**LAKELAND, FLORIDA: A SIMPLE APPROACH TO BURNING REFUSE AS A POWER PLANT FUEL**

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**ABSTRACT**

The City of Lakeland, Florida, Department of Electric and Water Utilities, owns and operates a municipal electric utility system for the generation and distribution of electric power. The 1978 expansion program includes a 364 MW coal fired steam electric unit which is jointly owned by the City of Lakeland and the Orlando Utility Commission of Orlando, Florida. Lakeland owns 60 percent of the plant and Orlando 40 percent. The unit is a conventional coal fired design with the capability of firing oil as a back-up fuel. An electrostatic precipitator is provided to remove stack gas particulates and a flue gas desulfurization system to remove sulfur dioxide while burning coal or oil. Other features of the plant include using effluent from the municipal wastewater treatment plant for make-up water for the cooling tower and the use of municipal solid waste as a supplemental boiler fuel. This paper describes the solid waste processing facility.

**SOLID WASTES AVAILABLE**

The City of Lakeland is located in Polk County, in the west-central part of Florida, almost midway between Tampa and Orlando. Polk County has a population of about 200,000. The population of the City of Lakeland is about 50,000. An additional population of 50,000 can be considered to be part of the greater Lakeland metropolitan area.

Solid wastes from Lakeland presently are trucked to a County-operated landfill. The quantity of waste delivered to the landfill from Lakeland is an average of 165 tons (150 t) per day. Essentially all wastes are collected during a normal 5-day work week, with only minor quantities collected on Saturdays.

It is considered that most of the wastes from the Lakeland metropolitan area can be handled by the new Lakeland waste reduction facility. The processible waste quantity available to the facility is estimated to average between 200 and 250 tons (181 and 227 t) per day. Normal variations in quantity are anticipated, due to daily and seasonal fluctuations.

Additional materials, in the form of yard trash and waste wood, are expected to be available to the proposed processing facilities. Should such materials be delivered to the processing plant, they will be required to be in a form which will be acceptable to the process.

**POWER PLANT**

The new boiler unit, provided by Babcock and Wilcox, will have a nominal rating of 364 MW. The normal fuel will be high sulfur pulverized coal, with complete redundancy provided by No. 6 fuel oil. The total heat input required at full load will be 3,323 million Btu/hr (3150 GJ/h). Its design will permit up to 10 percent of the full load heat input to be from shredded solid waste. As part of the provisions made for burning solid waste, the
boiler will have a dumping grate in its bottom. This latter feature will permit more complete combustion of heavy burnable waste particles which are not completely burned in suspension.

OBJECTIVES OF THE CITY OF LAKELAND

Because of the relatively small quantity of burnable solid waste being available, when compared to the waste burning capability of the new boiler, the City established certain objectives:
1. The processing facilities are to be simple.
2. The facilities will be designed to operate and be maintained with a minimum number of employees.
3. The maximum available heating value will be recovered from the wastes.
4. Process residues are to be a minimum.
5. The processing facility is to be operated for one shift per day.
6. Storage of raw or processed solid waste will be kept to a minimum.

The Department of Electric and Water Utilities will operate the plant, thereby providing sufficient control to meet the objectives.

BASIS FOR DESIGN

With the criterion of providing the simplest type of processing facility, the design of the plant was based upon the results of the St. Louis-Union Electric Company prototype system for processing and firing shredded refuse as a supplementary fuel to utility boilers. The initial St. Louis installation was not equipped with an air classifier, and the only material removed from the shredded waste before firing was magnetic metal. All of the remaining material was sent to the boiler. The particle sizes of the material fired were nominally 1-1/2 in. (38 mm) and smaller. Other than the expected pipeline abrasion and in the operation of small pneumatic feeders, no difficulty was experienced in handling this unclassified material. Small pneumatic feeders used to inject the material into pressurized pipelines leading to the boiler were subject to blockages. Some of the larger, dense particles in the shredded material tended to lodge between the rotors and the housing of the small feeders. However, no blockages occurred in the operation of a larger pneumatic feeder, which was used to transfer the shredded material from a receiving bin to a surge silo. It was concluded that the blockages occurring in the smaller feeders would have been minimized, if not entirely eliminated, if the feeders had been sized more generously.

