Incineration Emissions

Monitoring of incineration emissions is a demanding application for Continuous Emission Monitoring Systems. Incinerator emissions are highly corrosive, some of the gases are soluble and, because the waste being burnt is constantly changing, the resulting stack gas temperature can vary widely. The Procal exhaust gas analysers and emissions monitoring analysers are used in a wide range of applications and industries, and can be configured to monitor emissions and process gases for both reporting and control.

Together with heat, an incinerator produces both ash and flue gases. For incineration, the main conventional air pollutants are NO_X, SO_2, particulates and the greenhouse gas CO_2. Procal have a wealth of experience in both monitoring these emissions and controlling flue gas scrubbing systems.

In addition, to the gases above heavy metals and dioxins are also emitted to the air from incinerators. A residual product containing bottom ash, fly ash and air pollution control residues is left after the incineration process which can be disposed of in landfill. A modern incinerator plant can produce lower quantities of emissions than are produced by a coal fired power station for the equivalent amount of energy produced. The experience gained by Procal over 25 years has included applications with the following types of incinerators:

- Large domestic Garbage incinerators
- Waste to Energy Projects
- Biohazard & Chemical Industry Incinerators
- Thermal oxidisers in the Automobile industry
- Chemical & Biological Weapon destruction
- Pulp Mill Incinerators
- Crematoria & Animal Incinerators

With this experience Procal is well psitioned to assist its clients with the selection and installation of Procal gas analysers that can be deployed as either single, stand alone CEMs or fully integrated plant wide monitoring and reporting systems. Procal can also provide full maintenance and support through its warranty and service agreements which is especially important in a highly regulated industry such as incineration.

Incineration as an alternative to Landfill

Over the last decade, since the introduction of the European Union Directive (1999/31/EC) on the landfill of waste, the disposal of municipal waste has become a mounting problem. The aims of the Directive are to prevent or reduce negative effects on the environment from landfill. To achieve this aim a number of stringent technical requirements were introduced for both waste and landfills. Legally binding targets for reducing the amount of biodegradable municipal waste going to landfills have been set for each member country as a result of the Directive. In the UK, for example, the Waste Implementation Programme

(WIP) target is to reduce biodegradable municipal waste to 35% of the 1995 level by 2020.

One solution that has seen large scale expansion across Europe is waste incineration. Incineration provides a method of dealing with large amounts of municipal waste thereby reducing the need for landfill. The process involves the combustion of the organic substances contained in the waste materials with the heat produced being used for generating electricity and/or domestic heating. Incinerators that produce both heat and electricity are known as Combined Heat and Power (CHP) plants and are the most efficient in terms of displaced pollution. Incineration is economically favourable as part of the electricity generated is deemed to be from a Renewable Energy Source (RES) and provides taxation benefits for the operator. Depending on the composition of the municipal waste and the recovery of materials such as metals from the ash it is possible to reduce the solid mass by up to 80-85%. Incineration also provides for the safe disposal of both clinical waste and certain hazardous waste materials as pathogens and toxins are destroyed at high temperatures. Incineration as a method of waste disposal is also favourable in countries where land is scarce.

Dioxins and Furans

Public concern exists over the release of dioxins and furans as these are a serious hazard to health. Recent government regulations that require the use of emission control technologies have led to a significant reduction in the emissions of dioxins and furans. Dioxins undergo thermal breakdown when exposed to a sufficiently high temperature. However, Dioxins on the surface of fly ash may degrade when exposed to high temperature while those below the surface remain intact. In a modern incinerator a combination of high temperature and exposure time is introduced so that heat penetrates throughout the fly ash and also the volume of waste gases. To achieve this a modern incinerator design operating under the Waste Incineration Directive includes a high temperature zone, where the flue gas is exposed to a temperature above 850 °C (1,560 °F) for at least 2 seconds before it is cooled down.

Methane is released by anaerobic decomposition of the biodegradable part of the waste when municipal waste is used in landfill. Incineration of Municipal Solid Waste avoids the release of methane. Every ton of MSW incinerated, prevents approximately one ton of carbon dioxide equivalents from being released to the atmosphere.

