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# Coal Log Pipeline Research at the University of Missouri

## 4th Quarterly Report for 1993

## 10/1/93 - 12/31/93

**Henry Liu**
**Professor and Director**
**Capsule Pipeline Research Center**

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**Project Sponsors:**

**National Science Foundation (IUCRC Program)**

**State of Missouri (Department of Economic Development)**

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**Coal Log Pipeline Consortium:**
- Arch Mineral Corporation
- Associated Electric Coop.
- MAPCO Transportation, Inc.
- Union Electric Company
- Williams Pipe Line Company
- Williams Technologies, Inc.

**Small Business Participants:**
- Bonnot Company
- Gundlach Machine Company
- Erie Press Systems
- Nova Tech, Inc.
- Pro-Mark Process Systems
- Ramer & Associates

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# EXECUTIVE SUMMARY

During this quarter, **major progress** has been made in the following areas of coal log pipeline (CLP) research:

1. Completed the installation of the large ram extruder and succeeded in making good quality coal logs with this ram using as little as 3% emulsified asphalt (work based on Dr. Marrero and Mr. Burkett).
2. Tested the effectiveness of Orimulsion as a low-cost substitute for asphalt emulsion to be used as binder. It was found that the Orimulsion appears as effective as asphalt emulsion but costs much less (about $50 per ton as compared to $150 per ton for asphalt emulsion). This new binder may greatly enhance the economics of coal log fabrication. (Work based on Dr. Wilson and Dr. Ding).
3. Eliminated circumferencial microcracks in coal logs by using a two-piece split mold. Such logs are more abrasion-resistant in transport through pipeline than those made with a single-piece mold.
4. Succeeded in compacting and extruding coal fines (normally a waste material) without binder and at room temperature. Such logs, though not strong enough to be transported by pipeline over long distances, are sufficiently strong for handling and transport by trucks, trains, barges, ships and conveyer belts. It may provide an answer to coal companies' and utilities' coal fine problems. (Based on Dr. Lin and Becky Smith's work).
5. Found that by using a small amount (25ppm) of a polymer (polyethylene oxide) in a coal log pipeline operating at lift-off velocity, drag reduction as much as 75% can be achieved. This is equivalent to a reduction of pressure gradient (energy loss) in the pipe by 400%! It has immense implications for the energy conservation and the cost reduction of the CLP technology. (Based on Huang's work supervised by Dr. Liu).

6. Designed a coal log train separator that appears to be able to separate coal log trains prior to entering pump bypass. The separator-bypass system can operate automatically without relying on any coal log sensors. (Concept not yet tested). (Based on Du's work supervised by Dr. Nair).
7. Completed the first draft of a Ph.D dissertation "Dynamic Modeling of an HCP System and Its Control." This shows that the Center's long-term research on this complicated topic is finally yielding fruit. The dissertation provides detailed information on how to model and analyze the behavior of coal log trains passing through the injection system and the pump bypass. It forms the basis of computer control of coal log pipeline systems. (Based on Wu's Research jointly supervised by Drs. Lenau, Liu and Nair).
8. Completed all the experiments needed to verify a mathematical model to predict capsule behavior in unsteady flow of HCP and CLP. The experimental data showed good agreement with theory. The student has completed both experimental and analytical works, and has started to write his Ph.D dissertation. (Based on El-Bayya's research supervised by Dr. Lenau).
9. Revised an earlier design of commercial coal log fabrication machine. Improved the mold design by making it easier to operate. (Dr. Lin).
10. Developed a research plan for studying the heating, cooling, and drying of coal logs. (Based on Sun's work supervised by Dr. Marrero).

**Major activities planned for the next quarter include:**

1. Make 5.3" diameter logs, both by compaction and extrusion, for a field test to be conducted in a 6-inch existing pipeline in Conway, Kansas.
2. Test two new design concepts to improve the quality of coal logs fabricated by the single-piece mold: (1) tapered mold, (2) bell-shaped exit.
3. Complete a preliminary theory on coal log compaction in order to make predictions feasible.

4. Test three concepts on coal log fabrication with emulsified asphalt: (1) Compare logs made with varying amount of water in emulsion. (2) Compare negatively charged emulsion with positive and neutral emulsions. (3) Vary coal particle size.
5. Conduct a more complete assessment of the Orimulsion, including its (1) supply dependability and price stability, (2) combustion emission characteristics (what comes out the stack when Orimulsion is burnt with coal). More tests on its effectiveness as a binder is also needed at temperature up to 80°C.
6. Test zeta potential effect on coal log fabrication.
7. More tests on underwater extrusion.
8. Complete drag-reduction study in 2-inch pipe using Polyox. Try another polymer (Chemlink) and compare its effectiveness with Polyox. Add a small amount of fiber (pulp) to further enhance the effectiveness of polymers for drag reduction.
9. Complete analysis of train separator and test the concept in existing small-scale CLP demo model.
10. Conduct coal log wear test in pipe with artificial rough joints.
11. Prepare for and conduct capsule jamming test in 2-inch pipe loop.
12. Complete a Ph.D dissertation on dynamic modeling of CLP system, and a Ph.D dissertation on unsteady theory of capsule flow.
13. Complete two alternate designs on commercial coal log fabrication machines, one by Professor Yuyi Lin, and the other by Ramer/Gunlach. Submit both designs to Erie Press for evaluation.
14. Develop equations for predicting coal log heating, cooling and drying.
15. Conduct coal log water absorption tests aimed at verifying a theoretical model.
16. Write legal position papers on several issues relating to coal pipelines.

# Capsule Pipeline Research Center

## Quarterly Report

## (Period Covered: 10/1/93 to 12/31/93)

**Project Title:** Extrusion of Coal Logs Using Ram-Type Extruder

**Principal Investigators:** Thomas R. Marrero
Associate Professor of Chemical Engineering
William J. Burkett
Research Associate, Chemical Engineering

**Undergraduate Assistants:** Andrew Rockabrand
Erika T. Carter

### Purpose of the Research:

Test and evaluate ram-type extrusion to develop large diameter coal logs for commercial demonstration.

### Work Accomplished:

A commercial, (large) ram-type extruder was located, purchased, delivered, installed and is now in operation. This unit, a 100 ton extruder, was purchased from Great Lakes Research, Elizabethton, TN. New solid state controls for heating the die and mud pot were specified, procured and installed. In addition, new electrical power wiring and source were installed. Coal logs have been extruded in 100 pound batches, several times.

Since it appeared that an auger-type extruder produced logs with undesirable surface imperfections, a ram (piston) type extruder was sought. After a number of inquiries, a surplus unit was located and purchased.. The price ($15,000) included dismantling system, removal from building, truck transportation, unloading and installation. The extruder has three major pieces, namely, a pug mixer, a cooling chamber, and the extruder. Additional equipment included a set of dies from 2 to about 10 inches. A photograph of the extrusion system is at the end of this report.

The 100-ton extruder has been run three times using an emulsified asphalt binder. This formulation has allowed us to obtain operating experience and to correct minor equipment problems.

To operate the 100-ton extruder relatively large batches are required. Before using this large machine a small test unit, 1 3/4" by 2 1/2" was made to allow optimization of conditions.

Preliminary ram extrusion run data indicate 3 weight percent asphalt is needed at a pressure of about 5000 psi, without heating the coal feed mixture or the extruder. The coal log surfaces are much smoother than logs produced by the auger type extruder.

**Work Proposed for Next Quarter:**

Task 1. Using the 1 3/4" by 2 1/2" small unit explore formulas and conditions using the 1 3/4" by 2 1/2" small unit. This duplicates ram extrusion type conditions using only 2 pounds of feed material. On the basis of these tests, large batches of 100 pounds will be tried in the 100-ton extruder.

Task 2. The installed die produces 5.5" diameter logs. This is too large for use in a 6" pipe (Kansas test pipe). A modification to this die to produce 5.3" diameter logs will be built.

Task 3. Produce 5.3" coal logs for in-laboratory testing of strength and water absorption after a modified die is made.

Task 4. Explore the use of increasing the particle size from the laboratory 3/8" maximum to larger sizes currently commercial available.

