



# ENERGIA

## A Large-Scale Demonstration of a CAER Fine Coal Cleaning Process

B.K. Parekh

**A column flotation process has been developed at the CAER which enables the economical recovery of coal fines from fine refuse. Laboratory process design was extrapolated to pilot and commercial scales. The Powell Mountain Coal Company has successfully installed this technology at their Mayflower Coal Preparation Plant Complex.**

Fine refuse solids that are high in mineral matter content are usually discarded by U.S. coal preparation plants. This is because the recovery of clean coal using the conventional froth flotation method, more commonly used in mineral processing industries, has proven uneconomical and inefficient. In the coal industry, flotation techniques are practiced very sparingly. The principles of coal flotation utilize the differences in the surface chemistries of the coal and mineral matter (which includes pyrite) to enable their separation. In a typical arrangement, air is sparged into a vessel containing a suspension of coal in water to which a small amount of fuel oil and an alcohol (methyl isobutyl carbinol) are added. These additives, respectively, act to make the coal hydrophobic (repels water) and to stabilize the bubbles in the froth. The coal then preferentially attaches to the air bubbles, while mineral matter being hydrophilic (having an affinity for water) stays in the aqueous phase. The coal fines are carried with bubbles and removed from the suspension surface as a froth.

Engineers at the Center for Applied Energy Research (CAER) have developed an advanced column flotation technique (Ken-Flote) for the recovery of the fine and ultra-fine coal from high-ash fine refuse. The



*Installation of a large-scale demonstration of a CAER fine coal cleaning process at Powell Mountain Coal Company.*

laboratory process equipment consists of a circular tube about 20 feet high, with an internal diameter of 2 inches. The coal slurry mixture is introduced to the column at about two thirds of the distance from the bottom where it contacts air bubbles rising from the bottom of the column in counter-current flow. This action provides an effective separation mechanism in which ultra-fine coal attaches to the air bubbles. Separated coal fines are carried upwards with the air bubbles above the slurry entry point into the cleaning zone where a gentle spray of wash water removes any residually entrained mineral matter. The clean froth is taken off at the top of the column. The mineral matter travels downward towards the bottom of the column where it is removed.

Based on the in-house research results, a pilot plant study was conducted at the Powell Mountain Coal Company (PMCC) coal preparation facility at St. Charles, Virginia on their fine clean coal cyclone overflow (minus 100 mesh) slurry. The plant processes about 500 tons per hour of run-of-mine coal from multiple seams and produces compliance (low-sulfur) coal for the utility industry and non-compliance (high-sulfur) coal for gasification to make chemicals. The pilot plant study used a scaled-up 6-inch internal diameter column and showed that, for the fine refuse from both of these coals, a clean coal product containing 5 percent ash was obtained at about 80 percent combustible recovery.

Based on this study, PMCC Superintendent of Coal Preparation (W.J.

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## Eastern U.S. Oil Shale Development Program at the CAER

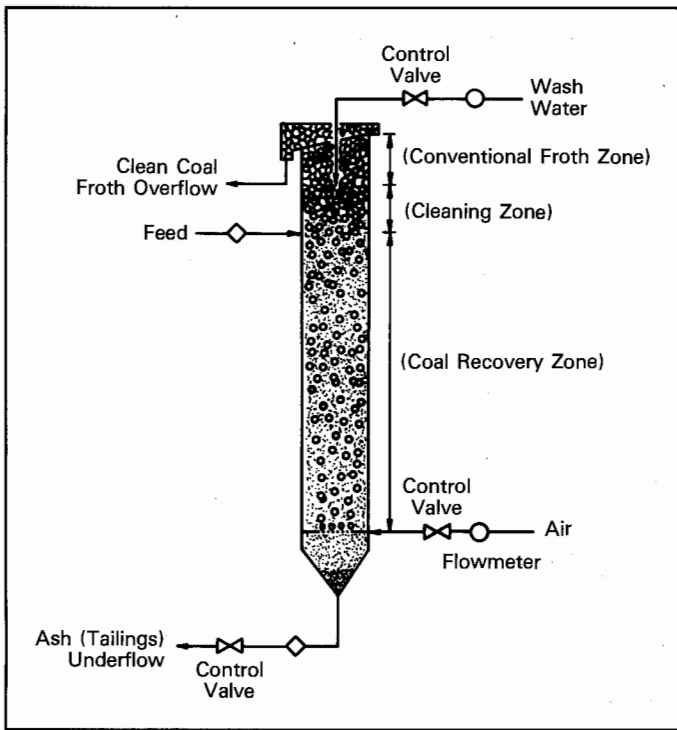
Thomas Robl, Aurora Rubel, Scott Carter, & Darrell Taulbee

