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Coal Log Pipeline Research at University of Missouri
3rd Quarterly Report for 1995
7/1/95 - 9/30/95

Henry Liu
Professor and Director
Capsule Pipeline Research Center

Project Sponsors:

National Science Foundation (State/IUCRC Program)

State of Missouri (Department of Economic Development)

U.S. Department of Energy (Pittsburgh Energy Technology Center)

Coal Log Pipeline Consortium:
- Arch Mineral Corporation
- Associated Electric Cooperative
- MAPCO Natural Gas Liquids Inc.
- Union Electric Company
- Williams Pipe Line Company
- Williams Technologies, Inc.
- Wilbros Butler Engineers

Small Business Participants:
- Bonnot Company
- Gundlach Machine Company
- Nova Tech, Inc.
- Pro-Mark Process Systems
- T. D. Williamson
- Permalok, Inc.

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CONTENTS

EXECUTIVE SUMMARY

During this quarter (7/1/95-9/30/95), major progress has been made in the following areas of coal log pipeline research, development and technology transfer:

1. Conceptual design of a test machine based on hydraulic presses to mass-produce 5.4-inch-diameter coal logs for testing in a 6-inch-diameter pipeline has been completed. The machine will be able to produce two logs in a minute. This test machine will be built as soon as funds are available for constructing it, anticipated within the next 6 months (Yuyi Lin).

2. Conceptual design of a rotary-press machine to produce 1.9-inch-diameter coal logs for testing in a 2-inch-diameter pipeline has also been completed. The machine will be able to produce 30 coal logs per minute. This test machine will be built one year after the hydraulic press, using information gained from testing the hydraulic press (Yuyi Lin).

3. It has been confirmed through experiments that molds with round-edge exit can make logs as good as those made with tapered exit. Round-edge exit is not only easier to construct than tapered exit, it is also shorter and hence costs less, and faster due to shorter stroke (Y. Lin).

4. Conducted a study to determine the effect of surface condition of mold and lubricants on the quality of coal logs. It was found that stainless steel mold is as good as and more practical than chrome-plated and Militec-1 treated molds. However, using MoS_2 as lubricant during compaction can greatly improve coal log quality if a small amount (less than 1%) of Orimulsion exists in the coal logs. It is also shown that compacting at 90°C without binder can produce logs slightly better than room-temperature logs with 3% Orimulsion. Even at room temperature and without binders, logs compacted with Mettiki coal in an unlubricated stainless steel mold with tapered outlet have less than 3% weight loss in 200 cycles through pipe loop at 85% lift-off velocity (Liu/Li).

5. Completed an evaluation of the effect of fiber (wood pulp) on coal log quality. While using 0.4% fiber reduces coal log wear substantially at room temperature for logs with diameter ratio $k = 0.81$ and circulated at lift-off velocity, for logs with $k = 0.88$ and at 85% lift-off the benefit of using fiber is insignificant. This shows that fiber is effective in reducing wear caused by impact, but it is ineffective in reducing wear caused by abrasion. It is to be used only in situations where impact damage is important (Gunnink).

6. Prepared an apparatus for testing fast compaction of coal logs -- 2 second per log (Gunnink).

7. Compacted coal logs in a 5.3-inch-diameter mold. It was found that a two-stage mixing process is effective. The process requires first to mix binder with coarse coal particles; then the mixture with coarse particles is mixed with fine particles (Wilson).

8. Completed a preliminary study to assess vacuum and steam heating systems to enhance coal log production and quality. It was found that during compaction at room temperature, vacuuming has a beneficial effect especially at high compaction speed and low-level of binder. Furthermore, direct steam heating was found to be more effective in producing good coal logs than indirect heating, especially at low levels of binder (Butler).

9. Changed the small-scale-CLP-demo loop from a once-through system to a recirculating system. Discovered certain problems when such a change was made and is in the process of solving such problems (Nair).

10. Completed revision of CLP economic model and revised the 1993 report (Liu and Noble).

11. Conducted preliminary economic analysis of 14 sites submitted for demonstration. Found that 7 sites are economically competitive with alternate modes of transportation. In addition, conducted economic analysis of several other long-distance pipeline projects such as Wyoming-to-Texas CLP, Wyoming-to-Missouri CLP (using Platte Pipeline), etc. (Liu/Marrero/Wu).

12. Drafted model laws for state eminent domain on right-of-way, rail cross, etc.

13. Pursued an EPRI-TC project -- in progress.

14. Conducted preliminary route selection for large pilot plant project in Thomas Hill. Associated Electric Cooperative has agreed to donate the needed land and right-of-way.

15. Conducted a 4-day workshop on coal log pipeline; the new CLP manual-of-practice was the text.

CAPSULE PIPELINE RESEARCH CENTER

Quarterly Report

(Period Covered: 7/1/95-9/30/95)

Project Title: Machine Design for Coal Log Fabrication

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

Graduate Research Assistant (50% of GRA support)**:** Guoping Wen, Kang Xue

Work Accomplished During the Period:

During this period we focused on two machine designs. One is the 100-ton rotary press for making 1.9" coal logs at the rate of about two seconds per log. A report on this preliminary design is being prepared by Kang Xue. In this report, a detailed assembly drawing contains all major components. Total power requirement, sizes of the large worm gear pair and speed reducer, and the sizes of the frame, the cam profile, the mold and the upper and lower punches have been carefully analyzed. Xue will continue to work on the detailed drawings of all the manufactured parts. As mentioned in the previous quarterly report, there is no similar machine available on the market, and a design of this machine may cost $100, 000 to $150,000. A commercial tableting machine with similar horsepower costs around $650,000. We believe that we can design and manufacture this machine at much lower cost. An outside consultant will be engaged to review our design before it is finalized and built. A copy of the assembly drawing is attached. The purpose here is not to show the details, but the basic concept and the scope of work being accomplished.

The other major R&D task our group is working on is the design of a 300-ton hydraulic press. Again, according to our market search, there is no available machine meeting the force, speed and other compaction requirements. During this quarter, however, we have received two cost estimates from companies. The estimates are based on our specifications [Lin, July 1995]. One company claimed to meet almost all specifications, at cost of $353,000, and a delivery time of four months. The other company did not meet our specification on speed and procedure requirement (for example, two main compaction cylinders instead of one), and the estimated cost was $373,000, with a delivery time of 6-9 months. Both companies stated that these estimates are not based on design, are for budgetary purpose only, and may be changed later on. Our estimated cost is about $175,000 (refer to basic structure shown in attached drawing, and report [Lin and Wen, Sept. 1995]). After group discussion, the center director has decided to:

1. Send our preliminary design for external expert review and advice.
2. Proceed with our internal detailed design of this machine.
3. Request partial funding from the College of Engineering to build the machine.

Future Plans:

For the next three months, the emphasis of our group will be on two major tasks. One is the rotary press for making 1.9" logs at a rate of about two seconds per log, and the other is to complete and finalize the design of the hydraulic compaction machine for making 5.4" logs at a rate of less than twenty seconds per log. More specifically, we plan to finish the following tasks:

1. Send out for expert review of the preliminary design report for the rotary press. The purpose of this review is to correct any possible structural, conceptual and global problems. It will be more expensive to make changes when the detailed design is completed.

2. The production design of major components of this rotary press will start, and going parallel with the review of the preliminary design. We plan to finish the detailed design by the end of the year. When the detailed design is completed, we may send the design out for biding for the cost for manufacture, or send out for another detailed design review before biding.

3. Send the conceptual design of the 300-ton hydraulic press for external expert review.

4. Finish the detailed design of the 5.4" 300-ton hydraulic press. This is the major and priority job. We have two graduate students working on this design, with some help from three undergraduates. The detailed design is to be completed by the end of the year. We are confident that we can finish this task, since we have a detailed design for a 30-ton press, which has similar subsystems, such as PLC controller, computer data acquisition system, two main hydraulic cylinder, and strong frame, and the compaction mold.

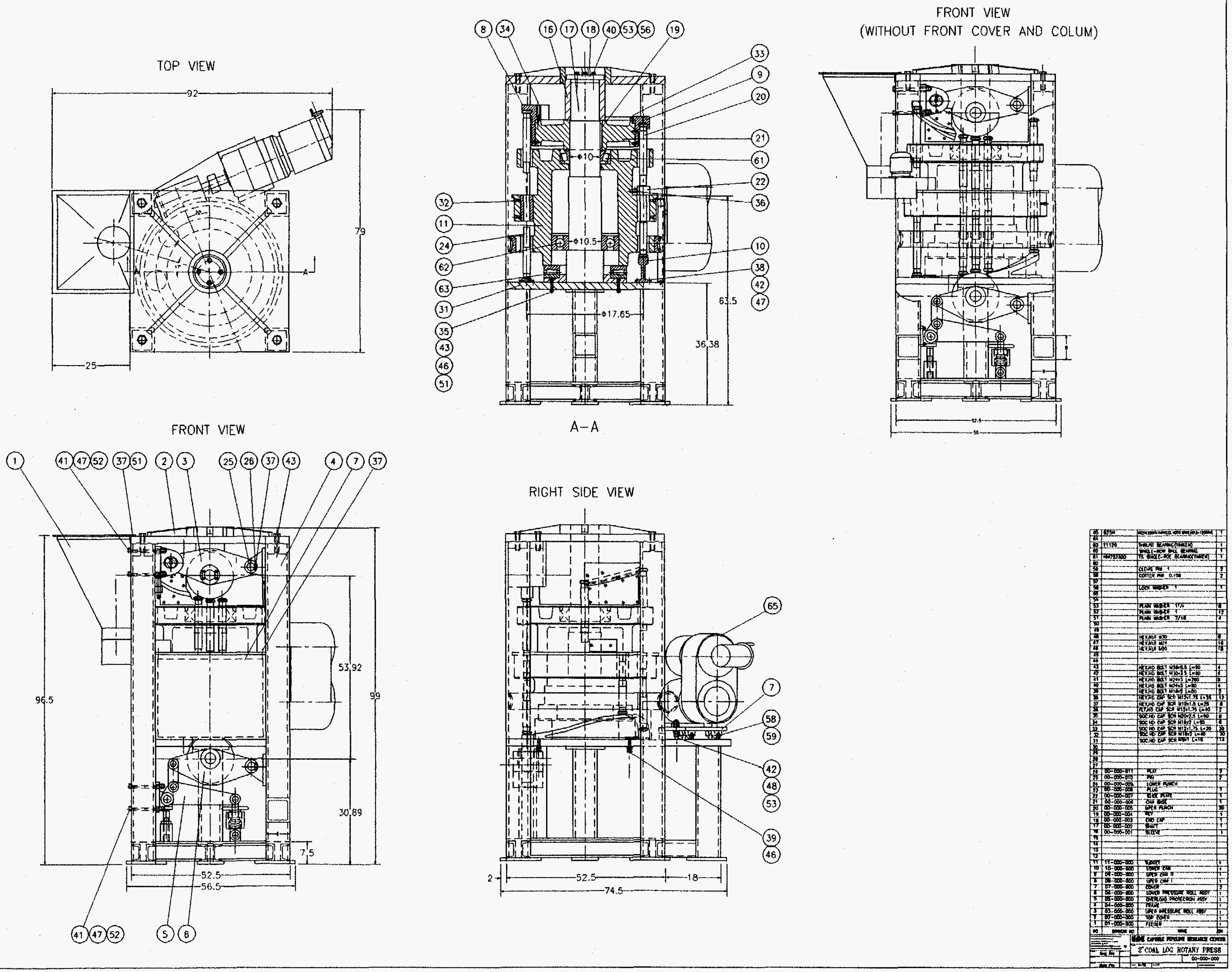
5. In late December, send the finished detailed 300-ton press design for external review, before asking for a bid on manufacturing of the machine.

Publications:

Lin, Yuyi, July 1995, Specifications of a 300T Fast Compaction Machine for 5.4" Coal Log Fabrication, CPRC Internal Publication.

Lin, Yuyi and Wen, Guoping, September 1995, Conceptual Design of a 300T Fast Compaction Machine for Making 5.4" Coal Logs and Cost Estimation, CPRC Internal Report.

Lin, Yuyi and Xue, Kang, September 1995, Preliminary Design of a 100T Rotary Press for Fast Compaction of 1.9" Coal Logs, CPRC Internal Report.



TOP VIEW
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A-A
φ10
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63.5
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FRONT VIEW
(WITHOUT FRONT COVER AND COLUM)
FRONT VIEW
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99
53.92
30.89
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52.5
56.5
RIGHT SIDE VIEW
2
18
74.5
THRUST BEARING(TIMKEN)
SINGLE-ROW BALL BEARING
COTTER PIN 0.156
LOCK WASHER 1
PLAIN WASHER 1
PLAIN WASHER 7/16
LOWER PUNCH
PLUG
CAM BASE
KEY
END CAP
SHAFT
COVER
LOWER PRESSURE ROLL ASSY
OVERLOAD PROTECTION ASSY
FRAME
TOP COVER
FEEDER
CAPSULE PIPELINE RESEARCH CENTER
2"COAL LOG ROTARY PRESS
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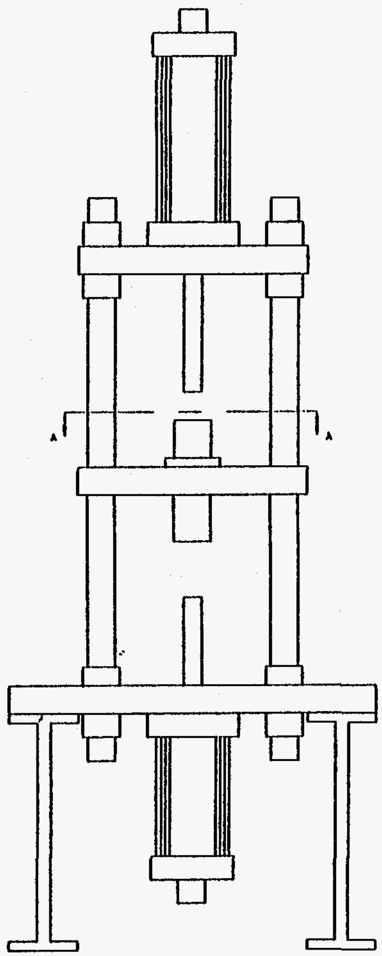
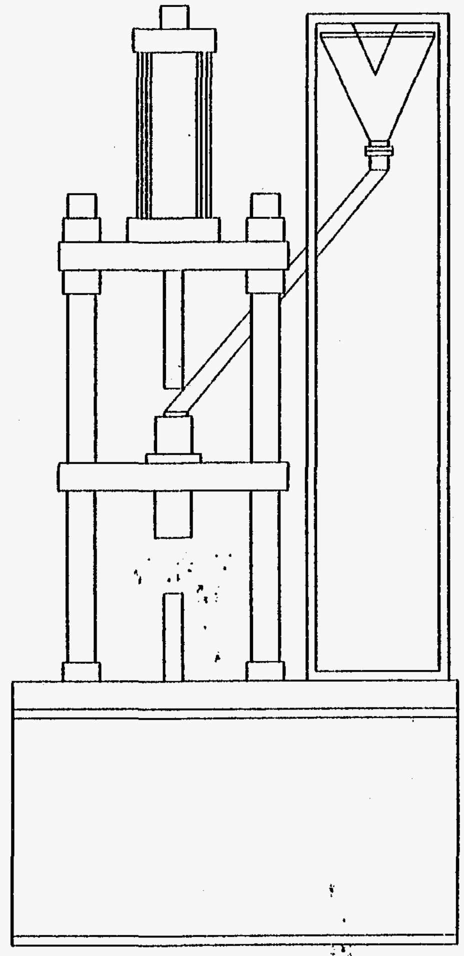
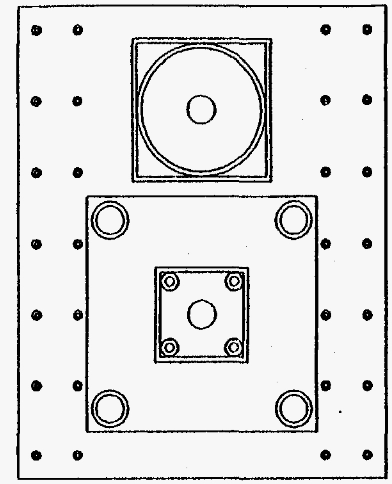
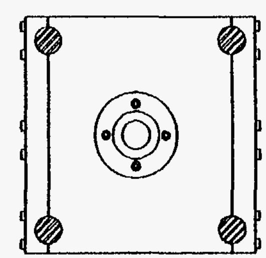




TOP VIEW



VIEW A - A



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PROPRIETARY: THE INFORMATION DESCRIBED HEREIN ARE THE PROPERTY OF CAPSULE PIPELINE RESEARCH CENTER AND MAY NOT BE USED PRODUCED OR DISTRIBUTED IN ANY FORM.

