

REFUSE DERIVED FUEL (RDF)

by

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Introduction

The term "RDF" is a relatively new member of the advancing mass of resource recovery jargon which is exchanged freely between those involved daily with the problems of recovering energy from solid waste. It is one of those three-letter acronyms that rolls easily off the tongue, but is dangerously ambiguous. Taken literally, "Refuse Derived Fuel" means any fuel derived from refuse including shredded fuel, pyrolysis gas and oil, landfill gas, etc. However, RDF in this paper is defined as that fraction of municipal solid waste composed mainly of cellulose and petroleum derivatives, whether mixed with other non-combustibles in its un-processed form, or in its various processed forms. The purpose of this paper is to discuss the direct combustion of this fraction in a steam generator.

Direct Combustion

Figure 1 shows where the direct combustion technique fits in the context of the rest of resource recovery technology. Two general groups can be defined; Materials Separation and Chemical Conversion. Materials Separation is the physical separation and/or sizing of the various components of solid waste without changing the chemical makeup of any component for the purpose of preparing them for further physical changes, chemical conversion, or disposal. A few of the many techniques in this general group are shredding, magnetic separation, density separation, screening, nonferrous separation, and various "wet" processes using water as a transport fluid. The second general group of which direct combustion is a part, is Chemical Conversion. This group includes techniques which change the chemical makeup of either processed or un-processed solid waste for the purpose of recovering the heat released in the chemical reaction and/or for changing the solid waste into a more usable form. Pyrolysis and Bioconversion are included as well as direct combustion.

This paper will discuss the two general forms of the direct combustion of RDF (as it has been defined earlier); the use of RDF as a primary fuel, and its use as a supplemental fuel. This paper will also attempt to identify needed areas of research for each of these direct combustion forms.

RDF as a Primary Fuel

This form of direct combustion uses RDF as the source of greater than fifty percent of the heat input to the steam generator. This requires a steam generator designed specifically for the combustion of refuse when using RDF in its un-processed form. In certain situations, depending on the type of solid waste processing used to produce the RDF, existing boilers can be modified to burn processed RDF as a primary fuel. In either case, the RDF heat input is usually supplemented by a "conventional" fuel such as gas, oil or coal. Figure 2 shows the typical processing steps required for the different ways of utilizing RDF as a primary fuel; unprocessed fuel firing (mass burn) and processed fuel firing. These are the two types of primary refuse fuel direct combustion now being practiced by certain facilities in this country and in Europe.

Unprocessed RDF Firing (Mass Burn)

There are several operating facilities of this type in the U.S., Canada and Europe. Table 1 gives the details of most of these facilities. Figure 3 shows the general arrangement of the equipment used in these facilities. The waste is dumped from the collection or transport vehicles into a pit for surge storage, then is moved to a hopper which feeds a traveling/reciprocating grate arrangement on which the refuse is burned. Heat is transferred by radiation and convection in the traditional manner to the boiler walls and hanging tube sections. Some systems separate bulky items such as refrigerators before firing and recover ferrous metal from the ash with magnetic separators.

Processed RDF Firing

In contrast to unprocessed fuel firing, this technique subjects the raw refuse to a number of different steps of materials separation before combustion. Most of the systems whether operating or in the final design of construction phases utilize a new, specially designed RDF boiler with a traveling grate, spreader stoker design originally used for crushed coal (see Figure 4). The refuse is typically shredded to a 3 to 6 inch (7.62 to 15.24 cm) nominal particle size and magnetically separated to recover a ferrous metal fraction before firing (some systems use air density separation as an additional step). When processed refuse is to be used as a primary fuel in an existing boiler, the raw refuse is typically subjected to additional shredding for smaller particle sizes, and density classified to remove additional noncombustibles. Boilers originally designed to use a solid fuel (coal, bark, etc.) can then be modified to burn this RDF as the primary fuel.

Table 2 gives the details of many of the systems operating, under design or under construction.

