CAPSULE PIPELINE RESEARCH CENTER--A STATE/INDUSTRY UNIVERSITY COOPERATIVE RESEARCH CENTER (S/IUCRC) ESTABLISHED BY THE NATIONAL SCIENCE FOUNDATION (NSF)

FINAL SUMMARY REPORT

for 1991-1999

and

YEAR - 8 REPORT

for 9/1/98 - 8/31/99

September 1, 1999

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September 30, 1999

Engineering Education and Centers Division
State/IUCRC Program
National Science Foundation
Room 585
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Re: National Science Foundation Cooperative Agreement EEC-9108841
University of Missouri Principal Investigator Henry Liu
Submission of Final Summary Report and Year 8 Report

Dear Mr. Misiorek:

Enclosed are three copies of the referenced report. Questions can be addressed to Dr. Liu at the telephone number provided on the cover sheet.

The University of Missouri appreciates the opportunity to participate in this research.

Yours truly,

Michael J. Warnock

Michael Warnock
Director
Office of Sponsored Program Administration

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

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Capsule Pipeline Research Center: Year 8 Annual Report/Proposal

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	months		

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CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators

I certify to the best of my knowledge that:

(1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and

(2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required project reports if an award is made as a result of this proposal.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is a criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Social Security No.*	Date
PI/PD Henry Liu	Henry Liu	523-68-7568	9/21/99
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Co-PI/PD			
Co-PI/PD			

Certification for Authorized Organizational Representative or Individual Applicant

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding Federal debt status, debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in the *Grant Proposal Guide (GPG)*, NSF 99-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of *Grant Policy Manual* Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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This certification is required for an award of a Federal contract, grant or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

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The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, and officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME/TITLE (TYPED) Deborah Caselman, Assoc. Director Sponsored Programs Administration	Deborah Caselman	9/30/99

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ABSTRACT

The mission of Capsule Pipeline Research Center of the last eight years (1991-99) has been focused on the coal log pipeline (CLP) technology. Year 8 saw the construction of a testbed (pilot plant) to test both CLP and other hydraulic capsule pipeline applications. Built with equipment, materials and services valued at over $400,000 donated by nineteen companies, the plant will ready the CLP technology for commercial use in two years.

During year 8, a rotary press was designed for compacting coal and biomass fuel, a coal log sensor was invented, and the U.S. Department of Energy sponsored a project which will develop a new biomass fuel for coal-fed power plants, using the compaction technology developed from coal logs research. In addition, significant advancements were made in the study of pneumatic capsule pipeline powered by linear induction motors including the construction of a laboratory test facility.

Also, during year 8, the Center hosted an international symposium and short course on underground transportation of freight by capsule pipelines. National and international experts on pipeline freight transportation attended this symposium and presented papers here.

Over the last eight years, the Center has greatly advanced various technologies related to capsule pipelines, readying them for commercial use. Future plans revolve around testing the CLP technology in the pilot plant in order to ready it for commercial use. The Center will also develop a new biofuel for use by power plants, and engage in further research in underground shipment of freight by pneumatic capsule pipelines.

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1. EXECUTIVE SUMMARY

A. Rationale for the State/IUCRC

The Center's mission for the first four years was focused solely on **coal log pipeline (CLP)** for transporting coal. Starting the fifth year (9/1/95), the Center gradually expanded its program to include some other types of capsule pipelines designed to transport other materials such as biomass, wasted coal fines and municipal solid waste. The seventh year (9/1/97-8/31/98 introduced a study, sponsored by Mid-America Transportation Center and Sumitomo Metal Industries, Ltd. in Japan, on the development of a linear induction motor to propel wheeled capsules through pneumatic capsule pipeline (PCP). Year 8 (9/1/98-8/31/99) saw the completion of analytical work on the electromagnetic theory and fluid mechanics of PCP-powered linear induction motors (LIMs). A PCP laboratory test facility was designed and built. A LIM was donated by industry for test purposes, and the study will continue for another year under sponsorship of the Sumitomo Metal Industries. Future work will focus on experimenting with a small PCP-LIM in laboratory. PCP can transport many cargoes such as mail, grain, construction materials, solid wastes, and consumer goods. The advanced PCP system being studied is an improvement over current commercial PCP, making the system more efficient and less costly.

Coal log pipeline development remained the top priority of the Center until 8/31/99—the end date for NSF and State funding. All the Center's major goals were achieved culminating in the construction of a coal log pipeline pilot plant, which will continue to perfect the CLP technology in a two-year program financed by industry.

The reasons for continued focus on CLP are: (1) Coal is the largest freight product in the United States; production rates are over one billion tons per year. Approximately sixty percent (60%) of the electricity in the nation, and 70% in Missouri, are generated from coal. Coal is usually transported hundreds of miles before it is used. (2) CLP development can be applied to other types of capsule pipelines.

The Center's R&D program has made great strides in responding to the public demand for expanded development of capsule pipelines for transporting solid wastes, grain, mail, and general merchandise. The new areas in PCP and HCP were phased in with great care so as not to distract or impede the development of CLP for coal transport.

Capsule pipeline will be a major freight transportation technology in the 21st Century. The Center's contribution in advancing the technology and brings it closer to commercial use is recognized worldwide. The Center's international reputation makes it the ideal point of contact for U.S. companies wanting to develop future freight pipeline contracts both at home and in the international market. Furthermore, the use of CLP and other types of capsule pipelines in the U.S. will reduce the transportation costs of coal and many other cargoes, making U.S. products more economically competitive in the world market. Application of coal log compaction technique to other materials such as biomass represents a major spin-off of the Center's research.

B. Accomplishments and Plans

(a) Progress During Last Year (Year 8)

During Year 8, the Center made substantial progress in the PCP (Pneumatic Capsule Pipeline) study sponsored by Sumitomo Metal Industries and Mid-America Transportation Center. The Center completed the derivation of the equations needed for analyzing PCP and for the LIM (Linear Induction Motor) needed for powering PCP. These equations are being used for optimizing the performance of PCP and LIM. Also, the Center conducted an analysis of an off-line loading/unloading system of PCP based on LIM. The proposed new system is expected to revolutionize the PCP technology—greatly enhancing system throughput, reducing unit transportation cost, and making the system more economically competitive with train, truck and conveyer belt. Finally, the Center completed the fluid mechanics analysis of a PCP system based on LIMs, and constructed a laboratory test facility for testing PCP-LIM.

In the solid waste compaction research area, the Center conducted some preliminary experiments to compact several biomass waste materials including sawdust, wood chips, waste paper and so forth. They were tried out successfully in both small (1.91-inch-diameter) and large (5.4-inch-diameter) sizes. The large logs were produced by using the new coal log compaction machine. We have proved that biomass waste materials can be compacted into strong logs without use of binder and heat.

Technology transfer activities include: (a) holding International Symposium on Underground Transportation of Freight and Other Tube/Tunnel Systems; (b) two work sessions with industry experts to discuss the pilot plant construction; (c) exhibition of new compaction machine pictures and products (5.4-inch-diameter logs) at an international coal technology conference; (d) published a newsletter; (e) visited companies and government agencies with interest in CPRC work; (f) reported results at national and international conferences.

(b) Accomplishments Over 8 Years

During the last eight years, the Center's extensive R&D resulted in great advancement of the state-of-the-art of hydraulic capsule pipeline (HCP) and coal log pipeline (CLP), bring them from a mere concept to a major technology approaching commercial use. More specifically, substantial progress has been made in the following areas:

- Developed a four-regime theory to enhance the knowledge in capsule pipeline and to improve the accuracy of predictions.
- Used the method of characteristics to explore unsteady flow in HCP; proved the correctness of the method by using experimental data.
- Tested and analyzed successfully the effect of slopes and bends on HCP and CLP.
- Demonstrated and explored the effect of drag reduction in HCP by using polymers.
- Tested and analyzed successfully slurry suspension of coal logs in CLP.
- Tested and analyzed successfully an automated system of CLP.
- Successfully produced coal logs that are both water-resistant and wear resistant.
- Advanced the theory of PCP powered by LIMs.

