# Experience in Slagging Pyrolysis Systems

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## BACKGROUND

The origin of the program described goes back to Connecticut Research Commission Research Support Award 67-14 Eggen and Powell (then faculty members of the University of Hartford) for a "Feasibility Study of a New Solid Waste System." This analytical study led to laboratory work under a continuation of the Award. The results were published in two reports, "Feasibility Study of a New Solid Waste System" (DUST/TR-6701; November, 1967) and "Final Report, Preliminary Study of a New Solid Waste System" (DUST/TR-6801; June 30, 1968).

This initial work led to the formation of Urban Research & Development Corporation with private funding in July 1968. To this date there has been no Federal or further State support for the program. URDC continued the work through an extensive development program. We are now at the stage of designing a complete full-scale municipal system which is to be the first full-scale demonstration of our new technology.

A schematic of the basic process is shown in Fig. 1. The heart of the system is the self-sustaining slagging partial combustion pyrolysis process. Combustion of fixed carbon with heated air in the counterflow packed bed of the pyrolysis reactor provides the energy to dry and pyrolyze the refuse. Temperatures and oxygen concentrations in the char combustion zone are high enough to oxidize the metals and form a single phase inorganic oxide melt. This melt consists of the oxidized metals, glass and ash. Combustion of the pyrolysis products in a separate fuel gas burner provides the energy required to preheat the partial combustion air.

This process evolved during the development program. Many aspects of the final configuration which are quite obvious from hindsight, were not so obvious at the beginning and we make no apologies for the occasional abrupt changes that occurred in the program's directions.

## THE FIRST SMALL PILOT PLANTS

The initial concept utilized a process closer to pure pyrolysis. That is, most of the heat required to dry and pyrolyze the refuse was supplied through the walls of a retort within the reactor. The main function of the partial combustion was to burn off the fixed carbon. The early pilot plants were all built with this approach. For simplicity, they used ambient temperature pyrolysis air.

The first pilot plant was built with refractory retort. Since heat had to be supplied through the walls, the walls had to run hotter than the process. They had to be as thin as possible to minimize thermal resistance. Furthermore, there is no easy way to provide structural support for a heated refractory

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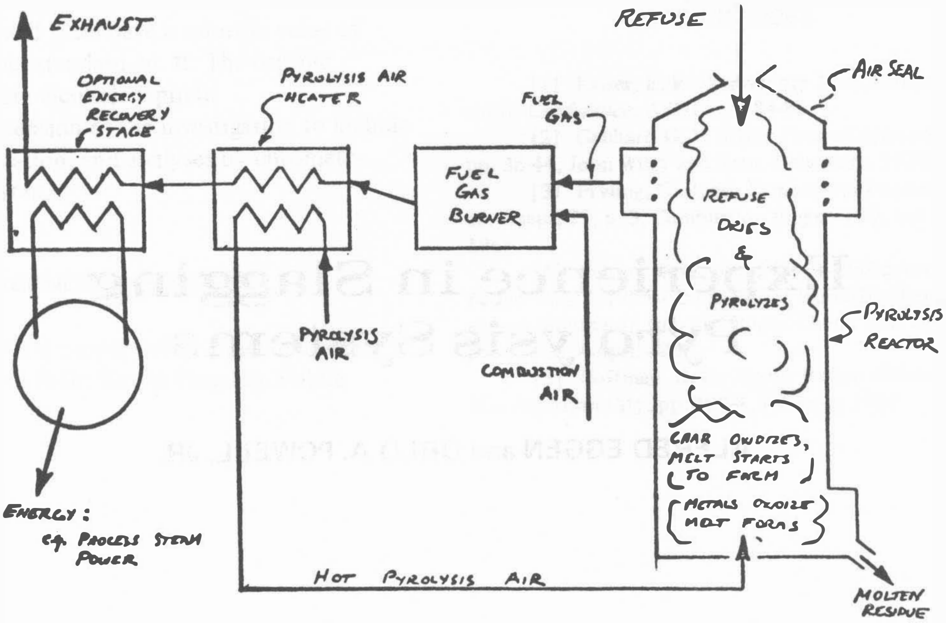


FIG. 1

retort. These factors combined with the strong dissolving power of the melt made cracking and erosion very difficult problems to deal with.

A number of alloy samples were tested in the pilot plant. They offered promise since the data indicated that the minimum process temperature was about 2000°F. From these tests, Incoloy 800 appeared to be a good choice as a retort construction material from a performance standpoint and the best choice from a cost standpoint. Later tests showed that Inconel 600 and RA 330 give good results in similar environments.

An alloy retort (12"x12"x30" deep) was fabricated from ¼" Incoloy 800. A proprietary air sealing refuse feeder was also incorporated. This pilot plant showed that it was possible to convert refuse into a molten slag and a fuel gas; that the fuel gas could be burned cleanly under the right conditions; that the proprietary feeder, although somewhat fragile, could handle surprisingly large, irregular objects with reasonably good gas sealing; that alloy retort construction appeared to be feasible. The retort bottom cracked after 200 hours of operation because of excessive stress levels. The retort was rebuilt but failed again because of poor weld preparation.

A second retort (16" dia. x 30" deep) was fabricated and ran for 3000 hours before failure. A crack started on a side wall in a locally hot area. The crack continued to open up because the wall was under tension. There was considerable erosion of metal in the immediate area of the crack. However, most of the retort remained in good condition. There were signs of attack (i.e., magnetic regions) but in general the alloy retained its ductility and showed no significant metal loss. On the basis of our experience wc concluded that alloy retorts were feasible provided:

1) Very conservative maximum allowable stresses are used in the design. These should be set by long time creep criteria. Local regions of excessive tensile stress must be avoided since cracks once formed cause an increase in local stress levels which in turn accelerates crack growth.

2) Provision is made to handle the erosion of metal by slag in the presence of oxidizing atmospheres.

3) Proper weld procedures are used.

4) Maximum temperatures are held to 2000°F, although short time over temperatures to 2100°F or even higher can be survived.