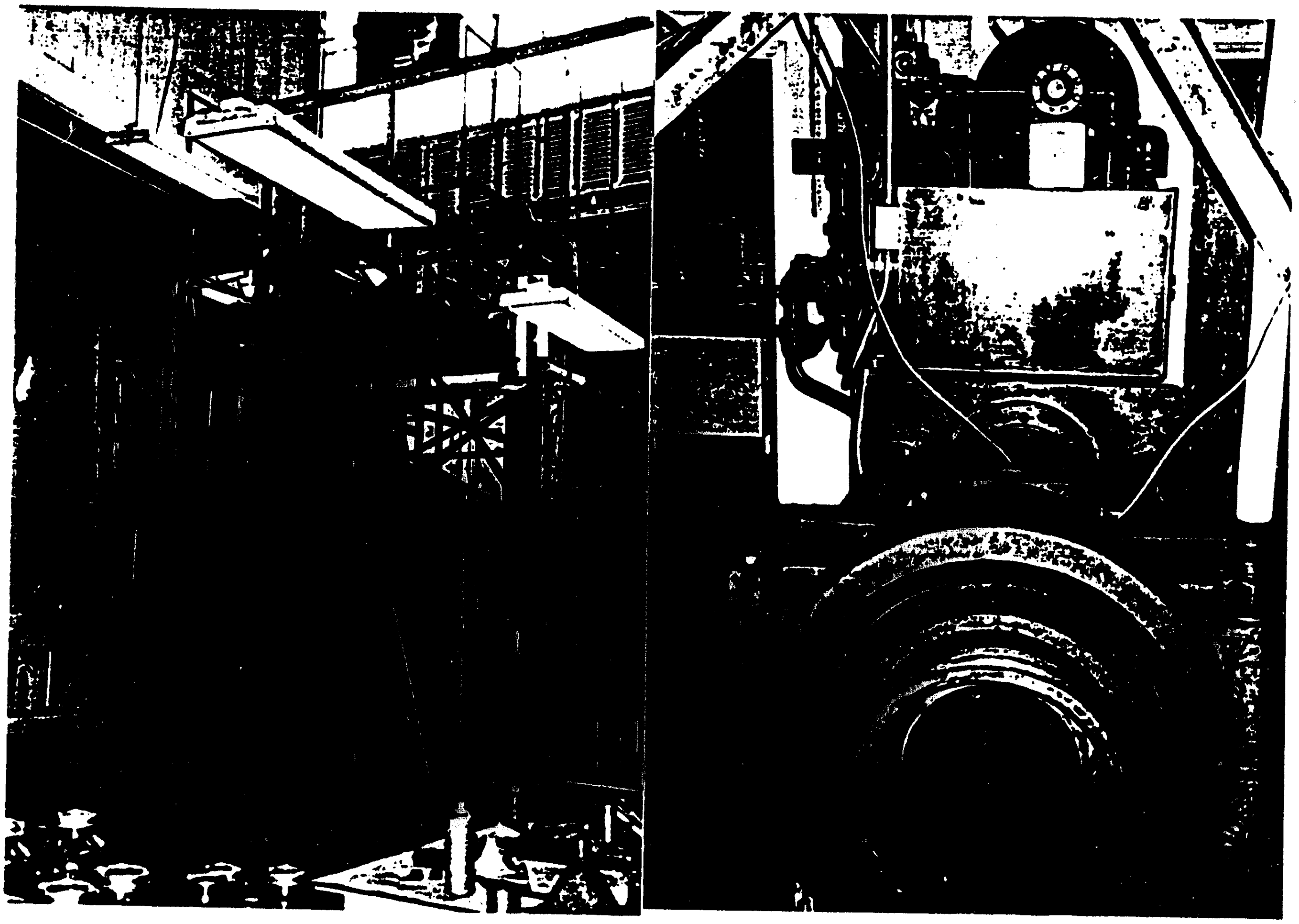

Figure 1. Elms 100-ton ram type extruder

# 4th Quarterly Report Coal Log Pipeline Project

Project Title: Coal Log Fabrication Using Hydrophobic Binders

PI: Dr. John W. Wilson

Post-Doctoral Fellow: Dr. Yungchin Ding

Graduate Research Assistant: Bing Zhao

## OVERVIEW:

The bench scale coal log fabrication experiments using Powder River Basin coal have been completed in this quarter (10/1/93-12/31/93). Several coal log fabrication process parameters, including compaction time, heating temperature, compaction pressure, and binder concentration, were investigated to determine the optimum operating conditions for coal log fabrication. The coal logs produced were also subjected to various tests, such as water absorption, tensile strength, and degradation, to evaluate the influence of fabrication parameters on the properties of coal logs.

Coal log fabrication using coal samples obtained from Mettiki Coal Corporation was also started in this quarter. A new emulsion binder (Orimulsion) was used as the binding agent. The test results todate show that the coal logs produced using Orimulsion have similar performance characteristics when compared with coal logs fabricated using asphalt emulsion (PC-150).

## PROGRESS TO DATE;

### A. Evaluation of Coal Log Fabrication Parameters (PRB coal)

Several operating parameters, including compaction time, heating temperature, compaction pressure, and binder concentration, were tested. The coal logs produced under various conditions were evaluated to determine the influence of these operating parameters on the performance of the coal logs manufactured.

1. Compaction time:

1-3/4" coal logs were fabricated at compaction times (peak loading time) of 5 to 20 min. The coal log fabrication conditions and test results were as follows:

Coal log fabrication: 2% asphalt (3.3% PC-150 asphalt emulsion)
6,000 psi compaction pressure
80°C heating temperature
Water absorption tests: 500 psi pressurized chamber
Degradation tests: 2 hrs in 2" test pipeline loop, at velocity of 7.5 ft./sec.

Table 1. Influence of compaction time on the performance of coal logs

| Compaction Time, min. | Density | Water Abs. Wt. gain, % | Degradation test Wt. Loss, % | Tensile Strength, psi |
|---|---|---|---|---|
| 5 | 1.18 | 8.03 | 13.6 | 52.9 |
| 10 | 1.18 | 7.56 | 7.5 | 56.7 |
| 15 | 1.20 | 7.48 | 6.7 | 56.9 |
| 20 | 1.20 | 6.08 | 5.5 | 58.7 |

As shown in Table 1, the duration of compaction time has only a slight influence on the properties of the coal logs. The water absorption test results show that the amount of water absorbed decreased as the compaction time increased. This suggests that the longer the compaction time the more dense the coal logs. Table 1 also shows that the longer the compaction time the higher the tensile strength of the coal log. In the pipeline degradation tests, the greatest weight loss was found on the coal log which was compacted for 5 min. This could be due to either the low strength of the coal log, or the high abrasion effect that the coal log was subjected to due to its leading position in all four coal logs tested in the pipeline.

2. Heating temperature

In order to evaluate the role of compaction temperature in the coal log fabricating process, the compaction temperatures in the range of 40 to 100°C were used to determine their influence on the properties of the coal log. The test conditions applicable and the results obtained are shown as follows:

Coal log fabrication: 2% asphalt (3.3% PC-150 asphalt emulsion)
6,000 psi compaction pressure
10 min compaction time
Water absorption tests: 500 psi pressurized chamber

Table 2. Influence of heating temperature on the performance of coal logs

| Heating Temp., °C | Density | Length in. | Water Abs. Wt. gain, % | Tensile Strength, psi |
|---|---|---|---|---|
| 40 | 1.13 | 3.31 | 8.03 | 16.6 |
| 60 | 1.14 | 3.24 | 7.56 | 36.4 |
| 80 | 1.18 | 3.12 | 7.48 | 50.4 |
| 100 | 1.18 | 3.02 | 6.08 | 86.1 |

In Table 2 the density of the coal logs increased from 1.13 to 1.18 as the temperature increased from 40°C to 100°C. This suggests that the higher the temperature applied during the compacting process, the more dense and water resistance are the coal logs produced. By examining the tensile strength test results, it can be seen that the higher applied temperatures resulted in higher strength coal logs.

3. Effect of compaction pressure

Compaction pressures ranging from 4,000 to 10,000 psi were used to evaluate the influence of compaction pressure on the properties of the coal logs. The test conditions and results are listed below:

Coal log fabrication: 2% asphalt (3.3% PC-150 asphalt emulsion)
80°C heating temperature
10 min compaction time
Water absorption tests: 500 psi pressurized chamber

Table 3. Influence of compaction pressure on the performance of coal logs

| Compaction Pressure, psi | Density | Length in. | Weight g. | Water Abs. Wt. gain, % | Tensile Strength, psi |
|---|---|---|---|---|---|
| 4,000 | 1.17 | 3.15 | 145.2 | 8.03 | 25.6 |
| 6,000 | 1.17 | 3.12 | 145.0 | 7.56 | 50.4 |
| 8,000 | 1.18 | 3.09 | 144.3 | 7.48 | 72.9 |
| 10,000 | 1.18 | 3.08 | 142.1 | 6.08 | 88.0 |

As shown in Table 3, the compaction pressure showed little influence on the density of coal logs. By comparing the weight and length of the coal logs, it was found that the higher compaction pressure resulted in more dense coal logs, and thus, less water was absorbed during the water absorption tests than those coal logs produced at lower pressures. The tensile strength test results also showed that the higher compaction pressure produced higher tensile strength coal logs.

