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TECHNICAL REPORT
December 1, 1991 through February 29, 1992

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

Principal Investigator: M.-I.M. Chou, Illinois State Geological Survey

Funded Co-investigator: D.H. Buchanan, Eastern Illinois University

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

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

Project Monitor: D.D. Banerjee, CRSC

ABSTRACT

A pre-combustion coal desulfurization process at 120 °C using perchloroethylene (PCE) to remove up to 70% of the organic sulfur has been developed by the Midwest Ore Processing Co. (MWOPC). However, this process has not yet proven to be as successful with Illinois coals as it has for Ohio and Indiana coals. In addition, the high levels of organic sulfur removals observed by the MWOPC may be due to certain errors involved in the ASTM data interpretation; this needs verification. For example, elemental sulfur extracted by the PCE may be derived from pyrite oxidation during coal pre-oxidation, but it may be interpreted as organic sulfur removed by the PCE using ASTM analysis.

The purposes of this research are to independently confirm and possibly to improve the organic sulfur removal from Illinois coals with the PCE desulfurization process reported by the MWOPC and to verify the forms-of-sulfur determination using the ASTM method for the PCE process evaluation.

In this quarter, the desulfurization data obtained from ASTM analysis on fresh IBC-104 coal on a larger scale operation also show a level of sulfur removal corresponding to that obtained by the University of Akron. This larger scale (50 g size) PCE extractions were repeated on a short term air oxidized IBC-104 coal, a long term air oxidized IBC-104 coal, and an Ohio 5/6 coal. These process feeds and products produced were distributed to the co-investigators for the independent analyses. A mass balance analysis will be conducted on the long term oxidized IBC-104 coal, and the Ohio 5/6 coal.

PCE treated coal with a high level of chlorine content is not desirable for combustion. The amounts of chlorine remaining in the PCE treated residues were determined. Without any washing, the PCE treated residue coal could pick up chlorine as high as 4 to 5%. Techniques for its removal from the process residue were examined. A proprietary method was found which can totally remove PCE and give the PCE treated IBC-104 residues with a chlorine content (0.03%) that is comparable to the untreated coal.

From a larger scale operation, the enhanced elemental sulfur removal and total sulfur reduction from the long-term air oxidized IBC-104 coal was further confirmed. Further study on the effects of other forms of pre-oxidation conditions on the PCE desulfurization is in progress.

MASTER

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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. A precombustion desulfurization process operating at 120 °C using perchloroethylene (PCE) to remove up to 70% of the organic sulfur in the elemental sulfur form has been reported by the Midwest Ore Processing Co. (MWOPC). The importance of oxidation and drying conditions as well as temperature control is stressed by the MWOPC. The process is effective in extracting organic sulfur and, in float-sink, separating pyrite fines from coal; the process can be operated at low temperatures with minimal loss of solvent (Leehe et al., 1988 and 1989; Lee et al., 1990) and was found to effectively remove organic sulfur from high-sulfur coals obtained from Ohio and Indiana. However, it has not yet proven to be as successful with Illinois coals (Lee et al., 1990; Buchanan et al., 1990). The MWOPC process evaluation was based on the ASTM data interpretation.

Over the past few years, the ISGS and Eastern Illinois University (EIU) have jointly developed analytical methods to measure forms of sulfur in the PCE extracts from PCE extraction of high-sulfur Illinois coals. Some elemental sulfur and limited amounts of organic sulfur have been removed from oxidized Illinois coals during these studies; however, these sulfur removals (<32%) were much lower than those reported by the MWOPC (>43%). Several hypotheses may explain these differences, but to date, no experimental supports have been reported. MWOPC assumed that organic sulfur removal was due mainly to the removal of aliphatic sulfur, and that the organic sulfur in the Illinois coals may contain less aliphatic sulfur than the other coals tested. Others have postulated that certain errors in interpreting ASTM data may result in higher organic sulfur removal reported by the MWOPC.