Types of Incinerator

There are several types of incinerator plant design such as moving grate, fixed grate, rotary-kiln, and fluidised bed and all modern incinerators have pollution mitigation equipment such as flue gas scrubbing systems installed as standard.

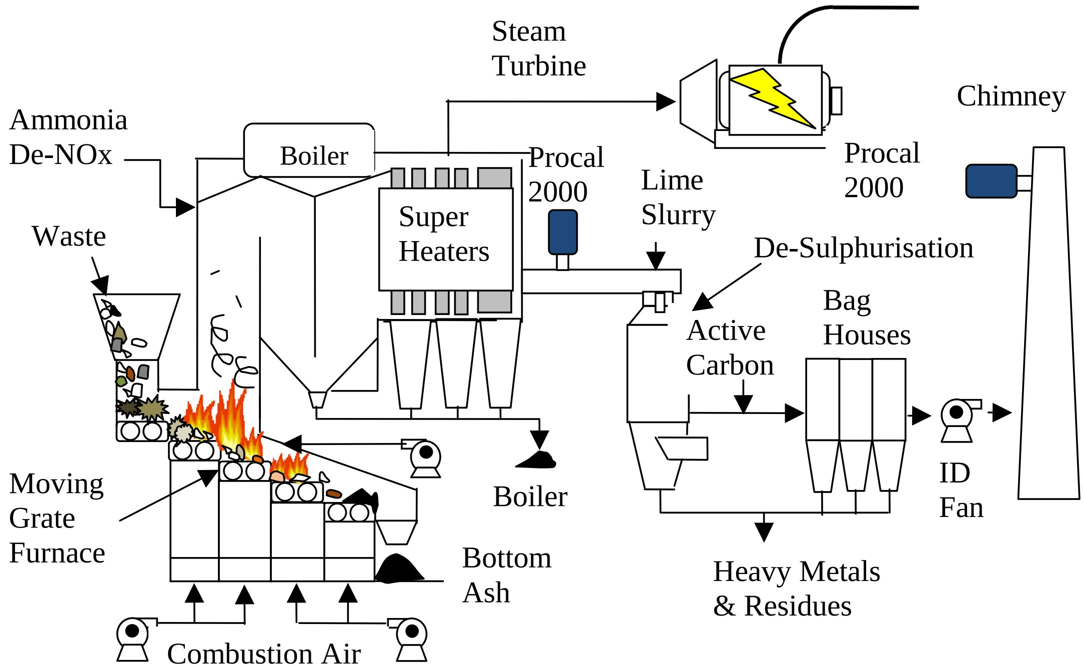


Figure 1. In-situ Procal 2000 Analysers on a Municiple Solid Waste incinerator

Moving Grate Incinerator

The typical incineration plant for municipal solid waste is a moving grate incinerator sometimes referred to as Municipal Solid Waste Incinerators (MSWIs). The moving grate enables the movement of waste through the combustion chamber to be optimised to allow a more efficient and complete combustion. A single moving grate boiler can handle up to 35 metric tons (39 short tons) of waste per hour, and can operate 8,000 hours per year with a single annual scheduled stop for inspection and maintenance. Figure 1 shows a schematic of a Municipal Solid Waste Incinerator with Procal 2000 analysers installed before and after the scrubbing systems.

The waste is introduced by a waste crane through the "throat" at one end of the grate, from where it moves down over the descending grate to the ash pit in the other end. Holes in the grate elements supply the main combustion air and also provide cooling for the grate so that its mechanical integrity is maintained. Gratings can be cooled internally by using air or water.

Nozzles above the grate provide a secondary combustion air supply into the boiler at high speed that aid complete combustion of the flue gases by introducing turbulence for better mixing and by ensuring a surplus of oxygen. In multiple/stepped hearth incinerators, the secondary combustion air is introduced in a separate chamber downstream of the primary combustion chamber.

To comply with the Waste Incineration Directive and ensure that flue gases reach a temperature of 850 °C (1,560 °F) for 2 seconds backup auxiliary burners (often fuelled by oil) are installed.

