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TECHNICAL REPORT
March 1, 1995 through May 31, 1995

Project Title: **BRICK MANUFACTURE WITH FLY ASH FROM ILLINOIS COALS**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)
ICCI Project Number: 94-1/3.1A-10M
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ABSTRACT

This investigation seeks to utilize fly ash in fired-clay products such as building and patio bricks, ceramic blocks, field and sewer tile, and flower pots. This goal is accomplished by 1) one or more plant-scale, 5000-brick tests of fly ash mixed with brick clays at the 20% or higher level; 2) a laboratory-scale study to measure the firing reactions of a range of compositions of clay and fly ash mixtures; 3) a preliminary study to evaluate the potential environmental and economic benefits of brick manufacture with fly ash. Bricks and feed materials will be tested for compliance with market specifications and for leachability of pollutants derived from fly ash. The laboratory study will combine ISGS databases, ICCI-supported characterization methods, and published information to improve predictions of the firing characteristics of Illinois fly ash and brick clay mixtures. Because identical methods are used to test clay firing and coal ash fusion, and because melting mechanisms are the same, improved coal ash fusion predictions are an additional expected result of this research. If successful, this project should convert a disposal problem (fly ash) into valuable products– bricks.

During this quarter we completed a manufacturing run at Colonial Brick Co. and began laboratory testing of samples from that run: clays, fly ash (from Illinois Power Company's Wood River Plant), and green and fired bricks— with and without fly ash. Bricks with 20% fly ash "scummed" during firing, and the fly ash failed to increase oxidation rate or water absorption, which were both expected. We obtained chemical and mineralogical analyses of the fireclays and shales at Colonial and Marseilles Brick Companies and began a series of selective dissolution analyses to more accurately determine the composition of the principal clay minerals in brick clays and the components in fly ash. We began related work of calculating 'normative' mineralogical analyses for all clays and fly ashes that we sample. Ilham Demir kindly gave us a copy of the chemical database from their ICCI study of commercial coals; this database has been reformulated to estimate the fly ash composition from each of these coals, which should allow us to select three standard fly ashes for next year's optimization studies. We completed a computer database of the locations and geological affinities of all ceramic clays studied by the Clay Minerals Unit since about 1930 (~25,000 entries). Dust from fly ash was an unanticipated problem at the brick plant. We will look for improved methods of handling next year's fly ash deliveries. A summary report on this project was presented to the Coal Advisory Committee of the Survey on May 15, 1995.

EXECUTIVE SUMMARY

This project seeks methods for the efficient utilization of coal combustion wastes. This project precisely meets this purpose by examining the use of Illinois fly ash in the manufacture of bricks and similar fired-clay products. The project is composed of three parts: 1) one or more plant-level manufacturing runs, and 2) a set of laboratory-scale experiments designed to predict the firing properties of mixtures of a range of compositions of fly ashes with clays and shales that represent the range of compositions typical of mines and power plants in Illinois; 3) a preliminary investigation of the potential environmental and economic benefits of brick manufacture with fly ash. The completion of these three program elements will provide strategies for maximizing the use of fly ash in bricks and related products.

The first task in this project is to obtain approximately 20 tons of fly ash from Illinois Power Co.'s Wood River Plant and ship it to Colonial Brick Company in Cayuga, Indiana, where in-plant tests of mixtures of Colonial's brick clays and I.P.'s fly ash will be made at the 20% or higher level. Colonial Brick will add progressively higher levels of fly ash until the bricks approach established specifications on water absorption. A single plant-scale run will probably be 5,000-10,000 bricks with fly ash, with pre- and post-fly ash baseline runs of several thousand bricks. A parallel part of the first task is to characterize the chemical and mineralogical content of the feed materials and to test the fired bricks by conventional procedures. A series of leaching tests also will be conducted on the feed fly ash, clays, and bricks. Procedures employed in previous ICCI studies will be used in the leaching tests of raw materials and bricks ([1]Dreher, Roy, and Steele, 1993). Chemical analyses of the feed materials will be by conventional methods. Methods developed in current investigations for ICCI will be used for mineralogical characterization ([2]Kruse et al., 1994; [3]Moore, Dreher, and Hughes, 1993).

In general, fly ash has a composition similar to raw materials used in brick manufacture. However, some fly ashes contain amounts of calcium (from calcite) and iron (from pyrite and marcasite) that would be considered too high by many manufacturers. If special procedures are used, fairly high levels of each of these constituents can be accommodated. If present as CaO or $Ca(OH)_2$, high levels of calcium can be corrected for by adding water in the cool-down part of the firing cycle. This was the method by which bricks known as "Chicago Commons" were manufactured. Both the color and lower melting point caused by high levels of iron are best adjusted for by increasing the quartz and/or kaolinite content of the clay/shale. If problems occur in the manufacturing run, we will resolve those in consultation with Colonial Brick Company.

The major goal of the first task is to make a realistic test under manufacturing conditions and detect and solve problems that might occur during scale-up at other sites. We have recently made arrangements for one or more plant-scale tests to be run during the second year of this investigation at Marseilles Brick Company.

