Catalysts Aid Cleaner Environment

THERMAL INCINERATION PROCESS ENHANCED BY PLATINUM-BASED CATALYST

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The growing concern over environmental issues has resulted in the successful implementation, in several countries, of legislation on automobile exhaust pollution. However, there are still many types of pollution emitters which cause concern. One of these being the emission into the air of noxious gases, potentially damaging and injurious to the atmosphere, from various industrial and manufacturing processes, and resulting generally in poorer air quality, and contributing to the damage to the protective ozone layer, or to the greenhouse effect.

It has thus become apparent, that more stringent control of the waste products of industrial processes would be required. In the U.K. this has resulted in the Environmental Protection Act of 1990.

Within Part I of the Act operators of industrial processes that result in the production of waste gases into the atmosphere must reduce the concentrations of these products to below specified limits. Volatile organic compounds, VOCs, arising from industrial solvent use in paint, ink and adhesive manufacture, and also from the petrochemical and chemical industries, have been implicated in a wide range of environmentally damaging processes, due to, in some cases, their own toxicity and in others resulting from chemical reactions within the atmosphere.

A large number of industrial processes generate VOC emissions significantly greater than the permitted limits, and therefore operators of these plants will have to assess the feasibility of greatly reducing these emissions before the stated date of compliance for their particular industry.

Many companies have completed a collection of data on their emissions to the atmosphere, which they have undertaken to enable them to determine the scale of the problem, and they are now considering selection of the most suitable method of emission reduction. Some may be able to reduce their VOC emissions satisfactorily by modifications to their processes or by changing the raw materials which they use; but the majority will need to install some form of pollution control system in order to achieve the required emission levels.

The range and types of pollution control systems are so many and varied that the selection of technology most suitable for a given process is a complex procedure. The financial investment required for such a system can be significant in both capital expenditure and running costs. Thus, the services of an experienced environmental consultant are recommended in order to identify the appropriate air pollution control system for an individual company.

Thermal Incineration: Benefits and Limitations

The most effective way of ensuring essentially complete destruction of VOCs present in gaseous effluent is by incineration. Thermal incineration of VOCs is a widely used technology, and can be performed by direct-flame heating in a combustion chamber, at temperatures of 760°C or more, depending upon the nature of the VOCs.

The three principles of thermal incineration are: time, temperature and turbulence. In order to achieve a high destruction of VOCs the following criteria must be satisfied: sufficient time – of 0.5 to 2 seconds, temperature – of 760°C or greater, and turbulence – to achieve good mixing of the VOCs with air. If any one of these criteria is not achieved, then the VOC

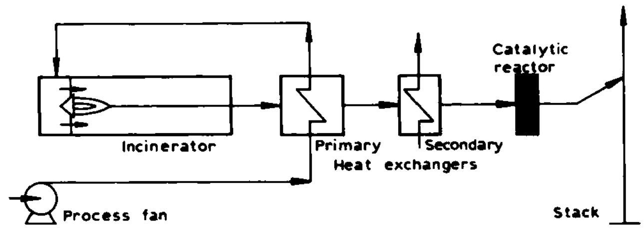

Fig. 1 Schematic of a typical thermal incineration system with a combustion chamber temperature of 760°C, retrofitted with a platinum-based oxidation catalyst into the incinerator exhaust duct and operating at 400°C

oxidation reactions will not be completed and excess emission levels will be generated.

Thermal incinerators can also suffer extreme thermal stresses, due to their high working temperatures, especially during cycles of heating to the operating temperature, and cooling during shutdown. This can result in the distortion of ductwork and heat exchange surfaces, creating the potential for cracks and leaks. Thus dirty process gases with high VOC content can contaminate the cleaned incinerator exhaust gas. Operating companies may then be faced with the prospect of a major capital outlay either to modify or replace equipment within their incinerator.

Return to Compliance with a Retrofitted Catalyst System

One technology which can help in this situation is catalytic oxidation. The technology for the successful catalytic oxidation of VOCs as an alternative to direct thermal incineration has been proven over many years through installation of catalytic oxidation systems to treat VOC emissions from a wide range of industrial processes. More recently catalysts have been brought to public awareness by fitting of catalytic converters to new cars.

The main advantage of catalytic oxidation is the ability of the catalyst to operate at significantly lower temperatures than direct thermal incineration. In many applications this can give lower capital costs and/or lower operating costs.

