DE/CE/15466-T6

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December 16, 1991

DOE/CE/15466--T6

DE92 004241

Mr. Glenn Ellis
Energy Related Inventions Program
U.S. Department of Energy
Forrestal Building, 5E-052
Washington, D.C. 20585

Dear Mr. Ellis:

The 5th quarterly technical report of the coal log pipeline project, for the period 8/25/91 - 11/25/91 is enclosed. Financial reports will be sent to you separately by the University's Business Office.

Please don't hesitate to contact me if you have any questions.

Sincerely,

Henry Liu

Henry Liu
Professor of Civil Engieering
Director, Capsule Pipeline Research Center

HL:ms
enc.
cc: Dr. Marrero
CLP Consortium Members

MASTER

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DOE Project Quarterly Report

Prepared by Henry Liu, December 1991

Project Title:	Coal-Log Pipeline System Development
Contract Number:	DOE DEFG0190 CE 15466
DOE Program:	Energy-Related Invention
DOE Technical Monitor (Invention Coordinator):	Glenn K. Ellis
Project Period:	August 24, 1990 - June 30, 1992

Project Tasks:

1. Perform the necessary testing and development to demonstrate that the amount of binder in coal logs can be reduced to 8% or lower to produce logs with adequate strength to eliminate breakage during pipeline transportation, under conditions experienced in long distance pipeline systems. Prior to conducting any testing and demonstration, grantee shall perform an information search and make full determination of all previous attempts to extrude or briquette coal, upon which the testing and demonstration shall be based.

2. Perform the necessary development to demonstrate a small model of the most promising injection system for coal-logs, and test the logs produced from Task 1.

3. Conduct economic analysis of coal-log pipeline, based upon the work to date. Refine and complete the economic model.

4. Prepare a final report for DOE.

Quarterly Report No.: 5

Period Covered: August 25, 1991 - November 25, 1991

Summary

TASK 1:

Perhaps the most significant accomplishment of the past three months is in coal log fabrication. Using direct compression in a cylindrical mold, we have succeeded in making binderless coal logs that are rather strong when they are dry. We don't know yet how they would behave when soaked in water under high pressure, but we will soon find that out when our water immersion test apparatus is ready. If these logs do not soak excessive water and do not weaken very much in water under pressure, then we very well may have succeeded in accomplishing Task 1 which is to demonstrate that we can make good logs with less than 8% binder.

More about our coal log fabrication study is given in the attached reports submitted by individual faculty and researchers working on the project.

TASK 2:

The small model of coal log pipeline, complete with an injection system and a booster station, has been completed. We are currently testing computer control of the system, and to improve the system whenever any problems are discovered. It is anticipated that the system will be fully operational and fully automatic (with the capability of manual intercept whenever desired) within the next three months. Then the system will be used for running various experiments, including tests to ascertain the behavior of coal logs passing through the pump bypass. Because the pipe used in this small model is transparent, the behavior of coal logs through the pump bypass can be studied both through direct observation and by video taping. The result will be very useful in helping to develop the equations to predict the motion of coal logs through injectors and pumps, a separate task undertaken by our unsteady flow group.

More about Task 2 is contained in the attached report prepared by Dr. Nair and his group.

TASK 3:

Work has been initiated to update and revise the economic report written a year ago. Most of the new cost data have been collected. We plan to intensify this work so that the revision of the report can be completed within the next three months.

OTHER TASKS:

Other tasks are those not required by DOE but required by the CLP Consortium and/or NSF Center. They are briefly described next.

Hydraulics of Coal Logs. The work here is to study the hydraulic behaviors of short logs (with aspect ratio in the range of 1.3-3.0) including their incipient velocity, lift-off velocity, energy loss and abrasion through pipe. The pressure gradient of various coal logs were measured in our 2-inch test loop and the result was compared to theoretical prediction with good agreement (see Jim Richards' report attached). Also, we have replaced 18 feet of the test section of the 2-inch steel pipe with a transparent plastic pipe so that capsule behavior can be observed and lift-off can be more accurately determined. Jim Richards will take a lot of data with the transparent section in the next three months. He plans to complete his M.S. degree in May 1992 using this research in his thesis.

Water Hammer Analysis and Unsteady Flow. We are making good progress in water hammer analysis and in predicting unsteady flow effect on capsule motion. Dr. Lenau and Mr. El-Bayya are currently writing two papers based on the study, one for publication in the Hydraulics Journal of ASCE, and the other for the 7th International Symposium on Freight Pipelines. Once this study is completed, we will be able to have a good understanding of, and will be able to predict accurately, the propagation of waves in pipelines filled with coal logs, and the effect of such waves on the motion of coal logs. See El-Bayya's report attached for further discussion.

Coal Logs with Impermeable Crust. Dr. Richard Luecke has initiated a study to assess the feasibility of adding an impermeable crust or surface layer on coal logs to reduce water absorption. He has already gotten some initial results and has prepared for a more detailed study over the next three months -- see his report attached.

