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ABSTRACT

The interest group got under way effective January 1, 1994, with nine utility members, EPRI, Bechtel, and the Illinois Clean Coal Institute. DOE participation was effective October 1, 1994. The first meeting was held on April 22, 1994 in Springfield, Illinois and the second meeting was held on August 10-11, 1994 at Johnstown, Pennsylvania. Technical reviews were prepared in several areas, including the following: status of low rank coal upgrading, advanced physical coal cleaning, organic sulfur removal from coal, handling of fine coal, combustion of coal water slurries.

It was concluded that, for bituminous coals, processing of fines from coal cleaning plants or impoundments was going to be less costly than processing of coal, since the fines were intrinsically worth less and advanced upgrading technologies require fine coal. Penelec reported on benefits of NOX reductions when burning slurry fuels.

Project work was authorized in the following areas: Availability of fines (CQ, Inc.), Engineering evaluations (Bechtel), and Evaluation of slurry formulation and combustion demonstrations (EER/MATS). The first project was completed.

PROJECT OBJECTIVES

The objectives of the Upgraded Coal Interest Group (UCIG) are as follows:

- Review and update the status of various coal upgrading technologies and developments and critically assess the results.
- Perform engineering screening analyses on various coal upgrading approaches.
- Perform commercialization analyses that will promote the availability and use of upgraded coal products by quantifying the benefits of using them. Identify market opportunities for introduction of upgraded coals.
- Perform critical analyses on a variety of coals and technologies in areas important to users but not readily available. Perform critical experiments which will show the differences between technologies.
WESTERN COAL UPGRADING TECHNOLOGIES

Possible Objectives of Upgrading

1. Drying (reversible or irreversible)
2. Cleaning (ash, sulfur, trace metals)
3. Reduce handling problems
4. Produce valuable by-products
5. Eligible for IRC §29 Tax Credits

Some General Concerns About Drying

1. Processes Almost Universally Make Fines
2. Reabsorption of moisture
3. Spontaneous Combustion
4. Combustion Properties

Three Types of Drying Processes

1. Ordinary (Low Temperature) Evaporative Drying ( ~ 250 °F)
2. High Temperature Drying (Incipient Pyrolysis ~300 - 600 °F)
3. Pyrolysis ( ~ 900 - 1200 °F)
Comparison of Drying Technologies

<table>
<thead>
<tr>
<th></th>
<th>Processing Cost</th>
<th>Moisture Content</th>
<th>Change to Coal Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temperature Drying</td>
<td>Lowest</td>
<td>Highest</td>
<td>Little</td>
</tr>
<tr>
<td>High Temperature</td>
<td></td>
<td></td>
<td>Significant</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>Highest</td>
<td>Lowest</td>
<td>Profound</td>
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</table>

Three Major Demonstration Projects

AMAX Thermal Dryer (5000 tons per day)
ROSEBUD SYNCOAL™ Partnership (300,000 tons per year Clean Coal Demonstration Project)
ENCOAL (1000 tons per day Clean Coal Demonstration Project)

Two excellent recent EPRI Publications:

Proceedings: Low Rank Coal Upgrade Technology Workshop EPRI TR-102700 (July 1993)
Upgraded Low-Rank Coal User Guidelines
Rosebud SYNCOAL™ PROJECT UPDATE
High Temperature Drying - "Advanced Coal Conversion Process"

- Combined high temperature thermal drying and physical cleaning process

- Coal is dried in two vibrating fluidized bed dryers and then physically cleaned in deep bed stratifiers where a rough specific gravity separation is made using air and vibration

- Produce a synthetic coal product which has increased heating value, low moisture, stable and hydrophobic

- Product produced from Rosebud Mine (subbituminous C) has properties similar to h-v bituminous C