When the performance of a thermal incinerator is falling short of legislated requirements, either due to a design limitation or to thermal stress-induced leakage, then the addition of an oxidation catalyst into the exhaust of the thermal incinerator can bring the incineration system back into compliance. The basic layout of a thermal incineration system fitted with a catalytic reactor is shown in Figure 1. The system comprises an incineration unit operating at a minimum temperature of 760°C together with a primary heat exchanger which preheats the inlet gases from the process. A secondary heat exchanger is normally installed to recover energy for other purposes. The temperature of the exhaust gas, after passing through a secondary heat exchanger, is typically around 400°C.

The temperature needed for the catalytic oxidation reaction for the majority of VOCs is between 280 and 400°C, and for carbon monoxide which can arise from partially combusted VOCs between 200 and 250°C. Therefore, the addition of a catalytic reactor into the exhaust duct of the incinerator presents the catalyst with the optimum temperature it needs to facilitate the complete oxidation of VOC and carbon monoxide emissions. Moreover, the catalyst is capable of operating at up to a temperature of 750°C, and it is therefore unlikely to be damaged, even under emergency venting of the thermal incinerator.

Catalyst Use in a Coil Coating Process

One such retrofit of a catalytic reactor into a thermal incinerator was completed by Johnson Matthey at Alcoa Manufacturing (GB), Swansea. Alcoa is the world's oldest and largest manufacturer of aluminium sheet for the beer, beverage and general purpose can manufacturing industry. Problems had been experienced with the thermal incinerator which treats fumes from the coil coating line, causing general concern

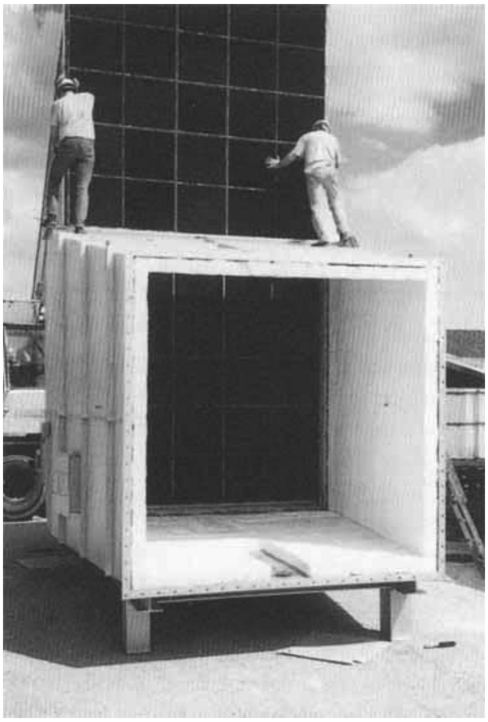

Fig. 2 The platinum-based catalyst, supplied in the form of metal honeycomb monoliths welded together to make two large panels, is being lowered into a purpose-designed reactor housing. The catalytic reactor is fully insulated to ensure maximum temperature of the gases reaching the catalyst, in order to attain the highest oxidation performance

about the odour and the level of VOC and carbon monoxide emissions into the atmosphere.

In the coil coating plant continuous aluminium sheet is coated with lacquers, which produce VOCs when passed through a high temperature treatment oven to make the finished product. The high concentration VOCs are destroyed by the thermal incinerator before exhausting to the atmosphere. However, after operating for 6 years the incinerator was found to be suffering from a leakage of VOCs across the primary heat exchanger into the cleaned exhaust gas. There was also some concern that the VOCs were not being effectively destroyed at the design incineration temperature of 720 to 760°C.

An on-site demonstration was undertaken by Johnson Matthey using a pilot-scale platinum-based oxidation catalyst connected so as to take a sidestream from the incinerator exhaust gas flow, at 380 to 425°C. During the extended trial the catalyst proved its capability not only in removing the odour from the incinerator exhaust gas, but also in achieving emissions containing very low levels of VOCs and carbon monoxide. As a result a full-scale catalytic reactor was designed for the maximum process flowrate of 70,000 Nm^3/h, taking into account the pressure drop limitations of the existing process exhaust fan and the available space in and around the incinerator exhaust duct.