For example, one hypothesis underlying the ASTM analysis is that pre-oxidation of coal may convert pyrite into PCE-extractable sulfur, and that this oxidation leaves behind pyrite-derived iron. This iron may not be extractable by HCl but may be extractable by HNO_3. If so, this iron would be counted as pyritic sulfur during the ASTM analysis. Since the ASTM "pyritic sulfur" appears to remain constant 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 ASTM method for the PCE desulfurization process evaluation, and (3) to determine the suitability of Illinois coals for use in the PCE desulfurization process. This is a joint effort by the ISGS, EIU, UI-UC, and UK. A total of 8 tasks, tasks 1 to 5 will be completed in the first year, and tasks 6 to 8 will be carried out in the

second year.

During this reporting period, task 1.1 is completed, and task 1.2, task 2, and task 4 are in progress. The purpose of task 1.1 is to perform PCE desulfurization on the selected Illinois coal under proper conditions described by the MWOPC procedures. Thus, the derived process intermediate products before and after PCE extraction can be used to evaluate the fate of sulfur transformation in the PCE process and also to verify the ASTM analyses. The results from product analysis on fresh IBC-104 coal reported in the first quarter were further confirmed in a larger scale operation. The data from total sulfur analysis based on ASTM method indicate that the level of total sulfur reduction from fresh F-IBC-104 has values ranging from 4.7% to 6.9% which is comparable to the level of sulfur removal (5%) from a similar fresh Illinois #6 coal published by Lee et al. of the University of Akron (1991). The larger scale (50 g size) PCE extractions were repeated on a short term air oxidized IBC-104 coal, a long term air oxidized IBC-104 coal, and an Ohio 5/6 coal. The process feeds and products from these scale up operations will be used for a mass balance study (task 1.2) and were distributed to co-investigators for the independent analyses (task 2).

Treated coal with a high level of chlorine content is not suitable for combustion. The amounts of chlorine remaining in the PCE treated coal residues were determined. Without any washing, the PCE treated residue coal could pick up chlorine and give a residue coal with a chlorine content as high as 4.68%. Various techniques for the chlorine removal from the process residue were examined. A proprietary method is found which can totally remove PCE and give the PCE treated IBC-104 coal residues with a chlorine content (0.03%) that is comparable to the untreated coal.

The purpose of task 4 is to determine the effect that various oxidation conditions have on PCE desulfurization. The results of the oxidization study reported before were further confirmed in a larger scale operation. The data indicate that the level of elemental sulfur removal and total sulfur reduction is greatly enhanced by a long-term (>5 years) air oxidation of the same IBC-104 coal. The extractable elemental sulfur obtained from this sample is 25 to 75 times greater than those from the short term oxidized IBC-104 coal samples. The total sulfur reduction from this sample is about four times greater than those from the unoxidized coal samples. Study on the effects of other forms of pre-oxidation conditions on the PCE desulfurization is continued.

Objectives

The goals of this research are: (1) to independently confirm and possibly improve the organic sulfur removal from Illinois coals with the PCE process, (2) to verify the ASTM forms-of-sulfur determination, and (3) to evaluate the suitability of Illinois coals for use in the PCE desulfurization process developed by the MWOPC. Successful removal of organic sulfur during PCE extraction or by other methods developed to improve PCE extraction of Illinois coals can greatly improve the marketability of high-sulfur Illinois coal.

Specific objectives are:

A. To conduct the PCE desulfurization of two coals under the proper process conditions. One coal, IBC-104, would be from the Illinois Basin Coal Sample Program, and the other, Ohio 5/6 coal, from the Horizon Coal Company.

B. To carry out an extensive material balance study on the feed materials and products from the two coals tested in the PCE desulfurization process.

C. To conduct ASTM-independent analyses with forms-of-sulfur determinations and compare the results.

D. To investigate coal oxidation chemistry and its effect on the mechanisms of sulfur removal by the PCE desulfurization process.

E. To examine the role that pyrite in coal plays during the PCE desulfurization process and its influence, if any, on process optimization.

F. To evaluate and possibly improve the effectiveness of the PCE desulfurization process for Illinois coals.

Introductions and Background

MWOPC has reported a method of removing organic sulfur from high-sulfur coal using perchloroethylene (PCE) leaching at 120 °C (Starbuck, 1980; Leehe et al., 1988, 1989). The process was partially supported by the Electric Power Research Institute (EPRI) and has been operated in a pilot plant of 1 ton/day capacity 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., 1990). Results from the mini-pilot plant indicated that the PCE process effectively extracts organic sulfur, and is equally effective in separating pyrite fines from coal. The process can be operated at low temperatures with a minimum loss of solvent (Lee et al., 1990). The importance of oxidation and drying conditions as well as temperature control is stressed by the MWOPC. Efficiency of organic sulfur removal is affected by the initial moisture content in 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 has been found to effectively remove organic sulfur from high-sulfur coals obtained from Ohio and Indiana. However, it has not yet proven to be as successful with Illinois coals (Lee et al., 1990).

