Block diagrams or process schematic diagrams of nine different fuel preparation processes, listed in the text and in Table 1, follow at the end of Appendix A. Typical material flows for assumed municipal solid waste inputs are indicated on some of the diagrams.

**DESCRIPTIONS OF FIGURES**

*Figure 1* system consists of single-stage shredding, drying, classifying, storing the dry fuel fraction and conveying the fuel fraction to the spreader-stoker-fired boiler. The prime fuel burning equipment is not shown. Ferrous metal separation is included.

The overhead crane carries the municipal solid waste from the pit to the shredder feed conveyor, which provides a well distributed feed to the shredder. The shredder reduces the municipal solid waste to approximately 100 mm (4-in.) particle size for further material handling within the process and suitable for spreader-stoker-firing. Shredding makes the municipal solid waste a more homogeneous mix and prepares it for drying and air classification.

During the drying process, the moisture level is reduced from a high of 40 percent to about 10 to 15 percent. The drying system increases the air classifier's efficiency in recovering more of the light combustible fraction, improves the pneumatic conveying systems' performance, and increases the processed fuel's heating value.

The air classifier's primary function is to separate the light and heavy fractions. The light combustible fraction continues to the storage bin and then to the boiler. The heavy portions proceed to the ferrous metal removal equipment.

The heavy refuse stream remaining after ferrous separation is trucked away for disposal at a selected landfill site.

*Figure 2* system is similar to *Figure 1* system except with the addition of second-stage shredding to reduce the municipal solid waste to approximately 32 mm (1/8 in.) particle size suitable for suspension firing.

*Figure 3* system shows one train of a multi-train central facility to produce a dry fuel suitable for suspension firing. This system is similar to *Figure 2* system except that a tipping floor and tipping floor conveyor are used rather than pit and crane municipal solid waste handling, a trommel screen is used upstream of the second-stage shredder to remove additional glass from the combustible fraction, and aluminum separation is provided.

*Figure 4* system produces a fine powdered dry fuel suitable for suspension firing or as a feedstock to other processes. The system consists of single-stage shredding, two screening stages, chemical treatment to aid in size reduction, air classifying to further reduce the processed fuel's ash content, and storing the fuel. A heat treatment system sterilizes the separated glass, dirt, and coarse materials prior to landfilling. Ferrous metal separation is included.

*Figure 5* system consists of a Hydrapulper, liquid cyclone, thickeners, and processed fuel feeder to a spreader-stoker or suspension fired boiler. Ferrous and nonferrous metals, glass, and aluminum separation are included.

As received municipal solid waste is conveyed to the Hydrapulper where pulpable materials are disintegrated and removed as a water slurry. A liquid cyclone separates glass and fine metals from the slurry after which the remaining nonrecoverable inorganic and organic materials are dewatered in thickeners to produce the fuel. The fuel can go through a dryer, if further reduction in moisture content is desired.
A junk remover takes metals from the Hydrapulper. The metals are washed and the ferrous metals are separated magnetically. The nonferrous materials, rejected from the ferrous metal removal system, and the separated glass and fine metals from the liquid cyclone are further processed to recover the aluminum, other nonferrous metals, and glass.

*Figure 6* system produces a pyrolysis fuel oil and char. The system consists of two-stage shredding, air classifying, drying, screening, pyrolysis reactor, char cyclone separator, and gas/oil separator column. Ferrous metal and glass separation are included.

The municipal solid waste is first shredded, followed by air classification to separate the inorganic fraction. Inorganics are separated into salvageable constituents for sale and nonsalvageable residue for landfill.

Following classification, the organic portion is dried, screened, and then passed through a secondary shredder, and from there to a pyrolysis reactor. The pyrolysis process produces a char, some of which is used as an auxiliary fuel and the remainder for sale. Combustible gas, all of which is used in plant, is also produced. The major by-product is a fuel oil.

Ferrous metals are removed by magnetic separation and glass by a flotation process.

*Figure 7* system produces a medium calorific value pyrolysis fuel gas. The system consists of single-stage shredding, pyrolysis shaft furnace, oxygen system, water quench tank, electrostatic precipitator, acid absorber, condenser, and gas compressor. Ferrous metal separation is included.

The shredded municipal solid waste is conveyed to ram feeders which charge it into the vertical shaft furnace. The shaft furnace includes three reaction zones: drying, pyrolysis, and combustion of char. Oxygen, fed into the combustion zone at the bottom of the furnace, reacts with carbon char residue from the pyrolysis zone. The hearth temperature is high enough to melt and fuse all noncombustible materials. The molten material is discharged to a water quench tank, where a hard, granular residue is produced. The hot combustion gases supply the heat of pyrolysis to the descending wastes. The hot pyrolysis gases flow upward to dry the entering wastes and are cooled. An electrostatic precipitator removes oil mist and flyash from the gases. The cleaned gases are passed through an acid absorber (may be omitted) and a condenser to remove water vapor. The oil mist and flyash are recycled back to the furnace's combustion zone.

*Figure 8* system produces a low calorific value pyrolysis fuel gas and carbonaceous fuel solids. The system consists of a pyrolysis shaft furnace, solids separator, solids pulverizer, water quench tank, regenerative air heater, combustion chamber for regenerative air heater, and fans (process air, combustion air, and induced draft).