At this stage a decision had to be made whether to continue with more sophisticated small-scale pilot plant work or to go to a larger prototype facility. Scaling seemed risky because of the relatively large scale of the refuse feed stock in comparison to the scale of the process apparatus and because of the complete absence of data on the behavior of larger scale systems similar to ours. These factors were coupled with the desire to reach the production

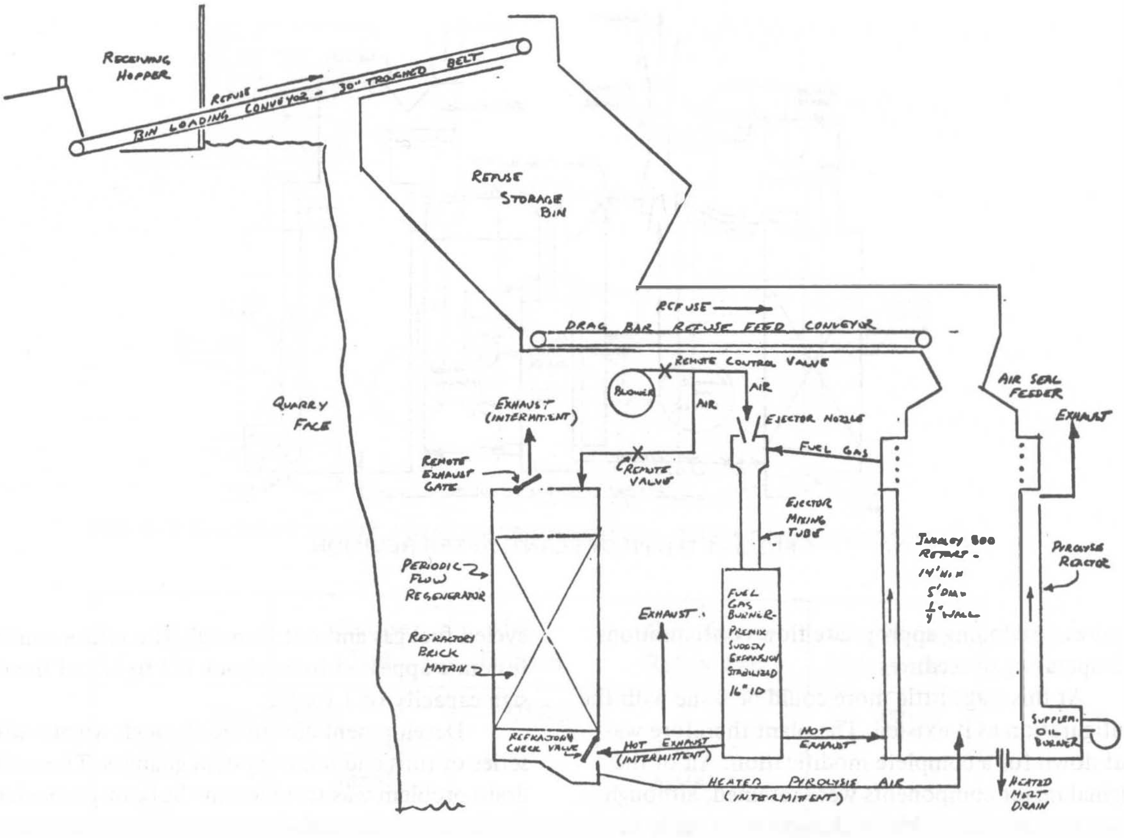


FIG. 2—1 TPH PILOT PLANT, INITIAL CONFIGURATION

hardware stage as quickly as possible and the willingness to take risks to achieve these ends. As a result the decision was made to go directly to a large-scale pilot plant.

## 1 TON/HR PILOT PLANT

Design of the 1 TPH nominal capacity pilot plant started in the Spring of 1969. Approval for the construction and operation of the plant was issued August 21, 1969. A schematic of the original plant is shown in Fig. 2. Responsibility for the design and construction of the refuse receiving and storage portion was taken by Roncari Industries, Inc. URDC had the responsibility for the design and construction of the refuse feeder and thermal processing system.

The first refuse was received on December 8. The initial development phase went through the Winter and into the Spring of 1970. During this time only a small quantity of refuse was processed. Problems developed due to winter weather, refuse hangups in hopper and bin, rain water leakage into the pyrolysis reactor, excessive air leakage into the reactor, miscellaneous mechanical problems, inadequate flexibility in the thermal processing system and uneven temperature distribution around the retort bottom.

After suitable modifications, we were able to make and burn fuel gas without smoke at moderate rates if everything was right, and consistently at very low rates. The combination of drag conveyer and proprietary feeder could feed ordinary packer body refuse into the reactor without problems provided we could get the refuse onto the conveyer. We took some reactor damage due to local overheating. We also had to change the supplementary fuel from No. 2 fuel oil to kerosene because of sulfur attack in the hot zones.

By March the temperature distribution situation was greatly improved, though certainly not solved. The next two months were spent in learning some of the intricacies of slag tapping. There are really only two basic conditions that must be met: adequate temperatures (i.e., approximately 2000°F minimum) must be maintained; a situation analogous to a clogged filter must be avoided. The first is essentially a straightforward design problem. Solving the second

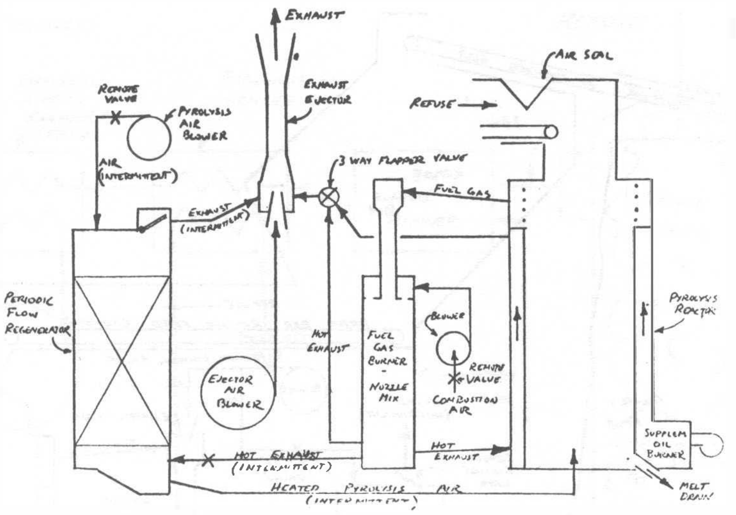


FIG. 3—1 TPH PILOT PLANT, AFTER REVISION

requires developing appropriate flow configurations and operating procedures.

