Incineration Review 2015 (Part 2) Industrial and Hazardous Wastes

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Refractories World Forum regularly reviews refractories development, production and use under their banner of "Hot Topics" within which the large scale incineration of industrial wastes certainly has to feature (Part 1 has been published in refractories WORLDFORUM **7** (2015) [4] 44–48). It is not only an application which involves the use of generally higher temperatures than those found in MSW (municipal solid waste) incineration but is also often hotly debated by environmental groups, local governments and OEM's (original equipment manufacturers). The reasons are that current industrial wastes are very diverse and often extremely hazardous to handle and dispose of with complete safety. In the past a great deal of industrial waste was simply abandoned and created immense health hazard and even ecological disasters. Some form of treatment is therefore not just desirable but absolutely essential to dispose of waste without creating new and potentially worse problems to humans, animals and plant life.

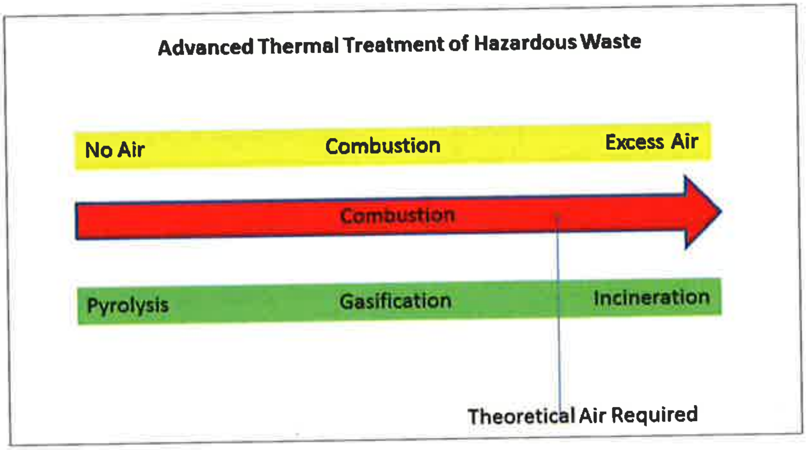

Fig. 1 The range of waste thermal treatments

Thermal waste treatments

One problem in accurately defining the scope of industrial incineration statistically is that there are a wide range of processes within the field of the advanced thermal treatment of wastes. These range from pyrolysis through gasification to high temperature incineration which while normally carried out at around 1200 °C can extend to treatments by plasma arc processes which can exceed 2000 °C. It should be noted, that in this report the number of furnace designs is so diverse that any illustration should be understood to be a diagrammatic representations of the process and not meant to resemble any specific furnace. Similarly, the number of lining materials and configurations are so different that refractory recommendations should be understood to be those representing only one of several possible combinations of lining solutions which reputable and experienced suppliers might offer OEM's and end users.

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Pyrolysis

Pyrolysis may be used to treat wastes of a very uniform nature and physical size. Pyrolysis starts to thermally degrade waste in the absence of oxygen by using external heating sources to raise the temperature of the materials under treatment. It requires anything between 400–800 °C and evolves gases containing complex hydrocarbons and leaves a charred residue, both of which require further treatment. The solid residues can be charged to another combustion unit in which there is excess air to produce heat and energy. The gaseous products emanating from pyrolysis can also be similarly burnt to produce heat or condensed to provide liquid fuels for another process, both of which would be exothermic and provide energy. There is often a denser fraction in the form of tars produced during pyrolysis which can again be used as a fuel although it is generally difficult to handle effectively.

