# Environmental Performance of the Robbins Resource Recovery Facility

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## INTRODUCTION

For many years there has been incremental improvement in the environmental performance of Municipal Waste Combustor (MWCs) facilities. These improvements were obtained by additional control hardware and additional chemical additives being applied to traditional grate combustion systems. This paper presents early environmental results from a new and different combustion system for MSW, the Circulating Fluidized Bed (CFB) boiler. These results indicate a significant improvement in the environmental performance of waste to energy facilities.

## DESCRIPTION OF FACILITY

The Robbins Resource Recovery Facility located in southern Cook County, Illinois, went commercial in January, 1997. It is designed to recover material for recycling and produce energy in the form of electricity from 1,600 tons per day (TPD) of municipal solid waste. The plant consists of two materials-recovery and fuel-preparation processing lines, two Refuse Derived Fuel (RDF)-fired CFB combustion systems, two state-of-the-art air pollution control systems, and a single turbine generator designed to produce more than 50,000 kW (gross) of electric power. The Robbins facility is a 24 hour-per-day, 365 day per year operation. The annual throughput of municipal solid waste (MSW) will be approximately 500,000 tons, assuming an 85% capacity factor.

This facility incorporates a combination of proven waste-conversion technologies in an innovative manner to exploit their inherent advantages, and the overall design builds on the industry's current experience.

### Materials-Recovery and Fuel-Preparation System

Two processing lines, each designed to process 85 tons per hour of MSW, operate at a nominal throughput of 64 tons per hour, 16 hours per day, five-and-one-half days per week.

Trucks deliver the waste to the MSW tipping building, where plant personnel direct the dumping onto the concrete tipping floor and inspect the waste for unacceptable and unprocessible material. Front-end loaders are used to separate unprocessible items, such as large appliances, and push the waste onto the in-feed conveyors. The MSW is conveyed past a picking station located ahead of the primary trommel, where personnel inspect the waste stream and remove additional unprocessible waste. The MSW tipping building is capable of storing 3,000 tons of MSW, or nearly two days of system feed requirements.

The fuel preparation system is shown schematically in Figure 1.

The primary trommel opens trash bags, breaks glass, and separates any material under six inches in size. The fraction of MSW not removed by the primary trommel is shredded using a horizontal hammermill to a particle size of 3.5 inches or less, and sent to RDF storage after passing a magnet for ferrous recovery.

Material removed by the primary trommel is conveyed first past a magnet for ferrous recovery then to a two-stage secondary trommel screen for separation into three streams:

- Glass and organics (yard and food wastes); (19% of waste stream)
- An aluminum-rich fraction (1%); and,
- A fuel fraction of burnable material (75%).

The glass-recovery system yields organic-free glass product (10% of waste stream) and a compostible organic material (9%). The glass product is sold for use as concrete aggregate and the compostible material is processed off-site into compost for use as a soil conditioner. Each processing line incorporates several overhead belt magnets strategically located and designed for the recovery of 90% of the ferrous metals, or approximately 5% of the total MSW throughput. RDF produced is conveyed to the RDF-storage building where an almost three-day (3,500 tons) intermediate storage capacity is provided. Direct-feed conveyors or front-end loaders transfer RDF to the CFB boiler feed system.

**CFB Boilers**

Each of the two CFB combustors is designed to burn 600 tons per day of RDF with a higher heating value (hhv) of 6,170 Btu/lb (3482 Kcal/kg) and produce 229,000 pounds per hour of superheated steam at 830° F and 900 psig. The furnace system is capable of handling fuel with hhv range of 4500-7000 Btu/lb (10,460-16,320 KJ/kg).

In each boiler, the RDF is fed through four feeders located on the front wall of the furnace. The top-supported furnace walls are water-cooled, welded tube-and-fin construction.

Following each furnace is a single high-efficiency cyclone completely cooled with saturated steam from the drum. The cyclone is constructed of Monowall$^{TM}$, a welded tube and fin construction. The cyclone separates entrained solids including unburned carbon from the flue gas and returns them to the furnace, providing excellent carbon burn-out. A cross-section of the boiler and associated air pollution control equipment is shown in Figure 2.