Comparison and Research Needs

Both the unprocessed RDF firing and processed RDF firing primary fuel systems have been constructed and have operating experience. The question of which form is more desirable is unanswered. A comparison between the two not only points out the advantages and disadvantages of each, but identifies certain areas for needed research.

Steam flow variation.--It has been shown that steam flow variations are less severe in a processed RDF primary fuel system than in an unprocessed RDF system.¹ Processed fuel has a higher degree of homogeneity than raw refuse creating a more uniform heat release, and a fire which is easier to control. Unprocessed fuel units have fuel firing systems which are modifications of systems originally designed for incineration of raw refuse. Many times, the goals of refuse incineration conflict with the goals of steam generation from unprocessed refuse. A goal of incineration is not necessarily to create a uniform heat release rate which is important in steam generation. An area for research is to identify how to control steam flow variations in an unprocessed fuel system. Areas for investigation are: boiler control technology, traveling or reciprocating grate design, and auxiliary fuel modulating techniques.

Corrosion.--Refuse derived fuel has been shown to be more corrosive than conventional fuels.² The small amount of testing which has been completed indicates that greater amounts and rates of chloride corrosion occurs in the fireside of the boiler apparently because of the polyvinyl-chloride polymer which exists in municipal waste in the form of trash bags, plastic wrap, etc. This problem is perhaps more acute in a system using RDF as primary fuel than in a supplemental fuel system. There is also speculation that this type of corrosion is more severe in a mass burn system than in a processed RDF system.

It is clear that only limited knowledge exists about the actual corrosion mechanism, and the conditions which control it, such as temperature, gas flow rate, excess air rate, boiler geometry, RDF composition, and firing system design. Research directed toward answering boiler corrosion questions could result in the design of more reliable refuse direct combustion systems.

Stack emissions.--Only limited stack emissions testing has been completed for steam generators using refuse derived fuel as a primary fuel. Considering the number of RDF systems either under construction or in the design or planning stages, a high priority research need should be the identification of stack emissions from RDF systems.

There is speculation about which of the primary RDF fuel systems has more severe emissions control problem. Since a higher gas flow is needed for complete combustion in a mass burn system, the problem is potentially greater. The East Hamilton SWARU (a processed fuel system)

boilers are designed for 37% excess air leaving the boiler as compared to an excess air figure of 84% at the boiler exit in the Nashville mass burn system. Higher air flow per Btu released means more gas to clean up. Research should address the effects on stack emissions of refuse fuel homogeneity, fuel composition, firing system design, boiler geometry, fire control with auxiliary fuel, and air pollution control equipment design and operation.

RDF as a Supplemental Fuel

The major differences between an RDF primary fuel system and a supplemental fuel system are that in the supplemental system, a conventional fuel (gas, oil or coal) supplies over 50% of the heat input and an existing boiler is usually modified for RDF supplemental firing. In certain situations, RDF can be used as a primary fuel in existing boilers (see Table 2), but modification costs are usually prohibitive. The primary attractiveness of the supplemental fuel concept is that when RDF is only used as a fuel supplement, considerable investment capital can be saved because an existing boiler can be modified for use at a relatively small cost. Even though a more extensive materials separation system is required to prepare an RDF with better fuel properties, the cost of these components is usually more than offset by the savings realized by the elimination of the necessity for a new, specially-designed boiler.

Figure 2, shows that there are two basic types of supplemental RDF systems; the shredded, classified fuel system and the densified RDF (d-RDF) system.

Shredded, Classified Fuel Supplemental System

The materials separation involved with this type of supplemental fuel system involves size reduction to typically under 1-1/2 inch (3.81cm) particle size (possibly two stages of shredding or milling) and density classification (usually air density separation). The fuel is then burned either on a traveling grate or in suspension. Table 3 shows the details of the steam generators which now or will fire supplemental shredded RDF. Supplemental rates range from 10% to a possible 50% in these existing steam generators. The only steam generators operating with a shredded RDF supplemental fuel on a day-to-day basis are those operated by the Ames Municipal Electric Service in Ames, Iowa. These three units have been utilizing RDF constantly for about one year at the date of this writing.