### 4. Effect of binder concentration

Table 4 shows the effect of binder concentration on the performance of coal logs. The test conditions were as follows:

Coal log fabrication: 6,000 psi compaction pressure
100°C heating temperature
10 min compaction time
Water absorption tests: 500 psi pressurized chamber

Table 4. Influence of binder concentration on the performance of coal logs

| Binder conc., % | Density | Length in. | Weight g. | Water Abs. Wt. gain, % | Tensile Strength, psi |
|---|---|---|---|---|---|
| 1.0 | 1.17 | 2.97 | 137.1 | 8.03 | 56.7 |
| 2.0 | 1.18 | 3.02 | 140.6 | 7.56 | 86.1 |
| 3.0 | 1.18 | 3.01 | 139.7 | 7.48 | 100.4 |

According to the test results shown in Table 4, the higher the binder concentration the higher the tensile strength and better water resistance of the coal logs.

Tables 1 to 4 demonstrate the evaluation of coal log fabrication parameters and their influence on the properties of coal logs. It is suggested that the selection of optimum operating conditions for coal log fabrication should be based on the strength and water resistance of coal logs, as well as the practical requirements of pipeline transportation.

## B. Comparison of Asphalt Emulsion PC-150 and Orimulsion

A new emulsion binder, named Orimulsion, was tested for coal log fabrication using Mettiki coal. In order to evaluate the performance of Orimulsion, the coal logs produced using Orimulsion were compared with coal logs made using asphalt emulsion PC-150, in terms of their water resistance and robustness. The coal log fabrication conditions and test results were as follows:

Coal log fabrication: Mettiki coal
2% asphalt (3.3% emulsion)
10 min compaction time
no heating, room temperature
Water absorption tests: 500 psi pressurized chamber

Table 5. Comparison of asphalt emulsion and Orimulsion

| Compaction Pressure, psi | Density | Length in. | Weight g. | Water Abs. Wt. gain, % | Tensile Strength, psi |
|---|---|---|---|---|---|
| | | PC-150 asphalt emulsion | | | |
| 4,000 | 1.28 | 2.28 | 115.3 | 8.03 | 19.6 |
| 6,000 | 1.29 | 2.21 | 112.7 | 7.56 | 26.6 |
| 8,000 | 1.29 | 2.18 | 110.9 | 7.48 | 33.8 |
| 10,000 | 1.29 | 2.16 | 109.5 | 6.08 | 34.2 |
| | | Orimulsion | | | |
| 4,000 | 1.28 | 2.25 | 113.9 | 8.03 | 12.3 |
| 6,000 | 1.29 | 2.17 | 110.3 | 7.56 | 20.9 |
| 8,000 | 1.29 | 2.18 | 110.4 | 7.48 | 21.0 |
| 10,000 | 1.29 | 2.17 | 109.5 | 6.08 | 29.3 |

Table 5 shows that the coal logs made using Orimulsion have slightly lower water resistance and tensile strength than coal logs made using PC-150 asphalt emulsion. It should be noted that these coal logs were fabricated under no heating conditions. It is anticipated that the difference between coal logs made with Orimulsion and asphalt emulsion will be negligible if the heat is applied during the compacting process.

# Capsule Pipeline Research Center Quarterly Report

**(Period Covered: 10/1/93-12/31/93)**

**Project Title:** Hydrodynamics of CLP

**Principal Investigator:** Henry Liu, Professor of Civil Engineering

**Graduate Research Assistants:** C.C. Cheng and X. Huang

**Undergraduate Assistant:** Mike Holder

**Purpose of Research:**

Explore remaining hydrodynamic problems important to the application of CLP. The two main areas studied during this period include coal log wear in pipe and use of polymer to reduce drag.

## Work Accomplished During the Period:

### (A) Drag Reduction in CLP Using Polymer

Tests of drag reduction in CLP have been conducted in a 2-inch recirculating pipe loop using Polyox (polyethelene oxide) at concentration ranging from 5 to 50 ppm. The greatest drag reduction occurred at 25 ppm. At this concentration and at the lift-off velocity, as much as 75% drag reduction occurred. This corresponds to a 400% reduction in drag from that of water alone flowing through the same pipe at the same speed. Similar drag reduction was found at a velocity 15% higher than lift-off. However, drag reduction was found to be less at 75% of lift-off velocity, and much less at 50% lift-off velocity.

Due to the use of a recirculating loop driven by a jet pump which in turn is driven by a high-speed centrifugal pump, rapid degradation of polymer by these pumps took place. This was not surprising given the fact that all previous investigators who tested drag reduction in laboratory loops found the same result without capsules or coal logs. What is significant is that the degradation rates with or without capsules were found to be approximately the same. This means capsules or coal logs do not appear to be a major source of damage to polymer. The damage was caused, as stated before, mainly by the pumps. Details of this study is given in an internal report (Ref. 1).

Note that commercial pipelines such as the Alaskan Pipeline, and pipelines operated by the Williams Pipe Line Company, all use polymers for drag reduction. They all inject polymers into the pipeline at the downstream side of each pump. It is envisioned that the same must be done for commercial CLP. The reason that drag reduction appears to be higher for CLP than for ordinary liquid pipelines is that CLP operates at higher velocities. Drag reduction is based on inhibiting turbulence and hence is more effective for highly turbulent flows.

### (B) Coal Log Wear in Pipe

As reported in the previous quarter, a new phenomenon, **"Capsule tilt,"** was discovered. It has practical implications on the operation of CLP and hence had to be studied and understood. Work on capsule tilt has been completed during this quarter and a paper has been written on this subject (Ref. 2).

The design of artificial rough joints for coal log wear test has been completed and it is waiting for fabrication and installation. It will be tested during the next quarter. During this quarter, Research Assistant (C.C. Cheng) completed a Ph.D dissertation proposal on coal log wear study (Ref. 3).

### (C) Coal Log Jam Test

Ordered materials (Plexiglas rods) for making a large number of simulated coal logs for jamming test in a 2-inch Plexiglas transparent pipe loop. Enough "logs" will be made for tests at a maximum of 90% limefill.

**References:**

1. Huang, X., "Some Tests of Polymer Drag Reduction in Hydraulic Capsule Pipeline (HCP)," CPRC Internal File Report, Jan. 1994, 33 pages.
2. Cheng, C.C. and Liu, H., "Tilt of a Stationary Capsule in Pipe," paper prepared for the Journal of Hydraulic Engineering, American Society of Civil Engineers (ASCE), 36 pages.
3. Cheng, C.C., "Wear and Damage of Coal Logs in Pipeline," Ph.D Dissertation Proposal, December 1993, 51 pages.

# Capsule Pipeline Research Center
# Quarterly Report
# for
# Individual Projects
# (Period Covered: 10/1/93-12/31/93)

**Project Title:** Unsteady Flow in Capsule Pipeline

**P.I.:** Dr. Charles Lenau, Professor of Civil Engineering

**Research Assistants:** (1) Majed El-Bayya and (2) Jianping Wu

**Purpose of Studies**: (1) To develop a methodology for analyzing unsteady flow and hydraulic transients generated by the operation of coal log pipelines. (2) To study the hydraulic transients associated with the operation of a pump bypass system and an injector system.

**Work Accomplished During the Period**:

(1) Unsteady Flow of Coal Logs

El-Bayya completed his experimental work and began writing his Ph. D. dissertation.

El-Bayya modified the theoretical model to include contact friction between the pipe wall and the coal log. Predicted values of coal log velocities and displacements with the modified model were in very good agreement with the experimental measured values except for coal logs that had a small diameter ratio ( k = 0.7). For the small diameter ration cases the agreement between theory and experiment is fair. It appears that for small diameter ratios the capsule end effects become more important. Moreover, for short logs and small diameter ratio significant and unstable angles of attract were observed. In other words the log seem to pitch back and forth as they move through the pipe.

(2) Pump Bypass and Injector Systems

Wu completed his numerical analysis of the injector and pump bypass system and has completed the first draft of his Ph. D. dissertation.

As reported last quarter Wu has developed a valve switch-over strategy for operation the injector system that would avoid severe discharge transients in the lock system.

**Work To Be Accomplished Next Period:**

1) Unsteady Flow of Coal Logs

El-Bayya will continue to write and rewrite his dissertation during the first quarter of 94. He should graduate at the end of the current semester (May 94).