- Developed several ways to produce strong coal logs at low cost.
- Explored thoroughly the phenomenon of coal log wear and the many factors affecting it.
- Developed a model to predict heating and drying rates of coal logs.
- Developed a sophisticated economic model to evaluate the cost-effectiveness of CLP.
- Explored and clarified many legal issues related to coal pipelines such as eminent domain, water rights, rights to cross railroads, etc.
- Successfully tested coal log transport through a 6-inch-diameter underground industrial water pipeline in Kansas.
- Constructed and demonstrated a unique coal log fabricating machine based on hydraulic press.
- Designed a rotary press for mass production of coal logs.
- Developed extensive knowledge in the field of compaction, and extended the study to biomass compaction in a DOE project.
- Made several important inventions. Submitted five patent applications; two resulted in patents, and three are pending.

(c) **Future Plans (Next 2 Years)**

- Conduct extensive tests with the new coal log machine.
- Complete construction of the 3,000-foot-long closed loop pilot plant CLP. Conduct extensive tests with this new pipeline.
- Seek industry funds for conducting the pilot plant test program.
- Select the first commercial demonstration project. Help the owner of the project to plan for the project.
- Submit a revised full proposal to NSF for converting CPRC into an ERC (Engineering Research Center) on Pipelines Infrastructure. Submit several other proposals to fund the Center's future research.
- Conduct another round of surveys to determine promising commercial CLP projects (work in progress).
- Complete revision of CLP economics analysis report.
- Complete revision of Manual of Practice of CLP.
- Expand research in a LIM-powered PCP system, making it the future new focus of CPRC mission.
- Seek NSF approval for a No-Cost Extension of one year, and a Supplemental Funding to conduct joint research with industry on an innovative coal log sensor (see Appendix 6).

2. ACCOMPLISHMENTS, INFRASTRUCTURE CHALLENGES, PARTNERSHIPS, AND CONTRIBUTION TO EDUCATION

A. Most Significant Accomplishments

A.1. Most Significant Accomplishments During the Past Year:

1. Construction of CLP Pilot Plant - Construction of a test bed (pilot plant) for large-scale testing of an entire coal log pipeline (CLP) system is being completed. It is important to construct this pilot plant so that industry will be interested in funding further research programs based on tests of the CLP pilot plant system.
2. PCP-LIM - Analytical work on the electromagnetic theory and fluid mechanics of pneumatic capsule pipeline (PCP) powered or driven by linear induction motors (LIMs) has been completed. A laboratory test facility has been designed and is under construction. The advanced PCP system being studied is an improvement over current commercial PCP, making the system more efficient and less costly, thereby more feasible as a transportation option.
3. Hydrodynamics of HCP (Hydraulic Capsule Pipeline)—The research on the hydrodynamics of HCP has been focused on testing the effects of bends and slopes on the behavior of HCP. This study will be completed at the end of Year-8.
4. CLP Compaction Machine Improvement & Design—Several improvements were made in the hydraulic press used for compacting coal and biomass waste materials into "logs" or solid cylinders. From the test results, a new machine based on the rotary press concept has been designed. This machine will be suitable for commercial mass production of coal and biomass logs at low cost.
5. Coal Log Sensor - A special sensor, based on the dielectric principle, has been invented and tested. It will detect coal logs in CLPs.
6. Biomass Compaction - The Federal Energy Technology Center (FETC) of the U.S. Department of Energy (DOE) has funded a large research project to CPRC for studying the compaction of biomass waste materials such as sawdust, yard wastes, waste paper and so forth, in order to turn them into upgraded fuel for combustion at coal-fired power plants. The same technology and machine developed for compacting coal logs are used in this DOE project to compact the biomass. Initial results of this project are very promising; most biomass waste materials can be compacted into good-quality logs without the use of binder and without heating.
7. National Survey - A national survey of potential commercial coal log pipeline sites is being conducted. An evaluation of the economics of each project will be conducted, and the promising sites will be selected for possible commercial development by the owners.

A.2. Most Significant Accomplishments Since Center's Inception:

1. **Development of the Coal Log Pipeline Cost Model**—For CLP to be accepted commercially, its market potential must be determined. An engineering cost model of a complete CLP system was developed and programmed for use on a PC. The model calculates the cost of transporting a ton of coal for any distance in $/T (dollars per ton) via CLP. It includes not only capital and operation-maintenance costs, but also a reasonable built-in profit for the investor. Thus, the unit coal transportation cost of CLP can be compared with that of railroads, trucks and barges to determine it's economic competitiveness in a given situation.

2. **Demonstration Site**—A survey of more than 100 coal and utility companies—nationwide—was conducted in 1995-96 to suggest sites where a CLP might be constructed to demonstrate the performance and benefits of the technology. These companies were asked to nominate sites where the coal transport distance is less than 100 miles and the volume shipped is less than five million tons per year. Fourteen sites were submitted to the Center for consideration, of which seven sites were judged to be economically feasible. They were further evaluated by Williams Technologies, Inc., an industrial sponsor of CPRC having extensive experience in evaluating energy projects. Results were presented to the utilities that owned the sites.

3. **Coal Log Manufacture**—The coal log manufacturing process is essential to commercial success of CLP. Without coal logs that can withstand the rigor of pipeline transportation over long distances, CLP would not be technically feasible. Several highly promising CLP manufacturing processes have been developed; they are all based on mold compaction rather than extrusion. The results from the testing program have confirmed that it is possible to produce high-quality coal logs. The best coal logs produced survived transportation in a 2-inch-diameter steel pipe loop in the laboratory over a distance of 200 miles with about 5% wear.

4. **Coal Log Machine Design**—Because coal logs cannot be manufactured at sufficiently low cost by using existing commercially available machines, CPRC designed and constructed a coal log manufacturing machine for testing. This special machine is a hydraulic press that uses a vertical mold to hold the coal. Upper and lower pistons compress the coal into logs. One of the unique and critical features of the machine is the ability to apply pressure to the log as it exits the top of the mold. This pressure—called back pressure—is essential to the production of high-quality logs. At such high compaction pressures, back pressure delivered by the machine preserves the structural integrity of the coal log, and prevents crack formation.

5. **Hydrodynamics of CLP**—Researchers at the Center have greatly advanced the hydrodynamics of coal log transport in a pipe. They developed a four-regime theory and equations to predict coal log behavior in pipelines. They also assessed and demonstrated the effects of polymer to reduce drag in a CLP, discovered ways to reduce coal log wear in pipe, and clarified the effects of bends and slopes on coal log behavior in pipelines.

6. **Injection, Ejection and Pumping of Coal Logs**—A fully-automated, operational model of a CLP system was put together in the Civil Engineering Hydraulics Laboratory. Experience gained from this model system will be extremely valuable in avoiding mistakes and making improvements when designing commercial systems.

7. **Commercial Pipeline Coal Log Test**—In September 1994, coal logs were tested in a 6-inch-diameter, 5-mile-long commercial pipeline in Conway, Kansas. Twenty-four coal logs were run through the pipe three at a time; some went through the pipe twice. The best (strongest) logs lost less than 1% weight due to abrasion; the worst broke up in the pipe but did not cause jamming. The results indicate that coal logs can be made robust enough to withstand travel for miles, and the pipe has an ability to pass broken logs. The tests also revealed the need to eliminate girth weld protrusions in future commercial CLPs. This test was an important verification of the feasibility of CLP and the log manufacturing processes that the Center had developed. Since then, much better logs have been made by new processes and the new machine. It is expected that logs made today (in 1999) would behave much better than those tested in Conway in 1994.

8. **Legal Issues Study**—A thorough study of the legal issues associated with the use of CLP was conducted. Issues researched were eminent domain rights for coal pipelines, water rights and permits, rights to cross railroads right-of-way, and the possibility of using the easement of liquid or natural gas pipelines for CLPs. Research results were published in legal journals, and a legal manual for CLP was completed.