CAPSULE PIPELINE RESEARCH CENTER
UNIVERSITY OF MISSOURI-COLUMBIA
COLUMBIA, MO 65211

MATERIAL DESCRIPTION

REVISIONS — DESCRIPTION — REVISION NO. — APPR. — DATE

CAPSULE PIPELINE RESEARCH CENTER

Quarterly Report
(Period Covered: 7/1/95-9/30/95)

Project Title: Surface Condition of Mold and Lubricant Effect on Quality of Coal Logs

Principal Investigator: Henry Liu, Director, CPRC

Post Doctoral Fellow: Yin Li

Research Assistant: Andy Rockabrand

Purpose of Study: To determine what type of mold surface produces best coal logs.

Work Accomplished during this Period:

Bituminous coal from the Mettiki Mine was used to compact coal logs in two separate 1.91-inch-diameter molds -- one having stainless steel surface and the other having chrome-plated surface. The four surface conditions tested were: unlubricated stainless steel mold, MoS_2 lubricated stainless steel mold, unlubricated chrome-plated mold, and Militec-1 treated stainless steel mold. All logs were tested at 85% lift-off in a 2-inch-diameter steel pipe loop.

Figure 1 shows that with the unlubricated stainless steel mold, wear loss of coal logs over 350 cycles through the loop was about 4.8% for logs compacted at room-temperature without binders; it was 3% for logs compacted at room temperature with 3% Orimulsion; it was 2.4% for binderless logs compacted at 90°C; and it was 2.3% for 90°C logs with 3% Orimulsion. The foregoing results show that rather good (wear-resistant) coal logs can be produced with or without binder in the unlubricated stainless steel mold. Binderless logs produced at 90°C appeared to be as good as or better than room-temperature logs with 3% Orimulsion. Even the room-temperature, binderless logs performed surprisingly well.

Figure 2 shows that the use of MoS_2 as lubricant greatly improves the quality of coal logs when a small amount of binder (Orimulsion) was used. Whether one uses 1%, 2% or 3% binder makes insignificant difference. This means a threshold amount of binder, less than 1%, exists for MoS_2 to be effective. Whether the threshold is 0.5%, 0.2% or else is unknown. It will be determined from future experiments.

Finally, Fig. 3 shows that the unlubricated stainless steel mold appears to be as good as if not better than the chrome-plated mold and the Militec-1-treated mold. For this reason, there appears to be little justification for using chrome-plated or Militec-1 treated mold.

Future Plan:

During the next quarter, MoS_2 will be used for compacting coal logs with less than 1% Orimulsion to determine the threshold value of binder concentration for MoS_2 to be effective in improving the quality of coal logs. Work is also needed to determine the best way to apply MoS_2 to mold and the economics of using MoS_2 and other dry lubricants.

References:

Y. Li, Experimental Studies on Lubricant Effects, Project Completion Report, Capsule Pipeline Research Center, University of Missouri-Columbia, October 1995, 51 pages.

Liu, H., Y. Li and A. Rockabrand. "Wall Friction and Lubrication During Compaction of Coal Logs," paper submitted to Powder Technology for possible publication, 1995.

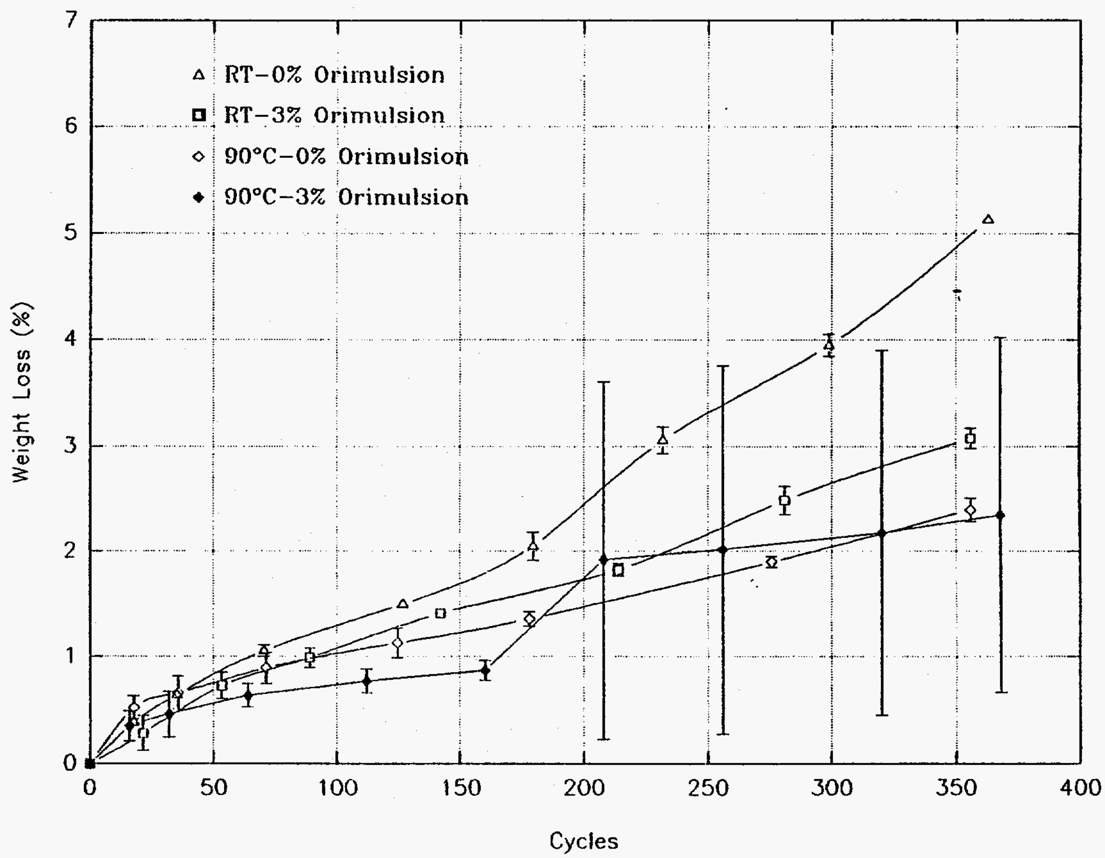

Figure 1 Coal logs compacted with unlubricated stainless steel mold

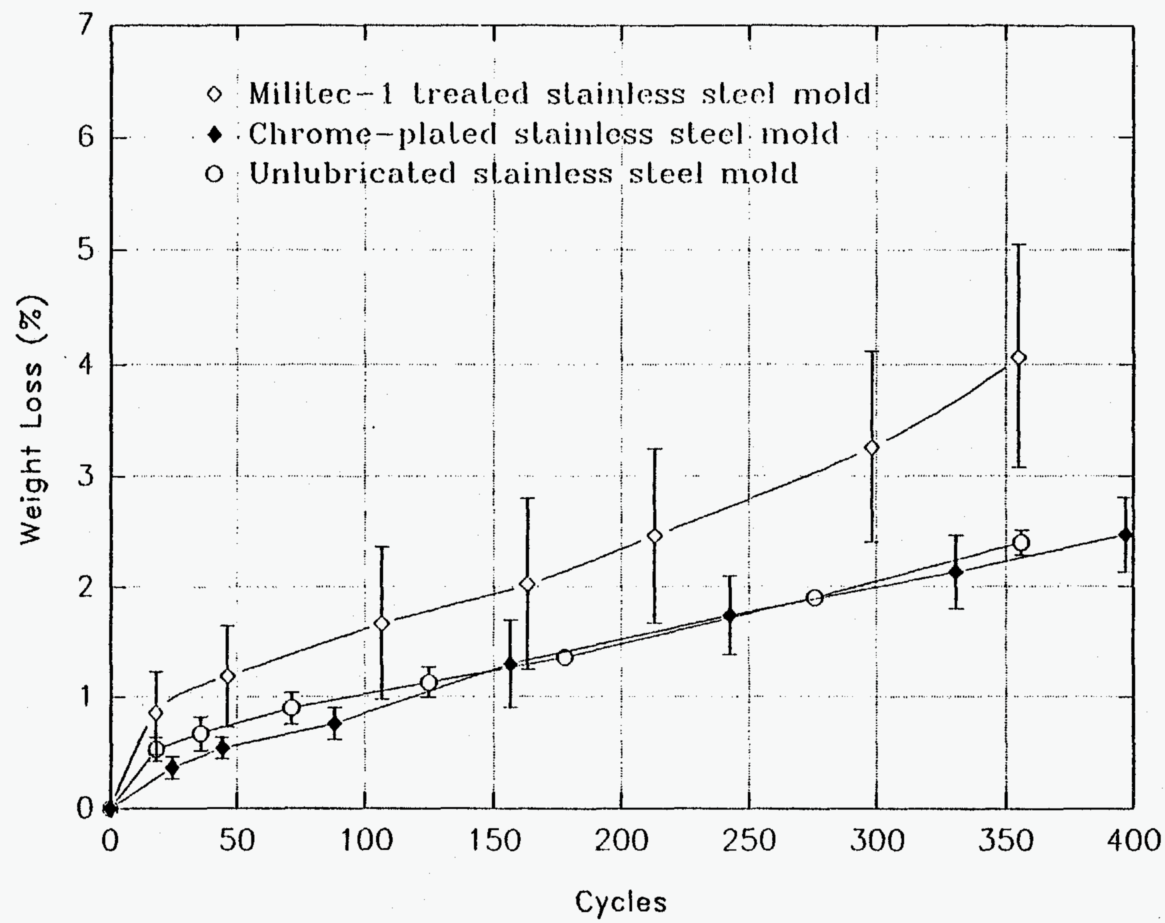

Figure 3 Comparison of logs made in molds of different surfaces
(90°C, 0% Orimulsion, 1.91" mold, 20,000 psi pressure)

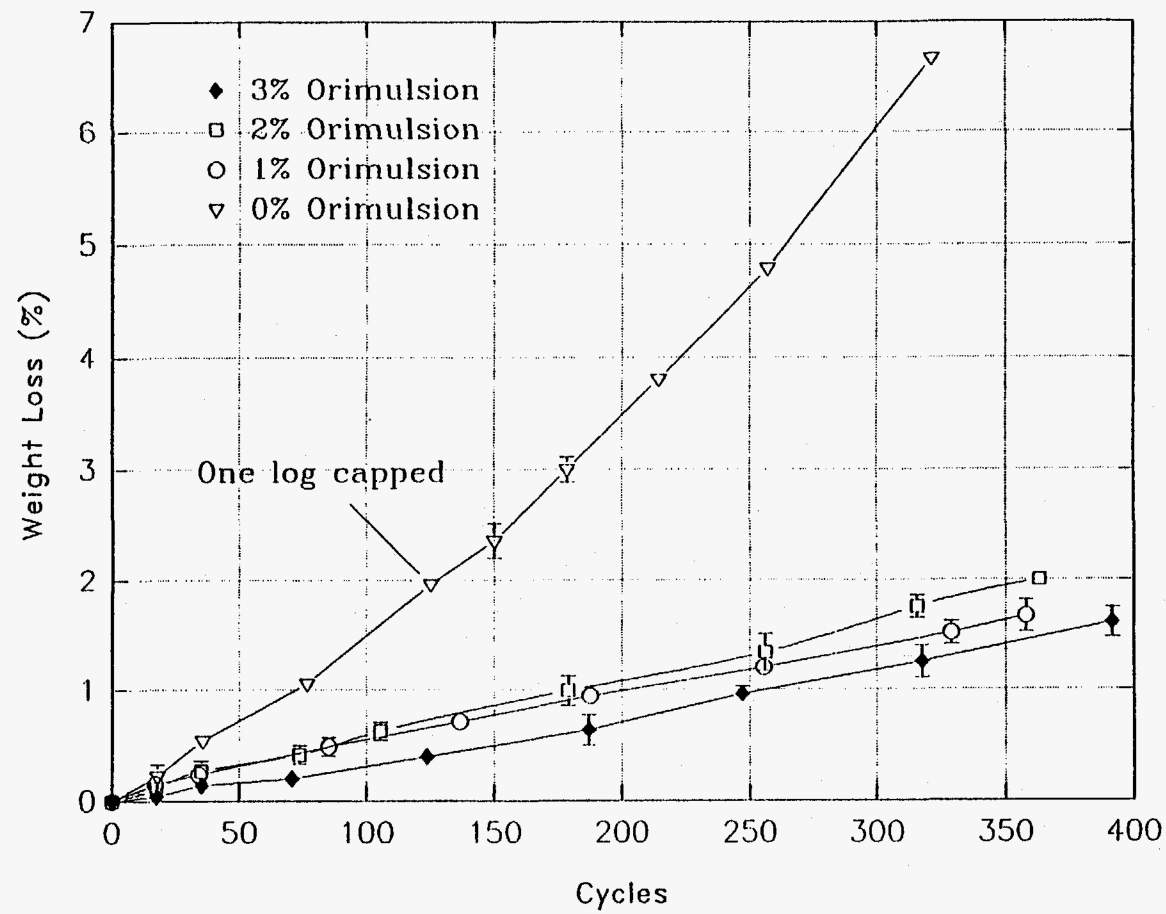

Figure 2 Comparison of MoS_2 effect at different binder concentrations (RT, 1.91" mold, 20,000 psi pressure)

CAPSULE PIPELINE RESEARCH CENTER

Quarterly Report
(Period Covered: 7/1/95-9/30/95)

Project Title:	Rounding Mold Exit to Improve Coal Log Compaction
Principal Investigator:	Henry Liu, Director, CPRC
Visiting Scholar:	Yu Lin
Research Assistant:	None
Purpose:	To determine whether rounding the exit corner (edge) of mold is as effective as tapering the mold exit in producing high-quality coal logs.

Work Accomplished During this Period:

During a previous quarter, it was found that coal logs made by tapered-exit molds are much better (stronger and more wear-resistant) than those made by straight-exit molds. However, tapering the exit of a mold increases the length of the mold which in turn increases the cost and the bulkiness of the coal log compaction machine. If the same improvement of coal log quality can be accomplished by rounding the edge of the mold exit instead of tapering, then the length of the mold and the machine cost can be reduced. Round-edge exit was expected to work due to reduction in coal log stress concentration during ejection phase.

