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TECHNICAL REPORT
March 1, 1993 - May 31, 1993

Project Title: **SULFUR REMOVAL FROM HIGH-SULFUR ILLINOIS COAL BY LOW-TEMPERATURE PERCHLOROETHYLENE (PCE) EXTRACTION**

DE-FC22-93PC92521

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Other Co-Investigators: J.W. Stucki, University of Illinois, Urbana-Champaign, G. Huffman and F.E. Huggins, University of Kentucky, Lexington

Project Manager: K. K. Ho, Illinois Clean Coal Institute

ABSTRACT

The purposes of this project are: to independently confirm and possibly to improve the organic sulfur removal from Illinois coals with the PCE process developed by the Midwest Ore Processing Co. (MWOPC), to verify the forms-of-sulfur determination using the ASTM method for evaluation of the PCE process, and to develop a dechlorination procedure to remove excess PCE from the PCE-treated coal. This is the second year of a two-year project.

The objectives for the second year are: to verify the possible effects of PCE treatment on coal-derived FeS_2, $FeSO_4$, and $Fe_2(SO_4)_3$ on ASTM coal analysis (task 6), to investigate the behavior of sulfur during oxidation and PCE desulfurization using the isotopically signatured coal sample (task 7), to investigate the effects of conditions and/or reagents on the oxidation of the organic-sulfur-model compounds (extended task 4), to evaluate the extended oxidation condition on the organic sulfur removal by PCE desulfurization (extended task 5), and to study other innovative pretreatment processes for the removal of organic sulfur from coal under mild conditions (task 8).

Tasks 6 & 7 were concluded in the second quarter. The extended tasks 4 & 5, initiated in the first quarter, were continued in this quarter. When air was bubbled through hot PCE solutions of model sulfur compounds, none of the model compounds showed significant oxidation. The oxidation reactions were repeated on the organosulfur model compounds with the presence of a promoter, either 9,10-dihydroanthracene (DHA) or diphenylmethane (DPM). These hydrocarbon additives are known to produce hydroperoxides during air oxidation. Analysis results for these reaction products are presented in this quarter.

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EXECUTIVE SUMMARY

The development of economical and practical processes to remove both organic and pyritic sulfur under mild reaction conditions would be highly beneficial to the Illinois coal industry. The Midwest Ore Processing Co. (MWOPC) has reported a precombustion desulfurization process operating at 120°C using perchloroethylene (PCE) that removes up to 70% of the organic sulfur as elemental sulfur. The MWOPC stresses the importance of oxidation and drying conditions as well as temperature control. The process was reported to effectively remove organic sulfur from high-sulfur coals obtained from Ohio and Indiana (Leehe and Sehgal, 1988; Leehe, 1989; Lee et al., 1989). The MWOPC process evaluation was based on the ASTM data interpretation; however, the process has not yet been proven to be as successful with Illinois coals (Lee et al., 1989; Buchanan et al., 1990). MWOPC assumed that organic sulfur removal was due mainly to the removal of aliphatic sulfur, and that the aliphatic sulfur component of organic sulfur in Illinois coals may be less than that of the other coals tested.

Two hypotheses underlying the ASTM analysis suggest that errors in interpreting ASTM data may have resulted in higher organic sulfur removal reported by the MWOPC. One error is that elemental sulfur extracted by PCE may be derived from pyrite oxidation during coal preoxidation, not from organic sulfur removed by the PCE. The ASTM forms-of-sulfur analysis does not distinguish between organic sulfur and elemental sulfur. Another hypothesis is that preoxidation of coal may convert pyrite into PCE-extractable sulfur, and a pyrite-derived form of iron. This iron is not extractable by HCl but is extractable by HNO_3. If the hypothesis is true, the HNO_3-extractable iron would be counted as pyritic sulfur during the ASTM analysis. Since the ASTM "pyritic sulfur" would appear to remain constant after PCE extraction and the ASTM organic sulfur is obtained by the difference between total sulfur and the sum of pyritic sulfur and sulfatic sulfur, this calculation would lead to an error in interpreting the ASTM results, making it appear that the removal of sulfur by PCE extraction is organic in nature.