9. **Heating and Drying of Coal Logs**—A detailed study was conducted to determine the most practical method to heat coal for compaction as part of the coal log manufacturing process. Several approaches were compared; the most practical method was found to be fluidized-bed heating. A separate study was also performed to determine how to predict the cooling and drying rates of coal logs. A sophisticated mathematical model was developed which couples heating with moisture change. Moisture content is a critical variable in the manufacture of quality coal logs.

10. **Construction of a CLP Pilot Plant**—The CLP pilot plant system under construction is near completion. It consists of a coal log manufacturing machine, coal preparation (grinding, mixing and handling) equipment, a 3,000 ft pipeline complete with pump bypass, injection, ejection and automatic control systems. Successful test of the pilot plant will pave the way for commercial use of CLP. The system can also be used for future tests of grain pipelines and other hydraulic capsule pipeline studies.

As required in NSF reporting guidelines, the Center's outputs and outcomes in education are quantified and listed in Table 1.

Table 1. Quantitative Center Outputs and Outcomes in Education and Publications Since Inception

CENTER GRADUATES	
Bachelor's degrees granted:	37
Master's degrees granted:	38
Doctoral degrees granted:	13
GRADUATE OUTCOMES	
Industrial employment--at Corporate site:	8
--at National Lab:	
--site unknown:	
--U.S. industry:	17
--foreign industry:	5
--Center members:	
Center graduates hired by academia:	5
Government employment--at National Lab:	
--not at National Lab:	4
--site unknown:	1
Graduate or professional school:	5
Unknown outcome:	53
CENTER INFLUENCE ON CURRICULUM	
New courses based on Center research:	
Courses modified to include Center research:	3
New textbooks based on Center research:	1
New degree programs:	
PUBLICATIONS THAT ACKNOWLEDGED NSF SUPPORT	
Peer reviewed technical journals--by Center personnel:	19
--with industrial coauthors:	1
Peer reviewed conference papers--by Center personnel:	66
--with industrial coauthors:	
Trade journals--by Center personnel:	8
--with industrial coauthors:	
Technical reports--by Center personnel:	47
--with industrial coauthors:	1
Books--by Center personnel:	1
--with industrial coauthors:	

B. Infrastructure Challenges and Changes

The Center's research program was planned to accomplish the stated goal which, for the first four years, is to research and develop the CLP (Coal Log Pipeline) technology for early commercial use. To attain this goal as soon as possible, and with the Center being the only institute in the nation engaged in CLP and HCP (Hydraulic Capsule Pipeline) research, all the unknown areas and unsolved problems pertaining to CLP have been studied simultaneously. This called for a wide range of research projects, and the mobilization of a large number of faculty and students from different fields. Even greater interdisciplinary involvement is required for the final year of the Center's research in capsule pipeline for transporting grain, solid wastes, and other freight. Starting Year 7, the Center initiated some research in solid waste compaction (into logs), and pneumatic capsule pipeline (PCP) for transporting mail and general cargoes. They are being phased in slowly so that they will not slow down the development and commercialization of CLP.

Unlike ordinary academic research which is unsolicited and initiated by individual researchers, the CPRC's research program is carefully planned and designed by the Center Director with input from individual faculty members, the Industry Advisory Board, the government sponsors, and technical consultants--especially the Williams Technologies, Inc., whose President Hank Brolick is serving as the Center's Principal Consultant. This approach in research planning is necessary in order to accomplish the stated mission of the Center. Several planning documents were issued by the Center in the last seven years. The Center's R & D plan has been updated periodically to reflect advancement in technology and changing circumstances.

The capsule pipeline field has come a long way since the establishment of CPRC in 1991. Through tireless efforts of many individuals associated with CPRC, the coal log pipeline (CLP) has advanced from a mere concept to a major technology. Volumes of information on CLP have been written and published. A large body of new knowledge has been generated. With the completion of the planned pilot plant research project, CLP technology will be ready for initial commercial use in the year 2002. The greatest intellectual/infrastructure challenges over the next year or two are: to complete construction of the CLP pilot plant and to execute the pilot plant study so that most of the technical information needed for designing a commercial CLP can be generated from the pilot plant study; to conduct thorough tests of the new coal log machine and, based on the test results, to design a new machine for commercial CLP use; to encourage and convince an electric utility to become the first user of CLP; to complete a good operation manual of CLP; to complete the analysis, design and test of a new PCP (Pneumatic Capsule Pipeline) system based on LIM (Linear Induction Motor); and to enter into other new research areas including PCP, grain pipelines, solid waste (biomass) compaction research and so on.

The most significant change since the Center's inception eight years ago is advancing the technology of CLP—bringing it from a mere concept to a major technology. The most significant change during Year 8 is the CLP pilot plant construction—a major step and the last step of CLP development before the technology can be used commercially.

Capsule pipelines will be a major transportation technology in the future. This is supported by the view of a recently published Task Committee Report of the American Society of Civil Engineers (Ref. 1), and by other documents included in the Appendix. The Center's program has made the United States the world leader in this new technology, enhancing our national competitiveness. Furthermore, future use of CLP in the United States will reduce coal

transportation cost, making U.S. coal more economically competitive in the world market. It also helps to reduce the cost of electricity, thereby benefiting many other industries and the public. Finally, use of capsule pipelines reduces the society's reliance on trucks and rails for transportation of freight. This helps to reduce traffic congestion on highways and railroads, improves transportation safety, and reduces air and noise pollution generated by trucks and trains.

C. Partnerships

One of the major accomplishments of the Center this year (1999) has been construction of the CLP Pilot Plant. Construction of this plant would not have been possible without internal and external partnerships and connections the Center has developed. Internally, within the University of Missouri System, the Center has developed strong ties with the faculty and the electronic and mechanical shops within the College of Engineering, with the Agricultural Experiment Station of the College of Agriculture, and with the Mining Engineering Department of the University of Missouri-Rolla. These ties have enabled the Center to call upon the expertise and services of these entities that were needed to keep the project on schedule and to produce a world-class facility for CLP research.

During Year 8, the Center was fortunate to get help from industry to provide construction services, pipeline materials, pumps, motors and controls, PLCs, parts and components for the CLP system. The Center received donations exceeding $400,000 during Year 8.

Since the establishment of the CPRC, strong partnerships have been forged between the Center and a group of companies interested in the development of the CLP and other capsule pipeline technologies. This partnership is reflected by these companies providing industry matching funds, by providing guidance to the Center through the IAB (Industry Advisory Board), by frequent contacts and visits with individual companies, by industry participation in CPRC research, and by helping to build major test facilities for CPRC. For instance, the Williams Technologies, Inc. has helped the Center to develop a good cost model for CLP, and has evaluated more than ten potential CLP demonstration sites. The MAPCO Company allowed the Center to test coal logs in a 5-mile-long pipe in Conway, Kansas, free of charge. The Williams Pipe Line Company constructed a 340-ft long pipeline at Rolla, Missouri, for the Center's UMR team. The Gundlach Machine Company, a small business participant of CPRC, constructed a new coal log compaction machine for CPRC. Most recently, the Williams Pipe Line Company demonstrated a special pipe grinder in Tulsa intended for construction of coal log pipelines with smooth joints. The Company also sent a construction crew to Columbia, Missouri to build a 3,000-ft long coal log pipeline (the Pilot Plant) for CPRC as part of its in-kind contribution. All these demonstrated strong partnership between CPRC and its industrial sponsors. They contributed greatly to the success of the Center's R&D.

The most important technology transfer activity of CPRC this year is the organization of an international symposium and short course on Underground Transportation of Freight by Capsule Pipelines and Other Tube/Tunnel Technologies, to be held in Columbia, Missouri, September 1-4, 1999. The Symposium culminates CPRC's eight-year research and development in capsule pipeline technology. World experts on capsule pipelines, representatives from sponsoring agencies, transportation planners, and shippers will be in attendance.

