# TECHNOLOGY AT WORK:
# RILEY'S MSW R & D COMBUSTION TEST PROGRAM

By

Craig. A. Penterson
Staff Engineer — Research and Development

and

Harry T. Culberson
Marketing — Services Manager

RILEY CONSOLIDATED, INC.
Worcester, Massachusetts 01606

Presented at the

Eighth Annual New England Resource Recovery
Conference and Exposition
Newport, Rhode Island
June 5-7, 1989

RST 81

RILEY STOKER CORPORATION
BOX 15040, WORCESTER, MA 01615-0040

# TECHNOLOGY AT WORK
# RILEY'S MSW R & D COMBUSTION TEST PROGRAM

by

**Craig A. Penterson**

and

**Harry T. Culberson**
**Riley Consolidated, Inc.**

**ABSTRACT** *Riley Stoker Corporation, located in Worcester, Massachusetts has built one of the few pilot-scale test facilities designed to evaluate changing the parameters of combustion in the incineration of Municipal Solid Waste (MSW). The purpose of the test facility is to improve combustion efficiency while maintaining stable operating conditions.*

*The current program was initiated to evaluate the potential for reducing emissions from the combustion of Municipal Solid Waste using natural gas reburning. The program is being conducted by the Institute of Gas Technology, the Gas Research Institute, Riley Stoker and Takuma Company Ltd. which includes three major ongoing tasks: (1) acquisition of baseline data from a commercial operating facility, (2) pilot-scale development and testing of the technology, and (3) field demonstration testing of the technology.*

*This paper will present an overview and description of the R & D facility and the technology being developed. We will focus on the results of task one and two listed above. Task 3, field demonstration testing of the technology will be introduced. The anticipated goals and benefits to both industry and the community will be presented. This will include: lower emissions; lower plant maintenance; and lower facility tip fees.*

## INTRODUCTION

The United States presently generates approximately 160 million tons of residential and commercial solid waste annually. It is anticipated this amount will increase close to 200 million tons by the year 2000. Combustion of municipal solid waste (MSW) in a resource recovery facility is a critical part of the solid waste management solution. Integrated management including waste reduction, recycling and landfilling along with resource recovery are all necessary in solving our solid waste crisis.

As a subsidiary of Riley Consolidated, Inc. (RCI), Riley Energy Systems (RES) is a full service contractor providing ownership, engineering, construction, operations and maintenance of today's resource recovery facilities. Established in 1987, RES is to pursue full service opportunities incorporating the products, technologies and services offered by Riley Stoker Corporation (RSC) our sister company (another RCI Company).

Riley Stoker Corporation, a leading manufacturer of steam generating and fuel burning equipment, was established in 1913. RSC has been involved in the evolution of combustion and energy conversion of conventional and unconventional fuels since its inception.

Riley is no stranger to the development and advancement of combustion processes in which Riley has been involved such as:

- Low NOx Burners for Utility and Industrial Businesses
- Fuel Additives for more Efficient Combustion
- Staged Combustion
- Fluidized Bed Combustion
- Gasifiers

Consistent with the development and advancements of the broad array of Riley products and technologies, Riley has now taken steps to advance the technology of burning MSW.

At the heart of a RES facility is the proven mass burn grate system of Takuma Co., Ltd. of Japan. Takuma, established in 1938, has in their own right established themselves as an important and integral part of the industries of the Far East. Takuma is a manufacturer of boilers and MSW combustion technology. To date, Takuma has installed more than 250 MSW facilities, more than any other technology supplier in the world. As these statistics would indicate, their development and advancements in the incineration of MSW is second to none.

Successful incineration of MSW must address the problems encountered with the inconsistencies of the fuel. The modern incinerator not only has to efficiently reduce the volume of waste, but must on a consistent basis, conform to the most stringent environmental requirements and regulations.

The Riley-Takuma combustion process incorporates a specific type of stoker construction and furnace geometry for the incineration of MSW. It is complemented by a sophisticated combustion air system and advanced combustion control method( 1). The reported and documented performance at both the Olmsted County, Minnesota and Jackson County, Michigan facilities, which incorporate the Riley-Takuma process, demonstrate the capability of the system.

In order to achieve even better combustion performance, more information still needs to be gained regarding the combustion characteristics of MSW. Of primary concern are the pollutant emissions produced during the combustion process and the ability to control these emissions. Similar to most combustion operations these pollutant emissions include oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), total hydrocarbons (THC) and particulates. The presence of chlorine raises concern regarding other pollutant emissions such as hydrogen chloride (HCI), polychlorinated dibenzodioxins (PCDD's) and polychlorinated dibenzofurans (PCDF's). Of additional concern is the impact of recycling on the region and the impact of more stringent emission requirements.

Riley has taken the first step in addressing the future design advancements in today's state-of-the-art MSW systems. In an effort to support the research needs, Riley Stoker Corporation designed and built in 1988 a new pilot-scale combustion test facility to burn processed MSW. The facility is located at the Research and Development Center of Riley Stoker Corporation in Worcester, Massachusetts.