The flue gases are then cooled in the super heaters, where the heat is transferred to steam, heating the steam to typically 400 °C (752 °F) at a pressure of 40 bars (580psi) for the electricity generation in the turbine. At this point, the flue gas has a temperature of around 200 °C (392 °F), and is passed to the flue gas scrubbing system.

Figure 2. Municipal solid waste in the furnace of a moving grate incinerator.

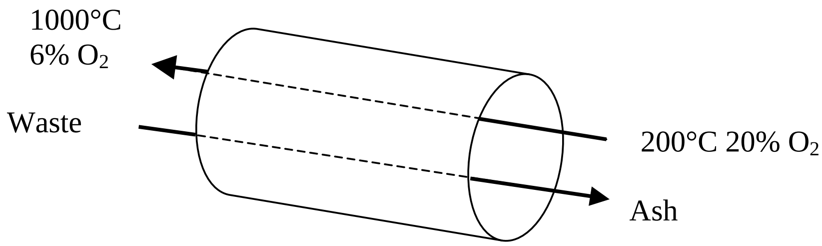
Fixed grate

The older and simpler kind of incinerator consists of a brick-lined cell with a fixed metal grate over a lower ash pit. The chamber usually has one hatch in the top or side for loading and another opening in the side for removing incombustible solids that are known as clinker.

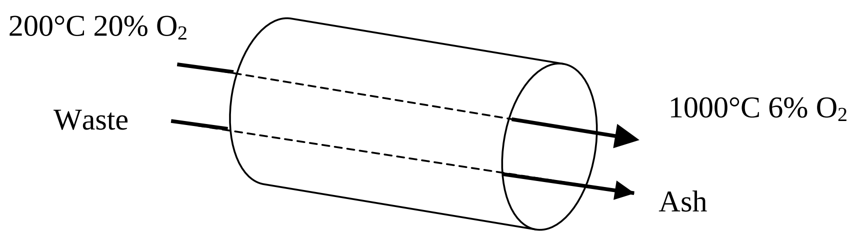
Rotary-kiln

The rotary kiln is the most versatile incinerator available as it can treat a large range of waste materials with low and high calorific values and different particle sizes. The rotary kiln consists of a slightly inclined rotating primary combustion chamber with waste introduced at the high end and ash collected at the low end. The cylindrical form and rotary motion of the kiln allow the waste to be uniformly heated and to transport the waste down the length of the kiln. A secondary combustion chamber is used for complete combustion of the flue gases. A rotary kiln incinerator plant is required to have flue gas treatment systems installed.

There are two different types of rotary kilns: the historical co-current and the modern, more elaborate, counter-current design as shown in figure 3. The co-current rotary kiln oxidises the total amount of waste under over-stoichiometric conditions (excess of oxygen), while the counter-current rotary kiln operates partly by under-stoichiometric oxidation (pyrolysis) of the waste. In this case, the pyrolysis gases are used to fuel the post combustion chamber and no auxiliary firing is required. In a co-current rotary kiln a permanent burner is required to maintain the required temperature level in the post combustion chamber.



Counter Current Kiln



Co-current Kiln

Figure 3. The two types of Rotary Kilns

A counter current rotary kiln allows a precise control of the flue gas stream and therefore its overall dimensions are much more compact than its co-current parent. As the combustion air is introduced at the lowest part of the kiln, the opposite end to the introduction of waste, the ash extraction area is also cooled preventing the occurrence of ash “slag”.

Fluidized bed incinerator

In a fluidised bed incinerator solid fuels are suspended on pumped air currents during combustion. This results in a turbulent mixing of gases and solids. The tumbling action is similar to a bubbling fluid and provides more effective chemical reactions and heat transfer. Fluidised bed combustion plants are flexible in that they can be fired on different types of fuel such as coal and biomass.

The addition of limestone can be used to precipitate out sulphates during the combustion and thereby reduce SO_2 emissions. As the heated precipitate is in direct contact with water tubes the conduction heat transfer efficiency is improved and more heat energy is captured.