Collaborative research with industry took place with several companies including: Williams Technologies, Inc. (on compaction research and machine design), T. J. Gundlach

Company (on machine design), TDW Pigging Products (on coal log sensor), Sumitomo Metal Industries (on PCP drag force and design), Force Engineering (on linear induction motor), Williams Pipeline (on pipeline construction), Nova Tech (on automatic control of pilot plant), and COMPACTCONSULT (on coal log machine design). T. J. Gundlach, Force Engineering, and Nova Tech are small businesses.

The Center continually seeks opportunities to work with industry on R&D projects and to promote technology transfer. Some of the ways the Center carries out this mission is to present its findings at conferences which are supported by active participation of industry. For example, each year the Center has presented multiple papers at the Coal Energy conference in Clearwater, Florida and has attended the Coal Technology conference in Pittsburgh. Through its presentation and participation, the Center has contacted, and has been contacted by, many companies. The contacts have resulted in many projects such as testing of materials for CLP components, and development of new inventions such as the dissolution of drag reduction agents into water.

These linkages have been essential to the progress made by the Center in its research and commercialization of CLP technology. The Center has limited resources and expertise at its disposal. However, it can significantly augment its resources through linkages: partnerships and connections to industry and within the University of Missouri system. Developing and maintaining these linkages is important due to the scarcity of Center resources and the tight schedule for completion. Without the linkages to assistance, the Center would not have made nearly as much progress in its research, nor would it be possible to construct the CLP pilot plant.

D. Integration of Research and Education

Educational activities include teaching pipeline engineering as an elective course for CE and MAE majors, and having engaged over 100 students in capsule pipeline research. Also, Director Henry Liu presented an educational paper on industry-university collaboration at ICEE'98 in Brazil and another at ICEE'99 in the Czech Republic. Both generated strong interests in different circles. During the last 12 months, there were over twenty publications in journals and conference proceedings, one U.S. patent granted, one U.S. patent application submitted, and two invention disclosures filed. Over the last eight years, there were over 100 publications, two U.S. patents granted, and three pending.

Since the Center's inception, all the graduate students who serve as research assistants on any CPRC project were required to write a thesis (for M.S.) or dissertation (for Ph.D.) on a coal log or capsule pipeline topic closely related to their work. This policy has resulted in close integration of research with graduate education. Many undergraduates also wrote honor's reports on coal log related studies. For instance, a former undergraduate in Chemical Engineering, Bill Knowles, studied vacuum dissolution of Polyox in water as an honors project. The study resulted in an invention disclosure. That student is now employed by the Dow Chemical Company.

During Year 8, three undergraduate honors students with GPA higher than 3.6 (Jamie Graham, ChE; Jamie Kiesler, CEE, and Amy Morgan, CEE) participated in the DOE biomass compaction program under NSF sponsorship—research experience for undergraduates (REU). They also were able to report the findings of their research projects at the international Coal Technology Conference in Clearwater, Florida, 1999.

During the 8 years of the Center, many efforts have been made to increase participation of women and underrepresented minorities. They resulted in the hiring of two women as post doctoral fellows, one as research associate and laboratory manager, two as Patricia Harris Fellows, three as NSF-REU fellows, and several as research assistants. Limited success was also encountered in involving a few minorities (blacks and Hispanics) as research assistants, work-study students, and a secretary. The past Associate Director of the Center is Hispanic and legally "handicapped."

During the last 8 years, 14 faculty members, 64 graduate students, 6 law students, 42 undergraduate students and 2 exceptionally qualified high school students benefited from working for CPRC. Most of the students finished their degrees.

Work for the Center has broadened the experience and expertise of faculty and students. Center research projects have allowed students to apply course and lab knowledge to advance CLP technology. The added requirement of satisfying industry needs has broadened the experience as well. Without Center projects, many of the faculty and students would not have had the opportunity to enrich themselves and the others working on these tasks. Students who worked for the Center have reported that they received special favorable considerations by industry during job interviews.

Research results on CLP and HCP have also been incorporated into the curriculum of CE/MAE 345 Pipeline Engineering. Chapter seven of the course is "Capsule Pipelines." The course notes are being expanded into a textbook. Also, scheduled for publication in 2000, a book entitled The Cutting Edge: Mining in the 21st Century, published by the Jesse Stuart Foundation in Ashland Kentucky, will include a chapter by Dr. Thomas R. Marrero and Dr. John Wilson, "Coal Transportation by Pipeline."

3. NUGGETS

(a). Industry Support for Pilot Plant Test—The Capsule Pipeline Research Center (CPRC) has been extremely successful in enlisting the support of industry to donate materials and services for completion of a Coal Log Pipeline (CLP) pilot plant. The pilot plant is an experimental CLP system (testbed). It contains all the components that will be found in a commercial CLP system, except that the pilot plant is much smaller in size and capacity.

For this pilot plant, 20 companies donated more than $400,000 in materials, products and services. The cooperation and generosity has enabled CPRC to construct the pilot plant. Without the pilot plant, the CLP technology has little chance of being commercially accepted and used.

A key to the Center's success in securing these donations was the process employed to identify and contact potential donors. In the first step, the appropriate vendors of the materials and products were identified through web sites and other means. Next, a letter from the Director providing a detailed explanation of how their product would be used in the pilot plant CLP system and how the company can benefit from participation was sent to the chief executive of the company. The letter was followed by a phone call by CPRC Manager Terry Maynard to the executive. If the company was willing to donate items, discussions with the company and Center technical experts would ensue to insure that the right products were supplied for the CLP system.

The foregoing procedure has worked well as attested to by the large number of companies that have provided generous assistance to the Center. Companies responded eagerly when they saw the fit of their products with the CLP system—which represented, in most cases, a potential new market and/or application for their product.

It was also important to contact the top executive first. Writing to the chief executives was much more effective than dealing with product managers or sales people who are much lower in the management hierarchy and do not have the authority to approve donations in most cases. Top executives seemed to appreciate the long-term possibilities of the Center's CLP system and how the donation of their company's product might payoff for them. Decisions were quicker too. Directives from the top executives produced rapid response and cooperation from company personnel lower in the management chain. Without support from the top executives, much time could be wasted trying to secure a donation which in the end was refused.

All told, the Center was fortunate to receive over $400,000 in donations. They have made the CLP pilot plant a reality—it is currently in the final stages of construction.

(b). International Symposium—Technology Transfer is an important task for any center. This year in carrying out that task CPRC is sponsoring the International Symposium on Underground Transportation of Freight by Capsule Pipelines and Other Tube/Tunnel Systems. Presenters and attendees from around the world will be convening in Columbia, Missouri for this symposium on September 2-4, 1999. Representatives from the academic community, from industry and from government agencies will be participating. This should be a landmark event that will accelerate the commercial development of capsule pipeline technology.

New technology needs sponsorship to gain acceptance. To gain sponsorship, affected organizations such as governments, industries and corporations need to be aware of what a capsule pipeline is and how it can benefit them. New technology also competes with existing technology so that its advantages over existing technology—and disadvantages—need to be highlighted. This international symposium will promote the awareness and help gain sponsorship for capsule pipeline technology. Greater awareness and more sponsors can lead to early development and early use of capsule pipelines as a significant mode of transport in the next century.

The Center was able to put together the Symposium by utilizing all the contacts and relationships that had been developed over its eight years in existence. By going back to the experts in the field and to government agencies with a vested interest in the capsule pipeline technology, and by contacting industry with potential product and technology interests in this area, the Center Director was able to attract a large number of co-sponsors for the symposium. The list of topics and presenters was also impressive.

One of the keys to success of the symposium is early planning and contact of potentially interested individuals, experts and organizations. Contacts should be made six months in advance to ensure maximum attendance and cooperation. Follow-up with the sponsors and presenters is important too. These people are busy and need to be reminded of their commitments and the need to get information to the Center on time.

Another important consideration is attention to detail. Much thought and planning must go into developing the agenda and program topics as well as the different styles of presentation such as short course, presentation, work shop or panel discussion. Developing the program and promotion materials requires constant attention to who is going to do what when and ensuring that the flow and sequence of the presenters and events in the symposium make sense from the perspective of the attendees. Attention to surroundings, meals, and lodging are important too since many participants will be traveling from other continents to attend the symposium sessions.