Downstream of the cyclone is a vestibule that encloses the steam-generating boiler bank and the pendant finishing superheater. The heat-recovery area (HRA) is the final segment of the steam generator. It encloses the primary superheater and economizer. All tubes in the HRA are designed on a large clear spacing with a low inter-tube velocity to minimize any accumulation of sticky ash deposits. Flue gas leaving the economizer passes through the air pollution control system prior to discharge to the exhaust stack.

The use of CFB-combustion technology provides the Robbins project with several conceptual advantages over conventional grate-type combustors and contributes to the high energy conversion and low pollutant emissions achieved by the facility. CFB combustors do not burn the solid waste on a grate or hearth as in conventional municipal waste combustors (MWCs). Rather, the waste is burned in a hot, fluid suspension of material, entrained in a substantial upward flow of gas. This fluid suspension, the "fluidized bed," consists of the RDF mixed with intensely hot particles (1600°F) of an inert bed material (a mixture of screened bed ash and sand).

Because of the inherent differences in the combustion process of conventional grate-type combustors and CFB combustors, several important advantages are realized with the use of CFB technology. These advantages include high combustion efficiency, low combustion temperature, reduced $NO_x$ formation, stable combustion, and clean stack emissions.

**High Combustion Efficiency.** The CFB's turbulent mixture of hot inert bed particles, fuel, and air results in excellent combination of the three T's of combustion: time, temperature, and turbulence.

Vigorous mixing of RDF with air, uniform combustion temperature within the entire furnace, and long residence time of the gases in the furnace contribute to high combustion efficiency.

The CFB's combustion capability is further enhanced by a highly efficient cyclone, which removes elutriated ash along with any unburned carbon from the flue gas. This ash, which normally would drop out into hoppers or be caught in the baghouse in a conventional combustor, is returned to the furnace for further carbon utilization.

Loss on ignition (LOI) testing show less than 1% carbon in the ash, giving 99% plus combustion efficiency, exceeding that of conventional solid-waste combustors, where only 97%-98% is achieved.

**Low Combustion Temperatures.** The CFB combustor typically operates in the range of 1525°-1675°F (829°-913°C). Besides reducing the potential for ash slagging and tube fouling, these relatively low temperatures reduce high temperature chlorine corrosion.

**Reduced $NO_x$ Production.** The low furnace temperature of the CFB combustor produces lower nitrogen oxide ($NO_x$) emissions than conventional high-temperature combustion. In addition, the introduction of combustion air in stages (different elevations) suppresses the generation of $NO_x$ even further. $NO_x$ emissions average under 100 ppmv in the CFB as compared with 200 to 350 parts per million volume (ppmv) typically achieved with grate combustors.

**Stable Combustion.** The CFB combustion process allows a large thermal mass to circulate between the furnace and cyclone. More material resides in the furnace at any given time than would be possible in a similar-sized grate type unit. A tremendous amount of heat is absorbed and retained by this large mass of inert particles. This gives the furnace a thermal inertia, maintaining a stable temperature throughout the furnace.

The intimate mixing of fuel and air due to the extreme turbulence greatly reduces the potential for hot spots or a localized reducing atmosphere. Thus, CFB technology is particularly able to effectively combust RDF that may vary dramatically in composition and heating value.

**Dioxin Emissions.** The highly turbulent mixing and prolonged gas-residence time in the CFB combustor provides for nearly complete destruction of dioxin precursors even at the lower combustion temperature.

## AIR POLLUTION CONTROL

Air emissions are controlled by the efficient combustion characteristics of the CFB boilers, a selective non-catalytic reduction (SNCR) system, and a semi-dry fluegas scrubber/baghouse system.

Due to the highly efficient combustion characteristics of the CFB technology at relatively low combustion temperatures (1500°-1700°F), together with staged combustion, $NO_x$ emissions are extremely low.

Acid gas and particulates are controlled by a combination semi-dry scrubber/fabric filter. The spray dryer reactor is a parallel downward flow type that utilizes multiple two-fluid nozzles for atomization of the lime and activated carbon slurry.

The fabric filter baghouse is a pulsejet with eight modules. Net/net (two modules out of service) air to cloth ratio is 4 to 1.

A continuous emissions monitoring system is used to control and record flue-gas opacity, sulfur dioxide, carbon dioxide, carbon monoxide, volatile organic compounds, and nitrogen oxide, ensuring compliance with applicable environmental standards. Tables 1 and 2 are daily summaries of the hourly averages from the CEM system for each unit for one day during the acceptance testing.