<table>
<thead>
<tr>
<th></th>
<th>Feed Coal</th>
<th>Product</th>
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</thead>
<tbody>
<tr>
<td><strong>Proximate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Moisture</td>
<td>24.07</td>
<td>0.96</td>
</tr>
<tr>
<td>% VM(MF)</td>
<td>36.1</td>
<td>38.0</td>
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<tr>
<td>% Ash(MF)</td>
<td>15.0</td>
<td>9.9</td>
</tr>
<tr>
<td>% FC(MF)</td>
<td>48.9</td>
<td>52.1</td>
</tr>
</tbody>
</table>

| **Ultimate MF**  |           |         |
| % Carbon         | 49.18     | 67.71   |
| % Hydrogen       | 6.57      | 5.20    |
| % Oxygen         | 30.99     | 15.78   |
| % Nitrogen       | 0.69      | 1.04    |
| % Sulfur         | 1.18      | 0.48    |

| **Heating Value**|            |         |
| Btu/pound        | 8412       | 11,832  |
SYNCOAL Plant
STATUS AS OF END OF 1993

- Initial operation March 1992
- Initial problems were encountered with fines production and spontaneous combustion of product. Plant improvements were made to conveying, cooling and load out systems.
- System has been operated since August 14, 1993 when major turnaround was completed.
- Over 60,000 tons of coal processed in a campaign ending in November. Operated 85% of available hours at 59 - 80% of full load, averaging 65% over a 76 day period.
- Product shipped to utilities and others, including Northern States Power, Montana Power, and WP&L.
- Two lignites were tested. Less fines were produced with lignite than subbituminous coal.
- In order to solve spontaneous combustion problem they are treating coal with a water soluble additive. The product ends up with 10,500 Btu/lb and 12-14% moisture.
UCIG --- Special Update
ROSEBUD SYNCOAL™ Project

- The plant is now producing in excess of its name plate capacity.

- Rosebud now describes the process as making 2 products - a Coarse, granular product with 11,700 Btu per pound (.5% sulfur and 9% ash) and a fine product (0.9% sulfur and 10% ash).

- Just completed a several weeks test of a 50-50 blend of coarse product and normal Rosebud coal at 160 MW Corette plant (CE tangentially fired Plant)
  - Operated at full capacity
  - Required 125 mile rail shipment
  - FIFO coal management system - several days residence
  - No fires

- Use of a water based stabilizer which raises product moisture back to 12-14% has hurt product acceptance.

- They are interested in collaborative efforts with utilities and groups such as UCIG.

- They might have funds to subsidize such an effort.

- They would like to give a presentation to UCIG.
Commercialization of Syncoal Technology

- Minnkota project announced in late 1993, involving Rosebud Partnership and Minnkota Power Cooperative

- $2 Million engineering evaluation (six month) to make a decision on an $80 Million plant to supply Minnkota’s 250 MW Milton Young Unit 1 in Center, North Dakota

- Based on upgrading ND lignite a reported 60% increase in Btu/lb and a 50% decrease in sulfur

- Rosebud is funding the $2 million engineering study at Young Unit 1, with some in-kind contributions from Minnkota, primarily in the form of personnel at the power plant.

- The project derives from a three year study by BNI, Minnkota's coal supplier, who concluded that Syncoal was the best technology for lignite upgrading. BNI conducted that study with help from the Lignite Research and Development Program, a partnership between the state of North Dakota and the lignite industry.

- It is rumored that the project is moving slower than planned, and is meeting resistance over the product moisture issue.

- The Rosebud partners plan to continue its commercialization efforts with both own-and-operate projects and licensing agreements.
ENCOAL PROJECT UPDATE

Pyrolysis - ENCOAL Mild Gasification Project

- Coal is fed to a rotary grate dryer where moisture is removed by contact with a hot gas stream. The temperature is controlled to minimize volatile matter removal. The solids are then pyrolized in a reactor where temperature and residence time are carefully controlled to control product quality and yield.

- 1000 ton per day demonstration under Clean Coal Technology Program located near Gillette, Wyoming

- Plant start up June 16, 1992 Two year operating period planned.