(2) Pump Bypass and Injector Systems

Wu will also continue to write and rewrite his dissertation during the first quarter of 94. He should graduate at the end of the current semester (May 94).

**References:**

El-Bayya, M., 1991, "Transient Flow in Hydraulic Capsule Pipeline," M. S. Thesis, Department of Civil Engineering, University of Missouri-Columbia.

Lenau, C. W. and El-Bayya M. M., 1992, "Treatment of Unsteady Flow through Capsule Pipelines: Capsule-Water Interaction," International Conference on Bulk Materials Handling and Transportation: Symposium on Freight Pipelines (Wollongong, Australia), Vol. 1, preprints of papers, The Institution of Engineers, Australia.

# Capsule Pipeline Research Center
# Quarterly Report

## (Period Covered : 10/1/93 - 12/31/93)

**Project Title :** Automatic Control of Coal Log Pipeline System

**Principal Investigator :** Satish S. Nair, Asst. Professor of Mechanical and Aerospace Engrg

**Graduate Research Assistants :** Hongliu Du and Jianping Wu

**Purpose of the Research :**

To study, design, test, and improve an automatic control system needed for reliable operation of coal log pipeline systems. To model the system dynamics as well as the interactions between the pumps, valves and the capsules for effective control design and system sizing.

**Work Accomplished During the Period :**

Hongliu Du, a Ph.D. student started on the project in Aug '93. His task was to continue the work of Sun, D-X pertaining to mechanical subsystem design for the CLP, which Sun completed in Aug'93 : "Design of Certain Mechanical Subsystems for an Automated Capsule Pipeline." Specifically, his report included mechanical design issues such as design, implementation and testing of Y-joints (4) ; design, implementation and testing of a high performance divertor ; design, implementation and testing of prebent pipe sections ; two proposed designs for train separator - electromagnetic brake and flow by-pass types ; a proposed design for automatic injection subsystem ; observational studies using the computer controlled testbed system based on upwards of 50 runs ; and extensions to large scale systems and future research.

After the conclusion of Sun's study, it was felt that the design of a train separator was the most critical, since, in comparison, the other issues were understood better. The first step in the design of the train separator was a good understanding of the conditions under which it would operate. Much time was spent on analyzing this realistically. The following objectives for the design were finalized : (i) the system should be capable of operation with any inter-capsule and intra-train spacing, i.e., assume that the capsules will be 'all together' as they arrive at the pump bypass system, with random spacing between them. (ii) the design should be simple, rugged and 'fail-safe'. (iii) pipeline operational velocity is 8 ft/s. (iv) an emergency stop procedure is required.

After considerable work, a design was arrived at that appears to be 'simple' and rugged, which would make the control easy and reliable. Note that, although fancy designs are easy to arrive at, for reliable functioning of the system over long periods, it is necessary to have the least reliance on sensors, computers, etc. and to let the mechanical design itself do 'most of the work.'

It consists of two flow bleed systems with water valves, a train stopper, and an emergency stopper. While a detailed discussion of the design is given in Du and Nair [1], a few key features are as follows : one of the bleeds reduces the capsule velocity and separates the capsules at its downstream end. This is primarily to reduce the force of impact of the capsules on the separator. The other bleed line further reduces the force on the stopper. Using this system and an intelligent sequence of operation of the valves, the stopper, and the divertor, the pump bypass can operate reliably without sensing of any kind, based only on time [1]. This design was worked out in detail and preliminary mathematical modeling has been performed using the method of characteristics.

J. Wu continues to work on the dynamic simulation study as detailed in the previous report and is currently completing his Ph.D. dissertation under the supervision of Drs. Liu, Lenau, and myself.

**Work Proposed for the Next Quarter :**

Since a reliable train separator design is crucial to the functioning of the pump-bypass system, the proposed design will be studied in detail. Specifically, the tasks will be to : (i) develop a mathematical model of the proposed scheme using the method of characteristics (MOC) to find the design parameters for flow bypass 1 and flow bypass 2, the method of valve closure for flow bypass 1, etc. by observing the transient and steady state behavior of the system with and without capsules. This development will be performed in a modular fashion and the overall model would serve as a good design tool to test different design configurations, (ii) design a reliable stopper and an emergency stopper for the train separator system., (iii) conduct observation experiments on the small-scale test bed facility developed by the group to test the designs developed. Many such experiments will be conducted including investigating train spacing changes during long duration travel, effectiveness of flow bypass in reducing capsule speeds, energy loss analysis, etc., (iv) test the train stopper and emergency stopper designs experimentally on the small scale test bed, (v) investigate whether the complete train separator design can be tested using the small scale system or some other existing loops will need to be used. A possibility is that only key concepts in the separator design are tested depending on the confidence gained with the simulation model being developed.

It is felt that the design of the control hardware configuration including the computer, PLCs, sensors, etc. should also be carried out in parallel and this will be pursued depending on the availability of funds and students. The important software issue is selection of appropriate SCADA software, with the control software being a relatively easy component in the development process.

[1] Du, H., and Nair, S. S., "Design of a Train Separator for the CLP System," Report submitted to the Capsule Pipeline Research Center, Nov '93.

**Project Title: Machine Design for Coal Log Fabrication and Extrusion Research**

**Principal Investigator:** Yuyi Lin, Assistant Professor of Mech. & Aero. Engineering

**Duration:** October 1-December 31, 1993

**Graduate Research Assistant:** Guoping Ji (50% of GRA support)

**Other Student Worked on Project:** Brent Leonard (undergraduate, approximate 20% FTE)

**Purpose of Research:**

The main objective of machine design project is to design conceptually a machine of coal log fabrication at commercial mass production rate. Coal log surface treatment equipment and other accessaries are also included in the design.

The purpose of coal log extrusion research is to explore the feasibility of extrusion of coal logs with minimum amount of binder or without binder.

**Need for Research:**

The machine design can suggest desirable improvements for laboratory coal log fabrication process, provide a basis for better estimation of the fabrication rate, and the cost of coal log fabrication in commercial operation. It is also a necessary step toward building large coal log machines for commercial use.

The fabrication of strong coal logs that can withstand up to 2000 psi water pressure and long distance transportation in pipeline without breakage, with minimum energy and cost, is of vital importance to future commercial success of the coal log pipeline technology. Also, it may be advantageous if coal logs from a fabrication machine can be injected directly into a pressurized, water-filled pipeline, so that the coal logs are not exposed to atmospheric air after fabrication. The underwater extrusion process could reduce adverse effect on extrusion due to gravity, increase the strength of the coal logs, reduce the manufacturing time, and simplify the process of coal log injection.

**Work Completed (Oct. 1-Dec. 31, 1993):**

(1). The conceptual design of a coal log compaction machine was revised. The major revision is on the mold design. According to the comments to last revision from our consult, Mr. Fred Infield, we improved the two end caps on the mold, and reduced the efficiency used in our calculation of recycled thermal energy so that the design is more realistic. We have also started working on the mold moving mechanism, so that it can support our claim on potential cycle speed better. The revised design was discussed in the January work session with our consultants.

We are going to revise and improve the design even more, so that finalized by May 94 Board meeting.

(2). Manufactured three 1.8" two-piece mold and a three-piece mold. piece mold is to verify if it is necessary to use a three-piece mold to gu coal logs manufactured. It is shown by experiments that a two-piece inside and with beveled edges is good enough, and the three-piece mc also learned from experiments that if the mold is rigid enough, there is between mold halves to confine the moisture and steam.

(3). Extruded binderless coal log at lower moisture content (about 1 extrude binderless logs at lower moisture content, from 24% to 13%, coal fines provided by the Southern Company Services.

(4). Partially finished a 5.3" split-mold design. The design will be production, due to some lessons learned from the 1.8" three-piece mol student, Mr. Chen, designed a simple and robust 5.3" inch mold with of this mold is for laboratory producation of coal logs that can be used Conway pipeline test. This mold is not suitable for mass production and weight.

**Plan for Next Quarter (1/1/94-3/31/94):**

For long range plan from Jan.1 1994 to Sept. 31, 1995, please plan developed by Dr. Liu. The tasks listed below are for the first qu

__Machine Design Area__:

(1). In the improved conceptual design of a commercial, mass-produc machine, the mold is the key to success. Since many are required in ea be inexpensive. They should be trouble-free for life time to curb the cost. They must be rigid enough to guarantee the quality of the logs factors that will be considered in the second revision of the machin second revision will be completed during the next quarter. More de justify the cycle speed assumed.

