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TREATMENT OF METAL-LADEN HAZARDOUS WASTES WITH ADVANCED CLEAN COAL TECHNOLOGY BY-PRODUCTS

QUARTERLY TECHNICAL PROGRESS REPORT

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EXECUTIVE SUMMARY

During the twelfth quarter of Phase 2, work continued on conducting scholarly work, preparing for field work, preparing and giving presentations, and making additional outside contacts.

Scholarly Work

The graduate student assigned to this project from the Department of Civil and Environmental Engineering has continued her work on evaluation of the long-term stability of Phase 1 samples.

Preparation for Field Work

The Mill Service Yukon Plant (MSYP) received a modification of its principal solid waste permit to allow the commercial use of dusty, dry clean coal technology by-products as stabilization/solidification treatment chemicals at the plant.

The staff of MAX Environmental Technologies, Inc., submitted to the Pennsylvania Department of Environmental Protection applications (1) for a minor permit modification for the installation of a new silo and new storage pads and (2) for a revision to the air permit to operate the baghouse on the new silo.

New federal Universal Treatment Standards were issued on August 24.

The TIDD by-product was moved to MSYP in September.

Reports and Presentations

A presentation was made on "Clean Coal Technology By-Products as Treatment Chemicals for Hazardous Wastes" at the Advanced Coal-Based Power and Environmental Systems '98 Conference on July 22 at the Morgantown site of FETC.

Outside Contacts

The principal and co-principal investigators met with staff members of CONSOL, Inc., to discuss projects on by-product utilization.

The principal investigator spoke with staff members of the Scrubgrass Generating Plant about their interest in ash utilization.

Professor C. N. K. Bansal of IIT, Delhi sent a letter to the principal investigator providing information about the Centre for Energy Studies at IIT, Delhi.

Plans for the Next Quarter

During the quarter from September 30 through December 30, 1998, work will continue on Tasks 4 and 5 of Phase 1. The graduate student assigned to this project will continue her scholarly work during this quarter.

Work on Task 1 of Phase 2 will continue. The principal investigator will maintain contact with MAX Environmental Technologies, Inc., as it plans the installation of equipment at the Mill Service Yukon Plant to conduct Phase 2 of the project.

INTRODUCTION

This sixteenth quarterly report describes work done during the sixteenth three-month period of the University of Pittsburgh's project on the "Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology By-Products."

This report describes the activities of the project team during the reporting period. The principal work has focussed upon new laboratory evaluation of samples from Phase I, discussions with MAX Environmental Technologies, Inc., on the field work of Phase 2, giving a presentation, and making and responding to several outside contacts.

LABORATORY AND FIELD WORK

Scholarly Activity

Jana Agostini, the graduate student in the Civil and Environmental Engineering Department, continued her work in the environmental laboratories on the ninth-floor of Benedum Engineering Hall. She continues her evaluation of the leachability of aged samples prepared during Phase I. A comprehensive report of her project will be provided in a formal document at a later time.

Preparation for Field Work

Ever since the continuation of the project on to Phase 2 was approved three years ago in mid-1995, the Mill Service Yukon Plant (MSYP) has been awaiting a modification of its principal solid waste permit (PAD004835146) to allow the commercial use of dusty, dry clean coal technology by-products as stabilization/solidification treatment chemicals at the plant. On July 8, 1998 that permit modification was finally issued.

In mid-July MAX Environmental Technologies, Inc. (MAX) submitted its application for a minor permit modification to the Pennsylvania Department of Environmental Protection (PaDEP) for the installation, among other pieces of equipment, of a new silo and new storage pads near the SWSS pits at MSYP. This portion of the planned new installation will allow MAX to regularly use dry dusty treatment chemicals, such as advanced clean coal technology by-products, to stabilize large volumes of solid, metal-laden hazardous waste.

In late August MAX submitted a request to PaDEP for a revision to the air permit to operate the baghouse on the silo. The revision is expected to be approved early in 1999. As soon as it is approved, a modification will be requested to the solid waste permit to dispose of the solid waste produced by treatment with the new chemicals. This modification is expected to be issued within eight weeks of the request. The project team is hopeful that MSYP can begin construction of the modifications in early spring 1999 and be ready to conduct the field work of Phase 2 soon thereafter.

Because of a major regulatory revision that occurred during this quarter, it is appropriate to revisit the subject of land disposal restrictions (i.e., Universal Treatment Standards — UTS) for metal constituents in hazardous wastes. Appendix A provides the summary, history and applicability of the new federal UTS regulations from pages 28559-28561 of the Federal Register (volume 63, number 100, May 26, 1998). It also shows both the current and new standards for K061 from 40 CFR 268.40(f). These newest regulations became effective on August 24. In Phase 1 the project team compared the stabilization results, which it obtained during that phase, to the then existing and proposed UTS. At that time the existing UTS for lead was 5.0 ppm and the proposed UTS for lead was 0.37 ppm. The current UTS for lead is 0.37 ppm and the new UTS for lead (after August 24) is 0.75 ppm.

The TIDD by-product, that had been stored at Dravo Lime Company for several years, was moved to MSYP on September 16.

REPORTS AND PRESENTATIONS

On July 22 the principal investigator made a presentation on "Clean Coal Technology By-Products as Treatment Chemicals for Hazardous Wastes" as part of the session titled By-Product Utilization at FETC's Advanced Coal-Based Power and Environmental Systems '98 Conference at the Morgantown (WV) site. An accompanying paper, coauthored by the co-principal investigator, was published in the proceedings of the conference. A copy of the paper in the proceedings is provided in Appendix B.

OUTSIDE CONTACTS

CONSOL Inc.

The principal and co-principal investigators met with several staff members of CONSOL Inc at that company's research laboratory in Library, PA on September 1. The CONSOL staff was briefed on the Engineering Center for Environment and Energy at the University and projects of the center on treatment of metal-containing wastes with clean coal technology by-products, ash-based autoclaved cellular concrete, and dewatering of wet by-products.

Scrubgrass Project

At the ceremony in Harrisburg, PA for the 1998 Governor's Award for Environmental Excellence on September 22, the principal investigator met the general manager, the fuels manager and two of the plant engineers of the Scrubgrass Generating Plant. The fuels manager suggested that the plant has a strong interest in ash utilization.

Indian Institute of Technology, Delhi

On September 22 Professor C. N. K. Bansal, Head of the Centre for Energy Studies of IIT, Delhi, responded to the University's letter of April 10 which had provided him with information about the School of Engineering Center for Environment and Energy and the programs being conducted by faculty associated with the center, including those relating to the utilization of coal combustion by-products. The letter from Prof. Bansal on September 22 is provided in Appendix C. It provides a description of the Centre for Energy Studies and announces that Dr. Avinash Chandra, Chief Scientific Officer of the Centre will visit the United States in October.

ADMINISTRATIVE ASPECTS

This section presents a note on one special action, provides the monthly highlights, and closes by comparing progress with the milestone chart.

Special Action

On August 20 notice of the third one-year, no-cost extension to the contract was sent by FETC to the University.

Monthly Highlights

Here are the highlights of the twelfth three-month period of the second phase of the project.

June 30 - July 30, 1998

- Mill Service Yukon Plant receives modification of its principal solid waste permit to allow the commercial use of CCT by-products.
- Mill Service Yukon Plant submits an application for a minor permit modification for the installation of a new silo and storage pads to allow the commercial use of CCT by-products.
- Presentation is given to the Advanced Coal-Based Power and Environmental Systems '98 Conference at the Morgantown site of FETC.

July 30 - August 30, 1998

- Mill Service Yukon Plant submits a request for a revision to its air permit to allow the operation of the baghouse on the new silo.

August 30 - September 30, 1998

- Visit is made to CONSOL Inc to discuss various ash utilization processes.
- TIDD by-product is moved to the Mill Service Yukon Plant.
- Discussion is held with staff members of the Scrubgrass Generating Plant.

Comparison of Progress with Milestone Chart

The following task for Phase 2 had been scheduled for completion during the first quarter of Phase 2:

- Task 1 - Test Plan for Phase 2

Task 1 still was not completed during the twelfth period of this phase. The decision in early April 1996 by METC that an environmental assessment of the Phase 2 project at the Yukon plant of Mill Service, Inc. (MSI), would have to be conducted and the subsequent withdrawal in late April 1996 by MSI from Phase 2 necessitated a search for a new subcontractor to host and participate in the commercial test of Phase 2. MAX Environmental Technologies, Inc., has rejoined the project team and is designing modifications at the Mill Service Yukon Plant (MSYP) to enable it to enter this business area and carry out the field work on this project. The test plan for Phase 2 will be prepared shortly before the permits are in place for the installation of the equipment at MSYP for carrying out the demonstration.

Work continued on two tasks from Phase 1:

- Task 4 - Treatment of Metal-Laden Waste with CCT Solid By-Product
- Task 5 - Data Analysis

Work on Tasks 4 and 5 of Phase 1 will continue into the thirteenth quarter of Phase 2. The fourth by-product and the final three residues are no longer being actively sought. When the Phase 2 testing program is initiated, consideration will be given to reestablishing this activity.

PLAN FOR THE NEXT QUARTER

During the quarter from September 30 through December 30, 1998, work will continue on Tasks 4 and 5 of Phase 1. The graduate student assigned to this project will continue her scholarly work during this quarter.

Work on Task 1 of Phase 2 will continue. The principal investigator will maintain contact with MAX Environmental Technologies, Inc., as it plans the installation of equipment at the Mill Service Yukon Plant to conduct Phase 2 of the project.

APPENDIX A

UNIVERSAL TREATMENT STANDARDS

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III. Revised Land Disposal Restrictions (i.e., Universal Treatment Standards) for Metal Constituents in all Hazardous Wastes, Including Toxic Characteristic Metals

Summary

There are two purposes to today's new treatment standards for metal-containing wastes. First, EPA is revising the numerical standards because new data are available on which to base more accurate standards. Second, EPA is including a new set of wastes in the current treatment standard regime, continuing EPA's efforts to apply the same LDR treatment standards when technically and legally possible. (In a subsequent section of this rule, EPA is expanding the treatment standard regime to include yet another set of wastes. These are characteristic mineral processing wastes that are not currently subject to land disposal restrictions.)