## HISTORY OF PERMIT REQUIREMENTS

Although the original permit to construct (PSD) was issued by the Illinois Environmental Protection Agency (IEPA) in June 1990, construction was not begun until 1994. The units are therefore regulated by the 1990 USEPA new source performance standards. A court order settling a procedural dispute in 1992 added Powdered Activated Carbon injection and a 80% mercury removal rate (below the previous requirement). An ambient monitoring program designed to show the effect of the facility on ambient pollutant levels was also instituted.

As a result of USEPA regulatory action in 1995, new federal requirements were added. Although the 1995 Emission Guidelines (40CFR60, subpart Cb) have been vacated by court order, the facility has submitted an application for an operating permit which contains those requirements.

Finally, in order to comply with a 1991 IEPA regulation concerning MWC metals, limits were placed on three additional metals: arsenic, nickel and chromium.

In the subsequent section, the emission test results are compared to the permit requirements. Since there are duplicative requirements for some pollutants, the permit requirements are a compilation of the above requirements and are the most stringent of the requirements.

## RESULTS OF TESTING

Compliance test results are compared to the regulatory limits in Table 3. While overall comparisons are favorable, a few results stand out. First, the CO concentration is extremely low, and has been continuously confirmed in this range by the CEM system. This is directly attributable to CFB combustion, as can the continuously low $NO_x$ emissions. This $NO_x$ result presented in Table 3 is without the urea injection system in operation, and again shows the low $NO_x$ potential of this firing method. The beneficial effects of the fuel processing system are evident in the low levels of heavy metals emission. The Mercury emissions data is with Powdered Activated Carbon being injected.

The CFB combustion process provides for increased fuel flexibility. This is shown in Table 4, which provides the air emission test results from burning an MSW mixture of 50% residential waste and 50% wood waste.

Although new construction activity for WTE plants is low in the U.S., European bidding opportunities are actually increasing. Table 5 presents the results in Table 3, converted to usual European convention. This Table also presents results from additional testing performed to begin a database on various other pollutants, which are a concern in Europe. Test results are compared to the required guarantees for a recent European request for proposals.

## POLLUTANT LOADINGS INTO THE APC

The most interesting aspect of the system performance is the contribution of CFB technology to the reductions in pollutant levels. Table 6 shows CFB outlet emissions for selected pollutants. As previously discussed, the $NO_x$ emission level shows the effect of limiting thermal $NO_x$ production during combustion and the staging of combustion air. Mercury levels reflect fuel processing, which eliminates practically all batteries and electrical components. The $SO_2$ emission is particularly notable. Emissions average a few ppm until the ash bed builds up, when $SO_2$ emissions drop near to zero. Keep in mind that this is a sand bed, not limestone as is usual with CFBs. (Limestone is usually added to the CFB bed material in order to capture sulfur. Because of the level of chlorine in the MSW, which is not captured at bed temperature, a traditional semi-dry scrubber is used for acid gas control.) As a matter of fact, $SO_2$ emissions on natural gas firing are higher than waste firing. This is thought to be the result of refinery gas (with low levels of $H_2S$) being blended into the natural gas pipeline. Absorption of the sulfur by the bed material also has an effect on the ash, as discussed below.

## RESULTS OF ASH TESTING

Robbins is unusual in the U.S., in that fly and bottom ash are not combined prior to disposal, but are handled separately. Also, due to the CFB combustion process, the ratio of bottom to fly ash is roughly the reverse of grate firing (recent testing shows 80% flyash, 20% bottom ash leaving the facility.)

Bottom ash is moved through the furnace area to an outlet location by a combination of an angled bed plate and the use of directional nozzles. Directional nozzles deliver the fluidizing combustion air, but in such a manner as to move the heavy bed material towards the discharge point. After cooling, the ash is screened and returned to the sand silo for bed make-up.

Fly ash is picked up from various boiler, scrubber and fabric filter hoppers and moved by drag conveyors to one of the fly ash storage silos. This ash is wetted during gravity loading into trucks, or can be transported dry if desired.

Table 7 provides results from TCLP testing of the bottom ash and flyash/scrubber residue. The excellent results are probably a combination of two factors. First, lower overall metals in the fuel, compared to mass burn, because of the fuel processing. Second, it appears that the conditions are right in the circulating fluid bed to form mineral combinations.