The following is an overview and description of the pilot-scale facility and a test program currently underway at Riley's R&D facility.

## PILOT MSW COMBUSTION FACILITY

The pilot-scale step grate design is a prototype of a full scale Riley-Takuma system for mass burning. As shown in Figure 1, the Takuma stoker consists of four separate sections; feeder table, drying and ignition grate, combustion grate, and burnout grate. Between the grate sections are two to three foot drops which reduce top to bottom fuel stratification and break up large agglomerations. Fuel drying, pyrolysis, and ignition occur on the drying and ignition grate. About 95 percent of the fuel combustion occurs on and over the combustion grate. The burnout grate provides time for carbon burnout and reduction of putriscibles under locally high excess air conditions. The Riley-Takuma system is designed to handle refuse throughputs from 100-1000 tons per day.

The pilot-scale stoker was designed in a similar fashion utilizing the Takuma technology. However, it was designed to burn refuse at a rate of 450 lb/hr or 5.5 tons/day. This will produce approximately 3 million Btu/hr heat input to the test furnace. The physical size of the pilot facility is too small to accommodate the large size of the constituents typical ly found in raw MSW. Therefore, processed refuse, from an RDF plant in Biddeford, Maine, rather than raw MSW, is burned. This precludes the potential plugging problems associated with handling raw MSW.

Figure 2 shows a schematic drawing of the Riley Pilot MSW Combustion Facility. The combustor section of the facility is 17' -0" tall x 11' -9" long x 3' -0" wide. Included in this section is a refuse feed chute, grate system, ash discharge hopper, overfire air (OFA) nozzles, natural gas injection nozzles, recirculated flue gas nozzles, undergrate air (UGA) and a startup gas burner. The furnace walls are water-cooled with high insulating refractory attached to the inside surface to produce a thermal environment typical of field operating conditions. Figure 3 shows photographs of the combustor section.

Refuse is first manually removed from a 45' trailer and dropped into a small fuel hopper mounted at the entrance to a drag chain conveyor. The covered conveyor then transports the refuse from the hopper up into the feed chute. Water sprays have been installed along the length of the conveyor to wet the refuse if required. The refuse then falls into the storage hopper of the combustor. As the refuse slides down the chute, it falls on top of a ram feeder which periodically pushes a portion of the refuse into the combustor. The feed pusher as well as all the grate sections are driven in a reciprocating motion by hydraulic cylinders. Similar to the Riley-Takuma system, the refuse then falls and cascades down the drying, combustion and burnout grate sections. Figure 4 shows a photograph of the individual grates looking from the ash hopper upwards, toward the feeder.