The numerical standards that EPA is revising are the universal treatment standards (UTS) for 12 metal constituents. The new UTS will apply to nonwastewater forms of any listed or characteristic hazardous waste that is already required to meet the UTS for those constituents in the waste. The revised UTS are less stringent for 7 constituents, and more stringent for 5. The rule does not affect the UTS for wastewater forms of these wastes, and does not change the UTS for any other constituents, including any of the organics.

The new set of wastes that EPA is bringing into the current LDR regime is the group of 8 wastes known as TC metal wastes--wastes identified as hazardous because they exhibit the toxicity characteristic due to the presence of the metals enumerated in 261.24 (Waste codes D004-D011). These are wastes that exhibit the toxicity characteristic because of high toxic metal content. By today's rule, that key metal must be treated to the UTS for that metal. Furthermore, any underlying hazardous constituents (UHCs) must be treated to UTS levels as well, whether these UHCs are organics or metals. Both wastewater and nonwastewater forms of the TC metal wastes are affected by today's rule, except for arsenic, for which only the wastewater forms are affected.

Hazardous wastes that exhibit both the TC for metals and the predecessor characteristic based on the Extraction Procedure (EP) are presently only required to be treated to reduce metal levels to below the characteristic level. Today's rule, for the most part, will require additional treatment of these metal constituents before land disposal can occur.

The Agency also finds that the treatment standards established in

today's rule are not established below levels at which threats to human health and the environment are minimized. See *Hazardous Waste Treatment Council v. EPA*, 886 F.2d 355, 362 (D.C. Cir. 1990). That case held that the statute can be read to allow either technology-based or risk-based LDR treatment standards, and further held that technology-based standards are permissible so long as they are not established "beyond the point at which there is no 'threat' to human health or the environment." *Id.* at 362. EPA's finding that today's standards are not below a "minimize threat" level is based on the Agency's inability at the present time to establish concentration levels for hazardous constituents which represent levels at which threats to human health and the environment are minimized. As the Agency has explained a number of times, determining these levels on a national basis--which requires determination of relevant exposure pathways and potential receptors for all hazardous constituents in hazardous wastes, with all the attendant uncertainties involved in such a national determination--has not yet proven possible. See, e.g., 55 FR at 6642 (February 26, 1990). Thus, the Agency continues to find that technology-based standards remain the best approach for the national treatment standards since such standards eliminate as much of the inherent uncertainty of hazardous waste land disposal and so fulfill the Congressional intent in promulgating the land disposal restrictions provisions. *Id.* However, the Agency believes that it may be possible to make valid determinations that threats to human health and the environment are minimized on an individualized basis in the context of certain site-specific remediations, and accordingly has provided in this rule a variance from technology-based treatment requirements for contaminated soils generated in certain remediations. See section VII below.

A. History of Metal Treatment Standards

Land disposal of hazardous wastes is largely prohibited by statute, unless the wastes meet the applicable treatment standards established by EPA prior to land disposal. See RCRA sections 3004(d)-(g), (m); (the exception for no-migration units is not relevant to today's rule). Until today's rule, metals that were characteristic because they failed the Toxicity Characteristic Leaching Procedure (TCLP) and also failed the Extraction Procedure (EP)--which preceded the use of the TCLP as a means of identifying whether a waste exhibited a characteristic of hazardous waste--were subject to treatment standards at levels equal to the TC levels (55 FR 22520, June 1, 1990). (Note that wastes that were characteristic according to the TCLP but did not fail the EP were considered, until promulgation of today's rule, to be newly identified wastes, and were not subject to the LDR requirements. Today's rule makes these wastes subject to LDR). However, the TC levels are typically higher than those treatment levels for which threats posed by land disposal of the wastes are minimized. (*Waste Management v. EPA*, 976 F.2d 2, 13-14, 26-27, 32 (D.C. Cir. 1992). Consequently, treatment to levels lower than the characteristic levels normally is required. *Id.*

In an effort to make treatment standards as uniform as possible while adhering to the fundamental requirement that the standards must minimize threats to human health and the environment, EPA developed the UTS. Under the UTS, whenever technically and legally possible, the Agency adopts the same technology-based numerical limit for a hazardous constituent regardless of the type of hazardous waste in which the

constituent is present (see 40 CFR 268.40; and 59 FR 47982, September 19, 1994). In the original Phase IV proposal, EPA proposed to apply the metal UTS, as measured by the TCLP (60 FR 43582, August 22, 1995; see 40 CFR 261.24), to all TC metal wastes. The TCLP measures the possibility that a waste may leach toxic metals above a designated concentration level under certain assumed disposal conditions, and so is a measure of the potential mobility of toxic metals in a waste.

Commenters in response to the original proposal took issue with the Agency's use of data previously used to establish metal UTS as a basis for establishing the treatment standards for characteristic metal wastes. The commenters raised three basic issues with regard to the data transfer. First, they said that characteristic metal wastes are extremely variable and the data used to calculate the treatment standards were not representative of the diversity of TC metal wastes. Second, the commenters said that although two treatment technologies--high temperature metals recovery (HTMR) and stabilization--were determined to be Best Demonstrated Available Technology (BDAT), the current metals UTS were based solely on HTMR, a technology not commercially available for many TC metal wastes. Finally, commenters asserted that individual metal UTS values were not uniformly achievable when waste streams with multiple toxic metals were being treated. In light of these concerns, the commenters urged the Agency to obtain additional data that would demonstrate the effectiveness of stabilization on TC metal waste streams and more fully characterize the diversity of treatment of these nonwastewaters. The following commenters provided the Agency with stabilization performance data: Battery Council International, American Foundrymen's Association, Chemical Waste Management, and the Environmental Treatment Council. While extensive, the data unfortunately was based on composite samples and could not be used as the basis for treatment standards (see USEPA, Final Best Demonstrated Available Technology (BDAT) Background Document for Quality Assurance/Quality Control Procedures and Methodology, Office of Solid Waste, October 23, 1991 and 62 FR 26041 for a discussion of grab and composite sampling).

The Agency, however, was convinced that additional data were needed to further assess the treatment of TC metal nonwastewaters. During September 1996, EPA conducted site visits at three hazardous waste treatment facilities and collected additional treatment performance data. One facility was a large commercial TSDF that employed conventional stabilization techniques to treat a wide array of inorganic metal wastes. Another was an on-site treatment facility that focused on the stabilization of inorganic metal slag. A third facility was commercial and focused on stabilization of inorganic materials using non-conventional stabilization techniques. During these site visits, the Agency either gathered performance data from company records or requested the collection of actual treatment performance data through sampling and analysis.

Treatment data were collected for the following types of hazardous waste: mineral processing waste, baghouse dust, battery slag, soils, pot solids, recycling by-products, and sludge. See the memorandum, Final Revised Calculation of Treatment Standards Using Data Obtained From Rollins Environmental's Highway 36 Commercial Waste Treatment Facility and GNB's Frisco, Texas Waste Treatment Facility, March 10, 1997 and the memorandum, Transferability of UTS to Mineral Processing Wastes, January 28, 1997 for a complete description of the waste constituents and concentrations. Most of the wastes contained multiple metals in various concentrations while some had

significant concentrations of typically two metal combinations, including lead and cadmium, barium and lead, and chromium and antimony. In addition, between October 1994 and December 1995, the Agency obtained performance data from one HTMR facility; (other HTMR data became available very late in 1997). The assessment of the new data sets began with the calculation of treatment standards for each of the two data sets representing stabilization and HTMR. The same methodology, sometimes called "C 99," and used in past LDR rulemakings, was used to calculate the treatment levels (see 56 FR 41164, August 18, 1991, and the BDAT Background Document for K061, dated August, 1991). Next, the Agency compared the treatment levels for stabilization verses HTMR. Based on this comparison, the Agency selected the highest level for each metal as the proposed UTS to allow for waste and process variability and detection limit difficulties. This approach is consistent with the legislative goal of providing substantial treatment through standards that are achievable by an array of well-performing, available treatment technologies. See 130 Cong. Rec. S 9184 (Daily ed., July 25, 1984) (statement of Senator Chafee).

As a result, the Agency issued a Second Supplemental Proposal on May 12, 1997 (62 FR 26041). In it, EPA proposed to change the numerical limits for all nonwastewater wastes containing the following metal constituents: antimony, barium, beryllium, cadmium, chromium, lead, nickel, selenium, silver, and thallium. (62 FR at 26047, May 12, 1997). The Agency also repropoed to change the numerical limits for vanadium in P119 and P120 nonwastewaters, and for zinc in K061 nonwastewaters. (62 FR at 26047, May 12, 1997). EPA also proposed these same UTS treatment standards for TC metal wastes identified as hazardous due to concentrations of barium, cadmium, chromium, lead, selenium and silver.

The Agency would like to correct in today's rule a prior error that was discovered in calculating the metals treatment levels using the HTMR treatment data. As previously stated, in the Second Supplemental and in today's preamble, in determining the treatment levels for each metal constituent, the Agency compared the treatment standards calculated with data from HTMR and stabilization. Based on this comparison, the highest level for each metal was chosen as the treatment standard. In reviewing the calculations from the HTMR data set, the Agency discovered an error in the calculations. When applying the methodology presented in USEPA, "Final Best Demonstrated Technology (BDAT) Background Document for Quality Assurance/Quality Control Procedures and Methodology," dated October 23, 1991, it was discovered that the Agency failed to conduct a "Z-score test" to remove any outliers--data that is either so high or so low that it is not considered to be representative of the population from which the data are drawn. EPA uses this statistical method to confirm that certain data do not represent treatment by a well-operated system, or reflect anomalously low levels which are not typically achievable. This error was found to have occurred only in the calculation of the treatment standards based on the performance of HTMR; the treatment standards based on the performance of stabilization were properly calculated. The proposed treatment standards for cadmium, chromium, nickel, and silver were affected. The application of the Z-score outlier test resulted in 2 data points out of 40 being eliminated as outliers for both cadmium and chromium. For nickel, 5 out of 122 data points were identified as outliers.

