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A UTILITY PERSPECTIVE ON FUTURE ENERGY SUPPLY

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ABSTRACT

This paper reviews the on-going study at Florida Power and Light Company to identify, evaluate and pursue generation technologies that best fit our future needs. Although nuclear and alternate technologies are reviewed, the primary emphasis is the utilization of coal in an acceptable form.

INTRODUCTION

On September 23, 1981, Mr. Marshall McDonald, Chief Executive Officer of Florida Power & Light Company, in a speech to the New York Society of Security Analysts said:

"By deferring construction of new plants, we will be able to take advantage of new technology when we do build—By the time we are ready to build again, today's research may offer us a better way to generate power."

This philosophy has been the guide to an on-going study to identify, evaluate, and pursue generation technologies that best fit Florida Power & Light's future needs. For a large utility, the conventional wisdom is that the only real options that can meet the large capacity additions that will be needed in the future are coal and nuclear. With the current regulatory morass that surrounds nuclear power and the continuing debate regarding nuclear waste disposal, the emphasis in most utility studies for future capacity centers on coal in some acceptable form.

With the current state of the art, the only proven coal-based option is direct-fired pulverized coal with supplementary environmental control devices. Direct-fired pulverized coal is inhibited by high capital costs, high operation and maintenance costs, high environmental liability, long-project lead times and limited potential for further technological development. Hence, a reasonable strategy is to try to secure a better generation choice through research and

development. By pursuing the leading alternate technologies, we can strive to reduce the technological uncertainties and to reduce costs and construction time. This then allows us to increase planning flexibility and to delay capital commitments as long as possible. The use of smaller modular units is one seemingly attractive means of reducing construction time and providing incremental capacity as it is needed with the resultant minimization of the impact on capital charges. However, this flies in the face of the "economies of scale" which have traditionally been responsible for past reductions in the cost of electricity. Certain types of generation however are inherently limited to modular units because of their physical characteristics. Fluidized bed combustion and some coal gasification units are examples.

It is also very desirable that future plants have the ability to use several fuels in the event that one particular fuel becomes exorbitantly expensive or is not available. It is clearly more desirable to burn high priced oil in a coal-fired unit and provide the needed generating capacity than it is to be left short of generating capacity through disruptions of coal supply.

The criteria against which an alternate generation technology must be evaluated, in addition to reliable operation at an acceptable cost, are public acceptance, regulatory acceptability, planning flexibility, and susceptibility to fuel market disruption.

COAL TECHNOLOGIES

Currently, the only proven coal technology is direct fired pulverized coal plants to which stack gas clean-up devices (primarily electrostatic precipitator and flue gas desulfurizing scrubbers) have been added. Alternative coal based technologies under development are coal mixtures, coal gasification, coal liquification and fluidized bed direct combustion. Each of these technologies seek to eliminate stack gas clean-up systems by

substituting clean-up before or during combustion or to facilitate handling coal in a liquid form. The advantage is that the volume of material to be cleaned up (either before or during combustion) is much less than the volume of the flue gas after combustion. Handling coal in a liquid form so as to utilize present fuel handling facilities is particularly attractive in retrofitting gas and oil fired plants to burn coal.

Coal Mixtures. Coal mixtures involve mixing finely-ground coal with water, oil, methanol or a combination of these liquids, with the fraction of coal being made as large as practical while retaining stability and pumpability. Both mechanical methods (ultrasonic or fluid impingement) and chemical methods (addition of surfactants or stabilizing agents) have been used to stabilize coal mixtures.

Perhaps the premier experiment with coal mixtures in the United States was carried out by Florida Power and Light Company at its Sanford Plant in 1980-81. A high quality (8% ash, under 1% sulphur) coal was pulverized (80% through 200 mesh) and mixed with residual (#6) oil and burned in their 400MW Sanford-4 unit. Mixtures as high as 42% coal by weight were burned on a continuous basis with little derating of the unit. Problems such as burner tip wear, slagging, and fuel stability were dealt with as the experiment progressed. The primary problem was the low fraction of energy (about 23% in a 42% coal slurry) that comes from the coal. The experiment is currently being evaluated in the light of the lower oil prices created by the "glut" of oil on the world markets today.