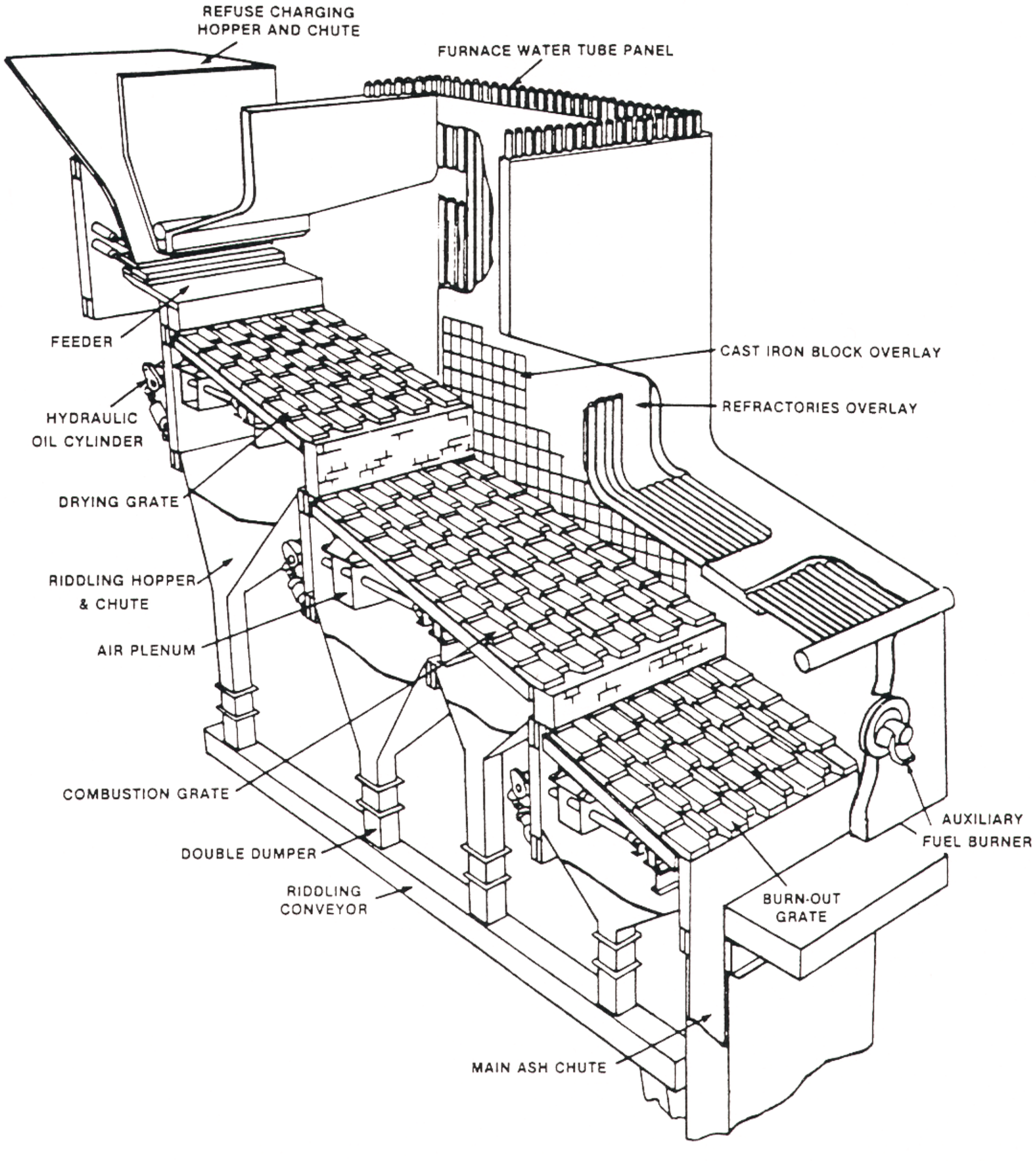


**Figure 1. Riley-Takuma MSW Stoler Grate**

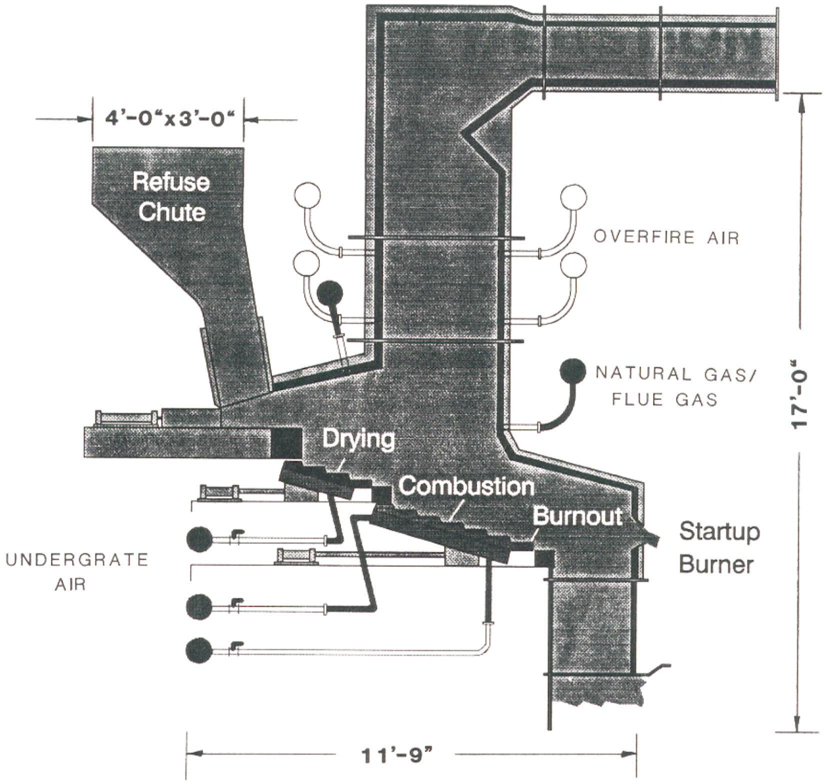


**Figure 2. Riley Pilot MSW Combustion Facility**

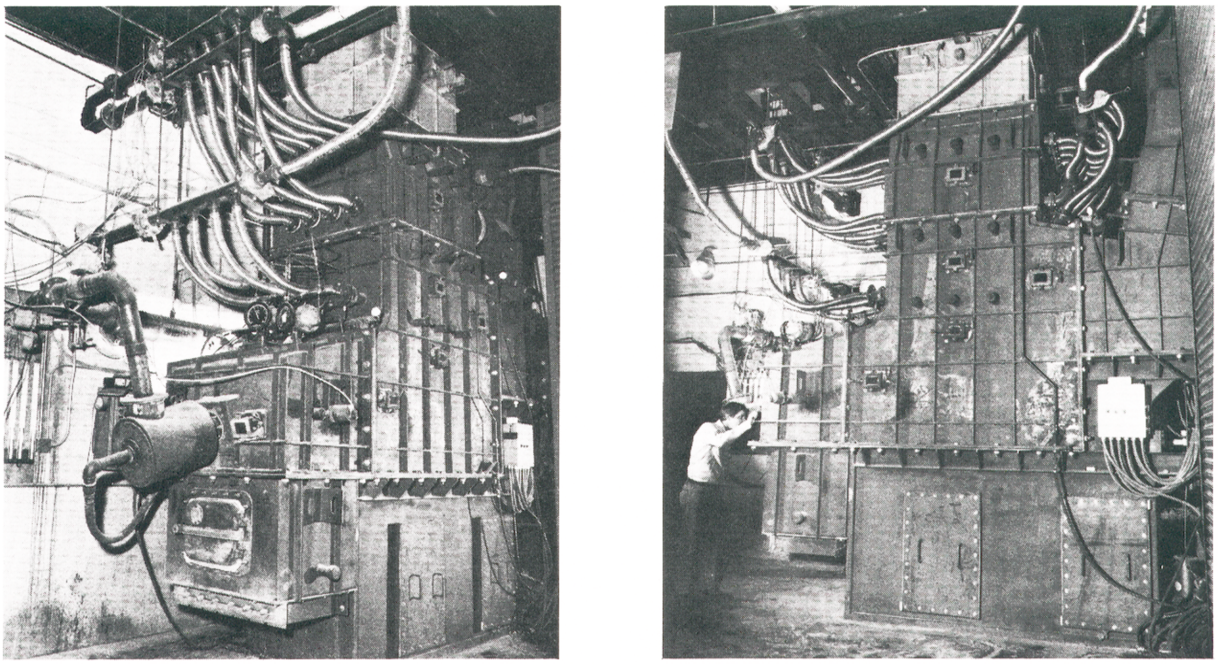

**Figure 3. Riley Pilot MSW Combustion Facility — Combustor Section**

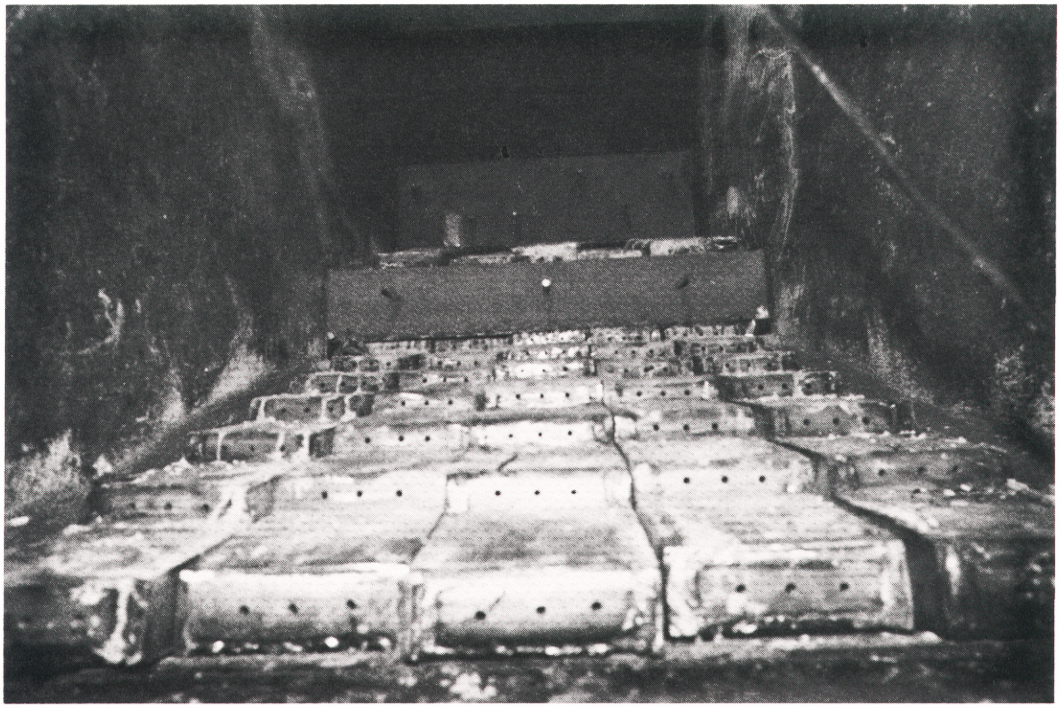

**Figure 4. Riley Pilot MSW Combustion Facility — Step Grate Sections**

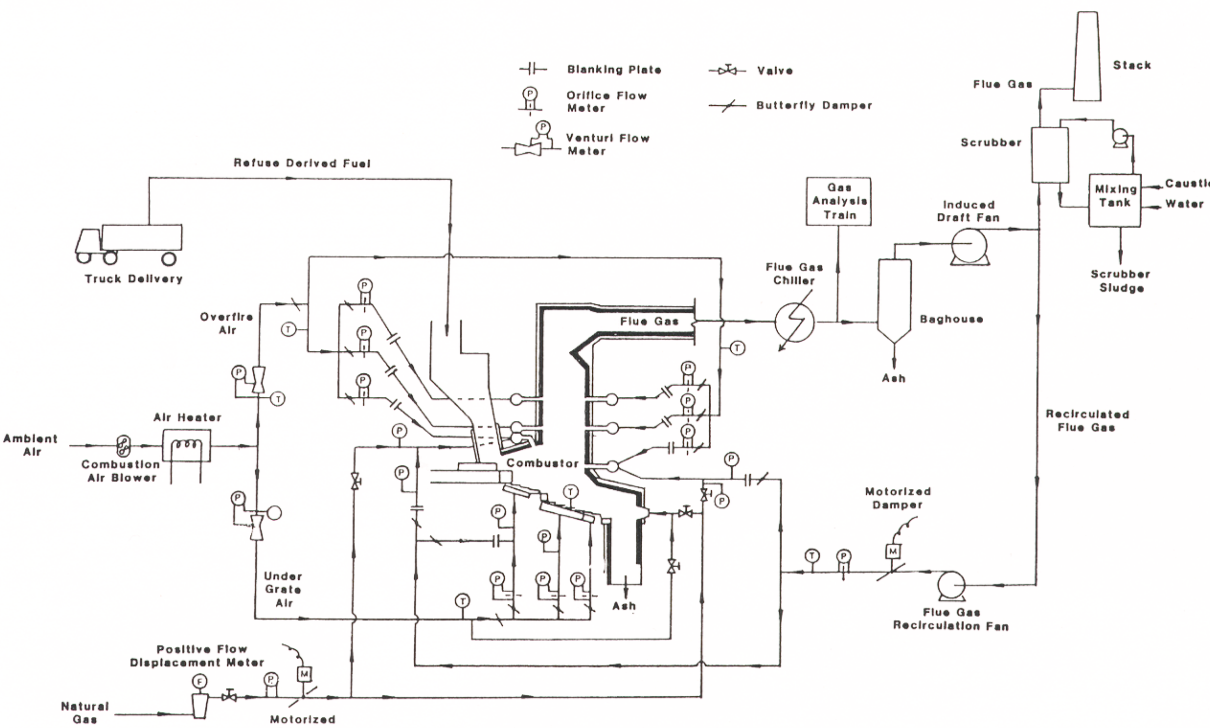


**Figure 5. Process Flow Diagram — Pilot MSW Combustion Facility**

The pilot MSW combustion facility utilizes the same backend cleanup and heat recovery equipment that Riley used on a similar 3 x $10^6$ Btu/hr combustion test facility orginally designed for suspension burning of coal, oil, and gas. As shown in Figure 5, this equipment includes a baghouse, acid gas scrubber, flue gas recirculation system, heat exchanger sections and stack.