The effectiveness of round-edge-exit mold was evaluated during this quarter by testing four mold exit shapes: (1) straight exit, (2) tapered exit (1° taper), (3) round-edge exit (R = 0.05"), and (4) round-edge exit (R = 0.10"). The results are shown in Figs. 1, 2 and 3, each of the three figures represents a different compaction condition, all using MAPCO Mettiki coal.

Figure 1 is for coal logs compacted at 15,000 psi, 25°C (room temperature), and without binder. Figure 2 is for logs compacted at 10,000 psi, 25°C and 2% asphalt (from Orimulsion). Figure 3 is for logs compacted at 10,000 psi, 97°C and 2% asphalt (from Orimulsion). Note that in all three cases, the straight mold had the highest wear loss, the large-radius round-edge mold had the second highest wear loss, and the small-radius (R = 0.05") round-edge mold and the tapered-exit mold (1° taper) had the lowest wear loss. This study demonstrated that the small-radius (R = 0.05") round-edge-exit mold is as effective as the 1°-tapered mold. Therefore, we have proved that rounding the edge of mold exit can be as effective as using tapered exit.

Plan for Next Quarter:

During the next quarter, we will compare the result of using the large-radius (R = 0.1") exit mold with the tapered mold by using coal mixed in the same batch, to confirm results obtained in Figs. 1, 2 and 3. We will also conduct a finite element analysis of the stress on the log in contact with the mold exit edge. From this finite element analysis, it is hoped that we can confirm that R = 0.05" is a better radius than R = 0.10" for the 1.9" mold. Once this is proved, we can use finite element analysis to determine what the optimum mold-exit radius is for molds of any given size.

Reference:

Lin, Y., Effect of Exit Shape of Compaction Mold on Coal Log Quality, Project Completion Report, CPRC, Oct. 1995.

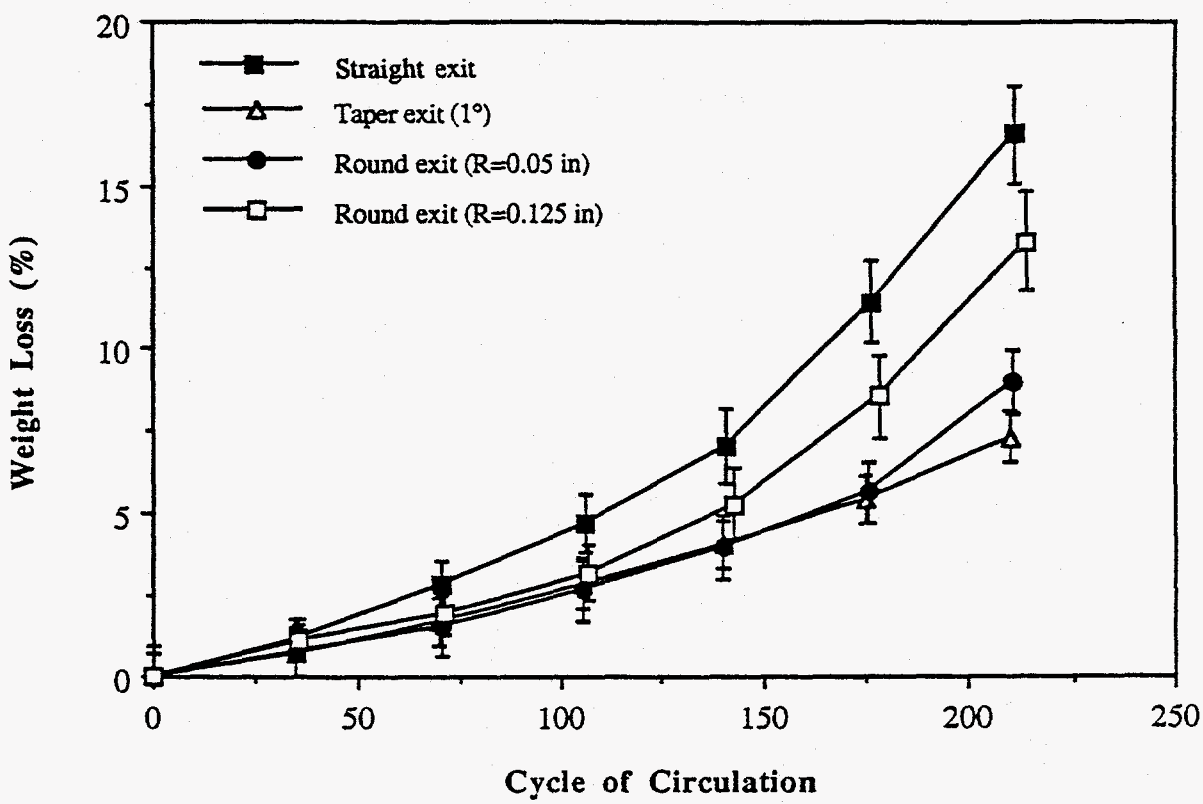

Fig. 1. Weight losses of coal logs due to wear in pipe as a function of circulating cycles (15,000 psi, 25°C, without binder)

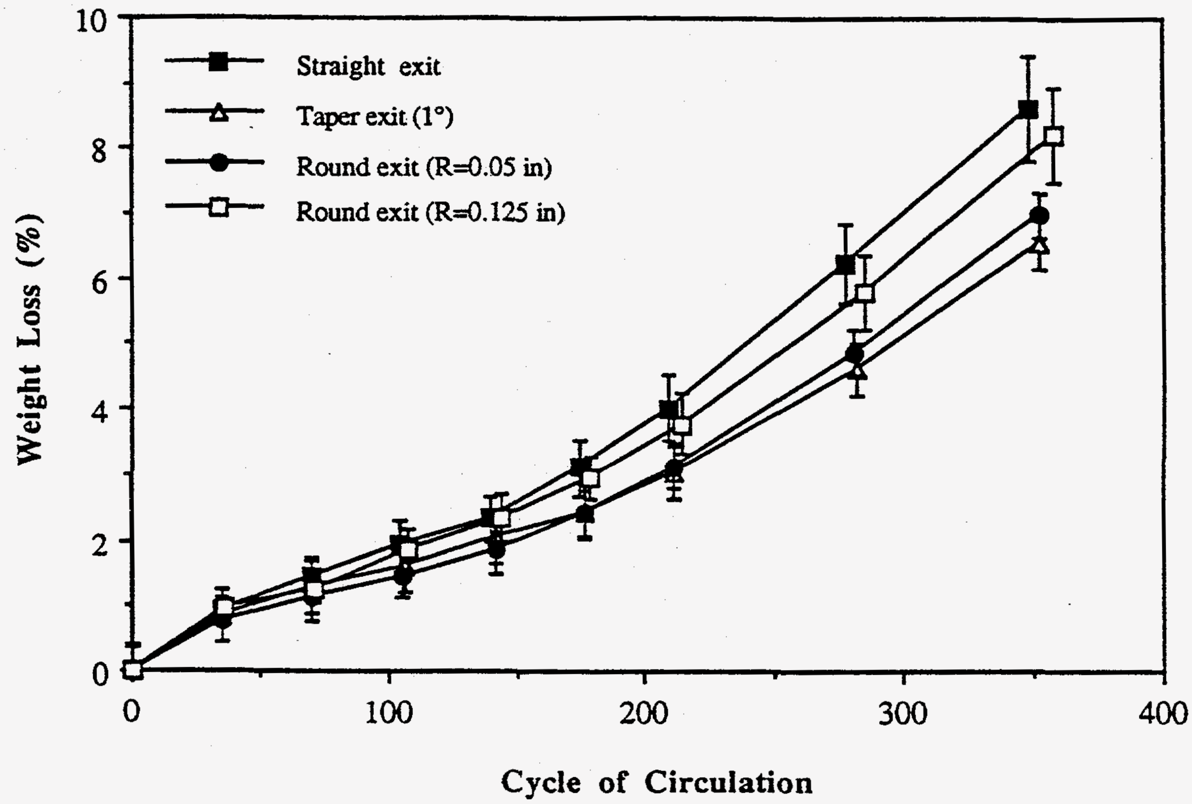

Fig. 2. Weight losses of coal logs due to wear in pipeline as a function of circulating cycles (10,000 psi, 25^{o}C, 2% asphalt)

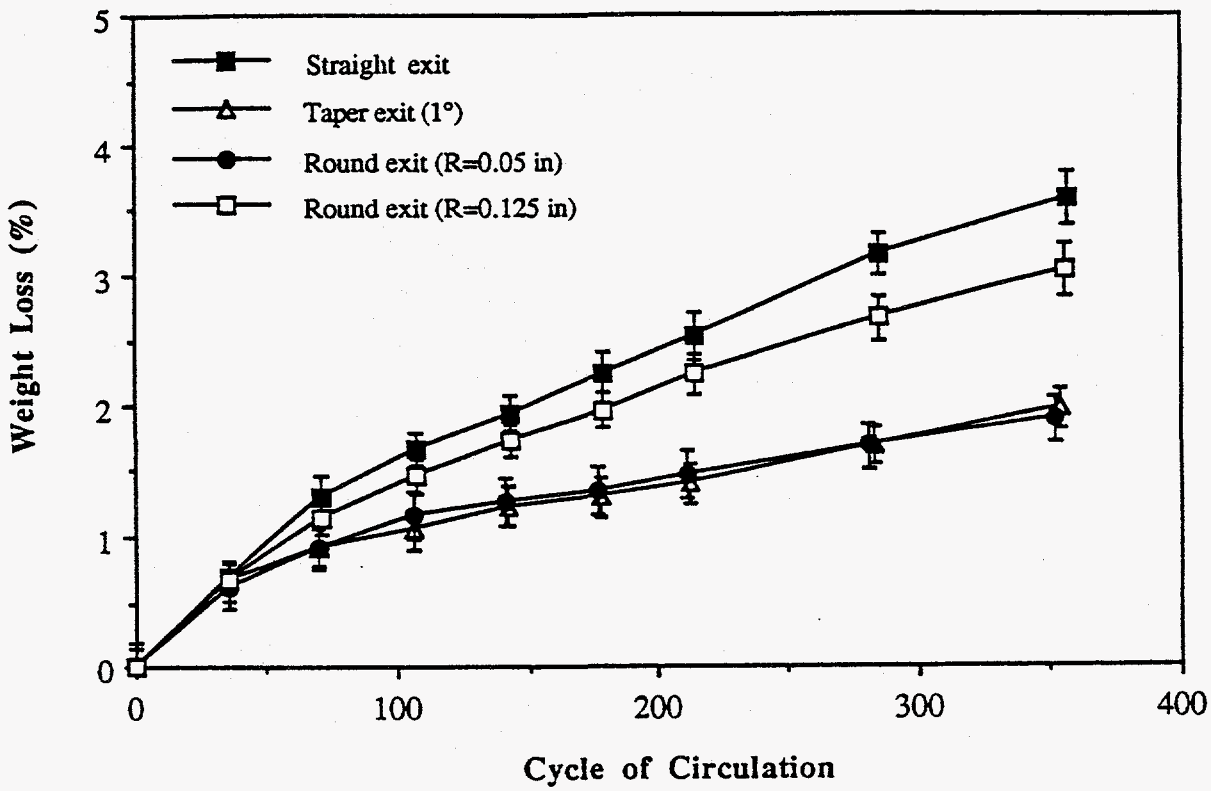

Fig. 3. Weight losses of coal logs due to wear in pipeline as a function of circulating cycles (10,000 psi, 97°C, 2% asphalt)

Capsule Pipeline Research Center

Quarterly Report

for

Individual Projects

(Period Covered: 7/1/95-9/30/95)

Project Title: 1. Conclusions of Effectiveness of Adding Fiber to Enhance Coal Log Quality
2. Very Rapid Compaction of Coal Logs

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

Research Assistants: Shiping Yang
John Jiang

Purpose of Study: 1. To determine whether using a small amount of low-cost, combustible fiber, such as wood pulp, can improve the wear resistance of coal logs.
2. To advance the speed of compaction of laboratory scale coal logs from approximately 30 seconds to less than 2 seconds.

Work Accomplished During the Period:

We have completed studying the effects of fiber addition on coal log circulation performance. Specifically, we have been investigating the effects of fiber concentration, compaction temperatures, and binder concentrations. Initially, wood pulp fibers produced by the Buckeye Cellulose Corporation of Memphis, Tennessee were used. The estimated cost of these fibers is \$800-\$1000/ton. Fiber that costs this much is too expensive for CLP use. Therefore, we also investigated the economics of adding waste fiber to coal logs. Preliminary information indicates that waste fiber is available at \$80 - \$100/ton of fiber. At a fiber addition rate of 0.4%, this amounts to approximately \$0.40/ton of coal logs. Preliminary cost estimates for the additional equipment, personnel, etc. to operate a hydropulper for handling the fiber indicate an additional cost of approximately \$0.15/ ton of coal logs. Raw material costs for emulsified bituminous binder is approximately \$1.11/ton of coal log/% bitumen added. Therefore, the partial replacement of binder with waste fiber appeared to be economically attractive.

Most of the test results on fiber reinforced coal logs have been presented in earlier quarterly reports. Mr. Shiping Yang has begun writing an MS thesis on this work. A summary of conclusions for this work follows.

Whether or not fiber addition significantly improves the circulation performance of coal logs is highly dependent on the both the compaction temperature and the hydrodynamics of the coal log circulation test.

Fiber reinforced coal logs, made at room temperature with a log diameter/pipe diameter ratio of 0.81 (1.75 inch diameter logs), that were circulated at their theoretical lift-off velocity had significantly less circulation weight loss when compared to non fiber-reinforced logs. However, for otherwise similar logs made at 90 °C, the improved circulation performance of fiber-reinforced was almost negligible. It is believed that this is due to the degradation of fibers at this elevated temperature.

Fiber reinforced coal logs, made at room temperature with a log diameter/pipe diameter ratio of 0.88 (1.9 inch diameter logs), that were circulated at 85% of their theoretical lift-off velocity had negligibly less circulation weight loss when compared to non fiber-reinforced logs. At smaller log diameter/pipe diameter ratios and higher circulation velocities, the log is much less stable while circulating. There is more impact type loading as the log frequently hits the walls of the pipe. Under these undesirable hydrodynamic conditions, fiber-reinforcement improves log circulation performance. For more desirable hydrodynamic conditions (i.e. 0.88 diameter ratio, 85% of liftoff) log weight loss is primarily due to abrasion and fiber-reinforcement has little effect.

In summary, there is little circulation performance improvement due to fiber addition of coal logs if the log is circulated under optimal hydrodynamic conditions. These conditions include logs aspect ratio ≥ 1.7, log/pipe diameter ratio = 0.88, and log circulation velocity = 85% of theoretical lift-off velocity. Because of this, there does not seem to be any economical advantage to adding fiber to coal logs.

Work Proposed for Next Quarter:

We will begin to decrease the compaction time for the fabrication of 1.9 inch diameter coal logs in the laboratory from the current 30 second compaction time to less than 2 seconds. This requires the use of the more sophisticated servo-controlled hydraulic test equipment that is available in the MU Civil Engineering Material/Structures laboratory. Some effort was made this past quarter on the training of the graduate students who will be operating the equipment and making the high compaction speed logs.

3rd Quarterly Report Coal Log Pipeline Project

Jul. 1 - Sept. 30 1995

Project Title: Coal Log Fabrication Using Hydrophobic Binders

Project Investigator: Dr. John W. Wilson

Research Assistant Professor: Dr. Yungchin Ding

Graduate Research Assistant: Bing Zhao and Brent Ward

OVERVIEW:

Large (5.3" in diameter) coal logs were fabricated using Mettiki (Maryland) coal at various compacting conditions and binder concentrations. During this reporting period the influences of two-stage mixing, compaction loading time, and minimum peak loading time on the performance of coal logs, were studied.