Progress on Binderless Coal Log Production

by

Brett Gunnink, 12/6/91

Design, fabrication and testing of the binderless coal log compaction apparatus is complete. As of this date, we have successfully made over 30 coal logs under a variety of conditions. A brief discussion of the experimental procedures employed and the results obtained follows.

All the data in this report came from logs made from powder river basin coal with a maximum particle size of 1/4" and a particle size distribution comparable to that obtained by crushing the coal to this top size. Bulk quantities of the coal were sorted into different size fractions. The fabrication of a binderless coal log begins with the heating and drying of the coal. Pans of coal containing the various size fractions are placed in a oven and dried at 110° F until their weight has stabilized (about 2 1/2 hrs.). Then, the appropriate amount of each size fraction of coal is placed into a mixing bowl and the desired amount of hot water added. The coal is mixed and placed into the hot compaction apparatus. The temperature of the coal-water mixture is monitored until the mixture reaches the desired compaction temperature. At this stage, vacuum is applied if desired and the compaction pressure applied.

Currently, all coal logs have been compressed at a maximum pressure of 20,000 psi and at 90° C. We have been able to make logs from coal with initial moisture contents of 10, 15, 20,and 25%. The density of the logs under these conditions is approximately 1.2 gm/cm^3. The compaction energy required to make the logs is approximately 8 BTU/lb. The compressive strength of the logs produced has ranged from 150 psi to 600 psi. For comparison purposes, the compressive strength of wood is about 1000 psi and conventional concrete, 3500 psi. This range of strength (150 to 600 psi) is quite large and this coupled with the fact that there seemed to be no discernable relationship between moisture content and strength as well as no discernable benefit from the application of vacuum puzzled us and caused us to carefully examine our experimental process. We discovered that in spite of large initial differences in moisture content that there was little variation in the after compaction moisture contents of the logs. Apparently, considerable moisture was lost during the temperature equilibration period when the coal water mixture was in the compactor. It is possible to seal the compactor during this phase, and for future logs the temperature equilibration prior to compaction will be done in the sealed compactor to prevent moisture loss. We made the observation that each new batch of logs that were made under what we thought were the same conditions had lower strengths that the previous batch. We believe that this was due in part to the fact that we were repeatedly rewarming the dried coal to prepare it for compaction. This caused fundamental changes to occur in the coal itself that were adversely affecting the strength of the logs. Finally, it appears that the strength of the logs are quite sensitive to the rate of load application and the duration of application of the maximum load.

In summary, we are able to consistently make logs with strengths in excess of 200 psi. However, we have been able to make some logs with strengths approaching 600 psi. We believe we are beginning to understand the subtle differences in the compaction process which cause this rather large difference in strength. We plan to focus on the details of the compaction process to see if we can consistently make logs at the high end of the strength range. Once we have done this we will begin to examine the effects of moisture content, vacuum, and other variables as we previously proposed.

December 1991

Coal Log Fabrication Studies

Tom Marrero, Associate Director
Capsule Pipeline Research Center

This quarterly project report summarizes progress made in coal log fabrication techniques by D.M. Berg, W.J. Burkett and R.H. Luecke. Significant results are as follows: (1) the extrusion of 1.6 inch diameter logs is extremely sensitive to the coal/asphalt feed properties and operating conditions, (2) fabrication of several large (25 pound) coal logs by compaction (direct press method) with 5 and 6 percent asphalt binder was successful, (3) a paper on coal log fabrication was presented at the biennial meeting of the Institute for Briquetting and Agglomeration (IBA), and (4) a new extruder for underwater extrusion tests was received from The Bonnot Company.

Coal Log Fabrication by Extrusion (D. Berg)

Small-scale coal logs have been successfully produced by extrusion with 5% asphalt binder. An experiment has been designed capable of making and testing logs under a variety of extrusion conditions. In general, the coal logs are produced by mixing pre-dried Hanna coal with AC-20 asphalt and extruding the mixture through a 6" length die, 1.6" diameter. Asphalt concentration, temperature, motor speed and the amount of fines in the coal are the variables studied in various combinations.

The quality of the extruded coal logs can be grouped into three sets. The first set of logs are those produced in continuous extrusion of adequate quality. The logs do not contain cracks and are visually more compact on exit from the extruder. The density of these logs is relatively constant over an extrusion run and ranges from 0.95-1.05 g/cm^3. The second set contains logs produced at adequate quality but do not continuously extrude. The density steadily increases from around 0.95 g/cm^3 to as high as 1.20 g/cm^3 until the extruder clogs. The third set consists of logs of an inadequate quality. These coal logs are loose and fall apart easily. Cracks are usually visible in the logs as they exit the extruder. The density of these logs is usually in the range of 0.85-0.95 g/cm^3.

The identification of the range of experimental conditions for a given coal over which the logs can be produced has been established. Changing the experimental conditions so that they fall outside this range produces either loose logs or a clogged extruder.