The goals of this research are: (1) to independently confirm and possibly to improve the organic sulfur removal from Illinois coals with the PCE desulfurization process developed by the MWOPC, (2) to verify the forms-of-sulfur determination using the ASTM method for forms of sulfur in evaluating the PCE desulfurization process, and (3) to develop a procedure to remove excess PCE from PCE-treated coals. This is a two-year project with a joint effort by the Illinois State Geological Survey (ISGS), Eastern Illinois University (EIU), the University of Illinois at Urbana/Champaign (UI-UC), and the University of Kentucky (UK). In year-1, the following objectives were met: demonstrated the operation of the MWOPC PCE desulfurization process, revealed the apparent reduction in ASTM organic sulfur to be elemental sulfur derived from ambient

oxidation of pyrite, and developed a dechlorination procedure to remove excess PCE from the PCE-treated coal.

Year-2 includes two original tasks (6 and 7), two extended tasks (4 and 5), and one slightly modified task (8). Task 6 verifies the possible effect of PCE treatment on coal-derived FeS_2, $FeSO_4$, and $Fe_2(SO_4)_3$ on ASTM coal analysis. Task 7 investigates sulfur behavior during oxidation and PCE desulfurization using IBC-107 coal, which contains isotopically signatured pyritic sulfur and organic sulfur. In extended tasks 4 and 5, the oxidation study using model sulfur compounds is being completed. The importance of the oxidation conditions or reagents on PCE organic sulfur desulfurization will be evaluated. If the results indicate that the extended oxidation procedure can be exploited as a desulfurization method, then an optimization study will be performed. Other thermal and/or chemical pretreatment processes for desulfurization under mild conditions also can be examined (task 8).

Tasks 6 and 7 were completed in the previous quarter. The effect of PCE during ASTM forms-of-sulfur analysis was determined and the results indicate that the effect of PCE on the ASTM forms-of-sulfur analysis, especially determination of pyritic sulfur, appears to be minimal. The results of a stable-sulfur-isotope-ratio study on coal oxidation in hot PCE and previous investigations suggest that the increase in elemental sulfur upon SO_2-stimulated oxidation is related to the amount of pyritic sulfur present in coal. The absolute amount of elemental sulfur produced also is related to pyritic sulfur content in coal.

In this quarter, the results of the oxidation study, which includes organosulfur model compounds (extended tasks 4 & 5), are presented. None of the experiments with organosulfur model compounds showed significant oxidation when the oxidation reaction was conducted without a hydrocarbon additive. The presence of a hydrocarbon additive which is known to easily produce hydroperoxides (a strong oxidation reagent) during air oxidation, does promote sulfite to produce sulfoxide and sulfone. However, there is no evidence for carbon-sulfur bond cleavage that is necessary for a preoxidation-sulfur removal process. Also, our oxidation experiments were conducted under more constrained conditions than those used by MWOPC. In other words, while a lower limit on the conditions necessary for air oxidation may have been set, the mild preoxidation conditions of coal described by MWOPC do not achieve the lower limit. In addition, the products of air oxidation that do occur in our experments are inconsistent with elemental sulfur, the product reported by MWOPC. Thus, it is clear that no other possible chemical reaction is required, except oxidation of coal-derived pyrite, to explain elemental sulfur formation and removal by PCE.

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OBJECTIVES

The goals of this research are: (1) to independently confirm and possibly improve the removal of organic sulfur from Illinois coals with the perchloroethylene (PCE) process developed by the MWOPC, (2) to verify the ASTM forms-of-sulfur determination, and (3) to develop a procedure to remove excess PCE from PCE-treated coals. This is the second year of the two-year project. In year-1 the following objectives were met: demonstrated the operation of the claimed PCE desulfurization process, revealed the apparent reduction in ASTM organic sulfur to elemental sulfur was derived by the ambient oxidation of pyrite, and developed a dechlorination procedure to remove excess PCE from the PCE-treated coal.

