# CHAPTER XII. PRODUCTION OF REFUSE-DERIVED FUEL (RDF)

## A. Background

Typically, the production of a combustible fraction (i.e., fuel) from mixed municipal solid waste (MSW) and its thermal conversion requires two basic and distinct subsystems -- namely, the "front-end" and the "back-end". The combustible fraction recovered from mixed MSW has been given the name "refuse-derived fuel", or simply "RDF". The composition of the recovered combustible fraction is a mixture that has higher concentrations of combustible materials (e.g., paper and plastics) than those present in the parent mixed MSW. Thus, the rationale for recovering a prepared fuel from mixed MSW is that the recovered fuel fraction is of higher quality than is raw (i.e., unprocessed) MSW itself.

The principal function of the front-end ("pre-processing") subsystem is to accept solid waste directly from the collection vehicle and to separate the solid waste into two fractions -- namely, combustible and non-combustible. The front-end separation produces the "feedstock" for several types of back-end recovery (or conversion) systems, among which are included thermal and biological systems.

The main components (i.e., unit operations) of a front-end subsystem are usually any combination of size reduction, screening, magnetic separation, and density separation (e.g., air classification). These unit operations and equipment are discussed in detail in Chapter VI, Materials Recovery and Recycling. The types and configurations of unit operations selected for the front-end design depend on the types of secondary materials that will be recovered and on the desired quality of the recovered fuel fraction. The fuel quality must be specified by the designer or supplier of the thermal conversion system.

Typically, systems that recover a combustible fraction from mixed MSW utilise size reduction, screening, and magnetic separation. Some designs and facilities have used screening, followed by size reduction (e.g., pre-trommel screening), as the fundamental foundation of the system design, while others have reversed the order of these two operations. A number of considerations enter into the determination and the selection of the optimum order of screening and size reduction for a given application. Among others, the considerations include composition of the waste. Other unit operations may also be included in the system design, including manual sorting, magnetic separation, air classification, and pelletization (i.e., densification), as the need dictates for recovery of other materials (e.g., aluminium, etc.) and for achieving the desired specification of the solid fuel product [1].

Some examples of RDF production configurations from former and current facilities in the United States are given in Figure XII-1. The processing configurations shown in the figure are arranged from left to right in the approximate order of their historical development. The maturation of the processing designs occurred as a consequence of several circumstances, which included either singularly or in combination, inadequate performance of equipment, inadequate energy yield, and unacceptably high RDF ash content.

An historical perspective of the maturation of RDF processing configurations in the United States is shown Figure XII-2, along with reasons for the modifications of the configurations.

An example of a pre-processing system to recover RDF is illustrated in Figure XII-3. The processing configuration depicted in the figure utilises a pre-trommel screen, secondary trommel screen, one stage of size reduction, and a magnetic separator as the key unit operations to effect recovery of a high-quality RDF.