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 pre-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 other experiments in which 50 g or more were used. The authors concluded that the source of the elemental sulfur extracted from coal by PCE under these conditions was pyrite and that little organic-sulfur was removed (Buchanan et al., 1990). These results differ from those of MWOPC's study where as much as 43% removal of organic sulfur from an Illinois coal has been reported.

The differences between the results of the MWOPC and EIU/ISGS may have been due to the use of different process conditions such as pre-oxidation, extraction apparatus, and sample size. For example, soxhlet extraction rather than batch extraction could decrease the activity of the catalyst that assists organic sulfur removal during PCE extraction. Extraction of smaller sample sizes could decrease the required temperature control. However, others have postulated that some possible errors in the ASTM analyses of sulfur may explain the discrepancies in the results. For example, during pre-oxidation, pyrite may convert into PCE extractable elemental sulfur and leaves the pyrite-derived iron behind. This iron may remain insoluble in HCl but soluble in HNO_3 during ASTM analysis. Because the elemental sulfur has been removed by PCE, the total sulfur content decreases, and therefore the calculated amount of organic sulfur also decreases. This calculation would lead to an error in interpretation of the ASTM results, making it appear that the removal of sulfur by PCE extraction is organic in nature (Buchanan, 1990). As of yet, these postulates have not been confirmed.

Experimental Procedures

Task 1: Processing of Illinois coals and a mass balance study

The purpose of this task is to perform PCE desulfurization on the selected Illinois coal under proper conditions described by the MWOPC procedures. Thus, the derived process intermediate products before and after PCE extraction can be used to evaluate the fate of sulfur transformation in the PCE process and also to verify the ASTM analyses.

As mentioned in the previous report, two coals, one from the Illinois Basin Coal Sample Program (IBC-104) and the other from the Horizon Coal Company (Ohio 5/6 coal) were selected for this project. Coal sample selection is based on the availability of the samples and of the reported desulfurization data by the MWOPC and the UA. (ISGS/EIU)

Table 1.

ASTM forms of sulfur in an Illinois No. 6 coal and an Ohio 5/6 coal before and after PCE extraction reported by Lee et al. of University of Akron (1991).

SAMPLE	SO_4	PYR	ORG	TOT
Feed (IBC-104) IL No. 6 F	0.01	2.54	1.55	4.10
PCE residue	0.01	2.52	1.36	$3.89^{-5\%}$
Feed Ohio 5/6 W	0.22	1.40	1.58	3.20
PCE residue	0.23	1.40	0.71	$2.34^{-27\%}$

F = fresh coal; W = weathered at room temperature, the higher level of sulfatic sulfur content indicative of the higher level of oxidation of the sample; $^{-5\%}$, total sulfur reduction from the feed coal.

A larger scale PCE desulfurization

In this reporting period, the process was refined in a larger scale operation, and the larger scale (50 g size) PCE extractions were repeated on one short term oxidized IBC-104 coal, one long term oxidized IBC-104 coal, and one Ohio 5/6 coal.

Azeotropic drying was conducted prior to each PCE extraction. The drying was accomplished by adding sample to well-stirred PCE at 70 to 100 °C in an open flask, heating the mixture until all of the water boils out and the temperature in the flask is raised to 121 °C and maintained at that temperature for 30 minutes to complete the extraction. The residue produced from PCE extraction was isolated by hot filtration.

The feeds and products from these scale up operations were split and distributed to co-investigators for the independent analyses in task 2. A mass balance analysis for the long term oxidized IBC-104 coal, and the Ohio 5/6 coal samples, and the forms of sulfur examination by the ASTM method are under investigation.

Chlorine up-take during PCE desulfurization

In addition to a scale up PCE desulfurization, the up-take of chlorine during PCE desulfurization is another focus of this investigation. The techniques for chlorine removal from the process residue were examined. The materials including boiling water, hot methanol, and a proprietary compound were used alone or in sequence to remove chlorine from the processed residues. The chlorine content of the treated products were analyzed by the ASTM method.