**A multiple, fluidized-bed process (KENTORT II) for eastern oil shales has been under development since 1984, at the University of Kentucky Center for Applied Energy Research (CAER). An integrated experimental system has demonstrated the process will enhance oil yields, generate valuable by-products (sulfur, ammonia, hydrogen-rich gas), and mitigate environmental problems associated with Kentucky oil shale development (SO<sub>2</sub> emissions, potential acid mine drainage).**

### Introduction

Eastern oil shale is a major untapped energy resource, with deposits in Kentucky, Ohio, Indiana, Michigan, Alabama, and Tennessee. An understanding of the potential importance of this resource was developed during the early 1980's when the nation faced liquid fuel shortages. Much effort was expended in the study of eastern oil shales and it was discovered that: 1) the resource in Kentucky and other eastern U.S. states is very large (~600 million barrels of oil equivalent), of the same order as that of the more thoroughly documented western U.S. oil shales, and 2) eastern oil shales have a significantly different chemistry from that of western U.S. oil shales. In particular, eastern U.S. shales produce oil which is much more susceptible to coking and cracking reactions. Because of these chemical differences, it was found that the optimum

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Schematic diagram of the CAER column flotation process.

### Coal Cleaning Process (continued)

Peters) decided to build and install wider 8-foot diameter columns. CAER engineers (J.G. Groppo and B.K. Parekh), in cooperation with W.J. Peters, designed the larger column using scale-up criteria developed in the pilot plant study.

In November 1989, four 8-foot diameter columns were installed at the Mayflower Coal Preparation Plant Complex, and were successfully operating by December 15, 1989. Each column is capable of processing up to 1000 gallons per minute of the fine refuse slurry (5 tons per hour of solids). The columns process about 20 tons per hour of fine solids and recover approximately 6 to 8 tons per hour of clean coal. The clean coal product from the columns averages 6 percent ash with about 75 percent combustible recovery, and is sent to a high-speed dewatering centrifuge

where it is dewatered with the coarse (28 mesh by 100 mesh) clean coal cyclone underflow product. The total moisture content of the final blended product increases by about 0.5 percent.

Presently, the PMCC and the CAER are evaluating three different types of air sparging systems on the columns. After the complete evaluation of the data, one sparging system will be selected for detailed parametric study. A technical paper describing the details of the PMCC project will be presented at the 11th International Coal Preparation Congress in Tokyo, Japan in October, 1990.

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### Eastern U.S. Oil Shale (continued)

economic performance could not be attained from eastern oil shale using those technologies which were developed for oil shales from other regions.