At this stage little more could be done with the configuration as it existed. The plant therefore was shut down for a complete modification. All of the original major components were retained, although some were modified. Major changes were made in process flow and control. A schematic of the revised system is shown in Fig. 3. The only part of the refuse handling system that could be significantly modified was the feeder. This was redesigned and relocated well away from the hot zone, sealing at the conveyer rather than downstream of it.

The fuel gas burner was converted to a sudden expansion stabilized nozzle mixing configuration. This eliminated flashback as well as the need to operate near stoichiometric fuel air ratios. Both of these were serious problems with the original burner configuration. A more potent torch igniter/pilot was also incorporated. The heating zone around the inner alloy retort was changed to a full tangential flow configuration. Potential leakage areas were positively sealed whenever possible. A new melt drain configuration was added.

The first run with the new system took place on June 26, 1970. The system proved capable of continuous refuse feeding and processing and continuous melt formation. However, it was not yet capable of continuous melt removal because of a local cold zone in the slag tapping area. The fuel gas produced from the refuse could be burned without smoke and with good combustion stability and reasonable temperature control. A high percentage of the heat required to dry and pyrolyze the refuse came from the burning of recycled fuel gas and not from oil. The refuse consumption rate appeared to be about 1/3 to 1/2 of the design capacity of 1 ton/hr.

Development continued through August with a series of runs and minor system changes. The melt drain problem was troublesome but not particularly fundamental. Excessive air leakage into the area around the hot zone of the retort cooled the melt drains too much to allow melt flow. This excessive air leakage occurred only while running and was caused by the vacuum produced in the bottom end by the induced draft system when adjusted to handle the high exhaust flows produced while processing refuse. The data indicated that most of the heat of drying and pyrolysis came from the partial combustion of the fixed carbon with the heated pyrolysis air. Very little came from the recycled exhaust products that provided heat flow through the retort walls.

A final set of changes were made. They included: improved flow control; a simple slag buggy system for melt collection; blocking the duct which recycled the hot exhaust around the retort. The last change was simple but fundamentally very significant. It converted the system to a straight partial combustion pyrolysis system in which all of the heat required to dry and pyrolyze the refuse came from the internal partial combustion process. This change not only simplified the system but it also eliminated the need to heat through the retort walls. This opened the design to either insulated or cooled reactors which could use either alloy or refractory walls. A schematic of this final version of the plant is shown in Fig. 4.

The first run with the final configuration was made on September 14, 1970. Approximately 5900

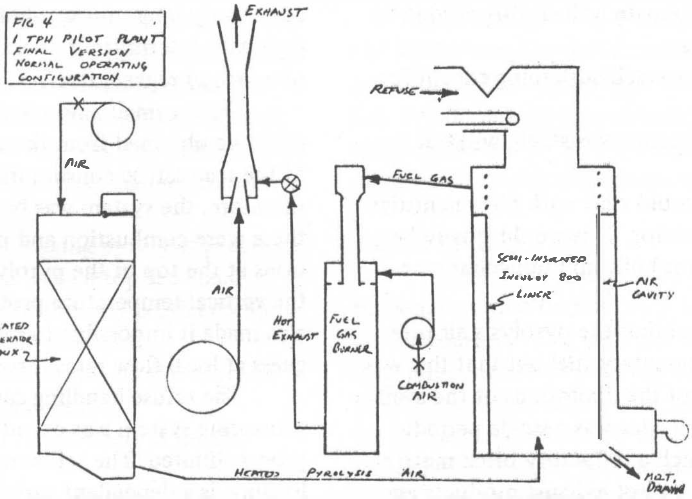


FIG. 4–1 TPH PILOT PLANT, FINAL VERSION NORMAL OPERATING CONFIGURATION

| Date | Refuse Fed | Melt Drained | Cumulative Refuse Fed | Cumulative Melt Drain. |
|---|---|---|---|---|
| New System | – | 750 lb | – | 750 lb. |
| 6/26/70 | 2,500 lb | | 2,500 lb | |
| 6/30 | 3,000 | | 5,500 | |
| 7/1<br>7/2 | 3,200 | | 8,700 | |
| 7/13 | 4,200 | | 12,900 | |
| 7/13-7/15 | | 1,700 | | 950 |
| 7/16<br>7/17<br>7/20 | 3,400 | 1,160 | 16,300 | 2,110 |
| 7/21 | 1,400 | | 17,700 | |
| 7/22 | | 780 | | 2,890 |
| Rebuild Feeder, Melt Removal System | | | | |
| 8/31 | 4,000 | | 21,700 | |
| Rebuild Melt Removal System, Flow Control; All Heat By Partial Combustion | | | | |
| 9/14 | 5,900 | 1,450 | 27,600 | 4,340 |
| 9/23 | 6,000 | 1,700 | 33,600 | 6,040 |
| 10/6 | 6,200 | 1,900 | 39,800 | 7,940 |
| 10/7 | 13,300 | 3,680 | 53,100 | 11,620 |
| 10/15/70 | 5,000 | 1,200 | 58,100 | 12,820 |

FIG. 5–RUN HISTORY 1 TPH PILOT PLANT

lbs. of refuse were consumed and 1450 lbs. of slag produced. This run and all of the succeeding runs were successful and all were consistent with each other. A run history is tabulated in Fig. 5. The behavior of the thermal processing system could be outlined as follows:

1) Essentially all of the pyrolysis heat was supplied by partial combustion with heated air.

2) Auxiliary burners were used to preheat the reactors. However, the preheat was not to full operating temperature and refuse processing started with some relatively cold residue in the reactor. Internal

heat generation was adequate to heat this residue to operating temperatures.

3) This process was self-sustaining except for startup and burnout.

4) The fuel gas burner was stable without requiring a pilot flame.

5) The process could start with fair quantities of old residue in the reactor. This would slowly be removed as temperatures built up in the char combustion zone.