A review of the several methods which could have been employed to correct the blockages in the pneumatic feeders in the prototype plant resulted in the decision to install an air classifier. The principal objective of the air classifier installation was to remove the denser and larger particles from the shredded refuse. This objective was accomplished, and resulted in substantial improvement in operation of the small pneumatic feeders. A secondary objective was to improve the quality of the supplementary fuel conveyed to the boiler. This secondary objective was only moderately successful. Over a period of about one year, the Midwest Research Institute, under contract with the USEPA, conducted tests at the prototype facilities. A summary of data comparing the average quality of the shredded material, both before and after air classification, is shown in Table 1.

Assuming that both the classified and the un-

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unclassified</th>
<th>Classified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity Milled</td>
<td>29,968* tms (26,530 t)</td>
<td>24,924 tms (22,660 t)</td>
</tr>
<tr>
<td>Heating Value</td>
<td>4,577 Btu/lb (10,660 kJ/kg)</td>
<td>4,797 Btu/lb (11,180 kJ/kg)</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>7.62 lb/c.f. (122.1 kg/m³)</td>
<td>6.12 lb/c.f. (98.0 kg/m³)</td>
</tr>
<tr>
<td>Glass</td>
<td>4.2 percent</td>
<td>2.9 percent</td>
</tr>
<tr>
<td>Nonmagnetic Metals</td>
<td>0.6 percent</td>
<td>0.4 percent</td>
</tr>
<tr>
<td>Moisture</td>
<td>24.43 percent</td>
<td>25.25 percent</td>
</tr>
<tr>
<td>Ash</td>
<td>23.19 percent</td>
<td>20.85 percent</td>
</tr>
</tbody>
</table>

*Not including metal removed by magnetic separation.
classified shredded waste would be deliverable to the boiler, the quantity of classified material would be about 85.7 percent of the unclassified material, although its heating value would be about 4.8 percent greater. The net loss in available heat from using the classified waste thus would be about 10.1 percent of the total heat potentially available from the unclassified waste.

Other comparisons show that air classification would reduce the bulk density by about 19.7 percent, reduce the glass content by about 30.9 percent, reduce the quantity of nonmagnetic metals by about 33.3 percent, increase the moisture content by about 3.3 percent, and reduce the ash content by about 10.1 percent.

Greater percentages of separation can be and have been achieved with air classifiers than those shown in Table 1. However, considering the variable nature of municipal wastes, it is doubtful that significantly greater efficiency of separating burnable material could be achieved and maintained consistently, in a single stage air classifier, without close monitoring and frequent adjustment. Single stage air classification therefore can be considered only as a means of partially improving the quality of refuse derived fuel. At the same time, air classification creates two additional problems, which, from the preceding tabulation, would be on the order of 14.3 percent of the waste, and that of removing dust from the airstream, which is large in volume.

COLLABORATING ORGANIZATIONS

The organizations collaborating on the project, and their respective functions, are as follows:

Owner — City of Lakeland, Department of Electric and Water Utilities
Power Plant Engineers — Charles T. Main, Inc.
Processing Equipment Supplier — Linder Industrial Equipment Company
Process Plant Designer — Horner & Shifrin, Inc.

Each of these organizations had a common goal; to provide a facility which would be simple and reliable. In the interest of providing the greatest assurance of success, several features were designed into the system which would result in additional operational flexibility. These features related principally to refuse/fuel quality, the degree of processing which would be required, and the amount of surge storage necessary for processed wastes.

PROCESSING FACILITIES

It was agreed that although air classification was difficult to justify, it would be installed to ensure satisfactory operation. It also was decided that provisions would be made to bypass the classifier, in order to permit the operators to have the option of greater operating flexibility, and to permit the burning of certain fuels, such as wood chips, which, having different air classification characteristics than shredded municipal waste, could be partially lost in the heavy fraction from an air classifier.