Other coal mixture candidates are coal-oil-water (typically 60%-30%-10%), coal-water (typically 70%-30%) and coal-methanol (Methacoal*) mixtures. These mixtures are less well-developed than coal-oil mixtures but appear to offer useful advantages. The coal-water mixture has the decided advantage that 100% of the energy comes from the coal, but there is a modest (about 5%) penalty associated with evaporating the water and considerable uncertainty regarding long-term materials problems.

Coal Gasification. The technology that may be best suited to FPL's medium term needs is coal gasification because it has a high potential for economic and technological improvement in the near-term. It provides for modular units compatible with system growth, and it has a potential for significant improvements in environmental acceptability. It can be retrofitted to existing oil plants with minor modifications through "over the fence" gasification plants, or it can be used to fuel high efficiency combined cycle plants. The latter allows the utility to defer capital commitments because the small unit-sized

modules can be built rapidly and provides a better fit for the financial planning. Finally, combined cycle has the potential for higher firing temperatures which will improve system efficiency with a consequent reduction in fuel cost.

Low BTU gas (70 - 170 BTU/cu. ft.) or medium BTU gas (200 - 350 BTU/cu. ft.) are produced in a gasifier depending upon whether air or oxygen is used as the oxidizer. In other words, the nitrogen from air is a diluent which simply reduces the BTU content in proportion to its presence. Substitute natural gas (SNG) is usually produced by upgrading low or medium BTU gas and is used primarily when the gas must be transported long distances.

There are three general gasification technologies in use today; namely the fixed bed, the fluidized bed and the entrained bed systems. The first generation of plants utilizing these technologies were developed primarily by Germany before World War II and some of them were used during the war to convert coal into gas that was ultimately converted into aviation gasoline for the Luftwaffe. Perhaps the best known of these technologies is the fixed bed Lurgi that is presently used by the South African Synthetic Oil Limited (SASOL) to produce medium BTU gas which is then utilized in a Fischer-Tropsch system to produce several high quality liquid fuels which are good substitutes for gasoline, diesel fuel and jet fuel.

There have been significant advances in recent years in the second generation of gasified systems due in no small part to the strong support provided by the Electric Power Research Institute. There are many pilot and demo plants either in operation or coming into operation in the near future. Several of these plants are listed in Table 1 where they are segregated by the type of bed involved. A comparison of the three types of gasification systems; i.e., the fixed bed, the fluidized bed, and the entrained bed systems are given in Table 2, which lists the physical characteristics of each, and the comparative advantages and the disadvantages.

When using gasifiers for retrofit in a power plant in which the gasifier is independent, there are usually significant losses of thermal energy which reduces the overall thermodynamic efficiency. Some recent designs have overcome this difficulty to a significant degree, but it is still not able to take advantage of the symbiotic relationship that is possible with close coupling. In the case of the combined cycle coal gasification system, integration does give a higher efficiency, but at the expense of complexity in the control system.

Coal Liquefaction. The liquefaction of coal can be performed directly through the application of

heat and pressure, usually in the presence of hydrogen and a catalyst, or indirectly by gasification followed by hydrogenation. Fischer Tropsch and M-gasoline are indirect liquification processes while SRC-2, Exxon Donor Solvent and H-Coal are direct coal liquification processes. All are sufficiently expensive, complex, and underdeveloped that they are not likely boiler fuel candidates except in very special circumstances.

Fluidized Bed Direct Combustion Systems.

Another technology that is currently being developed that could be available by the end of the 1980's is direct-fired fluidized coal combustion. This is essentially a bed of burning coal and limestone (or dolomite) supported by a flow of air or oxygen. The sulphur is removed by a reaction between the sulphur and the limestone during the combustion process. It provides high efficiency combustion coupled with an effective removal of the sulphur. The physical size of the modules are limited by flow stability considerations, while the power output is directly related to the rate of combustion within the module. Hence, those fluidized bed modules operating at atmospheric pressure have a lower power density than those operating at higher pressures.

The advantages of the atmospheric pressurized system is that it has a simple materials handling system; i.e., it does not use lockhoppers or other complex feed systems to carry material across pressure boundaries. Unfortunately, the size of the plant is quite large for a given capacity and multiple module systems are needed even for modest sized plants. In the case of pressurized systems, the technology is less well-developed and it does suffer from complex materials handling problems. The size of the units, however, is comparable to present utility plants, but the more complex system has potential maintenance and reliability problems.