A month prior to the symposium, one must continually update the program, the attendance list and to handle special requests such as computer compatibility for PowerPoint presentations.

All in all, the symposium is appropriate for advancing the technical and commercial acceptance of capsule pipelines. Many hours go into the preparation and production of a good symposium. However, the benefits of greater awareness and sponsorship to capsule pipeline technology that are likely to accrue because of the symposium are definitely worth the efforts.

Appendix 2 contains a sample of a newspaper article resulting from this Symposium, and Appendix 3 contains a copy of the Symposium Program.

4. CONTRIBUTIONS TO STATE AND LOCAL ECONOMIC DEVELOPMENT STRATEGIES

The Center has sought to maximize its research programs by submitting additional grant and research proposals in areas where the Center had developed superior expertise and/or processes or equipment. By leveraging its research and development strengths, the Center has been successful in winning additional funds to augment its base of support from NSF, the state of Missouri and industrial sponsors. An example of this success is the winning for the DOE Grand Challenge grant for Compacting Biomass and Municipal Solid Waste to Form an Upgraded Fuel. The total budget for the 2-phase project is over one million dollars. This Center development strategy is consistent with that of the strategic plan of the Department of Economic Development of the state of Missouri which calls for the creation of new jobs especially those paying greater than $10 per hour. Locally, the Center's projects provide jobs for faculty, students and staff and indirectly contractors and suppliers.

The Center is also one of the first research Centers at the University of Missouri-Columbia to take advantage of the new university technology transfer initiative whereby royalties from University of Missouri patent rights will be shared with investors in proportion to the magnitude of their investment up to 50% of the royalty amount. The Center has proposed a large multimillion-dollar, multi-year research project to outside investors where this royalty sharing is offered as an incentive for investment. When funded the project will bring funds to the local and state economy that will pay for good jobs, materials and services necessary for the project. Details of these new initiatives of the University are discussed in documents in Appendix 4.

To date, the Center has already contributed much toward the economic development of the local and state of Missouri economies. In the last 8 years, the state of Missouri has invested $1.8 million in the Center's work. Outside funds from NSF and private companies (both cash and in-kind contributions) has exceeded $4 million. In addition, almost a million dollars have been received from non-core research projects. And with the win of the DOE Biomass fuel project, the Center will receive more than one million dollars over the next 3½ years. These funds paid for salaries, goods and services to support work of the Center. Whenever possible on its research projects, the Center seeks to collaborate with Missouri-based companies. This not only helps economically but also helps transfer the Center's expertise to the company and vice versa.

Located in the Midwestern region of the United States, Missouri is dependent on economical, reliable and safe transportation to move goods and materials into and out of the state. Currently, the state's economy is robust and employment is at an all time high. The Center's work on capsule pipeline technology should become a strategic resource for the state in the years to come. For example, approximately 75% of the total cost of coal paid by Missouri utilities is for transportation from mines in Wyoming. CLP could lower coal transportation costs significantly. The savings would lower the final cost for Missouri utilities, thus, making energy costs more competitive for Missouri corporations. The public will benefit through reduced energy cost. The Center's capsule pipeline technology can also be extended to move other materials such as grain. This new transportation mode could help ensure more competitive transportation costs for Missouri farmers who are competing with farmers around the world in marketing their crops. Again, transportation costs are a large component of the delivered cost of the grain. In the future, capsule pipeline technology can effectively lower such costs.

Basically, capsule pipeline technology will help Missouri businesses by enabling utilities to maintain competitive fuel costs and provide energy at competitive prices. It could help the state Department of Transportation by reducing truck and rail traffic using the state's roads and rail lines. It can help shippers such as farmers by providing safer, lower-cost and more reliable delivery of commodities and products. In the Internet age, the cost of the physical distribution of products and materials will become increasingly critical. Capsule pipelines can help lower that cost and also provide safer and more reliable delivery of goods.

The Center takes advantage of the local, regional and state technology development organizations when their services are needed. In building the CLP pilot plant, the Center used assistance from other departments on campus at the University of Missouri-Columbia and the University of Missouri-Rolla. Through the representative from the state of Missouri's Department of Economic Development who sits on the Center's Industrial Advisory Board, the Center is kept apprised of the assistance capabilities that are available from other state programs and organizations.

5. RESEARCH PROGRAM

A. Research Strategy

The mission or goal of the CPRC is to advance the technology of capsule pipelines, especially the coal log pipeline (CLP) technology, to the point that they can be used commercially to benefit industry and the public. A set of strategies was employed to fulfill the mission or goal. The strategies were derived from an analysis of the need—what areas of research are needed to fill the gap and to hasten commercial use of coal log and capsule pipelines.

It was determined in the beginning of the Center (1991) that research is needed in many fronts before CLP or HCP can be used commercially. These fronts include hydrodynamics, unsteady flow generated by capsule injection and pump bypass, coal log manufacturing, coal log water absorption properties, coal log pipeline economics, automatic control of CLP and legal research.

In the hydrodynamics area, it was determined that research was needed to understand the behavior of capsule trains, not only in straight and horizontal pipes, but also in sloped pipes and bends. Research was also needed to understand the wear (abrasion) of coal logs in pipes, and use of polymers for drag reduction in order to save energy. In the area of unsteady flow generated by capsule injection and pump bypass, the biggest need was to develop the theoretical framework (equations) for predicting the unsteady flow generated with capsules in the pipe. In the area of coal log water absorption, the greatest need was to know whether coal logs absorb water and if so, how much water will they absorb and whether the absorption of water will harm the coal logs.

In the area of coal log manufacturing, the biggest initial need was to determine the factors affecting the strength of the compacted coal logs. Once all these factors were identified and their effects on the coal log strength were quantified, one could then design the best process for making the strongest coal logs at the least cost. After the coal log manufacturing process was well understood, it was discovered that there was a strong need for the design of a coal log manufacturing machine based on the process developed. So, machine design soon became an important area of research. In the area of automatic control, the research need was to design a practical control system and then to analyze the system behavior. Much was needed also to construct, test and demonstrate a small automatic CLP system in the laboratory. In the area or economics, the need was to develop a sophisticated model that could be used to predict the cost of future commercial CLP systems, and to compare the coal transportation cost by CLP with those of railroads, trucks and coal slurry pipelines. Finally, in the area of legal research, the biggest need was to investigate the issues of eminent domain for coal pipelines, water rights and the right of coal pipelines to cross railroads.

B. Research Thrusts (Past 8 Years)

The research under the Center's Core Program for the past eight years (9/1/91-8/31/99) can be classified into eight broad areas (thrusts) as follows:

B.1. Hydrodynamics of HCP and CLP

The hydrodynamics is the same for HCP and CLP. It must be clearly understood before one can design an appropriate HCP or CLP systems and expect them to work without difficulties. Prior to the establishment of the Center, many areas of the hydrodynamics of HCP and CLP were either unexplored or inadequately explored. This includes prediction of energy

loss, capsule lift-off, capsule velocity, capsule train behavior, effect of slopes and bends on capsules, abrasion (wear) of coal logs in pipeline, capsule jamming, capsule pumping and injection, effect of drag-reducing additive on the pressure drop of CLP and HCP, and so forth. Research conducted by the Center in the last eight years was focused in these areas. It has greatly enhanced the knowledge and state-of-the-art in these previously poorly understood subjects. This research is led by the Center's Director Dr. Henry Liu, Professor of Civil Engineering, who is an expert in hydrodynamics. Two other faculty members involved in this research were Dr. Charles W. Lenau, Professor of Civil Engineering, and Dr. John Miles, Professor of Mechanical & Aerospace Engineering. Dr. John Miles replaced Dr. James Seaba who left the University during the course of this study. Dr. Lenau has been the P.I. of projects involving predictions of unsteady flow and pressure surges (water hammer) in CLP and HCP. He is also instrumental in the design of the pilot plant CLP. Dr. Miles has supervised a project in drag reduction in a large (8-inch-diameter) pipe.