Anticipated Product Analysis

Proximate Analysis, Wt. %

<table>
<thead>
<tr>
<th></th>
<th>Feed Coal</th>
<th>Product</th>
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<tbody>
<tr>
<td>Moisture</td>
<td>30</td>
<td>5</td>
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<tr>
<td>VM (MF)</td>
<td>41.5</td>
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<tr>
<td>Ash (MF)</td>
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<td>FC (MF)</td>
<td>51.4</td>
<td>69.5</td>
</tr>
<tr>
<td>Heating Value (Btu/lb)</td>
<td>8,300</td>
<td>12,000</td>
</tr>
</tbody>
</table>

Status as of Late 1993

- Repeated failure of ESPs due to liquid condensation. Solved with new ceramic insulators

- PDF Quenching and cooling - Product was not stabilized according to expectations resulting in spontaneous combustion of product. A new approach was tried in a large batch test at the plant, where 1200 tons was prepared and stored since June 1992 on an open pile.
Operation limited to 50% of capacity. During two runs of two weeks each, unit was available 90% of the time after start-up. 4500 tons of PDF and 5500 bbls. of CDL (fuel oil) were produced.

Heat content of PDF > 12,000. Liquid products looked pretty much as expected though the specific gravity was high (1.07 compared to 1.03) and there were entrained solids (< 0.5% ash).

Initial test burn planned for WP&L cyclone boiler.

Combustion tests (100 lb./hr) have been completed and look good:
- CO and burnout equivalent to parent coal
- Flame less luminous than parent coal
- No problems with flame instability. Pressure pulsations were less than the parent coal.
- Blends of PDF/Feed coal were tested
UCIG -- Special Update  
ENCOAL Project

- At the end of last year, they completed construction of new equipment to improve the coal deactivation step and de-bottleneck the plant. They have learned that the deactivation step is much more difficult to control than they had thought and depends on both cooling rate and chemical reaction.

- The plant started again in mid January to test the new equipment, and was run for 8 days before shutting down to make changes. They have since made a total of 5 runs; the 8 day run being the longest.

- The modifications have yielded promising results regarding product stability and plant through put, but neither area has been up to specification. The product has not been stable enough to ship.

- They are ultimately looking for product which is stable on small loosely packed piles (note :ROM coal would fail this test). They are encouraged but not satisfied with the current product.

- The computerized data acquisition system (eventually control system) has worked well and helped in identifying the problems. Very close process control is a key feature of the ENCOAL process.

- The oil product has been sold in commerce as No.6 oil. It has passed the NIOSH tests and is neither toxic nor carcinogenic. It has a higher pour point than some users are accustomed to and requires advanced testing to assure compatibility with other system fuels. The oil is currently being sold to the Coal Gasification plant in Buella, North Dakota who are using it as a plant fuel in place of an internal tar stream which is freed up for upgrading.

- They would like to talk to the UCIG group at some future date after they are shipping product.
ADVANCED COAL CLEANING
FOR CONTROL OF SULFUR (AND TRACE METALS)

Types of Sulfur in coal

Sulfate - Removed by dilute HCl extraction and identified by precipitation of sulfate with Barium. In most cases sulfate is an oxidation product of pyrite. There is an iron sulfate form, Jarosite, Fe$_3$(SO$_4$)$_2$.2H$_2$O, which may only be partially extracted by HCl (reports as organic sulfur).

Pyrite - Removed by extraction of coal with HNO$_3$ after the sulfate determination (based on determination for iron in the leachate)

Organic - Sulfur remaining after sulfate sulfur and pyrite have been removed.

Types of Coal Cleaning

Physical - Removes only Mineral sulfur (Sulfate and pyrite)

Chemical - Generally thought of for removal of organic sulfur but can also be used for mineral sulfur

Biological - A form of chemical cleaning based on micro-organisms
PHYSICAL COAL CLEANING

Coarse Coal Cleaning  Crushing; Classification; Gravity Classification
Generally +28M coal

Fine Coal Cleaning  Advanced Processes for recovery of fines, -28M, and
ultra-fines, -100M, and sulfur reduction; Flotation
Processes, Agglomeration Processes, Special Heavy
Media

Advanced Processes can be used to recover natural fines from a conventional
cleaning plant or impound.