Gasification

Gasification can handle a wider range of feedstock, although it requires considerable pre-treatment to remove incombustibles and is a process in which waste is heated to over 600 °C but not completely combusted because the oxygen supply is restricted. The products generated by this exothermic process are ash and combustible gases of relatively low calorific value containing mainly methane, hydrogen and carbon monoxide. This process is always associated with collection and further processing of the products of combustion

Incineration

Incineration in the conventional sense is the third option where the wastes are heated to very high temperature of at least 1100 °C in the presence of excess oxygen to completely combust them into ash and flue gases; both of which then require to be collected and cleaned before eventual release. The incineration can be carried out in a wide range of refractory lined furnaces at temperatures between 1200–1500 °C and often involving a rotary kiln with a secondary combustion chamber as part of the process. Particularly, difficult wastes may also be treated in a plasma arc furnace at temperatures which are usually in excess of 2000 °C. This process can even help dispose of other refractory wastes such as spent aluminium electrolytic cell residues, ceramic fibres and even asbestos materials. Any gases produced during the combustion are thoroughly quenched and cleaned while solid waste is usually in the form of an inert glassy slag which is granulated and can be used again in construction products as an aggregate.

Industrial and other hazardous wastes

The total extent of industrial waste incineration is difficult to define even in Europe where there is relatively good information available. There is an organisation called the European Union for Responsible Treatment of Special Wastes EURITS which was established in 1994 and is currently headquartered in London/GB. They claim to represent over 90 % of the EU's specialist hazardous waste incineration sector which they estimate at about a total capacity of 2,5 Mt/a. They have 26 members in 12 EU member states plus Switzerland and Turkey and over 4500 well trained employees operating 36 different state of the art plants. If these figures are still currently valid today, then there is approximately 2,75 Mt of hazardous waste in total being handled throughout Europe. This compares with the total tonnage of materials being incinerated which is of the order of 40 Mt in up to 500 separate plants across Europe, including Switzerland and Turkey.

EURITS states that "it was established to promote the safe, legal and responsible high temperature incineration and treatment of special waste, including hazardous and other dangerous wastes. Membership of EURITS is open to all companies that operate a high-temperature incineration plant for special waste and wish to join to cooperate technically".

The European Commission has stated that "Europe needs a network of facilities to destroy waste that is so hazardous that it is dangerous to human health and the environment. In providing this network, the member companies within EURITS have two key roles in the effective operation of a recycling society:

- Acting as gatekeepers to prevent hazardous waste and other wastes containing dangerous components entering the recycling chain to ensure that the components do not end up in products (for example, general construction material, food and animal feedstuff) and have an adverse impact on human health and the environment.

- Being part of the recycling society by enabling the recovery of energy and materials from the high-temperature incineration process, either in their own plants or in the wider economy."

EURITS believes that dealing with special wastes involves treatment of hazardous waste as well as hazardous components present in other wastes. It is claimed by EURITS that some hazardous wastes cannot be destroyed by any other means than by high temperature incineration, and that these include such materials as refrigerants containing CFCs, PCBs, certain cyanide containing waste and more generally asbestos and ceramic fibre products. All member companies adhere to the strictest emission limits of any industry in the European Union, utilising state-of-the-art facilities including of course premium refractories combined with experienced management and well-trained operators.

Not included in the above figures are other diverse types of industrial incineration. These include automotive tyres through to poultry waste which are routinely disposed of by using as an alternative fuel to supplement the energy requirements of most modern cement kilns. The alternative fuel addition can also include coffee grounds, rice husks, biomass, spent lubricating oil and very many other materials. Indeed, Cembureau make a strong case that when refuse derived waste RDW is used as an alternative fuel in the cement industry as a supplement for coal there are very big environmental benefits to be gained. This is because solid residues are absorbed in the clinker, and gaseous emissions such as CO_2 are reduced because they too are partially absorbed in the process prior to further conventional gas scrubbing and cleaning. Sophisticated heat recovery and flue gas treatment can however redress much of the balance in any critical study comparing combustion in a dedicated custom designed incinerator compared to combustion as RDF in a modern cement kiln.

