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Project Summary

Co-Firing of Solid Wastes and Coal at Ames: Stoker Boilers

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This research program's objectives are to conduct an in-depth evaluation of the environmental, economic, and technical aspects of the resource and energy recovery system located in Ames, Iowa. The recovery system includes recovery of ferrous and aluminum metals, preparation of the refuse-derived fuel (RDF), storage for the RDF, and co-firing the RDF with coal in the City of Ames-owned power plant to produce electric power.

The full report includes evaluations of the refuse processing plant operation, economics of the total system and individual subsystems, flow stream characterization, performance of the stoker-fired steam generators, and environmental emissions of the stoker-fired steam generators. Previous studies at the Ames plant have been reported in three U.S. Environmental Protection Agency reports: EPA/600/2-77/205, "Evaluation of the Ames Solid Waste Recovery System, Part I—Summary of Environmental Emissions: Equipment, Facilities, and Economic Evaluations;" EPA/600/7-79/229, "Evaluation of the Ames Solid Waste Recovery System, Part II—Performance of the Stoker-Fired Steam Generators;" and EPA/600/7-79/222, "Part III—Environmental Emissions of the Stoker-Fired Steam Generators."

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, 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

The Ames Solid Waste Recovery System is a continuously operating system that is processing municipal solid waste (MSW) for use as a supplemental fuel in the steam generators of the Ames Municipal Power Plant. The total system consists of a nominal 136-Mg/day (150-ton/day) processing plant, a 454-Mg (500-ton) Atlas storage bin, pneumatic transport systems, and the existing municipal power plant. The processing plant incorporates two stages of shredding, ferrous and nonferrous metal recovery, and an air density separator. The three steam generators consist of one pulverized coal tangentially fired unit and two stoker-fired return traveling grate spreader units.

The full report is concerned with the following objectives:

- Evaluation of the refuse processing plant performance
- Economic evaluation of the Ames Resource Recovery System
- Characterization of the material flow streams within the refuse processing plant and the refuse-derived fuel produced
- Evaluation of the performance of the stoker-fired boilers
- Measurement of environmental emissions from the stoker-fired boilers
- Determination of boiler tube corrosion in the stoker-fired boilers.

The full report on this project presents the results and conclusions of the tests performed through the second year of evaluations (1977), and contains separate sections on each of the above six listed objectives.

Plant Description

This section addresses the operating experience of the general plant and the following subsystems:

- Tipping Floor
- Shredder System
- Air Density Separator System (ADS)
- Rejects
- Ferrous Metal Separation System
- Aluminum Separation System
- Pneumatic Conveying System (PSI)
- Atlas Bin

Figure 1 is a block flow diagram of the processing plant. MSW is delivered to the tipping floor which is 48 m by 32 m and has two entrances and exits. One is for commercial trucks and the other for private automobiles and pickup trucks. The commercial trucks are weighed on a truck scale, and the private vehicles are simply counted. A front-end loader is used to push the MSW onto the infeed conveyor C-1.

Raw refuse first enters the plant processing system via infeed conveyor C-1 into the first stage shredder, then via conveyor C-3 through the second stage shredder. A magnetic belt separator removes ferrous metal from the material flow stream between the first and second stage shredder. Conveyor C-6 transports the material from the second stage shredder into the air density separation subsystem. Light material is transported via a pneumatic conveying system to a storage bin (Atlas bin) prior to transport to the electric power generating plant. The heavy material drops out of the ADS onto conveying belts where it is transported to a reject bin. Material in the reject bin is periodically transported by truck to a landfill. Additional ferrous metal recovery is achieved from the ADS heavy material by a magnetic tail pulley and a magnetic head pulley. This ferrous metal is added to the ferrous metal recovered by the magnetic belt separator.