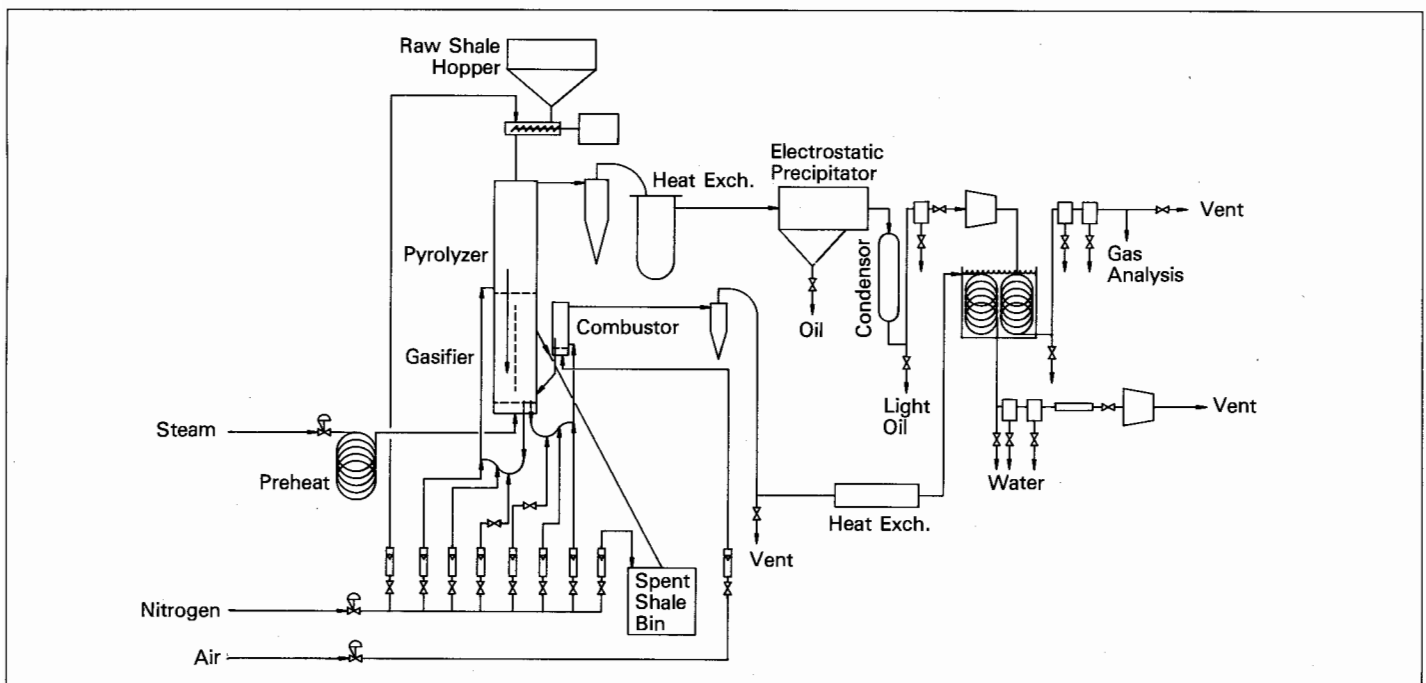
A process (KENTORT II) specifically designed to maximize the oil yield and product recovery from eastern oil shales has been under development at the University of Kentucky Center for Applied Energy Research (CAER) since 1984. The technology is currently being demonstrated in a 5-lb/hr (shale) integrated reactor system, and is supported by the Laramie Project Office of the Morgantown Energy Technology Center, U.S. Department of Energy.

A larger scale system is essential if the development of this process is to continue. It will allow for the collection of data for scale-up to commercial size, and a realistic evaluation of anticipated technical problems. Moreover, larger scale systems enable the generation of products and wastes in sufficient quantity to permit more extensive research and development in areas like crude shale oil upgrading and spent shale disposal and reclamation. Also, operation on a larger scale will provide an authentic simulation of commercial-scale conditions, necessary for further refinement of the concept. A proposal is currently pending with the U.S. DOE to develop a second generation process at a scale of 50-lb of shale per hour.

### The Process

Specifically, the process is a multiple, integrated, fluidized-bed system designed to improve oil yields, is thermally efficient and generates useful chemical by-products (sulfur, ammonia, and hydrogen-rich

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Flow diagram of the fluidized-bed process (KENTORT II) for eastern U.S. oil shale.

## EDITORIAL COLUMN

**Leonard K. Peters**  
Vice Chancellor for Research and Graduate Studies  
University of Kentucky

Many of our most challenging scientific problems confronting society today are by nature multi-disciplinary. Most major research universities are struggling with the role and place of multi-disciplinary research in the setting where the disciplines, of necessity, are the basic academic units. While the disciplines represent the ultimate "home base" for virtually all faculty and students, few problems are contained within these same boundaries. For example, it is becoming increasingly difficult, if not impossible, to define the interface between chemistry and biology in the agricultural and life sciences, between applied mathematics and physics or engineering, and between chemistry or physics and many areas of engineering science. And in the areas of medical science, the division between physiology and engineering or chemistry, or between pharmaceutical chemistry and biochemistry is becoming increasingly blurred. These multi-disciplinary facets of academic research are not restricted to science and technology alone; the broad area of behavioral sciences frequently includes clinical and social psychologists and sociologists along with other disciplinarians.