It should be noted that the pyrolysis air preheat came from supplementary fuel but that this was required only because of the limitations of the available hardware. The air heater was a single periodic flow regenerator in which a refractory brick matrix was alternately heated by hot exhaust products and cooled by pyrolysis air. This would have been acceptable with the original configurations since only part of the heat was to be supplied by pyrolysis air and therefore the flow could be intermittent. In the final configuration two regenerators would have been required for continuous steady-stage operation: one to supply the heat to the pyrolysis air and one to remove the heat from the exhaust, with flow alternating between them. The tests did demonstrate that the energy was there. Alternately, a direct-transfer regenerator could have been used and, in fact, was on the next pilot plant.

The system was not without its problems. The hardware had gone through a development program during which many changes were made. Components in the thermal processing system were modified to perform in ways considerably different from those for which they had been designed. Deficiencies in the refuse receiving and storing system could not be overcome by simple modification. As a result refuse feeding was a complex operation that required two people and a truck driver. Packer body refuse dumped at the East Granby landfill was loaded on to a dump truck or a small stake body truck and taken to our site a few thousand pounds at a time. The refuse was manually dumped into the receiving hopper. This had to be done slowly and continuously to minimize hopper and bin loading conveyer bridging. Feeding had to pretty well match the rate of removal of refuse from the storage bin or refuse would bridge from the sloping surface of the bin and never reach the feed conveyer.

As a result of these problems we were limited to a maximum run length of about one shift. The longest run consumed 13,300 lbs. of refuse and was terminated simply because we couldn't get any more refuse. Even if the logistics problem had been overcome, very long runs would have been impossible, except with intermittent operation, because of the lack of a second regenerator.

Only a small amount of reliable numerical data could be obtained from the system. No measurement of the true refuse consumption rate was possible. Furthermore, the system was basically leaky. As a result, there were combustion and partial combustion reactions at the top of the pyrolysis reactor which made the vertical temperature profiles meaningless. Leakage also made it impossible to make anything but a crude guess at local flow rates throughout the system.

The refuse handling capacity of the thermal processing system was essentially system and not process limited. The refuse consumption rate, or bed loading, is a dependent variable (i.e. it cannot be set independently by overfeeding as in a conventional incinerator). It is determined mainly by the pyrolysis air rate and temperature. Furthermore, bed temperatures are also dependent variables and increase as bed loading increases. As a result the maximum refuse processing rate of any given system will usually be set by its pyrolysis air capacity, its exhaust gas handling capacity and the maximum bed temperature that the operator will allow. In the case of the 1 TPH pilot plant, the exhaust handling system was somewhat marginal. In addition, the alloy wall was semi-insulated, placing a severe temperature limit on system operation.

In any case, our best estimates indicate that the refuse processing rate met or exceeded the nominal capacity of 1 TPH only for relatively short periods of time. The average rate for most runs was probably on the order of 1500 lb/hr.

Although detailed data was limited, the operational data and the crude overall performance measurements were extremely valuable. The results of the program could be summarized as follows:

1) Conveyerized handling of unshredded refuse is practical but very careful design is required. Conveyer loading is the most critical step.

2) Bin storage and automated unloading of unshredded refuse is not feasible with any known approach that we are aware of. It is possible that techniques could be made to work but we would expect that a significant development effort would be required.

3) There are small scale modeling techniques and analytical approaches that will give very useful data on what refuse can be expected to do in various handling systems.

4) The proprietary refuse feeder that was developed was capable of very gently aligning and feed-

ing quite large and irregularly shaped objects with fair air sealing properties. However, we have decided to go to double door air lock feeders for large municipal systems handling unshredded refuse for two reasons: the feeder is basically a low temperature device susceptible to damage by overheating; maintenance requirements are questionable.

5) A self-sustaining slagging pyrolysis process is both possible and practical using a top fed fixed refuse bed with refuse gasification by partial combustion of the fixed carbon with heated air.

6) Pyrolysis air temperatures on the order of 1500°F will give satisfactory results.

7) The pyrolysis air requirement is on the order of 1 lb air/lb refuse.

8) Minimum bed hot zone temperatures for practical melt producing rates are on the order of 2200°F to 2400°F; minimum temperatures for melt drainage are on the order of 2000°F.

9) Under normal controlled operating conditions (i.e. no channeling, no burning at the top of the bed and adequate fuel gas burner combustion air control) the system exhaust is completely clear and odorless.

10) The slag will severely attack any refractory that we have tried–if the temperature is high enough. However, brick of super duty or a little better quality (e.g. A.P. Green Mizzou, 60% alumina) has survived rather long time contact with slag at temperatures estimated to be 2200°F or a little higher without any sign of damage.

11) Either cooled refractory or cooled alloy reactor linings can be used. Hot zone wall cooling requirements could not be established but do not appear to be excessive. Air cooling should be adequate, at least for the order of bed loadings in question.

At this stage there was very little more that could be learned from continued operation of the plant. Both long time continuous operation or detailed numerical design data acquisition would have required extensive rebuilding. Furthermore, operation was expensive enough to be essentially beyond our resources. The plant therefore was shut down and dismantled in preparation for a hoped-for rebuilding. At the time we were in the midst of negotiations which would have provided funding for this next stage. We spent the next months redesigning the 1 TPH pilot plant. We also did some smaller pilot plant work on new pyrolysis reactor configurations suggested by Roncari Industries, Inc. All of these configurations used externally heated alloy reactors and no significant new knowledge was obtained.

In February 1971 the negotiations fell through and URDC was faced with a financial crisis. No demonstration plant of any type was running. We therefore decided to design and build a small (140 lb/hr rated capacity, 16″ ID reactor), minimum cost pilot plant based on our experience with the 1 TPH plant.

## 140 PPH PILOT PLANT

A schematic of this pilot plant is shown in Fig. 6. Design started on February 11 and the first run was on February 27. The behavior of the new pilot plant was quite consistent with the behavior of the 1 TPH plant. The potentially troublesome scale effects which we had worried about did not materialize. As of this writing 40 runs have been made in which almost 30,000 lbs. of refuse have been processed to produce over 9600 lbs. of molten residue. The runs are summarized in Fig. 7.

The refuse used for all runs is ordinary residential refuse picked up either in Windsor Locks or Manchester, Connecticut. Refuse handling problems require that we restrict ourselves to bagged refuse. The refuse is taken as it was found with the exception that we try to avoid large quantities (i.e. bags full) of yard waste and that we generally try to take refuse mainly from people who put out all of their refuse in bags. In this area most people dispose of garbage with the refuse so there is no shortage of food wastes in the refuse we use. As can be seen from the high inorganic residue contents, there is also no shortage of glass and cans.