NUCLEAR GENERATING TECHNOLOGIES

It is the common wisdom that except for those plants already under construction, the number of new nuclear units ordered in the decade of the eighties will approach zero, and hence those plants already under construction represent the only new nuclear generating capacity that will come on line in the rest of the twentieth century. There is, however, the nagging fact that even with modest growth in electrical demand (i.e. without any significant substitution of electricity for other fuels), the amount of additional generating capacity, and the financial resources required to build it, are staggering.

The total U.S. installed generating capacity as of December 1980 was 631,000 MWe, which includes a 30% reserve against the summer peak load. Based on a 2.5 to 4.7 percent national growth rate, electrical generating capacity should be adequate to at least 1988 even if 30% of plants presently scheduled for completion are cancelled or

delayed. However, the continued degradation of the financial health of the utilities could result in further cancellations and consequently produce inadequate generating capacity for the 90s. A growth rate of 2.5% per annum in the electrical demand between now and the year 2000 with a 20% reserve capacity would require the addition of 213,000 MWe generating capacity. For a more realistic 3.5% growth rate, the additional capacity needed in the United States would be 384,000 MWe. If all the capacity for a 2.5% growth were met by new 800 MWe coal plants, it would mean bringing on one new plant and all its related new mining, transportation, waste disposal and transmission facilities on-line every month. For a 3-1/2% growth it would be two plants every month. One is inevitably led to the conclusion that arbitrarily excluding one particular type of plant from the future is totally unrealistic and that nuclear power must come back from its present nadir if the United States is to have adequate electrical generating capacity beyond the year 2000.

Many utilities accept the fact that nuclear plants will be needed in the future, but few are presently giving serious consideration to specific nuclear plant proposals. There is disagreement as to whether nuclear power will come back in the form of standardized plants using light water reactors, or in a totally different form such as the CANDU (Canadian heavy water moderated reactor which uses proliferation-proof natural uranium as fuel), or the HTGR (the High Temperature Gas-Cooled Reactor with its inherent safety due to its long thermal time constants and high thermal capacity). There is agreement that future nuclear units must be perceived as "safe" by the public and that the public must perceive that the nuclear waste disposal "problem" has been "solved" before many new plants are ordered.

The breeder reactor is generally considered as necessary in the United States sometime during the early part of the twenty-first century. The current Clinch River Breeder Reactor and the follow-on advanced breeder reactor projects of the U.S. Government appear to be adequate for development of this technology. While there presently is some direct involvement of the utilities in these programs, there are no plans for utilities to build breeder reactors to meet their future electrical generating needs, nor are there any plans for the necessary fuel reprocessing plants to recover the newly bred fuel.

OTHER GENERATION TECHNOLOGIES

In recent years, it has been in vogue for activists to condemn "hard technologies", a euphemism for centralized generating technology, in favor of "soft technologies", which is generally construed to be technologies which utilize renewable energy resources. These renewable resources are found in the very nature of our earth, emanating from gravity, weather patterns and tidal changes, the

sun (light and heat) and the earth's core itself (heat). These include wind power, geothermal power, solar heating and cooling, solar thermal electric conversion, ocean thermal electric conversion (OTEC), wave, tide and stream energy, biomass fuels, fuel cells, photovoltaic electric conversion, and cogeneration. One common thread existing throughout these new energy options is that the resource is as vast as the earth and sun but as diffuse as the grains of sand on a beach.

The potential for these renewable energy options may be great enough to play an important role in Florida's energy strategy. FPL has studied most of these options on its own or in conjunction with others with special emphasis on those that have potential in Florida. Therefore, let us briefly review them.

Wind Power. Wind machines have been used for centuries to provide power to pump water and perform other tasks in areas of the world. Using modern engineering techniques and newly designed materials, vertical and horizontal axis machines have been demonstrated as technically and economically viable in areas where sufficient wind resource is available. Unfortunately, Florida does not have enough wind for large scale power production using the presently designed machines. Today's wind machines operate best at an average wind speed of 20 mph and are designed to shut down at between 7 and 10 mph. FPL data, which is consistent with NOAA data, indicate an annual mean wind speed of less than 9 mph.

Geothermal Power. Heat energy buried deep beneath the surface of the earth can be used to produce power. Most of the heat is too deep for currently used drilling methods. In certain areas, however, molten rock or magma may be found close to the surface of the earth. Steam for power production is obtained by injecting water into the magma. Steam produced by hot magma accounts for more than 900MW of electricity today. Unfortunately, Florida does not have any areas suitable for geothermal power. FPL did investigate the source of heated water on the West Coast of Florida, but the source was found inadequate for practical use.