By using a proprietary technique, a complete removal of the up-take

chlorine in the process residues of the IBC-104 coal was obtained.

Task 2: Independent analyses for forms of sulfur determination

The five subtasks were started and are in progress during this reporting period.

The results from a wet-chemical analysis (Task 2.1) will be used to compare with the results from the ASTM analysis. These data as well as the data from non-destructive spectroscopic techniques: *Sulfur K-edge X-ray absorption fine structures spectroscopy (XAFS), X-Ray Diffraction (XRD), Mössbauer spectroscopy, Scanning Electron Microscopy and Energy Dispersive x-ray (SEM-EDX)* (Tasks 2.2 - 2.5) will be used to determine the fate of organic sulfur, pyritic sulfur, and sulfur-containing iron salts in the PCE desulfurization process. (ISGS, UI-UC, & UK).

Task 3: Evaluating the Effectiveness of Using the PCE Desulfurization Process on the Selected Illinois Coal, and Verifying the ASTM Forms of Sulfur Analyses

The data obtained from Tasks 1 and 2 on sulfur removal for the coals processed will be examined, evaluated, and interpreted.

Data from ASTM analysis (Task 1.2) and LAH analysis (Task 2.1) will be compared on the basis of sulfur reduction using PCE desulfurization process as a whole and as in each step of the process. Data from spectroscopic analyses (Tasks 2.2 - 2.5) will be examined with respect to the transformation or removal of pyritic sulfur, aliphatic sulfur, and aromatic sulfur in each step of the PCE desulfurization process. Interpreting these data will allow us to explore the true identity of organic sulfur removal by PCE extraction and that of ASTM forms-of-sulfur analysis. (ISGS, EIU, UI-UC, and UK)

Task 4. Conducting PCE desulfurization under various process conditions

The purpose of this task is to determine the effect that various process conditions have on PCE desulfurization.

In the first quarter, a total of 19 PCE desulfurization tests were conducted under various oxidation conditions including those recommended by the MWOPC (Atwood, 1990). The results from product analysis of fresh IBC-104 coal (F-IBC-104) and air oxidized forms of this coal were completed in this quarter. The study on the effects of other forms of pre-oxidation conditions on the PCE desulfurization is in progress. (EIU/ISGS)

Task 5. Evaluating the parameters studied and their effect on process optimization

The results of the ASTM forms-of-sulfur analyses in oxidized coals will be compared with those in the non-oxidized coal. The possible effects that various pre-oxidation conditions have on sulfur removal during PCE

extraction will be determined. Data from the other variables studied will also be evaluated with respect to their effects on the process efficiency for the two coals tested. Data obtained from the optimum conditions (if any) will be compared with those reported by the MWOPC and UA. (ISGS, EIU, UI-UC, and UK)

Task 6. Verifying the possible effect of PCE treatment on coal-derived FeS_2, FeS, $FeSO_4$, FeS_2, and coal analyses

This task will be carried out in the second year for a base line study to verify the possible effect of PCE extraction on the ASTM forms-of-sulfur analysis. Separate experiments using control samples will be conducted. An IBC-104 coal, pyrite, and pyrite-derived iron phases (e.g., $FeSO_4$, FeS, etc.), and/or coals with added iron salts will be subjected to PCE extraction. The PCE extracts will be analyzed for elemental sulfur. Hot HCl and HNO_3 acid digestions of the residues will be analyzed for sulfur and total Fe. (ISGS/EIU)

Task 7. Using radioactive pyrite to monitor sulfur behavior during PCE desulfurization

This task will be carried out in the second year. The role that pyrite may play and the fate of iron and sulfur associated with pyrite during PCE desulfurization will be examined using a radioactive pyrite doping technique. (ISGS/EIU)

Task 8: Application of an acceptable PCE desulfurization process to Illinois coals

This task will be carried out in the second year. If it is found (Task 5) that significant amounts of organic sulfur are being removed from Illinois coal by the PCE desulfurization process, the optimized operation conditions of the process will be applied, and the applicability of the process to the most economically important Illinois coals will be examined. In addition, a complete PCE desulfurization process including the float-sink separation step will be performed. (ISGS)