The second task in this project is to attempt to improve the accuracy of methods that predict the firing characteristics of fired-clay raw materials. Part of the uncertainty about the exact level of fly ash that should have been used at Colonial in the manufacturing test is the result of inadequate methods of prediction of firing behavior. Improving the prediction of the firing behavior of fly ash-clay mixtures requires a set of working and practical relationships (predictive tools) that takes into account the firing properties of each of the major minerals in the feed material. The preferred materials for these fired-clay products occur as underclays and roof shales associated with coals and contain variable amounts of three basic groups of minerals. These groups are 1) relatively low-melting-point illite,

mixed-layered illite/smectite (I/S), and chlorite; 2) refractory kaolinite and mixed-layered kaolinite/expandables (K/E); and 3) somewhat refractory quartz. Common red-firing roof shales generally contain nearly ideal levels of groups 1 and 2, and adequate firing characteristics are obtained by blending clay-rich shale zones with sandier, quartz-rich zones. It is worth noting that some fly ashes probably will act as a sandier additive in combination with normal brick clays, although Colonial's test showed the opposite. If the manufacturer needs lighter color, greater strength, and/or increased refractoriness, a kaolinitic underclay (fireclay) is normally blended with zones from the shale. The individual minerals within each of the three mineralogical groups are similar enough that the three groups probably can be used in a simplified model. Furthermore, fly ash is made up of burned equivalents of these three mineral groups, and it should be possible to characterize the firing reactions of fly ash and fly ash-brick clay mixtures with the same simplifications.

The approach for task 2 will be to obtain from the ISGS reference collection clays that represent the range of compositional variation that is typical of fired-clay raw materials in Illinois. A set of Illinois fly ash samples will be selected to represent the range of composition of these materials. These samples will be fully characterized, and firing tests will be conducted to obtain data that describe the firing behavior of fly ashes, brick clays, and their mixtures.

Near the end of the project, existing information on brick clays and fly ash will be integrated with the results of this study to suggest solutions to problems that might inhibit use of fly ash in fired-clay products, to outline manufacturing and market strategies that might increase the use of fly ash in bricks, and to describe the environmental impact of using fly ash in these products. Methods to predict the firing characteristics of clays and fly ash, and of ash fusion of coals will be made available to interested parties. A preliminary evaluation will be made of potential benefits of the use of fly ash in fired-clay products. If the initial promise of this project is realized, we expect to be able to recycle large amounts of fly ash to valuable marketable fired-clay products such as bricks.

During the third quarter, we shipped 25 tons of fly ash from Illinois Power's Wood River Station and made a plant-scale brick manufacturing run at Colonial Brick Company. We had problems with dusting during the delivery of fly ash at Colonial. We will try to anticipate this problem in our future plant-scale tests. The fly ash-containing bricks scummed more than the controls and they 'burned out' (oxidized throughout) slower than expected. On the positive side, the impermeability caused the test bricks to have lower-than-expected water adsorptions. The firing problems do not appear to cause insurmountable problems. We are currently searching for fly ashes that might allow Colonial Brick to make arrangements for permanent use of fly ash in their plant. We completed characterization of initial clay samples from Colonial and Marseilles Brick, and we are nearly finished characterizing the shale and fly ash used in the production run at Colonial Brick.

We have constructed a computer database of the occurrence of Illinois brick clays. This database gives the location, type, and geological unit of all the clays evaluated by the Survey's Clay Minerals Unit in the last 60 years. A similar database of fly ash compositions has been calculated from Demir *et al.*'s database of the chemical composition of 34 coals, which they collected in 1992. This database will make possible in the next quarter the selection of three 'standard' fly ashes. Because brick manufacturers have problems with SO_2 emissions with clays, we will evaluate the potential of fly ash to absorb part of the SO_2 during firing of bricks. We expect to select two or three 50-pound reference samples for task 2 from Marseilles's clay pit.

We have revised the protocols from the characterization studies for coal combustion wastes and minerals in coals. We plan to complete these analyses early in the next quarter. The PI has begun a series of ceramic tests for another project that may yield better measures of firing performance. In the final report for year 1, these possible improvements will be discussed in detail.

On the management side of the project, Kristi K. Redding is leaving the project on May 31, 1995. The current discrepancy between projected and actual expenditures is due to delayed billing for shipping fly ash and for analyses. These shortfalls will be eliminated in the next quarter. Because the leaching tests are just being started, the sample after 6 months leaching will necessitate requesting a 6-month, no-cost extension of the project.

[1]Dreher, G. B., W. R. Roy, and J. D. Steele. 1993. Geochemistry of FBC waste-coal slurry solid mixtures, Final Technical Report to the Illinois Clean Coal Institute, September 1, 1992 through August 31, 1993, 26 pp. and Appendix, 10 pp.

[2]Kruse, C.W., R.E. Hughes, D.M. Moore, R.D. Harvey, and J. Xu. 1994. Illinois Basin Coal Sample Program, Final Technical Report to the Illinois Coal Development Board, Center for Research on Sulfur in Coal, Carterville, IL;

[3]Moore, D. M., G. B. Dreher, and R. E. Hughes. 1993. New procedure for x-ray diffraction characterization of flue gas desulfurization (FGD) and fluidized bed combustion (FBC) by-products. Project funded by the Coal Combustion Residues Management Program, Carbondale, IL.