Densified Refuse Derived Fuel d-RDF Supplemental System

The advantages of densified or pelletized RDF are: 1) densified RDF will store for longer periods of time than shredded RDF before decomposing and 2) the higher bulk density and shape of the densified fuel pellets

may allow this fuel to be handled with existing coal-handling equipment which is not compatible with shredded fuel, reducing boiler modification costs. Consequently, several companies now market systems or equipment which produce various forms of densified fuel. Figure 2 shows that the d-RDF is typically produced with either wet or dry methods involving size reduction to less than 1 inch (2.54 cm) nominal particle size, magnetic separation, density separation, drying, and densification.

No densified RDF supplemental fuel system is currently operating on a full-time daily basis. However, a number of tests of the firing of d-RDF as a supplement to coal have been done in existing steam generators. The details of some of these tests are shown in Table 4. All of the tests shown on the Table were conducted with no prior modifications to the fuel handling systems or to the boilers.

Comparison and Research Needs

Economics.--It appears that in certain situations, the capital and operating costs for a shredded, classified RDF supplemental system are lower than those for a d-RDF system. However, many of the special costs of supplemental firing with either shredded or densified RDF have not been identified such as: extra ash handling costs, extra maintenance costs due to higher boiler tube corrosion, shredded fuel conveying system maintenance costs (potentially high in pneumatic systems), etc. Research to identify these costs is needed.

Combustion.--Especially in a suspension firing arrangement, RDF particle size is very critical. Very little is known about what the optimum particle size is for the suspension firing of supplemental shredded, classified RDF for various sizes of steam generators. The optimum particle size for traveling grate firing systems is also not known for different systems and sizes of boilers. Research in this area could lead to the more efficient combustion of RDF. There has also been recent effort to test d-RDF in a mixture with coal as a fuel in a pulverized coal system. This would require that the d-RDF pellets be pulverized along with the coal in the existing pulverizing mills. Very little is known about the technical and economic feasibility of this concept. Research is needed in this area.

Conclusion

It is certain that the direct combustion of Refuse Derived Fuel will receive increasing scrutiny in the future as a technically and economically viable method for both solid waste disposal and energy production. Both forms of primary fuel RDF systems; unprocessed fuel firing (Mass Burn) and processed fuel firing, along with both forms of supplemental fuel RDF systems, shredded, classified fuel and densified fuel, have shown initial technical feasibility. Research in the areas of steam flow variation,

corrosion, stack emissions, economics, and combustion efficiency, could serve to reduce the uncertainty inherent in this new technology.

Footnotes

¹Sommerlad, Robert E. Quality and Characterisitcs of Steam Produced From Wastes, unpublished paper presented at the Engineering Foundation Conference on Present Status and Research Needs in Energy Recovery from Solid Wastes, September 21, 1976.

²Vaughan, D. A. Corrosion Mechanisms in Municipal Incinerators Versus Refuse Composition, unpublished paper presented at the Engineering Foundation Conference of Present Status and Research Needs in Energy Recovery from Solid Wastes, September 20 1976.

Comparisons and Remarks on Costs

Summary.—It appears that in certain situations, the capital and operating costs for a modified, classified MSW supplemental system are lower than those for a d-MSW system. However, many of the special costs of supplemental firing with either classified or d-classified MSW have not been identified such as: extra ash handling costs, extra maintenance costs due to higher boiler tube corrosion, elevated fuel conveying system maintenance costs (potentially high in packaged systems), etc. Research is definitely these costs is needed.

Conclusions.—Essentially as a supplementary firing arrangement, MSW particles also is very critical. Very little is known about what the system particle size is for the supplementary firing at supplemental classified, classified MSW for various sizes of steam generators. The smaller particle size the traveling grate firing systems to also not have for different systems and sizes of boilers. Research is this area could lead to the more efficient utilization of MSW. There has also been recent effort to use d-MSW in a rotary grate firing as a fuel in a pulverized coal system. This would require that the d-MSW pellets be pulverized along with the coal in the rotating pulverizing mills. Very little is known about the physical and chemical feasibility of this concept. Research is needed in this area.