Ocean Power. Since Florida is so close to the ocean, the concept of obtaining power from the waves, currents and ocean thermal energy seems logical. Harnessing the Gulf Stream by using large turbines has been proposed. Although the theory is intriguing, no models have ever been tested in the ocean. Preliminary studies indicate very difficult (and expensive) engineering problems.

Ocean Thermal Energy Conversion has been touted as the ultimate energy producer for coastal areas. The principle that OTEC uses is the potential energy of the temperature difference which exists between the surface of the ocean heated by the sun and the cooler ocean depths

more than a thousand feet deep. A working fluid with a low boiling point, such as ammonia, is pumped down to the bottom where the cold water condenses the vapor into a liquid. The cold liquid is then pumped up to the surface where it boils in the lower pressure and higher temperature, producing gas which powers a turbine-generator. After the energy is exhausted from the gas it is recycled to the depths again.

The concept is in the initial test stages where attempts to prove feasibility are under way. Even if proven feasible, the maximum efficiency of 3 - 4% means extremely large systems would be required. Siting requirements indicate distances of up to 150 miles from shore making transmission of the produced energy to shore a formidable task. Projects capable of producing even 100MW plant would dwarf even the largest ocean oil rigs.

Solar Energy. When we speak about solar energy we really mean the radiation of energy produced by the sun. The rate at which this radiation reaches the earth determines the power from the sun. In Florida, the maximum power density is approximately 100 watts per square foot. Obviously, less radiation reaches the earth's surface on a cloudy day than a clear day.

Sunlight reaching the earth without interference is called the direct component while the sunlight which is scattered by the atmosphere is called the diffuse component. Scattering the sunlight saps a portion of the energy from it. The cloud cover in Florida results in a substantial diffuse component of sunlight, which in turn affects the solar technology appropriate for use.

Solar Heating and Cooling. Our ancestors used the sun for heating and cooling since the first home was built centuries ago. Today, heat from the sun is gathered by solar collectors mounted on roof tops, for heating swimming pools, and for domestic hot water systems. Suitable climatic conditions also enable the heat from the sun to be used for space heating and evaporative cooling.

Solar domestic water heating began with cisterns left in the sun. Now although the systems are more sophisticated, the principles are the same. Until the middle 1940's more than one-half the population of the State of Florida used solar water heaters. Solar water heating systems consist of a solar collector, heat transfer fluid (usually water), the heat storage tank, auxiliary heat source (electricity), a pump, and a control system.

Solar air conditioning uses heat from the sun similar to the gas fired refrigerator of the past. The approach used in most systems is to pressurize a gas or liquid, causing an increase in temperature, above the ambient temperature. The heat is then expelled. The medium is then depressurized by expansion, decreasing the temperature. The gas or liquid is now cooler than the room to be cooled,

and absorbs heat from the room. The compression cycle (heat addition) may be performed by conventional or solar assisted means.

Florida Power & Light together with the Electric Power Research Institute is demonstrating the solar cooling technique at its Perrine Service Center in South Dade County. Although the system has demonstrated the technical feasibility of solar air conditioning, both the technical and economic parameters will require a great deal of improvement prior to widespread acceptance.

Solar Thermal Conversion. When the sunlight strikes an object, the surface gives off heat. If this heat can be transferred to a working medium (air or water), the heat may be used to power a turbine-generator and produce electricity. Solar thermal conversion involves the "power tower". Sun's rays over a large area are focused upon a single area on the tower, transmitting vast amounts of heat for power production. One may imagine the power able to be derived from gathering all the sun's heat over a square mile and focusing it on one small target area.

The barriers to central station power towers in Florida are threefold. The cost is still considerably greater than nuclear or coal plants, the availability even with storage is only about 40%, and Florida has the additional burden of considerable cloud cover for most of the year. Although sunlight passing through the clouds still has a considerable amount of energy, as anyone who became sunburned on a cloudy day will verify, the energy is in a diffuse state making focusing a problem. The land required to provide sufficient energy for a large modern power plant is more than a square mile (600 - 800 acres).

Biomass Fuels. Worldwide, approximately 40 quads of biomass are produced annually, of which 1 - 2 quads are in the United States. This includes crop residues, municipal solid wastes, forestry residues, and fuel wood. Costs for collection, conversion, and transportation are substantial and must be considered.