Two types of coal samples obtained from the Navajo Mine and La-Plata Mine, New Mexico (BHP Minerals), were used to fabricate 1.75" coal logs. Both types of coal have high ash contents (> 25%) which resulted in poor binding between coal particles during the fabrication of the coal logs. After the coal cleaning process (flotation), the ash contents of both types of coal were reduced by more than 13%. Through the coal cleaning process, competent coal logs were successfully made under standard fabrication conditions.

A plan to construct a 6" diam. pipeline at the UMR Experimental Mine has been developed to evaluate the testing of large 5.3" diam. coal logs. This 6" pipeline will be used to assess the overall coal log pipeline transportation system in a pilot scale manner.

PROGRESS TO DATE:

5.3" Mettiki Coal Logs:

To date, 86 large (5.3 inch diameter) coal logs have been fabricated and tested to determine their durability in the 2 ft. diameter tumbler. The coal log fabrication parameters that were evaluated in this reporting period, are listed as follows:-

a. Two stage mixing

b. Compaction pressure

c. Compaction loading time

d. Peak loading time, and

e. Binder concentration.

From the tumbling tests, some of the test results were found to be not as consistent as anticipated. After examining the breaking pattern of the coal logs tested, it was found that the inconsistencies of tumbling weight loss, were resulting from the non-uniform impact that occurred between the end edge of the large coal log and the tumbler wall, see Figure 1.

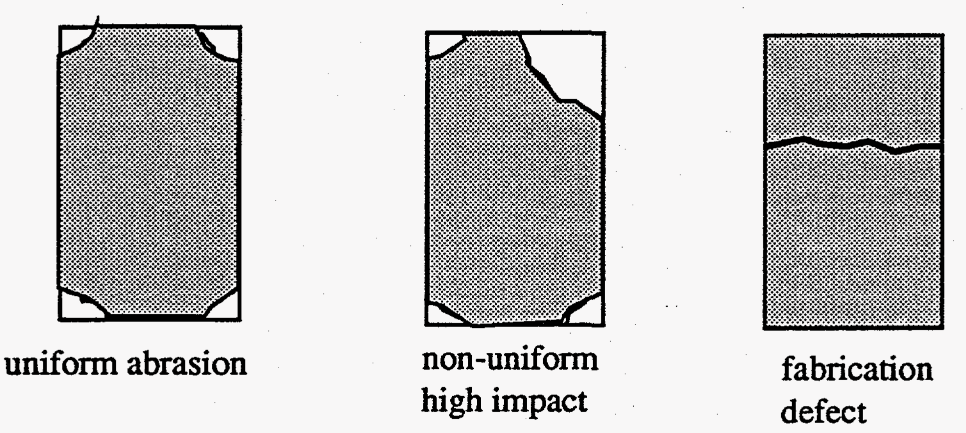

Figure 1. Breaking patterns of large coal tumbling tests.

As shown in Figure 1, uniform abrasion and non-uniform high impact damage patterns were observed on the large coal logs tested. Thus, consideration must be given to the fact that in a pipeline wear test there will be more abrasive type wear rather than high impact wear. However, the tumbling test is all we currently have to provide a relative measure of wear rate of coal logs, until a 6" pilot scale pipeline test loop is available.

1. Influence of peak loading time:

In the coal log fabrication process, the minimum peak loading time is believed to be one of the most important factors to the success of coal log fabrication machine design and the commercialization of the CLP system. Table 1 shows the weight loss of coal logs that were fabricated under various compaction pressures and peak compaction loading times.

Table 1. Decreased Peak Loading Time

	TUMBLING WEIGHT LOSS, %					
Comp. Press.	6,000 psi		8,000 psi		10,000 psi	
Tumb. Time	5 min	10 min	5 min	10 min	5 min	10 min
Peak Loading Time (sec.)						
0	5.0	45.1	NA	NA	22.0	35.6
15	2.8	17.3	22.2	59.3	6.1	44.3
30	0.1	4.9	15.8	53.2	3.8	21.3
45	1.1	13.7	12.0	31.8	17.0	22.3
60	2.0	11.5	14.5	29.4	4.4	5.3

Note: Coal log parameters were 1.5% binder, 98% -6M x 0 particle size distribution.

As shown in Table 1, the percentage weight loss of coal logs decreased as the peak compaction loading time increased from 0 to 60 sec, with a few exceptions due to some inconsistent test results. For commercial application, the selection of the minimum peak loading time and the relative wear resistance of the coal logs, will depend mainly upon the coal log travelling distance and the throughput of the pipeline.

2. Effect of low binder concentration and high compaction pressure:

Coal logs were also fabricated using 1% binder at higher compaction pressures and varying peak loading times. Six logs, each fabricated at 12,000 psi and 14,000 psi compaction pressures, and peak loading times of 0, 15, 30, 45, 60, and 300 seconds, were tested. These logs performed well after tumbling for 5 minutes (see Table 2).

Table 2. Decreased Binder with Increased Compaction Pressure

	TUMBLING WEIGHT LOSS, %			
Comp. Press.	12,000 psi		14,000 psi	
Tumb. Time	5 min	10 min	5 min	10 min
Peak Loading Time (sec.)				
0	NA	NA	25.4	NA
15	22.6	NA	5.2	44.0
30	8.3	46.8	17.2	47.4
45	4.2	49.1	5.3	27.5
60	4.6	38.7	4.0	45.5
300	4.8	NA	7.5	29.0

Note: Coal log parameters were 1.0% binder, 98% -6M x 0 particle size distribution.

3. Effect of two-stage mixing on coal log performance:

After studying the many fabrication parameters tested, it was found that the two-stage mixing process seemed to have the most significant impact on coal log durability. The effect of two-stage mixing was evaluated by separating -6M x 0 coal at 20M, 30M, and 50M, before the mixing operation. The large particles were mixed with Orimulsion, and then with fine particles. Binder concentrations of 1 and 2% were used.

Table 3. Two Stage Mixing

Log #	Binder, %	Size Separation	Loading Time	Peak Comp. Time	20 min. Tumbling Wt. Loss, %
1	2	50M	1 min.	5 min.	3.9
2	2	20M	1 min.	5 min.	5.4
3	2	30M	1 min.	5 min.	7.1
4	1	30 M	45 sec.	5 min.	7.3

As shown in Table 3, competent logs have been produced with two-stage mixing at low binder concentrations. Therefore, future research will be directed towards the study of a two stage mixing process as an integrated unit of overall coal log fabrication process.

1.75" BHP Coal Logs:

The particle size distribution of the coal samples obtained from BHP Minerals is shown in Table 4. It can be seen that the fraction of fine particles (-100 mesh) was very low (<20%) in both types of coal. Several small coal logs were made from the as-received particle size distribution, under standard fabrication conditions (i.e., 10,000 pressure, 2% binder, and room temperature), while other logs were made by adjusting the particle size distribution and compacting conditions, such as a smaller coal particle size (-30 mesh), maximum packing density, and heating (97°C), during coal log compaction. Tumbling test results showed that the coal logs made under these conditions could not satisfy the pipeline transportation requirements. Most logs possessed low strength and were easily broken by hand soon after water absorption tests.

Table 4. Particle Size Distribution of Coal Samples

Mesh	Navajo Coal		La Plata Coal	
	Ind. %	Cum. %	Ind. %	Cum. %
+ 10	17.2	82.8	17.6	82.4
10 - 30	37.5	45.3	33.9	48.5
30 - 50	18.9	26.4	19.1	29.4
50 - 100	12.1	14.3	13.0	16.4
100 - 200	8.1	6.2	8.9	7.5
- 200	6.2	0.0	7.5	0.0

Ind.: individual size percentage.
Cum.: cumulative passing percentage.

From the proximate analysis results, it was found that both BHP coal samples had high ash contents, that is, high hydrophilic mineral matters. Because of the hydrophilic characteristics of the ash-forming mineral matter, the high ash content reduced the binding capability of bitumen emulsion. In order to improve the quality of coal logs made from BHP coal, coal washing (flotation) was carried out on both coal samples. The proximate analysis of coal samples before and after washing, are shown in Table 5.

Table 5. Proximate Analysis of Coal Samples (Before and After Washing)

Sample Reference		Ash %	Moisture %	Volatile Matter %	Fixed Carbon %
Navajo	(before)	**27.95**	9.78	28.87	33.40
	(after)	**16.35**	3.53	35.50	44.62
La Plata	(before)	**26.58**	5.30	31.74	36.38
	(after)	**15.41**	1.63	36.75	46.21

The ash content of the coal samples was greatly reduced after the coal flotation process. The weight loss of the coal logs that were made under the standard fabrication conditions (10,000 psi., 2% Orimulsion, room temperature) were reduced to 4.5% after being subjected to water absorption and tumbling tests. From the test results, it was clear that the performance of coal logs were greatly improved by upgrading the quality of coal, i.e., reducing the ash content.

6" Pipeline Loop

In order to accelerate the commercialization of the Coal Log Pipeline Transportation System (CLP), a 6" diam. pipeline is urgently needed to evaluate the overall performance of the large coal logs to be used in the CLP system. This 6" pipeline will be used for a variety of tasks, such as:-

a. Coal log wear resistance evaluation:
The 6" pipeline will be used to examine the durability of commercial size (5.3" in diam.) coal logs that are manufactured from various types of coal under a variety of fabrication conditions.

b. Coal log water resistance evaluation:
Coal logs that are made from different types of coal under various fabrication conditions, will also be tested in the pipeline to evaluate their water resistance capability under different water pressure conditions.

c. Water quality evaluation and treatment:
The water used to transport coal logs in the pipeline will be monitored for conformity to environmental standards. The water treatment process will also be evaluated to meet the federal and state effluent requirements.

d. Hydraulic studies of coal log transportation:
The influence of water pressure and flow rate on the transportation of coal logs will also be studied using this pipeline.

The proposed 6" pipeline will be located on the UMR Mining Engineering Experimental Mine property, as shown in Figure 2. The pipeline loop layout and major components required, are shown in Figure 3.

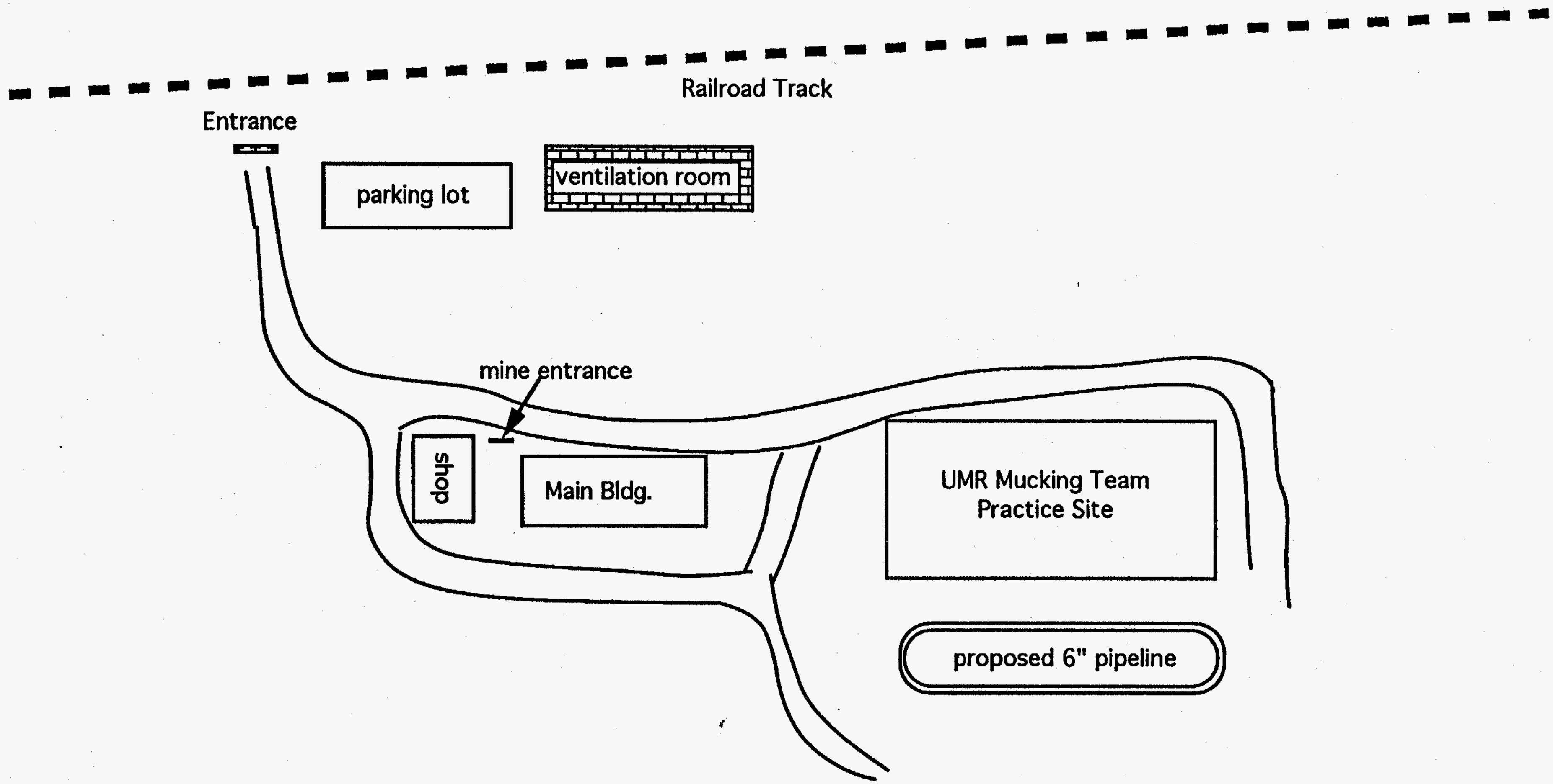

Figure 2. Location of proposed site for the construction of 6" pipeline.