An aluminum separation system (Almag) composed of a trommel screen and an electrical eddy current separator

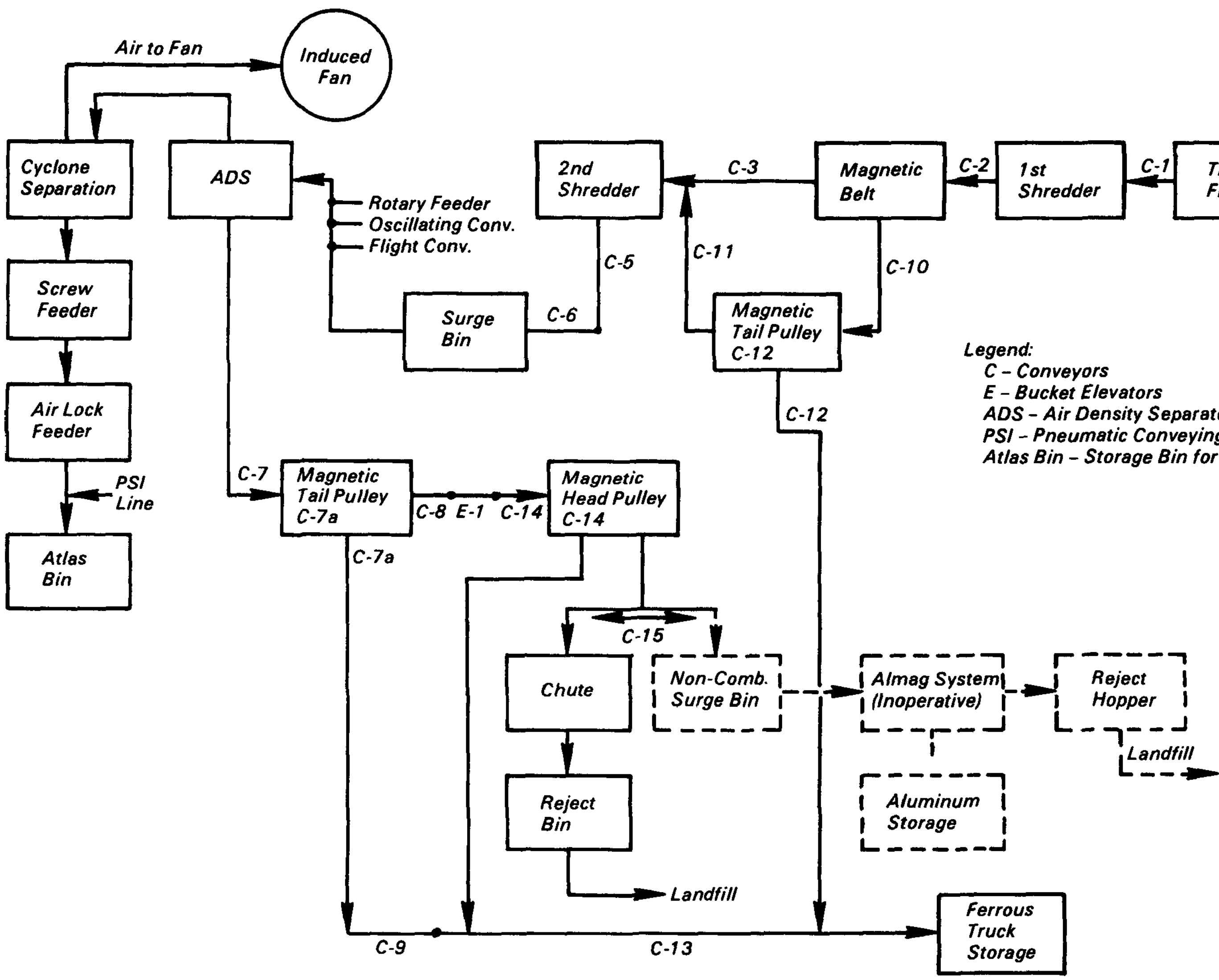

Figure 1. Flow diagram of Ames Solid Waste Processing Plant.

was originally installed at the plant, but this system is now inoperative. It is shown in dotted lines in Figure 1.

Operation of the process plant during 1977 represented the second year of operation. Processing occurred on a 5-day/week basis.

Economic Evaluation

This section presents an economic evaluation of the Ames Solid Waste Recovery System for 1977, its second full calendar year of operation. The experience gained in the first year of operation (1976) resulted in a reduction of overall operating expenses during 1977. While some costs were obviously reduced (e.g., lower overall costs), others actually increased. Those costs which increased were electrical energy and replaced parts primarily as a result of general economic inflation.

Initial capital expenditures have been estimated at $6.3 million, while initial capital investment for the refuse processing plant alone has been estimated at $4.1 million, and the capital costs of the storage bin and pneumatic transport system are estimated at $1.3 million.