What factors are driving these alliances among disciplines - alliances that have been accelerating over the past decade or so and show no signs of abating? Certainly, the complexity of basic and applied research problems facing us today is one major factor. The emergence of specialists has fashioned some magnificent solutions to narrow problems. But with many contemporary research problems, all of the knowledge does not and cannot reside in a single discipline. In fact, to artificially constrain a problem to a single discipline can limit imaginative solutions to the complex problems facing society today.

By employing strategic combinations of faculty and student researchers from the underpinning disciplines, comprehensive analyses of complex issues are prompted and can ameliorate and even overcome constraints within disciplines. One effective mechanism to achieve this



*Dr. Peters also serves as Professor in the Chemical Engineering Department where his research interests include atmospheric chemistry and transport.*

teamwork is through the development of multi-disciplinary centers and institutes focused on an applied research goal.

The University of Kentucky has over twenty such multi-disciplinary centers and institutes designed for these purposes. One such multi-disciplinary area concerns energy supply and utilization. Studies needed for the safe and efficient production of energy are

very diverse and require attention from chemists, engineers, geologists, economists, environmental scientists, materials scientists, and toxicologists; this list is not exhaustive but yet illustrates the breadth of disciplinary involvement. UK faculty, students, and staff have been doing energy research for many years and have focused on the multi-disciplinary aspects for over fifteen years. These activities have been in many departments, but also in multi-disciplinary units like the Institute for Mining and Minerals Research and Kentucky Geological Survey, and more recently, the Center for Applied Energy Research and the Environmental Systems Research Program. Research efforts have had a strong applied, fossil energy bent, but have also included investigation of advanced energy systems and fundamental models for the basic molecular structure of coal.

The strengths of UK's energy research programs will continue to be multi-disciplinary where researchers are sharing knowledge and expertise that are complementary. At the same time, research will continue to be well-founded in the basic science and engineering disciplines. Many knowledge bases are available, and the multi-disciplinary centers and institutes have been and can continue to be an effective structure to bring experts together.

### Eastern U.S. Oil Shale (continued)

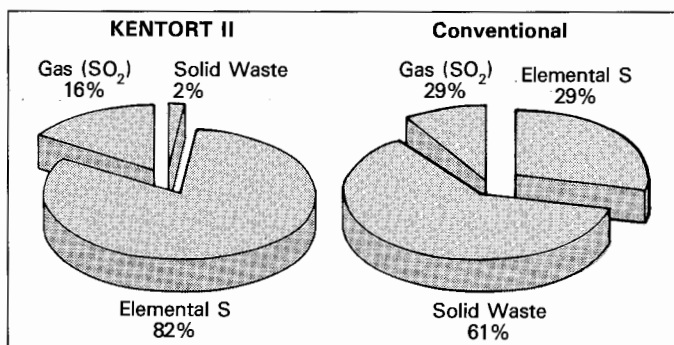
gases) while mitigating environmental problems. A unique feature is the integration of the pyrolysis with the gasification and the combustion steps.

**Pyrolysis.** Crude shale oil, the predominant product of the process, is generated in the pyrolysis zone. Fluidized-bed technology is capable of enhancing oil yields up to 50 percent above the processes designed for western U.S. shales. Other important advantages include rapid reaction rate, complete utilization of mined shale, and efficient heat and mass transfer characteristics. The fluidized-bed pyrolyzer is operated at atmospheric pressure, thus simplifying process operations and reducing costs.