In order to provide reasonable assurance of satisfactory operation of the pneumatic conveying systems with unclassified waste, it was agreed that two basic elements required consideration, control of particle size and the sizing of the pneumatic feeders. As an initial decision, a nominal maximum particle size of 1-in. (25.4 mm) was agreed upon. The most satisfactory method of maintaining particle size control was determined to be by means of a rotary disc screen, with the discs spaced to permit the passage of particles less than 1-in. (25.4 mm) in size. Oversized particles then would be returned to the tipping floor for reshredding.

To assist in minimizing blockage of the pneumatic feeders, they were selected to ensure that the pockets between the rotor vanes would be only partially full. Under normal operating conditions, this feature, together with oversized drive motors, is expected to provide reasonable reliability in operation.

A block diagram of the principal components of the processing plant is shown on Fig. 1. The processing facility will have a nominal capacity of 40 tons (36 t) of raw mixed municipal solid waste per hour. Only those waste types normally processible by hammermills will be accepted at the plant. All processing equipment, as well as the tipping floor, will be enclosed in a pre-engineered metal building. The principal elements of the processing equipment are as follows:

1. A hammermill, which will reduce the raw refuse to particle sizes of nominally one and one-half in. (38 mm) maximum. The mill will be sized with a capacity of 50 tons (45 t) per hour, in order to accommodate the remilling of oversized material from the rotary disc screen.

2. An electromagnetic separator, located above the head pulley of a transfer belt conveyor, which will remove most of the magnetic metals from the milled refuse.
3. A rotary disc screen, which will receive the shredded refuse from the hammermill. Material with a nominal particle size greater than 1 in. (25.4 mm) will be returned to the tipping floor. All other material, nominally less than 1 in. (25.4 mm) in particle size, will be discharged to a reversing belt conveyor for delivery to either the air classifier or directly to the distributor bin.

4. An air classifier, for optional use, with the light fraction discharged from the cyclone to the conveyor leading to the distributor bin, and the heavy fraction discharged to trucks for disposal to landfill.

5. A distributor bin, with only nominal storage capacity, equipped to divide the prepared supplementary fuel into four equal streams.

6. Four pneumatic feeders, with positive displacement blowers, which will receive the material from the distributor bin, and discharge it into pressurized pipe lines for delivery to the boiler.

The configuration of the processing equipment is shown on Fig. 2.

### DISCUSSION

The design of the Lakeland processing system, because of its simplicity, is different from recent practice. The prevailing trend has been to provide facilities which produce progressively higher quality fuels, or which are intended to recover materials, such as nonferrous metals and glass, from the solid wastes. These latter facilities necessarily must include additional processing steps to meet their objectives. Such additional processing steps have the effect of increasing capital costs, as well as operation and maintenance costs.

The Lakeland design provides for no materials recovery other than that needed to assure satisfactory operation. The primary intent is to produce fuel from the waste at the lowest cost. Since the new boiler and its ash handling system can accept any material in shredded municipal waste that can be delivered to the boiler pneumatically, there is no reason to employ costly means of removing extraneous inert materials. The principal concern therefore is of providing a reliable means of conveying the shredded material to the boiler. The use of a rotary disc screen to control particle size, together with generously sized pneumatic feeders, is believed to provide a degree of reliability consistent with the City's objectives.

One of the adverse effects of incorporating devices such as air classifiers is the creation of fractions which require disposal by other means. These fractions, unless they are subjected to further processing, will contain burnable materials, which will require disposal to landfill. The Union Electric - City of St. Louis prototype experience indicated the net loss in heating value due to air classification is at least 10 percent of that available. The probable high moisture content of Lakeland wastes during the summer months, resulting in a greater percentage of material in the heavy fraction, may cause an even greater loss of heating value. In addition, disposal of the heavy fraction to sanitary landfill will be more costly than disposal of the resulting ash along with the coal ash from the boiler. Sludge from the sulfur oxide scrubber will be chemically treated in such a way that the sludge will form a solid mass which is comparable to a low grade concrete. The resulting material will be used as fill. Coal ash, along with ash from refuse burning, will be mixed with the scrubber sludge, thereby simplifying the disposal problem.