The objectives for the year-2 study are:

1) to verify possible effects of PCE treatment of coal-derived FeS_2, $FeSO_4$, and $Fe_2(SO_4)_3$ on ASTM forms-of-sulfur analysis,
2) to investigate the behavior of sulfur during air/SO_2 oxidation and PCE desulfurization using the isotopically signatured coal sample,
3) to regulate the conditions or reagents that effect the oxidation of model organic sulfur compounds.
4) to evaluate the effect of the new degrees of oxidation on organic sulfur removal by PCE, and
5) to study other thermal and/or chemical pretreatment processes for the removal of organic sulfur from coal under mild conditions.

BACKGROUND

MWOPC has reported a method of removing organic sulfur from high-sulfur coal using PCE extraction at 120°C (Starbuck, 1980; Leehe and Sehgal, 1988; Leehe, 1989). Process studies, partially supported by the Electric Power Research Institute (EPRI), have been made in a 1 ton/day pilot plant by MWOPC at Plainville, IN. In addition, a mini-pilot plant of 5 lb/hr capacity is being operated at The University of Akron (UA; Lee et al., 1989). Results from the mini-pilot plant indicate that the PCE process effectively extracts organic sulfur from coal, and the process is equally effective in separating pyrite fines from coal. The process is reported to operate at low temperatures with a minimum loss of solvent (Lee et al., 1989). MWOPC stresses the importance of the oxidation process and drying conditions, as well as temperature control. Efficiency of organic sulfur removal is affected by the initial moisture content of the coal (Fullerton et al., 1990). A "catalyst" involved in the process, which renders organic sulfur more accessible to the PCE extraction, has been suggested (Personal communication to PI, G.A. Atwood, MWOPC, Feb. 1991). This process is claimed by MWOPC to effectively remove organic sulfur from high-sulfur coals obtained from Ohio and

Indiana. However, it has not been proven to be as effective with Illinois coals (Lee et al., 1989). A cooperative study (Buchanan et al., 1990) between Eastern Illinois University (Buchanan) and ISGS (Chaven and Hackley) was initiated in 1988. The procedure developed was different from that of MWOPC in that (-60 mesh) coals were used without oxidation prior to PCE extraction. Also, these experiments were mainly conducted in a soxhlet extraction apparatus using a small sample size (1 to 24 g) as compared to the MWOPC experiments in which 50 g or more were used. The authors concluded that pyrite was the source of the elemental sulfur extracted from coal by PCE under these conditions, and that little organic sulfur was removed (Buchanan et al., 1990). These results differ from those of MWOPC's study in which as much as 43% removal of organic sulfur from an Illinois coal was reported (Buchanan et al., 1990).

Different process conditions such as preoxidation, extraction apparatus, and sample size may have caused the differences between the results of the MWOPC and EIU/ISGS. For example, soxhlet extraction rather than batch extraction could decrease the activity of the catalyst that assists organic sulfur removal during PCE extraction. Soxhlet extraction also could decrease the consistency of temperature control. However, possible errors in the interpretation of ASTM analyses of sulfur that may explain the discrepancies in the results have been postulated. One postulate is that elemental sulfur extracted by PCE may have been derived from pyrite oxidation during coal preoxidation, not from organic sulfur. The ASTM forms-of-sulfur analysis does not distinguish between organic sulfur and elemental sulfur. This postulate was confirmed in the year-1 study. Another postulate is that during preoxidation pyritic sulfur might be converted into PCE-extractable elemental sulfur, and associated pyrite-derived iron might be precipitated in a form that is insoluble in HCl but soluble in HNO_3. In this case, iron no longer associated with sulfur would be calculated as pyrite. Because pyrite-derived elemental sulfur would have been removed by PCE, the total sulfur content and the calculated amount of organic sulfur would decrease. This calculation would lead to an error in the interpretation of the results from the ASTM method, making it appear that the PCE extraction removed organic sulfur (Buchanan, 1990). This postulate has been eliminated in the year-2 study by showing that the effect of PCE extraction during ASTM forms-of-sulfur analysis appears to be insignificant.