OBJECTIVES

The primary goal of the proposed investigation is to test the use of fly ash in fired-clay products such as bricks. This goal is achieved by three tasks, which have as their objectives:

1. the manufacture under normal plant-scale conditions of bricks with 20% or more of fly ash;
2. the measurement of the firing characteristics of the known compositional extremes of Illinois fly ashes and brick clays and shales, and, from those measurements, the derivation of practical correlations to predict the firing characteristics of any mixture of clays and fly ashes. And finally, the optimization of mixtures of brick clays with typical fly ashes. (Methods that more accurately predict the firing behavior of brick clays and fly ashes also should improve predictions of ash fusion temperature of coals.)
3. the integration of results of goals 1 and 2 with preliminary engineering and market assessments to evaluate the feasibility of large-scale utilization of fly ash in fired-clay products;

INTRODUCTION AND BACKGROUND

The large amounts of fly ash that are produced during the burning of Illinois coals represent a continuing disposal problem and a disincentive to increased consumption of those coals. If significant amounts of fly ash could be used in the manufacture of fired-clay products such as brick, this disposal problem would be eliminated and a valuable construction product would be created. Furthermore, the clay minerals in coals are fired during burning, and the energy for this firing is "saved" during brick manufacture. Manufacturers of fired-clay products also would reduce mining costs and clay use in direct proportion to the amount of fly ash used in their products. Because this project addresses the needs of industry at both the laboratory- and plant-scale levels, we believe the results can be more easily transferred to the private sector and that the time required for application of those results will be minimized.

Better methods of predicting the firing behavior of bricks and related products are a second important aspect of the proposed investigation. Although general principles guiding the selection of raw materials for fired-clay products have been known for many years (Grim, 1962; Burst and Hughes, 1994), the complexity of the firing reactions suggests the need for improved methods (Hughes, 1993). This need is emphasized by the proposed work at Colonial Brick Company. Because we lack adequate methods of prediction, we must resort to trial-and-error methods for our first plant-scale test. Completion of task 2 of this project will make it possible for us to analyze a ceramic producer's raw materials and locally available fly ashes, and suggest optimum levels of fly ash that could be employed. The large amount of background information at the ISGS and the sophistication of computer programs now available make possible a significant improvement in methods needed to evaluate all the compositions of fly ash, shale, and underclay that might be encountered.

Improved methods of predicting coal ash fusion temperature are a final important outcome that is expected from this study. These improvements should make it easier for consumers to use Illinois coals and should benefit our producers accordingly. If successful, the results obtained from this project should lead to an attractive solution, from an environmental and economic standpoint, to recycle fly ash to high-value marketable products.

The ISGS has a long history of research related to coal and fired-clay products. The utilization of coal combustion wastes was the subject of recent studies by the Principle

Investigator (Hughes and DeMaris, 1992). Efforts to find better raw materials and improve the manufacture of fired-clay products have taken place over the last six decades at the Survey. Relevant parts of these efforts are summarized in Hughes and Bargh (1982), Hughes (1983), Hughes, DeMaris, and White (1983), and Hughes (1993). Slonaker (1977) showed that acceptable bricks were produced from feeds of 72% fly ash, 25% bottom ash, and 3% sodium silicate. A general discussion of the properties of fly ash that are important to its use in fired-clay products can be found in Kurgan, Balestrino, and Daley (1984). They report a fairly high alkalinity for fly ash from this region, and this could improve dispersion of the clay body during forming of bricks. If calcium in these materials is in a form that can react with sulfide during firing, fly ash may reduce SO_2 pollution during firing.

The development and use of leaching tests for the measurement of environmental impacts of coal combustion residues has been conducted by one of the Investigators (Dreher, Roy, and Steele, 1993). The PI and another Investigator have recently developed mineralogical characterization methods for the IBCSP samples and coal combustion wastes, respectively (Kruse *et al.*, 1994; Moore, Dreher, and Hughes, 1993). Mineralogical characterization methods for clays and shales are described in Hughes and Warren (1989) and Moore and Reynolds (1989). During the past three years, the PI also has carried out extensive research in ceramic clay products that are closely related to bricks and similar fired-clay products, and he has extensive experience in the clay processing industry. The capabilities of the ISGS in mineral process engineering and technical-economic studies are illustrated in several projects.

EXPERIMENTAL PROCEDURES

Subtask 1.1. Brick manufacturing runs. Illinois Power Company will provide a minimum of about 20 tons of dry fly ash from one of its power plants, preferably the Wood River station. Colonial Brick Company will plan a manufacturing run that will make about 5,000-20,000 bricks without fly ash and a similar number with a 20% fly ash added to the normal clay. A single previous run with fly ash by Colonial Brick Company indicated that 20% fly ash additions resulted in bricks that were within standard specifications. A batch of bricks of each of the two compositions will be fired side-by-side in the kiln and tested. If the bricks remain well within standard specifications, a higher level of fly ash may be tested. If unexpected problems occur at 20% fly ash, a slightly lower level will be tested with the same experimental approach. This subtask will be completed during the third quarter of the first year of this investigation. Upon completion of the first runs, the standard properties of the bricks will be evaluated. If satisfactory results are obtained, additional tests will be planned for the second year of the study. Also, additional manufacturing tests have been arranged for at another brick company in Illinois for the second year of this project.

Subtask 1.2. Standard specification tests. This subtask will be carried out by Colonial Brick and measures the degree of conformance of the manufactured bricks with standard market specifications. Samples with and without fly ash will be taken during firing to provide a measure of "clearing" or time required to completely oxidize the core of the bricks. Water absorption tests will be carried out on the fired products, and color will be described by comparing bricks with and without fly ash additions.

Subtask 1.3. Characterization. In this subtask we will characterize chemically and mineralogically each feed material and the resulting bricks. The characterization will include the quantitative determination of major, minor, and trace elemental constituents, and major and minor mineralogical components. The segregation of elements between different mineral phases in the feed materials will be estimated by using a step-wise dissolution procedure in conjunction with X-ray diffraction analysis (Moore, Dreher, and Hughes, 1993).