Of significant concern in all pneumatic systems handling shredded refuse is the pipe line erosion...
FIG. 2 LAKELAND, FLORIDA, SOLID WASTE PROCESSING PLANT
created by the abrasive particles in the refuse. It is possible to remove some of these particles by air classification and even more by screening. However, even shredded paper, the principal constituent of the refuse, is abrasive to some degree. It is not believed to be practical, therefore, to completely eliminate erosion in pneumatic pipelines. Union Electric's experience at the St. Louis prototype facilities was that the rate of pipeline erosion was no different with classified material than with unclassified material.

One of the features desired by the City of Lakeland is provision for the filtered air from the dust collectors to be used for the pneumatic transport systems. Most of this filtered air will be discharged to a plenum chamber, from which the pneumatic blowers will take their suction. Both the inlet and the outlet silencers will be located in the plenum chamber, which will be acoustically treated for the control of noise. The plenum chamber will be equipped with louver, to ensure a proper balance between the quantity of filtered air and the requirement of the blowers.

Installation of the simple system proposed for Lakeland does not preclude modification of the installed equipment or the addition of other processing steps to improve either operations or the quality of the refuse derived fuel. Such possible modifications might include the following:

1. If a change in maximum size were desired the spacing between the discs of the rotary screen can be changed merely by increasing or decreasing the length of the spacers between discs.
2. If it were found desirable to remove the fine abrasive materials in the processed waste, a second rotary screen could be installed, with discs spaced to remove the smaller particles.
3. If blockage of the pneumatic feeders were to occur too frequently, momentary reversing devices could be installed on their rotors, to allow the offending particles to be dislodged and to fall into the pneumatic pipelines.

The layout of the waste processing facilities is such that the modifications described in the preceding paragraphs can be made easily, if they are required.

**ADVANTAGES OF OPERATING THE SYSTEM WITHOUT THE AIR CLASSIFIER**

The processing system has a number of major advantages and only minor disadvantages if it were operated without the air classifier.

1. The system is reduced to the essentials. It will be easy to monitor and operate, requiring the same careful control and precautions as any other single stage shredding system, but offering the option of operating without the additional control needed for air classification.
2. The system is low in capital cost.
3. Operation of the air classifier would result in an additional power cost of about $9,000 per year.
4. Maintenance of the proposed facilities will be significantly less if operated without the classifier. The equipment with predictably high maintenance, the hammermill and the pneumatic pipelines, would be essentially the same. Maintenance for the classifier system would not be necessary if it were not operated.
5. Essentially all of the material processed in the system will be conveyed to the boiler. This will permit a maximum amount of the available energy to be recovered. Little, if any process residues will require disposal by landfill. Unburnable materials will be disposed of with the ash from the boiler.
6. A minimum of operation and maintenance personnel will be required. The equipment, in a simple and compact configuration, will be within sight of the operators.
7. Dust control will be simplified.
8. Should modifications to the plant be necessary, such as those described, they can be made easily without major disruption of the installed equipment.
9. No extraordinary problems are foreseen in conveying non-combustible materials to the boiler. The quantity of such materials would be only a very small fraction of the total boiler fuel. Particle sizes would be confined to nominally one in. (25.4 mm) and less.
10. Since the boiler is equipped with a dumping grate, operation of the processing plant without the classifier will permit the use of additional desirable fuels, such as wood chips, a portion of which would be lost in the heavy fraction from a classifier.

The advantages of air classification include a reduction in the ash content of the refuse fuel, a reduction in the overall bulk density and a slight increase in the as-fired unit heating value. None of these are considered to be of importance in this application.

**FUEL VALUE AVAILABLE**

The processing facilities will have a nominal
capacity of 40 tons (36 t) of raw refuse per hr. About 6 percent of the refuse will be magnetic metal which will be removed. Process losses, including part of the moisture, when the air classifier is not used, will probably reduce the useable supplemental fuel to about 36 tons (32.5 t) per hr. The heat content of the processed material can reasonably be expected to fall within the range of 4200-4700 Btu/lb (9800 to 10,950 kJ/kg). Thus the nominal total heat contributed to the boiler by the processed refuse would be between 302 and 338 million Btu/hr (288 - 322 GJ/h), or about 10 percent of the full load boiler heat requirement of 3323 million Btu/hr (3150 GH/h). If the supplementary fuel were air classified, its available heat would be reduced to about 9 percent or less of the full load heat requirement.