The only serious problems which arose while running were caused by either melt drain heater burnouts, improper operating procedure, or hydrocarbon condensibles in the fuel gas. The first is a rather straightforward design/control problem. The second is simply following correct operating procedures (which can be automated) and the third is a matter of maintaining adequate fuel gas temperatures.

As the program progressed, it became evident that the pilot plant was capable of producing real numerical design data. Control techniques were improved, instrumentation added and the whole range of problems associated with taking reliable data were attacked.

Data from a fairly typical recent run is shown in Figs. 8 & 9. The feeding procedure is to fill the reactor and feed chute to the top initially. Every fifteen minutes or so the feed chute is refilled to the top. Therefore, the slope of the cumulative refuse fed plot (Fig. 8) gives the instantaneous refuse consumption rate. As can be seen from the data, this consumption rate is quite stable. The bed temperature profile

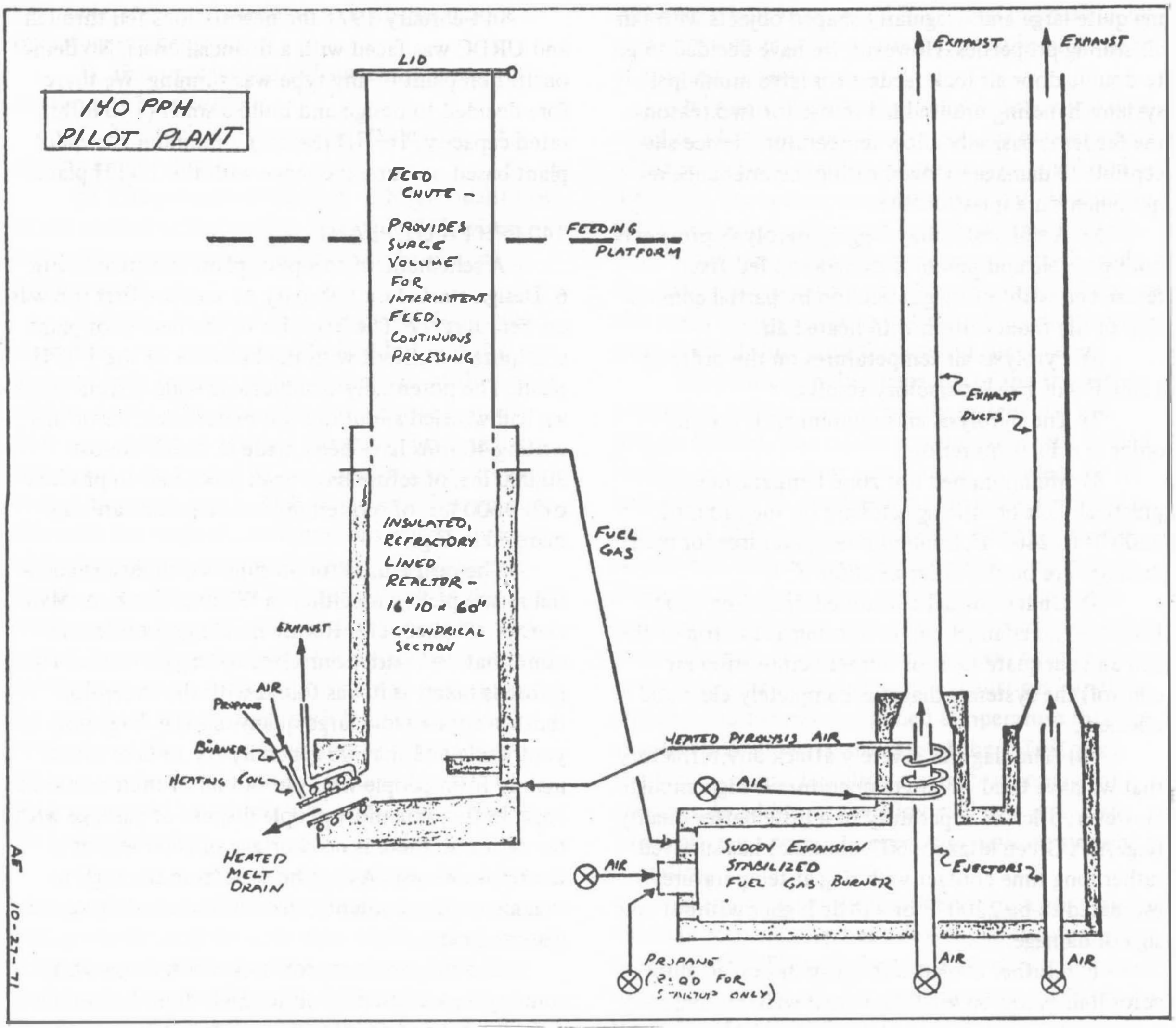


FIG. 6

(Fig. 9), is also reasonably stable. The best approach to dealing with bed temperature data is to think of it as analogous to a normal turbulent flow situation except that the time scale is stretched out by many orders of magnitude. As a result heavy thermocouples produce an instantaneous bed temperature reading fluctuating randomly about a steady state value. Time averages on the order of hours are required to produce the steady state values. Work on correlating the data is under way. Unfortunately, the pressures of time have severely limited progress.

Gas phase compositions have been measured for both the fuel gas and the char combustion zone of the bed. An analytical model of the bed process has been outlined. The model is generally consistent with both the performance data and the composition data. Approximate internal and overall heat and mass balances can be made for the complete bed which are in general agreement with both the data and the model. This approach has a great deal of promise as an extremely powerful design and performance prediction tool. Much work remains to be done and again, we have had little time to spend on it.