AXIOMS

1. Mineral matter (pyritic sulfur) must be liberated from organic matter to be
recovered.

2. Mineral matter is liberated by size reduction. For a given coal, the finer the
material, the greater is the degree of liberation.

3. Separation of liberated mineral matter is easier (more efficient and less
expensive) the coarser the coal.

4. Fine coal cleaning is more expensive than coarse coal cleaning.

5. Coarse product is easier and less expensive to de-water than fine product

6. Fine product has to be put back together (at considerable expense) if you
want to ship it.
ADVANCED PHYSICAL
FINE COAL CLEANING TECHNOLOGIES

- Agglomeration
- Flotation
- Advanced Flotation Combinations
- Advanced Heavy Media Cyclones

Applied to -28M often -100M or -200M or finer coal

Most of R&D under DOE sponsorship

Sampling of Major Projects

Agglomeration - Southern Company Services (2 tph)
Flotation - ICF Kaiser Engineers (2-3 tph)
Advanced Heavy Media Cyclone (Clean Coal)
## OIL AGGLOMERATION

**Plant Designs**

### Raw Coal Properties

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<thead>
<tr>
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<th>Upper Freeport</th>
<th>Pittsburgh</th>
<th>Illinois</th>
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<tbody>
<tr>
<td>Ash</td>
<td>13.6</td>
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<td>15.5</td>
</tr>
<tr>
<td>Total Sulfur</td>
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<td>2.2</td>
<td>1.9</td>
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<tr>
<td>Pyritic</td>
<td>2.0</td>
<td>1.5</td>
<td>1.2</td>
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<tr>
<td>Organic</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
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<tr>
<td>Sulfate</td>
<td>0.03</td>
<td>0.01</td>
<td>0</td>
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<tr>
<td>Btu/lb</td>
<td>13,300</td>
<td>10,167</td>
<td>12,430</td>
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<tr>
<td>lb SO₂/MBtu</td>
<td>4.26</td>
<td>4.25</td>
<td>3.11</td>
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### Product Properties

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<tr>
<td>Ash</td>
<td>5.9</td>
<td>5.3</td>
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<tr>
<td>Total Sulfur</td>
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<td>1.9</td>
</tr>
<tr>
<td>Pyritic</td>
<td>0.5</td>
<td>0.8</td>
<td>0.8</td>
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<tr>
<td>Organic</td>
<td>0.7</td>
<td>0.7</td>
<td>1.1</td>
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<tr>
<td>Btu/lb</td>
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<td>14,487</td>
<td>13,438</td>
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<tr>
<td>lb SO₂/MBtu</td>
<td>1.6</td>
<td>2.6</td>
<td>2.3</td>
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OIL AGGLOMERATION
Costs

Pre-cleaning Flowsheet

Incremental Cost per MBTU - 200 tph plant $0.86
Incremental Cost per MBtu - 500 tph $0.76

Equipment Cost Breakdown

- Agglomeration: 17.3%
- Grinding: 23.1%
- Pre-Cleaning: 11.5%
- Waste Treatment: 7.8%
- Size Enlargement: 32.5%
- Other: 7.8%
OIL AGGLOMERATION COSTS

Pre-cleaning Flowsheet

Incremental Cost per MBtu - 200 tph plant $0.86
Incremental Cost per MBtu - 500 tph $0.76

Without Size Enlargement - 8% Moisture

Incremental Cost per MBtu - 200 tph plant $0.62
(Binder cost alone is $0.17/MBtu)

Without Size Enlargement or Drying - 25% Moisture

Incremental Cost per MBtu - 200 tph plant $0.50

Natural Fines Processing

Cost per MBtu - 114 tph plant $0.49

Middlings Agglomeration

Cost per MBtu $0.42
LESSONS ABOUT FINE COAL CLEANING

- 70 - 80% Pyritic sulfur removal at 90% Btu recovery probably is usually achievable

- The sulfur removal step is affordable; making to a shippable product is costly

- Don't start out by grinding the coal to -200Mesh; The middlings agglomeration flowsheet looks like a promising approach.
  - Process much (most) of the coal at a coarse size
  - Coarse coal cleaning about ½ the cost per ton as fine coal cleaning
  - Easy to de-water coarse coal

- Natural fines or ponded fines are a good place to start

- A good bit of pyrite and organic sulfur remains after treatment

- Research should be focused on size enlargement and handling
UCIG NUGGETS

Low cost binder discovered

University of Kentucky Center for Applied Energy Research recently reported the use of a readily available by-product of the manufacture of beer (Brewex) for production of pellets from coal fines.

