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Project Summary

Environmental Assessment: Source Test and Evaluation Report—Riley Gas Producer

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In December 1979, Riley Stoker Corporation conducted a test of the Riley Gas Producer, fueled by North Dakota (Indianhead) lignite. The test, at Riley Stoker's research center in Worcester, MA, was sponsored jointly by Riley Stoker and American Natural Service Company of Detroit, MI. Radian Corporation performed a Source Test and Evaluation (STE) of the Gas Producer as part of EPA's program to define and evaluate the environmental effects of low-Btu gasification. The results of the STE are presented in this report.

The STE involved characterization of all inputs and outputs of the Gas Producer. Material balances were also developed. The output streams included the product gas, ash pan water, cyclone dust, and gasifier ash. The results indicate that all output streams have some potential for environmental concern, as either fugitive emissions (product gas) or discharge streams (dust, ash, ash pan water). Analyses of the leachates of the gasifier ash and cyclone dust showed that they were nonhazardous according to Resource Conservation and Recovery Act protocol and standards.

This Project Summary was developed by EPA's Industrial Environmental 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

Radian Corporation is under contract to the EPA to perform a comprehensive environmental assessment of low- and medium-Btu coal gasification. This program includes the performance of Source Tests and Evaluations (STEs) to gather data for the assessment of viable low- and medium-Btu gasification systems.

This report, a Source Test and Evaluation Report (STER), gives results of an environmental assessment of the Riley Gas Producer. Riley Stoker Corporation, the Riley Gas Producer licensor, operates a commercial-scale pilot plant at its research center in Worcester, MA. The test program, commissioned by American Natural Service Company (ANSC) of Detroit, MI, was conducted in December 1979. Radian Corporation performed the STE during this period.

Test Overview

The STE was designed to collect data pertinent to the environmental assessment of the Gas Producer. For the most practical application of the results, testing was performed under steady-state operating conditions. The discharge and process streams of the gasification process were characterized to determine the potential environmental impact of each. Four streams were characterized: product gas, gasifier ash, cyclone dust, and ash pan water.

The product gas was separated into two fractions at 115°C (240°F) by the sampling procedure. The separation allows the assessment of potential health and ecological effects of fugitive emissions by characterizing the vapors of the product gas which are the most likely source of fugitive emissions. The separation was achieved by collecting the aerosol phase of the product gas in an electrostatic precipitator (ESP) operated at 115°C

(240°F). The aerosol phase consists of particulate matter and mist consisting of liquid tars and oils. The vapors of the product gas were collected downstream of the ESP, in a condenser at about 15°C (60°F), followed by either an organics adsorption resin (for collecting organic vapors) or an impinger train (for collecting vaporous trace elements, ammonia, or hydrogen cyanide).

The Riley Gas Producer is a modification of the Morgan Gas Producer, developed in England in the early 1900s. Riley Stoker purchased the licensing rights to the Morgan Gas Producer and has updated several design features. The gasifier feedstock was North Dakota (Indianhead) lignite supplied by ANSC. (NOTE: In December 1978, EPA characterized a Wellman-Galusha gasification system, using North Dakota (Indianhead) lignite, at the U.S. Bureau of Mines' Twin Cities Metallurgy Research Center at Fort Snelling.)

Major findings of this program are:

- Health effects bioassay tests of both solids and neutral leachates of the gasifier ash and cyclone dust indicated no adverse health effects; ecological bioassay results of neutral leachates of the gasifier ash and cyclone dust showed significant toxic effects.
- Leaching studies of the gasifier ash and cyclone dust, to determine the effects of solid waste disposal, indicated that the materials are nonhazardous according to Resource Conservation and Recovery Act (RCRA) protocol and standards.
- Over 50 percent of the lignite sulfur is converted to reduced sulfur species in the product gas.
- The nitrogen content of the ammonia (NH_3) and hydrogen cyanide (HCN) in the product gas is equal to about 26 percent of the lignite nitrogen content.
- Enclosing and pressurizing the coal bin and using nitrogen purge on the gasifier pokehole significantly reduces fugitive emissions from these sources.

Results

A major concern about using coal and coal-derived fuels in industry centers upon emissions of sulfur dioxide (SO_2, nitrogen oxides (NO_x), and particulates. While the actual emissions of SO_2 and NO_x due to syngas combustion depend on application, the following correlations can be made.

The North Dakota (Indianhead) lignite gasifier feedstock for the 24-hour test had an average sulfur concentration of 0.44 g/10^6 J (1.02 lb/10^6 Btu). About 53 (31-100+) percent of the sulfur being fed to the gasifier was converted to reduced sulfur species in the product gas. If 100 percent of the reduced sulfur species in the product gas were converted to SO_2 during combustion, the resulting SO_2 emission level would be 0.49 g/10^6 J (1.10 lb/10^6 Btu), based on the heat content of the lignite.