Because the ash in the bed is absorbing the sulfur, chemical reactions occur which appear to be binding metals in various sulfite and sulfate combinations. Future research includes looking for potential additives to improve the characteristics of the ash, increasing its market value.

## CONCLUSIONS

The environmental benefits of using CFB technology are fully realized at the Robbins facility. One quarter of the waste stream is recycled. Air emissions to the atmosphere are very low, both for criteria pollutants and for those considered a health risk. Electrical power is produced which replaces the use of coal at the local utility, reducing overall air emissions.

The CFB ash stream has the physical and chemical properties which can be utilized by industry. This not only reduces disposal costs, but reduces impact on the environment caused by the ash transportation and disposal.

This fully integrated facility has the potential for a 100% reduction in waste.

## BIBLIOGRAPHY

1. M. Matuny, "Circulating Fluidized Bed Combustor to Fire RDF in Integrated Recycling, Waste-to-Energy Facility," Fourth Annual Conference on Incineration, Manchester, UK, 1995.
2. B. C. Studley, R.H. Moyer, " Start-up Experience at the Robbins Resource Recovery Facility while focusing on the Environment," 5th Annual North American Waste-to-Energy Conference, 1997.

Table 1. CEM daily log, Unit A

Robbins Resource Recovery Facility.
Robbins, Ill. Unit A
Daily Summary Report-Stack

| Date | Time | $NO_x$ ppm | $SO_2$ ppm | CO ppm | THc ppm | $SO_2$Remove% |
|---|---|---|---|---|---|---|
| 01/16/1997 | 00:59 | 60 | 0 | 0 | 0 | 1.000 |
| 01/16/1997 | 01:59 | 64 | 0 | 1 | 0 | 1.000 |
| 01/16/1997 | 02:59 | 62 | 0 | 5 | 0 | 1.000 |
| 01/16/1997 | 03:59 | 56 | 0 | 6 | 0 | 1.000 |
| 01/16/1997 | 04:59 | 74 | 0 | 2 | 0 | 1.000 |
| 01/16/1997 | 05:59 | 76 | 0 | 4 | 0 | 1.000 |
| 01/16/1997 | 06:59 | 75 | 0 | 3 | 0 | 1.000 |
| 01/16/1997 | 07:59 | 65 | 3 | 1 | 0 | 0.785 |
| 01/16/1997 | 08:59 | 77 | 3 | 8 | 0 | 0.575 |
| 01/16/1997 | 09:59 | 73 | 0 | 1 | 0 | 1.000 |
| 01/16/1997 | 10:59 | 73 | 0 | 2 | 0 | 1.000 |
| 01/16/1997 | 11:59 | 66 | 0 | 1 | 0 | 1.000 |
| 01/16/1997 | 12:59 | 67 | 0 | 2 | 0 | 1.000 |
| 01/16/1997 | 13:59 | 72 | 0 | 3 | 0 | 1.000 |
| 01/16/1997 | 14:59 | 77 | 0 | 1 | 0 | 0.983 |
| 01/16/1997 | 15:59 | 61 | 0 | 1 | 0 | 1.000 |
| 01/16/1997 | 16:59 | 64 | 0 | 1 | 0 | 1.000 |
| 01/16/1997 | 17:59 | 83 | 0 | 12 | 0 | 0.862 |
| 01/16/1997 | 18:59 | 97 | 0 | 6 | 0 | 0.954 |
| 01/16/1997 | 19:59 | 91 | 0 | 35 | 0 | 0.916 |
| 01/16/1997 | 20:59 | 76 | 0 | 1 | 0 | 1.000 |
| 01/16/1997 | 21:59 | 77 | 0 | 5 | 0 | 1.000 |
| 01/16/1997 | 22:59 | 74 | 0 | 0 | 0 | 1.000 |
| 01/16/1997 | 23:59 | 74 | 0 | 0 | 0 | 1.000 |
| AVERAGE | | 72 | 0 | 4 | 0 | 0.961 |