The total plant expenses during 1977 were $992,270. This amount includes depreciation and interest on the capital expenditures and the refuse processing operational costs. Total revenue was $498,626 which was derived from the sale of RDF, metals, wood chips, and paper; fees charged for commercial and private haulers; and reimbursements and refunds.

The amount of refuse processed in 1977 was 43,891 Mg (48,381 tons). Based on this amount, the net cost for processing the refuse was $13.90/Mg ($12.61/ton). The average usage of electrical energy was 52 kWh/Mg of processed refuse.

Flow Stream Characterization

Initial flow stream sampling began July 5, 1977, and continued through July 13, 1978, in order to allow for characterization on a monthly and a seasonal basis. Sampling was conducted at 12 locations. Eleven locations were inside the process plant and one on top (inlet) of the Atlas storage bin.

Samples were taken by using a container attached to the end of a rod and passing it back and forth in a free-fall flow stream until the container was full. Samples were taken at 1.5 hr intervals beginning approximately 15 min after process plant start-up. Weekly composite samples for each location were generated, and from these, appropriate subsamples were prepared for the various analyses.

Performance of the Stoker-Fired Steam Generators

The conceptual design of the solid waste recovery system specified burning RDF in suspension in the pulverized coal-fired unit 7 (33 MW) at a firing rate of 20% (by heat input) or about 7.26 Mg/hr. Initial operation in fall 1975 resulted in a high dropout of unburned material into the bottom ash hopper. The power plant then began burning RDF in the stoker-fired boilers until a solution could be developed. The final solution was the installation of a dump grate at the furnace bottom. It was concluded that a dump grate configuration is also necessary in small- to moderate-sized suspension-fired steam generators.

The major research emphasis was on the thermal and environmental evaluation of the stoker-fired units.

Unit 5 is a Riley RP steam generator with a Riley overthrow spreader and traveling grate. Unit 6 is a Union Iron Works steam generator with a Hoffman underthrow spreader and continuous return traveling grate.

The RDF is pneumatically conveyed from the Atlas storage bin through two 31.5 cm transport lines and is blown into the furnace approximately 3.4 m above the grate. Two rows of nozzles in the rear furnace wall and two rows of nozzles in the front wall supply overfire air for turbulent mixing of the furnace gases.

Both units have dry pneumatic vacuum grate ash hopper and mechanical collector hopper ash removal systems.

Initial program objectives were to test boilers 5 and 6 at 60%, 80%, and 100% of rated steam load and at RDF firing rates (based on heat energy input) of 0%, 20%, and 50%. Three tests were made at each condition. The experience gained from firing unit 5 at 100% load with RDF demonstrated that this firing condition was not practical. For unit 6, nine tests were performed at 80% load. High particulate emissions occurred during tests at 80% of steam load, with varying RDF flow rates. A block diagram showing all sample locations and type of samples collected is shown in Figure 2.

Environmental Emissions of the Stoker-Fired Boilers

The preceding section includes descriptions of the Ames stoker-fired steam generators used for the tests. Both units have dry pneumatic vacuum bottom and fly ash removal systems. Mechanical dust collectors are installed on both units.

For this study, the independently controlled variables were load, based on steam flow, and RDF quantity, based on heat energy input to the boiler. Nominal load levels selected were 60%, 80%, and 100% of rated capacity; RDF quantities were 0%, 20%, and 50% of heat energy input.

For each steam flow and each quantity of RDF, three experimental runs were accomplished. For unit 5 the statistical design was 3 x 3 x 3 full factorial experiment with 27 runs needed to fill the data matrix of the experiment. These experimental runs were accomplished during 1976. After observing the operation of unit 5, a steam load of 80% was chosen as typical of boiler demand. Also at 80% load wall slagging was reduced, and excess air supplied for the coal and RDF combustion was optimum. Therefore, nine additional tests selected at 80% load were accomplished on unit 6. Testing of two boilers of similar type but different size allowed the investigators to observe whether boiler size had any effect on emissions.

Sampling of effluents was done according to EPA-prescribed techniques. Stack effluents, including particulate samples, were obtained at numerous prescribed points in the stack cross section. Three sampling trains operated simultaneously. An additional train was located before the particulate collector. Input fuel and grate ash were sampled at regular 1-hr intervals throughout the test period and then mixed to yield a composite sample. Hopper (fly) ash was sampled at the completion of each experimental run. Combustion air to the boiler was monitored by wet and dry bulb thermometry. Steam flow rate, temperature, and pressure were also recorded at regular intervals.