RESULTS AND DISCUSSION

The PCE desulfurization process was refined in a larger scale on fresh IBC-104 coal (F-IBC-104), and the results from product analysis reported in the first quarter were further confirmed. The data from total sulfur analysis based on ASTM method indicate that the level of total sulfur reduction from fresh F-IBC-104 has values ranging from 4.7% to 6.9% (see Table 2) which is comparable to the level of sulfur removal (5%) from a similar fresh Illinois #6 coal published by Lee et al. of the University of Akron (1991). The larger scale (50 g size) PCE extractions were repeated on one short term oxidized IBC-104 coal, one long term oxidized IBC-104 coal, and one Ohio 5/6 coal. The process feeds and products from these scale up operations were distributed to co-investigators for the independent analysis (Task 2). Also, a mass balance analysis of the long term oxidized IBC-104 coal, and the Ohio 5/6 coal by the ASTM method is in progress.

In addition to a scale up PCE desulfurization, chlorine up-take during PCE desulfurization, and techniques for its removal from the process residue were investigated. This is because that the overall success of this process also relies on the removal of the chlorine from the PCE treated residue coal, which could be as high as 4.68% (Table 2). Steam stripping technique was used by the MWOPC to give a residue Illinois No. 6 coal with a chlorine content of 0.9% (Atwood, 1991). Comparing the chlorine content of a run of mine Illinois No. 6 coal (Table 2: 0.03% in C32079), the steam stripped residue coal has a chlorine content which is not suitable for the coal to be used in an electrical boiler. In this reporting period, a proprietary method (Prop. as indicated in Table 2) has been found which can totally remove PCE and give the PCE treated residue coal (C32090, C32035, and C32037) with a chlorine content of 0.03% (Table 2).

Table 2.

PCE desulfurization and the process residues chlorine removal on a fresh (F-IBC-104) and an oxidized IBC-104 (O-IBC-104), and an Ohio 5/6 coal.

Lab No.	Sample, Method of washing	TS(dry)%	TSR%	S°(dry)%	Cl(dry)%
C32079	F-IBC-104	4.09	NA	--	0.03
C32086	F-IBC-104-PCE, NONE	3.90	4.7	0.00⊕	4.68
C32088	F-IBC-104-PCE, H_2O	3.81	6.9	0.00	2.96
C32087	F-IBC-104-PCE, MEOH	3.81	6.9	0.00	0.17
C32090	F-IBC-104-PCE, Prop.	3.87	5.4	0.00	0.03
C32035	O-IBC-104-PCE, Prop.	3.32	19.0	0.07	0.03
C32037	O-IBC-104-PCE, Prop.	3.31	19.0	0.07	0.03
C31996	Ohio 5/6	3.50	NA	--	0.11
C31922	Ohio 5/6-PCE, NONE	2.97	15.0	0.10	4.90
C31988(S5622)	Ohio 5/6-PCE, H_2O	2.78	21.0	0.10	1.73
C32032	Ohio 5/6-PCE, i-prOH, H_2O	2.78	21.0	0.10	0.89
C32102	Ohio 5/6-PCE★, Prop.	2.75	21.0	0.10	0.16

TS, Total Sulfur content in wt%; TSR, total sulfur reduction; S°, Elemental sulfur; Cl, Chlorine content in wt%; Prop., sequential washes using methanol, H_2O, a proprietary reagent; ★, extraction time 15 minutes; ⊕, not detectable.

PCE desulfurization under various oxidation conditions including those recommended by the MWOPC (Atwood, 1990) (task 4) were tested in the first quarter. The results of the oxidation study indicate that the level of elemental sulfur removal and total sulfur removal is greatly enhanced by a long-term (>5 years) air oxidation of the same IBC-104 coal. As indicated in the previous report, the extractable elemental sulfur obtained from this sample is 25 to 75 times greater than those from the short term oxidized IBC-104 coal samples. In this reporting period, the enhanced elemental sulfur removal from the long-term oxidized IBC-104 coal was further confirmed. In addition, a total sulfur removal of 19% (table 2) was obtained by a larger scale operation, which is about four times greater than those removed from the fresh IBC-104 coal samples (4.7% to 6.9%). The effect of other short-term pre-oxidation conditions on PCE desulfurization is still in progress.