- Corrected to $7\%O_2$

Table 2. CEM daily log, Unit B Robbins Resource Recovery Facility.
Robbins, Ill. Unit B
Daily Summary Report-Stack

| Date | Time | $No_x$ ppm | $SO_2$ ppm | CO ppm | THc ppm | $SO_2$Remove% |
|---|---|---|---|---|---|---|
| 01/16/1997 | 00:59 | 74 | 0 | 6 | 0 | 1.000 |
| 01/16/1997 | 01:59 | 81 | 0 | 6 | 0 | 0.968 |
| 01/16/1997 | 02:59 | 75 | 0 | 7 | 0 | 0.996 |
| 01/16/1997 | 03:59 | 78 | 0 | 8 | 0 | 0.973 |
| 01/16/1997 | 04:59 | 86 | 0 | 10 | 0 | 0.947 |
| 01/16/1997 | 05:59 | 83 | 0 | 10 | 0 | 0.946 |
| 01/16/1997 | 06:59 | 86 | 3 | 8 | 0 | 0.836 |
| 01/16/1997 | 07:59 | 73 | 0 | 5 | 0 | 0.964 |
| 01/16/1997 | 08:59 | 79 | 1 | 4 | 0 | 0.882 |
| 01/16/1997 | 09:59 | 82 | 0 | 7 | 0 | 0.959 |
| 01/16/1997 | 10:59 | 77 | 0 | 4 | 0 | 0.977 |
| 01/16/1997 | 11:59 | 82 | 0 | 6 | 0 | 1.000 |
| 01/16/1997 | 12:59 | 76 | 0 | 3 | 0 | 0.979 |
| 01/16/1997 | 13:59 | 77 | 0 | 3 | 0 | 0.968 |
| 01/16/1997 | 14:59 | 89 | 0 | 5 | 0 | 0.894 |
| 01/16/1997 | 15:59 | 89 | 0 | 6 | 0 | 0.707 |
| 01/16/1997 | 16:59 | 89 | 0 | 5 | 0 | 0.647 |
| 01/16/1997 | 17:59 | 92 | 0 |  | 0 | 0.872 |
| 01/16/1997 | 18:59 | 91 | 0 | 8 | 0 | 0.612 |
| 01/16/1997 | 19:59 | 97 | 0 | 6 | 0 | 0.992 |
| 01/16/1997 | 20:59 | 93 | 0 | 4 | 0 | 0.986 |
| 01/16/1997 | 21:59 | 89 | 0 | 2 | 0 | 0.981 |
| 01/16/1997 | 22:59 | 98 | 0 | 6 | 0 | 0.994 |
| 01/16/1997 | 23:59 | 90 | 0 | 4 | 0 | 0.994 |
| AVERAGE |  | 84 | 0 | 6 | 0 | 0.920 |

- Corrected to $7\%O_2$

Table 3. Comparison of Compliance Stack Test Results to the Emission Permit Limits.

| Pollutants | Units | Burning 100% RDF<br>Unit A | Unit B | Permit Limit |
|---|---|---|---|---|
| Particulate | gr/dscf | 0.0015 | 0.0056 | 0.01 |
| $SO_2$ | ppm | 1.0 | 0.5 | 30 |
| HCl | ppm | 4.6 | 6.2 | 25 |
| CO | ppm | 4.4 | 2.2 | 100 |
| $NO_x$ (1) | ppm | 73.1 | 90.4 | 130 |
| VOC | ppm | 1.5 | 0.6 | 10 |
| Total dioxin-furans | ng/dscm | 2.1 | 4.9 | 30 |
| Total TE (89 EPA) | ng/dscm | 0.05 | 0.13 | NA |
| Arsenic | $\mu$g/dscm | 0.2 | 0.2 | 10 |
| Cadmium | $\mu$g/dscm | <detection limit (0.01) | 0.3 | 40 |
| Chromium | $\mu$g/dscm | 4.8 | 5.6 | 120 |
| Lead | $\mu$g/dscm | 3.6 | 30.9 | 490 |
| Mercury | $\mu$g/dscm | 15.8 | 2.9 | 80 |
| Nickel | $\mu$g/dscm | 3.1 | 3.1 | 100 |

- All concentration are at 7%$O_2$, dry.
- NA = Not Applicable
- (1) $NO_x$ values are without SNCR system in operation.
- Average of 3 test runs
- 3-hr. test runs for all pollutants, except 4-hr. for PCDD/F

Table 4. Comparison of Compliance Stack Test Results to Emission Permit Limits.