## THE FUTURE

By July we had reached the stage where we no longer had the manpower to run an experimental program. Pilot plant operation since then has been for demonstration purposes and data acquisition has been

| Run No. | Date | Refuse Fed | Melt Drained | Cumulative Refuse Fed | Cumulative Melt Drained | Comments |
|---|---|---|---|---|---|---|
| 1 | 2/27/71 | 444 lb | 92 lb | 444 lb | 92 lb. | |
| 2 | 3/2 | 713 | 257 | 1,157 | 349 | |
| 3 | 3/3 | 622 | 487 | 1,779 | | |
| 4 | 3/4 | 489 | | 2,268 | 836 | |
| 5 | 3/5 | 458 | 240 | 2,726 | | Reactor Cleaned out- 80 lb Melt |
| 6 | 3/9 | 779 | | 3,505 | 1156 | |
| 7 | 3/16 | 327 | 68 | 3,832 | 1224 | |
| 8 | 3/18 | 915 | 300 | 4,747 | 1524 | |
| 9 | 3/19 | 840 | 211 | 5,587 | 1735 | |
| 10 | 3/25 | 631 | 160 | 6,218 | 1895 | 30% Average Melt |
| 11 | 3/26 | 906 | 234 | 7,124 | 2129 | |
| 12 | 3/30 | 2060 | 501 | 9,184 | 2815 | Reactor Cleaned out-185 lb Melt |
| 13 | 4/8 | 820 | 166 | 10,004 | 2981 | |
| 14 | 4/15 | 908 | 214 | 10,912 | 3147 | |
| 15 | 4/16 | 513 | 198 | 11,425 | 3393 | |
| 16 | 4/22 | 786 | 240 | 12,211 | 3633 | |
| 17 | 4/23 | 790 | 315 | 13,001 | 3948 | |
| 18 | 4/30 | 972 | 220 | 13,973 | 4168 | |
| 19 | 5/6 | 642 | 237 | 14,615 | 4405 | |
| 20 | 5/12 | 626 | 278 | 15,241 | 4683 | 31% Average Melt |
| 21 | 5/14 | 718 | 255 | 15,959 | 4938 | |
| 22 | 5/25 | 795 | 242 | 16,754 | 5180 | |
| 23 | 5/26 | 886 | 300 | 17,640 | 5480 | |
| 24 | 6/2 | 811 | 247 | 18,451 | 5727 | |
| 25 | 6/3 | 663 | 285 | 19,114 | 6012 | |
| 26 | 6/14 | 700 | 297 | 19,814 | 6309 | |
| 27 | 6/28 | 406 | 136 | 20,220 | 6445 | |
| 28 | 7/1 | 705 | 200 | 20,925 | 6645 | |
| 29 | 7/16 | 704 | 263 | 21,629 | 6908 | |
| 30 | 7/20 | 904 | 301 | 22,533 | 7209 | 32% Average Melt |
| 31 | 7/23 | 739 | 314 | 23,272 | 7523 | |
| 32 | 7/29 | 800 | 239 | 24,072 | 7762 | |
| 33 | 8/6 | 578 | 105 | 24,650 | 7877 | 10 lb Melt Removed from Reactor |
| 34 | 8/11 | 689 | 206 | 25,339 | 8083 | |
| 35 | 8/12 | 1062 | 277 | 26,401 | 8360 | |
| 36 | 8/31 | 870 | 250 | 27,271 | 8610 | |
| 37 | 9/17 | 816 | 285 | 28,087 | 8895 | |
| 38 | 10/6 | 674 | 271 | 28,761 | 9166 | |
| 39 | 10/15 | 538 | 247 | 29,299 | 9413 | |
| 40 | 10/21 | 608 | 219 | 29,907 | 9632 | 32% Average Melt |