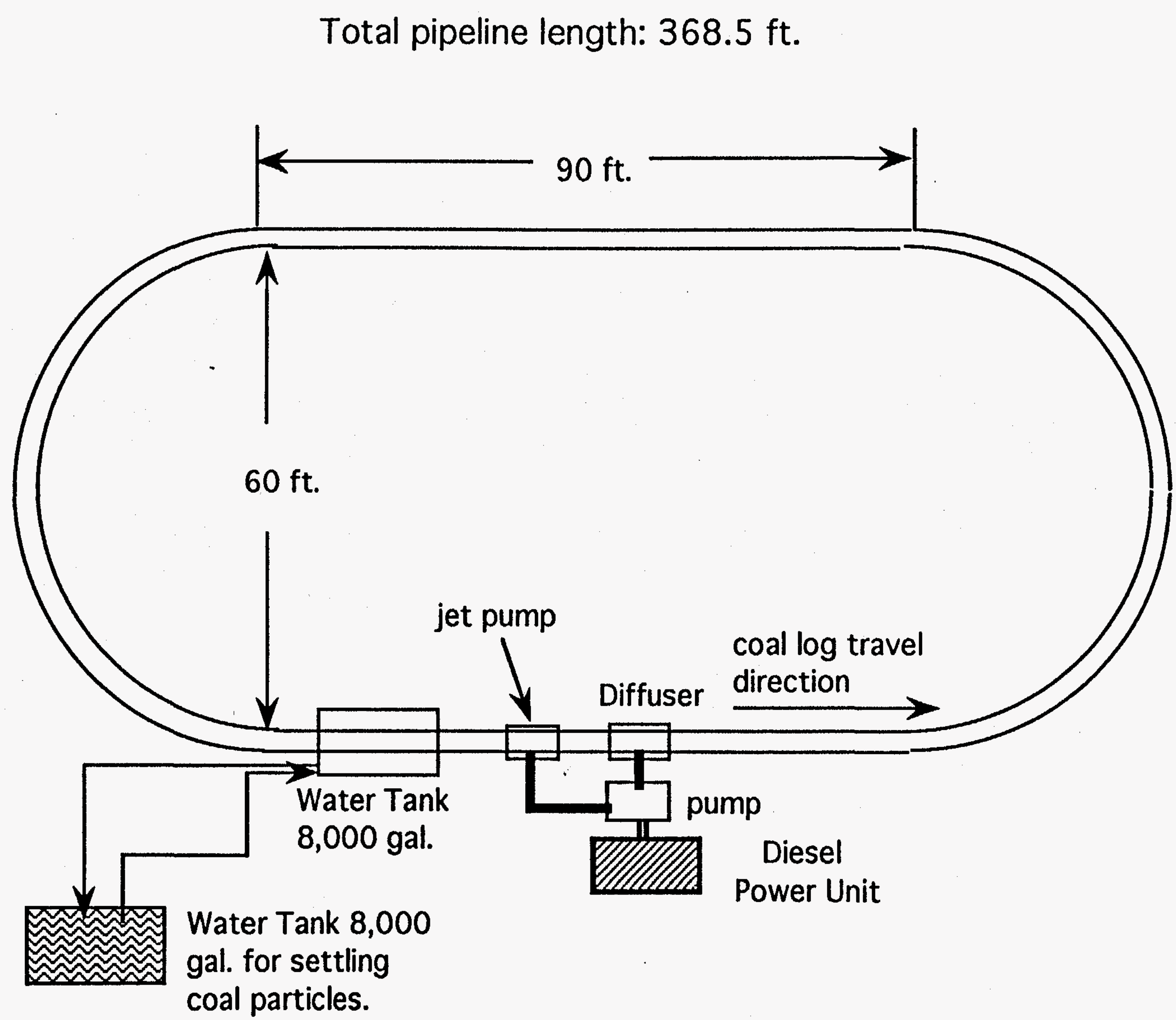

Figure 3. 6" pipeline layout.

Capsule Pipeline Research Center
Quarterly Report

(Period Covered : 7/1/95 - 9/30/95)

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 (Ph.D. student)

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 :

Train-Separator Design

Modifications continue to be made on the novel train separator sub-system designed to ensure proper functioning of the booster station. The details of the system will be disseminated (as cited in the earlier report) to the engineering community using videotapes at a major international conference in November: Nair, S. S. and Du, H., "Automation and Control Design Issues for Hydraulic Capsule Pipelines," *ASME International Mechanical Engineering Conference and Exhibition*, San Francisco, CA, 12-15 Nov. 1995.

The recirculating loop has just been added to the small-scale system (Fig. 1) after fabrication of

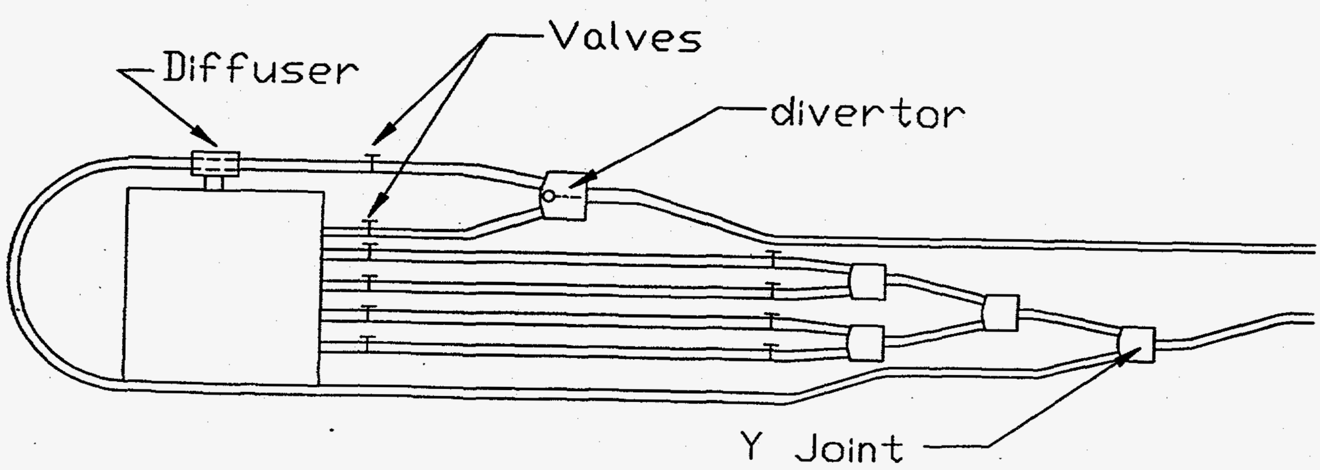

Figure 1. Modifications for which trouble-shooting is currently in progress.

the complex parts. We have experienced several problems when running it in the recirculation mode. The first was the fact that the main pump will have to be shut off and the system run with only the auxiliary pump for the recirculation runs. This was found to result in negative pressures in the pump-bypass section leading to air entrainment. Since the air entrainment was considerable, the system functioning was impaired. Several strategies were tried to alleviate the problem including increasing the base pressure by keeping the main pump on with zero flow but this caused leakage at several pipe joints. We are now in the process of adding an accumulator at the upstream section of the pump bypass system to minimize the problem. Note that the negative pressure problem will not exist in the commercial pipeline since the length of the bypass locks will be approximately 1000 ft. in that case, while, in the laboratory, the length is about 5 ft. The valve switching time is approximately equal to the time taken for the lock to be emptied, in the laboratory, which is the cause of the problem. Once the problem is fixed, we should be able to conduct several tests to check the reliable functioning of the train separator system.

SCADA System Design Issues

The Post-Doctoral student associated with this part left the group to join an excellent position with the Product Engineering Center at John Deere, Inc., Waterloo, IA. Before departure he had written several documents, as cited in the previous report, summarizing the tasks related to this area. We are still to hire a replacement for him to continue the development associated with the SCADA system.

Work Proposed for the Next Quarter :

(i) Solve the problems with the train separator such as negative pressure, flow reversals, etc. and ensure reliable functioning of the system (Hongliu Du).

(ii) Conduct extensive observation experiments including investigating train spacing changes, effectiveness of flow bypass in reducing capsule speeds, energy loss analysis, etc. (Hongliu Du).

(ii) Complete a patent application for the novel train separator sub-system developed by CPRC. (Nair and Du).

(iii) Develop a control strategy for the distributed control architecture, taking into account reliability and safety. (Hongliu Du and new student who will replace the Post-Doc who left recently)

(iv) Acquire all the components needed for the SCADA system and interface them with the computer. In the chapter written for the manual of practice this design has been developed in some detail and implementation on the small-scale system will begin immediately (will require a new student).

(v) Initiate development of a SCADA type display package for the small scale system using Visual-C (new student).

Capsule Pipeline Research Center

Quarterly Report

for

Individual Projects

(Period Covered: 8/1/95-9/31/95)

Project Title: Unsteady Flow in Coal Log Pipeline

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

Post Doctoral Fellow : 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 develop a methodology for the hydraulic design of pump bypass and an injector systems.

Work Accomplished During the Period:

The paper "Hydraulic Design of Coal Log Pipeline Injection System" was presented at the 8th International Symposium on Freight Pipelines at Pittsburgh, Pa. in September by Dr. Liu. This paper gives the various possible configuration of an injection system depending upon the coal log feed rate.

Revisions in the computer model of the diffuser used the injection system is underway.

Work To Be Accomplished Next Period:

The revision of the computer model of the diffuser should be completed and used to check out some designs.

Reference:

Lenau and Wu, Hydraulic Design of Coal Log Pipeline Injection System, 8th International Symposium on Freight Pipelines, Pittsburgh, Pa., Sept. 1995.

10-6-95

Capsule Pipeline Research Center

Quarterly Report

(Period Covered: 7-1-95 to 9-30-95)

Project Title: **Legal Aspects of CLP**

P.I.: Dr. Peter N. Davis, Isidor Loeb Professor of Law

Research Ass'ts: none

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) *Model remedial legislation.* Drafted remedial legislation to enhance viability of coal pipeline projects. It will cover right-of-way and water rights acquisition, crossing highways & railroads, and conversion of petroleum & gas pipelines to coal transport. In progress. [Peter Davis]

Publication work:

none.

Work Proposed for Next Quarter:

Research work:

(1) *Proposed federal property rights statute.* Summary of statute which defines compensable takings under environmental statutes and the Endangered Species Act. [Peter Davis]

(2) *Is pipeline water diversion a "beneficial use" under prior appropriation law?* [Peter Davis]

(3) *State waste discharge regulation.* Summary. [Peter Davis]

(4) *State wetlands disturbance regulation.* Summary. [Peter Davis]

(5) *Endangered Species Act.* Summary. [Peter Davis]

(6) *State environmental impact report requirements.* Summary. [Peter Davis]

(7) *Model remedial legislation.* Finish drafting remedial legislation to enhance viability of coal pipeline projects. In progress. [Peter Davis]

(8) *Platte Pipeline easements in northern Missouri.* Determine easement language used in sample recorded easements for Platte Pipeline in some northern Missouri county. [not yet assigned]

Publication work:

(1) *Manual of Practice: Legal Aspects.* Complete preparation of third draft of the legal chapter for the Manual of Practice. [Peter Davis]

(2) *Law review articles.* Continue preparation of one or two law review articles on right-of-way and water rights issues based on Florida conference paper Davis, Cress & Sullivan, *Legal Aspect of Coal Pipelines in the United States -- Preliminary Findings* (Apr. 1993), and on the Manual of Practice (final draft). The Manual of Practice manuscript will be used as the basic text for these articles. [Peter Davis]

Key Results of Recent Work:

Model remedial legislation. Draft legislation is being modelled on state legislation which already has been enacted in some states. Since the organization, context, syntax and legislative drafting traditions vary widely between states, it does not seem practical at this time to draft uniform model legislation for parallel enactment by the states. Existing legislative provisions have been modified as examples of the types of legislation which ought to be enacted. Draft legislative provisions have been prepared on the following topics: right-of-way eminent domain (broadening of Missouri provision for all public utilities), right-of-way across railroads (Louisiana), and water rights eminent domain (Washington).

Statistical corrections. In preparation of remedial legislation, errors in the number of states which have enacted coal pipeline eminent domain statutes were discovered. These statistics have been corrected in the draft Manual of Practice.

Type of statute	2d draft 6-23-95)	correction
r-o-w eminent domain:		
express authority-coal pipelines	13[1]	13[2]
all pipelines	9[3]	8[4]
no r-o-w eminent domain	0	1[5]
cross railroad eminent domain:		
express authority-coal pipelines	6[6]	3[7]
same power as railroads	4[8]	4[9]
no eminent domain to cross	1[10]	2[11]
water rights eminent domain:		
express authority-coal pipelines	1[12]	3[13]
no eminent domain	2[14]	4[15]

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[1] Florida, Iowa, Louisiana, Montana, North Carolina, North Dakota, Ohio, Oklahoma, South Dakota, Texas, Utah, West Virginia and Wyoming.

[2] No change.

[3] Alabama, Colorado, Hawaii, Illinois, New Jersey, Rhode Island, South Carolina, Tennessee and Virginia.

[4] Same, except Virginia.

[5] Virginia.

[6] Alabama, Louisiana, South Carolina, Texas, Virginia and West Virginia. Utah allows eminent domain of publicly owned land, but not privately owned land.

[7] Louisiana, South Carolina and West Virginia, and Utah under limited circumstances. Alabama, Texas and Virginia were incorrectly listed here.

[8] Montana, North Carolina, North Dakota and Oklahoma.

[9] No change.

[10] Iowa.

[11] Iowa and Virginia.

[12] Virginia.

[13] All pipelines: North Dakota, South Dakota and Washington. Virginia was incorrectly listed here.

[14] Oklahoma and Texas.

These statistical changes will require redrafting of the illustrative maps.

Publications:

none.

Unpublished Research Reports:

none.

rpt1095

[15] Louisiana, Oklahoma, Texas and Virginia.

CAPSULE PIPELINE RESEARCH CENTER

Quarterly Report

(Period Covered: 7/1/95 - 9/30/95)

Project Title: Vacuum Systems to Enhance Coal Log Production and Quality

Principle Investigator: Dr. Alley C. Butler, Asst. Professor, Mechanical & Aero. Engineering

Graduate Research Assistants: Jun-Jun Tang

Purpose of the Research:

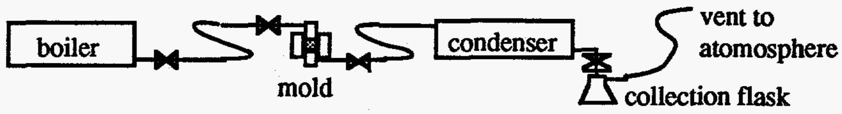
To investigate the effects of vacuum (and direct contact steam preheating) on the fabrication of coal logs, as a means of improving the speed of manufacture as well as increasing coal log quality. The focus is on improving compressive processes as a method for coal log fabrication.

Work Accomplished During the Period:

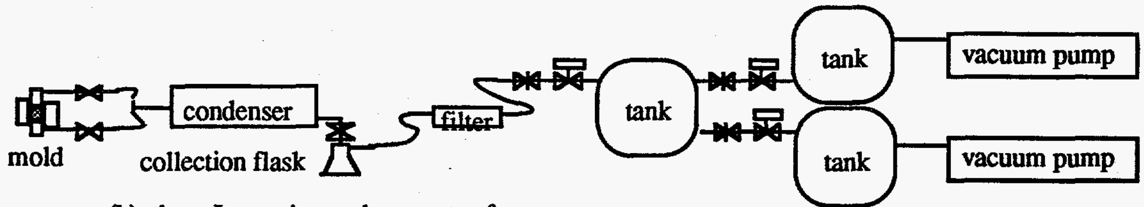
This research task is developed to investigate the use of vacuum and direct contact steam preheat are applied to coal in the 1.75 inch floating, split mold. Work undertaken in this period completed experimentation, with the apparatus shown in Figure 1. This experimentation involved two parametric studies in which the amount of asphalt binder (as Orimulsion) was varied, and the time used for compaction was also varied. One set of parametric studies determined the effects of vacuum, at various levels, against the use of atmospheric pressure (no vacuum) as a control. The other set of parametric studies evaluated the effects of indirect heating against the effects of direct contact steam heat. The relationships inherent in these studies are summarized in Figure 2. It should be noted that for most experiments, a second identical experiment was conducted to confirm results. In general, the results (of the confirming experiments) were different numerically, but on a relative basis the trends exhibited were consistent with the first experiment.

In each experiment, a set of procedures were rigorously followed. This included heating the mold to 97^{o} C before commencing the experiment, and allowing the mold to cool for 45 minutes after the experiment. For vacuum experiments, the vacuum was applied for 5 minutes before compaction through 5 minutes after compaction. The "slow" logs which took 16 minutes for compression spent: 1) five minutes to achieve the 20,000 psi maximum compression pressure, 2) six minutes at peak load, and 3) five minutes for unloading. In contrast, the "fast" logs took 58 seconds to achieve the 20,000 psi peak load and 2 seconds for unloading, without holding the peak load. Additionally, binder percentages were based on weight of asphalt to dry weight of coal, with water added to achieve 18% water in the asphalt-coal mixture used for compaction. These procedures, also, included techniques to minimize variation in results due to other process parameters.