Subtask 1.4. Leaching tests. Leach testing procedures developed by Dreher *et al.* (1988, 1989) will be used to determine the extent to which environmentally toxic constituents might leach from bricks to the environment. Batch extraction and wet-dry leaching experiments, in which the substrate is exposed to deionized water for a given time period, will be conducted using raw fly ash, the mixture of clay and fly ash used in the brick-making process, and crushed and whole bricks prepared with up to five fly ash-clay mixtures. Except for the analyses conducted in Subtask 1.3, each solid will be analyzed chemically and mineralogically prior to extraction and leaching experiments.

In leaching whole bricks, five faces will be protected from leaching by application of an epoxy coating. One long face of each brick will be left uncoated to simulate exposure of one face to weathering.

Batch experiments will be conducted at solution-to-solid ratios of 4:1 for periods of 3, 10, 30, 90, and 180 days for each of the solids. Each batch extraction container will be agitated periodically during the extraction period to assure adequate contact between solution and solid. At the end of each extraction period, the solution and solid phases will be separated for chemical analysis. The solids also will be analyzed mineralogically. A total of up to twelve solids, that is, raw fly ash, clay, and up to five brick compositions (crushed and whole) will be tested in duplicate, for a total of up to 24 batch extractions.

Subtask 1.5. Integration. Upon completion of the manufacturing run and characterization described in subtasks 1.1 - 1.3, an evaluation will be made of the feasibility of manufacture of fired-clay products with fly ash additions. This evaluation will be used to modify plant-scale tests during year 2 and to focus detailed experiments planned for the research effort in Task 2.

Task 2. Predicting the Firing of Fly Ash and Brick Clay Mixtures.

Subtask 2.1. Background. This subtask seeks to assemble background information on the composition of Illinois fly ashes and on clays and shales used in fired-clay products manufacture. For fly ashes, data are needed on the range of chemical and mineralogical composition that is possible and on the plant location where these fly ashes are generated. For clays and shales, information must be collected together that describes where typical deposits occur and the relative content at each locality of the three basic raw materials used in fired-clay products in Illinois– 1) clays and shales with a red-firing or "shale-type" composition; 2) clays with refractory or "fireclay-type" compositions; and 3) sandier red-firing shales that are often blended with shaley and refractory clays.

Subtask 2.2. Selecting samples. Based on the results of the background search, three fly ashes and two or three clays or shales will be selected to represent the range of composition encountered in Illinois. Fresh 50-pound samples of all six materials will be collected and stored at field moisture content.

Subtask 2.3. Characterizing samples. In this subtask, selected samples will be characterized chemically and mineralogically. The characterization will include the quantitative determination of major, minor, and selected trace elements and the mineralogical composition of the samples. The step-wise dissolution procedure in conjunction with X-ray diffraction analysis also will be conducted in order to estimate the segregation of elements among various mineralogical phases (Moore, Dreher, and Hughes, 1993).

Subtask 2.4. Firing tests. Determinations of the melting temperature or pyrometric cone equivalent (PCE), water adsorption, and color will be made for each of the six samples and for 30 mixtures and replicates that measure all possible combinations of the materials. Six replicate and eight standard PCE samples will be included to "calibrate" the method and measure errors.

Subtask 2.5. Predicting firing. Using results from 2.4, factorial and regression computer software will be used to obtain equations that measure the effect on fired properties of additions of each of the basic components from the raw materials. The results of these computer runs also include an estimate of error, and this estimate will be used to confirm that sufficient samples were tested or that more experiments must be run.

Subtask 2.6. Programming. The equations generated in subtask 2.5 will be incorporated within one or more computer programs. These programs will be made available to interested parties.

Task 3. Integration, Evaluation, and Technology Transfer

Subtask 3.1. Integration and evaluation. This subtask will bring all the results together, evaluate them from an engineering- and market-oriented point of view, and estimate the overall feasibility of using significant amounts of fly ash in fired-clay products. This subtask will evaluate the technical, economic, and environmental aspects of recycling Illinois fly ash in bricks.

Subtask 3.2. Quarterly, interim final, and final reports. The results from all phases of this project will be brought together in a final report. This report will include a description of any computer programs that are generated.

Subtask 3.3. Technology transfer. The investigators will communicate the results of this study to interested parties in the public and private sector. This transfer of information will include presentations, publications, and visits or telephone calls with industrial representatives.

RESULTS AND DISCUSSION

During the third quarter of this project, we completed the plant-scale manufacturing run at Colonial Brick Company. Based on recommendations from Illinois Power Company, fly ash was obtained from their Wood River Plant. The dust associated with unloading fly ash at Colonial Brick was an unexpected problem. We tried to minimize this problem by pumping the fly ash under a large tarp that had its edges staked to the ground. However, this method did little to reduce dusting, and for year 2 testing, we need a solution that provides better dust control at Marseilles Brick Company. If fly ash is used on a more permanent basis, various ways to dampen this material may be required at the power plant.

The results of the production run were somewhat unexpected. We expected the fly ash to increase gas movement into and out of the bricks, and the reverse occurred. Essentially, the fly ash decreased the permeability of the bricks to oxidation, although we expected the fly ash to "open up" the bricks during firing. The bricks with fly ash had noticeably more "scumming", which also was unexpected. This scumming causes a white to cream dusting on the outside of the bricks and is mostly due to the crystallization of calcium sulfates during firing. We will attempt to confirm this assumption with our chemical analyses. The problem can be corrected by adding barium carbonate, or it may be possible to simply select a fly ash with lower calcium sulfate content. The positive side of the effect of fly ash on gas permeability was the absence of the expected increase in water adsorption.