The sampling was conducted on a regular basis except that of heavy organic species, which were sampled intermittently.

The composite coal and RDF samples were analyzed in the Ames laboratory. Ultimate analyses and heating values were obtained by standard ASTM methods. Trace elements were determined by x-ray fluorescence (XRF).

The size distribution of the particulates after the dust collector was determined by an Andersen cascade impactor. Particulate samples obtained with the EPA Method 5 sampling train were analyzed by SRF. The impinger solutions from the

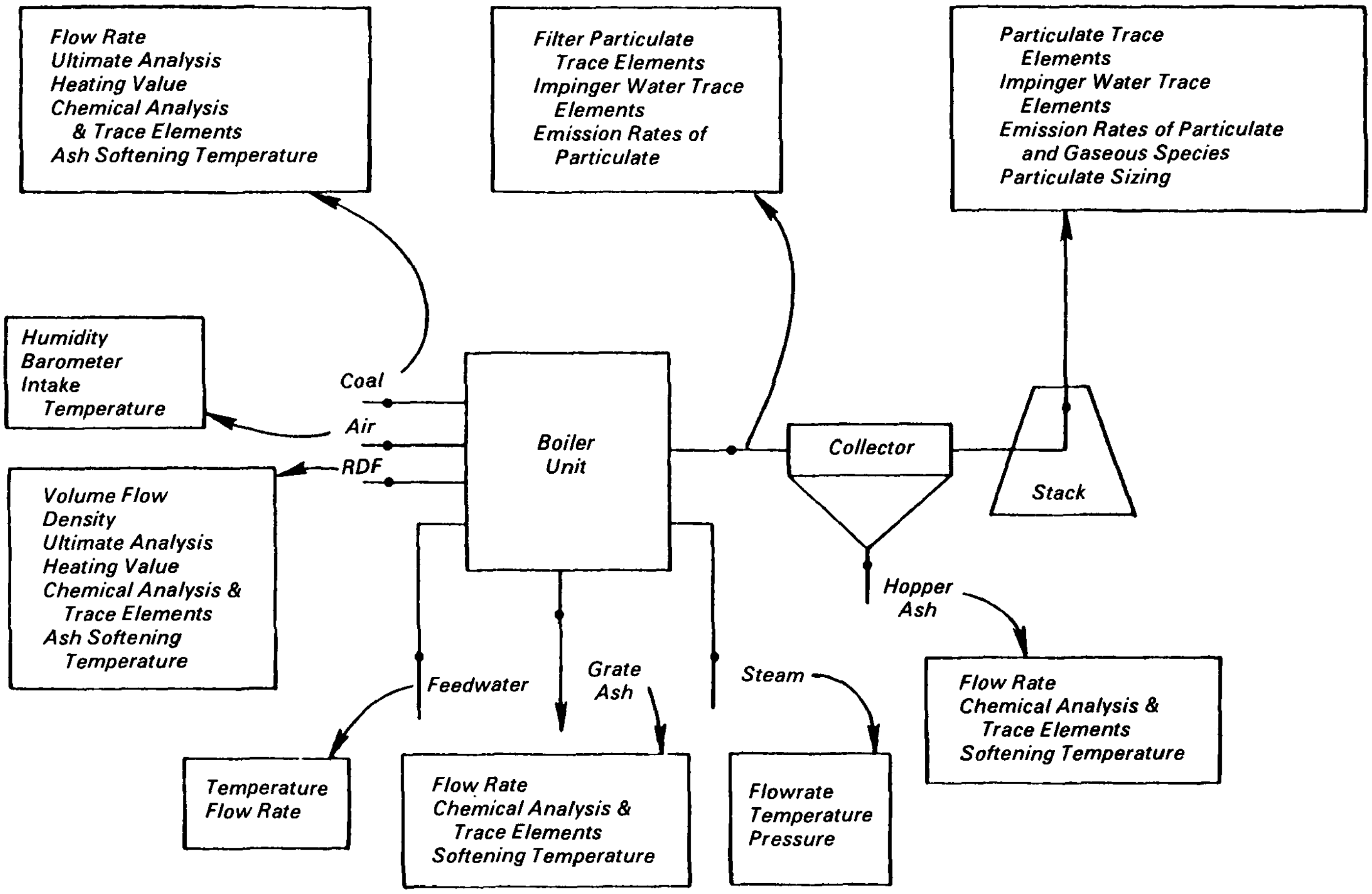

Figure 2. *Sample locations and items sampled.*

Method 5 train were analyzed with an inductively coupled plasma system.