- Very inexpensive compared to other binders ($0.02 per pound)
- Low use rate (2 - 5% of MF coal)
- Pellets produced on an ordinary disk pelletizer
- Tested with Alabama and Upper Freeport Coal fines; gave better pellets than starch
- Treatment of the pellets with 0.05% asphalt emulsion renders the pellets water-proof

Cost Calculation: At 3.5% usage (based on MF coal) the cost would be 5¢ per MBtu compared to 17¢ in the SCS study. At least 12¢ savings.

STATUS: Tested on small scale with Alabama and Upper Freeport coals. Looking for large scale tests. Would be very interested in working with UCIG or members.
Mulled Coal Development may be an inexpensive way to handle wet fines

Mulled Coal Process
- A process, developed under DOE sponsorship, which converts wet filter cake sludge (15 - 40% free moisture) to a dry looking agglomerated free flowing solid which can be handled like crushed coal but which has all of the original moisture contained within the mulls
- Works best for bituminous coals
- Agglomeration with oil not oil agglomeration. Uses 0.5 to 3% oil, often about 1%; Vendors proprietary capability is to choose proper oils and dosage for the circumstances
- Able to thermally dry the mulls without destroying them
- Wet mulls still flow when frozen
- Cost reported in the DOE study of only $3 per wet ton for making the mulls (this would be $0.14 per MBtu for the fine clean coal by agglomeration) - Probably room for economy of scale
- Very expensive to make a 65% stable CWF ($0.43 per MBtu, mostly for the additive package); Very little incremental cost if the coal will be used immediately (eg, in an unstable slurry); This is the primary area which will require additional work before the technology is used.
- Energy International is planning a test to demonstrate transportation and handling in existing commercial equipment
- Trucks, rail, barge, and ocean vessels
- Open ground storage, blended ground storage, layered storage, cold weather
- Samples could be provided to UCIG
- Could use this technology for upgraded coal from fine coal cleaning, or for transporting live or ponded fines from a conventional cleaning plant
- EI would be happy to provide more information or to collaborate in evaluation of mulling for UCIG applications
THE JOYS OF BURNING SLURRY
Penelec Co-Firing Coal Water Slurry Fuel in 32 Megawatt PC Boiler

Potential Benefits of CWS Co-Firing

- Low Cost Coal - Penelec projected a cost of about $0.80 MBtu
- Savings on Oil for Start up and stabilization
- NO\textsubscript{X} Reduction
- Pulverizer life extension

Penelec Project

- Test low concentration slurries (40 - 50% coal) without chemicals needed to produce a long term stable slurry
- Seward #14 B & W (1950) PC Boiler - located 35 miles from Homer City Coal Prep plant
- Two levels of 3 burners (recently installed EER Low NO\textsubscript{X} Burners) - Bottom level was modified by installation of slurry air-atomizing nozzles for CWS co-firing up to 40% capacity
- CWS prepared off-site by treating Homer City in 3 tph pilot plant
  - Feed - 100 Mesh Stream from Homer City
  - Separate out 28 x 100 in classifying cyclone
  - Clean true -100 Mesh by flotation
  - Thicken the clean coal in a thickener and filter press for storage
  - Prepare CWS from cake
  - 100 Mesh cleaned from 18% ash and 1.2 % S to 10% ash 1.27% S in flotation\textsuperscript{1}

- Resulted in a 15 -20 % NO\textsubscript{X} reduction at Seward
- CO, SO\textsubscript{2}, and particulates were essentially unchanged, but CO was highly variable.
- May be an ideal test site for advanced slurry and coal cleaning technologies.