SUMMARY AND CONCLUSION

Desulfurization data obtained from ASTM analysis on fresh IBC-104 coal are comparable to that obtained by the University of Akron. Coal pre-oxidation before PCE extraction does enhance total sulfur reduction and elemental sulfur extraction. The PCE extractions were repeated in a larger scale (50 g size) on one short term oxidized IBC-104 coal, one long term oxidized IBC-104 coal, and one Ohio 5/6 coal. The process feeds and products will be used for the independent analysis and a mass balance analysis. Along with sulfur removal which is still under investigation, the removal of the chlorine from the PCE treated residue coal is of

importance to the overall success of the PCE desulfurization process. This is because the PCE treated residue coal could have a level of chlorine content which is not suitable for combustion. In this reporting period, a proprietary method has been found which can totally remove PCE and give the PCE treated IBC-104 coal residues with a chlorine content of 0.03%.

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PROJECT MANAGEMENT REPORT

December 1, 1991 through February 29, 1992

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

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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, J.K. Frost

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

Project Monitor: D.D. Banerjee, CRSC

COMMENTS

Contract for EIU, and analyses services from the other co-investigators 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.

This project is funded by the U. S. Department of Energy (PETC) and by the Illinois Department of Energy and Natural Resources as part of their cost-shared program.

Year-1

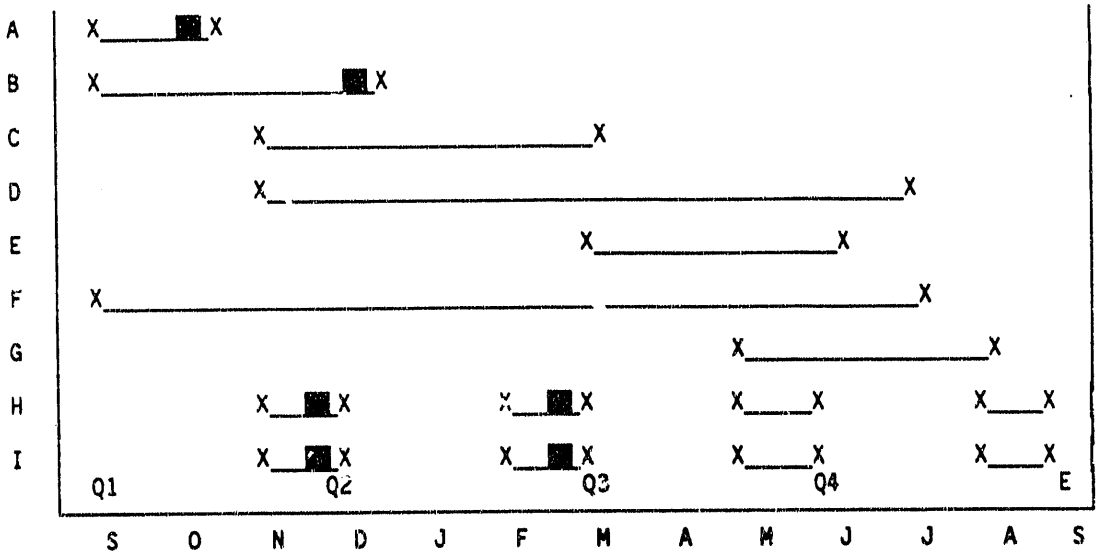
EXPENDITURES - EXHIBIT B

Projected and Estimated Actual Expenditures by Quarter

Quarter (cumulative by quarter)	Types of Cost	Direct Labor	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Costs	Total
Sept. 1, 1991 to Nov. 30, 1991	Projected	6,442	1,250	100	0	10,000	1,797	19,589
	Est. Actual	6,000	188	531	0	0	672	7,390
Sept. 1, 1991 to Feb. 28, 1992	Projected	12,883	2,250	900	0	20,000	3,594	39,627
	Est. Actual	11,575	306	531	0	476	1,315	14,203
Sept. 1, 1991 to May 31, 1992	Projected	19,324	2,750	1,150	0	31,368	5,391	59,983
	Est. Actual							
Sept. 1, 1991 to Aug. 31, 1992	Projected	25,766	3,000	1,750	0	41,368	7,188	79,072
	Est. Actual							