The average NH_3 concentration of the product gas was 7.8 x 10^5 μg/Nm^3 and the average HCN concentration was 1.8 x $10^5$$\mu$g/Nm^3. The nitrogen content of the product gas NH_3 and HCN is equal to about 26 percent of the lignite nitrogen content.

The particulate loading of the product gas stream was 4.76 x 10^5 μg/Nm^3, downstream of the cyclone. The particulate was assumed to be of the same composition as the cyclone dust, and the cyclone dust ash content (39.93 percent) was used to calculate the particulate emissions from combustion. Basing the adjusted particulate loading on the heat value of the lignite feedstock, the particulate emission after combustion would be 0.26 g/10^6 J (0.06 lb/10^6 Btu). This emission estimate does not consider possible particulate formation resulting from incomplete combustion of tars and oils.

Fugitive emissions of hydrocarbons were measured in the area of the gasifier by several methods. Hydrocarbon concentrations were less than 6.5 x 10^2 μg/Nm^3 (<1 ppm as CH_4). Hydrocarbons were also measured in the off-gases of the nitrogen-pressurized coal bin: the concentrations were 3.2 to 3.9 x 10^3 μg/Nm^3 (5 to 6 ppm as methane, CH_4). Readings of two carbon monoxide (CO) monitors maintained by Riley Stoker were recorded during the sampling: the maximum recorded concentration was 2.7 x 10^4 μg/Nm^3 (24 ppm), with readings generally well below this value. The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for CO is 5.7 x 10^4 μg/Nm^3 (50 ppm). There is no OSHA regulation for hydrocarbons as a compound class. Propane, the lightest hydrocarbon regulated by OSHA, has a PEL of 1.8 x 10^6 μg/Nm^3 (1000 ppm).

STEs have been performed for a Chapman low-Btu gasifier (with a bituminous coal feedstock) and a Wellman-Galusha low-Btu gasifier (with an anthracite coal feedstock). The Chapman STER gives results for coal feeder vent gases for hydrocarbons ($<C_7$) of 2.5 x 10^6 μg/Nm^3 and CO of 2 x 10^7 μg/Nm^3. The coal hopper gases at the Wellman-Galusha facility (anthracite) were reported in the STER as 1.4 x 10^6 μg/Nm^3 CH_4 and 2.7 x 10^8 CO. Related values measured at the Riley Gas Producer are several orders of magnitude less. These data demonstrate the relative reduction of fugitive emissions achieved by the controls used on the coal bin at the Riley Gas Producer.

Trace elements enter the gasification process with the lignite feedstock and are subjected to the high temperatures of the process. Many elements, especially the more volatile ones, are volatilized in the hot areas of the system and may: (1) remain a vapor in the product gas, (2) condense homogeneously, or (3) condense on aerosol particulates. Other elements, chemically transformed into gaseous species, are emitted in the product gas. Most trace elements remain in the coal solids and are emitted in the gasifier ash. Even though the majority of most elements are emitted with the solid waste streams, RCRA extraction procedures analysis results in the classification of these solids as nonhazardous.

Minor and trace elements can be grouped according to the mechanisms by which each is discharged. The elements found primarily in the product gas are considered highly volatile or transfomed into gaseous compounds. Moderately volatile elements, those found predominantly in the cyclone dust or product gas particulate, can be evaluated on the basis of volatilization and recondensation. Elements discharged predominantly in the gasifier ash are considered to be nonvolatile.

For this STE, an element was considered to be highly volatile if 25 percent or more of its total mass was found in the vapor portion of the product gas. These were:

bromine	gallium	silicon
cesium	iodine	sulfur
chlorine	mercury	tellurium
fluorine	selenium	

An element was classified as moderately volatile if 25 percent or more of its total mass was found in the cyclone dust and aerosols of the product gas. These were:

antimony	lead
arsenic	tin
chromium	zinc
germanium	

The following elements require additional data to characterize their behavior definitively:

- beryllium
- bismuth
- cadmium
- dysprosium
- erbium
- europium
- gold
- holmium
- iridium
- neodymium
- osmium
- palladium
- platinum
- praseodymium
- rhenium
- rhodium
- ruthenium
- silver
- tantalum
- terbium
- thallium
- thulium
- uranium
- yterrbium

Figure 1 shows the elemental distributions in the discharge streams, in the order of increasing boiling points. In general, as the elemental boiling points increase, the predominance of elemental distribution shifts from the product gas to the gasifier ash. Although a general trend is evident, there is no direct correlation between elemental boiling point and distribution. The distribution of individual elements in the system depends not only on elemental boiling point, but also on much more complex properties. These may include chemical reactions in the gasifier, the volatility of compounds containing the elements, and solubility of compounds in the tars and oils.