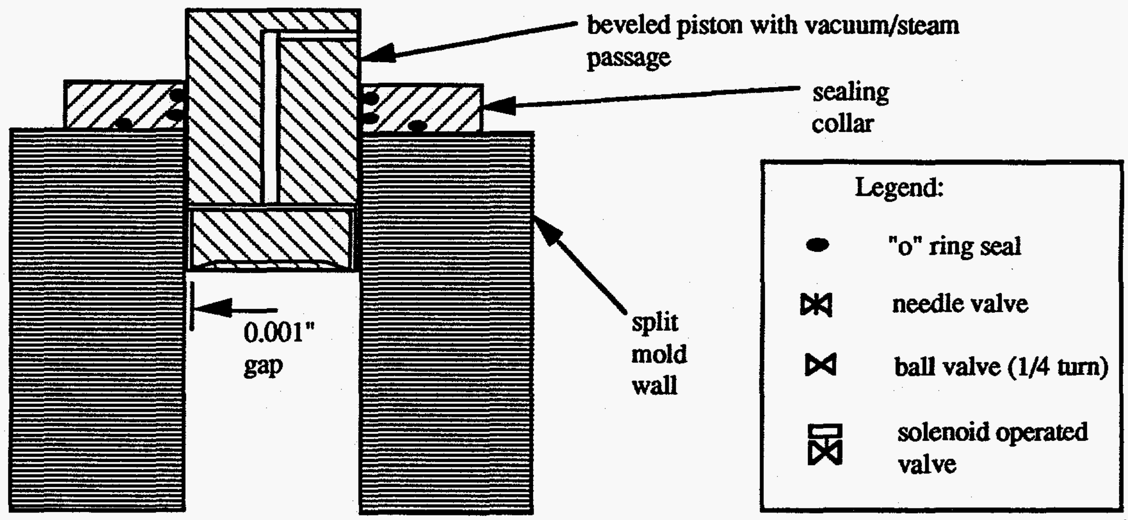
The results of these parametric studies are shown in Figures 3 through 16 which provide a graphical representation of results from laboratory pipeline wear tests on the 1.75 inch coal logs. It is apparent that vacuum generally has a positive effect on coal log compacts. The effect of vacuum appears to change with the amount of binder used and with the speed of compaction.



(a) phase I experimental apparatus for steam heating



(b) phase I experimental apparatus for vacuum



(c) section view of split mold with piston and sealing collar

Figure 1 - Experimental Apparatus for Phase I

		Method & Binder Parameter			
		Vacuum 2% Binder	Vacuum 0.5% Binder	Steam 2% Binder	Steam 0.5% Binder
Speed Parameter	Slow (16 min)	See Figure 3	See Figures 4 & 5	See Figure 10	See Figures 11 & 12
	Fast (1 min)	See Figures 6 & 7	See Figures 8 & 9	See Figures 13 & 14	See Figures 15 & 16

Figure 2 - Experiments with Vacuum and Steam Heating

Work Accomplished During the Period (Continued):

With slow compaction and 2% asphalt higher levels of vacuum (-27 inches of mercury) seem to produce better results, as shown in Figure 3. However, as the level of asphalt drops the vacuum level at which the best logs are made also drops to -9 inches of mercury, as shown in Figures 4 and 5.

For "fast" compaction, intermediate levels of vacuum are best with 2% asphalt, and this effect is even more pronounced for "fast" compaction with 0.5% asphalt. See Figures 6 and 7 for 2% asphalt and Figures 8 and 9 for 0.5% asphalt. With direct contact steam heat, wear tests results presented in Figures 10 through 16 show that direct contact steam heating produces better logs. The beneficial effect is apparently more pronounced for logs made with less (0.5%) asphalt, and for logs compacted at faster speeds.

Future Plans:

Research with the apparatus shown in Figure 1 is complete. Remaining questions involve determining the cost of vacuum and direct contact steam heat. This will provide information on the which of the two technologies is most economically attractive. This will involve revisiting the design of the coal log fabrication machine, and deciding what additional provisions must be made to employ vacuum or direct contact steam heat.

As a next experimental effort, the effects of vacuum (and preheating) of coal will be tested prior to loading in the 1.75 inch mold. This involves the use of a conveyor for moving and preparing the coal, as shown in Figure 17. This process employs vacuum (and/or preheating) of the coal and asphalt mixture prior to feeding the mixture into the compaction mold with a prototype system. Measurements regarding increases in the speed of compression will be taken, and automation through process instrumentation and control will be employed. As a major point of emphasis, the demonstration of increased compaction compaction speed will be sought. Due to the high speeds, the experiment will be controlled using a micro-computer with Labview software. This will result in experience with automatic feeding of compaction molds, and increases in the speed with which coal logs can be manufactured will be determined. By demonstrating automated coal feeding and high speed compaction with a manufacturing prototype system, confidence in the commercialization of the coal log fabrication process can be gained.

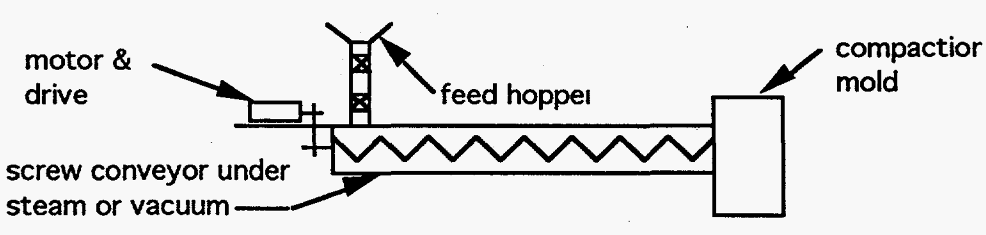


Figure 17 - Manufacturing Prototype System

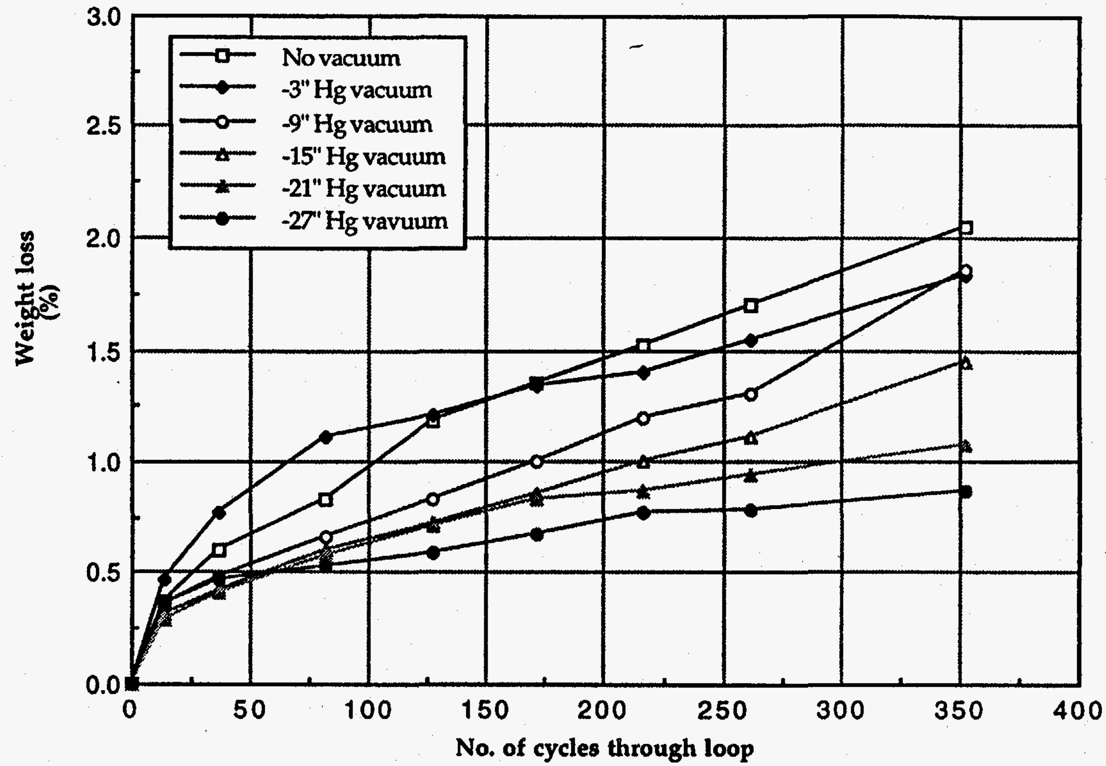


Figure 3 - Coal Log Weight Loss for 2% Asphalt, 16 Minutes Compaction under Vacuum Conditions (Average of 3 Logs, Except No Vacuum as an Average of 9 Logs)

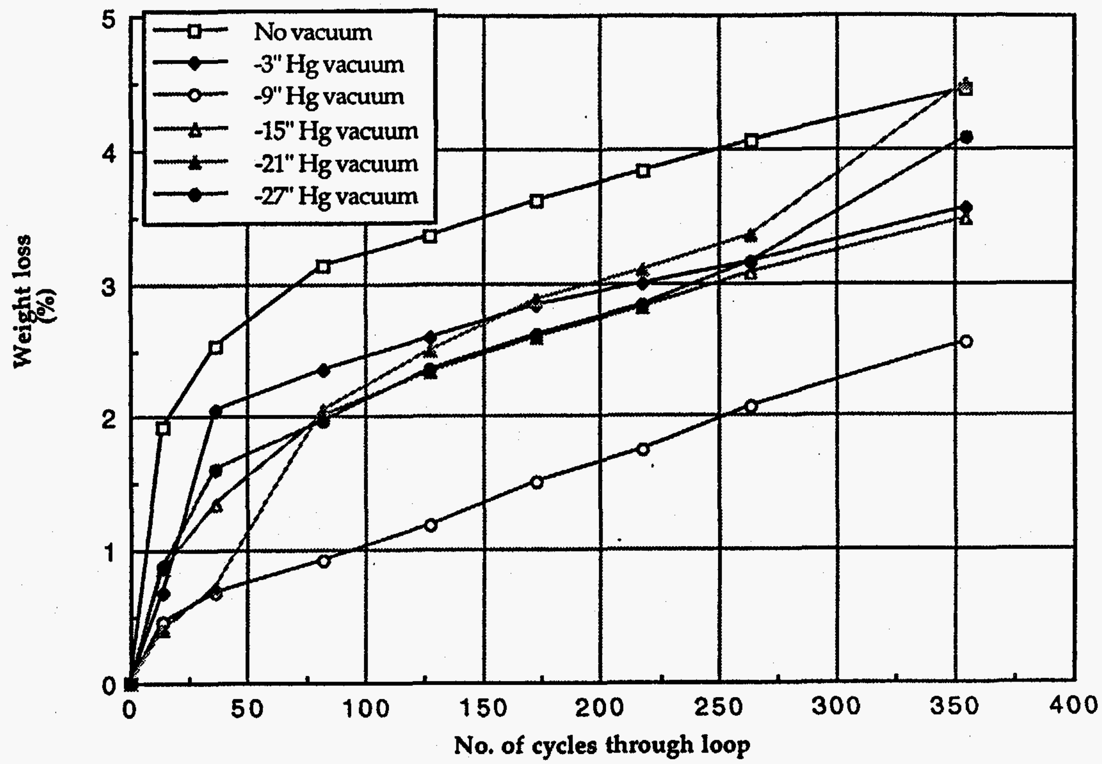


Figure 4 - Coal Log Weight Loss for 0.5 % Asphalt, 16 Minutes Compaction under Vacuum Conditions (Average of 3 Logs, Except No Vacuum as an Average of 9 Logs)

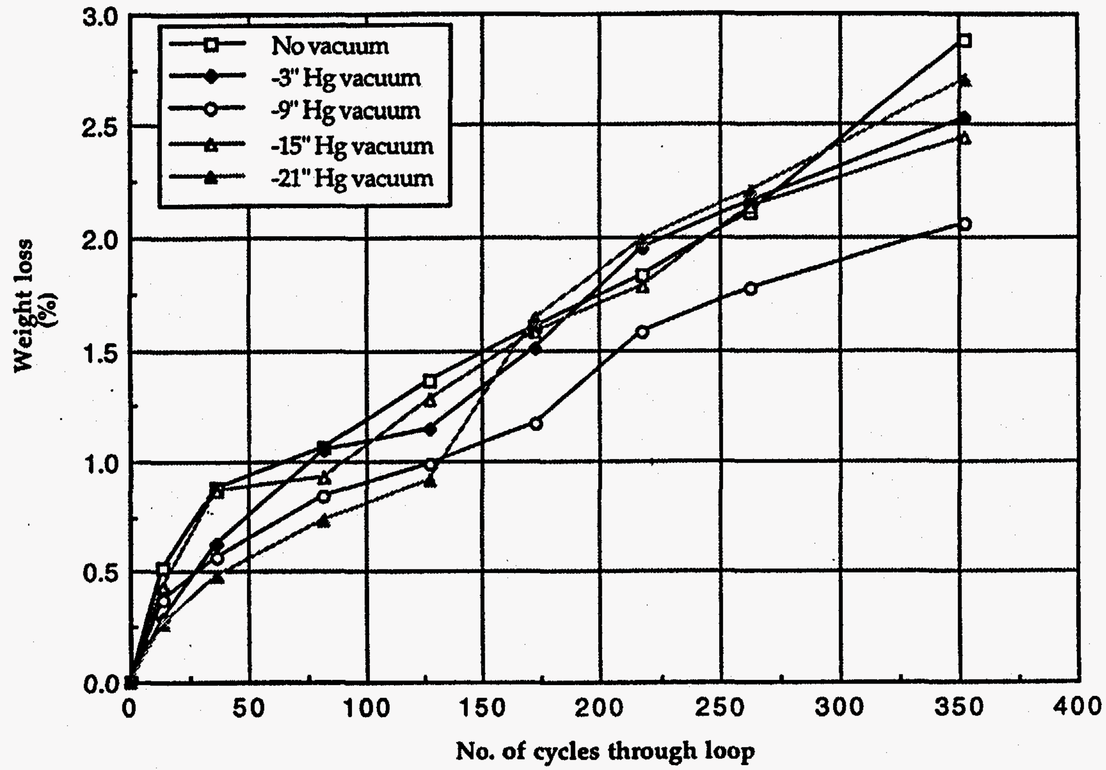


Figure 5 - Coal Log Weight Loss for 0.5 % Asphalt, 16 Minutes Compaction under Vacuum Conditions, Second Experiment (Average of 3 Logs, Except No Vacuum as an Average of 6 Logs