Major accomplishments in the hydrodynamic research in the past eight years include the following:

(a) Theory for Predicting HCP Flow Behavior:

Based on the concept that there are four distinctly different regimes of HCP flow, equations have been derived for each regime to predict the hydrodynamic behavior of HCP flow. The theory can accurately predict the capsule pressure gradient, capsule velocity, capsule drag and lift, capsule incipient velocity and capsule lift-off velocity (Ref. 2 & 3). Research in this area during Year 8 focuses on predicting capsule train behavior, and the behavior of capsules (or logs) in bends and slopes.

(b) Coal Slurry Suspension and Transport of Coal Logs:

A study was completed to test coal slurry suspension of coal logs. The test was done using the coal slurry prepared for the Black Mesa Pipeline which is a slurry that contains 50% solids by weight. The study found that the pressure drop (headloss) of the two-phase flow of coal logs in slurry is almost identical to that of slurry flow alone. Other interesting features of this type of flow were also found (Ref. 4 & 5). The coal-log/slurry flow was found to have some special advantages such as it transports more coal and uses less water than either the coal slurry pipeline or the ordinary coal log pipeline. Furthermore, the slurry provides larger buoyancy than water to suspend coal logs, and this lowers the lift-off velocity and reduces contacts between the logs and the pipe. It is a technology that may play a role in future transportation of large-diameter, heavy coal logs over long distances.

(c) Drag Reduction in Coal Log Flow:

A study was completed in a 2-inch pipe to determine the effect of a conventional drag-reducing polymer (polyethylene oxide, trade named "Polyox") on the headloss (energy consumption) of HCP and CLP. It was found that at polymer weight concentration of 25 ppm (parts per million), the Polyox can produce as much as 75% drag reduction which is equivalent to four-fold reduction in the pressure gradient or energy consumption (Ref. 6). This finding has strong implications to future operation of CLP and HCP systems. It makes long-distance transportation of coal logs and capsules far more economical than realized before. Degradation of Polyox due to shear in flow can be minimized by injecting polymers downstream of each

pumping station, as practiced in ordinary pipelines, such as the Trans-Alaska Pipeline. Research in this area during Year 8 involved testing the effectiveness of polymer drag reduction in a large HCP--the 8-inch-diameter pipeline test loop in the UMC Research Park. Again, maximum drag reduction of 75% was observed.

(d) Coal Log Jamming in Pipe:

Research has been conducted to study different ways that coal logs may jam in a pipe. The research has led to a good understanding of the different jam mechanisms and causes, and effective strategies to prevent jamming (Ref. 7). Ways to unclog a coal log pipeline once it jams have also been developed. Future research will focus on verifying the effectiveness of jam prevention strategies in a long (3,000 ft.) test pipeline to be built.

(e) Coal Log Wear in Pipeline:

The phenomenon of coal log wear has been studied extensively during the first five years of the Center (Ref. 7), and is still receiving continued attention in research. Many factors contributing to coal log wear in pipeline have been identified and tested. Findings include: coal logs made of subbituminous coal are more wear resistant than those made of bituminous coal; logs with large diameter ratio and large aspect ratio are more wear-resistant; logs with beveled rear end suffer less wear; minimum coal log wear is produced when fluid (water) velocity in the pipe is approximately 85% lift-off velocity; coal slurry increases wear of coal logs; high pressure in the pipe decreases coal log wear; and the wear is minimum over a wider range of velocities than realized previously--between 80% and 90% of lift-off. The wear of coal logs was also tested in a 5-mile long industrial water pipeline in Conway, Kansas. The best logs suffered less than 1% weight loss due to wear.

Future research in the Hydrodynamics of HCP and CLP will focus on testing coal log wear and degradation of drag reduction in the pilot plant facility. A proposal will also be submitted to NSF to study the velocity field and the pressure field around a capsule in pipe. The measured fields will be compared to those predicted from numerical modeling.

B.2. Unsteady and Transient Flow in HCP

The operation of HCP and CLP requires periodic closing and opening of valves, and startup and shutdown of pumps. Such unsteady operations generate pressure surges, whose effect on the capsules, pipes, valves and pumps must be carefully evaluated. The evaluation can be done by using a specific mathematical technique called the **"method of characteristics"** which is commonly used for analyzing water hammer (pressure surges). As a result of this research, a technique (including equations and computer programs) has been developed that can analyze the behavior of capsules and the pressure waves in an HCP under various operational conditions such as capsule injection, pump startup, shutdown, and valve switching at both the intake and at pump bypasses (booster stations) (Ref. 8 & 9). The accuracy of the theory has been validated by experiments (Ref. 10). The technique and analyses enable us to improve and optimize CLP and HCP system design and operations. Dr. Charles Lenau, Professor of Civil Engineering and an expert in hydraulic transients, was the P.I. of this completed research. Future research in this area will focus on verifying the predictions of unsteady HCP flow generated in the pilot plant.

B.3. Coal Log Manufacturing

During the last eight years, several promising ways to fabricate good coal logs have been investigated. These include binderless underwater extrusion, hot-water compaction of binderless, high-strength coal logs, making hydrophobic coal logs and so forth. Seven faculty members (Butler, Gunnink, Lin, Luecke, Marrero, Miles and Wilson), two post-doctoral fellows (Ding at UMR and Li at UMC), four visiting scholars (Yu Lin of the Southern Metallurgic Institute in Ganzhou, Jiangxi China; Kyoung-Hoon Rhee, Assoc. Prof. of Civil Engr., Chonnam Nation University, Korea; Jihuai Xu and Zhengwang Li of the Central Coal Mining Research Institute, Tangshang, Hebei, China), three research associates (Burkett, Smith and Lin) and more than twenty students worked in this area during the last eight years.

This area has been given the greatest emphasis in the past due to its practical importance and insufficient previous knowledge and know-how in making good, economical coal logs. As a result of this intensive effort, Gunnink's group in Civil Engineering has succeeded in developing a hot-water drying process to produce binderless logs that maintain strength in high-pressure water and that have passed an abrasion resistance test (Ref. 11 & 12). Lin's group in Mechanical Engineering was able to extrude binderless logs that retain strength in high-pressure water (Ref. 13). Marrero/Burkett's group in Chemical Engineering has succeeded in extruding good logs using a large ram-extruder installed in 1993 (Ref. 14). Wilson/Ding's group (UMR Mining Engineering) has succeeded in making water-resistant, durable coal logs at low (less than 80 °C) temperature with no more than 2% emulsified asphalt or Orimulsion--a low-cost substitute for emulsified asphalt (Ref. 15). Liu and Lin have demonstrated that the strength of binderless logs made at room temperature can be increased 50% by neutralizing the zeta potential (Ref. 16). Luecke/Smith/Bahr have demonstrated that good quality coal logs can be made with fast compaction and with little excess water. And Li's group has demonstrated that much better coal logs can be produced by either using a solid lubricant to lubricate the mold, or by treating the mold with a special surface conditioner. A theory has also been proposed with equations derived to predict the behavior of compaction of coal logs in a cylindrical mold (Ref. 17). Research in coal log manufacturing resulted in the development of a 3-D model to predict the variation of density and stresses in any coal log under compaction, and when the log is being ejected. This theory enables the optimization of mold design and prediction of the properties of coal logs before they are compacted. Finally, during Year 8 the value of back pressure during coal log ejection from mold was demonstrated. Works in this area led to one U.S. patent and two pending patents. Future research in this area will focus on producing strong logs for wear tests in the CLP pilot plant, and the compaction of materials other than coal including biomass.