(2). The simple but heavy 5.3" mold will be manufactured in this designing a lighter mold to be used in the future commercial applica novel idea of tapered liner, which hopefully can eliminate the need eliminating the locking pins and hinges. Self locking end piston idea as meeting will still be used.

(3). My colleague, Dr. Alley Butler has started working on a vacuu enhance the loading speed, and the log quality of compaction machines. His design will become a sub-system of the commercial machine in our design.

**Extrusion Area:**

(1). A new graduate student, Mr. Guoping Wen, has just started working on extrusion. He will conduct a series of binderless coal log extrusion to find out the optimal set of parameters for the auger-type extruder. If the quality of logs fabricated this way is good enough for transportation and handling, the process will be practical and economical. The center plans to apply for a patent on this process.

(2). Mr. Wen will also work with Mr. Yu Lin, trying to enhance the quality of extruded logs by changing the zeta potential of the material.

(3). Some extrusion with the auger type machine using only a small amount of binder emulsion (1%-3%) will be conducted. If the result is promising, then underwater extrusion of 2'' log with low binder will be tested.

(4). Design a fixture to conduct underwater extrusion with the 100 ton ram extruder.

(5). Construct a ram extrusion model for coal using finite element analysis tool. This model will be useful for die design.

# Capsule Pipeline Research Center

## Quarterly Report

## (Period covered: 10/1/93 - 12/31/93)

| | |
|---|---|
| **Project Title** | Heating, Cooling, and Drying of Coal Logs |
| **Principal Investigator** | Dr. Thomas R. Marrero<br>Associate Professor of Chemical Engineering |
| **Research Assistant** | Ssu-Hsueh Sun |

## Purpose of the Research

The purpose of this study is to predict the heating, cooling, and drying rates of coal logs under various practical conditions encountered in CLP processes on the basis of bench-scale experiments.

## Work Accomplished During this Period

A research plan for heat and moisture transfer studies of coal log was developed, as attached.

## Work Proposed for Next Quarter

1. Derive the general equations for heat and moisture transfer in coal logs.
2. Conduct a literature search on the effects of freezing and thawing of coal logs.
3. Generate selected numerical solutions of equations that simulate coal log characteristic when heated and cooled.

## Doctoral Research Plan (Outline)

## Title: Heat and Moisture Transfer in Coal Logs

### Purpose

The purpose of this study is to develop a coupled heat and moisture transfer model to predict the temperature and moisture distributions inside coal logs during heating, cooling and drying processes, and to predict the rate of heating, cooling and drying of such logs under various conditions.

### Scope of Work

This research will investigate the temperature and moisture distributions and the heat and moisture transfer rates of coal logs under the following general conditions:

1. Heating/cooling of coal logs in a compaction mold.
2. Cooling of coal logs in ambient air.
3. Cooling of coal logs immersed in water.
4. Drying of coal logs in ambient air.

5*. Freezing of coal logs in winter time.

The proposed research plan consists of three major activities: theory, experiment, and applications. They are outlined as follows:

---

* Freezing study is optional.

## I. Theory.

### A. Literature Review.

Basic concepts and theories of heat and moisture transfer in porous media will be reviewed since coal logs will be treated as a porous cylinder.

### B. Development of Conceptual Model.

A conceptual model will be constructed to describe the mechanisms of heat and moisture transfer in a coal log. All the possible mechanisms involved will be listed and discussed. The importance of each transport mechanism will be estimated from available information.

### C. Development of Mathematical Model.

1. General model for porous media.

A mathematical model for porous media in general will be derived from conservation equations and thermodynamics. This is the most rigorous way to derive a complete set of equations for heat and moisture transfer in porous media. The assumptions used in deriving these equations of porous media will be identified and discussed.

2. Pertinent equations for coal logs (Luikov Equations).

Due to their simplicity and practicality, the Luikov equations will be used to simulate the drying processes. Assumptions needed to derive the pertinent equations for coal logs will be specified.

3 Equation validation.

In order to check the numerical procedures, more assumptions will be introduced to further simplify the general equations for a few specific cases. Numerical solutions of these limited cases will be attempted and the result will be compared with known solutions in the literature.

### D. Define Appropriate Boundary Conditions for Coal Logs.

The following three cases are to be initially considered.

1. Heating/cooling of coal logs in a compaction mold by sudden changes in surface temperature. The mold is assumed to be impermeable.
2. Forced convection heat and moisture transfer at the boundaries.
3. Natural convection heat and moisture transfer at the boundaries.

**E. Numerical Solutions.**

The following problems will be considered:

1. One-dimensional Luikov equations with constant parameters for both very long and very short logs.
    - i. numerical method to solve the equations.
    - ii. validation with the solutions for those limited cases, see I-C-3.
    - iii. convergent test to the factors in numerical methods, such as grid size, step size, coupled, de coupling, and approximated formula .
    - iv. sensitivity analysis to check the disturbances caused by the initial condition and boundary condition.
    - v. sensitivity analysis to check the disturbance caused by each parameters.
2. One-dimensional Luikov equations with variable parameters.
3. Two-dimensional Luikov equations for finite coal logs including the gravity effects and other effects.
    - i. investigate the difference between vertical and horizontal coal logs.
    - ii. investigate the effects of aspect ratio, the ratio of length and diameter.

**F. Inspectional Analysis.**

Inspectional analysis will be applied to the derived equations and boundary conditions in order to find the dimensionless parameters characterizing the problem.

## II. Experiments.

Five types of experiments will be conducted to validate the theoretical model. If experiments differ from theory, we will modify the model or improve the experiments. These experiments are outlined as follows:

### A. Thermal conductivity and thermal diffusivity.

The thermal conductivity and thermal diffusivity will be measured by the transient hot wire method. A tiny electrical heater with constant power input will be imbedded through the center of a coal log to simulate a linear heat source with constant heat flux. Thermal conductivity and thermal diffusivity will be simultaneously calculated from the transient temperatures obtained at a point near the heater.

### B. Coal log heating/cooling in axial direction.

In order to obtain all the needed parameters and to validate the model, transient heating/cooling experiments will be conducted. In these experiments, the ends of coal logs will be heated/cooled by sudden changes in surface temperature. For a one-dimensional model, coal log heat and moisture transfer will be restricted to the axial direction by making the log circumferential surface impermeable and adiabatic. Changes in coal log temperature and moisture distributions under transient conditions will be recorded. Temperature will be measured by a set of thermocouples imbedded in the coal log. The coal log moisture distribution will be measured by a gravimetric method. In this method, the coal log will be cut into many little disks and the moisture content of each disk is measured by observing the weight changes of disk before and after drying.

In addition to thermal conductivity, other model parameters, thermal-gradient coefficient, moisture conductivity, and relative vapor diffusion coefficient, can be calculated from the coal log temperature and moisture distributions. However, it is difficult to measure the moisture content in real-time basis by the gravimetric method. Other real-time and non-destructive measuring methods will be investigated. For example, the moisture content can be measured by using electrical conductivity.

**C. Coal log heating/cooling in radial direction.**

A similar experiment to simulate the radial heat and moisture transfer of a infinite long coal log will be conducted to further test the model. Since temperature can be measured precisely and accurately, transient temperature will be used to validate the model. The use of coal log moisture content is less meaningful because of its inherent errors.

**D. Drying of coal logs by forced convection.**

The model also will be tested in a forced convection drying experiment. A coal log will be dried under forced convection. The ambient conditions, such as the velocity, humidity, and temperature of the air, will be totally controlled. The changes in weight and temperature of the coal will be measured and compared with those predicted by the model.

**E. Freezing experiments on small and large logs.**

Simple observations on the freezing and defrosting of coal logs will be conducted to determine if there is any critical behavior in coal logs during the winter time and their practical implications.

## III. Applications.

The mathematical model will be used to predict coal log behavior in various situations. These situations pertain to coal log manufacture and storage. The applications involve coupled heat and moisture transfer. Examples of anticipated results are tabulated below:

Table 1. Applications of Proposed Model for Coal Log Processes

| EXAMPLE | APPLICATION |
|---|---|
| 1 | Predict temperature rise during coal log heating in fabrication mold. |
| 2 | Predict temperature drop during coal log cooling in fabrication mold. |
| 3 | Predict changes in coal log moisture distribution during fabrication and storage processes. |
| 4 | Predict coal log drying rates when stored vertically and horizontally. |
| 5 | Predict scale-up effects on coal log temperature and moisture distributions under ambient conditions. |
| 6 | Predict the freezing behavior of coal logs. |

# Capsule Pipeline Research Center

# Quarterly Report

# for

# Individual Projects

(Period Covered: 9/1/93-12/31/93)

**Project Title:** Compaction of Binderless Coal Logs

**P.I.:** Dr. Brett Gunnink, Assistant Professor of Civil Engineering

**Research Assistants:** Jayanth Kanunar, and Feng Chen

**Purpose of Study:** To explore and optimize a compaction technique for making binderless coal logs.

## Work Accomplished During the Period:

Work accomplished during the past quarter continued the development of Hot Water Dried (HWD) coal logs. HWD logs are high strength water resistant logs. The HWD logs have performed very well and we believe that their development constitutes a major breakthrough in coal log fabrication. The HWD logs meet the durable coal log test performance criteria adopted by the CPRC in May of 1992.