We have completed our characterization of brick clays available at Colonial Brick and Marseilles Brick Companies (see Table 1). The mineralogical contents of these clays will be used to estimate their chemical composition, and these estimates will be compared to actual analyses. During the third quarter, we finished constructing a data base of the occurrence of brick clays in Illinois. This database contains more than 25,000 records of the location, type, and geological unit for all the clays worked on in the Clay Minerals Unit since the 1930s.

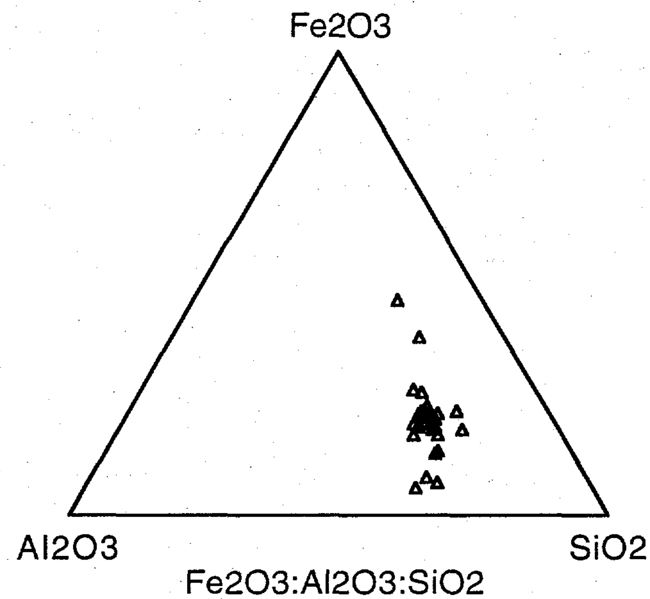


Figure 1. The ratio of Fe_2O_3 to Al_2O_3 to SiO_2 for a 'fly ash' calculated from Demir et al.'s chemical analyses of the Illinois commercial coals in 1992.

We obtained from Ilham Demir a spreadsheet copy of the large database of the chemical composition of 34 Illinois coals that Dr. Demir and colleagues collected in 1992 for ICCI projects. This database was processed to simulate the production of fly ash from these coals. Triangular plots of the calculated ash content were constructed (Figs. 1, 2), and these plots will be used to select 3 'representative' fly ashes. Generally, we will select locally available fly ash compositions that are relatively rich in 1) SiO_2+Al_2O_3, 2) Fe_2O_3, and 3) CaO (Fig. 2). These constituents represent most of the ash content of Illinois coals, and the ratio of these oxides to Na_2O and K_2O is relatively constant. We also plan to obtain chemical analyses of fly ashes produced from the coals represented in Demir's database. These analyses will be compared with spreadsheet predictions, and adjustments will be made if they seem necessary. A final goal in this area for the next quarter is to construct regression equations between the chemical and mineralogical contents of the IBCSP coals and use those equations to estimate the mineralogical content of Demir's 34 commercial coals.

An unanticipated benefit from using fly ash may be its ability to capture sulfur from the clays during firing. Problems with SO_2 emissions are common in brick production, and the testing of high-CaO fly ashes has been added to the project for that reason.

We recently reviewed and revised the protocols from the characterization studies for coal combustion wastes and minerals in coals that were part of ICCI's projects last year. A new SOP has been constructed for step-dissolution analyses. This protocol uses a high liquid:solid, 2N HCl, and sampling on an exponential time scale (1 hr, 4 hr, ... 256 hr). Completely stirred, 50 ml samples will be extracted at each sampling time; the samples will be centrifuged; the supernate will be submitted for ICP chemical analysis; and the solid will be mixed and smeared on an X-ray diffraction slide. We plan to begin these analyses early next quarter. The PI has begun a series of ceramic tests for another project that may yield better measures of firing performance for the second year of this study. Near the end of the first project year, these possible improvements will be discussed in detail.

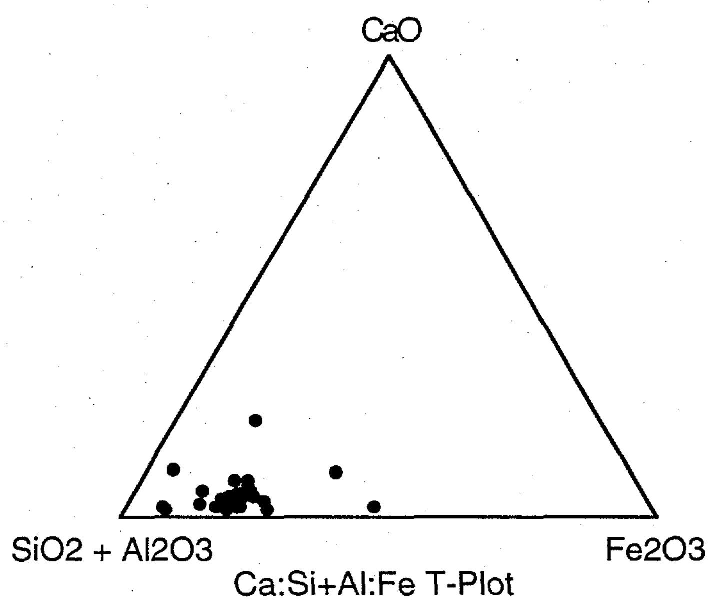


Figure 2. A plot of CaO to $SiO_2 + Al_2O_3$ to Fe_2O_3 calculated in the same way as Figure 1.