Flue gas composition, including NOx, $O_2$, CO, THC, CO2 and SO2 is continuously monitored at the furnace exit. The facility is currently being equipped to monitor HCl. In-furnace gas composition and temperatures are measured as desired through various sampling ports located throughout the combustor. A data acquisition and computer system is used for direct on-line data analysis of various test conditions.

## GAS REBURNING TEST RESULTS

The first program that is benefiting from this new facility is a research contract Riley Stoker has with the Institute of Gas Technology and the Gas Research Institute. During this test program we are studying the potential for reducing pollutant emissions, primarily nitrogen oxide, from refuse combustion systems using natural gas reburning in combination with low excess air operation (2). Natural gas, amounting to 10-15% of the total heat input, is injected into the main combustion zone, through the lower level of nozzles shown schematically in Figure 6. This provides the proper reducing conditions and flue gas chemistry for destroying NOx. Overfire air is then introduced through the upper level of nozzles to complete the burnout. The other anticipated benefit of natural gas reburning is the reduction of other pollutant emissions or products of incomplete combustion, such as carbon monoxide, unburned hydrocarbons and dioxins.

The pilot MSW combustion facility is being used during this research program to determine the best configuration for natural gas injection, recirculated flue gas injection and overfire air mixing to achieve the desired NOx reduction levels.