\textsuperscript{1}Tested for treatment by advanced agglomeration could be further lowered to 5% ash; 1.0% S.
CUSTOM COALS CLEAN COAL PROJECT

Uses very fine magnetite (-5μm) to allow heavy media cyclones to operate on -28M fines

- Separate large size fractions to produce a very low gravity (1.3) clean coal and high gravity (1.8-2.0) refuse
- Crush/grind the middlings to liberate additional pyrite
- Size the products and separate into high and low gravity fractions again, as above
- Additional grinding of the middlings
- etc.
- Produce briquettes or pellets from the fines

- Meets the criteria of maximizing large pyrite removal at largest size
- Relatively simple sounding process concept, though there are innovations and uncertainties regarding preparation and recovery of the ultra-ultra fine magnetite and removal of the very fine clays from the feed coal (to allow magnetite recovery)
- Key fine coal cleaning steps reported to have been tested at CQ (2 and 10 inch cyclones). Private data.

- The above product is known as Carefree Coal
- Self-Scrubbing Coal is Carefree Coal with Limestone blended into the fine briquettes.
Commercialization Plans

- At the end of 1993 it was announced that Custom Coals had signed a Continuation Agreement with DOE, allowing them to go ahead with the construction phase of their $76 Million Clean Coal Round IV award (Laurel Project).
- Located in Somerset, PA, it will process 500 tons per hour of coal.
- Approx. 1 year construction.
- 18 month demonstration period.
- Have obtained environmental approvals.
- Have a "private placement memorandum" offering to sell Limited Partnership Interests for 99% ownership of the plant.
- Not clear that there is a firm customer for the product. Duquesne Light is rumored to be considering whether to test Carefree coal, while Richmond Power & Light and Centerior Energy are eyeing the Self-Scrubbing coal.

- Custom Coals purchased PP&L's Dilltown 750 ton per hour conventional cleaning plant which can meet mid-sulfur specs required for Clean Coal Phase 1 with local coals.
- Plans to convert to Custom Coals technology by 2000 for phase 2.
- Claim to have identified other opportunities in Pennsylvania, Ohio and Illinois.
- Seeking 10% of the domestic coal market.

- Working on" removal of organic sulfur by a two step leaching process wherein the coal is restructured. During this process organic sulfur is first oxidized and then rent (torn) from coal molecules".
- Have obtained a private letter ruling from the IRS stating that fuel produced as described above qualifies for the IRC § 29 Alternative Fuel Tax Credits (~$1/MM Btu).
- Plan to build as many qualifying plants as they can before the end of 1996 (the chance of a life time! ed.)
- More to follow....

- Custom Coals seems to want to be a coal supplier rather than a technology supplier.
- They would very much like the opportunity to interact with UCIG.
A UCIG ANALYSIS
LOW RANK COAL UPGRADING

• Both the SYN COAL and ENCOAL Pilot Plants have been in operation since mid 1992. Neither has yet completed the major utility burns which were contemplated.

• Both processes have had problems with fines production and "spontaneous combustion" which were not anticipated from the extensive smaller scale work which preceded each.

• Most of the commercial interest seems to be in the lignite production / utilization states.

• The products are likely to require extra effort with respect to transportation, handling, and storage.

• All products qualify for Nonconventional fuel tax credits for all products (as long as the projects otherwise qualify, e.g. sale to an unrelated party, timing etc.).

• Because of the product related products the world is not beating a path to the developers door, though we do know of some projects being seriously considered.

• It could be a good time to pursue a project for an aggressive utility willing to make extra effort to accommodate the product problems in return for a good deal on the coal.

• There may be good opportunities for cooperative projects with industrial customers of the utility.

• Beware of the start up time needed to get a plant based on a new technology on stream.
UPDATE ON RESEARCH PERTAINING TO IRC SECTION 29 TAX CREDITS
CREDIT FOR FUEL FROM A NON-CONVENTIONAL SOURCE

- Provides a tax credit for liquid, solid, or gaseous synthetic fuels produced from coal (including lignite), including such fuels when used as feedstocks.