For silver, 3 out of 114 data points were identified as outliers. Three of the resulting, calculated treatment standards changed slightly and are slightly more stringent than the proposed standards: cadmium from proposed 0.20 to corrected 0.11 mg/L TCLP; chromium from proposed 0.85 to corrected 0.60 mg/L TCLP; and nickel from proposed 13.6 to corrected 11 mg/L TCLP. Silver, on the other hand, changed from the proposed 0.11 mg/L TCLP to a corrected, slightly less stringent 0.14 mg/L TCLP. (Note: In re-calculating this standard, the Agency added an additional 74 data points which were submitted by the INMETCO Company (a high temperature metal reclaimer) in their comments to the May 12 supplemental proposal.) The Agency believes that these re-calculations are not significant because these four revised standards are each still achievable. See Memorandum, "Calculation of Universal Treatment Standard (UTS) for HTMR Residues Using Data Submitted by Horsehead Research Development (HRD) Co., Inc. And INMETCO," December 17, 1997.

B. Applicability of Metal Treatment Standards

As noted earlier, today's rule finalizes LDR treatment standards in two ways. First, it revises the UTS levels for 10 metal constituents in nonwastewater forms of hazardous wastes. The 10 include antimony, barium, beryllium, cadmium, chromium, lead, nickel, selenium, silver, and thallium. These treatment standards will replace the existing UTS values. In addition, EPA is applying UTS for the first time to 8 TC metal wastes: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The UTS apply to both wastewater and nonwastewater forms of the wastes (except for TC arsenic wastes, for which the UTS apply to wastewater forms only), and to both organic and metal underlying hazardous constituents in them. No TC metal wastes have had to meet standards for underlying hazardous constituents before today, and wastes exhibiting only the TC and not the EP were not yet prohibited. (Note, some subcategories of mercury and arsenic TC metal wastes have treatment methods requiring use of a specified technology, and are not affected by today's rule.) The Agency is also adjusting the treatment standards for vanadium in P019 and P020 nonwastewaters as well as zinc in K061 nonwastewaters.

The metal treatment standards being promulgated today have broad applicability. They apply to the following metal-containing hazardous wastes: (1) characteristic metal wastes, including both the newly identified wastes that, heretofore, were not prohibited from land disposal; and metal wastes that were identified as hazardous under the predecessor leaching protocol, the Extraction Procedure (EP), which remain hazardous because they also exhibit the TC by the TCLP; (2) mineral processing wastes which exhibit the toxicity characteristic for metal (this is actually a subset of wastes in (1) above); (3) listed hazardous wastes which have metal constituents; (4) underlying hazardous constituents (UHCs) that are metals in any characteristic hazardous waste (including mineral processing waste which exhibit a characteristic) that is disposed in other than a Clean Water Act (CWA) or CWA-equivalent wastewater treatment system (see 40 CFR 268.2(i); 59 FR 47982, September 19, 1994); and (5) radioactive wastes mixed with the wastes mentioned in (1)-(4) above.

UTS (prior to August 24, 1998)

K061	Emission control dust/sludge from the primary production of steel in electric furnaces:	Antimony	7440-36-0	NA	2.1 mg/l TCLP
		Arsenic	7440-38-2	NA	5.0 mg/l TCLP
		Barium	7440-39-3	NA	7.6 mg/l TCLP
		Beryllium	7440-41-7	NA	0.014 mg/l TCLP
		Cadmium	7440-43-9	0.89	0.19 mg/l TCLP
		Chromium (Total)	7440-47-3	2.77	0.86 mg/l TCLP
		Lead	7439-92-1	0.69	0.37 mg/l TCLP
		Mercury	7439-97-6	NA	0.025 mg/l TCLP
		Nickel	7440-02-0	3.98	5.0 mg/l TCLP
		Selenium	7782-49-2	NA	0.16 mg/l TCLP
		Silver	7440-22-4	NA	0.30 mg/l TCLP
		Thallium	7440-28-0	NA	0.078 mg/l TCLP
		Zinc	7440-66-6	NA	5.3 mg/l TCLP

UTS (after August 24, 1998)

Note: NA means not applicable.

Waste code	Waste description and treatment/regulatory subcategory ¹	Regulated hazardous constituent		Wastewaters	Nonwastewaters
		Common name	CAS ² No.	Concentration in mg/l ³ ; or technology code ⁴	Concentration in mg/kg ⁵ unless noted as "mg/l TCLP"; or technology code
K061	Emission control dust/sludge from the primary production of steel in electric furnaces.	Phenol	108-95-2	0.039	6.2
		Cyanides (Total) ⁷	57-12-5	1.2	590
		Antimony	7440-36-0	NA	1.15 mg/l TCLP
		Arsenic	7440-38-2	NA	5.0 mg/l TCLP
		Barium	7440-39-3	NA	21 mg/l TCLP
		Beryllium	7440-41-7	NA	1.22 mg/l TCLP
		Cadmium	7440-43-9	0.69	0.11 mg/l TCLP
		Chromium (Total)	7440-47-3	2.77	0.60 mg/l TCLP
		Lead	7439-92-1	0.69	0.75 mg/l TCLP
		Mercury	7439-97-6	NA	0.025 mg/l TCLP
		Nickel	7440-02-0	3.98	11 mg/l TCLP
		Selenium	7782-49-2	NA	5.7 mg/l TCLP
		Silver	7440-22-4	NA	0.14 mg/l TCLP
		Thallium	7440-28-0	NA	0.20 mg/l TCLP
		Zinc	7440-66-6	NA	4.3 mg/l TCLP

APPENDIX B

PROCEEDINGS PAPER FOR “CLEAN COAL TECHNOLOGY BY-PRODUCTS AS TREATMENT CHEMICALS FOR HAZARDOUS WASTES”

Clean Coal Technology By-Products as Treatment Chemicals for Hazardous Wastes

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Introduction

In the fall of 1994 the University of Pittsburgh (Pitt) embarked upon a two-phase program for the evaluation of the use of by-products from three advanced clean coal technologies, which have been installed recently at U.S. coal-fired utility and cogeneration plants, as treatment chemicals for metal-laden hazardous wastes. Treaters of metal-laden hazardous wastes generally use inexpensive chemical by-products, such as the calcium oxide manufactured in the production of acetylene from calcium carbide, to provide alkalinity for stabilizing metal ions which are mobile under the more acidic conditions present in the untreated wastes. They may also include a cementitious material, such as portland cement, to encapsulate small particles of concentrated hazardous species. By-products from advanced clean coal technologies, which are now being installed throughout the electric power sector, contain high levels of both alkalinity and pozzolanicity.

Objective

The objectives of this program are:

1. To provide pertinent data on the properties of these new treatment chemicals;
2. To acquire useful information on the ability of these new treatment chemicals to stabilize solid waste streams of commercial interest;
3. To demonstrate the performance of several waste/by-product mixtures at commercial scale.

The program's goal is the development of a new niche market for this emerging class of coal combustion by-products, namely, their sale to hazardous waste treaters.

Approach

During the first two years of the program, Dravo Lime Company (DLC) collected and thoroughly analyzed multiple samples of three by-products [1,2]. Bench-scale treatability studies were performed by the University and by the Mill Service Yukon Plant (MSYP) of MAX Environmental Technologies, Inc., to show the effectiveness of the three by-products as treatment chemicals for seven metal-laden wastes [3,4]. Solidification studies were conducted on successful products of treatment [5]. The successful products of treatment of one of the wastes by two by-products were viewed by x-ray diffraction and scanning electron microscopy to demonstrate the project team's ability to discover the method of stabilization [6].

For a variety of reasons (discussed below) a period of two years was required following successful completion of the benchscale tests before a commercial demonstration could be initiated [5]. Currently the Mill Service Yukon Plant is designing modifications that will allow it to regularly store and transport large quantities of these new dusty chemicals and to use them to stabilize and solidify wastes in its treatment pits. The installation of these modifications is scheduled for this fall. Once they are in place, the demonstration can begin.

Project Description

ADVANCED CLEAN-COAL TECHNOLOGY BY-PRODUCTS

Advanced clean-coal technology by-products generally are produced in systems where a calcium-based sorbent (usually slaked lime, limestone, or dolomite) is injected directly into a furnace, ductwork, precipitator, or scrubber vessel to capture sulfur dioxide. The sulfur-laden sorbent leaves the system as a dry powdered or granular product, as opposed to the slurry associated with a traditional wet scrubbers. The dry by-products have neutralizing, sorptive and cementitious properties that make them interesting as potential reagents for hazardous waste stabilization because they contain large amounts of free quicklime (CaO), anhydrous calcium sulfate (CaSO_4) or sulfite (CaSO_3), and pozzolanic ash.

Three advanced clean-coal technology by-products were used in the bench-scale portion of the program, (1) dry scrubber residue, (2) residue from a coal-fired pressurized fluid bed combustor (PFBC), and (3) residue from a coal-waste-fired circulating fluid bed combustor (CFBC).

The dry scrubber residue was produced in a spray drier at the outlet of a pulverized coal boiler burning high-sulfur eastern coal. In this unit ash-laden flue gas enters the bottom of the spray drier and a lime slurry enters the top. All of the sulfur-capture residue rises through the upper port with the fly ash.

Residue from a coal-fired PFBC was obtained from the Tidd Station of Ohio Power Company. In this demonstration facility (which has ceased operation) dolomite was co-fed with coal to the

combustor. Dolomite, instead of limestone, was used as the sorbent because it was both more porous (and thus more reactive) and easier to handle without bridging in the piping system.