The platinum-based catalyst was supplied in the form of metal honeycomb monoliths which were welded together to form two large panels and then lowered into a purpose-designed reactor housing, see Figure 2. The catalytic reactor was fully insulated to ensure maximum temperature of the gases reaching the catalyst, in order to attain the highest oxidation perfor-

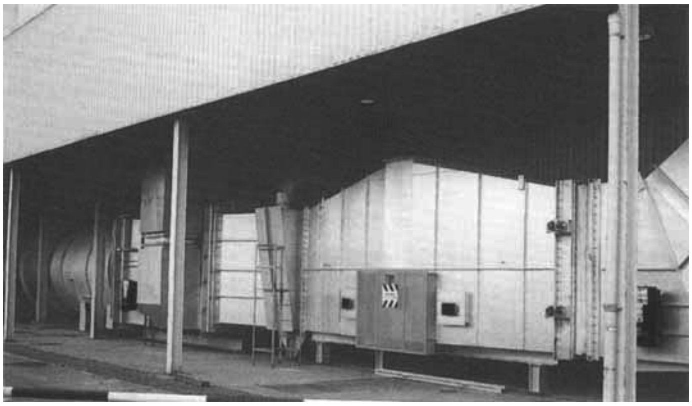

Fig. 3 Installation of the catalytic reactor at Alcoa Manufacturing (GB), Swansea, was completed within 48 hours, requiring the minimum shutdown on the coil coating plant. As presented in a consultant's initial evaluation the catalytic reactor has shown significant savings both in capital cost and in process downtime when compared with the alternative methods for returning the thermal incinerator to compliance

mance. Installation of the catalytic reactor was completed within 48 hours, requiring the minimum shutdown on the coil coating plant, see Figure 3.

As presented in the initial evaluation from the consultant of the options for Alcoa, the overall investment in the catalytic reactor installation has shown a significant saving both in capital cost and in process downtime when compared with the alternatives available.

Continuous monitoring of the stack emissions shows the catalyst to be achieving VOC and carbon monoxide emissions well within the limits set by the Environmental Protection Act.

Continuing Benefits from a Catalyst Retrofit

Once an oxidation catalyst has been retrofitted into a thermal incinerator exhaust duct there is the potential for significant savings in operating costs through a reduction of the combustion temperature in the incinerator. In Germany, following the retrofit of a platinum-based catalyst system by Johnson Matthey, the operator of a phenolic resin coating plant has been able to reduce his incineration temperature to less than 600°C. This has resulted in a reduced efficiency within the thermal incinerator which presents the downstream catalyst with greatly increased concentrations of VOCs and carbon monoxide.

However, the catalyst effectively oxidises these harmful gases and has brought the incinerator into compliance with the strict German air pollution control regulations (T. A. LUFT) while providing considerable savings in incinerator fuel for the operator. Moreover, operation at lower temperature has the added benefit of reducing thermal stresses in the incinerator, which would be expected to extend its operating life.

Platinum-based catalysts used for VOC control in industrial applications have been proven to have a typical lifetime of between five and seven years. Therefore, retrofitting a thermal incinerator with an oxidation catalyst represents a long-term solution to the problem of non-compliance with existing legislation, and can even be an answer to meeting future, more stringent, environmental legislation.

Tunable Iridium Based Infrared Detector

The detection of infrared radiation at wavelengths 0.75 to 20 micrometres is important for industrial process control, scientific imaging, thermography and radiometry, and surveillance; infrared cameras can be built from arrays of Schottky barrier detectors. The response of infrared detectors, based on Schottky diodes or heterostructures, to incident radiation is limited by the height of the internal potential barrier, and the cut-off wavelength depends on their construction. The longest cut-off wavelength, of 12 micrometres, has recently been achieved by iridium and platinum based Schottky detectors and by a SiGe/Si heterostructure. The cut-off wavelength can be changed only by lowering the Schottky barrier height, and the detectors can be tuned to only a few tens of meV.

However, if a detector had an asymmetrical metal-semiconductor-metal heterostructure, there should be modulation of several hundred meV, and an improved photoresponse. Now, researchers from France Telecom-CNET, have fabricated such a detector, which utilises an iridium electrode, and is tunable. The cut-off wavelength has moved from 2 to over 6 micrometres (I. Sagnes, Y. Campidelli and P. A. Badoz, *J. Electron. Mater.*, 1994, **23**, (6), 497–501).

The tunable infrared photoemission sensor, TIPS, of iridium/silicon/erbium silicide/silicon, is effectively two back-to-back Schottky diodes separated by silicon, creating an asymmetric potential barrier between the iridium and erbium silicide films. An iridium diode was made from evaporated iridium film; iridium and erbium silicide contacts were attached to the diode and an iridium dot, respectively.

With an external bias applied between the iridium and erbium silicide electrodes, the variation in the effective barrier height is over ten times larger than that of a standard Schottky barrier, and the cut-off wavelength can be modulated over a large range. On infrared illumination photocurrents are created, two, specific to TIPS, have tunable thresholds, of size depending on the incident photon energy, and on the applied bias. High detection levels are expected at 2 micrometres wavelength and at 125 K, and if it is combined with large focal plane arrays and with developing microelectronics technology novel detectors can be produced.