Table 1. Mineralogical analyses of Colonial (a and T) and Marseilles Brick clays (b)

Sample	%I/S	%I	%K/E	%K	%C	%Q	%Kf	%Pf	%Cc	%Py
Shalea	10	25	0	8.9	11	39	0.1	5.9	0.0	0.0
Fireclaya	45	10	0	7.8	0.0	34	0.0	1.3	0.0	2.1
Shale bricka	15	19	0	5.7	6.5	47	0.2	6.0	0.0	1.5
Fireclaya repeat	45	10	0	7.8	0.0	33	0.0	1.3	0.0	3.1
Fireclayb	19	3.4	22	7.6	0.0	44	0.4	0.0	0.0	2.9
Shaleb	17	18	0	3.1	7.4	48	0.4	5.8	0.0	0.0
ShaleT	17	16	0	5.3	5.1	47	1.3	8.2	0.0	0.0
ShaleT repeat	15	19	0	6.1	7.6	46	0.0	6.8	0.0	0.0
FireclayT	27	6.9	14	7.6	2.1	37	0.0	1.7	0.8	2.1
FireclayT repeat	33	6.4	13	7.0	1.6	34	0.4	1.4	0.8	2.0
Fly ashT						11				
Fly ashT repeat						12				

Key: Samples a, b, T = Colonial Brick 3/94, Marseilles Brick 10/94, and Colonial Brick 4/95, respectively; I/S = mixed-layered illite/smectite; I = illite; K/E = mixed-layered kaolinite/expandables; K = kaolinite; C = chlorite; Q = quartz; Kf = K-feldspar; Pf = plagioclase feldspar; Py-Ma = pyrite-marcasite; shale-brick* = shale from green brick.

CONCLUSIONS AND RECOMMENDATIONS

Additions of fly ash at the 20% level increased scumming and 'burn-out' problems during plant-scale tests at Colonial Brick Company. Therefore, we will put more emphasis in the next quarter on identifying the composition of fly ashes available in the area. These problems are not expected to cause insurmountable difficulties, but they need to be addressed in the near future. In particular, we will look for fly ashes high in CaO and alumina-silica. With that information and an analysis of the fly ash that we used in the Colonial Brick tests, we may be able to test another fly ash at this brick plant. When we know the composition of fly ashes at each source, we also can select the three (3) that will act as 'standards' in our optimization study. With clays and fly ashes in hand, the task 2 firing experiments can be started. We revised step-dissolution protocols from previous studies, and we are now ready to complete those analyses early in the next quarter.

Characterization of the clays used at Colonial and Marseilles Brick Companies was completed in the third quarter. A large computer database of the ceramic clays of Illinois also was completed, and Demir *et al.*'s 1992 database of commercial coals was processed to estimate the fly ash composition that would be derived from burning each coal. This information will be used to locate representative fly ashes for task 2, and it may be possible to extrapolate a mineralogical composition for these 34 coals.

It may be possible to run some firing tests for task 2 at Marseilles Brick Company next year. Early in the next quarter, we will visit the Company and explore this possibility.

Recent studies of the firing behavior of bricks and related materials suggest that we may need to expand the number of tests that are used to quantify the quality of fired-clay products. This expansion might add water adsorption, shrinkage, rate of burnout, and hardness to the planned pyrometric cone equivalent (PCE) tests for year 2.

By speeding up the work on task 2 and completing most of task 1, we are at or ahead of schedule for all parts of the project, except the leaching tests. Those experiments are being set up, so only the 6-month sample will be unfinished at the end of the contract year.

REFERENCES

Burst, J.F. and R.E. Hughes. 1994. Clay-based ceramic raw materials; In D.D. Carr, (ed.), 6th Edition, Industrial Minerals and Rocks, Soc. Mining Eng., Denver, CO, 317-324.

Dreher, G. B., M. Rostam-Abadi, W. R. Roy, D. M. Rapp, S. C. Mravik, I. Demir, J. D. Steele, R. R. Ruch, and R. L. Berger. 1988. Factors affecting management of ISGS Aggregate Flotation waste solids. Final Technical Report to the Illinois Coal Development Boar, Center for Research on Sulfur in Coal, Champaign, IL, 29 p.

Dreher, G. B., M. Rostam-Abadi, W. R. Roy, J. D. Steele, D. M. Rapp, W.-T. Chen, and R. L. Berger. 1989. Factors affecting management of fine-coal cleaning waste solids. Final Technical Report to the Illinois Coal Development Board, Center for Research on Sulfur in Coal, Carterville, IL, 50 p.

Dreher, G. B., W. R. Roy, and J. D. Steele. 1993. Geochemistry of FBC waste-coal slurry solid mixtures, Final Technical Report to the Illinois Coal Development Board, Center for Research on Sulfur in Coal, Carterville, IL, 26 p. and Appendix, 10 p.

Grim, R.E. 1962. Applied Clay Mineralogy. McGraw-Hill Book Company, Inc., New York, 422p.

Hughes, R. E. and B. L. Bargh. 1982. The weathering of brick: causes, assessment, and measurement. Contract Report on Joint Funding Agreement between ISGS and USGS (also in NTIS), 76 p.

