth promotes distribution of the waste across the width of the hearth. It also breaks up the solid tube of waste, which would otherwise be formed.

A MACROburn 330B with Automatic Feed
At Clin-X Waste Management Services –
Wadeville, Germiston, South Africa

A sharp step at the end of the hearth further assists in breaking and opening up the advancing waste bed. Gentle opening of the bed promotes combustion without entraining excessive fly ash.

A set of cast iron tuyeres, built into the hearth, admits forced draught under fire air underneath the fire bed. The tuyeres are so arranged that the air passages blast downwards preventing molten plastics and other liquids from running into the air holes.

The burnt out ash either falls off the end of hearth onto the riddle flap, which is opened periodically to drop the ash into the trolley below.

The trolley is emptied once or twice per shift. The riddle flap is switched off during emptying of the ash trolleys to prevent an inrush of air and entrainment of fly ash.

The Auxiliary Burners

The primary burner is located relatively high in the sidewall of the primary chamber. The flame is angled downwards, but not so far as to fire directly onto the waste. When the rate of combustion of the waste is low, a vortex motion of the gases in the chamber carries heat down the opposite wall and under the far side of the fire bed. This promotes rapid primary combustion.

When the rate of combustion is high, volatiles from the waste deflect the burner flame up, away from the fire bed and into the flame port at the entrance to the secondary chamber. Thus whenever the rate of combustion is too high, heat onto the fire bed is reduced and the primary burner provides secondary heat. This action is self-regulating and contributes to automatic control of the combustion rate.

The secondary burner provides heat for combustion of the volatiles after they have left the fire bed. It is located on the sidewall of the primary chamber, directly opposite the flame port. It is not angled downwards. It fires straight across the top, rear of the primary chamber and into the secondary, mixing chamber. This upstream location of the burner provides a longer secondary zone and hence longer secondary retention time. The heat is introduced before the gases pass through the flame port where high velocities and maximum turbulence occur. This vastly improves mixing of the secondary heat with the combustion gases.

The Air Supplies

Secondary air is introduced at the flame port to further improve turbulence and mixing. High gas velocities in the flame port induce secondary air by venturi action. The higher the gas velocities, the more air is induced.

A small percentage of the primary air is introduced through the tuyeres described above. It is temperature controlled.

The balance of the primary air is induced by the draught (negative pressure) in the primary chamber. Most of this air is admitted through the burner quarl and follows a path similar to the primary flame. It is also automatically deflected into the secondary chamber when the combustion rate is high.

Instantaneous, short term, control of the combustion rate is thus achieved by automatic regulation and deflection of the heat and air supplies. The principal is also known as "Controlled air", "Starved air" or "Pyrolisis". The feed inlet tunnel also limits the amount of air and heat reaching fresh waste. All of the above effects are instantaneous. No moving parts are involved. The system is rugged and absolutely reliable. Wear and tear is non-existent.

The Refractory and Insulation

The vermiculite based insulation around the side and the back walls is 115 to 200mm thick. This ensures low surface temperatures, higher internal temperatures and lower fuel usage.

The Front face of the incinerator is insulated with calcium silicate that has a very low conductivity to ensure low surface temperatures.

MACROCeramic Filtration

The principle of the MACROCeramic filter is very similar to that of the conventional reverse pulse bag filter.

The fabric bags in the conventional filter are subject to temperature limitations (approx. 200°C), to sparks causing hole in the bags as a result of localised burning and to mechanical wear and tare.

In the MACROCeramic filter the bags are replaced with rigid ceramic filter elements that are capable of withstanding temperatures higher than 1000°C. MACROtech places a general temperature limitation of 600°C on the filters as a whole. This is due to design considerations relating to other materials used and to expansion and contraction allowances. None the less, the 1000°C resistance of the elements is of great benefit in ensuring that sparks do not burn holes through the filter medium.

MACROceramic CF28 Filter

Acid gas neutralisation in MACROburn Incinerators takes place mainly in the incinerator itself. Fine ash and any residual neutralising agent in the flue gas is trapped on the surface of the elements. The acid gases are forced into intimate contact with the residual agent and with fine ash, which is, in itself, an excellent neutralising medium.

Neutralising components in the ash include oxides and carbonates of calcium, magnesium, sodium and potassium. These combine with acid gases to form salts. If there is insufficient neutraliser in the ash, provision is made for the addition of additional neutraliser into the primary chamber of the incinerator. The neutraliser to be used depends on the price, fineness and availability of commercial products. Technically any of the oxides or carbonates mentioned as components of the ash can be used. Current market availability indicates that Sodium Bicarbonate is most likely to be used. This does not preclude the use of other neutralisers.

Early conversion of halogens to salt, at the feed inlet in the primary chamber, is very beneficial. The halogens are trapped before they can take part in the formation of dioxins and furans. The early entrapment of halogens in MACROburn units is in contrast to other systems where neutralisation only starts after the gases have left the secondary combustion zone, allowing plenty of time for the formation of dioxins and furans in the incinerator.

Fine particles of salt, formed by neutralising action in the incinerator, are trapped on the surface of the elements. Other fine particulates such as heavy metals are also trapped on the surface of the elements. The accumulated particulates are periodically removed from the elements by automatically controlled very short pulses of compressed air blown through the elements in a reverse direction.

Mechanical Handling of Waste

The illustration and the description above relate to a fed system that was designed to handle medical waste in boxes. The volume of each load was 168 liters. The current tendency is to use 240 liter wheeled bins in place of the boxes. MACROtech have designed a feeder suitable for loads of 270 liters. This allows for some overfilling. The bins can weigh as much as 70 kg

MACROtech are also able to supply bin tipplers to offload the bins.

Incinerators for Liquids and Gases

MACROtech have designs for specialized incinerators to dispose of waste liquids and gases. These incinerators are often custom built to suit client's requirements.

Two Incinerators at SAPPI – Usutu Pulp
Designed and built by MACROtech specifically for burning phenolic liquor

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