**RELIABILITY**

The processing plant will consist of a single line of equipment. Any malfunction of one component will result in loss of production. This, in itself, is not considered catastrophic, since refuse disposal redundancy is provided by sanitary landfill, the method presently used for disposal. The most vulnerable subsystem in the plant is considered to be the shredder. This equipment takes the brunt of accommodating the heterogeneous materials comprising raw municipal waste, and must be of extremely rugged construction. All shredder systems in similar service, no matter how rugged their construction or how carefully they are operated, are subjected to a certain amount of unscheduled downtime. Outages of short duration, 30 - 60 min., should not affect production significantly since the anticipated quantity of refuse delivered to the plant normally can be processed in less than an 8-hr. operating shift. There may be occasions when it could be justifiable to extend operations partially into the second operating shift. Scheduled maintenance functions, such as retipping or replacing hammers in the shredder, normally should be performed during the second shift. In general, only major outages, such as those required for replacement of vital components of the system, should be of such duration as to cause significant loss of production. It is estimated that major outages of the shredder system may cause an annual production loss on the order of 5 percent.

The remaining equipment in the system, exclusive of the air classifier, such as conveyors, the magnetic separator, the rotary disc screen and the pneumatic feeders, also can be expected to have occasional outages, due to blockages and malfunction of components. The same rationale as that described for the shredder system applies to this equipment. Only major failures of vital components should cause an overall loss of production. It is doubtful that more than a 10 percent annual production loss would accrue from malfunctions of this equipment. Some additional production loss potentially could accrue from the air classifier subsystem. This presumes that scheduled maintenance, such as the replacement of liners and bearings, would be performed during the second shift.

**PROJECTED ECONOMICS**

The coal-fired boiler unit, to which the refuse fuel will be fired, is scheduled for completion in October, 1981. The waste reduction plant therefore cannot be used until then. It is anticipated that the installed cost of the waste processing facilities will approach $5,000,000. The capital recovery factor used by the City of Lakeland, including interest and depreciation, is 12.55 percent per year. Thus, the amortization cost can be considered to be about $627,500 per year.

Annual operation and maintenance costs are expected to be less when the facilities are operated without the air classifier than when operated with the air classifier. Similarly, the credits accruing from refuse burning are expected to be greater without air classification than with air classification. A greater percentage of the fuel value available from the shredded waste is expected to be utilized from the unclassified material. A summary of the relative economics of operation with and without the classifier is presented in Table 2.

The differences in the economic elements of operating with and without the air classifier may be summarized as follows:

1. Less supplemental fuel will be produced with the classifier (about 10 percent less).
2. Operation and maintenance labor and materials will be slightly greater with the classifier.
3. Power costs will be about 10 percent greater with the classifier.
4. Residue disposal cost with the classifier will be about three times that without the classifier.
5. Incremental ash disposal cost will be slightly greater without the classifier.

The estimates shown in Table 2 indicate that in 1982 the anticipated credits will exceed costs by
### TABLE 2 SUMMARY OF PROJECTED ECONOMICS WITH AND WITHOUT AIR CLASSIFICATION

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<th>Without Classification</th>
<th></th>
<th>With Classification</th>
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<tbody>
<tr>
<td>Processible Raw Waste Available</td>
<td>50,000 T/year (45,370 t/year)</td>
<td>50,000 T/year (45,370 t/year)</td>
<td></td>
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<tr>
<td>Supplemental Fuel Produced</td>
<td>45,000 T/year (40,830 t/year)</td>
<td>40,000 T/year (36,300 t/year)</td>
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</tr>
<tr>
<td>Magnetic Metal Recovered</td>
<td>3,000 T/year (2,720 t/year)</td>
<td>3,000 T/year (2,720 t/year)</td>
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**Estimated Annual Costs (1982)**