FIG. 7 – RUN HISTORY 140 PPH PILOT PLANT

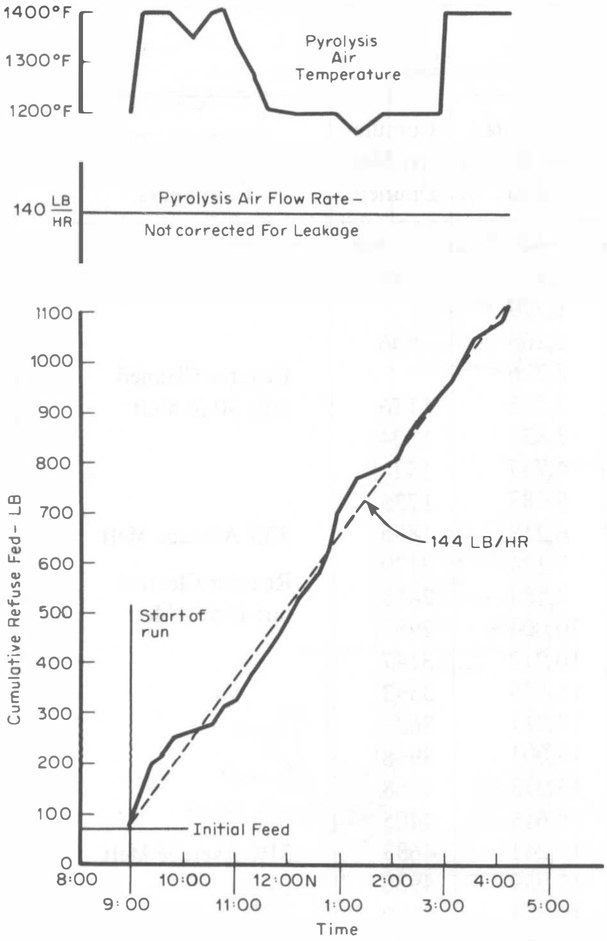


FIG. 8

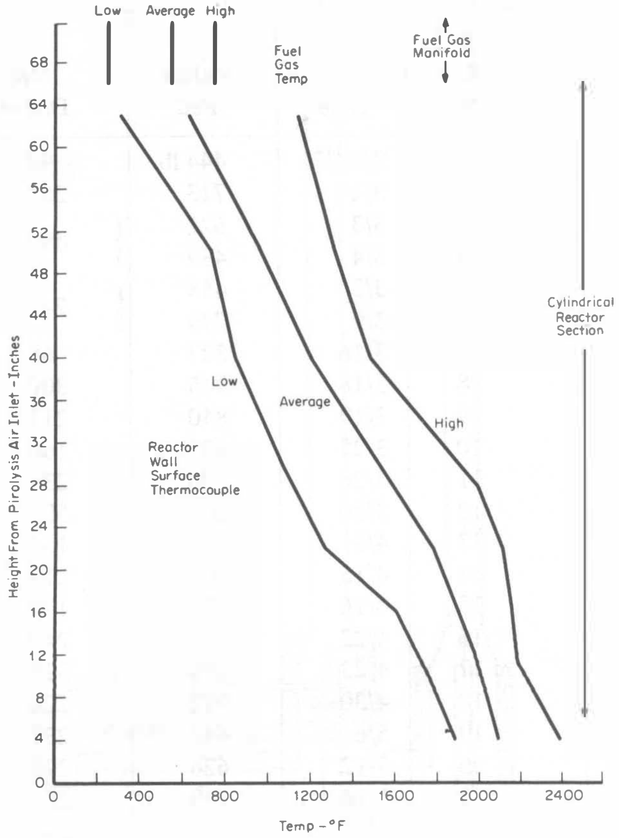


FIG. 9

an incidental activity. We are convinced that we have the bulk of the data required to design a full-scale system although there are still several specific tests we would like to make before completing the design. For example, rule-of-thumb exhaust emission tests indicate that we should be able to pass present date particulate emission codes without any pollution control device other than the bed itself. However, we certainly would like to have legitimate particulate emission measurements. Another area in which we would like to get some measurements is in reactor wall cooling requirements. These tests are peripheral to the main design effort and could be completed in a few months.

In the long run we feel that a continuing modest small-scale pilot plant program would be of immense value in developing the design tools required to optimize the system. The processes involved are simple enough and separable enough so that a really meaningful analytical model of the process appears quite feasible. The same is not true for conventional incinerator configurations in which processes occur with so much controlled and uncontrolled interaction that a really meaningful model is very difficult to imagine and probably not possible to obtain.

A great deal of our effort has been going into the design of the full-scale system. Schematics of two variations are shown in Figs. 10 and 11. Refuse receiving and storage is a simple floor dump system using a small articulated loader to stack refuse and feed the conveyer. We design for three day storage capacity.

The thermal processing system is designed around modular, shop fabricated (12 ft. OD) pyrolysis reactors with a design capacity of 125 TPD. This size is large enough to have bulky waste capability without requiring shredding. Scaling is conservative since bed loading (100 lb/hr-ft$^2$ at design point) and L/D are held constant. This results in a much lower refuse consumption per unit volume in larger systems. In addition, approximately 50 percent over capacity is provided.

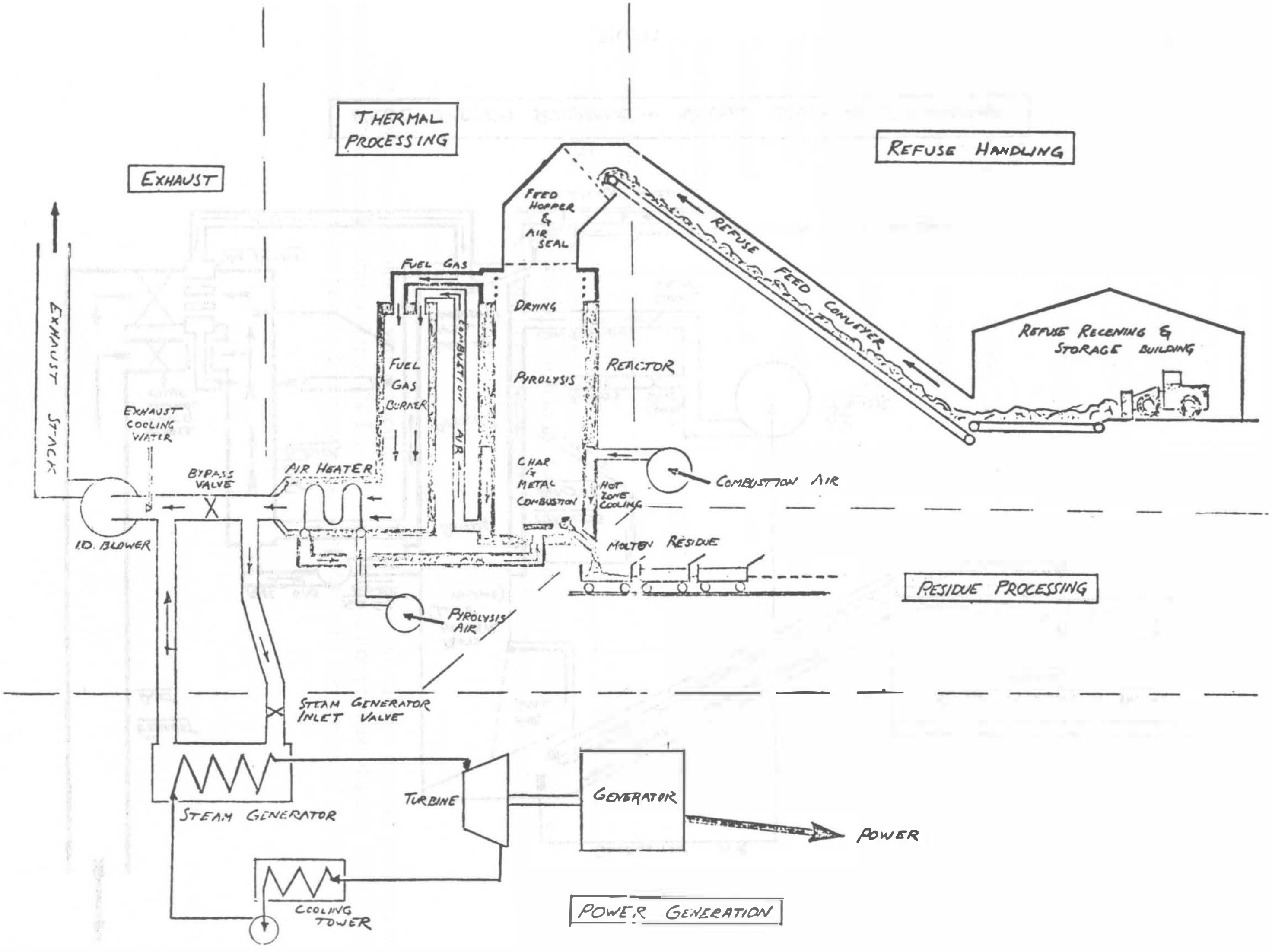
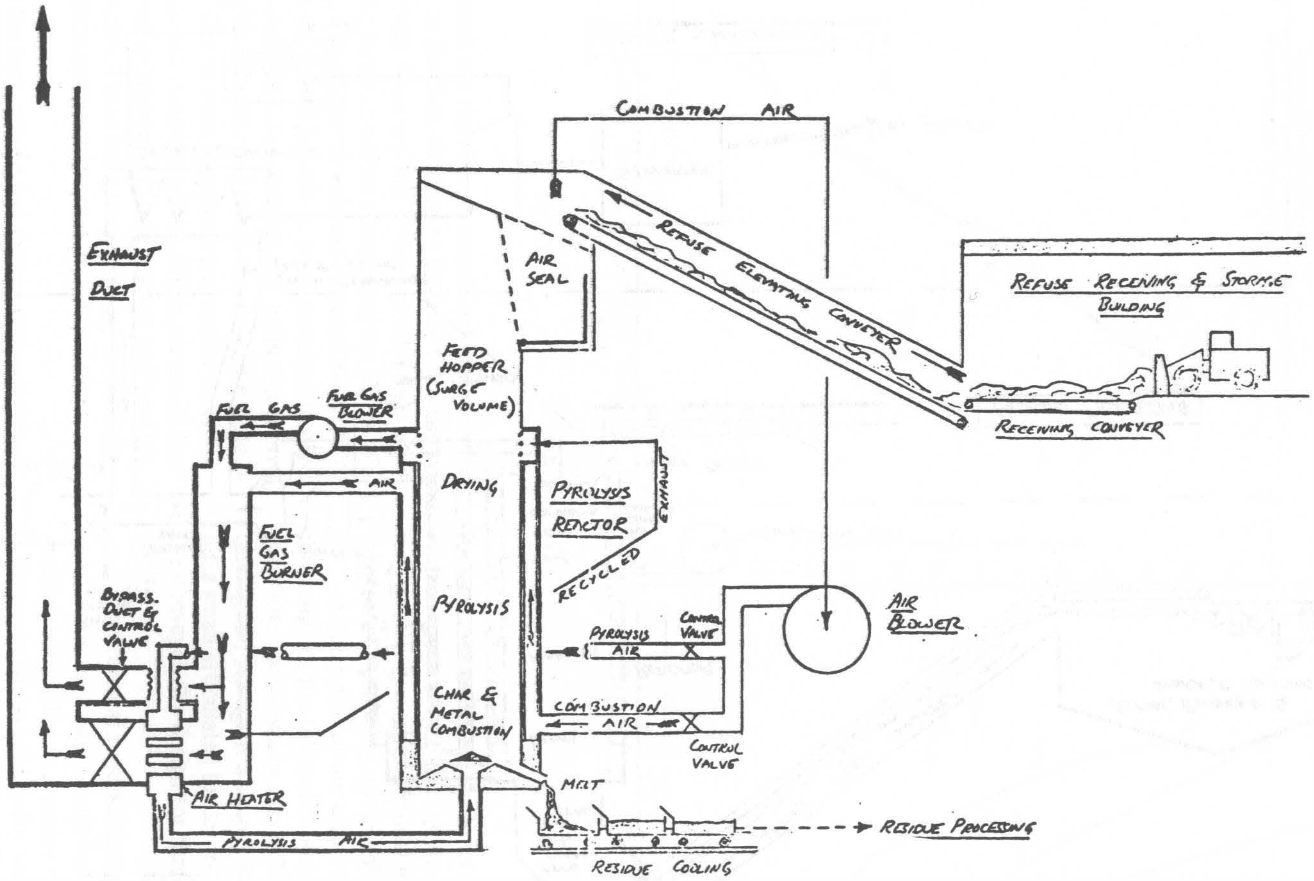