Residue from a coal-waste-fired CFBC was obtained from a commercial cogeneration plant in western Pennsylvania. The coal waste fed to the combustor has a sulfur content between 1.4 and 2.0 percent. The limestone, which is co-fed with the coal, is 83% CaCO_3 . The fly ash from the combustor is removed in a ten-segment baghouse and conveyed to a silo. Approximately 70% of the by-product in the silo is baghouse ash; 30% is bottom ash.

Dravo Lime Company collected ten dry samples from each of the three by-product sources. In general, samples came from a homogeneous by-product matrix produced under stable, well-defined plant operating conditions. Samples of the first by-product, the dry scrubber residue, were obtained at the terminus in western Pennsylvania of the bulk transport of this material back from the power plant in New Jersey, where it was produced. The other two by-products were sampled at the points of their production. For each sample, ten 5-gallon plastic buckets (with lids) of material were collected. These were distributed among the three project partners — DLC, MSYP and Pitt — for their respective analysis and use. All containers were filled as full as possible and tightly sealed to minimize sample contact with air and moisture. A clear chain of custody and QC procedure was established and utilized.

METAL-LADEN HAZARDOUS WASTES

The seven metal-laden hazardous wastes used in the bench-scale portion of the program were selected from among the materials processed commercially by Mill Service Yukon Plant, a centralized hazardous waste treater in southwestern Pennsylvania. The selected wastes were:

1. Sludge from lead-acid storage battery production
2. Contaminated soil from a munitions depot
3. Contaminated soil from a multi-use industrial site
4. Baghouse dust from basic oxygen furnace steelmaking
5. Ash from a municipal solid waste incinerator
6. Contaminated soil from a former waste water treatment plant
7. Sandblast dust from a paint-removal operation.

MSYP collected approximately 250 pounds of material for a sample of each of these wastes. The samples were drawn from the bulk containers (20 to 60 cubic yards) delivering the wastes to MSYP. Samples were obtained at a minimum of three locations distributed evenly along the length of the container. Moist materials with a relatively even distribution of small particles, such as wastewater treatment plant residues, were sampled with a trier forced into the material. Dry materials, such as dusts and sandblast wastes, and materials with large or uneven particle sizes, such as soils, were sampled using a shovel or scoop. The individual samples of each waste were composited into a clean sample container.

Samples of the wastes were obtained for analysis and for use in the extraction procedure by the quartering method detailed in ASTM C702-87. Waste samples were characterized to determine

the total concentration of each of fifteen metals by SW-846 Methods, using inductively coupled plasma-atomic emission spectroscopy (ICP) or atomic absorption spectroscopy. MSYP performed TCLP extractions at its on-site laboratory. These extracts were analyzed for the same fifteen metals as the wastes.

TREATMENT STUDIES

Bench-scale stabilization experiments consisted of mixing by-products with hazardous wastes at weight ratios of 1:10, 1:3 and 1:2 with minimal moisture addition. Sampling of the stabilized mass was done immediately after treatment for evaluation of TCLP leachate compositions. Preliminary solidification studies were conducted on samples of the treated masses, as described below.

MICROSTRUCTURAL ANALYSES OF TREATMENT PRODUCTS

Two sandblast waste aliquots, one treated with a 30% aliquot of spray drier residue and the other with a 30% aliquot of PFBC residue, were each blended with water to approximately a 1.5 inch slump. The composition and morphology of the two resulting solidified products after 28 days, as well as the sandblast waste itself, were evaluated by scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques.

Results

ADVANCED CLEAN-COAL TECHNOLOGY BY-PRODUCTS

Average values of Dravo Lime Company's standard analyses of ten samples of each of these three by-products are given in Tables 1, 2 and 3.

Geochemical analysis shows that each of the three CCT by-products contains a significant amount of free lime (CaO). The spray dry scrubber residue contains the highest percentage of CaO, at 28.9%, while the PFBC and CFBC residues contain 20.9% and 10.6%, respectively. These high percentages of CaO represent beneficial properties for hazardous waste stabilization. Each of these by-products also contain appreciable amounts of inorganic compounds, such as SiO_2 , Al_2O_3 , and Fe_2O_3 , which are commonly found in coal fly ash. The CFBC residue contains the highest percentages of silica and alumina, which is a result of burning low grade, high ash fuel. The presence of these pozzolanic compounds represents desirable characteristics for waste treatment, as they have the potential to produce a highly solidified material which may help limit the leaching of contaminants into the environment. The PFBC residue contains the highest percentage of MgO, which is expected as the sorbent fed to the boiler was dolomite instead of lime or limestone. These by-products also contain appreciable amounts of sulfur (both as sulfite and sulfate), which is expected as sulfur sorption was the primary purpose for the utilization of the CCT processes employed. The sulfur present in the spray dry scrubber residue is mostly in the form of sulfite, as opposed to sulfate found in both the FBC residues. This difference is mainly due to sulfur sorption at lower temperatures in the spray dry scrubber process. The presence of sulfur in treated waste mixtures could be detrimental to the development of compressive strength over time, and may therefore be responsible for increased contaminant leaching, as a result of

Table 1
Mean Comparison of By-Product Geochemical Properties

Geochemical Analysis (%)	Spray Dryer Residue	PFBC Residue	CFBC Residue
CaO	28.91	20.94	10.61
MgO	0.70	12.89	1.26
SiO ₂	20.18	21.75	48.56
Fe ₂ O ₃	6.39	10.78	6.92
Al ₂ O ₃	10.24	9.39	18.45
CO ₂	3.94	9.98	0.68
Total Sulfur as S	10.03	4.47	2.3
SO ₃	3.11	10.58	5.23
SO ₂	17.55	0.47	0.41
LOI @ 1100 °C	13.13	11.23	5.28
Total of Elements Determined	100.21	98.03	96.69
Reactivity			
Temperature Rise (°F)	2	5	8
Calcium Carbonate Equivalency (% CaCO ₃)	43.8	52.6	11.6
Available Lime Index (% CaO)	3.7	0.9	4.0
pH	12.36	11.92	12.52
Mixed Ratio (lbs/gal)	13	20	16
Physical Properties			
Specific Gravity (g/cc)	2.41	2.83	2.7
Bulk Density - Loose (lb/ft ³)	36	59	52
Bulk Density - Tamped (lb/ft ³)	42	70	60
Blaine Fineness (cm ² /g)	10,700	5,588	8,506
Passing 200 Mesh (%)	93	88	57
Passing 325 Mesh (%)	84	81	48
Specific Surface Area (m ² /g)	6.87	2.93	10.64
Particle Size Distribution			
Passing 80 Mesh (%)	98.9	94.2	49.8
10% passing (µm)	2.0	2.6	3.4
50% passing (µm)	11.88	10.95	26.59
90% passing (µm)	42.17	55.49	110.49
Average Particle Size (µm)	17.74	21.39	42.67

sulfur expansion. Finally, these by-products contain varying amounts of unburned organic material, as measured by the percent of material by weight that is lost on ignition at 1100 °C. The spray dry scrubber residue contains the highest percentage of unburned organic material, at

19.8%, followed by the PFBC and CFBC residues, at 11.2% and 5.3%, respectively. The presence of unburned organic material in treated waste mixtures could hinder the development of significant compressive strength.

Reactivity of the by-products was determined by measuring temperature rise, calcium carbonate equivalency (CCE), available lime index, pH, and mixed ratio. The temperature rise indicates the amount of heat generated by the hydration of quicklime and anhydrite. A higher temperature rise indicates that more lime is present in the anhydrous (quicklime) state. The spray dry scrubber residue has the lowest temperature rise among the three by-products. This indicates that the free lime is in the hydrated form, which is expected as slaked lime (a slurry of lime in water) was used as the sorbent in this process. The calcium carbonate equivalency measures the acid-neutralizing capacity of the material and is expressed as weight percent of calcium carbonate present. Both the PFBC and spray dry scrubber residues have higher calcium carbonate equivalencies, at 52.6% and 43.8% CaCO_3 , respectively, as compared to the CFBC residue, which contains 11.6% CaCO_3 . Although the CFBC residue contains less CaCO_3 , the high temperature rise of this by-product indicates that the lime is present in a form that is more reactive than the more abundant slaked lime found in the spray dry scrubber residue, which has a relatively low temperature rise. The available lime index gives a measure of the amount of constituents available to enter into reaction. The spray dry scrubber and CFBC residues both have significantly higher values for the available lime index, at 3.7% and 4.0% CaO , respectively, as compared to the PFBC residue which has an available lime index of 0.9% CaO . The pH of the three CCT by-products is very similar, with the pH of the CFBC residue being slightly higher than that of the PFBC residue. Finally, the mixed ratio of the spray dry scrubber residue is the lowest among the three by-products. This indicates that the material has the ability to absorb large amounts of water, thus having a high stabilization potential.

The physical properties reported in Table 1 include measurements of density, fineness, and surface area. The bulk density of the spray dry scrubber residue is significantly less than that of either of the two FBC residues. Fineness, measured either through the use of the Blaine air permeability apparatus or a sieve analysis, gives an important indication of reactivity. Fineness affects the rate of hydration and the heat released. Greater fineness increases the rate of hydration and thus accelerates compressive strength development. All three of the CCT by-products analyzed have a greater fineness than either Portland cement or fly ash, two materials commonly used as reagents in waste stabilization. Among the three by-products, the spray dry scrubber residue has a significantly higher fineness than either of the two FBC residues. The CFBC residue was found to have a significantly smaller percentage passing the 325 mesh sieve. This corresponds to the significantly larger average particle size of the CFBC residue, which is primarily due to its bed ash content. In contrast, the spray dry scrubber residue has the smallest average particle size of 17.74 μm . Thus, the finer spray dry scrubber residue is more reactive, a good property for hazardous waste stabilization.