Coal characteristics will dramatically alter the conditions for good extrusion. For the first batch of Hanna coal, conditions for good extrusion were 5% asphalt, a motor speed of 1 1/2 rpm, a 1.6" diameter, 6" length die and an extrusion temperature of 160° F. The second batch of Hanna coal would not extrude well under any conditions attempted with the same die. However, a 7.5" length die is now being used to produce logs with this coal. The best conditions found favorable for extrusion at an adequate quality are: 4% asphalt, a motor speed of 2 rpm, a 1.6" diameter, 7.5" length die and an extrusion temperature of 170° F.

The die, to a large extent determines the extrusion process range. Experimentally, we have determined that a 1.6 inch diameter die yields the most consistent results. The 1.5" die used has a tendency to consistently clog, and the 1.7" die produces logs of an inadequate quality. When varying the length of the die, the 1.6" diameter die produces logs of varying quality. At conditions defined above, die lengths of 6" produce loose logs and 9" tend to clog the extruder. Additional work includes capping the end of the auger with a cone to achieve more uniform extrusion results.

Coal Logs by Compression (W.J. Burkett)

A large amount of coal-asphalt mixture (25 pounds at 5 and 6 weight percent asphalt) was compressed by means of a 3,000,000 pound force strength testing machine. The coal logs are 7.5 inches in diameter and about 14 inches long. The log mold was specially fabricated from thick-walled pipe and is not heated in the compression process. In the compaction process, the mixture was held under 6,000 psi pressure for one hour. Specifically, the logs were compressed by pushing the filled mold against a stationary piston. Two types of logs were produced: those compressed from one end, and those compressed from both ends. All these logs had a relatively uniform density with respect to length.

When logs were released from the mold, their diameters expanded by approximately 1.7%. Two tests are to be conducted on the logs produced in this manner. The tests will yield information concerning coal log water absorption and compressive strength.

Water Penetration Tests (W.J. Burkett, R.H. Luecke, T.R. Marrero)

In order to gain an understanding of water penetration through coal-asphalt, new tests have been initiated. The tests will measure the loss of water from asphalt-coal wafers as a function of time. The preliminary results agree with general drying theory. See Dr. Luecke's report attached for details.

Additional Activities

The University has given us a large room for coal log fabrication study. The laboratory equipment and project area assignment are in the planning stage. Currently, this lab is now being emptied of other equipment and will have to be renovated to meet coal log fabrication requirements. The lab will contain at least two extruders, and have isolated areas for coal handling and other studies.

In addition to facilities planning, an extrusion data acquisition system has been specified in order to obtain more quantitative information on the process. The specification of equipment to support coal log fabrication is also underway.

Conditions favorable for the fabrication of consistently acceptable coal logs are being evaluated. Current operations are being reevaluated to identify factors that are hindering the fabrication of quality coal logs during extrusion. Continuous extrusion of coal-asphalt mixtures has been achieved, but changes in coal, asphalt, and operating conditions have sometimes resulted in products that are not uniform or sometimes producing unacceptable logs. We are currently seeking to understand the reasons for this.

A paper on coal log fabrication was presented by W.J. Burkett and T.R. Marrero at the recent IBA meeting, see attachment. There was more interest than ever before on coal log pipeline. Several contacts were made with equipment vendors and mining companies. These discussions more than justified attendance.

December 13, 1991

WATER ABSORBANCE AND PERMEABILITY

Richard H. Luecke
Professor of Chemical Engineering

The general objective of this work is to determine the water susceptibility of coal that has been coated with asphalt for use as a casing for coal-logs. The coated coal in the casing would prevent water infiltration into the log and may add other desirable properties such as strength, impact absorbance and ablation resistance. We are primarily interested at this time in studying the water absorbance and water permeability.

The methods described here can also be used to evaluate other log construction designs to repel water infiltration, such as a solid coating of asphalt.

WATER ABSORBANCE:

Discussion:

The best way to study water absorbance seems to be to measure the rate of drying of asphalt treated coal that subsequently has been soaked in water. The drying curve can be analyzed in such a way to distinguish between gross surface moisture, moisture in the interstices between particles and moisture absorbed into the interior of coal particles. This information offers a measure of the effectiveness or completeness of asphalt coating of the particles and also should be of use beyond the question of water absorption.

A procedure is being developed to allow very rapid and simple characterization of the water susceptibility of coal. This procedure is based on analysis of the drying curve of coal samples that have been saturated with water. Ground coal is mixed with asphalt and compressed into small disks 1.25" diam x 1/8" thick. Each disk is soaked in water and hung by a string in a microbalance with a desiccant that maintains near-anhydrous air in the balance enclosure. The rate of drying is determined from a record of time vs. weight of the sample.

Drying of the coal disk proceeds in four distinct steps. Analysis of the drying rate curve allows us to identify the amount and location of absorbed water. By inference, this information is indicative not only of the moisture distribution but also of other features such as completeness of particle coating, volume and connectivity of interparticle voids, etc.