- Currently extended to include facilities placed in service before January 1, 1997 pursuant to a binding written contract in effect before January 1, 1996.

- Value of credit is $0.97 per million Btu.

- For the purposes of taking the credits, facilities originally placed in service after December 31, 1992 may take the credit through January 1, 2008.

- Synthetic Fuels were not define per se in P.L. 96-223 (The Crude Oil Windfall Profits Tax of 1980) which was the basis for what is now Section 29. The IRS has interpreted it by reference to P.L. 95-618 (The Energy Tax Act of 1978), which established investment tax credits for certain "Alternative Energy Properties" IRS Section 48.

- A fuel is a material that produces usable heat upon combustion. To be "synthetic", the fuel either must differ significantly in chemical composition, as opposed to physical composition, from the alternate substance used to produce it...".

- An alternate substance is any substance or combination of substances other than an oil or gas substance. Alternate substances include coal, wood, and agricultural, industrial, and municipal wastes or by-products. Alternate substances do not include synthetic fuels or other products that are produced from an alternate substance and that have undergone a chemical change as described above.

- Originally excluded coke and coke gas (Section 48), but P.L. 96-223 added these to the definition of synthetic fuel. Also Solvent Refined Coal is specifically allowed as a "solid synthetic fuel". This change has been the basis for a number of rulings which allow substantially "all solid" synthetic fuel products. The original intent was clearly limited to coal liquefaction and gasification.
• 2 REVENUE RULINGS regarding solid synthetic fuels from coal

86-100 - Coal Water Slurry does not qualify even if including pyritic sulfur removal and additives to allow use in place of oil.

85-81 - (Relative to section 48) Coke is a synthetic fuel.

• Six Private Letter Rulings

8635021 - Thermal processing of low rank coals- SYNCOAL?
8738085 - Gasification plant used for urea and other NH3 chemicals.
8805043 - Mild pyrolysis to produce solid product
8836071 - Mild Pyrolysis - ENCOAL?
9233002 - Coke or char and liquid
9412026 - Low sulfur solid boiler fuel - Chemically cleaned Custom Coal

• Other Important Learnings

Close coupled operations ok so long as there is a legitimate sale to an unrelated party.

Sale of electricity doesn't count as a sale to an unrelated party.
Coal Recovery from Slurry Ponds and Fines
Potential Uses of Fine Coal

- PC boiler fuel (>1.2 lbs SO₂/MBtu)
- PC boiler fuel (<1.2 lbs SO₂/MBtu)
- Coal-water fuel (<1.2 lbs SO₂/MBtu)
- Pelletized or briquetted fuel (<1.2 lbs SO₂/Mbtu)
- Briquetted waste fuel (coal and other combustibles)
Economic Factors

- Cost of fines recovery and processing
- Cost of transportation to the user
- Compliance coal price premiums
- Pelletizing/briquetting costs
- Natural gas and oil prices
- Tipping fees for combustible wastes
- Value of other benefits
Estimate of Coal Fines Resource

Abandoned impoundments: >1.5 billion tons
Active impoundments: 800 million tons
Current production of raw fines: 38 million tons/year
## CQ Inc.

### Projected Costs for Producing the Coal Component of a Premium Coal-based Fuel Using Advanced Coal Cleaning Methods

**SO₂ Compliant Fuels for PC Boilers**

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Heavy-media Cycloning</th>
<th>Selective Agglomeration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Time (Hours)</td>
<td>5100</td>
<td>7560</td>
</tr>
<tr>
<td>Production Rate (TPH)</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Minimum Clean Coal Yield (Wt.%)</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Plant Life (Years)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Financing (%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cost of Money (%)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total Capital Cost ($)</td>
<td>50,000,000</td>
<td>114,000,000</td>
</tr>
<tr>
<td>Annualized Capital Cost ($/raw ton)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total First-year O&amp;M Cost ($)</td>
<td>9,000,000</td>
<td>45,000,000</td>
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<tr>
<td>Annualized O&amp;M Cost ($/raw ton)</td>
<td>3.5</td>
<td>12</td>
</tr>
<tr>
<td>Total Cost ($/raw ton)</td>
<td>6.5</td>
<td>17</td>
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<tr>
<td>($/clean ton)</td>
<td>9</td>
<td>23</td>
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</table>
Projected Costs for Producing the Coal Component of a Premium Coal-based Fuel Using Advanced Coal Cleaning Methods (Cont'd)