As received, municipal solid waste is fed to the top of the vertical shaft furnace. High temperature air, preheated by passing it through a regenerative air heater, is used in the shaft furnace. Sufficient heat is produced in the combustion zone near the bottom of the furnace by the oxidation of the carbon char residue from the pyrolysis zone to melt and fuse all noncombustible materials. The molten slag is discharged to a water quench tank to produce an inert aggregate. The hot gases from the combustion zone permeate upward through the waste column and provide the heat for pyrolysis and drying. The hot off-gas passes through a solids separator which removes the carbonaceous solids. The gas is then transported to the fuel gas use.

The carbonaceous solids are pulverized for use as a solid fuel. Part of the fuel gas is used in a combustion chamber to supply heat to the regenerative air heater.

*Figure 9* system produces a low calorific value pyrolysis fuel gas. The system consists of single-stage shredding, shredded waste surge bin, rotary kiln, and quench tank. Ferrous metal separation is included.

Shredded municipal solid waste from the surge bin is fed continuously into a rotary kiln by ram feeders. Fuel oil and air are burned at the low end of the kiln and produce hot gases which pyrolyze the waste as it moves toward the low end. The pyrolysis produces oils, gases, and char. The char and noncombustibles are discharged from the kiln's low end into the quench tank. The quench tank feeds a residue separation system, which magnetically recovers the ferrous metals and discharges the wet char. The hot fuel gases leave the kiln's front end and are transported to the fuel gas use.
FIG. 3 PROCESS SCHEMATIC DIAGRAM; RESEARCH-COTTRELL INC., TWO STAGE SOLID WASTE RESOURCE RECOVERY FACILITY — FUEL NO. 3
FIG. 4  BLOCK DIAGRAM-COMBUSTION
EQUIPMENT ASSOCIATES, SOLID WASTE
RESOURCE RECOVERY FACILITY — FUEL
NO. 5

FIG. 5  BLACK CLAWSON FIBRECLAIM, INC. —
FUEL NO. 6
AS-RECEIVED MUNICIPAL SOLID WASTE (MSW) 350 TPD

PRIMARY SHREDDER

AIR CLASSIFIER

SCREEN

FINE GRIND (SECONDARY SHREDDING)

INORGANIC PROCESSING SUBSYSTEM (FROTH FLOTATION)

CLEAN GLASS 20 TPD

FERROUS METALS 32 TPD

UNRECOVERED SOLIDS TO DISPOSAL 18 TPD

FIG. 6 BLOCK DIAGRAM OCCIDENTAL RESEARCH AND DEVELOPMENT CORPORATION FUEL NO. 7

AS RECEIVED MUNICIPAL SOLID WASTE (MSW) 350 TPD

SHREDDER AND MAGNETIC SEPARATOR (ADDITIONS TO LATEST SYSTEM)

OXYGEN GENERATION STORAGE

GRANULATED METAL & GLASS 70 TPD

FIG. 7 BLOCK DIAGRAM-UNION CARBIDE "PUROX" SYSTEM-FUEL NO. 8
FIG. 8 CARBORUNDUM ENVIRONMENTAL SYSTEMS, INC. (TORRAX DIVISION) FUEL NO. 9
FIG. 9  BLOCK DIAGRAM-MONSANTO LANDGARD SYSTEM-FUEL NO. 10

* NOT REQUIRED FOR OPTIONAL USE OF OFF-GAS AS FUEL GAS
Our experience with several water-walled furnace, solid waste fired boilers indicates that boilers to be considered for conversion to a high percentage of heat input by direct solid waste firing should comply closely with the following design criteria, as found necessary for boilers designed specifically for waste firing. (These criteria provide conservative factors in the construction that recognize the fouling potential, the maintenance of proper gas temperature and afford protection against corrosion and erosion):

1. Tube metal temperatures limited to approximately 455 deg C (850 deg F) to minimize the possibilities of fireside corrosion. Based on wall tube temperatures about 28 to 56 deg C (50 to 100 deg F) above steam temperature, limit steam temperature to say 399 to 427 deg C (750 to 800 deg F), preferably 399 deg C (750 deg F) to be conservative. The higher limit to be considered for processed waste — a cleaner fuel with a lower fouling potential plus the use of firing systems, such as suspension or spreader stoker firing, which provide good mixing of fuel and combustion air to minimize local areas of reducing atmospheres that accelerate corrosion.

2. Furnace volumetric heat release for fully prepared solid waste between 597 and 634 MJ/m³ (16,000 and 17,000 Btu per cubic foot) with design temperature of the furnace exit gas entering the convection bank to be approximately 871 deg C (1,600 deg F).

3. In the hot portion of the convective bank, in-line tubes with the clear space between rows at least 76 to 102 mm (3 to 4 inches).

4. In the cooler portion of the convective bank, in-line tubes with at least 51 mm (2-inch) clear lanes.

5. Maximum gas velocities in the boiler bank at 6.1 m/s (20 feet per second).

6. Gas velocities in the furnace uptake, 4.6 to 6.1 m/s (15 to 20 feet per second.)

7. Minimum exit flue gas temperatures to precipitator, 232 deg C (450 deg F).

8. Economizer gas velocities, 9.1 to 12.2 m/s (30 to 40 feet per second).