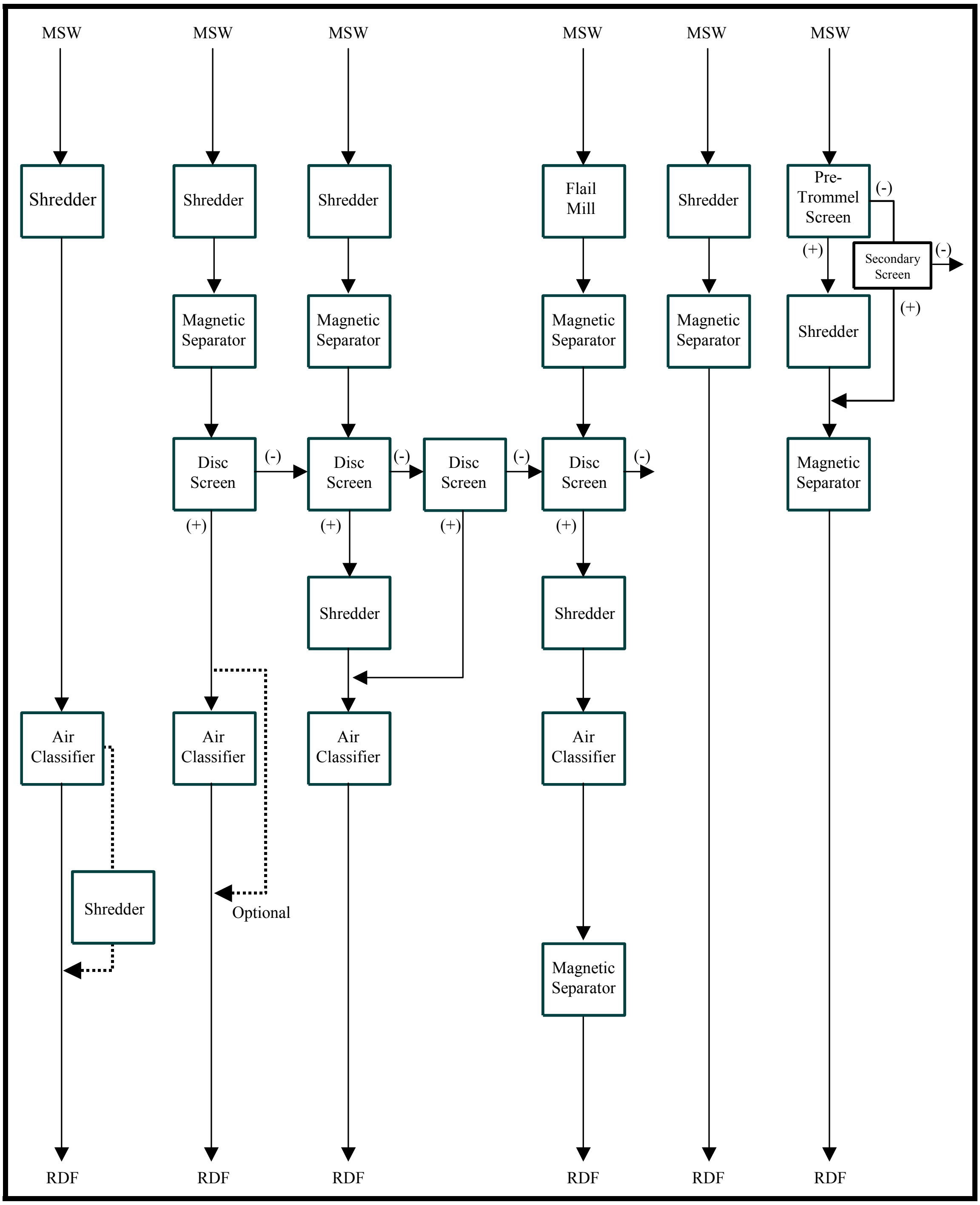


**Figure XII-1. Examples of front-end configurations used in the United States for RDF production**

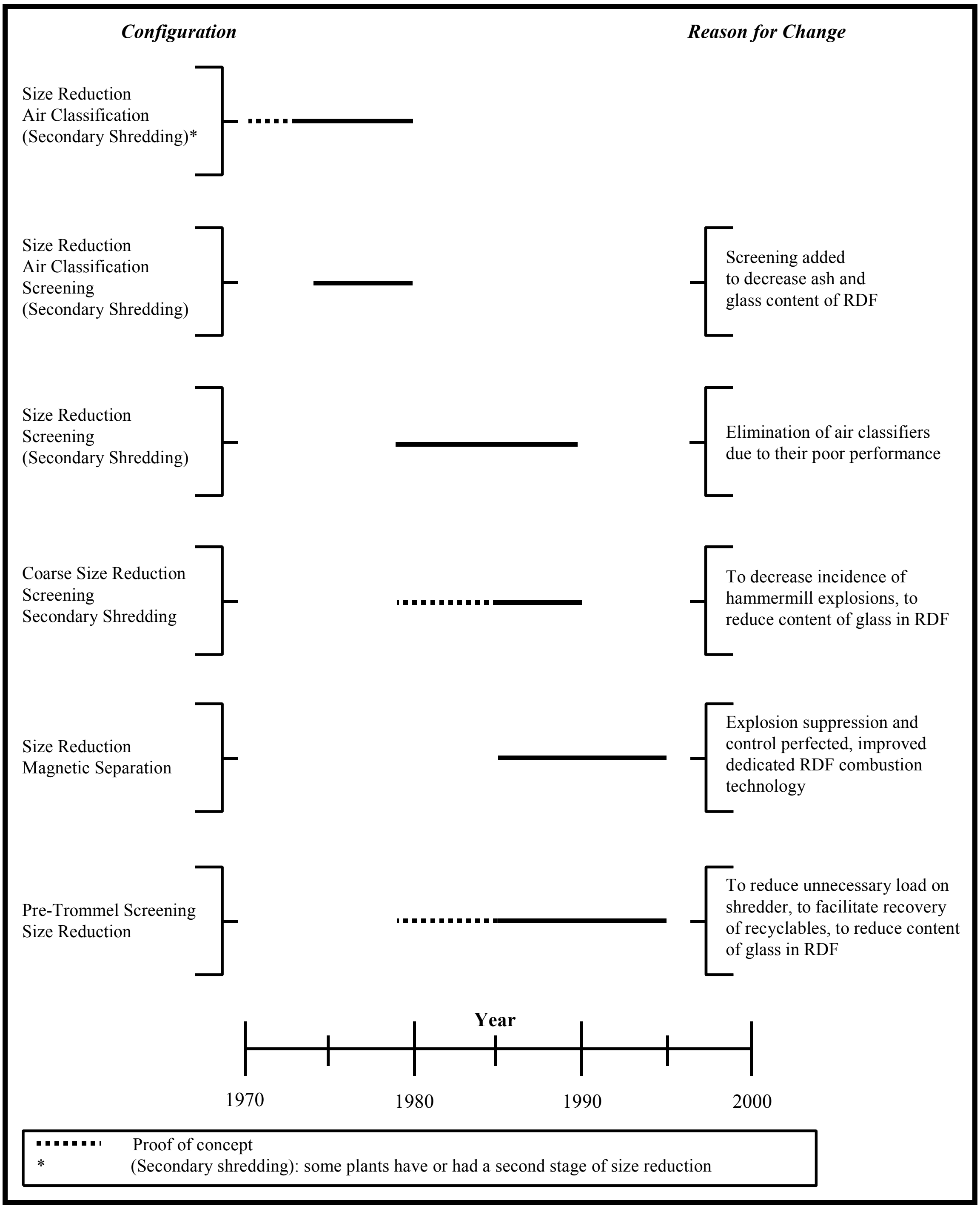


**Figure XII-2. Historical perspective of front-end configurations for RDF production**

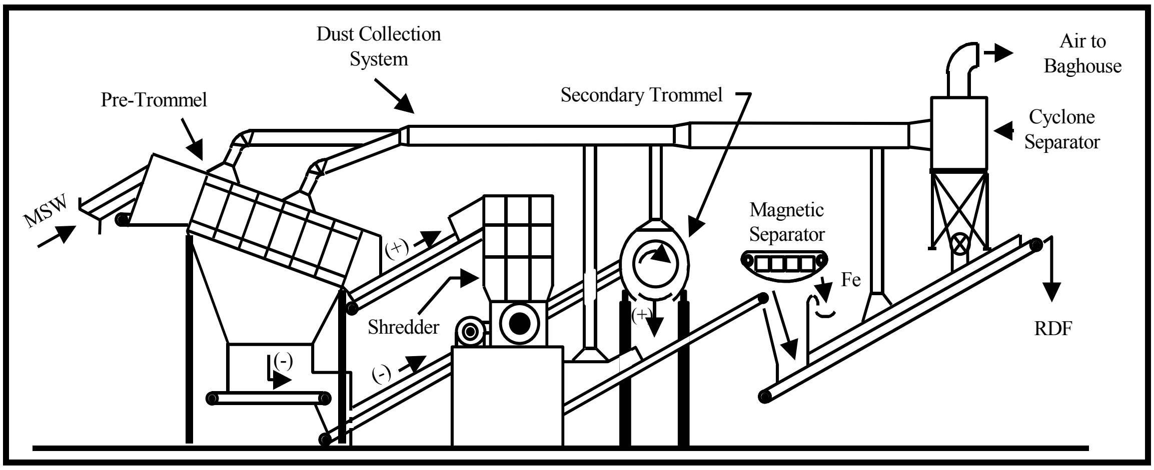


**Figure XII-3. RDF production system with pre-trommel configuration**

In terms of applications, RDF has been used in industrialised countries as a fuel supplement for coal-fired utility boilers and as the sole fuel for firing in dedicated boilers (i.e., boilers that use RDF exclusively). When fired as a supplemental fuel in coal-fired boilers (i.e., co-fired), experience has shown that RDF with heating values in the range of 12,000 to 16,000 J/g (wet wt basis) can successfully contribute up to about 30% of the input energy.