Initial testing focused on characterizing the operation of the pilot combustor to ensure proper simulation of full-scale unit operation. The impact of firing rate, UGA and OFA distribution and excess air on combustor performance was studied to achieve the desired conditions (3). Table 1 compares the results of operating the pilot unit at the design conditions with field data collected at a 100 ton/day

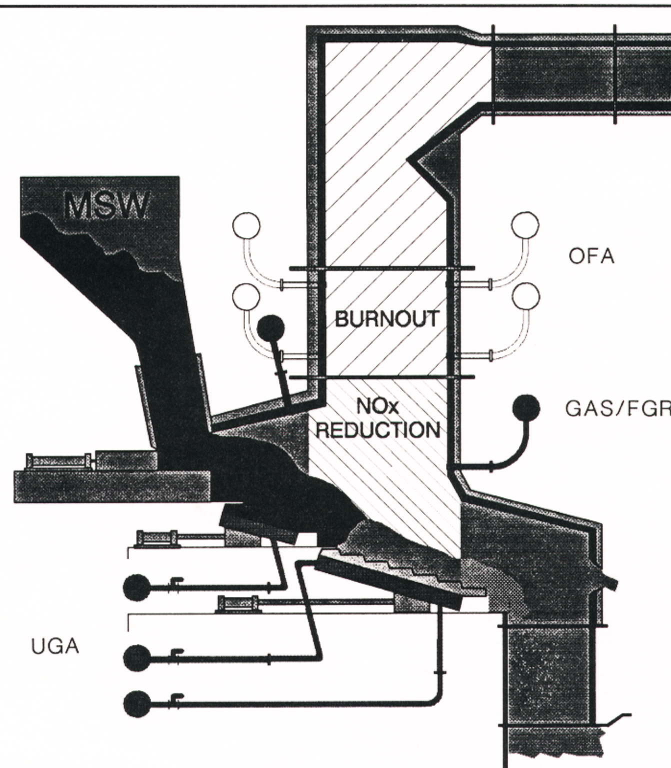


**Figure 6. MSW Gas Reburning Concept**

Waste-to-Energy facility owned and operated by Olmsted County, Rochester, Minnesota. The results showed excellent agreement in regards to flue gas emissions and furnace temperatures. The only major difference was available gas residence times. Olmsted County exhibited twice as long residence times. However, based on fundamental testing conducted at IGT early in this program, longer residence times in the gas reburning zone are more beneficial for NOx reduction (4).

Results of testing the gas reburning concept in the Riley pilot unit are shown in Figure 7. The results demonstrate the impact of reburn zone stoichiometry and residence time on controlling NOx emissions. The uncontrolled emissions ranged from 120 to 160 ppm (at 12% 02) depending on excess air level which was similar to the full scale characterization results. When gas reburning was applied the NOx emissions were reduced to levels inversely dependent on the stoichiometry and directly dependent on residence time in the fuel rich zone (3). The residence times were changed by moving the overfire air injection ports higher in the furnace. These results indicated that reductions of over 50% could be achieved while reburning with natural gas amounting to 7-15% of total furnace heat input and with residence times consistent with typical furnace volumes.

Figure 8 again shows the importance of reburn zone residence time on NOx reduction. Significant NOx reduction can be achieved while operating at residence times greater than 1.5 seconds. Future work will focus on testing residence times approaching 2 seconds.

CO emissions were also shown to be comparable or slightly reduced from baseline conditions. As shown in Figure 9, CO emissions with gas reburning typically averaged less then 25 ppm at 12% 02 while THC emissions were negligible.

## FUTURE EFFORT

Testing in the Riley Pilot MSW Combustion Facility will continue to further optimize the gas reburning system. Longer residence times in the reburning zone will be evaluated along with in-furnace characterization testing in an effort to achieve > 50% NOx reduction while maintaining excellent CO and THC emission burnout.

Assuming success with the final pilot scale testing, plans for a field demonstration test of this technology in a commercial operating facility will be finalized. A detailed economic and boiler performance analysis of the gas reburning technology will also be conducted to determine the commercial impact of utilizing natural gas for emissions control. The analysis will specifically address the following issues:

### COMPARISON OF PILOT-SCALE TEST DATA WITH BASELINE FIELD TEST DATA

| | Field Test Unit | Riley Pilot Unit |
|---|---|---|
| Test No. | 21 | 7 |
| MSW Heating Value, Btu/lb | 6037 | 5447 |
| Load, $10^6$ Btu/hr | 37.5 | 2.36 |
| Excess Air, % | 73 | 70 |
| OFA Flow, % | 34 | 38 |
| OFA Configuration | Standard | Standard |
| Combustion Products | | |
| $O_2$, % | 9.3 | 8.7 |
| CO, % | 10.1 | 10.9 |
| $NO_x$, ppm | 134 | 142 |
| CO, ppm | 29 | 27 |
| THC, ppm | 0 | 0 |
| Furnace Exit Temperature, °F | 1620 | 1570 |
| Reburn Zone Temperature, °F (1) | 2220 | 2181 |
| Residence Time to Furnace Exit, s | 3.8 | 2.0 |

[1]Calculated from Measured Furnace Exit Temerature

**Table 1.**

- Impact on boiler performance
  - Thermal Efficiency
  - Slagging and Fouling
  - Corrosion
  - Superheat Temperature
- Cost Comparison to Thermal DeNOx

If these final analyses are encouraging, a field demonstration program of the gas reburning technology will be implemented.