There are two fundamental methods of converting biomass to fuels; thermochemical conversion, and biochemical conversion. Energy can also be derived from biomass by direct combustion. Thermochemical conversion includes such processes as pyrolysis, gasification, and liquefaction. Biochemical conversion includes fermentation and anaerobic digestion.

Biomass derived fuels are consistently more expensive than similar coal derived fuels primarily due to the higher feedstock cost. For example, present alcohol production used to supplement transportation fuels is based on government incentives. When a specific situation exists where large quantities of waste biomass are available at low or no cost, conversion to fuel or direct combustion are reasonable alternatives. FPL

currently is a participant in the Dade county garbage burning power plant project which is just being started up. The economics of this operation are dependent on payment by the County for disposal of the garbage.

Florida Power and Light is currently buying surplus power generated using bagasse (the dry pulp remaining from sugar cane after the juice has been extracted) as a fuel from U.S. Sugar Corporation. From mid-November through mid-March, they produce an average of 8000 to 10,000 MWh per month of surplus power which is fed into FPL's grid.

Fuel Cells. Fuel cells can be combined with coal gasifiers and central station power plants to provide an efficient central station with very low emissions. Power stations utilizing current phosphoric acid fuel cell stacks could achieve an overall efficiency of 40%. In 1977, a 1-MW pilot plant, funded by nine utilities and United Technologies, was demonstrated. A full scale 4.8MW power plant is currently being listed by EPRI, DOE, Consolidated Edison, and United Technologies. Manufacturing cost and cell stack life are limitations of the phosphoric acid fuel cells employed in the demonstrator.

Molten carbonate fuel cells which are at an earlier stage of development offer a number of advantages over phosphoric acid fuel cells. Materials are comparatively inexpensive; noble-metal catalysts are not needed, reject heat is of high quality, and the potential exists for a very low heat rate (on the order of 6700 BTU/kwh). The overall power plant cost and efficiency is largely determined by the ability to utilize waste heat streams to preheat reactants and produce auxiliary power.

Photovoltaic Conversion. Photovoltaic energy conversion generates power directly from the photons in sunlight. As the photons from the sunlight are absorbed by a semiconductor material, it creates a flow of electrons or direct current which may then be converted to alternating current for most uses. The most appealing trait of photovoltaic cells is the utilization of diffuse light. As a result, the photovoltaic cell has the greatest potential benefit to Florida of all the solar technologies. Moreover, photovoltaic systems are modular and, therefore, may be mass produced rapidly and assembled in building blocks of almost any size.

Florida Power & Light joined in a project with the Florida Solar Energy Center and Lincoln Laboratory of MIT to construct, operate, and monitor an experimental home at Cape Canaveral. We contributed some of the photovoltaic modules installed on the roof, a DC to AC converter, data acquisition instruments, metering equipment, technical assistance and back-up power to the 1300 square foot house. The photovoltaic system is connected in parallel with

the distribution system so the house receives FPL electricity when power requirements cannot be met from the output of the cells. During favorable sunlight conditions, the cells supply the 3 bedroom, 2 bath home with 5 kilowatts of peak power. Power output is reduced when the panels do not receive direct sunlight, but they continue to produce electricity.

Many problems must still be worked out prior to mass marketing of large scale photovoltaic power systems. The cost has decreased from \$500 per watt to \$8 - \$10 per watt for the cells. Even this price is an order of magnitude too high to be comparable to other energy sources. Cell efficiency of 5 - 8% is not acceptable for large scale power production. Materials capable of exhibiting efficiencies of 15% or greater must be developed to minimize the support structure, wiring costs, and land area requirement.

Cogeneration. Industrial cogeneration has the advantage of using less fuel to provide a given amount of useful energy than a conventional utility power plant provided that the industry can use the energy in the form in which it is available. The majority of industrial owned cogeneration will likely be derived from steam cycles. High pressure steam will be passed through a turbine which generates electricity, and the turbine exhaust used for process steam. Cogeneration can be an effective way to conserve energy and reduce costs when there is a localized need for a substantial quantity of steam at lower temperatures and pressures.