Hughes, R. E. 1983. Part 2: Mineralogy and potential economic uses of colliery waste from the Historic Longwall Mining District, north-central Illinois. Illinois Geological Survey Contract Report to the Abandoned Mined Lands Reclamation Council, Springfield, Illinois. 21 p.

Hughes, R. E., B. L. Bargh, and W. A. White. 1983. The expansion and weathering of brick. Proceedings of the 18th Forum on the Geology of Industrial Minerals, Bloomington, Indiana. 183-197.

Hughes, R. E., P. J. DeMaris, W. A. White, and D. K. Cowin. 1987. Origin of clay minerals in Pennsylvanian strata of the Illinois Basin. Proc. 8th Intern. Clay Conference, Denver, Colorado, July 28-August 2, 1985, 97-104.

Hughes, R. E. and R. L. Warren. 1989. Evaluation of the economic usefulness of earth materials by X-ray diffraction. Proceedings of the 23rd Forum on the Geology of Industrial Minerals, R. E. Hughes and J. C. Bradbury, eds., North Aurora, Illinois, May 11-15, 1987, Industrial Minerals Notes 102, Illinois State Geological Survey, 47-57.

Hughes, R. E. , P. J. DeMaris, and W. A. White. 1992. Underclays and related paleosols associated with coals. In I. P. Martini and W. Chesworth, eds., Weathering, Soils and Paleosols, Elsevier, Amsterdam, 618 p.

Hughes, R.E., and P.J. DeMaris. 1992. DUCCR Program Final Report: Utilization of Coal Conversion Residues; Coal Combustion Residues Management Program, Southern Illinois University, Carbondale, IL, 49p.

Hughes, R.E. 1993. Clay resources associated with lower Pennsylvanian coals. In Preprints Symposium on Economic Resources of the Lower Pennsylvanian of the Illinois Basin, Indiana Geological Survey, Bloomington, IN, November 10-11, 1993, 29-37.

Kruse, C.W., R.E. Hughes, D.M. Moore, R.D. Harvey, and J. Xu, 1994, Illinois Basin Coal Sample Program, Final Technical Report to the Illinois Coal Development Board, Center for Research on Sulfur in Coal, Carterville, IL.

Kurgan, G.J., J.M. Balestrino, and J.R. Daley. 1984. Coal combustion by-products utilization manual. Volume 1: Evaluating the utilization option. Electric Power Research Institute, CS-3122, Volume 1, Research Project 1850-1, Palo Alto, CA, 3-1 to 3-34.

Moore, D. M., G. B. Dreher, and R. E. Hughes. 1993. New procedure for X-ray diffraction characterization of flue gas desulfurization (FGD) and fluidized bed combustion (FBC) by-products. Project funded by the Coal Combustion Residues Management Program, Carbondale, IL.

Moore, D. M. and R. C. Reynolds Jr. 1989. X-Ray Diffraction and the Identification and Analysis of Clay Minerals. Oxford University Press, New York, 337 p.

Slonaker, J.F. 1977. The role of fly ash brick manufacturing in energy conservation; Coal Research Bureau, College of Mineral and Energy Resources, W. Virginia University, Report No. 149, Morgantown, WV, 6p.

PROJECT MANAGEMENT REPORT
March 1 through May 31, 1995

Project Title: **BRICK MANUFACTURE WITH FLY ASH FROM ILLINOIS COALS**

DOE Cooperative Agreement Number:	DE-FC22-92PC92521 (Year 3)
ICCI Project Number:	94-1/3.1A-10M
Principal Investigator:	Randall E. Hughes, ISGS
Other Investigators:	Gary Dreher, ISGS; Tanda Fiocchi, Ill. Power Co.; Joyce Frost, ISGS; Duane Moore, ISGS; Massoud Rostam-Abadi, ISGS; Daniel Swartz, Colonial Brick Co.
Project Manager:	Dr. Daniel B. Banerjee, ICCI

COMMENTS

No significant variances in project management have occurred. A reduction in actual expenditures results from the delay in a personnel appointment until March 1, 1995 and delayed payments for analytical services. These budget anomalies are expected to "zero-out" by the end of the contract year. In particular, the $20,000 difference between projected and actual expenditures is exactly matched by $20,000 of commitments in **Other Direct Costs**. Kristi K. Redding has been employed 50% time on this project and has informed us that she is leaving the Survey effective May 31, 1995. Because we knew about this in advance, we focused her efforts on tasks that she needed to complete this year. Those tasks have been completed. We have hired Kamran Ghiassi as a temporary hourly assistant this summer.

The only difficulty in project scheduling resulted from delays in obtaining fly ash from Illinois Power's Wood River Plant. Those delays should be eliminated in the near future. However, leaching tests that run for 180 days will have to be completed in Year 2 of the research. For this reason, we expect to need a no-cost extension. Otherwise, all personnel are in place, and the project is proceeding as planned.