In several presentations and personnel communications, Atwood and Leehe of Mid West Ore stated that preoxidation of coal was the key to their PCE-based process for removing organic sulfur from coal, and that aliphatic sulfur was being removed. They speculated that the brief oxidation they gave the coal made aliphatic sulfur more susceptible to removal. In our proposal reference is made to earlier work by Bronikowski, et al. (1989) in which they used small amounts of SO_2 in air as an oxidizing agent to enhance sulfur removal from coal. In their papers they also claimed that air/SO_2

oxidized (and maybe desulfurized) dibenzothiophene (DBT). It has been demonstrated in our year-1 study that oxidation of coal in water/PCE prior to extraction with hot PCE increases the amount of elemental sulfur recovered in the PCE extract. In view of the increase in elemental sulfur extracted when air containing a small amount of sulfur dioxide is used as the oxidizing agent, it is important to determine the source of the extracted elemental sulfur. In particular, it is important to ascertain whether any of that elemental sulfur was derived from the organic sulfur or the pyritic sulfur. The year-2 study along with previous studies suggests that the increase in elemental sulfur after SO_2-stimulated oxidation is related to the amount of pyritic sulfur present. The absolute amount of elemental sulfur found also is related to pyritic sulfur content.

To search for conditions or reagents which might promote the sulfur oxidation which Mid-West Ore Processing Co. claims is necessary for successful coal desulfurization in their PCE desulfurization process, the oxidation study has been extended to include organosulfur compounds that simulate those found in coal. The air oxidation of these model compounds was examined under several sets of conditions including the addition of various promoters (extended Tasks 4 & 5). The results of this investigation are reported in this quarter.

EXPERIMENTAL PROCEDURES

Year-2 study includes two original tasks (6 and 7), two extended tasks (4 and 5), and one slightly modified task (8).

Task 6: To verify the possible effect of PCE treatment on coal-derived FeS_2, $FeSO_4$, and $Fe_2(SO_4)_3$ on ASTM coal analysis.

Completed

Task 7: To monitor sulfur behavior during oxidation and PCE desulfurization using coal with organic and inorganic sulfur that is isotopically unique.

Completed

Extended tasks 4 and 5: To further investigate and to evaluate the air/SO_2 oxidation reaction using model sulfur compounds.

Oxidation of organosulfur model compounds without hydrocarbon additives was completed in the first quarter. The reaction was conducted by bubbling air through a hot PCE solution of the model sulfur compounds - the conditions previously used for coal oxidation. The three model compounds were di-n-octyl sulfide, dibenzyl sulfide, and dibenzothiophene (DBT). The same oxidation experiments were initiated in the second quarter to examine various

hydroaromatic hydrocarbons additives as possible catalysts for organic sulfur oxidation. These oxidations were carried out in wet PCE in the presence of easily oxidized hydrocarbons such as 9,10-dihydroanthracene (DHA), which might act as intermediate oxidants of the organic sulfur in coal. The conditions used in the studies with PCE solvent were those reported last quarter for stimulating sulfur removal from coal.

Oxidation experiments without PCE for the model compounds reported in this quarter were carried out in sealed glass tubes, 8 mm x 10 cm, in an electrically heated oil bath. The experimental approach was to determine the minimum conditions under which air oxidation of organosulfur model compounds would occur, and then compare these conditions to the MWOPC conditions. The model sulfur compound and an equal molar amount of promoter, if present, were well mixed and placed in the bottoms of several identical tubes, which were flushed with either nitrogen gas (for controls) or air and sealed with a torch. For reactions in the absence of light, the tubes were well wrapped with aluminum foil and loaded horizontally in a large oil bath maintained at 125°C. For analyses of 24, 76, and 216 hours, tubes were withdrawn, cooled quickly in ice water and carefully cracked open. No extra gas pressure was observed, nor were low-molecular-weight sulfur compounds detected by smell. The tube contents were dissolved in methylene chloride, filtered, diluted and examined by GC or GC/MS. For reactions in the presence of light, the tubes were not wrapped with foil and were suspended in the hot oil bath about 20 cm from a 400 W photoflood light. Tubes were removed at pre-selected times and analyzed as described for the experiments conducted in the absence of light. In addition to the times listed above, dibenzylsulfide samples were also taken at 8, 52, and 120 hours. For several reactions of dibenzyl sulfide, a small amount of a reaction solution taken from a 76-hour oxidation reaction (either in light or darkness) was used as the oxidant-promoter-catalyst in place of air plus DHA or DPM. These tubes were flushed with nitrogen gas before sealing, so all oxidation was due to intermediates formed in the previous 76-hour reaction.