Most industrial waste and all hazardous waste which is burnt are treated in specially designed and built incinerators, which have some form of heat recovery as well as very efficient flue gas treatment to remove harmful components from the eventual emissions, which are designed to be minimised as far as possible. This could also be said to be true of RDW incineration in cement kilns because they operate with burning zone temperatures of around 1600 °C, and modern kilns today are always fitted with dust collection and gas cleaning equipment of high efficiency. The refractory lining of the cement kiln and its ancillaries such as pre-heaters and coolers are not specifically designed with the incineration aspect of the process as a priority. There are cases however, where the lining design has to be physically altered, for example if it is required to feed tyres chippings into the pre-heater or indeed compete tyres or small bales of RDF directly into the pre-heat zone of the kiln as it continues to rotate. The linings are mainly designed with best cement manufacturing practice as the principal objective. However ,in very many cases it is true to say that the RDF incinerated can have a significant impact on refractory performance. Many of the RDFs will contain elements, such as alkali salts, which are volatilized during combustion. They then tend to be carried around the system, where they can condense in critical areas such as on the hot face of tertiary air duct dampers. Some of the entrained alkalis can in fact continue to circulate in the system and become more concentrated, which makes the eventual alkali attack of exposed refractory surfaces more severe as time progresses. It has been found that, the major alkali component in many cases is usually potassium and this can accumulate on and just behind the hot face of the refractory resulting in major refractory attack. Used dampers analysed after service have indicated alkali concentrations more than forty times greater than in the original refractory. In the case of dampers, this can cause the dampers to grow and distort as well as much higher tensile stresses in the lower damper blade, which often results in failure of the blade by horizontal cracking and eventual separation. It can be seen therefore, that solving one or more problems by disposing of RDF as an alternative fuel can in fact create greater or new problems for the refractories which then require upgrading in very specific areas.

A custom designed incinerator for hazardous wastes would have a relatively short inclined rotary kiln where combustion is initiated. Solids or indeed liquid slag which may often be created is quenched and collected below the outlet end of the kiln. If the build-up of slag on the outlet nose ring becomes too excessive, it must be removed periodically and this may result in further refractory wear. The products of combustion then pass into a secondary combustion chamber where they undergo further treatment. They would then normally pass to secondary crossover ducting before being quenched and cleaned prior to reaching the flue. In some units, the temperature in the crossover duct combined with low melting point materials entrained in the products of combustion can cause the build-up of a substantial glassy phase on the hot face of the refractory. This may cause bricks to exhibit a cobble stone effect or cause monolithic linings to become unstable and collapse.

A modern hazardous waste rotary kiln incinerator might typically be lined with basic brick, but with an area at the discharge end installed in alumina chrome bricks for extra wear resistance. The combustion chamber could be lined in silicon carbide bricks. The crossover duct would require either high alumina bricks or a phosphate bonded high alumina plastic retained on anchor bricks. Repairs in typical secondary combustion chambers and ducts have made use of gunning or even shot-creting where it is physically possible to install these, but cement bonds in the refractory can sometimes be susceptible to chemical attack from acids or other components as can anchors. Refractories in the cooler sections may be of lower quality, but must sometimes resist acid attack when chlorides or sulphur compounds condense in the presence of water below the dew point.

Chemical waste incinerators may have a solid hearth above which primary combustion takes place. They may also have a fluidised bed configuration in which material is burnt. In this case, the hearth would be in the shape of an inverted dome with numerous inlets through which high pressure air is introduced. This causes the waste, which when fine may be mixed with sand and fuel, appears to adopt some of the properties of a fluid, and be combusted. There is usually a secondary combustion space above this where more waste in the form of a liquid could be introduced, but where the primary consideration is to completely combust the waste before the products of combustion are carried forward to a tertiary combustion chamber or to recover heat, and the gases cleaned as far as possible before emission to the atmosphere.

The hearth may be in an ultra-low cement castable based on a high alumina aggregates, perhaps also containing a significant amount of silicon carbide grain in the aggregate fraction for maximum density and strength the hearth, which would be in the shape of an inverted dome and could be assembled in pre-cast sections. The main refractory wear mechanism in this area is hot abrasion. Above this, in the secondary combustion chamber would be high alumina bricks or monolithics to withstand fluctuation temperatures of up to 1600 °C.