Initially moisture is lost while the sample comes into thermodynamic balance between heat and mass transfer. A constant drying rate period then ensues as long as a film of free moisture is present on the surface. In the third stage, the drying rate decreases as moisture in the interstices between coal particles must be transported to the exterior surface for evaporation. Finally, a large decrease in drying rate signifies exhaustion of moisture on the coated surfaces of the packed particles. After this, the transport of moisture from internal pores in the coal particles occurs at a much lower rate than the surface processes.

At present we are defining the procedures with respect to measurement intervals required to define adequately the drying curve. On the basis of two scouting experiments, it appears that drying at room temperature (in a desiccated atmosphere) can be accomplished in two to four hours. Each data curve requires about twenty five data points at five to ten minute intervals. The experimental procedure consists of recording the weight and takes less than 30 seconds per reading. Thus one person can either combine this experiment with other (briefly interruptible) duties, or could run several drying curves simultaneously if we can locate additional microbalances.

PERMEABILITY:

We are also designing a simple apparatus for measurement of water permeability. While all of the details are not finalized, the proposed device will consist of a tube (about 1.5 " diam) with a lip to support a coal disk. The coal disk will be sealed to the ledge with gaskets and/or caulk. Water is added on the top of the disk and a container containing desiccant is sealed around the bottom. Periodic weighings of the desiccant (and container) will used to compute the rate of water transport through the disk.

SCHEDULE:

It will not be possible to make a firm schedule for the moisture absorbance experiments until one or two more preliminary experiments are completed. This has been delayed in part because the end of the semester is a difficult time for student research assistants to budget time for this work.

A very rough idea of the time schedule for experimental work can be estimated by consideration of the factors and variables that seem to need exploring:

1. Particle size range of the ground coal (3 sizes).
2. Weight ratio of asphalt to coal (3-4 levels).
3. Thickness of the disks (2 thicknesses).
4. Pressure during formation of the disk (2 pressures).
5. Water pressure during the soaking step (2 pressures).
6. Replications (4 replications at one or two sets of conditions).

A Latin square type of experimental design is not required for these variables since many of the interactions can be ignored. We will require far fewer experiments than this for the scouting phase, at least. (Later we may wish to investigate some of these variables in greater depth.)

Thus there are probably about 30 - 40 experiments requiring a total of about 100 hours of elapsed time. At 10 hours per week, this would represent 10 weeks or about three months.

While the drying experiments are proceeding, the permeability apparatus will be designed, constructed and tested.

Head Loss Model Development for the Coal Log Pipeline (CLP)

by James L. Richards, Research Assistant

December 12th, 1991

One of the major design criteria for the Coal Log Pipeline is the estimation of head lost due to the presence of coal logs in the pipe. By developing a model that can reasonably estimate this headloss, the designers can place pumping stations at proper spacings and etc. Over the last quarter, a model, based on the most current theoretical developments, has begun to take shape.

Because the 4 basic regimes in capsule pipeline transport are quite different for calculation of headloss, each regime is modeled separately. Briefly, regime I is when the coal logs are stationary, regime II is when the coal logs slide along the pipe at a velocity slower than fluid velocity, region III occurs when a micro-lift develops under the logs and their velocity exceeds the fluid velocity, and regime IV occurs when the fluid velocity exceeds the liftoff velocity. Currently, the model is in good agreement with experimental data for regions II, III, and IV (see attached figure). The experimental data in the figure was collected from coal logs of 1.83" in diameter in a 2.175" I.D. pipe.

Two basic observations from the model have been the sensitivity of the program to the coefficient of dynamic friction (in region II) and the relative roughness (in region IV). The model itself is similar to one that was developed by Pituk (1991) in his Masters thesis entitled "Prediction of Headloss in Hydraulic Capsule Pipeline."

In the upcoming quarter, the model will be completed, abrasion tests on coal logs will begin, and other hydrodynamic data will be taken. These tests include liftoff data and low velocity data. Also included in the next quarter is the projected graduation of the author with his Masters Degree in Civil Engineering.