Flue Gas Treatment

The raw flue gases from an incinerator are normally cooled before being treated and released to the atmosphere. Cooling may be done either by quenching (wet flue gas treatment) or through a heat exchanger. The media used in the heat exchanger can be steam, thermal oil or air. If steam is generated, it can be used to drive a turbine generator or to heat other process equipment. Heat exchangers are installed either in-line or in a by-pass of the process flow. Hot air from the process can be used for materials drying. Waste water from wet scrubbers must be passed through a waste water treatment plant before being released into the environment.

The quantity of pollutants in the flue gas from incineration plants is reduced by several processes.

Removal of Particulates

Particulate is collected by particle filtration with electrostatic precipitators (ESP). In addition, bag house filters systems are very efficient at removing fine particles (PM_{10} and $PM_{2.5}$) from the flue gases. The Procal 2000 analyser works well in the high dust applications of cement plants and has also been successful in high dust incineration applications. A bag house is required in the case of dry scrubbing with sodium bicarbonate to filter out particulates. The Procal system can be expanded to incorporate Oxygen, Particulate/Opacity and Velocity measurements as well as measuring the flue gases. This integrated approach to emissions analysis enables, when required, the concentrations to be normalised, reported on a dry basis and in mass measurements.

Reducing HCl, HF and SO_2 emissions

A number of auxiliary materials are used in the flue gas cleaning processes. Calcium carbonate ($CaCO_3$) for example is used to remove hydrogen chloride (HCl) and hydrogen fluoride (HF). For control of Incinerator flue gas scrubbing systems, the Procal 2000 produces very stable HCl measurements in the presence of high levels of water vapour, and its rapid response time makes it an ideal instrument for scrubber control. Typical ranges that have been configured for the Procal 2000 in HCL measurement are HCl (0-500mg/Nm^3), HF (0-200mg/Nm^3), H_2O (0-20%), CO_2 0-20%, SO_2 (0-800mg/Nm^3) and CO (0-800mg/Nm^3).

Acid gas scrubbers are used to remove hydrochloric acid, nitric acid, hydrofluoric acid, mercury, lead and other heavy metals Heavy metals are often adsorbed on injected active carbon powder, which is collected by particle filtration. Lime slurry can also be injected into the flue gas to provide dry desulphurisation and reduce the amount of SO_2 emissions. Sodium hydroxide (NaOH) can be used as an alternative to lime to also neutralise sulphur dioxide(SO_2).The Procal 2000 in situ infra-red analyser with heated probe, resists corrosion from the acid gases by keeping the sample gas above the dew point. With integral automatic zero and calibration capability, this instrument presents low installation and maintenance costs.

Oxides of Nitrogen

A side effect of breaking the strong molecular bonds of the dioxins is the potential for breaking the bonds of nitrogen gas (N_2) and oxygen gas (O_2) in the combustion air supply. As the exhaust flow cools, these highly reactive detached atoms spontaneously reform bonds into reactive oxides such as NO_X

in the flue gas which must be further neutralized with selective catalytic reduction (SCR) or by a high temperature reaction with ammonia in the furnace in selective non-catalytic reduction (SNCR). The Procal 2000 provides measurements for analysing gases associated with oxides of Nitrogen and their removal by Ammonia injection. This de-NO_X process, if carried out alongside scrubber measurements using a second analyser, can exploit the multi-analyser control capability of the Procal 1000 controller with sophisticated reporting capability. Typical gas ranges measured by the Procal 2000 are NH_3 (0-100mg/Nm3) and NO (0-500mg/Nm3).

Solid Outputs

Incineration produces both fly ash and bottom ash in a similar way to coal combustion. Approximately 4-10% by volume and 15-20% by weight of the original municipal solid waste is converted to ash. Fly ash which is more of a potential health hazard as it often contains high concentrations of heavy metals amounts to about 10-20 % of the total ash. The US EPA regard bottom ash as non-hazardous waste i.e. it does not contain significant levels of heavy metals.

Incinerators compete with alternative emerging technologies that are now available or in development such as Mechanical Biological Treatment, Anaerobic Digestion (MBT/AD), Autoclaving or Mechanical Heat Treatment (MHT) that uses plasma arc gasification (known as PGP) which is a form of incineration that uses electrically produced extreme high temperatures.

Figure 4. The Maishima waste treatment center in Osaka, designed by Friedensreich Hundertwasser, uses heat for power generation.