While RDF has advantages over mixed MSW as a fuel in terms of quality and uniformity of characteristics, it also has some disadvantages. One of the disadvantages is the fact that a cost is associated with the front-end processing to recover the fuel fraction. Another disadvantage is that the unit yield of energy (i.e., kJ per kg of MSW) in the case of RDF is less than that of the parent MSW.

**B. RDF characteristics**

Pre-processing provides the means of recovering a high-quality fuel fraction from solid waste. An additional and equally important benefit of pre-processing is that it characteristically serves to control the fluctuations in characteristics of the RDF. In other words, within the usual limits of the time-varying characteristics (e.g., composition) of MSW, the pre-processing of MSW yields a combustible fraction whose properties are relatively uniform over time when compared to the variation in the properties of the parent MSW.

Various qualities of RDF can be produced, depending on the needs of the user or market. The range of qualities of RDF with regard to the more important thermal properties is presented in Table XII-1. The data shown in the table are for refuse-derived fuels produced from the solid wastes of industrialised countries. A high quality of RDF would possess a higher value for the heating value, and lower values for moisture and ash contents. As shown by the data in the table, RDF is a fuel of higher quality than is unprocessed MSW. For those properties listed in Table XII-1, the values for RDF are closer to those of typical sub-bituminous coals than those for MSW. The quality of RDF is sufficient to warrant its consideration as a preferred type of fuel when solid waste is being considered for co-firing with coal or for firing alone in a boiler designed originally for firing coal.

As mentioned above, the ranges of thermal properties for RDF shown in Table XII-1 are representative of RDF recovered from MSW from industrialised countries. In the case of economically developing countries that have high concentrations of materials with high moisture content in their solid waste, the RDF can be expected to be of lower quality unless extraordinarily complex methods of processing are employed. Specifically, the heating value on a wet wt basis, while relatively uniform, nonetheless would be at the lower end of the range in Table XII-1, or less, because much of the moisture will be absorbed by and adhere to the predominantly combustible materials (represented by paper and film plastic in the wastes) present in the recovered fuel fraction. In effect, the heating value is diluted by the substantial concentration of moisture.

**Table XII-1. Important fuel properties of RDF[a]**

| Type of Fuel | Heating Value As-Received (J/g) | Moisture Content (%) | Ash Content (%) |
|---|---|---|---|
| RDF | 12,000 to 16,000 | 15 to 25 | 10 to 22 |
| Coal | 21,000 to 32,000 | 3 to 10 | 5 to 10 |
| MSW | 11,000 to 12,000 | 30 to 40 | 25 to 35 |

Source: CalRecovery, Inc.

[a] Typical of RDF recovered from municipal solid wastes generated in industrialised nations.

**C. Use of RDF**

In keeping with the present state of technology, when RDF is used as a fuel or as a supplement, it is fired in a moving grate furnace or a boiler equipped with some form of grate. The experiences had with the co-firing of RDF and pulverized coal in suspension-fired coal boilers, which have no bottom grates, fell well short of expectations except in some isolated cases. The reasons for the disappointment included difficulty in feeding RDF into the boiler, higher percentage of excess air, inadequate residence time for complete combustion of the RDF while in suspension, and its lower heating value when compared to most coals. The incomplete combustion of the RDF, along with its higher production of ash per unit of energy released, combined to cause overloading of the ash handling systems of the suspension-fired coal boilers. Additionally, incomplete combustion adversely affected the overall thermal efficiency of the energy recovery system.

RDF can also serve as a feedstock for other types of thermal systems, e.g., pyrolysis and fluidised bed systems. The relative uniformity of properties and higher quality of RDF compared to mixed MSW has led in the past to a preference for RDF in some applications.