For the GC analyses, a 0.53 mm x 20 m DB-5 capillary column in an H-P 5890 Series I gas chromatograph equipped with an FID detector was used. Peak identification was made by co-injection with standard reference compounds (from Aldrich or prepared in-house as reported previously.) DBT sulfone also was confirmed by HPLC analysis using a C-18 reverse-phase column. Additional confirmation of several products was made using a 0.25 mm x 30 m DB-5 column in an H-P 5890 II GC equipped with a 5971 mass spectrometer (MS) detector. Identification was obtained by computer matching of the mass spectra with the Wiley MS Database. At this point we have been unable to obtain mass spectra of sulfoxides and sulfones because of their thermal decomposition, either in the injector or MS transfer line of the GC/MS. We suspect the decomposition probably occurred in the latter, since

these compounds can be observed with the FID on the other GC.

Task 8: To study the optimization conditions for the PCE desulfurization or other innovative pretreatment processes for the removal of organic sulfur from coal under mild conditions.

If the extended oxidation technique results in an exploitable desulfurization method, the optimization conditions for PCE desulfurization will be determined.

If the results of the oxidation studies confirm the conclusions of the year-1 study that the apparent reduction in ASTM organic sulfur is solely elemental sulfur derived from the oxidation of pyrite, other thermal and/or chemical pretreatment processes for removal organic sulfur can be examined.

RESULTS AND DISCUSSION

The first and second objectives of the year-2 study were met in the previous quarter. Based upon an extensive mass balance study on both iron and sulfur, the conclusion is that PCE treatment did not have any significant effect upon the ASTM procedure for forms-of-sulfur analysis. The year-1 results, in combination with the results of a separate study of stable sulfur isotope ratios of coal oxidation in hot PCE, indicate that the increase in elemental sulfur upon SO_2-stimulated oxidation is directly related to the amount of pyritic sulfur present. The absolute amount of elemental sulfur produced also is related to the pyritic sulfur content of the coal.

The air oxidation of model organosulfur compounds was examined under several sets of conditions (extended tasks 4 & 5). The purpose of these experiments was to search for conditions or reagents which might promote the sulfur oxidation which Mid-West Ore claims is necessary for successful coal desulfurization in their PCE desulfurization process. The results for model-compound oxidation are discussed in the following.

The oxidation on the organosulfur model compounds without additives was conducted by bubbling air through hot PCE solutions of the compounds - the conditions used for coal oxidations. The data indicate that none of the organosulfur compounds tests showed significant oxidation under these conditions.

The oxidation on the organosulfur model compounds was repeated with the presence of a hydrocarbon additive, which is known to easily produce hydroperoxides (a strong oxidation reagent) during air oxidation. Two hydrocarbon additives were tested: 9,10-dihydroanthracene (DHA) and diphenylmethane (DPM). According to

Table 1: Oxidation of Model Sulfur Compounds: Dibenzothiophene (DBT), DiBenzyl Sulfide (BS), and Di-n-Octyl Sulfide (OS) With and Without Promoters
(T = 125°C, No Solvent, Sealed Tubes, 24 - 218 Hrs.)

Compound	Light	Promoter	Oxidized Products Sulfoxide	Solfone
Under air at 1 atm and 20°C				
DBT	No	None	-	0
DBT	No	DHA	-	+++
DBT	No	DPM	-	+
DBT	Yes	None	-	0
DBT	Yes	DHA	-	++
DBT	Yes	DPM	-	++
BS	No	None	+	+
BS	No	DHA	+++++	++
BS	No	DPM	++	0
BS	Yes	None	++	+
BS	Yes	DHA	+++	+
BS	Yes	DPM	+++	++
OS	No	None	+	0
OS	No	DHA	++	0
OS	No	DPM	+	0
OS	Yes	None	+	0
OS	Yes	DHA	+	0
OS	Yes	DPM	++	0
Under N_2 at 1 atm and 20°C				
BS	No	None	0	0
BS	No	DHA Rxn Solution	++++++	0
BS	Yes	DHA Rxn Solution	++++++	0
BS	No	DPM Rxn Solution	+++++	0
BS	Yes	DPM Rxn Solution	++++	++