The Pilot MSW Combustion Facility can also be used in the future for performing combustion analysis on other waste materials such as:

- Non-Recyclable MSW
- Automobile Shredder Residue
- Refinery Sludge
- Sewerage Sludge
- Chemical Process Waste Streams

Emissions analysis including heavy metals, dioxin concentration, putriscible content, total combustibles content and elemental analysis of the grate as well as the fly ash could be characterized for each waste fuel. Riley is performing EP toxicity analysis on the refuse ash during the gas reburning tests. In addition, the impact of burning these waste materials on slagging, fouling and ash deposition could be studied using simulated tube bank assemblies installed in the convective section of the pilot facility. Research work in this area has been performed by Riley in the past while burning micronized coal and coal water slurries.

The Pilot MSW Combustion Facility is a significant addition to Riley capabilities. It shows the company's dedication to address the municipal solid waste management problem. Riley is now able to offer a unique research facility which will support the experimental testing requirements of the industry at a small economical scale.

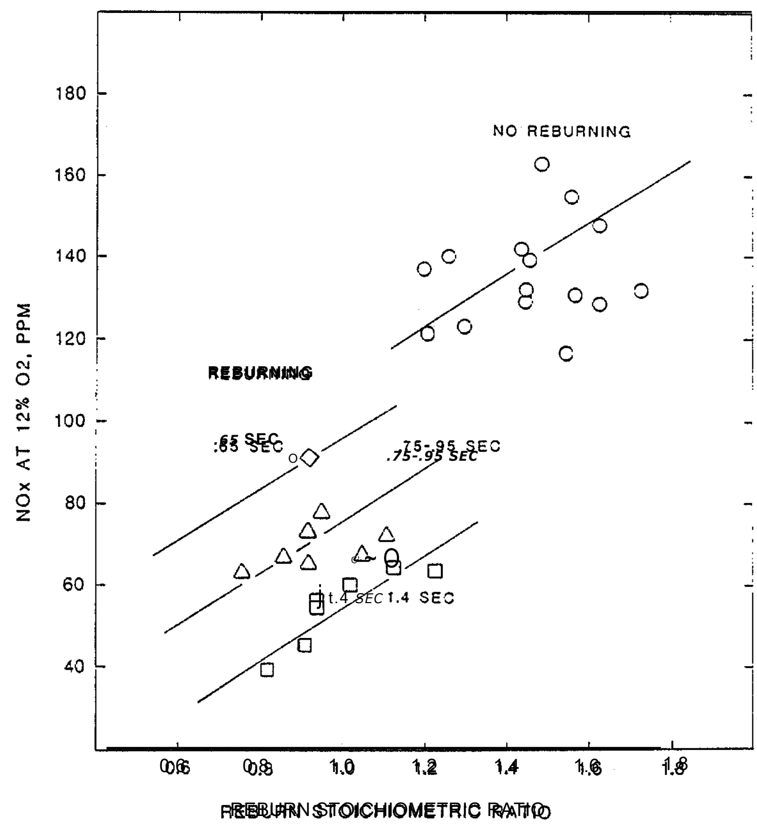


Figure 7. The Effect of Reburn Zone Stoichiometric Ratio and Residence Time on NOx Emissions in Riley Pilot Unit ( Rebuming with 10-15% Natural Gas Transported with 6-17% FGR)

