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Project Summary

Municipal Waste Combustion Assessment: Fluidized Bed Combustion

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This report describes an assessment of combustion control practices to minimize air emissions from refuse-fired fluidized bed combustors (FBCs). The three FBC configurations are described along with the design and operating characteristics of each, and the manufacturers of refuse-fired FBCs are identified. The waste-fired FBC population is overviewed, including existing, planned and/or projected, and recently cancelled facilities. Operating and emissions data are presented for the two existing U.S. facilities and one Swedish circulating bed plant.

The good combustion practice (GCP) design, operating/control, and verification recommendations developed for FBCs as part of this assessment are summarized. The GCP recommendations comprise a set of specifications and procedures designed to minimize emissions of organic compounds. Quantitative recommendations are provided for a number of the components; where lack of data or dependence on site-specific factors precludes quantitative guidance, generic recommendations are presented.

Two model plants developed to represent the population of FBCs projected to be placed in operation after the end of 1989 are described. The models are evaluated to determine the extent to which the GCP recommendations are incorporated within the projected population.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Based upon its analysis of Municipal Waste Combustors (MWCs), EPA has determined that MWC emissions may reasonably be anticipated to contribute to the endangerment of public health and welfare and warrant further regulation. As a result, EPA's Office of Air Quality Planning and Standards is developing emission standards for new MWCs under Section 111(b) of the Clean Air Act (CAA) and guidelines for existing MWCs under Section 111(d) of the CAA. In support of these regulatory development efforts, the Air and Energy Engineering Research Laboratory in EPA's Office of Research and Development has conducted an in-depth assessment of combustion control practices to minimize air emissions from MWCs. This report documents the results of that assessment for one specific MWC technology: fluidized bed combustors (FBC).

Objectives of this report were to identify the population of existing and planned refuse-fired FBC facilities in the U.S., examine the design characteristics and operating practices employed, define one or more model plants representative of the projected population, and develop recommendations for implementing good combustion practices for the control of organic emissions from FBCs.

Two Types of Combustors

Two types of FBCs are currently used or projected for use for refuse firing in the

U.S., bubbling bed FBCs and circulating fluid beds (CFBs). The two are distinguished primarily by the bed configuration. The relatively low fluidizing air velocity in the bubbling bed produces a stationary bed (consisting of approximately 99% inert material and 1% fuel) that resembles a violently boiling liquid. The higher fluidizing air velocity of the CFB entrains a significant portion of the bed material and carries it out of the reactor vessel. Solids are disengaged from the CFB gas stream in a hot cyclone and reinjected into the reactor.

The existing population of waste-fired FBCs in the U.S. consists of four units at two facilities. All of the units in the population are bubbling beds. The Western Lake Superior Sanitary District (WLSSD) co-fires 120 tons/day of RDF and 350 tons/day of wood chips in two Energy Products of Idaho FBC units at their French Island Generating Facility in La Crosse, WI. Both facilities have demonstrated total tetra- to octa-chlorinated dibenzo-p-dioxin and dibenzofuran (CDD/CDF) emissions rates below 20 ng/Nm^3 in compliance tests.

The planned and projected refuse-fired FBC population includes two units at one facility in the construction stage and 13 to 16 units at seven facilities in the feasibility study or early planning stage. Seven other facilities that were included in EPA's list of planned and projected facilities in May 1988 have either been cancelled or altered the project in a way that caused its removal from the FBC population.

GCP Recommendations

GCP recommendations consist of combustor design and operating specifications and procedures designed to minimize emissions of organic compounds. GCP recommendations were presented in the Report to Congress for three MWC technologies; these recommendations have subsequently been updated to account for recent data and expanded to cover the full range of MWC technologies. The design and operating parameters affected by the GCP recommendations are: Fuel feeding, temperature at fully mixed conditions, combustion air capacity and distribution, mixing, particulate matter carryover, auxiliary fuel capacity, and downstream gas temperature. These components were selected because each is individually necessary to the implementation of proper organic emissions control and the set, as a whole, is sufficient to ensure adequate control. Quantitative GCP recommendations were developed during this assessment for the temperature at fully mixed conditions, overfire air capacity, downstream gas temperature, and CO in flue gas; generic recommendations were identified for the other components.