Burning 50% Residential Waste and 50% Wood

| Pollutants | Units | Unit B | Permit Limit |
|---|---|---|---|
| Particulate | gr/dscf | .0047 | 0.01 |
| $SO_2$ | ppm | 0.6 | 30 |
| HCl | ppm | 2.4 | 25 |
| CO | ppm | 1.9 | 100 |
| $NO_x$ (1) | ppm | 82.5 | 130 |
| VOC | ppm | 0.9 | 10 |
| Total dioxin-furans | ng/dscm | 2.1 | 30 |
| Total TE (89 EPA) | ng/dscm | 0.053 | NA |
| Arsenic | $\mu$g/dscm | 0.3 | 10 |
| Cadmium | $\mu$g/dscm | 0.1 | 40 |
| Chromium | $\mu$g/dscm | 5.9 | 120 |
| Lead | $\mu$g/dscm | 22.1 | 490 |
| Mercury | $\mu$g/dscm | 0.5 | 80 |
| Nickel | $\mu$g/dscm | 3.1 | 100 |

- All concentration are at 7%$O_2$, dry.
- NA = Not Applicable
- (1) $NO_x$ values are without SNCR system in operation.
- Average of 3 test runs
- All test runs 3-hr., except 4-hr. for PCDD/F

Table 5. Robbins RRF's Compliance Stack Test Results vs. European Air Emission Requirements.

| Pollutants | Unit A | Unit B | Recent European Requirement |
|---|---|---|---|
| Total Particulates | 2.62 | 9.76 | 15 (hourly) |
| Hydrochloric Acid | 5.34 | 7.2 | 10 (daily av.) |
| Sulfur Dioxide | 1.89 | 1.02 | 50 (daily av.) |
| Carbon Monoxide | 3.92 | 1.96 | 50 (daily av.) |
| Volatile Organic substance, given as total carbon (THC) | 0.07 | 0.3 | 5 (daily av.) |
| Nitrogen Oxide | 107 | 132 | 200 (daily av.) |
| Ammonia | <1.9 | <1.9 | 10 (daily av.) |
| Hydrogen Fluoride | <.06 | <.06 | 1 (daily av.) |
| Cadmium + Thallium | .001 | .002 | 0.05 |
| Mercury (Hg) | 0.01 | .002 | 0.05 |
| Pb + Cr + Cu + Mn + Ni + As + Cd + Hg | .08 | .06 | 2 |
| * Dioxins and Furans (ITE) | .039 | .10 | 0.10 |
| Polynuclear Aromatic Hydrocarbon (PAHs) | .0007 | .0008 | 0.05 |
| Chlorophenol | <.0006 | <.0006 | .001 |
| Hydrogen Cyanide (HCN) | <.004 | <.004 | 0.50 |
| Chlorobenzene | <.00005 | <.00005 | .001 |

- All concentration are mg/Nm$^3$ at 11% $O_2$ except noted otherwise.
- *ng/NM$^3$ at 7% $O_2$
- Average of 3 test runs
- All tests 3-hr. duration, except 4-hr. for PCDD/F
- Ammonia detection limit with CEM

Table 6. Emission at the CFB Boiler Outlet

| Pollutant | Units | Unit A | Unit B |
|---|---|---|---|
| CO | ppm | 4.4 | 2.2 |
| $NO_x$ | ppm | 73.1 | 90.4 |
| $SO_2$ | ppm | 6.6 | 1.7 |
| HCL | ppm | 357.5 | 351.2 |
| Mercury | $\mu$g/dscm | 60.7 | 141 |

- All concentrations corrected to 7% $O_2$.
- Average of 3 test runs

Table 7. Summary of Ash Analytical Results.

Flyash Performance Test Samples

| Parameter | Regulatory Limit | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|
| TCLP arsenic | 5 | <0.05 | <0.05 | <0.05 |
| TCLP barium | 100 | <5 | <5 | <5 |
| TCLP cadmium | 1 | 0.2 | <0.05 | <0.05 |
| TCLP chromium | 5 | <0.5 | <0.5 | <0.5 |
| TCLP lead | 5 | <0.5 | <0.5 | <0.5 |
| TCLP mercury | 0.2 | <0.05 | <0.05 | <0.05 |
| TCLP selenium | 1 | <0.05 | <0.05 | <0.05 |
| TCLP silver | 5 | <0.5 | <0.5 | <0.5 |
| Putrescibles | NA | <0.01% | <0.01% | <0.01% |

Bottom Ash Performance Test Samples.