We have completed our study concerning the applicability of the HWD process to various coals. We have successfully made HWD coal logs using five different coals. These coals ranged form low rank subbituminous coal to high rank bituminous coal. Post adsorption log specific gravity increased with coal rank, whereas, log strength decreased with rank. In all cases there was coal benefaction associated with the log making process (decrease in equilibrium moisture content). This benefaction was largely insignificant for high rank bituminous coal, but significant for low rank sub-bituminous coal.

We have made 10 HWD logs using a multi-part mold. We believed the use of this type of mold (or perhaps a tapered mold) would eliminate or at least minimize the detrimental circumferential cracks that we had observed in logs made using the solid cylinder mold. Apparently, this belief was well founded. We have made 10 HWD logs at 200 °C and 20,000 psi compaction pressure in a multi-part mold. The logs were made from the Antelope coal (subbitumious Powder River Basin coal). All but one of these logs exceeded the CPRC durability criteria (circulation for 1 hour, with less than 3% weight loss).

We have completed the design of a mold for making 5.3" diameter coal logs. The mold is currently being fabricated. This is will be a chrome plated multi-part mold. It will be used to make the 5.3" diameter logs that will be circulated in the 6" diameter pipeline in Conway, Kansas, this summer.

**Work Proposed for Next Quarter:**

This next quarter we will:

1. Complete fabrication of 5.3" diameter mold;
2. Begin making coal logs, using the 5.3" diameter mold, for the Conway Kansas test.
3. Complete an M.S. thesis (J. Kanunar) concerning the HWD process, and the strength and durability of HWD coal logs;
4. Begin a refereed journal article concerning HWD coal logs (to be submitted to *Fuel Processing Technology*);
5. Begin a patent application concerning HWD coal log fabrication;
6. Test modifications to the HWD process that simulate the process employed by a commercial coal log compaction machine, and evaluate the effect of these modifications on log quality.

**Publications Resulting from Work on this Project:**

Gunnink, B.W., Kanunar, J., and Liang, Z. "Compaction of Hot Water Dried Coal Agglomerates", Preliminary Invention Disclosure, April 15, 1993.

Gunnink, B.W. and Liang, Z., "Compaction of Binderless Coal for Coal Log Pipelines", accepted for publication in *Fuel Processing Technology*, Elsevier, Amsterdam.

Liang, Z., (1993) "Compaction of Binderless Coal for Coal Log Pipelines", thesis presented to the University of Missouri-Columbia, at Columbia, Missouri, in partial fulfillment of the requirements for the degree of Master of Science.

Gunnink, B.W. and Liang, Z., (1992) "Compaction of Binderless Coal Logs for Coal Pipelines", *Proceedings 17th International Conference on Coal Utilization and Slurry Technologies*, Coal and Slurry Technology Association, 677-686.

## *CAPSULE PIPELINE RESEARCH CENTER*

## *QUARTERLY REPORT*

*(Period Covered: 10/1/93 to 12/31/93)*

| | |
|---|---|
| *Project Title* | Impregnation of Dry Coal Logs |
| *Principal Investigator* | Dr. Richard H. Luecke<br>Professor of Chemical Engineering |
| *Graduate Student Assistants* | Daniel Carney<br>Rebecca Smith |
| *Undergraduate Assistant* | Andrew Rockabrand |
| *Purpose of the Research* | To produce coal logs from dry coal and to impregnate these logs with asphalt or with a slurry of coal fines in asphalt to prevent water infiltration. |

### *SPLIT MOLDS*

Coal logs are now being made in molds that split into two parts to release the log rather than requiring it to be forced out of the barrel with an axial ram. Previously, logs made in one-piece cylindrical molds, often were found to have circumferential cracks extending through the interior of the logs. We believe these internal flaws were caused during expulsion of the logs from the mold either by the drag between the log and the wall of the mold (from adhesion and/or friction), or by the stress concentration caused at the mold outlet where the log suddenly expands due to the pressure release. In subsequent failure of the log from any cause (from moisture, tensile tests, etc.), the breakage usually was observed to occur along these cleavage planes. Existence of interior flaws was also indicated by the observation during the wax impregnation experiments that elimination of air from the log occurred from cracks previously unseen on the surface. Inspection of fractured logs has shown that a large fraction of the impregnated asphalt is stored in these interior flaws.

The problem of drag between the log and the mold is especially accentuated with logs made from dried coal from Western mines. Apparently dried Western coal has a smaller coefficient of expansion than the metal of the mold so that it becomes wedged in even a half of the split mold. Even with the split molds, force was required to release the log from the opened mold. This problem was solved by polishing and chrome plating the interior of the split mold. Even though the log still adheres to a half of the mold, it is released by a light tap which apparently does not damage the log.

Logs made in the chrome-plated two-piece mold seldom show the circumferential cracks. When made under previous "standard" conditions of 20,000 lbs force and 190°C temperature, the logs after impregnation with asphalt showed high tensile strength, resisted water infiltration at 500 psi for virtually unlimited time both before and after the endurance tests in the test circulation pipeline. As noted elsewhere in this report, "hot water dried" logs made in the chrome-plated split mold also demonstrated consistent good performance.

The interior surfaces of the chrome-plated mold remained smooth and shiny even after more than three months of use. The steel molds showed discoloration and evidence of surface roughness after that amount of usage. Chrome-plating should be considered for a commercial coal log mold.

## *LOW DENSITY LOGS*

### *Summary*

An important objective for the last quarter of 1993 was to explore conditions to produce coals logs with low density but with satisfactory strength to reduce power consumption during transport in the pipeline. Coal logs made at the temperature and pressure given above have densities before impregnation with asphalt of about 1.23 to 1.28, and after impregnation of 1.25 to 1.32. Such densities require a relatively high liftoff velocity in the pipeline. A reduction in density would be especially effective for long distance transfers and hence this work was carried out on Western coals. This coal had been dried to 1-3% moisture.

A broad range of combinations of maximum mold temperatures and maximum ram compression forces have been investigated. The results discussed here are preliminary because not all of the experiments have been completed and not all of the data have been fully analyzed. However, a general picture is emerging:

1. Although the low density logs are weaker than those made at the higher pressures and temperatures, acceptable strength and density combinations seem possible.

2. As would be expected, the low density (i.e., high porosity) logs can absorb a large fraction of asphalt during the impregnation process, bringing the post-impregnation density to similar levels as the less porous logs.

3. As was not expected, even the large fraction of asphalt (20-30%) failed to protect the logs from damage during the high pressure water tests.

4. As was even less expected, the logs often appear to be damaged by the asphalt impregnation process itself. Not only were surface cracks often visible after the impregnation procedure, but in some cases fracture of the logs occurred during asphalt impregnation.

### *Low Density Logs*

Logs with densities ranging from 1.005 to 1.30 (non-impregnated) were produced.

Low densities were produced at low temperatures and pressures (120°C and 7500 lbs force). A preliminary correlation for the densities as a function of temperature and pressure is:

$$Density = 393.24 + .0455\ Temp^{0.4638} - \frac{394.04}{Force^{0.00040386}}$$

Figure 1 shows a plot of this equation for several parameters of force and also shows calculated and measured values of the densities.

Figure 2 shows a preliminary correlation for tensile strength vs. density. The tensile strength of the non-impregnated logs was reduced as the density was reduced. Note that the lower densities give very low tensile strengths. It could be expected that impregnation with asphalt would increase tensile strength as well as provide protection against water infiltration and damage. Since all of the low density logs were damaged by the 500 psi water immersion tests, the dry tensile strengths of impregnated logs was not measured.