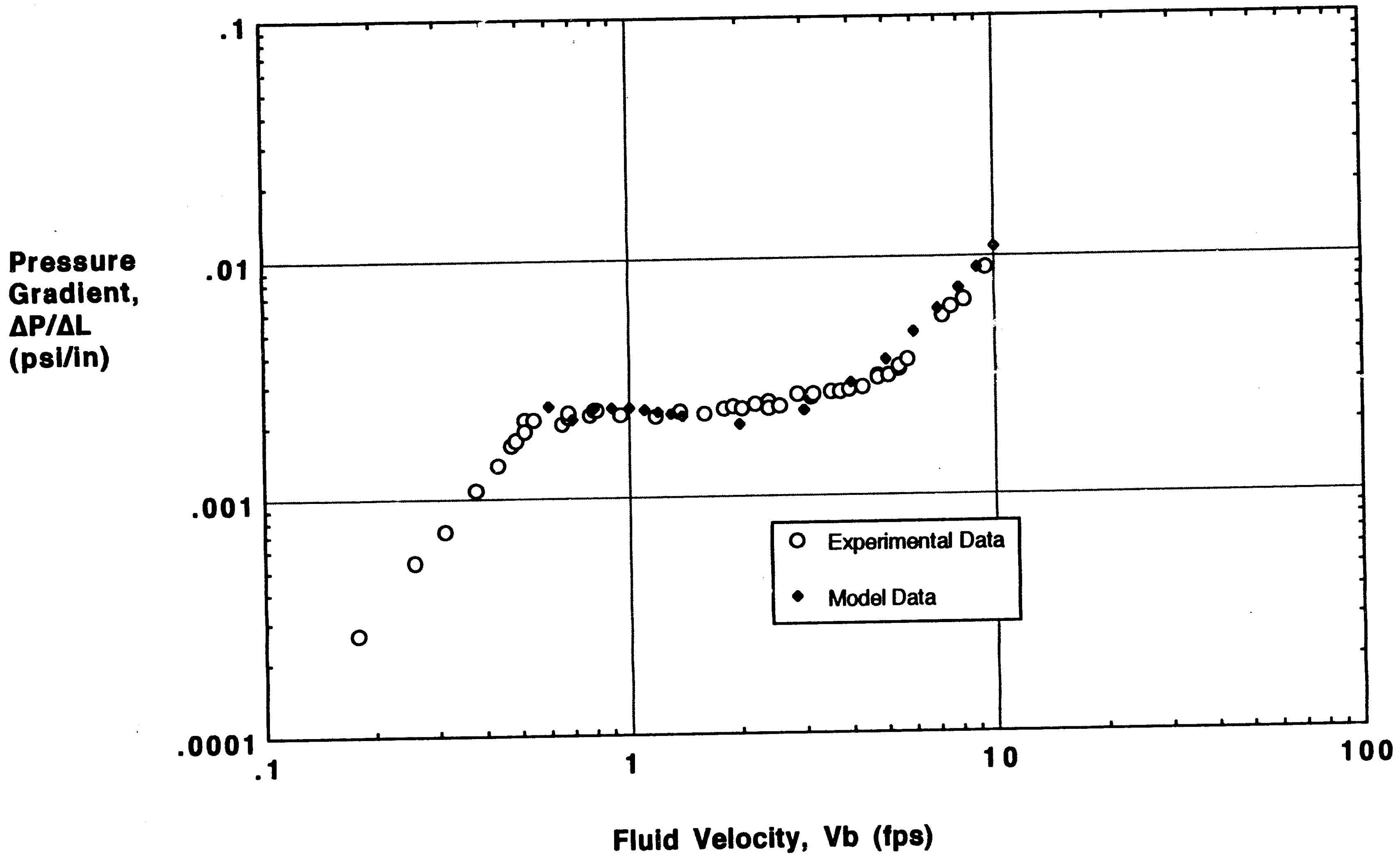

Figure 1. Comparison of Theoretical Model to Test Data in a 2" Pipe (a=3.79, k=0.84)

December 1991

Water Hammer in Hydraulic Capsule Pipeline

by: Majed M. El-Bayya (research assistant)

Most of the work done in the area of Hydraulic Capsule Pipeline (HCP) has been devoted to steady state flow. While steady flow in HCP is the first step in the understanding of the system operation, the operation of the HCP is by no means steady. Water hammer effect on the system could be very dangerous if not controlled. It could lead to capsules destruction because of collision, capsules jamming and pipes failure. In El-Bayya's Master Thesis, four mathematical models have been developed to numerically simulate the water hammer action in a Hydraulic Capsule Pipeline with a single capsule (HCP). These models varied from simple to very sophisticated models. In his thesis, he recommended that model four, which assumes the capsule a point mass, to be tested numerically and to be compared with the other three models. He also recommended to expand the analysis to a train of capsules.

ACHIEVED TASKS:

During the last three months, the following tasks have been achieved:

1) Model four (modified point mass capsule) has been coded and numerically tested and compared with the other three models.
2) The analysis of water hammer in HCP has been expanded to a train of capsules.
3) A paper describing the three models developed in El-Bayya Mater Thesis, has been prepared for possible publication in the "Journal of Hydraulic Engineering, ACI."

RESULTS:

It was found that Model four gives more realistic result than model three does. The pressure vs. time curve and the capsule velocity vs. time curve were similar in shape to those obtained by models one and two.

A computer program was also developed to deal with both a train of capsules and a single capsule. This computer program, at this stage, analyze a simple system in which the spacing between capsules is relatively large. When completed, the program will be able to analyze a very complicated system like the one in our Pipeline Lab. The early results of this computer program show that the maximum fluctuating pressure due to water hammer in a capsule pipeline system, like the one discussed in El-Bayya's thesis, is greater for a train of capsules than for a single capsule.

FUTURE TASKS:

In the next three months, the following tasks will be performed:

1) The computer program for analysing capsule trains will be modified to eliminate the numerical instability which occurs when using a large time interval.

2) The program will be expanded to the case where the spacing between capsules is small.

3) Finding a solution to make the computer program capable of handling collisions of capsules.