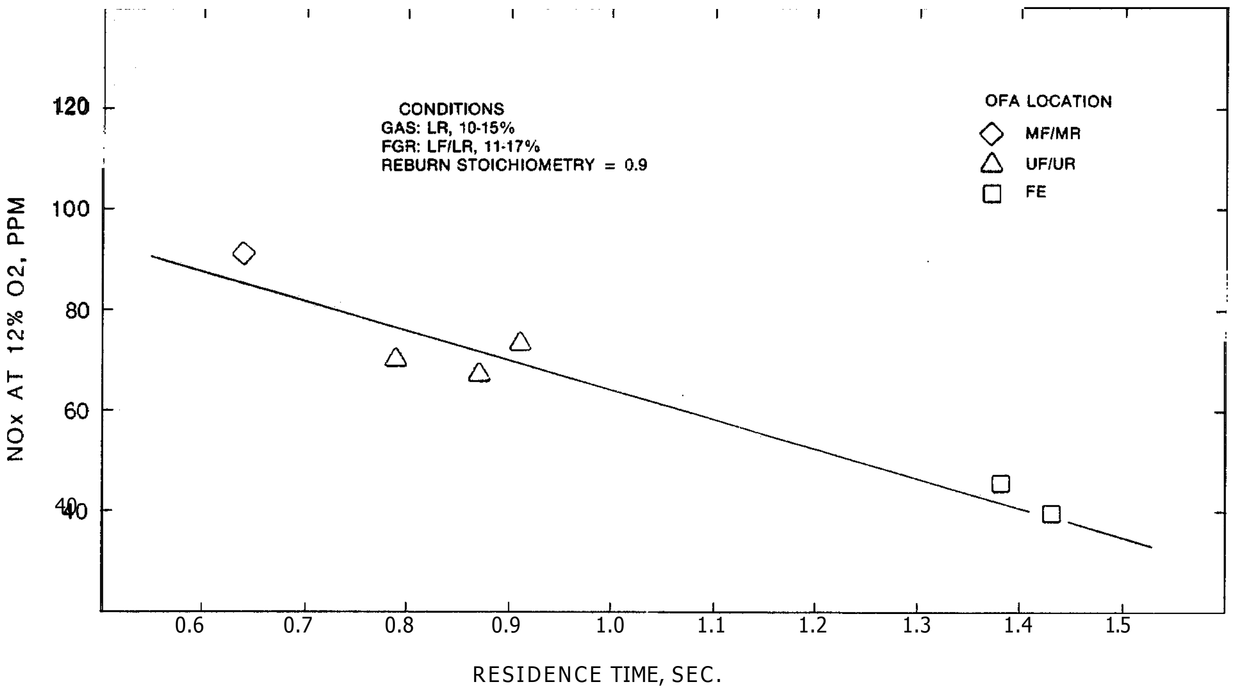


**Figure 8. The Effect of Reburn Zone Residence Time on NOx Emissions in Riley Pilot Unit**

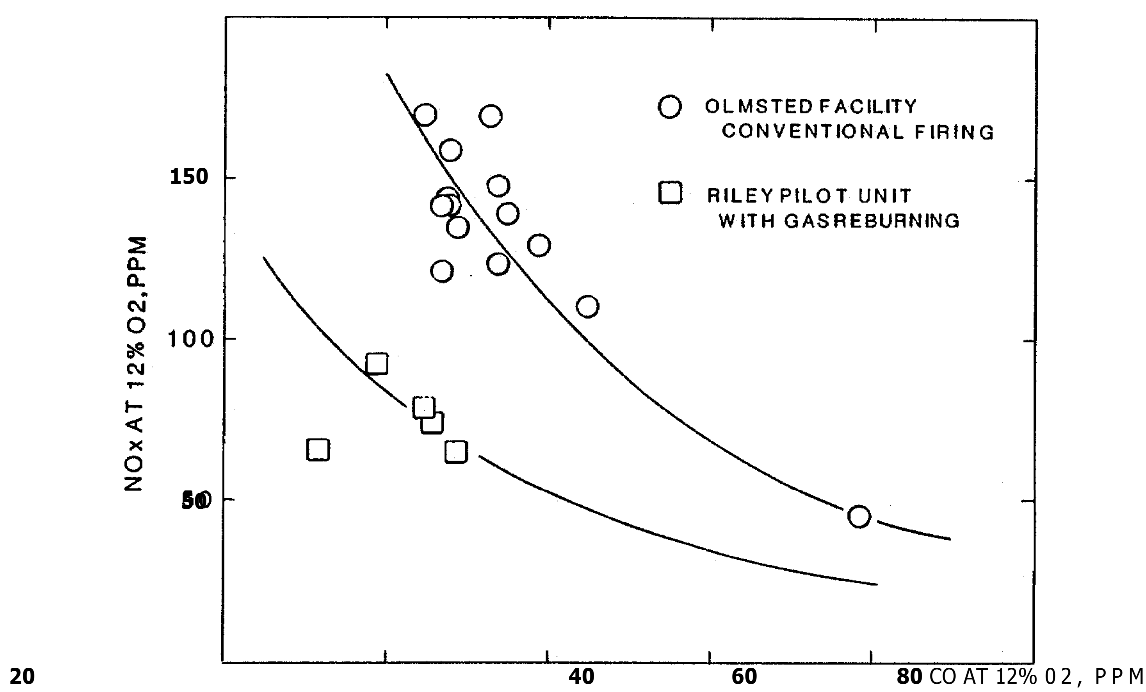


**Figure 9. Relationship Between NOx and CO Emissions**

## REFERENCES


1. Itse, D.C. and Penterson, C.A., "Riley-Takuma Technology for Refuse Combustion Plants", presented at the AFRC International Symposium on Incineration of Hazardous, Municipal and Other Wastes, Palm Springs, California, November, 1987.

2. Penterson, C.A., et al., "Reduction of NOx Emissions from MSW Combustion Using Gas Reburning", presented at the 1989 Joint Symposium on Stationary Combustion NOx Control, San Francisco, California, March, 1989.

3 Linz, D.G. and Seeker W.R., "Advanced Natural Gas Firing for Pollutant Control from Municipal Solid Waste Combustion Systems", presented at the American Power Conference, Chicago, Illinois, April, 1989.

4. Abbasi, H.A., Penterson, C.A., et al., "Pilot Scale assessment of Natural Gas Reburning Technology for NOx Reduction from MSW Combustion Systems", presented at the International Conference on Municipal Waste Combustion, Hollywood, Florida, April, 1989.