**D. Presence of contaminants**

Although RDF has relatively high concentrations of paper and plastics, both of which have a high heating value (paper, about 17,460 J/g; plastics, about 37,250 J/g) in comparison to most coals, it also contains materials that: have a relatively high percentage of ash, can be damaging to burners and boilers, and can exert a seriously adverse effect on the quality of the exhaust gases. For example, RDF typically contains materials that have substantial concentrations of chlorides. During the course of combustion, some or all of the chlorine may be converted to hydrogen chloride ($HCl$) by combining with the hydrogen released from the water inherent in the combustible fraction or with the water formed from the oxidation of hydrogen. As is well known, under many conditions $HCl$ can have a corrosive effect on the internal surfaces of the burner and sections of the boiler, especially the boiler tubes. Of course, mixed MSW also contains chlorides and, therefore, it also suffers from these same shortcomings when viewed as a potential fuel.

The presence of small particles of metal and of glass fines (<0.125 cm) in RDF can present problems in the combustion system. The exclusion of these small particles in RDF is a difficult exercise in process design as a consequence of their inherent physical and aerodynamic characteristics and of the inherent inefficiencies of mechanical processing equipment. Although the resulting contamination in pre-processed MSW may be considerably less than 1% by wt, a build-up of silicon dioxide and metal oxide deposits on the heat transfer surfaces of the boiler eventually occurs (the combustion of MSW shares this drawback also). The resulting fouling can lead to the loss of the heat transfer capacity of the surfaces. In extreme cases, the fouling could be sufficiently extensive as to necessitate a premature (i.e., unscheduled) shutting down and overhauling of the boiler. An encouraging note is that recent advances in metallurgy and in surface coatings for boiler tubes have led to substantially reduced fire-side corrosion in solid waste-fired boilers.

With respect to ash, in the production of a given amount of energy, ash production resulting from combustion of RDF can be four to six times that which would be experienced with the combustion of coal. Consequently, even with the use of RDF in a co-firing situation with coal, some provision must be made for handling the additional burden of ash.

Even though RDF more closely approaches homogeneity than does raw solid waste, the approach is far from great enough to justify RDF being regarded as a clean or high-quality fuel in terms of combustion. The reason is that RDF is a combination of many materials, each of which has its particular set of characteristics. The consequence is that in comparison to more homogeneous solid fuels, such as wood or coal, the maintenance of an efficient combustion process is more difficult when RDF is used as a fuel.

**E. Beneficiation of RDF**

The use of mechanical screening to produce a very high-quality RDF in terms of a reasonably high heating value, a low moisture content, and a low ash content was demonstrated at the University of California (USA) [2] in the mid-1970s and the concept was put into practice in several locations.

E1. HEATING value

The key design feature required for the recovery of a very high-quality RDF is the proper use of a screening operation in the sequence of processing. Screening operations either before or after the size reduction step have proven successful. Additionally, the trommel screen historically has been the equipment of choice, although exceptions exist. Through a judicious selection of a proper screen opening size, most of the minute contaminants (fines) can be removed from the RDF; they pass through the screen openings. On the other hand, the combustible fraction is retained by the screen, and exits the screen as the oversize stream. Generally, from 40% to 60% of the waste disposed in industrialised countries fits this category. Since the fines characteristically are inert materials having little or no heating value, their elimination has a twofold effect: 1) the overall heating value of the RDF is increased as a result of concentrating the combustible paper and plastic materials (screened RDF is about 95% paper; whereas prior to screening, it is only 60%); and 2) the ash content is materially lowered. Studies have shown that on the order of 90% or more of materials that have a low heating value can be removed with the use of a trommel screen [2,4].

The substances that collectively give RDF its heating value belong to one of two groups: those that have a high inherent heating value, and those that have a low heating value. Those that have a high heating value are almost exclusively in the form of paper, paper products, and plastics. The heating value of this group averages about 18,600 J/g. Inorganic fines (e.g., glass particles) and fine, wet organic matter (e.g., food preparation waste) make up the fraction having a relatively low heating value, i.e., on the order of 10,800 J/g. Obviously, the inclusion of the latter category in an RDF lowers the overall heating value of the RDF. In terms of thermal efficiency, the removal of the finely sized, inorganic (i.e., non-combustible) particles and the fine, wet organic particles from RDF can bring about an increase in the heating value of RDF by 20% over that of an RDF in which the non-combustible and fine, wet organic particles are retained.