11/26/91

To: Dr. Liu, Dr. Nair

From: Richard Oberto, Electronic Technician

Subject: Branch Pipeline Computer Control Progress Report.

There have been some modifications made in the sensor mounting positions. This was done because the pneumatic valves needed sensors that indicated the presence of a coal log in the actual moving portion of the mechanism. This lowers the amount of computer program time and increases the safety of the operation of the valves; only a single scan of the sensors in each valve is needed to make a logical decision.

All 12 of the pneumatic valves had to be removed from the system. Four water tight fittings were mounted within a distance of less than one coal log from each other to allow fiber optic image conduit to be inserted in the pipe. All 12 valves were fitted with four fittings.

All of the valves have been reinstalled in the system and the sensors have been mounted on the fittings. The sensors consist of two infrared light emitting diodes and two phototransistors. These have been wired to the computer input circuitry and are being tested.

MODELING AND CONTROL IMPLEMENTATION FOR THE SMALL-SCALE COAL LOG PIPELINE UNIT

Satish Nair, Asst. Professor, and S. L. Chang, Graduate Student
Dept. of Mechanical and Aero. Engrg.
Jianping Wu, Graduate Student,
and Richard Oberto, Research Electronics Technician
Dept. of Civil Engineering
University of Missouri-Columbia

This report details the on-going work with the small-scale demonstration unit of the entire coal log pipeline (CLP) system at the Center for studying important system characteristics including control. The basic design and construction details of this CLP demo system were described in [1,2] and the previous quarterly report [3].

SMALL -SCALE COAL LOG PIPELINE UNIT

The three major subsystems, shown in Figures 1 and 2, have been constructed and assembled. These figures were included in the previous report and have been repeated here for convenience. The injection subsystem consists of 4 conveyor belts, 16 valves and the auxiliary pump. These 16 valves are shared by the pumping subsystem also, which, in addition has a main pump. The valves are controlled using a 486-based IBM compatible computer which is described in a later section. This allows for rapid filling of the four branches while simultaneously establishing a steady stream of coal logs in the main pipe. The pump bypass system (Figure 2) consists of a regular centrifugal pump, two coal log bypass lines, and eight valves. The outlet consists of a conveyor belt which transports the coal logs out of the reservoir at 6 fps for storage. All these as well as the train separator operation are controlled by the personal computer.

MODIFICATION OF OPTICAL SENSOR INSTALLATION

Several optical sensors form part of the sensor module for the small scale unit. Each sensors consists of an infrared light emitting diode and a photo-transistor. In the earlier approach a sensor each at both sides of a valve was used to detect the presence of a log in the valve. When such a configuration was tested, it was found that detection of the presence of a coal log in a valve could not be done with certainty. The reason for this is that the length of the demo logs is smaller than the smallest spacing possible between the sensors and the demo logs tend to stay together sometimes making the task of 'counting' difficult for the sensors employed.

A redesign was performed where the optical sensors were mounted directly on the valves to ensure that the distance between the two sensors is less than a coal log. All twelve of the pneumatic valves had to be removed form the system. Four water tight fittings were mounted within a distance of less than one coal log from each other on each of the valves. With this configuration only a single scan of the sensors in each valve is needed which enhances safety. It also lowers the control loop time. Optical sensors are being installed in addition to these at other locations for counting purposes. All the valves have been reinstalled in the system and the sensors have been mounted on the fittings. These have been wired to the computer input circuitry and are being tested.

CONTROL SOFTWARE DEVELOPMENT

A 486-based IBM compatible computer is used as the control station. The primary interface card is the Metrabyte PIO-96 which is a high density parallel digital I/O card with TTL/DTL compatible lines. The operating systems used will be Microsoft DOS 5.0 and MS Windows. The control code is being developed in a modular fashion using C language. The controller will have several modes of operation including system startup, diagnostics, individual device operation, and options for single/multiple coal log train transport, continuous operation and orderly system shut down. Safety software monitoring the system operation will be running concurrently to take care of component malfunctioning. This code will issue appropriate warnings and trigger system shutdown if necessary.

The control program was tested on the unit using one of the four injection inlets. It performed well and we envisage no major difficulties with the software development efforts. The mechanical system and sensor design seem to be the area which has limited progress of software development so far and much attention is being paid to ensure enough bandwidths for the hardware systems and control design for several planned studies using the demo system.

DEVELOPMENT OF A DISPLAY CAPABILITY

Display of the system status at any instant allows visualization of the system dynamics so that corrective action can be taken by manual override if necessary. This effort is being performed as a separate project using an MS Windows interface and an independent computer. The display is currently intended to indicate the status of the controlled valves, a count of the coal logs and pressure/velocity values at specific locations.