| Parameter | Regulatory Limit | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|
| TCLP arsenic | 5 | <0.05 | <0.05 | <0.05 |
| TCLP barium | 100 | <5 | <5 | <5 |
| TCLP cadmium | 1 | 0.05 | <0.05 | <0.05 |
| TCLP chromium | 5 | <0.5 | <0.5 | <0.5 |
| TCLP lead | 5 | <0.5 | <0.5 | <0.5 |
| TCLP mercury | 0.2 | <0.05 | <0.05 | <0.05 |
| TCLP selenium | 1 | <0.05 | <0.05 | <0.05 |
| TCLP silver | 5 | <0.5 | <0.5 | <0.5 |
| Putrescibles | NA | <0.01% | <0.01% | <0.01% |

- TCLP metals concentrations are in PPM.
- NA = Not Applicable
- Putresicible not detected at indicated concentration

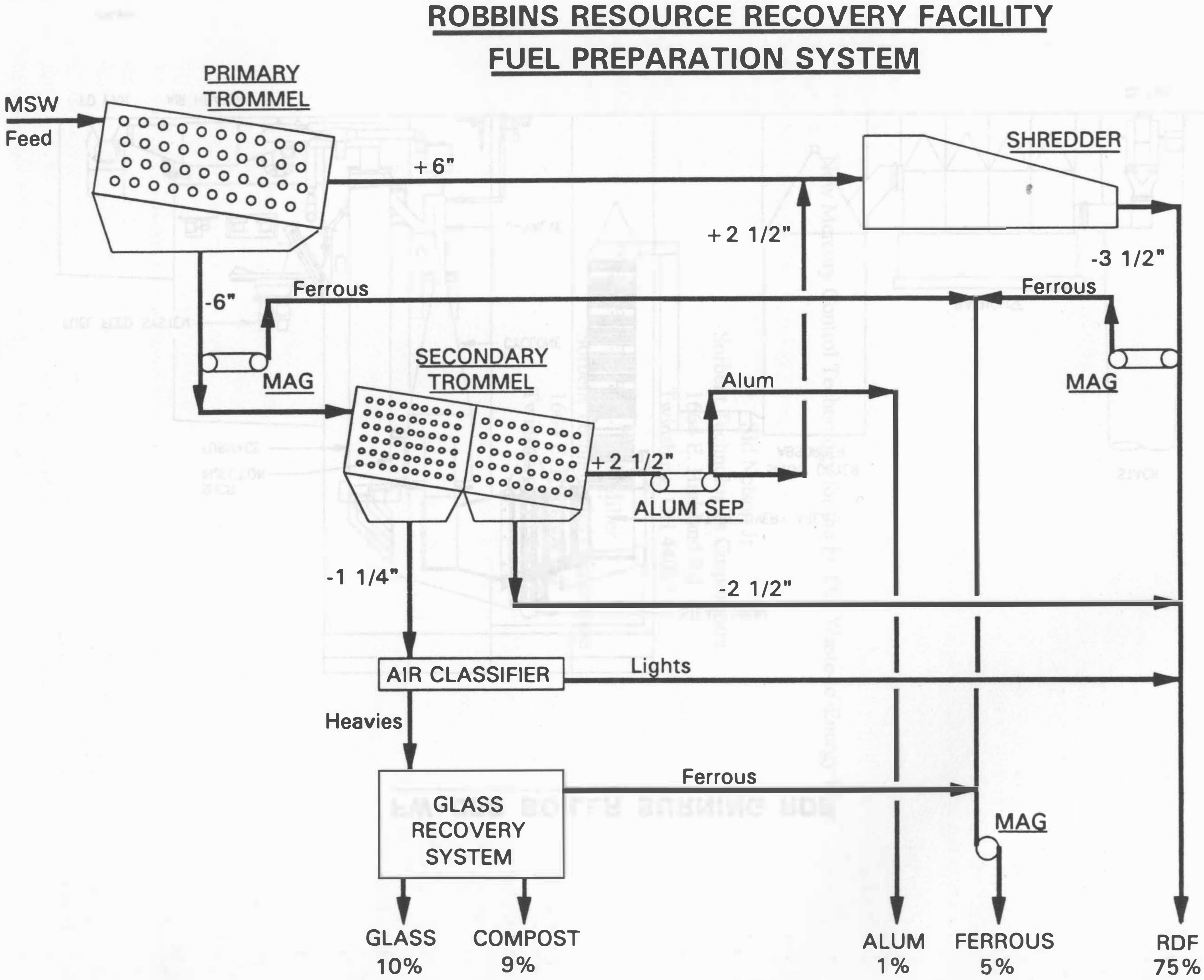

Figure 1. Fuel Preparation System

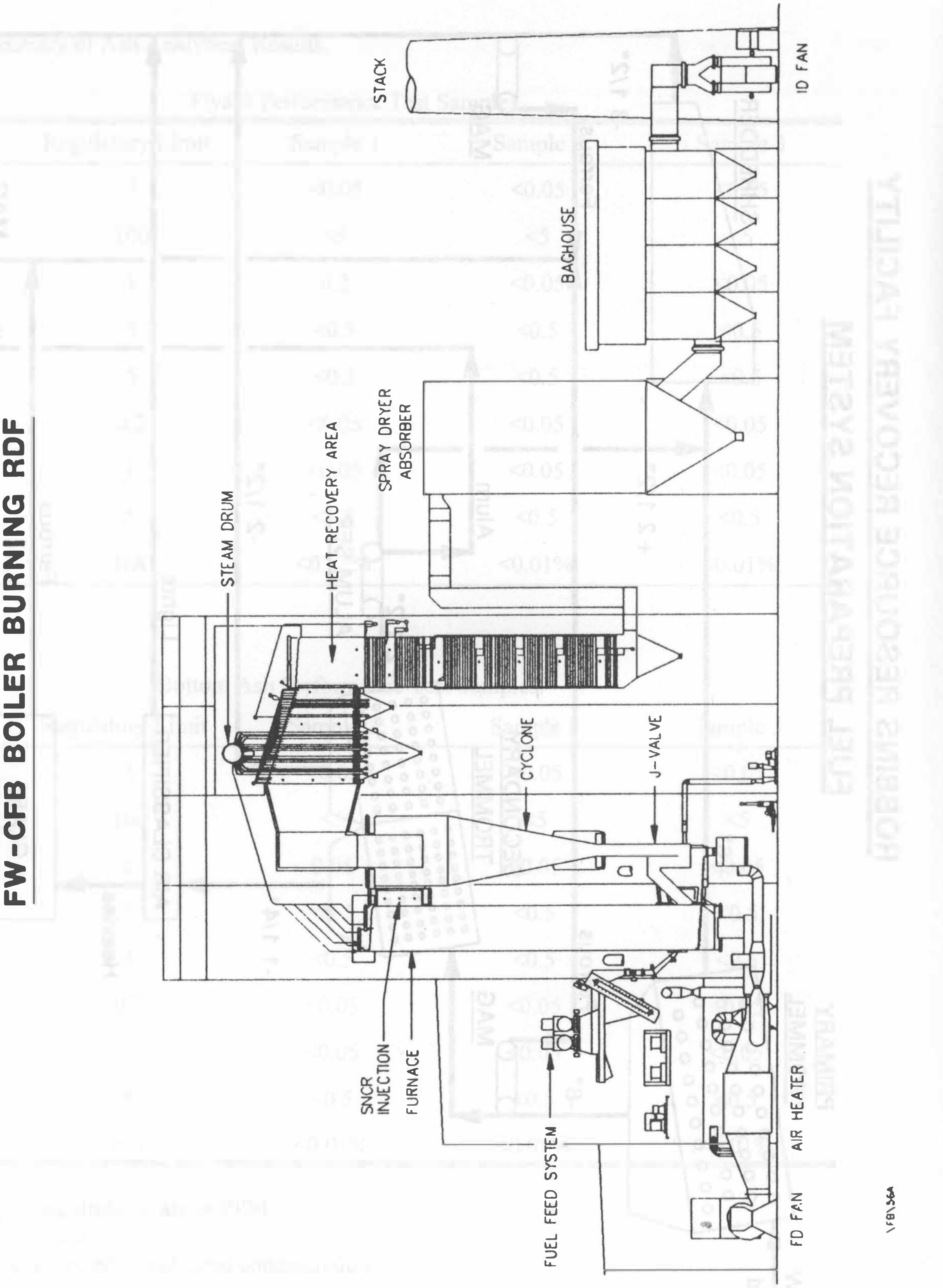

Figure 2. Cross-section of CFB and Air Pollution Control Equipment.