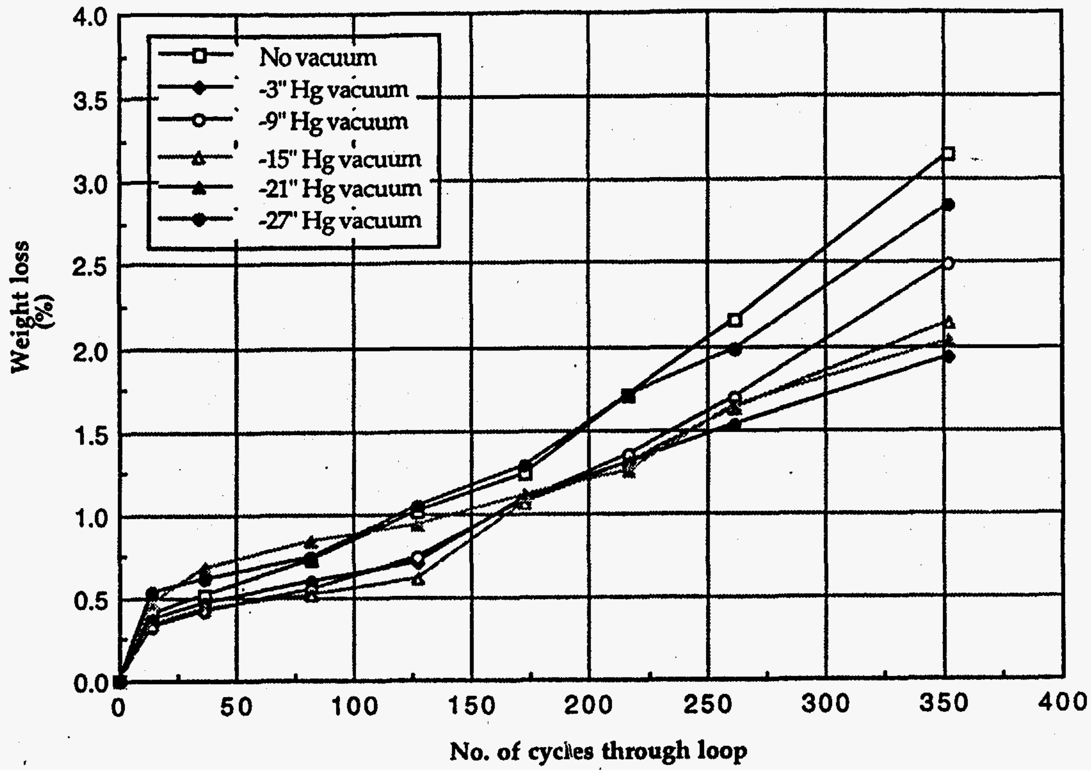


Figure 6 - Coal Log Weight Loss for 2 % Asphalt, 1 Minute Compaction under Vacuum Conditions (Average of 3 Logs, Except No Vacuum as an Average of 9 Logs)

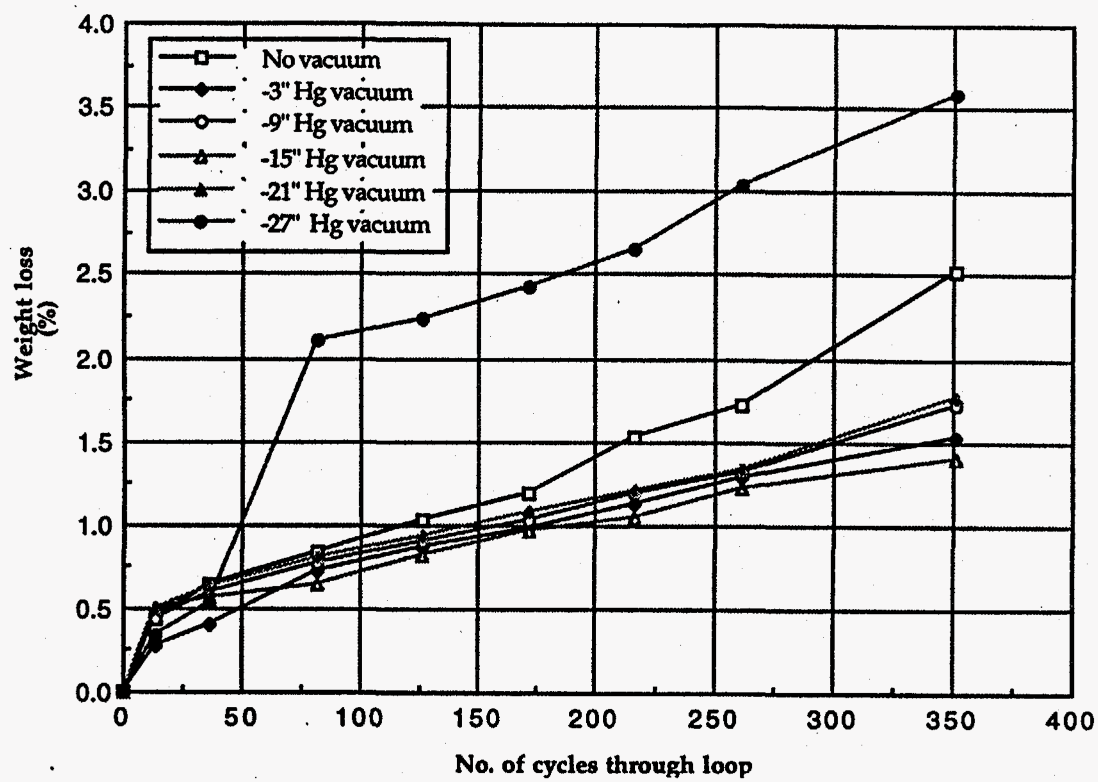


Figure 7 - Coal Log Weight Loss for 2 % Asphalt, 1 Minute Compaction under Vacuum Conditions, Second Experiment (Average of 3 Logs, Except No Vacuum as an Average of 6 Logs

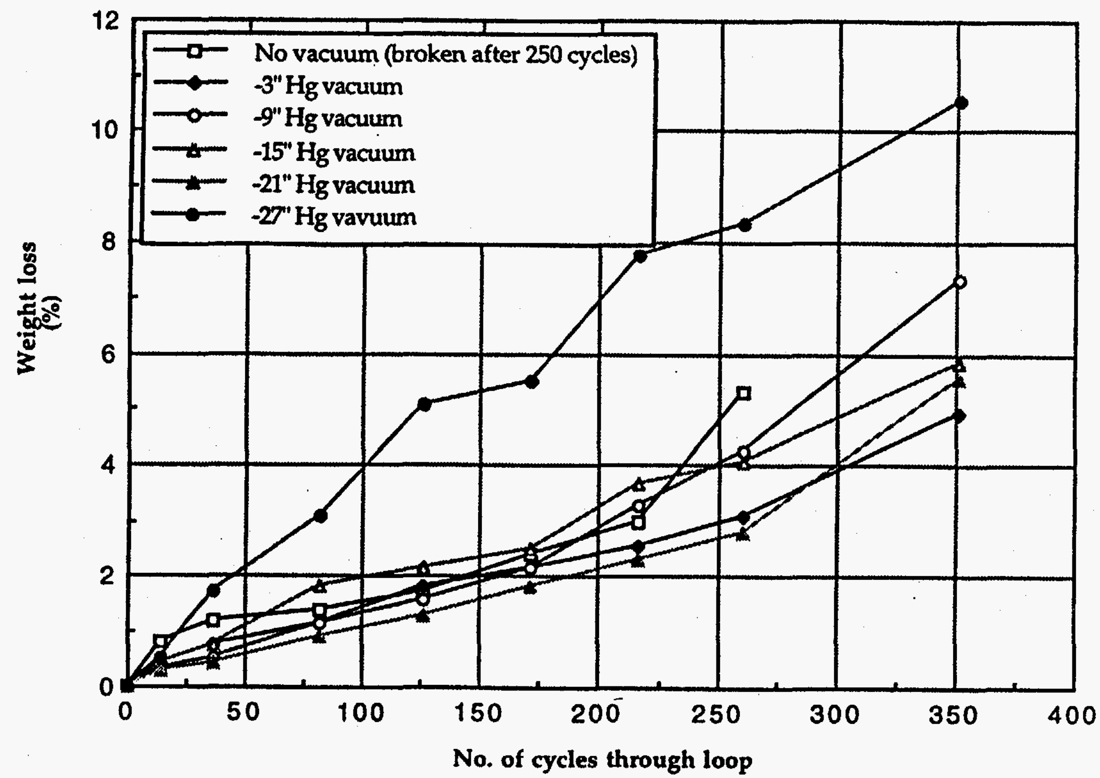


Figure 8 - Coal Log Weight Loss for 0.5 % Asphalt, 1 Minute Compaction under Vacuum Conditions (Average of 3 Logs, Except No Vacuum as an Average of 9 Logs)

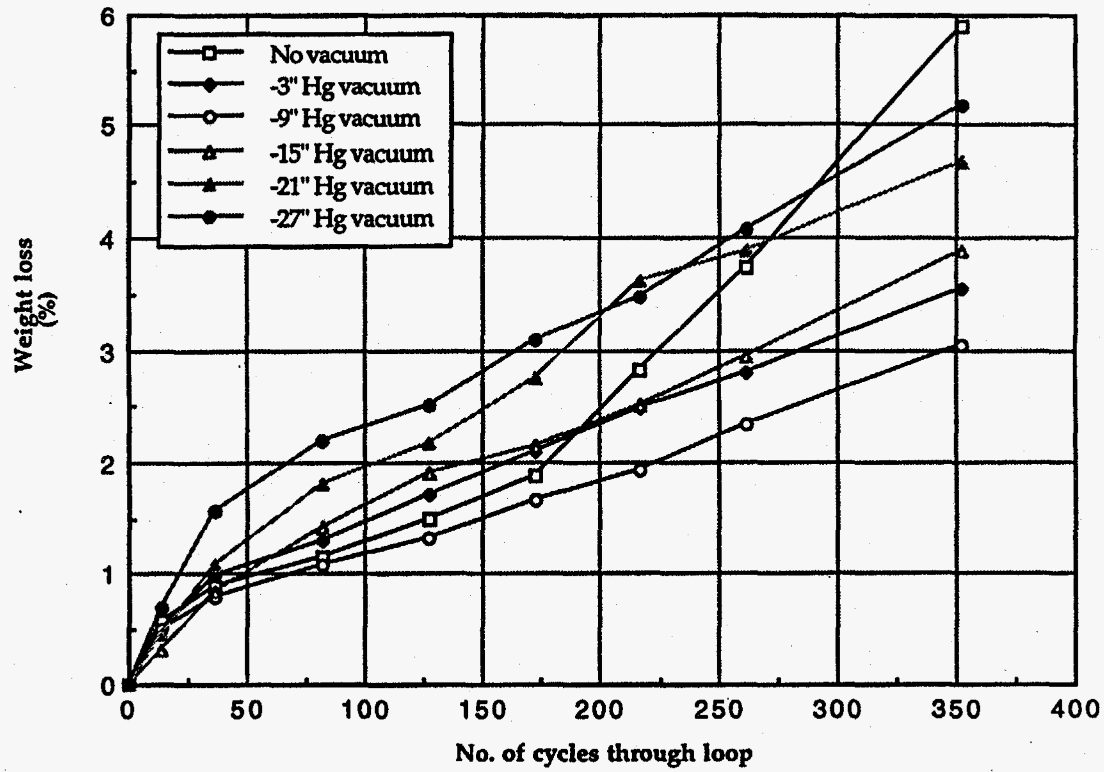


Figure 9 - Coal Log Weight Loss for 0.5 % Asphalt, 1 Minute Compaction under Vacuum Conditions, Second Experiment (Average of 3 Logs, Except No Vacuum as an Average of 6 Logs

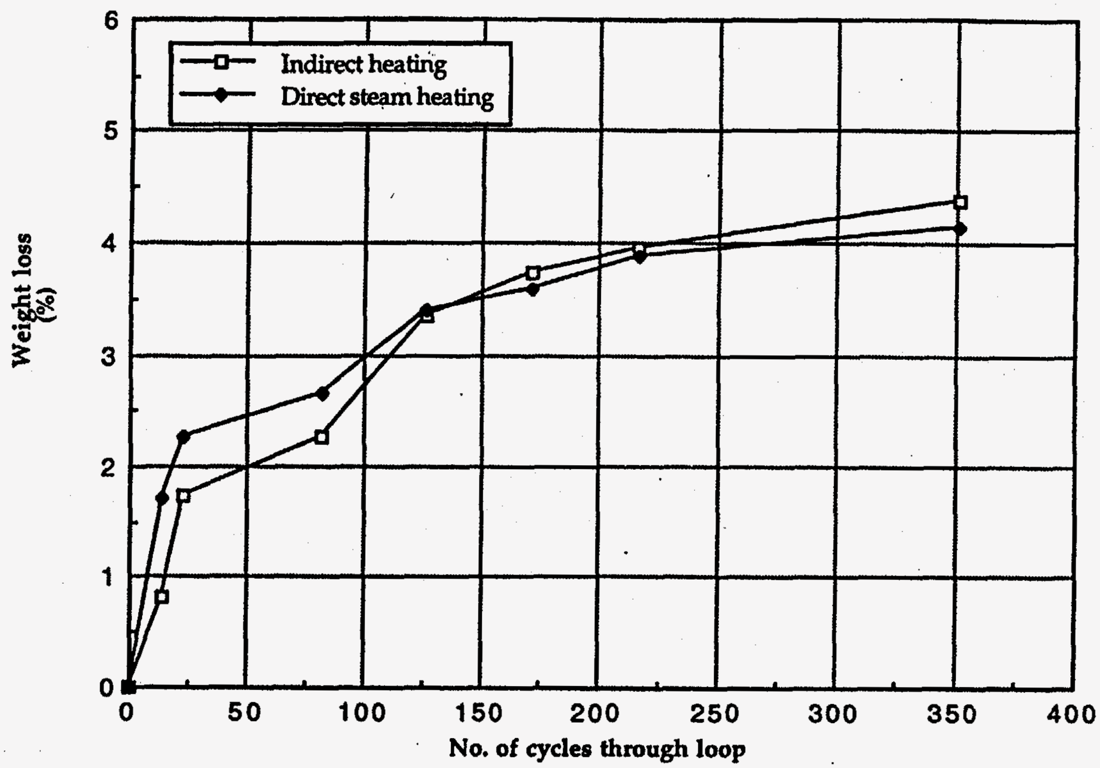


Figure 10 - Coal Log Weight Loss for 2% Asphalt, 16 Minutes Compaction with/without Direct Contact Steam Heating (Average of 3 Logs)

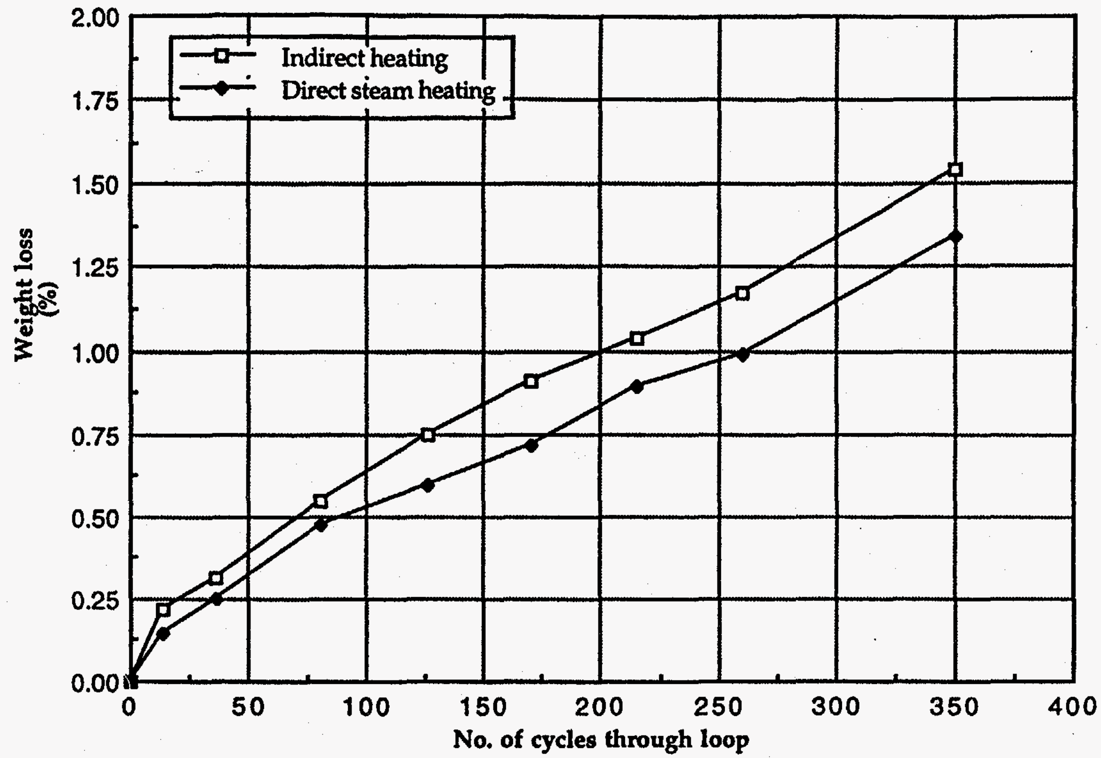


Figure 11 - Coal Log Weight Loss for 0.5 % Asphalt, 16 Minutes Compaction with/without Direc Contact Steam Heating (Average of 3 Logs)