The results of this by-product characterization are consistent with what was expected from a review of the literature. Examination of the aforementioned by-product properties reveals differences due to the CCT process employed, composition of coal burned, and composition of specific sulfur sorbent utilized. Overall, however, the high fineness and small particle sizes of

these by-products indicate that they should have the potential to rapidly enter into hydration reactions, which would make them useful reagents in stabilization/solidification applications. In addition, they also contain high percentages of CaO, another beneficial property for waste stabilization. The spray dry scrubber residue, specifically, has the highest percentage of CaO, lowest mixed ratio, smallest average particle size, and highest fineness. The properties characteristic to this by-product could provide for superior stabilization.

A comprehensive metals analysis of each of the three CCT by-products utilized for the purposes of this treatability study was performed in order to demonstrate that the by-products were not inherently hazardous in their own right and that they would not contribute to the leachable metals concentrations of the resulting treated waste mixtures. The metals analyzed included the eight RCRA metals (As, Ba, Cd, Cr, Pb, Hg, Se, and Ag), which are currently regulated under the U.S. EPA's Toxicity Characteristic Program, and seven other metals (Sb, Be, Cu, Ni, Tl, V, and Zn) which are currently considered underlying constituents under the Uniform Treatment Standards (40 CFR Section 268.48). Although the Uniform Treatment Standards (UTS) do not currently apply to characteristic hazardous wastes, there is potential that these metals could be regulated in the future.

A total constituent analysis (TCA) was performed in order to determine which metals were present and in what concentration. Total metals concentrations, however, do not indicate whether a material is considered hazardous or not. The presence of high concentrations of metals in a material does not necessarily mean that the metals are in a form that will leach, or that the metals will have the opportunity to come into contact with the leaching solution. Total metals concentrations do, however, give some insight into the potential for a material to be considered hazardous.

In order to determine which of the metals present in the material have the potential to exceed the TCLP limit (as established by the current BDAT Standards) assuming that 100% of the metal present were to leach, it is necessary to correlate the TCLP limits expressed in mg/L to total metals concentrations expressed in mg/kg. In the TCLP test, a liquid to solids ratio of 20:1 (volume:weight) is utilized. Therefore, multiplying the TCLP limit by 20 will give the concentrations on a mg/kg basis for comparison. To provide for a margin of error, a multiplying factor of 80% (0.8 times the mg/kg metal concentration) was used as the threshold value above which the metal would be of concern. Any metal which has a concentration greater than that of the threshold value has the potential to leach in excess of the TCLP limit given 100% leachability. The results of the total constituent analysis of each of the three CCT by-products, as well as the corresponding limits for concern, are given below in Table 2.

Table 2 reveals that there are a number of heavy metals present in each of the three CCT by-products. This is expected as trace metals are commonly found in coal fly. Table 2 shows that arsenic was found to be the only metal of concern under the current BDAT standards when utilizing either of the two FBC residues in stabilization applications, as it has the potential to leach at levels that exceed the current BDAT standards. If the UTS eventually replace the current BDAT standards, then beryllium and vanadium would also become metals of concern for all three by-products, as these two metals have the potential to leach at levels that exceed the UTS.

Table 2
Total Constituent Analysis of the CCT By-Products

Metal	Limits for Concern (mg/kg)	TCA (mg/kg)		
		Spray Dryer Residue	PFBC Residue	CFBC Residue.
Antimony (Sb)	33.6*	<4.0	<4.0	<4.0
Arsenic (As)	80.0	41.0	140.0	95.0
Barium (Ba)	1600.0	97.0	150.0	160.0
Beryllium (Be)	0.224*	2.22	2.60	2.00
Cadmium (Cd)	16.0	6.6	4.8	10.0
Chromium (Cr)	80.0	29.0	15.0	50.0
Copper (Cu)	NR [#]	20.0	17.0	35.0
Lead (Pb)	80.0	3.0	4.6	3.6
Mercury (Hg)	3.2	0.55	<0.10	1.10
Nickel (Ni)	81.6*	23.0	12.0	21.0
Selenium (Se)	16.0	<0.2	<0.2	<0.2
Silver (Ag)	80.0	<2.0	<2.0	<2.0
Thallium (Tl)	1.248*	<0.5	<4.0	<4.0
Vanadium (V)	3.68*	54.15	26.10	55.25
Zinc (Zn)	84.8*	34.0	78.0	52.0

*As these metals are not currently regulated under the U.S. EPA Toxicity Characteristic Program, the Uniform Treatment Standards for underlying constituents were used instead of the BDAT standards in calculating the threshold limits for concern.

[#]NR: This metal is not currently regulated under the U.S. EPA Toxicity Characteristic Program or as an underlying constituent under the Uniform Treatment Standards.

In addition to determining the total metals concentrations in the by-products and which of those metals are present at concentrations of concern, the actual leachable (TCLP) metals concentrations were also measured. The results of the TCLP metals analysis are given in Table 3. Although the total concentration of arsenic was found to be of concern in the FBC residues, it did not leach significantly during the TCLP test. Table 3 demonstrates that the by-products are not inherently hazardous in their own right, nor are they expected to contribute to the leaching of heavy metals in the treated waste mixtures, as none of their TCLP metals concentrations exceed the current BDAT standards. As these by-products do not contain highly mobile constituents, they are suitable materials for stabilization applications. If the UTS eventually replace the current BDAT standards, however, the CFBC residue may no longer be suitable material for hazardous

waste stabilization as its leachable vanadium concentration exceeds the projected future standard of 0.23 mg/L.

Table 3
TCLP Metals Concentrations of the CCT By-Products

Metal	Regulatory Standards (mg/L)		TCLP Concentrations (mg/L)		
	BDAT Standards	UTS	Spray Dryer Residue	PFBC Residue	CFBC Residue
Antimony (Sb)	NR*	2.1	<0.020	0.022	0.024
Arsenic (As)	5.0	5.0	<0.01	<0.1	0.89
Barium (Ba)	100.0	7.6	<5.0	<5.0	<5.0
Beryllium (Be)	NR	0.014	<0.001	<0.001	<0.001
Cadmium (Cd)	1.0	0.19	<0.1	<0.1	<0.1
Chromium (Cr)	5.0	0.86	<0.1	<0.1	<0.1
Copper (Cu)	NR	NR	<1.0	<1.0	<1.0
Lead (Pb)	5.0	0.37	<0.1	<0.1	<0.1
Mercury (Hg)	0.2	0.20/0.0025	<0.01	<0.01	<0.01
Nickel (Ni)	NR	5.1	<0.1	<0.1	<0.1
Selenium (Se)	1.0	0.16	<0.1	<0.1	<0.1
Silver (Ag)	80.0	0.3	<0.1	<0.1	<0.1
Thallium (Tl)	NR	0.078	<0.005	<0.005	<0.005
Vanadium (V)	NR	0.23	0.074	0.013	0.316
Zinc (Zn)	NR	5.3	<1.0	<1.0	<1.0

*NR: Not currently regulated under the applicable treatment standards

METAL-LADEN HAZARDOUS WASTES

The principal hazardous constituent of concern for all seven wastes was found from total metals concentrations to be lead. The range of total lead concentration in these seven wastes was from 750 to 43,000 mg/kg solids as received. Other hazardous constituents were found, but when the seven wastes were extracted by the TCLP protocol, only the lead concentrations fell above RCRA regulatory limits.

Those other hazardous constituents, found in the seven wastes, included three other RCRA hazardous constituents of concern — cadmium and chromium (five wastes) and barium (one waste). Four wastes contained other constituents which, although not currently regulated under EPA's TC program, are considered underlying constituents in the Universal Treatment Standards for non-characteristic wastes. All four of these were contaminated with copper and zinc and one, in addition, with nickel and vanadium.

TREATMENT STUDIES

The metals content of the TCLP extracts of the treated samples were evaluated to determine 1) if the by-product/waste mixture continued to exhibit the hazardous waste characteristic(s) exhibited by the untreated waste, 2) if the by-product/waste mixture exhibited any other hazardous waste characteristic, based on the parameters of concern identified from the total metals analyses performed on the waste and by-product, and 3) if the by-product/waste mixture achieved the LDR treatment standards.

The analytic data generated from the stabilized waste testing was reviewed jointly by MSYP and Pitt to determine which of the by-product/waste dosages most effectively treated the wastes. Effectiveness is defined as resulting in a non-hazardous treatment residue capable of land disposal under RCRA regulation. In the event multiple dosages achieved comparable results, the most economical dosage was judged to be the best.

Table 4 summarizes the results of this review. In the table the minimum weight ratio of by-product to waste, that successfully stabilizes the waste, is shown. A blank space indicates that even the 1:2 treatment ratio failed to stabilize the waste.

Six of the ten successful treatments were evaluated for solidification. For each evaluation, aliquots of the hazardous waste and the by-product were blended in the ratios shown in Table 5. For the PFBC and CFBC residues, these were in the same ratio as shown in Table 4 — namely 1:2. For the spray dryer residue, the ratios were shifted to 1:3 and 1:2 for the two treatments, respectively. The optimal amounts of moisture to be added to each mixture were determined to be that at which the wetted mass would produce an immediate "slump" in the neighborhood of 1.25 inches to 2 inches. Table 5 presents the 90-day unconfined compressive strength developed by the treated product (in pounds per square inch).

The mixtures with PFBC and CFBC residues yielded products of satisfactory unconfined compressive strength. These products are of interest for use in structural fills and road bases. The mixtures with the spray drier residue yielded unsatisfactory products.

Table 4
Success of By-product/Waste Combinations

Waste	Spray-Drier Residue	PFBC Residue	CFBC Residue
Battery sludge	1:10		
Munitions soil	1:10	1:2	
Industrial soil	1:10	1:2	
BOF dust			
Incinerator ash			
WWTP soil	1:10	1:2	1:2
Sandblast waste	1:10	1:2	

Table 5
Strength Developed by Treatment Products

By-product	Waste	By-Product/ Waste Ratio	90-Day Strength (Pounds per Inch ²)
Spray drier residue	Battery sludge	1:3	46
Spray drier residue	Munitions soil	1:2	31
PFBC residue	Industrial soil	1:2	378
PFBC residue	Munitions soil	1:2	188
PFBC residue	WWTP soil	1:2	364
CFBC residue	WWTP soil	1:2	539

MICROSTRUCTURAL ANALYSES OF TREATMENT PRODUCTS

The speciation of the hazardous constituent within the raw waste was found to be a basic lead carbonate, as determined by XRD analysis. Phase characterization by XRD also indicated that the metal speciation of the raw waste remained unchanged in the resulting treated waste mixtures. Microstructure characterization by SEM revealed that the particles of basic lead carbonate scattered throughout the treated waste mixtures were surrounded by or encapsulated in a matrix of very fine material consisting of calcium, sulfur, and silicon. The results of the XRD analysis, when interpreted in conjunction with the results of the SEM analysis, imply that physical encapsulation on a microscopic scale is the principal mechanism responsible for stabilization.