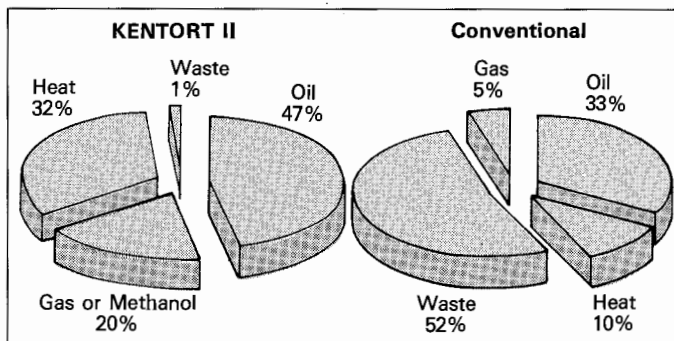
**Gasification.** The intermediate gasification zone is a unique feature of the process which is particularly suited to eastern oil shales. The gasification stage is central to the high heat transfer efficiency of the system. Recirculating hot shale from the gasifier to the pyrolyzer provides the heat by direct solid-solid contact to drive the pyrolysis reactions. The reducing atmosphere in the gasification zone removes the inorganic sulfur from the shale as hydrogen sulfide, which can then be converted with existing technology to elemental sulfur, a valuable by-product. The removal of sulfur prior to combustion is important because it lessens the emission of sulfur dioxide and the need for elaborate scrubbing systems. Gasification introduces other advantages in that iron species are converted to forms that will not cause particle agglomeration during combustion. Additionally, 15 to 20 percent of the residual carbon following pyrolysis can be converted to a hydrogen-rich gas which can be used directly as a fuel or as a source of hydrogen for upgrading.

**Combustion.** In the combustion zone, the carbon after pyrolysis and gasification is burned to provide the process heat requirements. The hot

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Comparison of sulfur conversion between KENTORT II process and conventional retorting technologies.



Comparison of carbon conversion between KENTORT II process and conventional retorting technologies.

UNIVERSITY OF KENTUCKY  
CENTER FOR APPLIED ENERGY RESEARCH

# FINE COAL PROCESSING WORKSHOP

The Center for Applied Energy Research of the University of Kentucky cordially invites you to attend a FINE COAL PROCESSING WORKSHOP. Discussions will feature new recovery processes and economic benefits, together with government sponsored support for demonstration of innovative technologies. The workshop will be held on March 29, 1990 at Spindletop Hall 3414 Iron Works Pike, Lexington, KY 40511.

Please R.S.V.P. (phone, fax, or mail) to:

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## Eastern U. S. Oil Shale (continued)

combusted shale attains a temperature of at least 750 °C, and makes an excellent heat transfer medium, providing an efficient, direct source of heat to the pyrolysis and gasification zones.

This configuration (pyrolysis, gasification, and combustion) facilitates the management and reduction of waste streams (solid, liquid, and gas) at the source, through the control of reactor conditions. This approach has directly addressed the issues of environmental control and resource utilization, and is inherently more efficient and cost effective than early processes designed to operate with other shales.

### Recent Findings

The viability of the KENTORT II process has been demonstrated at moderate gasification temperatures and shale residence times. The gasification step removes up to 90 percent of the original sulfur as hydrogen sulfide while converting 20 percent of the starting carbon to a hydrogen-rich gas. Sufficient carbon (15 to 20 percent of the original) remains after pyrolysis/gasification to provide process heat via combustion. Fully integrated operation has demonstrated that enhanced oil yields can be maintained when shale recirculation is used for heat transfer. A final spent shale product which contains little residual carbon and sulfur and small acid-generating capacity has been produced. Thus it has been demonstrated that the KENTORT II process can recover most of the energy potential of eastern oil shales, while producing a spent shale amenable to environmentally safe disposal.

*Thomas Robl is the Program Manager for the eastern U.S. oil shale processing project. Scott Carter is the Principal Investigator on the project, and is a senior engineer responsible for the development of the process system design. Aurora Rubel is a Co-principal Investigator responsible for the development of fundamental pyrolysis, gasification, and combustion information from bench-scale reactors. Darrell Taulbee is a Co-principal investigator responsible for product characterization and interpretation of process chemistry.*

**Energeia** and **Highlights** are published on alternating months by the Center for Applied Energy Research (CAER) and the Institute for Mining and Minerals Research (IMMR), both of the University of Kentucky. The publications feature complementary aspects of mineral and energy resource development and environmentally related topics. Subscriptions are free and may be requested as follows: Judith M. Hower, Editor of **Energeia**, CAER, 3572 Iron Works Pike, University of Kentucky, Lexington, KY 40511-8433, (606) 257-0305; David Lazar, Editor of **Highlights**, IMMR, 233 Mining and Minerals Resources Bldg., University of Kentucky, Lexington, KY 40506, (606) 257-8636, Copyright ©1990, University of Kentucky.

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