0 = none detected; - = compound unstable; + = relative amount of compound present, all less than 1% except +++++ (4%);
DHA = 9,10-dyhydroanthracene; DPM = diphenylmethane;
Rxn Solution = reaction solution

Mill, (1992), DHA was the most successful compound in promoting the air oxidation of dimethyl sulfide and di-n-butylsulfide to sulfoxides. The presence of a hydrocarbon additive, either DHA or DPM, does promote sulfite to produce sulfoxide and sulfone. However, quantitative analyses of these reaction products were difficult because of the partial thermal decomposition of sulfoxides and sulfones during the GC/MS analysis. Qualitative results from the large number of reactions are summarized in Table 1. Reactions in the absence of air showed no oxidation of the organosulfur compounds tested. When the tests were conducted with no organosulfide present, both promoters, DHA and DPM, were found to be oxidized in the presence of air. These oxidized products for DHA are anthracene and anthrone, and the oxidized product for DPM is benzophenone. When organosulfur compounds were used with DHA and DPM (Table 1), no high-yield conversion of the starting organosulfide to other products was observed. The oxidized products were always present in minor amounts, usually less than 1%. When dibenzyl sulfide was oxidized using the reaction solution isolated after 76 hours in either the light or dark of another dibenzyl sulfide oxidation promoted by DHA as the oxidant (identified as DHA Rxn Solution in Table 1), approximately 2% - 4% of benzylsulfoxide was detected. The complex mixture of minor products (some unidentified), which vary with reaction time, is understandable, because all oxidation reactions are kinetically controlled.

SUMMARY AND CONCLUSIONS

* During air oxidation in the presence of promoters, dibenzyl sulfide was the most reactive model compound. It is followed in degree of reactivity by di-n-octyl sulfide and dibenzothiophene.

* The oxidized products observed were benzylsulfoxide and benzylsulfone, octylsulfoxide, and dibenzothiophene sulfone (DBT-1, 1-dioxide). The DBT sulfoxide was not observed, because this compound is unstable and is likely to convert to sulfone.

* DHA is a slightly better promoter for sulfide air oxidation than DPM.

* For all three model organosulfides, DHA promotes more oxidation in the dark than in the light, however DPM promotes more oxidation in the light than in the dark.

* Small amounts of hydrocarbons found may have been produced by thermal decomposition of sulfone during GC/MS analysis of the sulfone. Traces of biphenyl and dibenzyl were formed from DBT sulfone and benzylsulfone, respectively. Octane or hexadecane

was not found in di-n-octyl sulfide reactions nor was there evidence for the sulfone.

* The oxidation reactions are complex and in each case are accompanied by the production of trace amounts of unidentified compounds which increase with time. The reaction solution of dibenzyl sulfide with DHA or DPM in the presence of air contained an active oxidizing agent. This was supported by the conversion of dibenzyl sulfide to sulfoxide or sulfone in the reaction solution without air present. The highest yield of benzylsulfoxide (4%) was obtained by this reaction condition.

* Air oxidation of dibenzyl sulfide and di-n-octyl sulfide in the absence of promoters showed the presence of trace amounts of sulfoxide after 24 hours of heating, which in some cases decreased with further heating.

* Elemental sulfur was not detected with any of these oxidation reactions.

Overall, these results should set a lower limit on the conditions necessary for air oxidation of the type of organosulfur compounds found in coal. Mid-West Ore Processing Company claims that coal desulfurization takes place when coal is preoxidized in air as a suspension in PCE at about 70°C for one-half hour prior to their PCE desulfurization process. The mild preoxidation treatment of coal described by MWOPC for removal of organic sulfur does not produce enough oxidized organic sulfur to support their claim. Furthermore, when air oxidation of coal-like organosulfur compounds does occur, the products are inconsistent with production of elemental sulfur, the product reported by MWOPC. In previous reports, we have demonstrated that the conditions described by MWOPC are quite sufficient for the production of elemental sulfur from pyrite, either within coal or by itself, and that no other chemical reaction is required to explain the level of elemental sulfur formation and removal with PCE for MWOPC's coal desulfurization claims.