SCHEDULE OF PROJECT MILESTONES

Year 1



September 1, 1991 through August 31, 1992

Milestones:

A. Coal sample preparation
B. PCE desulfurization (Task 1.1)
C. Material balance study (Task 1.2)
D. Multiple independent analysis (Task 1.2)
E. Desulfurization data evaluation (Task 3)
F. Study various parameters for PCE desulfurization (Task 4)
G. Data evaluation (Task 5)
H. Technical reports
I. Financial reports

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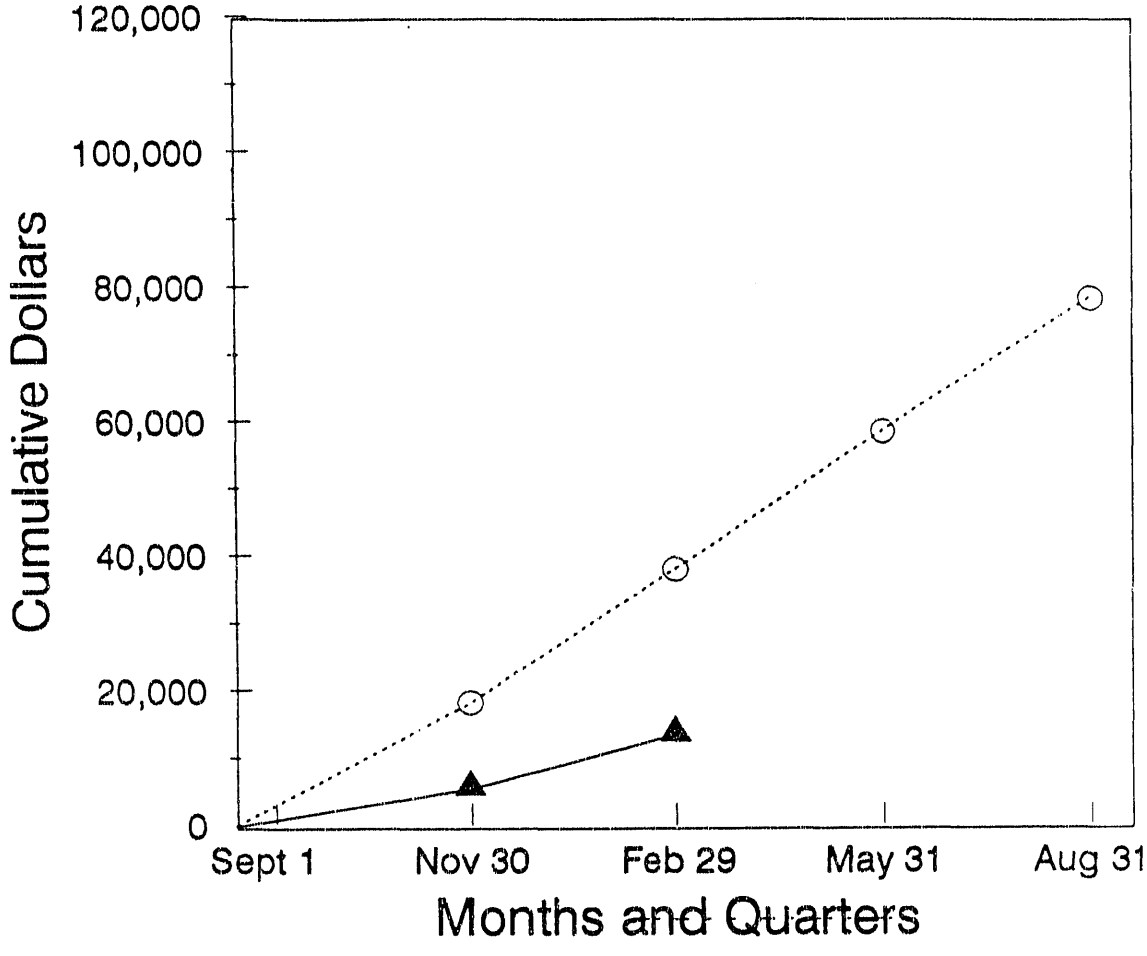
COSTS BY QUARTER - EXHIBIT C

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



○ Projected Expenditures $39,627

▲ Actual Expenditures $14,203

Total CRSC Award $79,072

END

DATE
FILMED
10/1/92