Summary

It is possible that the direct combustion of MSW, d-classified fuel with specific incinerating structure in the future as a substantially and economically viable method for both solid waste disposal and energy production. Both forms of primary fuel MSW systems supplemented fuel firing (MSW burn) and processed fuel firing, along with both forms of supplemental fuel MSW systems, modified, classified fuel and d-classified fuel, have shown limited technical feasibility. Research is the areas of steam flow variation,

TABLE I

OPERATING STEAM GENERATORS FIRING UNPROCESSED REFUSE (MASS BURN)

Location	Operator	Start-Up Year	Capacity short tons/day (metric tons/day)	Boiler Design Data		Auxiliary Fuel	Boiler Manufacturer
				lb/hr x 1000 (Kg/hr x 1000)	psia, °F (Kg/cm ² , °C)		
Chicago, Illinois	City of Chicago	1972	1800 (1633)	4 units, each 110 (50)	275, 414 (19.3, 212)	gas	Walther GmbH
Braintree, Mass.	Town of Braintree	1971	240 (218)	2 units, each 30 (13.6)	250, sat. (17.5, sat.)	gas	Riley Stoker Corp.
Harrisburg, PA	City of Harrisburg	1972	720 (653)	2 units, each 92.5 (37.4)	250, 456 (17.5, 236)	oil	Walther GmbH
Montreal, Que	City of Montreal	1970	1200 (1088)	4 units, each 100 (45.3)	225, 500 (15.8, 260)	oil	Dominion Bridge Co.
Nashville, Tenn.	Nashville Thermal Transfer Corp.	1974	720 (653)	2 units, each 135 (61.2)	400, 600 (28.1, 316)	gas	B & W
Norfolk, VA	U.S. Navy	1967	360 (327)	2 units, each 50 (22.7)	275, sat. (19.3, sat)	oil	Foster-Wheeler Corp.
Quebec Cty, Que.	Quebec Urban Community	1974	1000 (907)	2 units, each 81 (36.7)	680, 600 (47.8, 316)	oil	Dominion Bridge Co.
Suagus, Mass.	RESCO	1975	1500 (1361)	2 units, each 185 (83.9)	890, 875 (62.5, 486)	oil	Dominion Bridge Co.

TABLE 2

STEAM GENERATORS FIRING PROCESSED RDF AS A PRIMARY FUEL

Location	Operator	Status	Refuse Capacity, short tons/day (Metric tons/day)	Boiler Design Data		Supplemental Fuel	Comments
				lb/hr x 1000 (kg/hr x 1000)	psia, F (Kg/cm ² , C)		
New Boilers:							
Akron Ohio	City of Akron	under construction	1000 (907)	3 units, each 126 (57)	560, 479	#2 oil	density separation included in fuel processing
East Hamilton Ont., SWARU	City of Hamilton	in operation since 1972	600 (544)	2 units, each 106 (48.1)	250, sat. (17.5, sat)	oil	No steam market
Hempstead, N.Y.	Hempstead Resources Recovery	under construction	2000 (1814)	400 (181)	---	oil	Steam sold to Lor, Island Lighting Co for electricity pro duction.
Existing Boiler:							
Rochester, N.Y.	Kodak	operating	180 (163)	77 (34.9)	---	#6 oil	Also burns dried wastewater sludge Kodak uses steam internally.