Gross alpha and beta radioactivities were determined on two samples of lignite, a composite cyclone dust, and a composite gasifier ash. In addition, gamma and alpha spectrometry was used for specific isotope analyses of these solid samples. Complete analytical results for gross alpha, beta, and specific isotope analyses are given in the full report.

Bioassay tests of the solid gasifier ash and cyclone dust indicated little or no health hazard. A neutral leaching of the two solid streams provided a liquid for bioassay testing that showed a high level of potential ecological hazard. However, subjecting the gasifier ash and cyclone dust to RCRA leaching studies resulted in the solids being classified as nonhazardous.

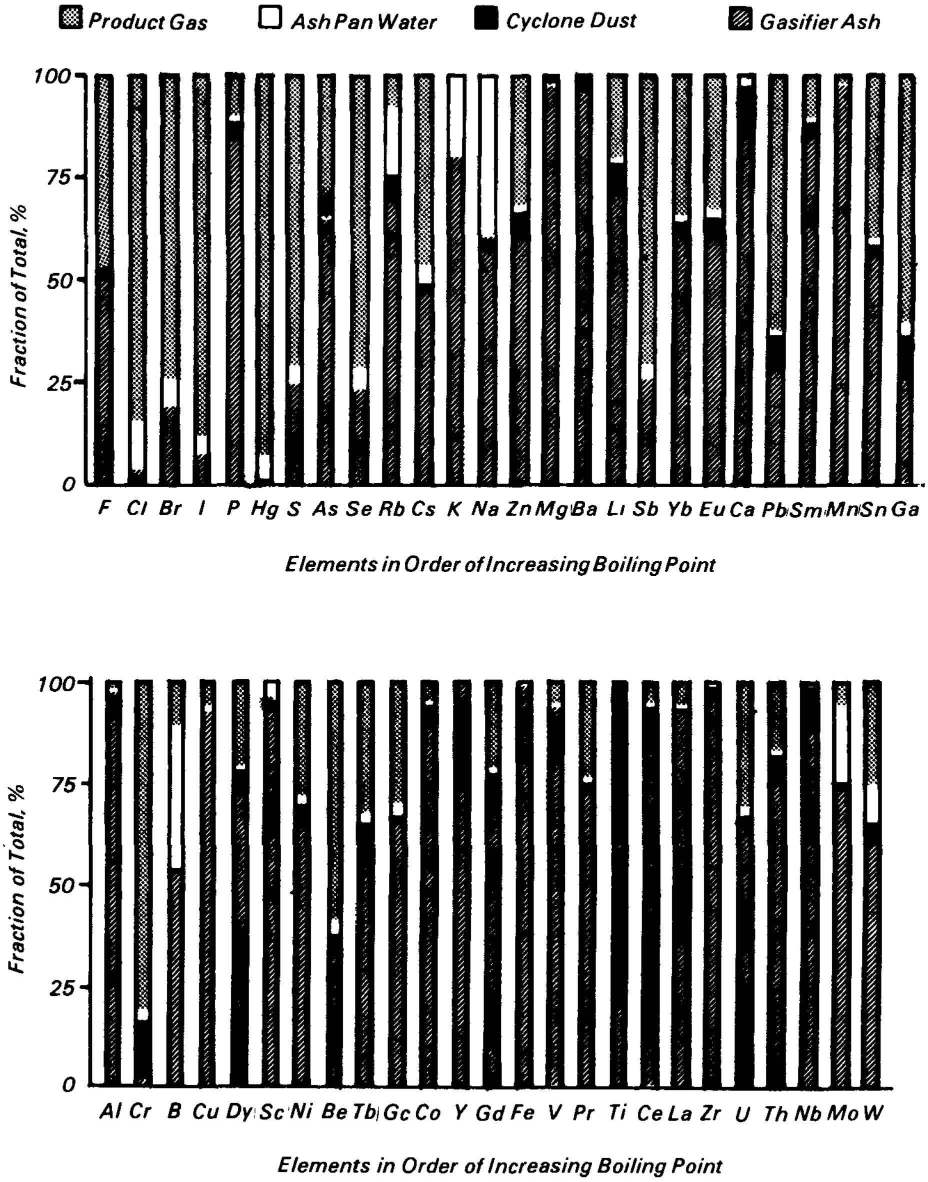

Figure 1. *Stream elemental distributions or percentage of combined discharge streams.*

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The complete report, entitled "Environmental Assessment: Source Test and Evaluation Report—Riley Gas Producer," (Order No. PB 84-246 396; Cost: $31.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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