CONCLUSION

Planning to meet future generation needs involves carrying out an engineering evaluation of all generation technologies and a ranking of them. There needs to be utility involvement in the development of the best candidate technologies to achieve the best fit with the utility's requirements. There would also need to be an identification of the various state-of-the-art uncertainties and the specific actions needed to resolve these uncertainties. The level of utility participation needed in demo plants to achieve the design competence and the knowledge of the best technology has to be determined. This means working with the Electric Power Research Institute to assure the availability of adequate funding mechanisms within the industry to carry out the needed demonstration projects.

It is also clear that coal and nuclear power must each play a large role in providing our future generating capacity from now until 2000. Other alternative generation technologies can contribute but will have no major effect until technological breakthroughs occur to make them more economic.

TABLE I
SECOND GENERATION GASIFIER SYSTEMS

<u>FIXED BED</u>	<u>FLUIDIZED BED</u>	<u>ENTRAINED BED</u>
SLAGGING LURGI (BGC WESTFIELD)	WESTINGHOUSE	TEXACO (COOL WATER)
KILNGAS (WOODRIVER)	SASOL-II	SHELL
	RHEINBRAUN	C-E
	HT WINKLER	KRUPP-KOPPERS TOTZEK

TABLE 2

COMPARISON OF GASIFICATION SYSTEMS

(A) SIGNIFICANT PHYSICAL CHARACTERISTICS

<u>FIXED BED</u>	<u>FLUIDIZED BED</u>	<u>ENTRAINED BED</u>
<ul style="list-style-type: none">o GRAVITATING BED OF COAL ASH WITH MECHANICAL GRATES/ DISTRIBUTORSo DISCRETE ZONES<ul style="list-style-type: none">-PREHEATING DRYING DEVOLATIZATION-GASIFICATION-COMBUSTIONo TEMPERATURE GRADIENT	<ul style="list-style-type: none">o FLUIDIZED BEDS ARRANGED IN ONE OR MORE ZONESo UNIFORM TEMPERATURE AND COMPOSITIONS THROUGHOUT EACH FLUIDIZED ZONE	<ul style="list-style-type: none">o UP FLOW OR DOWN FLOW SUSPENSION GASIFICATIONo HIGH TEMPERATURE-HIGH RATE PROCESS

(B) COMPARATIVE ADVANTAGES

<u>FIXED BED</u>	<u>FLUIDIZED BED</u>	<u>ENTRAINED BED</u>
<ul style="list-style-type: none">o HIGH CARBON CONVERSION EFFICIENCYo LOW ASH CARRYOVERo LOW TEMPERATURE OPERATIONo LOWEST AIR/OXYGEN REQUIREMENT	<ul style="list-style-type: none">o HIGH DEGREE OF PROCESS UNIFORMITYo EXCELLENT SOLIDS/GAS CONTACTo LOWER RESIDENCE TIME THAN FIXED BED GASIFIERo HIGHER COAL THROUGHOUT PER UNIT VOLUME OF REACTOR	<ul style="list-style-type: none">o HANDLES ALL TYPES OF COAL-NO PRETREATMENTo LOW STEAM CONSUMPTIONo EXCELLENT SOLIDS/GAS CONTACTo NO TAR OR PHENOL FORMATIONo ABILITY TO SLAG ASH WHICH IS INERTo HIGH CAPACITY PER UNIT VOLUME OF REACTOR

(C) COMPARATIVE DISADVANTAGES

<u>FIXED BED</u>	<u>FLUIDIZED BED</u>	<u>ENTRAINED BED</u>
<ul style="list-style-type: none">o SIZED COAL REQUIREDo COAL FINES MUST BE BRIQUETTEDo LOW CAPACITYo LOW OFFGAS TEMPERATUREo PRODUCES TARS AND HEAVIER HYDROCARBONSo HIGH STEAM CONSUMPTIONo PRODUCES PHENOLSo USE OF CAKING COALS NOT COMMERCIALY PROVEN	<ul style="list-style-type: none">o SIZED COAL REQUIREDo DRY COAL REQUIRED FOR FEEDINGo REQUIRES COMPLICATED GAS DISTRIBUTORo CAKING COALS REQUIRE PRETREATMENTo HIGH CARBON LOSS WITH ASHo FLUIDIZATION REQUIREMENT SENSITIVE TO FUEL CHARACTERISTICS	<ul style="list-style-type: none">o REQUIRES FINELY CRUSHED COAL 70% 200 MESHo SMALL SURGE CAPACITY REQUIRING CLOSE CONTROL