B.4. Coal Log Water Absorption

During the first two years of the Center's operation, three methods of coal log surface treatment were investigated: using coal/water slurry to seal the surface pores of dry logs (Ref. 18), impregnating coal log surface with an impermeable material such as wax or asphalt (Ref. 19), and heat treatment of coal log surface (Ref. 20). All three methods did not result in a practical way of treating dry logs. Consequently, this area of research was abandoned, and efforts were re-directed towards making coal logs that are already saturated with water so that upon entry into pipe, the logs will not absorb additional water and hence are able to maintain their strength and integrity. The new approach turned out highly successful, and it forms the basis of current practice. This approach has resulted in a U.S. patent. The effect of water pressure on

coal log quality has been studied. It was found that high water pressure reduces coal log abrasion. Future research in this area will focus on testing the drying rate of PCP systems.

B.5. Coal Log Machine Design

Conventional briquetting and extrusion machines cannot make coal logs fast enough for commercial CLP transportation of coal. It was important that a special machine be designed to make good logs at a fast rate so that the number of machines required to supply a single pipeline can be kept to a minimum. Dr. Yuyi Lin, Associate Professor of Mechanical and Aerospace Engineering, with the help of three graduate students, successfully designed a rapid-compaction coal log machine (Ref. 21). The machine design focused on compaction rather-than extrusion. The design was revised several times as the coal log compaction process continued to evolve. The final designs were based on two concepts: hydraulic press and rotary press. Both designs were reviewed by outside consultants, before final revisions were made. Note that the hydraulic press is considered the first generation coal log machine for commercial use, whereas the rotary press is considered the second generation. The rotary press is much faster and more cost effective for commercial use.

During Year 7, the CPRC-designed coal log compaction machine was constructed by the Gundlach Company with Flo-Products as the principal subcontractor. The machine performance was tested and researchers determined that it met design objectives, especially in terms of speed and maximum force. A coal material feeder and coal log removal device was manufactured and installed. Log removal devices included a slide, soft-landing chute and conveyor belt. The machine was designed to produce one coal log in every 20 seconds. The machine was tested thoroughly during Year 8. Valuable data were generated, yielding information that can be used to improve the design of the second generation machine. Other machine design research involves investigating the optimum shape of molds and pistons (punches) used for compacting coal logs, and the best material that the molds and pistons should be made of.

Future research in this area will focus on design and testing of a rotary press for compacting coal and other materials.

B.6. Automatic Control of CLP System

Automatic control is a must for CLP systems. Operation of any future commercial CLP system, including the injection, pumping and ejection of coal logs, can best be controlled by a centralized computer called SCADA (Supervisory Control and Data Acquisition) system interacting with microprocessors or small computers scattered at different locations to control individual components such as a booster station or an injection station. Because coal log pipelines operate quite differently from ordinary liquid or gas pipelines, the control hardware and strategies are also different. This calls for the design of special hardware and software for the control of CLP systems.

It should be realized that proper control of a CLP system depends not only on proper use of signals derived from transducers and use of computers, it also depends on a good knowledge of the hydrodynamic behavior of coal logs and the flow. Some hydrodynamic equations must be included in the computer software for controlling the coal log pipeline. For this reason, the hydrodynamic group and the control group members have worked closely together in their

research. Dr. Satish Nair, Associate Professor of Mechanical and Aerospace Engineering (MAE), led the automatic control research area.

Major accomplishments in this area of research during the last eight years include the completion of three reports on automatic control of CLP (Ref. 22-24), and the construction of a computer-controlled, automated CLP system in the laboratory which has proven to work very well. A coal log train separator was also designed and tested successfully in 1995. During Year 8, a coal log sensor was invented and tested. It showed great promise as a means to sense not only coal logs and capsules, but also pigs and two-phase flow in pipelines.

Future research in this area will focus on testing the automatic control of the pilot plant facility.

B.7. Legal Research

The legal research was focused on identifying legal and institutional obstacles that may impede the future implementation of coal log pipelines, and suggesting ways to remove or reduce such obstacles. Subjects under legal research include water rights, eminent domain rights, the right to cross railroads, conversion of ordinary oil or gas pipelines to coal log pipelines, and others. Dr. Peter Davis, MU Professor of Law, directed this research. Good progress has been made (Ref. 25). A Legal Manual of Practice on Coal Pipelines was prepared (Ref. 26).

Future research in this area will involve drafting legislation for implementing capsule pipelines.

B.8. Economics of CLP

A rigorous study has been completed on the economics of coal log pipeline (CLP) as compared to other freight transportation modes including truck, train and slurry pipeline. The study resulted in a detailed report (Ref. 27). This report defines unit cost as the cost of transporting a ton of coal for any prescribed distance in $/T (dollars per ton), and it includes not only capital and operational costs, but also a built-in profit for the investor. The unit cost of coal log pipeline can be compared with the current tariffs for coal transportation charged by railroad, truck and other competing modes to determine whether it is economically competitive in a given situation. The study was conducted for different transportation distances and throughputs. Based on this comparison, conditions are established under which coal log pipeline is more economical than slurry pipeline, truck and train. An abbreviated version of this report is published in 1998 in TRANSPORTATION RESEARCH (A), an Elsevier Science published journal (Ref. 28).

B.9. PCP Research

During the 7th year, research was initiated on PCP (Pneumatic Capsule Pipeline). PCP is an existing technology with limited success in commercial use in Japan. The main problem with the current PCP systems is that their cost effectiveness is marginal when compared with truck and other competing transportation modes. CPRC has discovered that the cost effectiveness of PCP can be greatly enhanced by increasing the throughput of PCP. The throughput can be increased several times by using a LIM (Linear Induction Motor) based propulsion system and off-line loading/unloading. A totally new (revolutionary) PCP system is being investigated at CPRC based on LIM and off-line loading/unloading (Ref. 29). The project was sponsored jointly by the Sumitomo Metal Industries, Ltd. in Japan, and the Mid-America

Transportation Center. The equations for predicting the behaviors of a PCP-LIM system have been derived and used in making practical predictions (Ref. 30-32). The current (Year 8) work, sponsored by Sumitomo Metal Industries, is focused on predicting the behavior of the LIM-PCP system., and design optimization. Good progress has been made in these areas. An experimental system to test the concept of PCP-LIM is under construction.

Future research in PCP will focus on testing a PCP-LIM in laboratory, and designing an entire PCP-LIM system.

C. Comparative Analysis

The Center, being mission oriented, has focused its efforts on core projects. Therefore, greatest accomplishments have been made in core projects. Non-core projects do not relate directly to the mission of the Center and hence have been kept to a minimum in order not to distract from the central mission. Only during Year 8 did the Center undertake a major non-core project, funded by DOE to compact biomass as power-plant fuel. The total non-core funding over the past eight years is $924,549.

Being a not-for-profit organization, the Center's success is not measured by the amount of money that it has received or spent, but rather by the tasks that it has accomplished. As reported in the previous sections, the Center has accomplished a great deal of tasks and advanced the capsule pipeline technology substantially by using the money received from NSF and other sponsors.

1. INDUSTRIAL COLLABORATION/TECHNOLOGY TRANSFER

A. Non-Core Research

The Non-Core research projects do not directly fall under the Center's central mission. Yet, they are very valuable because they provide additional support to study new technologies and concepts spinning off the Center's core research program. Instead of being long-term support such as provided by NSF, the State Department of Economic Development (MDED) and industry (the CLP Consortium), most Non-Core projects are short-term grants or contracts of lesser amounts than each Core contribution. Nonetheless, they are as valuable as Core program projects on a per-dollar basis. The subject area of a grant is a key factor in classifying a project as "Core" or "Non-Core." For instance, the newly funded DOE project of $394,338, is classified as Non-Core because the research is in compacting biomass which is a spin-off of coal log compaction research. In contrast, an earlier 3-year grant from DOE, in the amount of $218,000, is classified as a Core support because the grant was intended to supplement the CLP Consortium contribution.

As shown in the table below, the total funding from non-core projects received in the past 8 years is $924,549.