### *Impregnation Procedure Using Asphalt*

Since the tensile test is destructive, a second batch of logs was made with densities of 1.05 to 1.17. These were impregnated with asphalt using the standard procedure:

1. The logs were heated for 1 hour above the surface of molten asphalt while a pressure of 0.1 atm is maintained.

2. The log were then immersed under the surface of the asphalt for 1 hour at the pressure of 0.1 atm.

3. The vacuum was released and air pressure above the asphalt was raised to 50 psi. for 1 hour.

### *Impregnation with a Slurry of Coal Fines*

Research continued from the last quarter using a coal/water slurry in impregnation. Results indicated, however, that absorption of slurry water by the dry log during impregnation was damaging the log structure. Lowering impregnation pressure, altering the weight percent solid in the slurry, decreasing particle size in the slurry, and lowering the impregnation time still resulted in damaged logs. After deciding that the water was the major cause of the damage, efforts were made to find a new slurry carrier fluid. The fluids were judged by several criteria:

1. Possible reaction with coal
2. Hydrophobic characteristics
3. Suitable viscosity
4. Cost
5. Safety Hazards
6. Suitability as a fuel component

Two fluids were selected: stearic acid and asphalt. The same general impregnation process that is used for asphalt has been modified for use with the slurry. The principal difference is that the log is immersed in the slurry during the evacuation phase and pressure is not used to force the slurry into the log. A heating mantle is placed below a glass reactor, and the reactor is connected to a vacuum pump. If the coal fines in the slurry enter the pores of the coal log, less slurry liquid fraction will be required and the impregnated log will be less prone to cold, viscous flow.

Powder River Basin coal is being used for the tests. As with the asphalt impregnation tests, the coal is dried at 105°C until the moisture content is below three percent.

### Impregnation with a Slurry of Coal Fines in Stearic Acid

Two compaction temperatures were being examined, 150°C and 200°C. Compaction at 200°C frequently produces logs that have broken ends. The 150°C logs exhibit more circumferential cracks. The 150°C logs absorb more slurry possibly due to the presence of these cracks. These logs generally fail within a couple of hours in the 500 psi water absorption test, while the 200°C logs on average lasted over 10 hours. It appears that compaction temperature has the most effect on water absorption duration, possibly by its effect on log strength.

The stearic acid aids the adhesion of fine coal particle to the surface of the logs to further reduce water absorption. Presently, the main factor that reduces log quality is the circumferential cracking resulting from the compaction process.

### Impregnation with a Slurry of Coal Fines in Asphalt

Asphalt slurry experiments have only recently begun. The slurry used has been a mixture of 80 wt% AC-20 asphalt and 20 wt% coal fines. In an attempt to produce logs of lower density, compaction temperature and pressure have been decreased. Although the density of the non-impregnated log is very low, the increased void fraction causes significant density increases after impregnation. These low density logs are weak and often break during impregnation. So far all samples have failed in the 500 psi water absorption within a couple of hours although some log fragments (up to 1/2 log) seem to be unscathed.

### Future Plans

Repeats of some of the above experiments using asphalt alone are planned to make sure that some procedural problem did not cause the negative results. We then shall run some exploring tests with milder conditions for the asphalt impregnation particularly with shorter impregnation times and no pressure for asphalt infiltration. Tests with asphalt slurry will also continue using milder impregnation conditions.