Fig. 2 Refractory damage from alkalis in a kiln with RDF alternative fuel

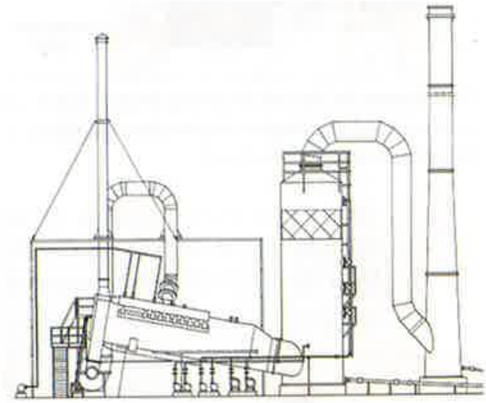

Fig. 3 Rotary kiln waste incinerator (with acknowledgement to Cleanaway)

These combustion chamber sections would have significant insulation backup to conserve heat, so that when the gases pass to the heat recovery boiler, it would ensure a high degree of heat recovery and energy conversion into either superheated steam to drive a turbine to generate electricity or in some cases as district heating.

Very few installations currently exist to consume hazardous waste by plasma arc furnace, but it is proposed as the most effective way to destroy very dangerous waste materials such as asbestos or poisons or other hazmat. The furnace generally resembles a tall cylindrical vessel with a larger diameter domed top. The mixed hazardous materials are fed in and very much in the same way as a cupola or blast furnace operates, there is a counter current heat transfer. Heat from the plasma torches combusts the material after some of it has been dried and gasified higher in the furnace. The product of combustion is slag and solids from the bottom of the furnace and synthetic gas from the top. The syngas is collected and after cleaning can be

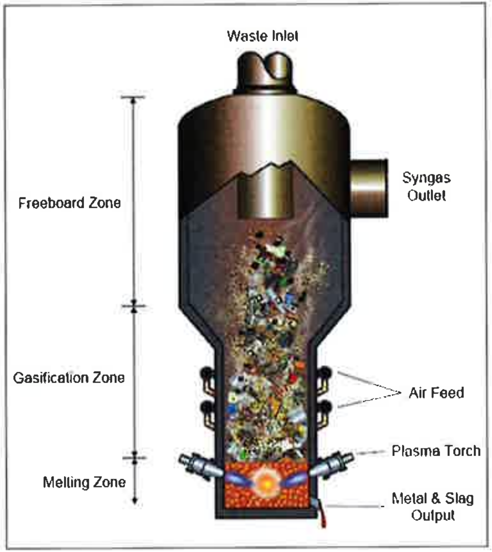

Fig. 4 Plasma arc furnace for waste incineration (with acknowledgement to Westinghouse Plasma Corporation and their partners)

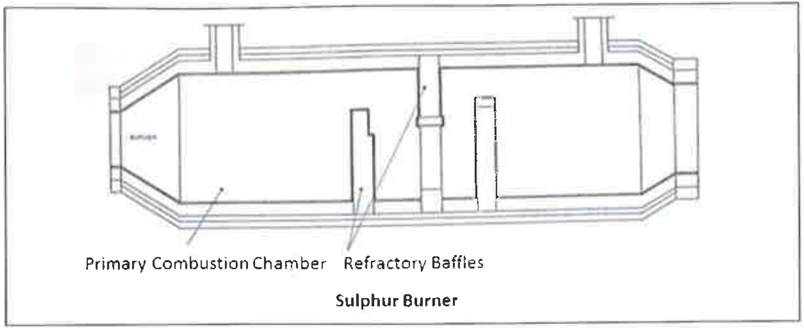

Fig. 5 Sulphur burner

used as a fuel to create electricity or even distributed as a gas for public use. As in the rotary kiln process, the highest temperature zone with most wear can be lined with materials like alumina-chrome bricks. Higher up in the furnace in the gasification and preheat zones monolithics in the form of castables, gun mixes shotcrete or high alumina plastics may be employed. Very large units operate continuously, can handle a wide range of feed at up to 40 t/h, and exhibit high efficiency at a relatively low operating cost. No doubt, more and bigger units are being commissioned or are on the drawing boards around the world.