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PROJECT MANAGEMENT REPORT

March 1, 1993 - May 31, 1993

Project Title: SULFUR REMOVAL FROM HIGH-SULFUR ILLINOIS COAL BY LOW-TEMPERATURE PERCHLOROETHYLENE (PCE) EXTRACTION

Principal Investigator: M.-I. M. Chou
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Funded Co-investigator: D.H. Buchanan
Eastern Illinois University (EIU)

ISGS Co-investigators: J.M. Lytle, R.R. Ruch, C.W. Kruse, C. Chaven, K.C. Hackley, R.E. Hughes, R.D. Harvey

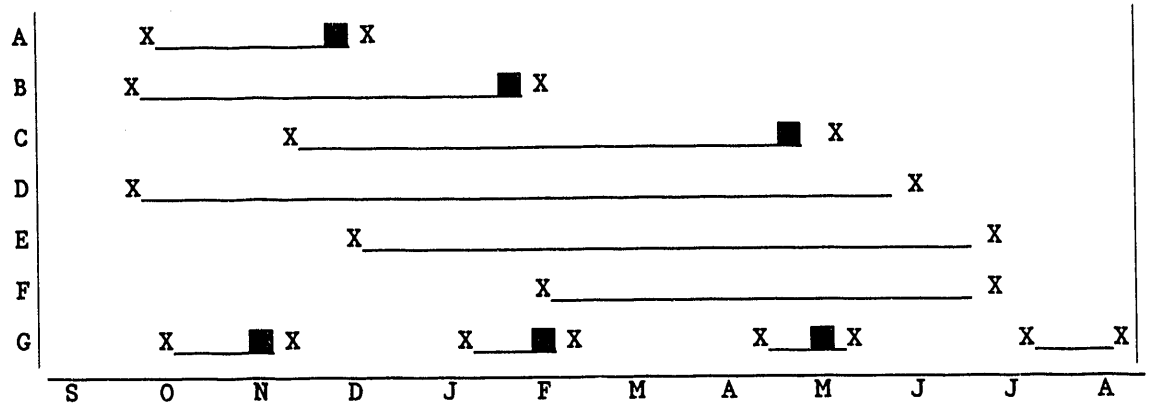
Other Co-investigators: J.W. Stucki, University of Illinois, G.P. Huffman and F.E. Huggins, University of Kentucky

Project Manager: K. K. Ho, Illinois Clean Coal Institute

COMMENTS

Contract for EIU, and analyses services from coal analysis laboratory have not yet been paid. These works are in progress but payments are made on a cost reimbursement basis after the works are completed. Thus, expenditures were less than expected for this quarter.

SCHEDULE OF PROJECT MILESTONES



Milestones:

A. Sample requisition and student helper hired
B. Base line study (Task 6)
C. Radioactive trace study (Task 7)
D. Oxidation study (Extended Task 4)
E. Data evaluation (Extended Task 5)
F. Process application and/or optimization (Task 8)
G. Technical project management reports prepared and submitted