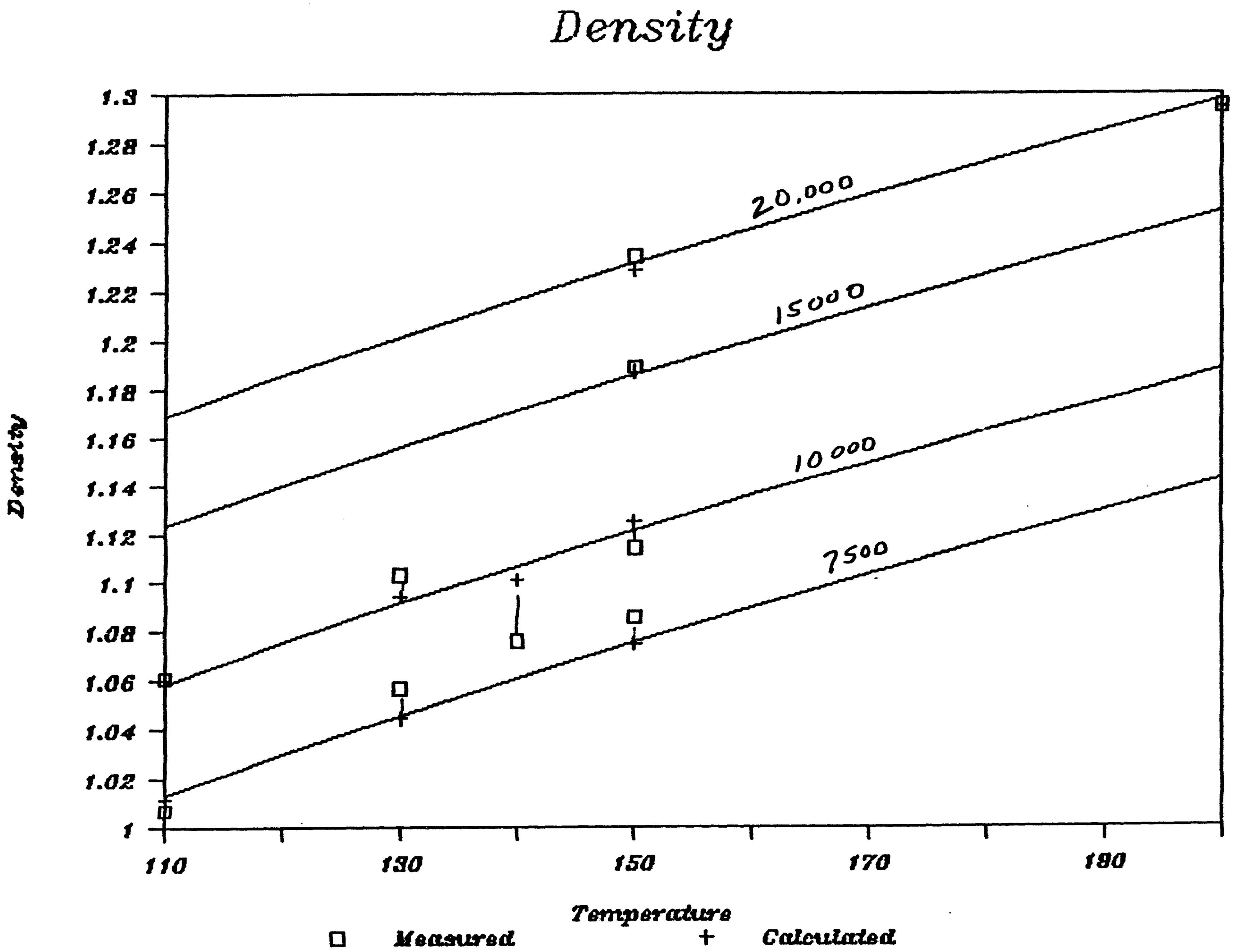

Figure 1 - Density as as Function of Manufacturing Temperature and Pressure

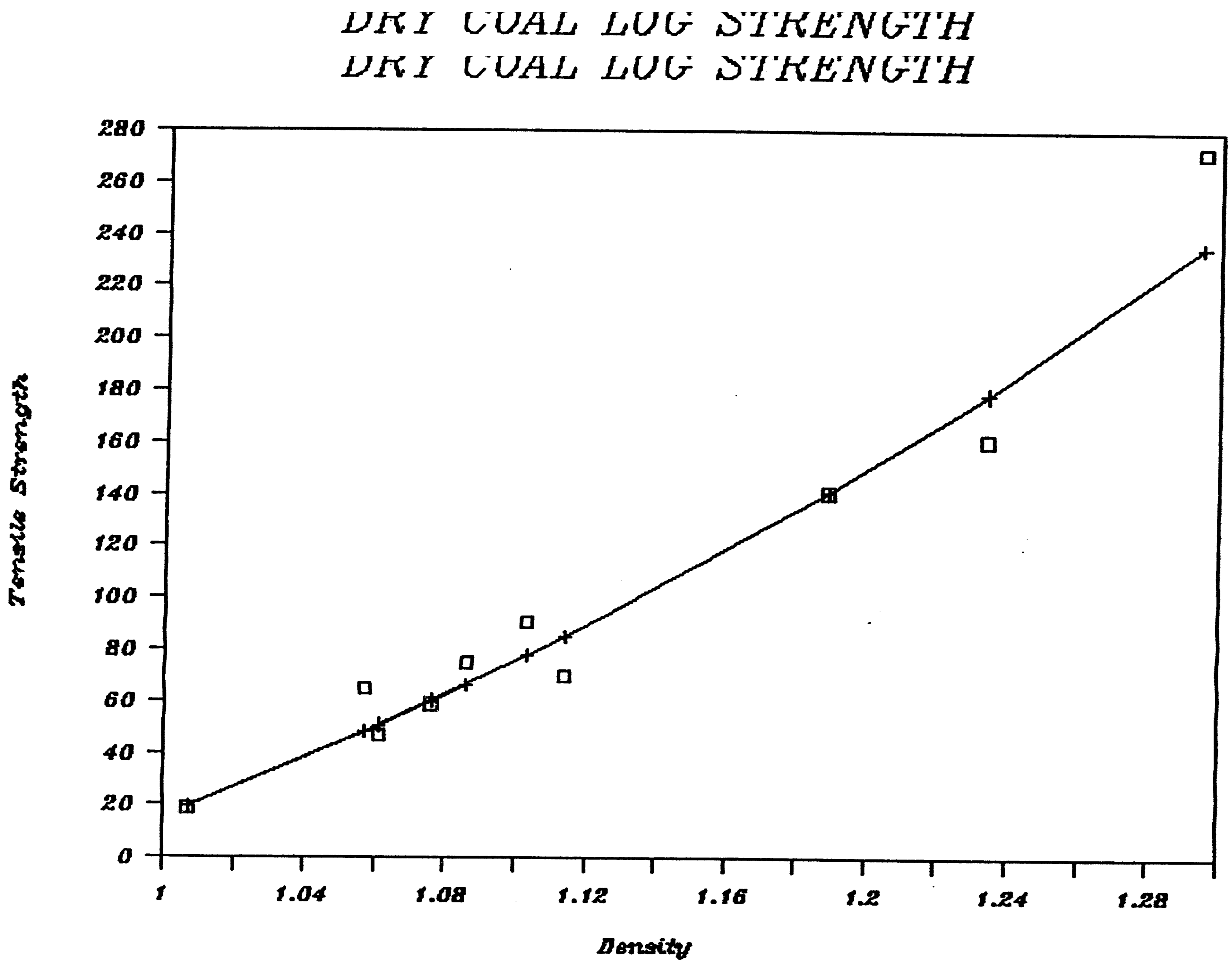

Figure 2 - Coal Log Tensile Strength as a Function of Density

1-25-94

## Capsule Pipeline Research Center

## Fourth Quarterly Report

(Period Covered: 10/1/93 to 12/31/93)

| | |
|---|---|
| **Project Title:** | **Legal Aspects of CLP** |
| **P.I.:** | Dr. Peter N. Davis, Isidor Loeb Professor of Law |
| **Research Ass'ts:** | James Kelly, Eileen Petito |
| **Purpose of Study:** | To explore legal issues involved in commercialization of CLP, including eminent domain powers for right-of-way and water rights acquisition, nature of water rights acquired by voluntary transfer, right to cross railroads, conversion of existing pipelines, pipeline waste disposal, environmental assessment, etc. |

**Work Accomplished During the Period:**

Research conducted during the period:

(1) *Operation of pipelines by railroads.* Began research on authority of railroads under Interstate Commerce Act and state railroad and pipeline statutes to construct and/or operate pipelines. [Jim Kelly]

(2) *Authority of Indian Tribes to convey their water rights to non-Indians.* Began research on this topic. It is important since several tribes in recent years have considered such sales. Indian water may be a significant source for pipeline water. [Jim Kelly]

(3) *General authority of federal agencies to authorize diversions from federal reservoirs.* Completed research on this topic. Although this topic is inspired by *ETSI Pipeline Project v. Missouri*, 108 S.Ct. 805 (1988), this research was general and did not address site-specific issues, such as Missouri River diversions. [Jim Kelly, Eileen Petito]

(4) *Transfer of water rights under eastern diversion permit statutes.* Begin research on this topic. [Peter Davis]

(5) *Transfer of water rights under western prior appropriation permit statutes.* Completed research on this topic. [Eileen Petito]

(6) *Cases interpreting state anti-export regulatory statutes.* Completed research on this topic. [Eileen Petito]

**Work Proposed for Next Quarter:**

Research work:

(1) *Authority of Indian Tribes to convey their water rights to non-Indians.* Continue research on (a) Indian water rights and their relationship to state water rights systems, and (b) transfer rights. [Jim Kelly]

(2) *Pipeline environmental impact statement issues.* Begin work on typical environment issues discussed in Environmental Impact Statements prepared under the National Environmental Policy Act for pipeline construction projects in the midwest. [Eileen Petito]

(3) *Transfer of water rights under eastern diversion permit statutes.* Analyse eastern state diversion permit statutes to determine criteria for transfer of water rights.

Publication work:

(1) *Law review article.* Continue preparation of law review article based on Florida conference paper Davis, Cress & Sullivan, *Legal Aspect of Coal Pipelines in the United States -- Preliminary Findings* (Apr. 1993).

**Key Results of Recent Work:**

(1) *Operation of pipelines by railroads.* While railroads generally obtain Interstate Commerce Commission to buy competing forms of transportation, this requirement does not apply to the purchase of pipelines. 49 U.S.C. § 11343. Therefore, there does not seem to be any restriction on railroad purchase or construction of pipelines.

(2) *Authority of Indian Tribes to convey their water rights to non-Indians.* Indian reserved rights were recognized in *Winters v. United States*, 207 U.S. 564

(1908), and subsequent cases. These Indian reserved rights generally are superior to non-Indian water rights created under state law, because the Indian reservations usually were established before settlement. Several cases indicate that Indians can transfer their water rights to non-Indians, provided the tribe and Congress consent. We are investigating this law further.

(3) *General authority of federal agencies to authorize diversions from federal reservoirs.* The federal government does not have general authority to authorize diversions from either navigable waters and tributary waters; that is a matter of state law. *California v. United States*, 438 U.S. 645 (1978).

Obstructions to navigation in navigable waters, such as bridges, dams, and intake and outlet pipes cannot be built without federal permits under Rivers & Harbors Act of 1899, § 10.

The federal government has rights to reserve water rights for the purposes of federal reservations. The amount of water which can be reserved is limited to that needed for the purpose of the reservation at the time the reservation was established. Those reserved rights cannot be used elsewhere.

Water can be diverted from Bureau of Reclamation reservoirs for industrial and other non-irrigation purposes, provided that irrigation uses are not impaired and that affected water-users associations consent. 16 U.S.C. § 590z-7; 43 U.S.C. §§ 390b, 485h, 521; *EDF v. Morton*, 420 F.Supp. 1037 (1976); *EDF v. Andrus*, 596 F.2d 848 (1979).

Water can be diverted from Corps of Engineers reservoirs for domestic and industrial uses, provided they do not interfere with the purposes for which the reservoirs were built. 33 U.S.C. § 708; *ETSI Pipeline Project v. Missouri*, 484 U.S. 495 (1988).

(4) *Transfer of water rights under western prior appropriation permit statutes.* The law on transfer of water rights in the western states varies considerably between the states. In general, there are two propositions. First, there is a general right to sever the water rights from the land and to transfer them. Second, transfers cannot be made if they cause significant adverse impacts on other appropriators. The variation between the states involves the magnitude of adverse impacts which will trigger denial of a transfer application.

(5) *Interpretation of state anti-export regulatory statutes.* No cases were found interpreting these statutes. [Eileen Petito]

(6) *"Property rights" statutes. See* third quarterly report, dated Sept. 29, 1993.

**Publications:**

Patrick Sullivan, *Regulatory Takings--The Weak and the Strong*, 1 MISSOURI ENVT'L LAW & POLICY REV. 66-73 (Fall 1993).

This article discusses that effect of *Lucas v. South Carolina Coastal Comm'n*, 112 S.Ct. 2886 (U.S.Sup.Ct. 1992), on the law of regulatory takings, and reviews recent state statutes which either (1) require preparation of "takings impact statements" as part of land use regulatory actions, or (2) define what constitutes a regulatory taking.

This research underlies a future examination of the effect of regulatory taking law on administration of prior appropriation diversion permits and state water anti-export statutes, and the granting or denial of federal and state permits for rights-of-way across public lands.

**Unpublished Research Reports:**

(1) Report on the authority of the federal government to grant diversion permits, federal reserved rights, and Indian water rights. (Jim Kelly)

(2) Report on the authority of the federal government to authorize diversions from federal reservoirs. (Eileen Petito)

(3) Report on the federal statutory authority of railroads to build pipelines. (Jim Kelly)

(4) Report on eastern state diversion permit statutes. (Peter Davis)

(5) Report on transfer of water rights under western prior appropriation permit statutes. (Eileen Petito)

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