The display program is designed using Borland C++ software development package. Using the package, pull-down menus and dialog-boxes are being built according to system needs. At present, animation of the movements of coal logs has been successfully done. The operation of the valves are driven by a pre-set timer which can be adjusted to reflect changes in velocity. Current efforts in this section focus on interfacing the display program with the actual system, i.e., to receive the sensor signals directly from the capsule pipeline as inputs to the display program. The other issue being considered is an integrated computer system performing different tasks, one of which will be display. A local area network (LAN) needs to be built for this purpose. Since Microsoft Windows has built-in ability for supporting networking, such an integration will be easier.

DYNAMIC MODELING FOR CONTROL AND OPTIMIZATION STUDIES

The focus of this investigation is to analyze the hydraulic dynamics of the demo system for control algorithm development and optimization. Specifically, the objectives are :

i) derive the hydraulic equation of the CLP systems using quasi-steady approach to predict the behaviour of fluid and coal logs in the system during various phases of operation (with Dr. Liu). ii) develop a mathematical model for the unsteady flow in the system using lumped parameters (with Dr. Nair). iii) conduct experiments on the demo unit and validate the simulation models. iv) use the simulation as a test bed and develop control strategies for system operation.

The following assumptions pertain to the quasi-steady approach : a) the system is on a horizontal plane, b) the flow is incompressible and effects of wave propagation generated by the closure or opening of valves are neglected, and c) the entire coal log train is treated as one unit. Finite difference approximations are used to solve the differential equations. Gauss elimination is used to solve the simultaneous linear equations generated by the pipe network. The head, fluid velocity and coal log velocity are calculated along he pipes at each time instant. The head loss along the pipes with coal log present in it will be evaluated based on an earlier study [4]. The unsteady flow model will use lumped parameters to model the fluid as well as the coal logs. ACSL (Advanced Continuous Simulation Language) will be used for model development in this case. The lump length is selected to be such that all the relevant frequencies of the system are considered. Selecting it smaller than the coal log length is found to be advantageous.

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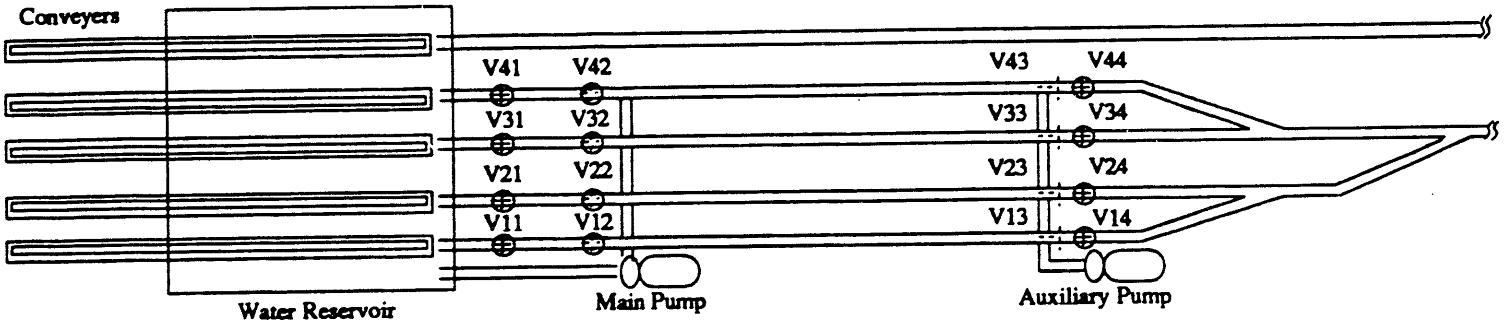
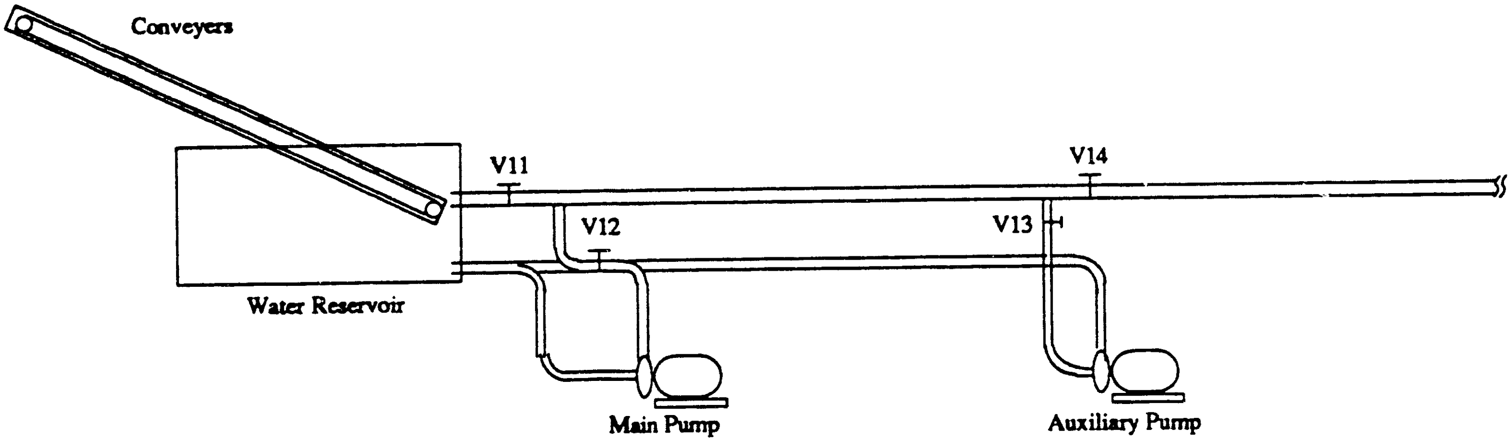
3. Nair, S. S., and Wu. J. P., *Computer Control of Coal Log Pipeline*, NSF Quarterly Progress Report , August, 1991.
4. Paksanonda, P., Prediction of Headloss in Hydraulic Capsule Pipeline, MS Thesis, Department of Civil Engineering, University of Missouri-Columbia, 1991.
5. Woodson, R.J., Lenau, C.W., and Liu, H., *Analysis of Pressure Surges in a Pump Bypass System for Hydraulic Capsule Transport*, Freight Pipelines, 6th International Symposium on Freight Pipelines, Hemisphere Publishing Corp., New York, pp. 359-363.