EXPENDITURES - EXHIBIT B

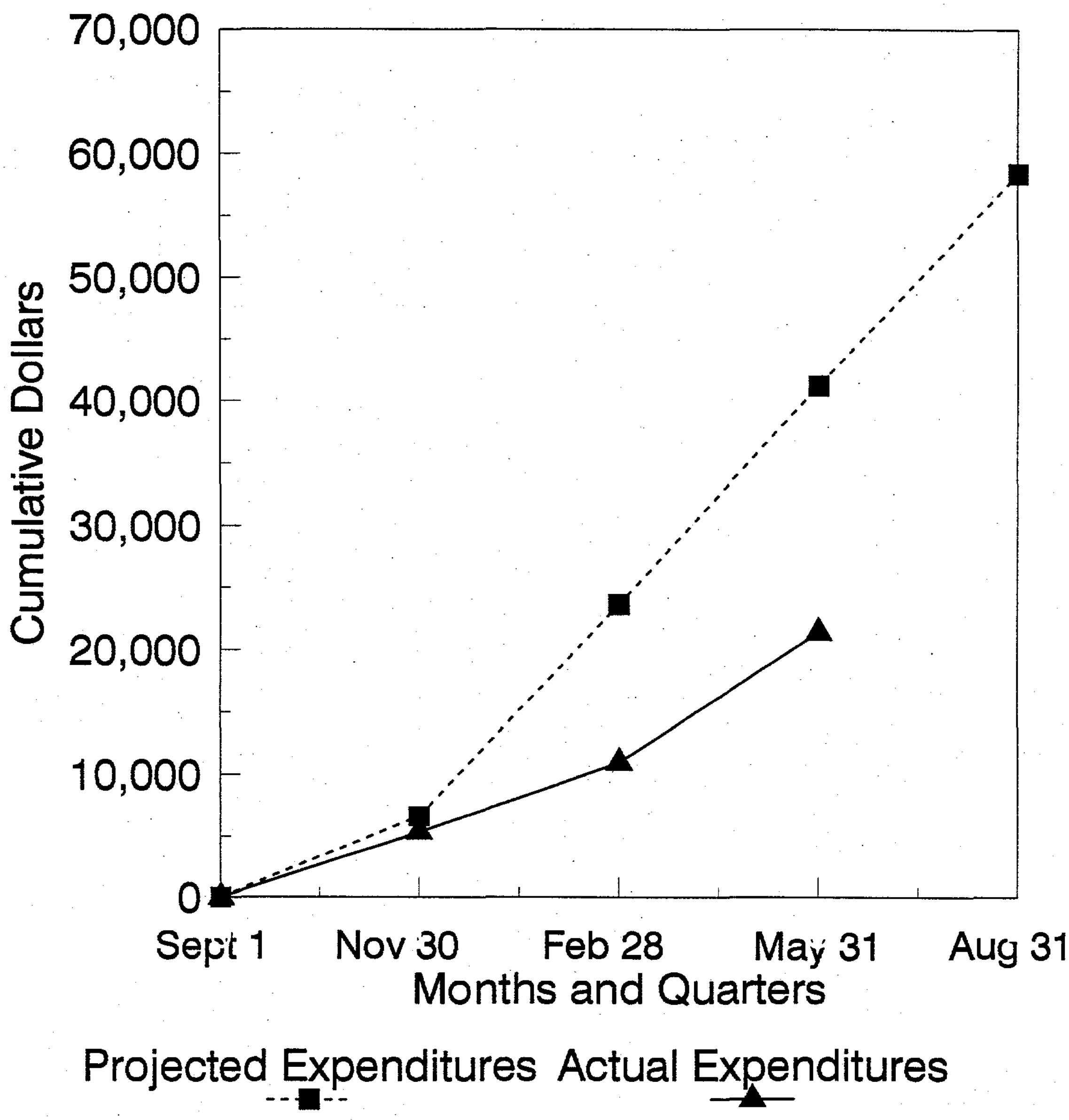
. Projected and Estimated Expenditures by Quarter

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials & Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Costs	Total
9/1/94 to 11/30/94	Projected	6157	752	130	150	0	3000	601	6613
	Estimated	3693	329	0	0	0	835	486	5343
9/1/94 to 2/28/95	Projected	12314	1505	410	350	0	10202	2150	23652
	Estimated	7386	658	208	36	0	1675	996	10960
9/1/94 to 5/31/95	Projected	18470	2257	615	950	0	17404	3747	41219
	Estimated	13763	1469	516	886	0	2845	1948	21428
9/1/94 to 8/31/95	Projected	23457	3009	820	1200	0	24606	5309	58401
	Estimated								

***Cumulative by Quarter**

CUMULATIVE COST BY QUARTER - EXHIBIT C

BRICK MANUFACTURE WITH FLY ASH FROM ILLINOIS COAL



Total ICCI Award $ 58,401

SCHEDULE OF PROJECT MILESTONES

Begin 9/1/94	S	D	M	J	S	D	M	J	S	End 8/31/96
A	X		X		●		X		X	
B	X		X		●		X		X	
C	X					0 X			X	
D	X								X	
E			X		X- - - 0			X	X	
F		X		X■						
G		X		X - - - 0						
H			X		X					
I			X			X				
J				X				X		
K						X		X		
L		X							X	
M		Q1■	Q2■		Q3■	F1	Q5	Q6	Q7	F2
N		X							X	

Milestones:

Task 1. Plant Scale Manufacture of Bricks With and Without Fly Ash

A 1.1. Manufacturing runs at brick plant
B 1.2. Testing brick for standard specifications
C 1.3. Characterization of raw materials
D 1.4. Leaching tests (drained Yr1 and wet/dry Yr2)
E 1.5. Integration of results

Task 2. Predicting Firing Characteristics of Fly Ash-Clay Mixtures

F 2.1. Background assessment
G 2.2. Sample selection
H 2.3. Characterization
I 2.4. Firing tests
J 2.5. Predicting firing behavior
K 2.6. Programming results

Task 3. Integration, Evaluation, and Technology Transfer

L 3.1. Integration and evaluation
M 3.2. Quarterly, interim final, and final reports
N 3.3. Technology transfer