COMMERCIAL DEMONSTRATION

The results of the bench-scale treatments, shown in Table 4, are very encouraging. In particular, the spray drier residue shows excellent ability to stabilize metal-laden hazardous waste. As a consequence, in the third quarter of 1995 the University of Pittsburgh began to seek a commercial partner for a demonstration of this technology. The partner built into the project from the outset was MSYP. However, an unforeseen regulatory requirement forced MSYP to resign from the project. The project team searched for over a year for a replacement. That search continued through mid-1997, when the regulatory requirement, which had caused the MSYP to leave the project, appears to have been rescinded. MSYP then returned to the project. Since that time, the MSYP has been adjusting its operation (as noted earlier) in a changing business and regulatory climate to accommodate the project. Active work on the commercial phase of the project is expected to begin in the fall of 1998.

The next portion of this paper offers a brief history of the search and of barriers to its success, which were experienced.

The initial commercial hazardous waste treater for this project, MSYP, was already considering the use of coal combustion by-products (CCBs) as treatment chemicals when first approached by the university to join the project at its outset. They were very enthusiastic about a demonstration until told that the program's sponsor had determined, after lengthy consideration of the presence of hazardous wastes in the work of the project, that a federal environmental assessment (EA) would be required for this project. An EA would open another avenue for public scrutiny of the company's operation. The company had been exposed to public scrutiny at the state level on a number of occasions in the past and felt that the cost of further scrutiny at the federal level for this project would not be repaid sufficiently. It therefore with disappointment withdrew from negotiations early in the second quarter of 1996.

The second company approached quickly decided not to consider participating in the demonstration because of the general intrusiveness they felt of an EA.

The third company approached declined to participate at the time they were contacted (late in the second quarter of 1996). This company's decision was at first based principally on their desire not to be distracted by an EA while their Part B permit was being considered for renewal. A little

later in the discussions they indicated that they would be open to considering participation after the renewal was received, although they admitted that the presence of a federal sponsor of the program was a concern. They questioned whether having such a sponsor might expose them to future scrutiny.

As the approach to a fourth company was being developed, the program's sponsor reconsidered its requirement for an environmental assessment. In consideration of the fact that hazardous waste treaters are fully scrutinized at the state level and operate only under carefully reviewed permits, the level of environmental scrutiny was expected to shift to the review of the project's response to an environmental questionnaire. Consideration of the questionnaire does not include the opportunity for redundant review by the local affected population.

The fourth company approached was located outside the Appalachian coal province. The other three had been located well within that province. After a lengthy, thorough analysis, in the middle of the fourth quarter of 1996 they concluded that, while the project was of technical interest and their plant was permitted for an operation of this type, they could find no economic benefit for their company to join with the university to conduct this demonstration. Not only were there no apparent sources of this type of treatment chemical within an economic range of their plant, but also the general availability of the results of the demonstration would be an asset more to hazardous waste treaters in the Appalachian coal province than to themselves. They offered to examine closely any revised proposal for conducting the project at their plant that would provide a positive change in the economic outlook for long-term commercialization there.

The university, in consultation with the program sponsor, decided to refocus its search on a close-by company in the Appalachian coal province. In the first quarter of 1997 it recontacted MSYP and found that, a year having passed since breaking off earlier discussions and the requirement for an EA having been taken away, the company was open to negotiations to return to the project, which were successful. As noted earlier, plans are progressing for conducting the demonstration at MSYP.

Application

A successful conclusion to the demonstration will be reported to the two interested technical communities — the coal-fired utility sector and the hazardous waste treatment sector. The university envisions that entities in these two sectors will establish sales/purchase agreements, and advanced clean coal technology (CCT) by-products will be used to treat metal-laden hazardous wastes on a wide commercial basis. The amounts of CCT by-products that will be utilized in this manner likely will never come up to the quantities that can be utilized in the construction sector. However, any amount utilized by waste treaters will be a welcome sale economically for those utilities that establish them as customers.

Whether utilities will welcome potential sales to waste treaters from the standpoint of liability, is another matter. Significant barriers exist, which have been examined recently by the U.S. Department of Energy. These will now be reviewed in some detail.

BARRIERS TO BENEFICIAL USE OF CCBs

Before embarking upon a discussion of the barriers to beneficial use of CCBs, a report of one other specific experience, which the University of Pittsburgh had while conducting this project, will be instructive.

It will be noted that the original clean coal technology by-product is not among the three examined in this project, namely, residue from a coal-fired fluid bed combustor (FBC). Many of these units are in operation across the United States and their by-product has moved into the mainstream of CCBs in the marketplace. Ash brokers have been engaged by the operators of the cogeneration plants which utilize coal-fired FBCs to aggressively market this by-product and carefully dispose of that which can't be sold. While planning and conducting the bench-scale tests of this project, the university engaged in extensive negotiations with a major CCB broker to obtain a sample of coal-fired FBC residue to include in the program. It was unsuccessful in doing so. Generators of CCBs retain the right of approval on all by-product uses, suggested to them by their brokers. Testing of their by-product as a hazardous waste treatment chemical in a publicly reported program such as this one, failed to receive generator approval because of concern for potential liability for cleanup of sites "contaminated" with hazardous materials, even though (1) the wastes treated with their by-product would be rendered non-hazardous and (2) the generator is once or twice removed from the by-product sale — once if the broker takes ownership of the by-product as a product of commerce and twice if the transporter of the by-product takes ownership first before it passes to the broker.

The barriers that have been experienced by this project are typical of those being encountered across the nation by all who are trying to increase the utilization of CCBs. This problem is sufficiently pronounced that Congress asked for a special report from the DOE on it. The report was provided to Congress in July 1994 [7]. The appendix of this paper contains the statement of the barriers, contained in the Executive Summary of the report.

Here are barriers, which were identified in the report, that the University of Pittsburgh has encountered in conducting this project. The immediately preceding paragraphs and section have already given the background for much of this discussion.

1. This project was initiated to provide data to the public domain on the use of clean coal technology by-products as treatment chemicals for hazardous wastes. Inadequate information is available in the literature on this byproduct use technology.
2. Coupled with the first barrier is inefficient technology/information transfer in the case of residue from coal-fired FBCs for this use technology.
3. The data from this project can be used by the E-50 Committee of the American Society for Testing and Materials to create a specification for byproduct use in this technology. The university has already met with this committee and it intends to participate in standards development when the demonstration is complete.

4. Attitudinal barriers have been encountered. The initial decision to require an environmental assessment for this project arose in a climate of concern for the legal definition of a non-hazardous product of a permitted hazardous waste stabilization process. The resulting hesitance of three companies to participate in the commercial phase of the project could be considered to some extent to be a product of "public misconception of the risk" of hazardous waste stabilization, a misconception which results in acrimonious public meetings when permit applications and environmental assessments are opened for public review.

5. The "lack of discrimination between beneficial reuse application and disposal" contributes strongly to an economic barrier. In general, if a material is disposed to a waste treatment plant and carries a tipping fee, even if it is used beneficially — in this case as a treatment chemical — it is still legally defined as a waste and is regulated as such. However, if it is purchased by the plant, it generally can be claimed as a product of commerce and used as a treatment chemical. The requirement that a by-product must be sold to a hazardous waste treatment plant in order for it to be considered not a waste, severely limits the ash dilution of the alkaline components in the by-product. Ash is essentially an inert which takes up relatively expensive landfill space in ultimate disposal. A hazardous waste treater cannot afford to "purchase" much ash accompanying the alkaline component. If the seller of the active ingredient in the by-product could provide the funds (through a tipping fee) to landfill the ash component which is just along for the ride, a better economic case could be made for more use of this by-product for hazardous waste treatment.

6. The basic concern over "the potential for liability associated with the use of a material designated as a waste material" has had a generally chilling effect on the interest of by-product producers to participate in this project. It should be noted that the last paragraph of the Appendix, from which the quotation in the preceding sentence is taken, was actually directed at the complex of issues related to Bevill wastes [8]. Advanced clean coal technology by-products fall into this category. A full discussion of this topic and its impact on their use as a treatment chemical is a subject for an extensive paper of its own.

Future Activities

The University of Pittsburgh and the Mill Service Yukon Plant are committed to conducting the demonstration during FY 1999. A time extension on the original contract has been requested for this purpose. Following a successful demonstration, the university will encourage commercialization of this concept.

Contract Information

This work is being performed under Contract No. DE-FC21-94MC31175. The Contractor is the University of Pittsburgh. The Principal Investigator is James T. Cobb, Jr., 1137 Benedum Hall, Pittsburgh, PA 15261, FAX 412-624-9639. The FETC Contracting Officer's Representative is Scott Renninger. The initial period of performance was October 1994 through September 1996.

Two one-year no-cost contract extensions have been necessary and another final one has been requested for next year. MAX Environmental Technologies, Inc. (the parent company of the Mill Service Yukon Plant) and Dravo Lime Company have been the primary subcontractors. Several companies have provided by-products.

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Appendix

Barriers to Increased By-product Utilization

The following is reproduced from the Executive Summary of "Report to Congress. Barriers to the Increased Utilization of Coal Combustion/Desulfurization Byproducts by Governmental and Commercial Sectors" [7].