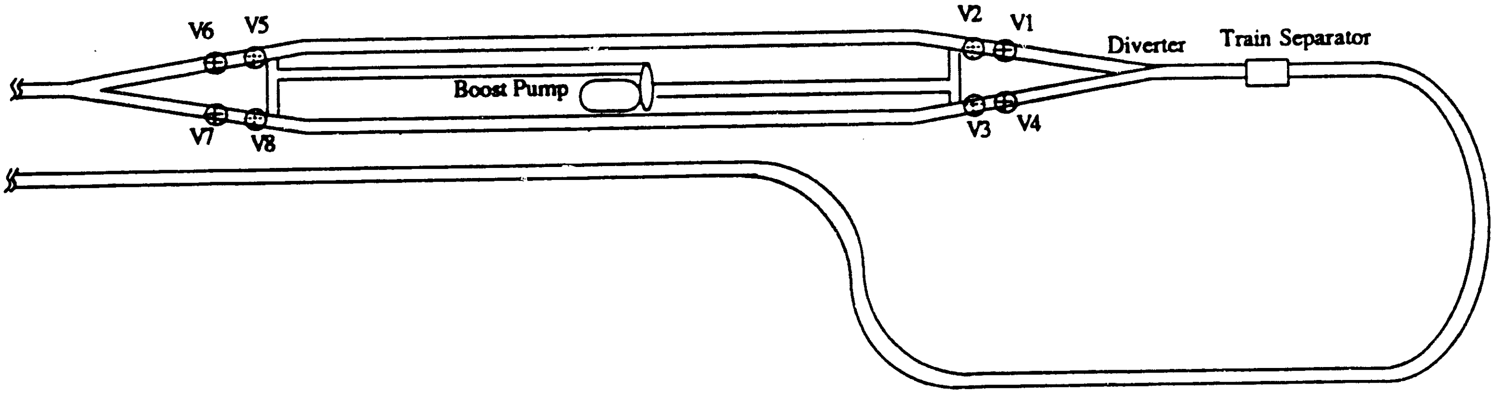
Top View



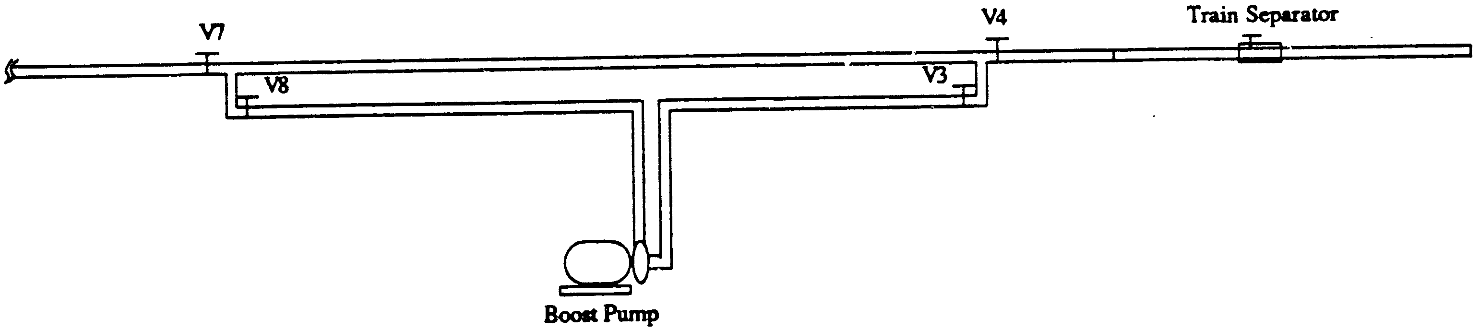
Side View

3 ft

Fig. 1: Coal Log Injection & Ejection System



Top View



Side View

Fig. 2: Pump Bypass & Coal Log Train Separator Systems

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