Much smaller units handing equally hazardous materials are employed in many large hospitals to dispose of clinical waste of all types, including even syringes and scalpels. The waste in sealed bags is fed into hoppers and transferred into the furnace by hydraulic ram. It may progress into the furnace propelled by new waste behind it, or by a pulsation system or bottom screw conveyor. High efficiency burners combust the feed as it passes along the hearth through the furnace. As in all incinerators, great care is taken to achieve complete combustion, and to separate and collect inert solid and gaseous products of combustion.

Whether operated continuously or as batch process, each night attention still has to be paid to remove any scalpel blades not totally destroyed and still present in the residue as they are high nickel-chrome and the time and temperature may not always completely destroy them. Such incinerators are usually relatively small units and the combustion chamber lining may be a mixture of pre-cast high alumina shapes and high alumina, low cement castable placed in situ to resist the abrasion from the materials pushed in front of the ram and the high variable temperature during operation.

In the same general category as hospital incinerators are cremation units formerly operated mainly by local governments but increasingly built and operated perhaps more sensitively by large private companies. These may consist of pre-cast trays which sit on bearer arches between the combustion chamber and a pit beneath the arches. Most of these units employ alumino-silicate bricks or castables as the main lining, and the normal wear mechanism is a combination of high temperatures and thermal shock.

Sludge of many types after pre-treatment, dewatering and drying can be used as an alternative fuel source in cement kilns although multi-hearth type furnaces are also a very effective means of disposal of this and similar types of by-product. A multi-hearth furnace would comprise of a tall large diameter cylindrical vessel with a central rotating shaft fitted with rabble arms. The sludge in damp powder or cake form is introduced on the top hearth and the rabble arms distribute it across the refractory hearth from which it is removed through the central drop hole.

On subsequent hearths, the material exits from each hearth alternately through the central or peripheral drop holes, being raised in temperature on each until it is completely combusted into an inert ash with the products of combustion being led off for collection. The original hearths on furnaces such as these were constructed from special shaped bricks sprung from skewbacks installed around the furnace lining. Hearths have been successfully cast in situ however using high strength ultra-low cement castable. Each hearth can be one large casting of around 30 t, but must be very carefully dried and preheated using a number of thermocouples to measure and control the heating rate.

Control thermocouples should be installed at a central position at the base of each hearth where it is thickest and will measure the mean temperature of the refractory which would be heated by hot gases on both the top and bottom faces simultaneously. This type of unit usually operates under very stable conditions, and can give long trouble-free refractory lives after the initial commissioning.

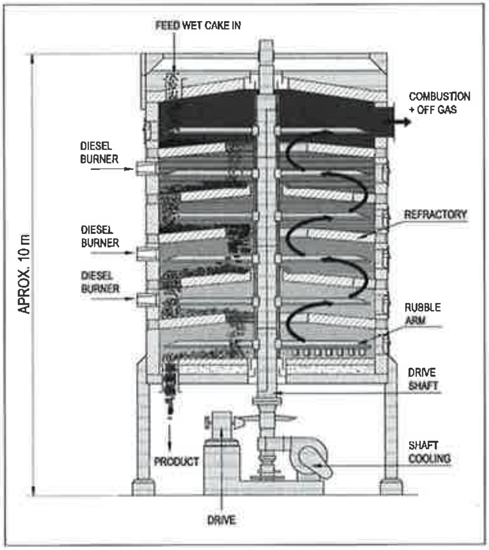

Fig. 6 Multi-hearth furnace (with acknowledgement to Adelaide Control Engineering)

Other relatively small specialised units exist within chemical and petrochemical plants, and examples of these would be sulphur burners, flare tips which may be pre-cast castable units 30 m in the air on the end of flues or even in oil producing areas very large shallow burn pits lined with good quality fire bricks to combust excess oil products and waste.

At the least, this short report should highlight the myriad of different feeds and incinerator types currently on the market. It can be readily understood therefore the necessity of the client, the OEM, and the refractory supplier and installer working very closely together to arrive at the safest most effective solution in each and every set of circumstances involving the disposal of hazardous waste materials of all the many varieties encountered today.