The findings of the study suggest that institutional, regulatory, and legal barriers are very much interrelated. The institutional barriers can be summarized into the following major areas:

Inefficient Technology/Information Transfer. Available information is not transferred or is not transferred in a timely fashion to regulators or potential users of byproduct utilization technology. There is an apparent information or communications gap among the producers of byproducts, end users, and regulators.

Lack of Coordination/Leadership in Development and Promotion of Coal Byproduct Utilization. There is a national industry group for promotion of coal byproduct reuse. However, an organization is needed within the Federal Government to support that promotional role within the governmental sector.

Inadequacies of State Programs to Promote Beneficial Reuse. Coal byproduct disposal and beneficial reuse are regulated by the States. Across the States there is inconsistency in State regulations for what constitutes beneficial reuse and how it should be regulated. Few State procurement programs support use of recovered materials such as coal byproducts.

Non-Existent or Inadequate Specifications for Byproduct Use. There is a lack of recognized technical specifications for use of coal byproducts even in proven technology.

Existence of Attitudinal Barriers. Designation of coal byproducts as a solid waste, while fostering public misconception about the risk of these materials, stymies attempts to develop or expand markets for their use.

The lack of discrimination in the Federal and State regulatory systems between coal byproducts for beneficial reuse application and disposal is central to the regulatory barriers to increased byproduct utilization. Without this discrimination, the "waste" designation can trigger case-by-case approval which makes utilization impractical.

There is also the need in the regulatory field to develop environmental compliance tests which determine realistic environmental impacts.

The chief legal barrier to increased coal byproduct use is the potential for liability associated with use of a material designated as a waste material. It is a concern of producers and users of coal byproducts that their liability is unacceptably extended beyond that normally associated with use of a commercial material.

APPENDIX C

**LETTER FROM PROFESSOR C. N. K. BANSAL,
SEPTEMBER 22, 1998**

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Dr. James T. Cobb
Associate Professor
Co-Director for Service
Engineering Centre for Environment
& Energy
1249 Benedum Hall
Pittsburgh, Pennsylvania 15261
USA

14th Sept., 1998

Dear Dr. Cobb,

May I first apologise in responding late to your letter of April 10, 1998 which we received in time towards the end of April 10, 1998. I am thankful to you for showing interest in developing a strong relationship with our centre on subjects of mutual interest. I am sending a more detailed profile of our centre to have a closer look into the area of possible collaboration in the areas of Environmental Technologies.

One of my senior colleague Dr. Avinash Chandra, Chief Scientific Officer, is like to visit St. Louis during the middle of October, 1998. His interests of work are Electrostatic Precipitator and indoor air quality. Will it be possible for him to visit your centre and talk about our centre and his activities. Needless to mention, I am closely associated with him.

I look forward to hear from and in the mean time, with kind regards,

Yours sincerely,

N.K. Bansal
(N.K. Bansal)

Centre for Energy Studies:

Activities, Expertise and Facilities

1. Introduction

Energy is an essential input to the daily activities and more importantly to the industrial growth and progress of the country. Energy consumption in India has been increasing steadily in terms of absolute values as well as in terms of per capita consumption. There has been a rapid growth in power generation. However, there is always a deficit of 5 to 6% between demand and supply, rising to 20 to 25% during the peak hours. There is therefore, a need to adopt measures of energy efficiency and provide alternatives to cope up with the situation.

With rapid growth in coal based power generation and industrialization, there have been alarming proportions of pollution levels especially in major cities of India. Most of the metropolis in India also have dense vehicular movement resulting in still more pollution which needs to be taken very seriously and immediate measure have to be taken to curb it.

The above requirements can be met only by providing adequate man power in the field of energy efficiency, environment and renewable energy by directed R&D efforts. Such an effort also needs interdisciplinary inputs. In the year 1976, the IIT council decided to establish the Centre for Energy studies at the I.I.T. Delhi with an aim to provide Energy Education at the post graduate level, to conduct R&D in relevant areas of Energy and Environment and to develop environmental friendly technologies.

The Centre therefore, works in different energy technologies and areas of Energy and Environment. A few of the important areas and activities are described here.

1. Energy Efficiency

Energy conservation is one of the important steps towards solving some of our energy problems. Energy is essentially used in the form of heat, electricity and oil (for transport). The work therefore concentrates in this area on the following topics.

- **I C Engines**
- **Electrical Energy Systems**
- **Energy Efficient Buildings**

1.1. Internal Combustion Engine

The Internal combustion Engine laboratory possesses various facilities for basic engine testing and for analysing the exhaust for measuring CO, HC and N_{ox} emissions. Using various alternate fuels like ethanol , methanol, hydrogen and biogas, the group undertakes engine design modifications to achieve higher efficiencies and low CO, PM and N_{ox} emissions. The IC engine group is involved in various National mission projects like developing a fuel injection system, a four stroke engine for two wheelers and plasma based nitride coating on vulnerable engine parts like cylinder or pistons.

The activities in the area of IC engines also cover computer aided design in agriculture, power generation and transportation section.

1.2 Electrical Energy Systems

Some of the problems which make operation of the inter connected power systems difficult even at the regional level are the growing proportions of thermal power plants as compared to hydro. Poor power management has resulted in high transmission and distribution losses accompanied with a low power factors. The activities in this group therefore concentrate on real time monitoring and control of power systems, power system reliability and production costing analysis, energy conservation in power distribution and utilization systems, reactive power compensation etc.

The group also works on devising, testing, fields trials and subsequent industrialization of developed equipment.

1.3 Energy Efficiency in Buildings

One of the main aim of buildings is to provide internal environment where one can have visual as well as thermal comfort. This is partly provided by an energy efficient buildings design and/or by provide energy efficient end use devices. By using sophisticated computer modelling, the building group in the Centre assists the architects to arrive an optimum design to achieve better day lighting and minimise the air conditioning load. Additionally, the group can also undertake the design and fabrication of building automation system to reduce operating costs of energy.

1.4 Energy Audit

Aided by portable instruments for measuring thermal, electrical, combustion and other parameters, the Centre can undertake extensive energy audits to identify where and in what form the energy is being used in an organisation, intensity of energy use and identification of energy conserving opportunities. The audit report presented to the organisation contains detailed techno-economic evaluation of each of the energy conserving opportunities and priority wise recommendations for implementation. The technology improvements for achieving better energy efficiencies are worked out through constant R&D activities.

2. Fuel Technology

The biggest problem in effective utilization of Indian coals has all along been its high mineral content. Coal liquefaction and gasification being capital intensive, the returns so far, have come from washing the coal, where a trade off is made between the floats, middling and rejects. In this context, new initiatives have been taken at the IIT Delhi resulting in solubilisation of the major part of the coal substance by extraction at the atmospheric pressure with combinations of polar organic solvents which are recycled. The extract is zero ash and can be treated as organic feed stock for further processing.

Bioleaching and biosolubilization have been found suitable to diminish the coal. Other activities in the fuel technology include (i) conversion of coal to liquid, (ii) utilisation of coal extracts for value added end uses such as a chemical feed stock, (iii) conversion of the products of coal gasification to synthetic natural gas methane and to provide alternative energy transport systems.

Other interests of the group include oil from waste, hydrocarbon extraction from energy plantation and other alternate routes.

3. Environmental Pollution

Quality of air, indoor as well as outdoor, is a major concern nowadays. Indoor quality is severely effected through release of radioactive as well as chemical emission from various building materials. One such source is the emission of radon into the indoor air due to high inflow from soil, building materials & natural gas. Similarly chemical fumes deteriorate the indoor air quality leading to so called sick building syndrome. The efforts are made to provide indices for indoor air quality in a combination of climatic parameters and the emission.

Facilities are available to quantify the emission in the exhaust of an industry and IC engines in the transport sector and constant efforts are made to upgrade the technology to check emission from the exhaust. Performance evaluation and upgradation of Electrostatic precipitator [ESP] in Thermal power plants has been undertaken.

4. Renewable Energy Sources

Solar, wind, Biomass, Water and other energy sources are cleaner and perennial energy sources which the nature has provided for the use of man kind. The centre has done pioneering work on solar thermal technologies and solar photovoltaic systems. Design of solar hot water systems, drier, space heating/cooling system is performed by using state of art computer software's. Similarly solar photovoltaic , Systems and

components are tested and complete design is provided for different load and different climatic conditions.

Recently work has been initiated in integrated solar, wind, diesel systems. Test facility is being created for microhydro systems. Extensive data base is available on meteorological parameters, products and other items.

5. Plasma Science and Technology

The activities in this group essentially fall on theoretical and experimentally oriented work in plasma physics. The theoretical group is engaged in working on waves, instabilities in the Ionosphere Magnetosphere and laboratory (fusion) plasmas. However, at high power a variety of nonlinear phenomena occur. The group is therefore working on nonlinear dynamics of plasmas and chaos to study plasma behaviour at high power particularly in fusion phenomenon.

In the year 1990, the plasma group especially the experimental one oriented itself towards industrial applications of plasma. A very special facility has been created in the centre for plasma coatings on the surfaces to achieve the required hardness.

6. Facilities in the Centre

Excellent facilities are available in the centre for different uses of the industry and for educational and training programmes.

Software

- **Energy Simulation Laboratory**

A collection of excellent software backed by a comprehensive data base. The software packages can be used for Energy Efficient Building Design, Solar Photovoltaic and Solar Thermal System Design, Hybrid System Design and Calculation of AC loads. Optimal Power System Expansion model including the Environmental Impacts and design and analysis of electrostatic monitoring precipitator.

Fuel Technology

- Gas Chromatograph : Gas Analyser
- Muffle Furnace : Proximate Analysis of Fuels
- Coke Reactivity Index
- BOD Incubator with rotary shaker
- Soxhlet Extractor
- Bomb Calorimeter

Environment Pollution

- Indoor Comfort Meter
- Low Pressure Biogas burner testing facility
- Rodex potentiometer
- pH meter
- High rate (upto 500 kW_{th}) oil burner, combustion chamber, channel and exhaust system.