THERMAL PROCESSING
REFUSE HANDLING
EXHAUST
FEED HOPPER & AIR SEAL
REFUSE FEED CONVEYER
REFUSE RECEIVING & STORAGE BUILDING
FUEL GAS
DRYING
FUEL GAS BURNER
COMBUSTION AIR
PYROLYSIS
REACTOR
EXHAUST STACK
EXHAUST COOLING WATER
BYPASS VALVE
AIR HEATER
CHAR & METAL COMBUSTION
HOT ZONE COOLING
COMBUSTION AIR
I.D. BLOWER
MOLTEN RESIDUE
RESIDUE PROCESSING
PYROLYSIS AIR
STEAM GENERATOR INLET VALVE
STEAM GENERATOR
TURBINE
GENERATOR
POWER
COOLING TOWER
POWER GENERATION

FIG. 10



URDC SYSTEM SCHEMATIC ~ NORMAL OPERATING CONFIGURATION

FIG. 11

ESTIMATED TYPICAL URDC SYSTEM COSTS
(1970 CONTRACT BASIS)

| Size (ton/day) | 125 TPD | 250 TPD | 500 TPD | 1000 TPD |
|---|---|---|---|---|
| No. of Thermal Processing System Modules | 1 | 2 | 4 | 8 |
| Refuse Processed 3 Shift 5 Day Operation | 32,500 ton/yr | 65,000 ton/yr | 130,000 ton/yr | 260,000 ton/yr |
| Population Served @ 5 Lb Refuse/Person-Day | 35,000 | 71,000 | 140,000 | 280,000 |
| Turnkey Plant Cost[1] | $1,200,000 | $1,900,000 | $3,100,000 | $5,400,000 |
| Cost/Ton Per Day Capacity | $9,600/TPD | $7,600/TPD | $6,200/TPD | $5,400/TPD |
| Startup & Operator Training Cost[2] | $72,000 | $120,000 | $190,000 | $330,000 |
| Total Personnel | 9 | 14 | 21 | |
| Yearly Operating Cost | $187,000 | $299,000 | $470,000 | |
| Operating Cost/Ton | $5.75/ton | $4.60/ton | $3.62/ton | |

NOTES: 1. No land, steam or power.
Residue output is in the form of aggregate similar to crushed stone.
2. In addition to normal operating costs during startup-operator training period.

FIG. 12

The projected economics are very attractive, especially with respect to construction costs. Fig. 12 summarizes the results of our latest economic studies. If all goes well and our financial problems are resolved, we hope to have the first 125 TPD plant in operation by the summer of 1973.