<table>
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<tr>
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<th>Without Classification</th>
<th></th>
<th>With Classification</th>
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<tbody>
<tr>
<td>Operation and Maintenance Labor</td>
<td>$73,500</td>
<td>$82,700</td>
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<tr>
<td>Maintenance Materials</td>
<td>30,400</td>
<td>33,000</td>
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<tr>
<td>Equipment Replacement</td>
<td>60,000</td>
<td>62,000</td>
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<tr>
<td>Front End Loader Maintenance</td>
<td>10,000</td>
<td>10,000</td>
<td></td>
<td></td>
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<tr>
<td>Electric Power</td>
<td>93,500</td>
<td>102,200</td>
<td></td>
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</tr>
<tr>
<td>Residue Disposal</td>
<td>15,000</td>
<td>45,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incremental Ash Disposal</td>
<td>17,000</td>
<td>15,000</td>
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<td></td>
</tr>
<tr>
<td>Miscellaneous Expense</td>
<td>25,000</td>
<td>25,000</td>
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<tr>
<td><strong>Total Operation and Maintenance Cost</strong></td>
<td>$324,400</td>
<td>$374,900</td>
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<tr>
<td>Amortization</td>
<td>$627,500</td>
<td>$627,500</td>
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<tr>
<td><strong>Total Annual Cost</strong></td>
<td>$951,500</td>
<td>$1,002,400</td>
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</tbody>
</table>

**Estimated Annual Credits**

<table>
<thead>
<tr>
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<th>Without Classification</th>
<th></th>
<th>With Classification</th>
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<tbody>
<tr>
<td>Supplemental Fuel</td>
<td>$699,300</td>
<td>$629,370</td>
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</tr>
<tr>
<td>Magnetic Metal</td>
<td>30,000</td>
<td>30,000</td>
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<td></td>
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<tr>
<td>Savings in Tipping Fees</td>
<td>300,000</td>
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<tr>
<td><strong>Total Annual Credits</strong></td>
<td>$1,029,300</td>
<td>$959,370</td>
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About $77,000, if the system were operated without the classifier, but that 1982 costs would exceed credits by about $43,000 if the classifier were used. With the passage of time, both modes of operation show improvement in their economic attractiveness. In 1987, the anticipated fifth year of operation, credits are estimated to exceed costs by about $360,000/year without the classifier and by about $193,000 per year with the classifier.

The tipping fees reflected in Table 2 are based upon fees applicable at present. It is anticipated that these fees will increase substantially when the landfills are upgraded to accommodate more stringent requirements.

### SUMMARY

The Lakeland refuse processing system does not follow the accepted industry practice to upgrade refuse-fuel quality, or to recover materials such as nonferrous metals and glass from the raw refuse. The reason: the City's main objective is to obtain low cost fuel to generate electricity.

The Lakeland system will not be applicable everywhere. Many of the current problems of supplementary fuel systems do not exist in Lakeland. Some of these are:

1. The City has control over waste collection and disposal, as well as over its power generation facilities. Institutional problems therefore are minimized.
2. The new power plant, particularly the boiler and its ash handling system, incorporates features which are intended to facilitate refuse burning. There are no problems of adaptation.
3. The processing facility is adjacent to the power plant. No transportation problem exists.
4. The refuse processing plant operation will be under the control of the power plant. This eliminates conflict in jurisdiction.
5. The new steam-electric plant has the capability of burning a high percentage of waste fuel. There is no reason to provide more than minimum storage capacity for processed waste.
6. The waste processing and firing facilities are part of the fuel supply system. There are no significant financing problems.

7. The existing landfill will be available to accommodate wastes during outages of either the processing plant or the power plant. Additional redundancy is unnecessary.

The conditions prevailing in Lakeland permit a minimum facility to be built with corresponding economy in capital, operation and maintenance costs. The facility will provide low cost fuel for generating electricity and at the same time accommodate the greater part of the waste disposal problem for Lakeland.

Key Words
Boiler
Burning
Public Utility
Fuel