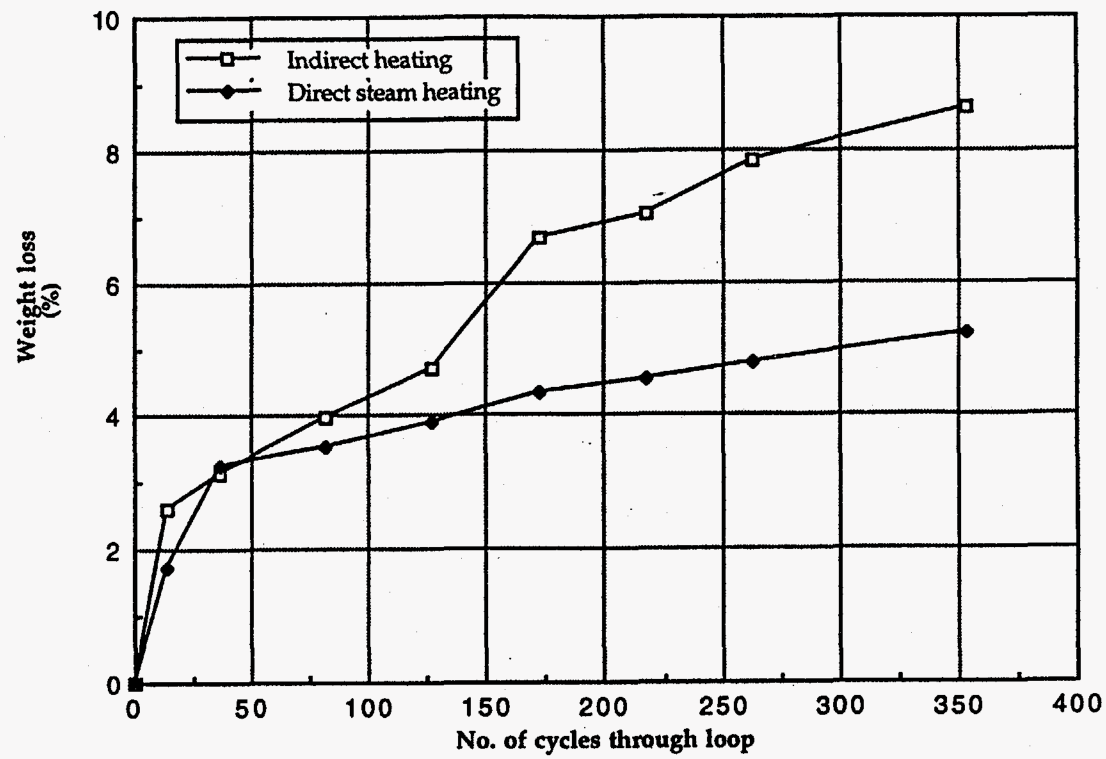


Figure 12 - Coal Log Weight Loss for 0.5 % Asphalt, 16 Minutes Compaction with/without Direc Contact Steam Heating, Second Experiment (Average of 3 Logs)

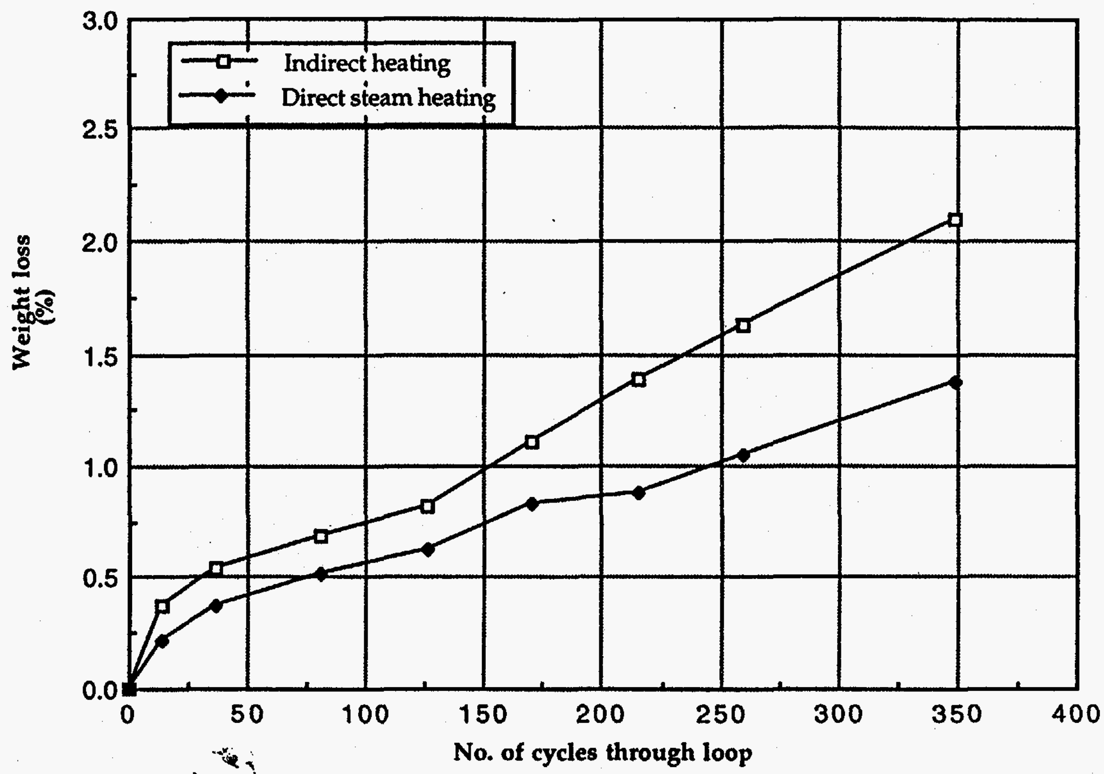


Figure 13 - Coal Log Weight Loss for 2 % Asphalt, 1 Minute Compaction with/without Direct Contact Steam Heating (Average of 3 Logs)

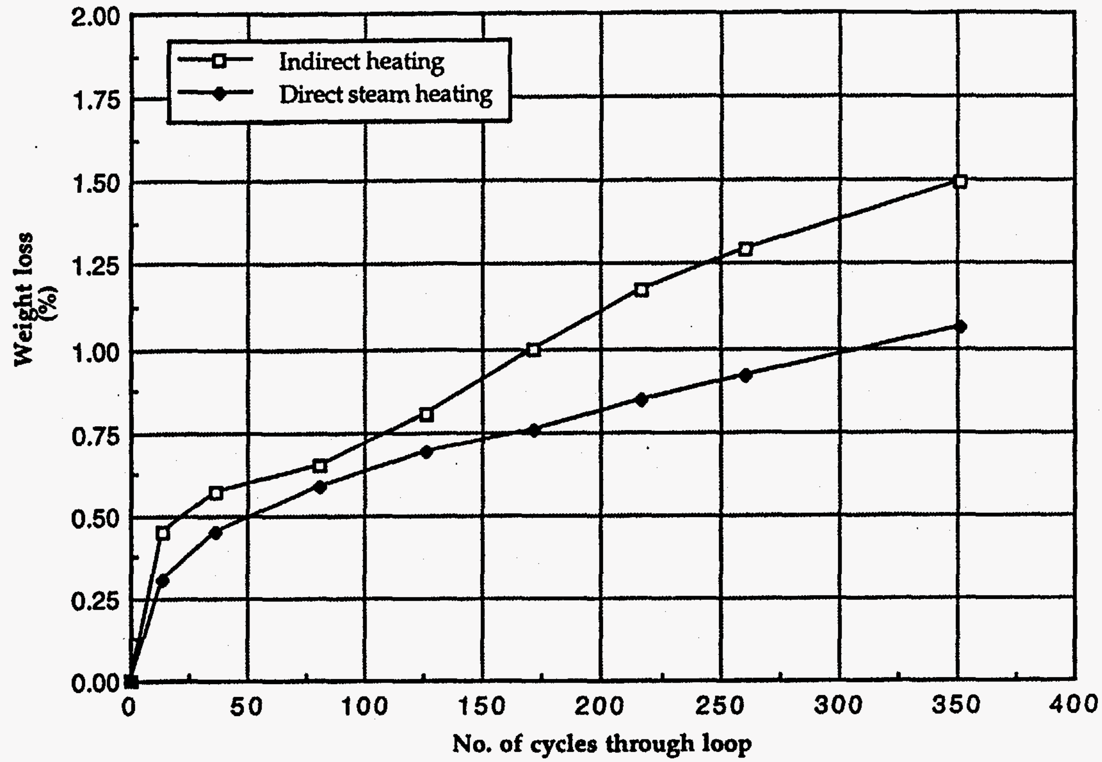


Figure 14 - Coal Log Weight Loss for 2 % Asphalt, 1 Minute Compaction with/without Direct Contact Steam Heating, Second Experiment (Average of 3 Logs)

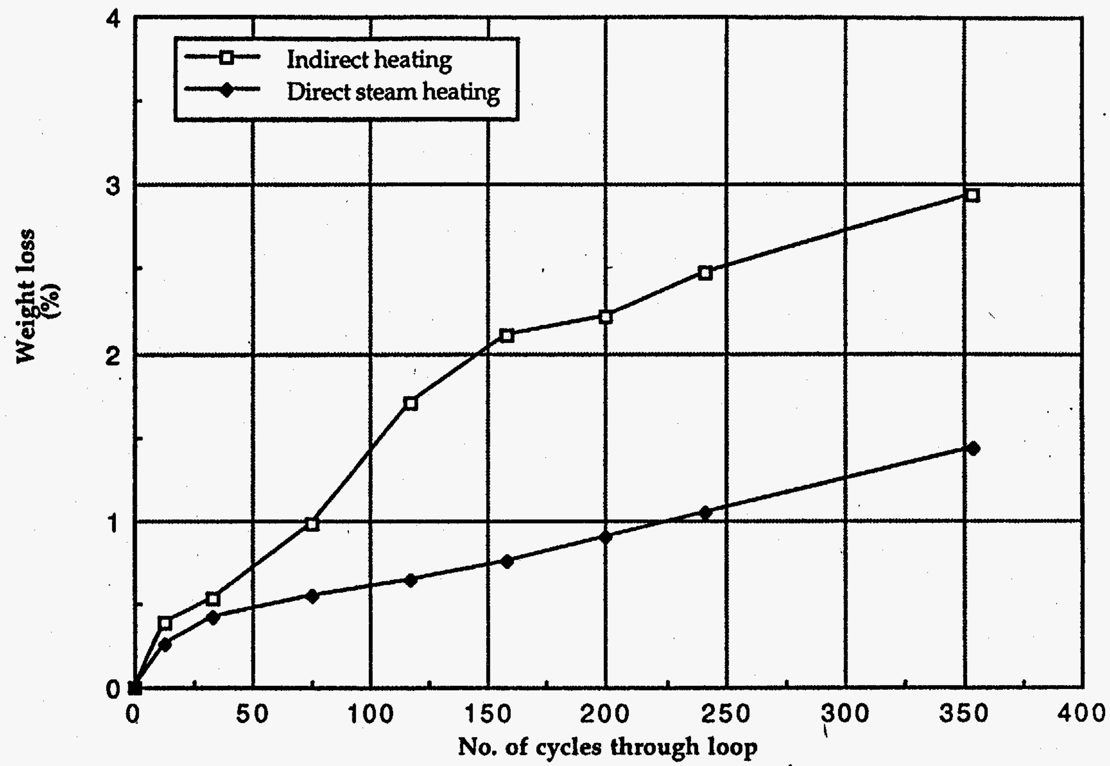


Figure 15 - Coal Log Weight Loss for 0.5 % Asphalt, 1 Minute Compaction with/without Direct Contact Steam Heating (Average of 3 Logs)

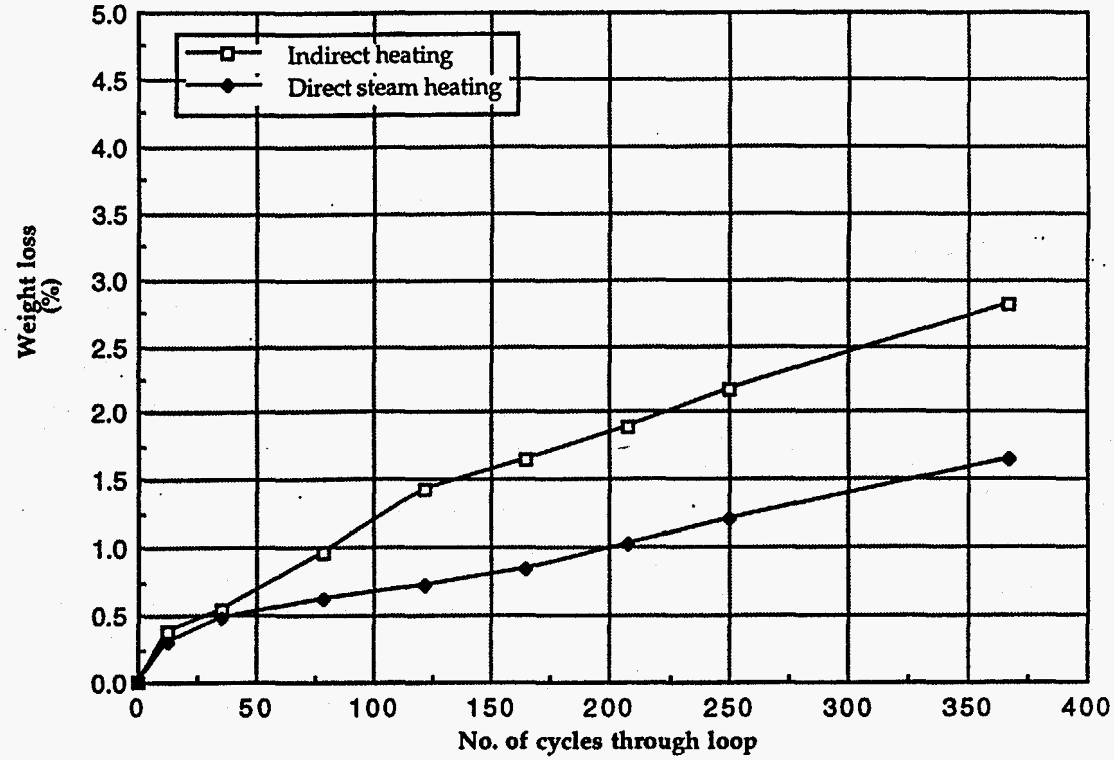


Figure 16 - Coal Log Weight Loss for 0.5 % Asphalt, 1 Minute Compaction with/without Direct Contact Steam Heating, Second Experiment (Average of 3 Logs)