Coal-water Fuels for Retrofitted Boilers and Engines

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Selective Agglomeration</th>
<th>Advanced Chemical Extraction</th>
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</thead>
<tbody>
<tr>
<td>Operating Time (Hours)</td>
<td>7560</td>
<td>7560</td>
</tr>
<tr>
<td>Production Rate (TPH)</td>
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</tr>
<tr>
<td>Minimum Clean Coal Yield (Wt.%)</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>Plant Life (Years)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Financing (%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Cost of Money (%)</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total Capital Cost ($)</td>
<td>52,000,000</td>
<td>65,000,000</td>
</tr>
<tr>
<td>Annualized Capital Cost ($/raw ton)</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Total First-year O&amp;M Cost ($)</td>
<td>30,000,000</td>
<td>53,000,000</td>
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<tr>
<td>Annualized O&amp;M Cost ($/raw ton)</td>
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<td>14</td>
</tr>
<tr>
<td>Total Cost ($/raw ton)</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>($/clean ton)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>
Alternative Fuels

- Coal water fuels
  - Feed to gasifiers
  - Stationary diesels
  - Cofiring with pulverized coal
  - Tests at Penelec's Seward Station show reduced NO$_x$
## Future Coal-water Fuel Applications and Expected Quality Requirements

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Application</th>
<th>Ash Content (Wt.%)</th>
<th>Coal Content of Slurry (Wt.%)</th>
<th>Coal Particle Size (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>PC Co-firing</td>
<td>10 - 15</td>
<td>65 - 80</td>
<td>20 - 30</td>
</tr>
<tr>
<td>Boiler</td>
<td>Conversion from Oil or Gas</td>
<td>2 - 5</td>
<td>65 - 80</td>
<td>20 - 30</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>Pre-combustion Chamber or Direct-fired</td>
<td>&lt;3</td>
<td>50 - 60</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>Slagging Combustion Chamber</td>
<td>&gt;20</td>
<td>50 - 60</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Diesel Engine</td>
<td>Direct-fired</td>
<td>&lt;3</td>
<td>50 - 55</td>
<td>5 - 15</td>
</tr>
</tbody>
</table>
Sorvent Silo

Turbocharger

Cyclone

Bag House

Ammonia Tanks

Waste Heat Boiler (Steam to 1.4 MW Steam Turbine)

SCR Reactor

Coal Slurry Fuel

Slurry produced in Maryland

Coal cleaned at mine in Ohio

6.3 MW Engine, 400 RPM

15.5-in. Bore

Cooper Bessemer LSVB-20
Alternative Fuels

E-Fuel™

- CQ Inc.-developed briquetted fuel combining coal fines and waste products

- Potential stoker product

- Successful test burn at Indiana University of Pennsylvania in March, 1994
Conclusions

- PC boiler fuel (>1.2 lbs SO$_2$/MBtu)
  - Current market prices limit utilization
  - Handling costs discourage increased sales

- Pelletized or briquetted fuel (<1.2 lbs SO$_2$/MBtu)
  - Production energy costs exceed current
    market prices of compliance coal

- Briquetted waste fuel (coal and other combustibles)
  - Site specific factors control economics
  - Non-economic factors may dictate decision-making
Conclusions (Cont’d)

- PC boiler fuel (<1.2 lbs SO₂/MBtu)
  - Advanced heavy-media cycloning
  - Selective agglomeration
  Potential
  Moderate
  Some

- Coal-water fuel
  - Selective agglomeration
  - Chemical extraction
  Potential
  Good
  Good