E2. MOISTURE content

Another major benefit accruing from the pre-processing of MSW for recovery of a quality fuel is a lowering of the moisture content of the recovered RDF fraction in comparison to that of the parent MSW. This benefit is of particular relevance in the case of developing countries, where the wastes commonly have high concentrations of wet, putrescible matter. The lowering of the moisture content is a result of the disproportionate removal of moisture that accompanies the removal of waste materials during processing that occupy the lower range of the particle size distribution (i.e., finer sized materials) of MSW. These materials (e.g., food preparation and garden wastes) characteristically are wetter than the materials occupying the upper range of the distribution (e.g., paper). The removal of the finer-sized particles is most easily and usually conducted with screens (usually trommel screens), which allow the finer-sized materials to pass through the screen openings. The removal is disproportionate because the average moisture content of the "undersize" fraction is appreciably greater than that of the "oversize" fraction. Depending on the local conditions and the design of the pre-processing system, an RDF potentially can have a moisture content that is 25% to 50% lower than that of the parent MSW. At the same time, the heating value is increased proportionately.

**F. Precautions**

Proper design of a front-end system is obviously imperative for the successful operation of a fuel production facility. The key function of the pre-processing system is the segregation of the combustible components from the non-combustible components. In the production of a solid fuel (RDF), particular attention must be paid to the combustion unit in which the fuel is to be burned. For example, in order to facilitate handling, storage, and transportation, it may be necessary in some cases to produce a densified fuel.

The processing of municipal solid wastes for the production of a fuel is seemingly straightforward in terms of design and system operation. The performance and operation of the processing system is strongly and fundamentally determined by: the characteristics of the solid waste feedstock, the type of equipment chosen, and the location of the equipment in the overall processing configuration. Although some of the equipment available for solid waste processing applications may have been proven to be well suited to the processing tasks of other industries (e.g., mining, forestry, etc.), it must be remembered that raw solid waste differs substantially from the raw materials that serve as feedstocks for other industries. The failure to take the difference into account, particularly in some industrialised nations, resulted in a number of operational problems at waste processing facilities. The problems arose in many cases from the use of equipment that was improperly applied, designed, or operated. After a lengthy period of learning, plant operators and designers now recognise the need for a thorough understanding of the operating parameters of each piece of equipment as they pertain specifically to solid waste. This need for specialised knowledge extends to a detailed familiarisation with the physical and chemical characteristics of the wastes [3].

**G. Summary**

RDF most certainly can be used in some coal-burning facilities that are (or can be) equipped with grates to accommodate complete combustion of the RDF and that are (or can be made) capable of handling the additional ash production. Of course, existing coal-fired combustion facilities would have to be modified to accept and store the RDF and to inject it into the combustion chamber.

An important prerequisite for the successful combustion of RDF in a combustion system, whether fired solely or in combination with another fuel, is the development of the proper fuel specification. The fuel specification should be provided to the RDF system designer by the supplier of the combustion system. The combustion system supplier should be knowledgeable regarding RDF and its materials handling and combustion characteristics, as well as with fuel handling systems, combustion systems, and air pollution control systems. Obviously, in practice, the required quantities and characteristics of the RDF must be reliably and consistently supplied by the RDF system to the combustion system.

The compatibility of the RDF with all of the applicable elements of the combustion system cannot be over emphasised. Additionally, for financial reasons, optimum performance of the combustion process and thermal conversion system is required. Therefore, the properties of the RDF must be carefully evaluated and selected. As noted above, these requirements and conditions apply in the case of a thermal conversion system dedicated to RDF and to co-firing situations with coal.

Pre-processing system design for RDF recovery in developing countries must take into account the composition of the wastes to be processed. Characteristics of particular relevance are moisture content and content of inert materials, such as ashes from domestic cooking and heating. These characteristics present some special, but not unsolvable, challenges to the design of technically and financially successful RDF facilities.

## H. References


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