Electrical Energy Systems

- Double Coated PCB making machine upto 16" x 16" size
- 11 KV prototype substation model for power factor and unbalance voltage testing.
- Electronic circuit design & testing
- Real time monitoring of micro alternator

Renewable Energy

- Photovoltaic Module and system Test Facility Including PV pump.
- Indoor/outdoor Test facility for solar Distillation system
- Thermal conductivity Analyser
- U value Measurements
- Alphanometer and Emissometer
- Solar Transmittance Measurements
- Solar Cooker Test Facility
- Crop Drying Simulator

I.C. Engines

- Facility for basic engine testing of performance and emission characteristics.
- Dynamometer for evaluating engine performance.
- Gas analyser for measuring CO, HC and NO_x emissions. Cylinder gas pressure measuring and processing unit. Varimax Research Engine with facility to vary compression ratios, valve timing, ignition/injection timing and to operate on spark.
- 4 cylinder FORD Automobile Research Engine
- Wankel engine

Plasma Laboratory

- Plasma deposition of thin films.
- Dielectric barrier discharge for flue gas cleaning
- Negative ion generating system
- High speed coating and surface treatment using thermal plasma
- Broadband power amplifiers in RF & LF ranges up to a few hundred watts.
- Spectroscopic system for (a) measuring flame temperature up 3000 K (b) spectrum analysis of light sources in visible range.
- Microwave generator at 2.45 GHz up to 5 kW power.

Energy Audit & Conservation

Portable energy audit instruments like temperature, humidity, velocity meters, surface temperature reading instruments, clamptype voltmeter, ammeter and power factor.

7. Human Resource Development

Adequate human resource generation is the key to solve technological problems in Energy and Environment. The centre runs the following M.Tech programmes in the field of energy.

1. M.Tech (Morning) programme for full time as well as part time students.
2. M.Tech (Evening) programme in Energy for sponsored candidates on part time basis.
The course contents of this programme have been revised thoroughly to include energy & environmental managements. inputs. The revised programme may lead to a degree in M.Tech in Energy and Environmental Management.
3. UNU programme for foreign students from other developed countries for a comprehensive course in renewable energy. The programme is fully sponsored by the United Nations University Tokyo.

The faculty in the Centre can advise the prospective clients about energy efficient building designs, solar energy systems including hot water, dryer, refrigeration and airconditioning, heat pump, photovoltaic pumps, solar home systems, solar lighting and communication systems. Wind power turbine designs are also being worked out alongwith. The faculty is well versed and capable of finding solutions to energy and environmental problems and developing major technologies.

CENTRE FOR ENERGY STUDIES

The Centre for Energy Studies is an interdisciplinary centre deriving its strength from the basic disciplines of Physics, Chemistry, Chemical Engineering, Electrical Engineering and Mechanical Engineering. Supported by an excellent faculty, the Centre imparts teaching, conducts research and provides consultancy in various facets of Energy System such as Fuel Technology, Environmental Pollution, Renewable Energy, IC Engines, Electrical Energy Systems, Plasma Science and Technology and Energy Conservation and Planning. The Centre offers M.Tech. and Ph.D. programmes besides providing consultancies. Under the banner of the United Nations University, an international program leading to a certificate in Renewable Energy is also conducted by the centre.

The centre has several facilities which can be used by the Industry and other institutions. Some of these facilities are described below:

Software

- Energy Simulation Laboratory

A collection of excellent software backed by a comprehensive data base. The software packages can be used for Energy Efficient Building Design, Solar Photovoltaic and Solar Thermal System Design, Hybrid System Design and Calculation of AC loads. Optimal Power

System expansion model including the environmental impacts and Design and analysis of electrostatic monitoring precipitator

Fuel Technology

- Gas Chromatograph : Gas Analyser
- Muffle Furnace : Proximate Analysis of Fuels
- Coke Reactivity Index
- BOD Incubator with rotary shaker
- Soxhlet Extractor
- Bomb Calorimeter

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- Low Pressure Biogas burner testing facility
- Rodex potentiometer
- pH meter
- High rate (upto 500 kW_{th}) oil burner, combustion chamber, channel and exhaust system.

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- 11 KV prototype substation model for power factor and unbalance voltage testing.
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- Real time monitoring of micro alternator

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- Photovoltaic Module and system Test Facility Including PV pump.
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- U value Measurements
- Alphanometer and Emissometer
- Solar Transmittance Measurements
- Solar Cooker Test Facility
- Crop Drying Simulator

I.C. Engines

- Facility for basic engine testing of performance and emission characteristics.
- Dynamometer for evaluating engine performance.
- Gas analyser for measuring CO, HC and NO_x emissions. Cylinder gas pressure measuring and processing unit. Varimax Research Engine with facility to vary compression ratios, valve timing, ignition/injection timing and to operate on spark.
- 4 cylinder FORD Automobile Research Engine
- Wankel engine

Plasma Laboratory

- Plasma deposition of thin films.
- Dielectric barrier discharge for flue gas cleaning
- Negative ion generating system

- High speed coating and surface treatment using thermal plasma
- Broadband power amplifiers in RF & LF ranges up to a few hundred watts.
- Spectroscopic system for (a) measuring flame temperature up to 3000 K (b) spectrum analysis of light sources in visible range.
- Microwave generator at 2.45 GHz up to 5 kW power.

Energy Audit & Conservation

Portable energy audit instruments like temperature, humidity, velocity meters, surface temperature reading instruments, clamp type voltmeter and anemometer.

Expertise

The faculty in the Centre can advise the prospective clients about energy efficient building designs, solar energy systems including hot water, dryer, refrigeration and air conditioning, heat pump, photovoltaic pumps, solar home systems, solar lighting and communication systems. Wind power turbine designs are also worked along with. The faculty is well versed with finding solutions to environmental problems and developing major technologies.

Increasing electrical bills can be reduced through power factor matching, demand side management, automatic building control, energy conservation measures etc. Expertise is available on Real Time Monitoring of Power systems, Static Var

system voltage control, micro alternator set up, micro hydro and other power generating systems. Excellent expertise is available to increase the efficiency of IC engines and modifications in the existing IC engines for fuels like alcohols, hydrogen etc.

Energy audit and conservation measures are dealt scientifically with comprehensive planning. Plasma based expertise for technological applications for industries with particular reference to surface treatment, ceramic coating, ion sources and MHD power generation are available. High pressure, thermal, low pressure thermal and nonequilibrium plasma systems with sophisticated diagnostics can be made available to prospective users.

Some Sponsored Projects

- Security constrained Power System Optimization. High Power Microwave
- Plasma Interaction using Slow Wave Structure.
- Investigation of Soil and Environmental Conditions for Optimum Growth in Greenhouse
- Intense Short Pulse Laser Plasma Interaction.
- Optimization, Designing and Development of an Integrated Solar Multiple Crop/Grain System.
- UNESCO Chair Project in Energy Engineering Education.
- Security Analysis and State Estimation of Power System.
- A New Approach for Fast Plasma Deposition, and Processing Advanced Materials.
- Efficient plasma technology for surface treatment of automobile components
- Volume Generation of Negative Ions in Hydrogen Plasma.
- Bioprocessing Studies on Indian Coals and Lignites to develop a Convenient Process to get Value added Fuels and Chemicals from Indian Coals by Bioconversion under Milder Conditions. (Biochemical Route for Deashing Indian coals).
- Improvement of Coking characteristic of Non coking coals.
- Integrated rural energy system planning for India using IREP Survey Reports.
- Channel for a MHD Retrofit of an existing Thermal Plant.
- Use of Industrial Wastes as Fuels in Cement Film.
- Solar Distillation.
- Building automation system for industrial buildings.
- Solar hot water systems
- Energy Conservation at Banswara Mills.
- Adjudicator in the case of Ashok manufacturing Co. Pvt. Ltd.
- Evaluation of Electrical Performance of Solar Lantern.
- Environmental issues in the Power Sector, World Bank consultancy project.
- Voltage Collapse Studies in power Systems.

- Development of Test Standards for Thermal Performance Evaluation of Solar Cookers.
- Designing of a Solar Crop Dryer.
- Advice on: (a) Water Purification, (b) Solar PV Lantern, (c) Solar PV Vehicle, and (d) Solar Thermal System.
- Techno-economic Feasibility Study for Commercial Conversion of Assam Coal and Refinery.
- Residues into Liquid Fuels using HRI's Coal-Oil Processing.
- Evaluation of Solar Cell Module.
- Evaluation of Solar Photovoltaic Module of 75 Watt of Simen's Sunlight.
- Inspection of Solar Power System at Kanda, Gohar and Kubitute Mandi.
- Evaluation or Inspection of 10A Solar Modules installed at Yangthang, Tabo and Killer in H.P.
- Preparation of Project Report on 50 MW Solar PV Plant Project.
- Evaluation and Measurements of Thermo-optical Properties of Coatings.
- Curricula for ITI and Diploma Level Courses in Renewable Energy.
- Evaluation of Savior Double Galzed Unit.
- Software for Building Simulation for CPWD Projects.
- Passive Building Design Concepts for 3 storeyed Building in Shillong.
- Monitoring of CPWD types III Energy Efficient Building.

- Technical evaluation of a New Electronic ignition System.
- Energy Saving windows
- Solar Photovoltaic for petrol pumps.
- U & G values of windows developed by Kapurthala Rail Coach Factory.

Faculty with Specialization

Professors

Babu M.K.G., Ph.D

Internal Combustion Engines,
Emission Control and Energy
Conservation.

Balasubramaniam R., Ph.D.

Electrical Power Systems:
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Energy System Planning.

Bansal N.K., Ph.D. (Head)

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Dahiya R.P., Ph.D.

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Instrumentation & control,
Solid State Physics.
Air pollution control

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Organic Sulfur in Coal.
Determination of Components of
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liquids) Petroleum Components.
Organic Process Development for
Coal and Chemicals. Solvent
Extraction of Coal and Biomass.
Coke Making and Coke Testing.

Fuel technology, coal deashing,
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