TABLE 3

STEAM GENERATORS FIRING SHREDDED, CLASSIFIED SUPPLEMENTAL RDF

Location, Facility	Operator	RDF Produced By:	Boiler Design Data		Firing System	Supplemental Rate	Primary Fuel	Status
			lb/hr x 1000 (Kg/hr x 1000)	psia, °F (Kg/cm ² , °C)				
Ames, Iowa Units 5, 6, & 7	Ames Municipal Electric Service	City of Ames Solid Waste Recovery Syst.	# 7 360 (163) # 6 125 (57) # 5 95 (43)	900, 900 (63, 482) 725, 825 (51, 441) 710, 825 (50, 441)	Tangential travelling grate travelling grate	8% - 10% 10% - 50% 10% - 50%	coal, gas coal, gas coal, gas	operating regularly with RDF since Nov., 1975
Bridgeport, Conn., Bridge- port Harbor Station Units # 1 and #2	United Illuminating	Resource Recovery Associates	----	----	cyclone burners	30% - 40%	coal, oil	RDF plant under design
St. Louis, MO Meramec Plant	Union Electric	St. Louis Demon- stration Plant	2 units, each 925 (420)	----	tangential suspension	9% - 27%	coal, gas	demonstration plant no longer operating regularly
Wisconsin Oak Creek Power Station	WEPCO	Americology, Milwaukee Resource Recovery Plant	----	----	suspension	10%	coal	RDF plant under construc- tion

TABLE 4

STEAM GENERATORS TESTED WITH THE SUPPLEMENTAL FIRING OF d-RDF

Location Facility	Operation	Date and Duration of Test	Boiler Design Data		Boiler Mfg.	d-RDF made by	Primary Fuel	Supplemental Rate (Btu basis)
			Firing Method	lb/hr x 1000 (Kg/hrx 1000)				
Piqua, Ohio Boiler No. 4	Piqua Electric Utilities Power Plant	June 27, 1975 7 hours	Chain Grate Stoker	150 (68)	454,750 (31.9, 399)	CF	Black Claw- coal son (#2 fuel, 3/8" dia.)	20 - 24%
Wright Patterson AFB Boiler Plant	U.S. Air Force	Aug. 1975 30 hours	Travelling Grate Spreader Stoker	2 units, each 80 (36.3)	125, sat. (8.8 sat.)	Edge Moor Iron Works	Black Claw- coal son (#2 fuel, 3/8" dia.)	23 - 27%
Oshkosh, Wisc. University of Wisconsin, Oshkosh Campus Boiler Plant	University of Wisconsin	Aug. 1976 8 hours	Vibrating Grate	50 (22.7)	115, sat. (8.1, sat.)	Wickes	Gruman (5/8" dia.)	20 - 24%*