GCP recommendations in EPA's 1987 Report to Congress for other MWC technologies specified a mean fully mixed temperature of 980°C; however, these recommendations were based on the need to maintain a conservative minimum temperature of 900°C where significant spatial and temporal temperature variations have been observed. FBC systems inherently have extremely efficient mixing and uniform temperature cross-sections, so the application of a safety factor to account for temperature variations is not necessary. Compliance tests for the two existing U.S. FBC facilities conducted at between 815 and 870°C resulted in low CDD/CDF emissions. Also, precedence for a lower temperature requirement has been established in permit limits set by the Pennsylvania Department of Environmental Regulation for the Erie County CFB (790°C) and the Wisconsin Department of Natural Resources for the French Island facility (815°C). These factors support the establishment of 815°C as the GCP recommendation for fully mixed temperature in FBCs.

The compliance tests at the NSP and WLSSD FBC facilities were conducted while the units were operating with approximately 40 and 0% of total air as overfire air, respectively. Both compliance tests resulted in low CDD/CDF emissions. However, the WLSSD system is designed such that RDF is injected near the bottom of the bed. In systems where overbed feed is employed, overfire air above the feeders may be essential to ensuring good mixing of fuel and air. Thus, FBC design recommendations include incorporation of an overfire air system capable of supplying 40% of the total combustion air. The 40% figure is based on engineering judgment of the overfire air jet momentum requirements.

Pilot scale and field test data from a wide variety of sources support the existence of a mechanism whereby CDD/CDF is formed downstream of the combustor by the catalytic action of fly ash constituents on the gas stream. Formation has been observed at temperatures between 200 and 400°C, with maximum formation at about 300°C. Downstream formation is thought to be minimized if the gas and solids residence time at between 200 and 400°C are minimized, i.e., the quench rate through these temperatures is maximized. In terms of practical GCP recommendations, the system should be designed such that the gas temperature at the inlet to the ESP or baghouse is maintained below 230°C.

Flue gas CO concentration is a good measure of combustion conditions. As such, it serves as a convenient, though inexact, surrogate parameter for CDD/CDF emissions, which also have been correlated to good combustion. The Gotaverken CFB in Sundsvall, Sweden maintained CO concentrations below 50 ppm. The WLSSD FBC also produced CO levels of less than 50 ppm. The NSP CO emissions of nearly 300 ppm, have been attributed to the compactness of the freeboard. Less than 2.7 m of furnace height separates the top of the bed from the entrance to the first convective section. While this space may be sufficient for oxidation of gas-phase organics which occurs essentially instantaneously (assuming the other GCP recommendations are in place), it is not sufficient to complete oxidation of CO to CO_2. Thus, 50 ppm (4-hour average) has been specified as the flue gas CO GCP recommendation for FBCs.

Two FBC model plants were developed to provide the basis for EPA health and economic impact analysis of the MWC regulation. Separate models were required because of the significant variation between bubbling bed and CFB CDD/CDF emissions. The bubbling bed model plant represents the population of new bubbling bed facilities expected to be placed in operation after regulation proposal at the end of 1989. Based on existing performance and emissions data, the bubbling bed model plant was judged to incorporate all of the GCP design and operation/control recommendations. The CFB model plant was based on the Gotaverken design, the only CFB design in the planned/projected population. The CFB model plant was judged to incorporate all of the GCP recommendations except minimizing particulate matter (PM) carryover. If the primary PM control device allows a significant fraction of the PM to pass into the boiler, organic and organic precursor material adsorbed on the PM may escape destruction. Field test data from a mass burn waterwall and an RDF spreader stoker MWC have shown a strong correlation between PM carryover and CDD/CDF emissions. The relatively high CDD/CDF emissions from the CFB model plant are also attributed to this mechanism. Unless a more efficient primary PM collection device can be incorporated into the design

further reductions in organic emissions may have to be effected through in-furnace sorbent injection and/or add-on pollution control devices.

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The complete report, entitled "Municipal Waste Combustion Assessment: Fluidized Bed Combustion," (Order No. PB 90-164 054/AS; Cost: $15.00, subject to change) will be available only from:
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