The gases CO_2, CO, O_2, and N_2 in the stack were determined by Orstat techniques. EPA Method 7 was used for evaluation of NO_x levels, and the EPA Method 6 train was used for measurement of SO_x and chlorides. Grab samples of stack gas were obtained for measurement of C_1 through C_5 hydrocarbons by gas chromatography. Several modifications of the EPA Method 5 train were used to collect samples for analysis of aldehydes and ketones, chlorides, mercury, and other trace metallic elements. All inputs to and outputs from each boiler were evaluated including fuel, combustion air, bottom-ash, steam, fly ash, and stack gas.

Polynuclear aromatic compounds were sampled by drawing stack gas through a column of macro-reticular resin and also by extraction from particulates collected in the stack. Gas chromatography and mass spectroscopy were used for identification.

The uncontrolled particulate emissions from unit 5 have no discernible trend within the data scatter for 1976. However, the data taken during 1977 indicate a nearly linear increase in emissions of about 30% from 0% RDF to 50% RDF at a boiler load of 80%. This trend is similar to that indicated for unit 6, but the effect is much less exaggerated in unit 5. At 100% load, unit 5 was not stable in operation when the amount of RDF was increased to 50% which may account for considerable uncertainty in the data at this operating condition. The scatter in the 1976 data also reflects changes in uncontrolled factors in the tests while the operators were learning how to run the boilers when burning RDF with coal.

Uncontrolled particulate emissions from unit 6 increase about 100% in a nearly linear fashion from 0% RDF to 50% at boiler loads of both 60% and 80%. The trends for the data for 1976 are similar to those of the data for 1977. However, at 80% load, the magnitude of the uncontrolled particulate emissions on unit 6 was about one-third higher during 1976 than during 1977. In large part, this may reflect the learning experience of the boiler operators in controlling the amount of additional air routed to the boiler for burning the fuel. Increased air flow through the boiler appears to help carry proportionately more fine particulates through the boiler passages to the particulate collectors.

The increase in uncontrolled particulates with increases in RDF is believed to be due to the additional amount of air routed into the stoker-fired boilers in order to properly burn the RDF and to maintain a proper firebed on the boiler grates. The air flow through the boiler appears to carry additional particulate matter (fly ash) through the boiler passages in nearly direct proportion to the amount of the increase in air with RDF. The effect on unit 6 is exaggerated because of its physical size in cross sections is about the same as unit 5. However, boiler 6 generates 12 MW, while boiler 5 generates 7.5 MW. Thus, the air flow through boiler 6 is significantly larger than that through boiler 5.

Conclusions

RDF in combination with coal was successfully fired in the stoker boilers with no insurmountable problems. The operation of the boiler improved in terms of stability and consistency of measured variables from 1976 to 1977. This is believed to be a "learning effect" on the part of the boiler operators in properly firing the RDF and coal mixtures.

The combustible properties of the fly ash and the bottom (grate) ash became similar as the RDF approached 50%. The ash softening point of the ash lowered and the fouling index became more detrimental as the RDF was increased in the fuel input.

Uncontrolled particulate emissions tended to increase with corresponding increases in the RDF fraction of fuel input. This appears to be a result of both lighter particulates and increases in air flow through the boiler when burning RDF. Controlled emissions also appeared to increase with increases of RDF on unit 6, but the trend was uncertain on unit 5.

Both the oxides of nitrogen (NO_x) and oxides of sulfur (SO_x) decreased while chlorides increased significantly with increases in RDF. No discernible trends within the data scatter were noted concerning formaldehyde or hydrocarbon emissions. Increased emissions of the trace elements copper, lead, and zinc correspond to increases in RDF. Further studies of the trace element emissions are being performed.

Further studies are still in progress at the Ames facility. Thus, more specific conclusions cannot be made at this time. The final data from Ames, both economic and technical, will provide valuable design information for future plants and will aid operators of existing waste-to-energy plants.

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***Michael Black** is the EPA Project Officer (see below).*
The complete report, entitled "Co-Firing of Solid Wastes and Coal at Ames: Stoker Boilers," (Order No. PB 86-115 151/AS; Cost: $22.95, subject to change) will be available only from:
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