*Tested for about one hour at 100% d-RDF

RESOURCE RECOVERY TECHNOLOGY

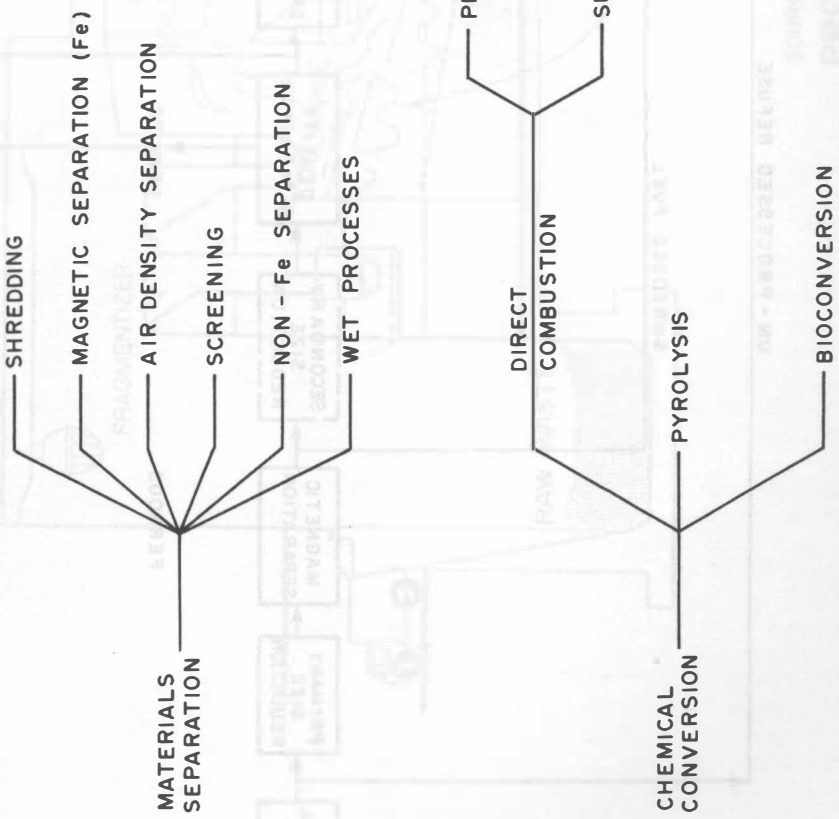


FIGURE 1

PROFILE OF
 DIRECT COMBUSTION - FRYE BOILER PLANT
 SAUGUS, MASS.