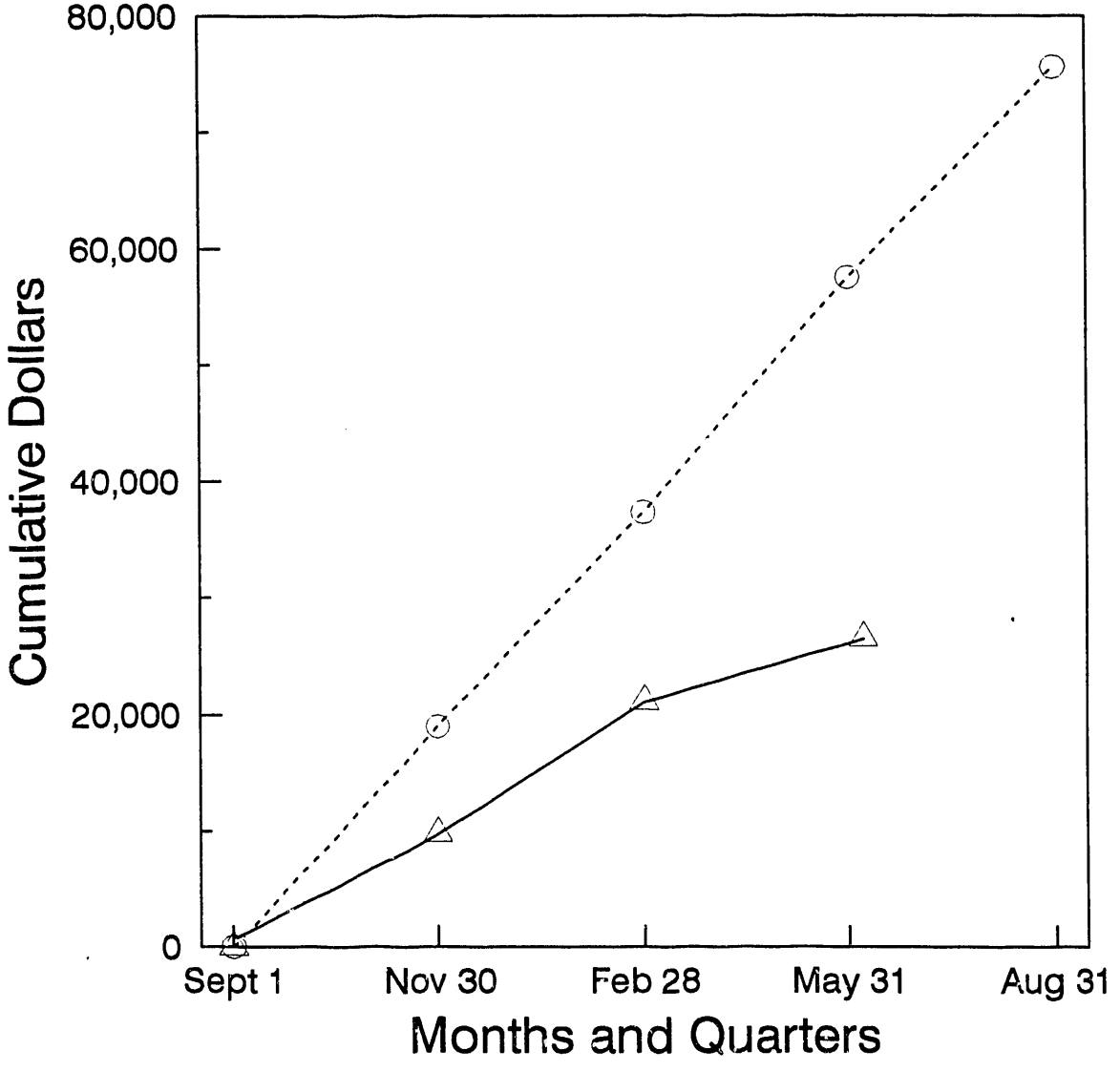
Projected and Estimated Actual Expenditures by Quarter

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1992 to Nov. 30, 1992	Projected	7,350	960	1,000	0	0	7,962	1,727	18,999
	Estimated	6,000	600	800	0	0	800	820	9,020
Sept. 1, 1992 to Feb. 28, 1993	Projected	14,700	1,919	1,420	0	0	15,923	3,396	37,358
	Estimated	14,000	1,400	900	0	0	2,500	1,358	20,158
Sept. 1, 1992 to May 31, 1993	Projected	22,049	2,879	1,840	150	0	23,885	5,080	55,883
	Estimated	18,500	2,200	1,200	0	0	2,500	2,930	27,330
Sept. 1, 1992 to Aug. 31, 1993	Projected	28,334	3,669	2,350	300	0	32,489	5,648	72,820
	Estimated								

*Cumulative by Quarter

COSTS BY QUARTER - EXHIBIT C

SULFUR REMOVAL FROM HIGH-SULFUR ILLINOIS COAL BY LOW TEMPERATURE PERCHLOROETHYLENE (PCE) EXTRACTION



○ Projected Expenditures - - - - - - - - - - - - -

△ Actual Expenditures ————————

Total CRSC Award $ 72,820

DATE
FILMED
9/23/93

END