DIRECT COMBUSTION

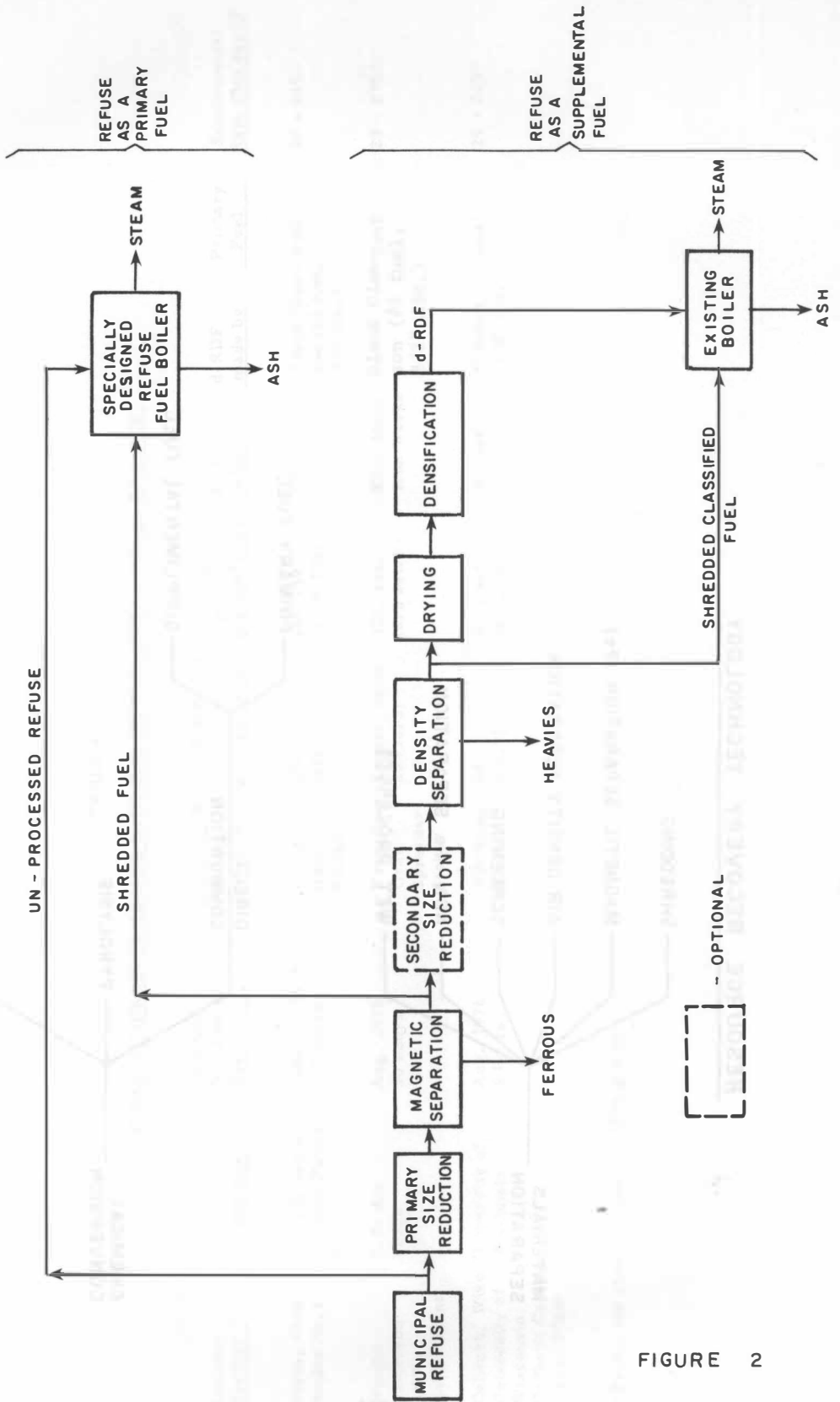
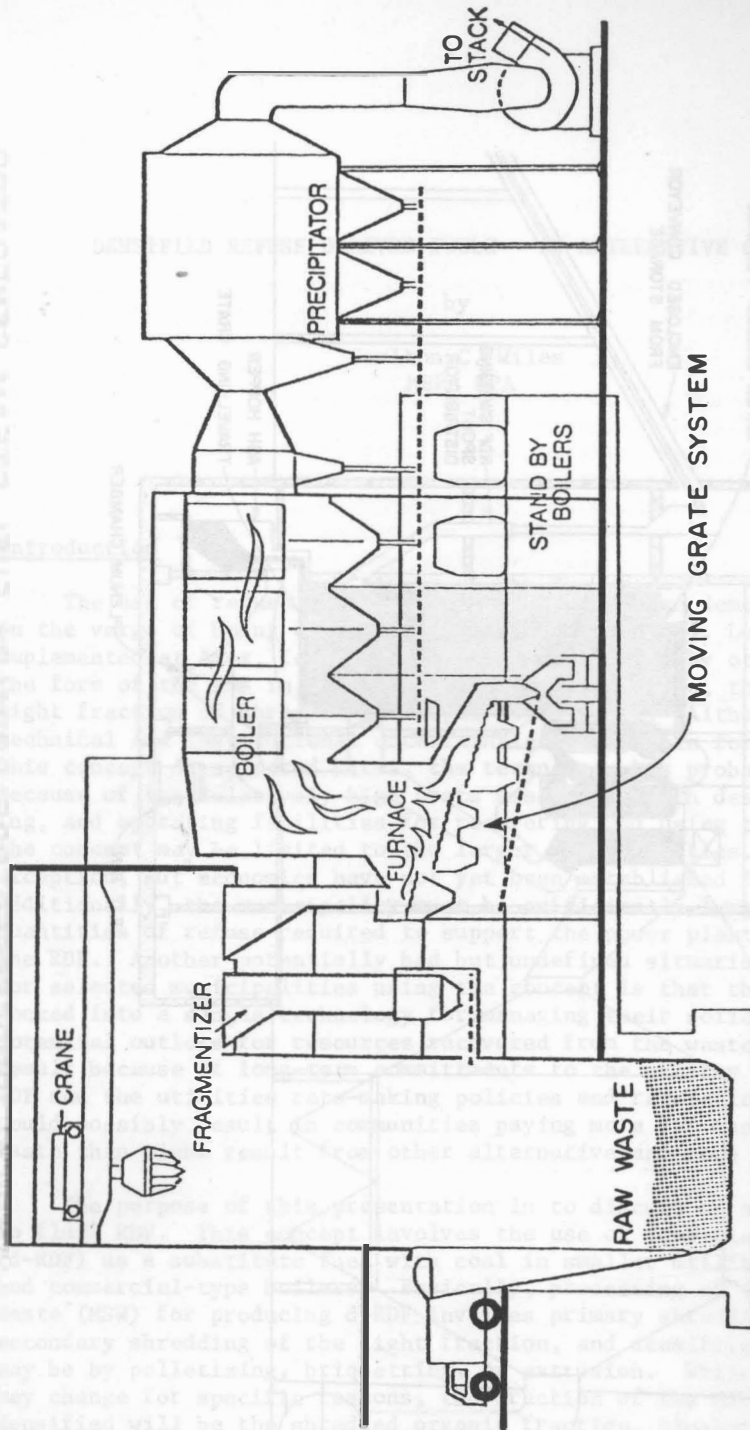
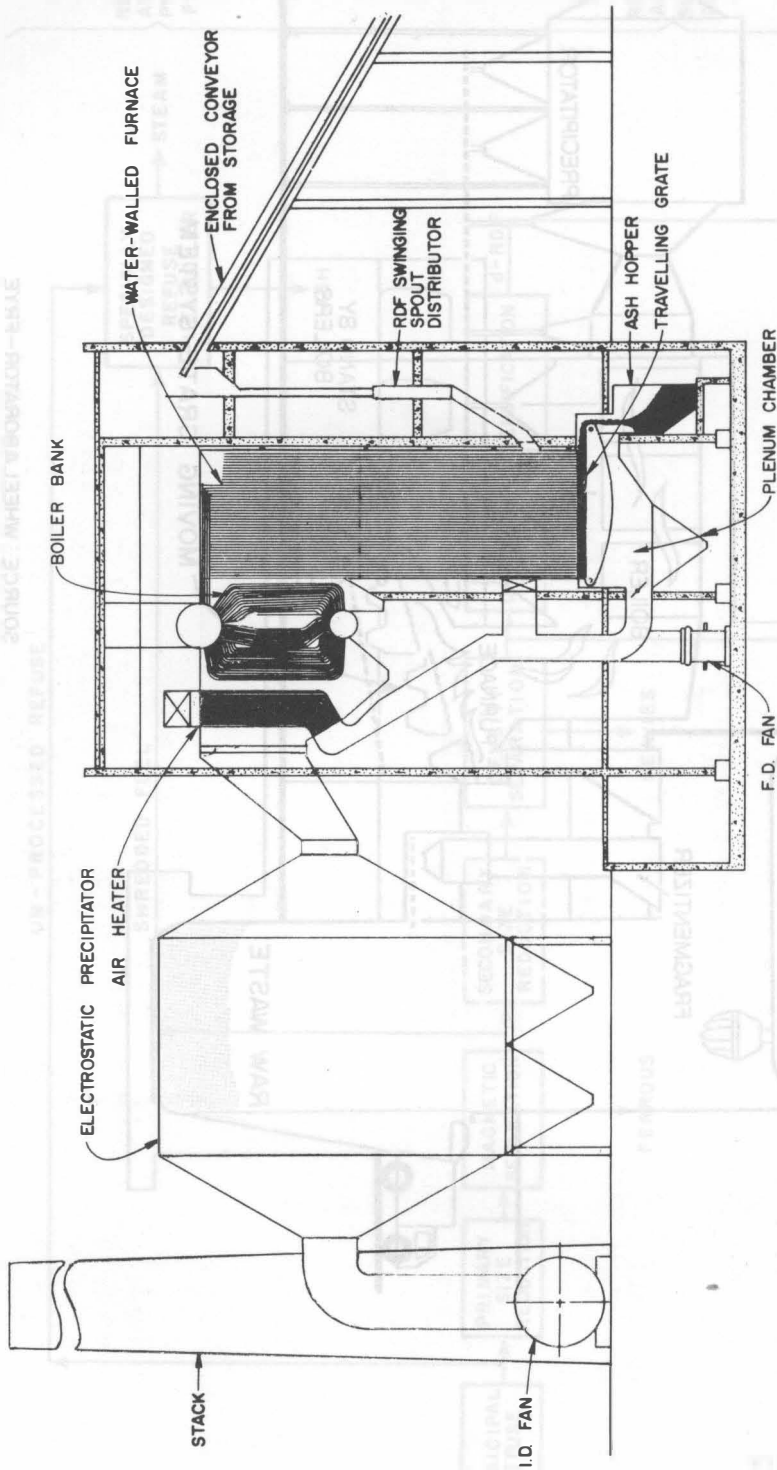


FIGURE 2



SOURCE : WHEELABORATOR-FRYE

**PROFILE OF
WHEELABORATOR - FRYE BOILER PLANT
SAUGUS, MASS.**



TYPICAL PROCESSED RDF PRIMARY FUEL STEAM GENERATOR