Non -Core Projects During Past 8 Years of CPRC (9/1//91-8/31/99)

Project Title	*Sponsor*	*Periods*	*$ Amount*
Coal Log Pipeline System Development	DOE Energy Related Inventions Program	8/24/90-6/30/92	40,000
End-of-Pipeline Study	Electric Power Research Institute (EPRI)	1/13/92-12/31/92	50,000
Patricia Robert Harris Fellowships	U.S. Department of Education	1/1/84-12/31/89	84,000
Advanced PCP System for Transporting Freight	U.S. Department of Transportation Mid-America Transportation Center	10/1/98-9/30/99	49,365
Ultrafine Coal Single Stage Dewatering & Briquetting Process	Illinois Clean Coal Institute (Research done at UMR)	9/1/94-8/31/95	85,203
Pilot Scale Single Stage Fine Coal Dewatering and Briquetting Process	Illinois Clean Coal Institute (Research done at UMR)	9/1/95-8/31/96	109,994
Commercialization of Single Stage Fine Coal Dewatering and Briquetting Process	Illinois Clean Coal Institute (Research done at UMR)	9/1/96-8/31/96	111,649
Compacting Biomass and Municipal Solid Wastes to Form an Upgraded Fuel	U.S. DOE	12/1/98-5/30/99	394,338
		Total	**924,549**

*Acquisition Cost & In-kind contribution

There are three types of companies supporting the Capsule Pipeline Research Center: those that provide financial support (cash) to the Center, those that provide in-kind contribution, and those that contribute both. The in-kind service is usually in the form of providing needed equipment, materials, or special services for the Center's research, development or technology transfer (RD&T).

As shown in Table 2 there was an enormous support for the Center in year eight although most was in the form of in-kind material and service contributed by many corporations, for construction of a CLP testbed—the CLP pilot plant. Cash contributions during Year 8 decreased due to the drop out of two utility members from previous years and no new cash members joining during the year. During the year, many of the contributors were companies that became newly acquainted to the Center's mission and areas of research and development. The Center made a concerted effort to get the CLP pilot plant completed in 1999. Due to budget constraints it had to rely on the generosity of industry to provide the necessary materials and services to

complete the pilot plant. Industry responded to the Center's request most generously. As a result all of the major components and equipment needed to finish the pilot plant have been committed. The fabrication services have been committed too but will not be completed until the end-of-the-year if current schedules are met.

Table 2: Industrial Participation for the Current Year (Year 8)

			Company Size				
Name/Company	Member Category (1)	Yrs. of Partici-pation	Small Business	MID-SIZE	Fortune 500	Joint Resrch. (y/n)	Funds Provided Core/Non Core
Allen-Bradley Co., Milwaukee, WI dba Rockwell Automation	Associate	8			X	n	48,604
Commercial Resins Co.	Affiliate	8	X			n	8,210
COMPACTCONSULT, Inc.	S.B.	5-8	X			y	5,000
Dataforth--A Burr-Brown Company	Affiliate	8		X		n	3,865
Garney Companies, Inc.	Affiliate	8	X			n	5,250
GIW Industries, Inc.	Associate	8		X		n	14,397
Kistler Instrument Corporation	Associate	8		X		n	43,779
Krohne, Inc.	Affiliate	8	X			n	7,140
T. J. Gundlach Machine Co.	S.B.	1-8	X			y	5,000
Maverick Tube Corporation	Associate	8	X			n	22,500
Rotork Control, Inc.	Associate	8		X		n	43,766
Siemens Energy & Automation, Inc.	Affiliate	8		X		n	4,640
Square D Company	Associate	8			X	n	19,660
Sumitomo Metal Ind., Ltd.	Principal	6-8			X	y	30,000
Trans Metrics, Inc.	Affiliate	8	X			n	2,625
Tulsa Tube Bending Co.	Associate	8	X			n	5,300
Tyco Flow Control	Associate	8			X	n	21,000
VALVTECHNOLOGIES, Inc.	Principal	8		X		n	106,845
Williams Pipe Line Co.	Principal	1-8			X	y	75,000
Williams Technologies, Inc.	Member	2-8			X	y	5,000
T. D. Williamson, Inc. (T.D.W. Pigging Products)	Member	3-8		X		y	9,161
							484,540

(1) ***Membership*** Definition: Annual minimum fees are $30,000 for ***Principals***, $15,000 for ***Members***, and $5,000 for ***Small Business (S.B.)***. These companies have signed Agreements with CPRC. ***Associate*** and ***Affiliate*** have not signed Agreement. ***Associate*** refers to companies that donated labor and/or equipment/materials for CPRC's pilot plant operation valued at over $10,000. ***Affiliate*** refers to companies that donated labor and/or equipment/materials valued at less than $10,000.

B. Technology Transfer & Industry Involvement

Since its inception, many outputs and outcomes have resulted from the Center's technology transfer program. Table 3 is an NSF form that summarizes the Center's technology transfer activities. With the exception of companies started and software licenses, the work of the Center has been fruitful with the promise of more to come in the future when the CLP system is tested in the operation of the pilot plant. It is premature at this point to have start-up companies on CLP since the technology is not yet ready for commercial use.

Table 3: Quantitative Center Outputs and Outcomes in Technology Transfer Since Inception

Spin-off companies started:	0
Inventions disclosed:	6
Patent applications filed:	5
Patents granted:	2
Patent licenses:	5
Software licenses:	0
Copyrights:	0
Research developments (1)	7
Transfer developments (2)	4
Commercial developments (3)	3

(1) The number of important research developments since inception; see brief summary description in Section 6.B in this report.
(2) The number of events involving transfer of knowledge, processes or technology to industry and provide a brief summary description in Section 6.B of the report.
(3) The number of significant commercial developments since inception; see brief summary in Section 6.B in this report.

Table 4 shows how active Industry has been in the Center's technology transfer activities.

Table 4: Quantitative Data on Special Technology Transfer Activities Since Inception

Company Name	Size L/M/S	Foreign (Y/N)	FS (1)	FI (2)	IC (3)	JP (4)	LS (5)	LT (6)	GH (7)	SS (8)	TB (9)	PA (10)	OT (11)
Ameren (Union Electric)	L	N	1	--	2	--	--	--	--	--	--	--	--
Arch Mineral Corp.	M	N	1	1	1	--	--	--	--	--	--	--	--
ARCO Pipe Line Co.	M	N	1	1	1	--	--	--	--	--	--	--	--
Associated Electric Co.	M	N	1	1	4	--	--	--	--	--	--	--	--
Bonnot Company	S	N	1	1	1	1	--	--	--	--	--	--	--
COMPACTCONSULT	S	N	1	1	1	1	--	--	--	--	--	--	1
Electric Power Research Inst.	M	N	2	2	2	--	--	--	--	--	--	--	--
Erie Press Systems	S	N	5	5	5	--	--	--	--	--	--	--	--
Force Engineering	S	Y	--	1	--	1	--	--	--	--	1	1	--
Gifford-Hill-American	M	N	1	1	1	--	--	--	--	--	--	--	--
Gundlach Machine Co.	S	N	3	1	3	1	--	--	--	2	1	1	--
Kansas City Power & Light	M	N	1	1	1	--	--	--	--	--	--	--	--
Loomis Products	S	N	4	4	4	--	--	--	--	--	--	--	--
MAPCO Transportation	M	N	1	1	1								
Nova Tech, Inc.	S	N	1	1	1	1	--	--	--	1	1	--	--
New Century Energies	L	N	2	1	1	--	--	--	--	--	--	--	--
Peabody Holding Co.	L	N	1	1	2	--	--	--	--	--	--	--	--
PERMALOK	S	N	2	2	2	--	--2		--	--	--	--	--
Pro-Mark Co.	S	N	1	1	1	1	--	--	--	--	--	--	--
James Ramer & Associates	S	N	1	1	1	--	--	--	--	--	--	--	--
STI International Associates	S	N	2	2	2	--	--	--	--	--	--	--	--
Sumitomo Metal Ind. Ltd.	L	Y	--	1	3	3	--	--	--	--	--	--	1
TDW Pigging	M	N	2	3	3	1	--	--	--	--	--	1	--
U.S. Dept. of Education PHR Fellowships	L	N	--	--	--	--	--	--	--	--	--	--	--
U.S. Department of Energy	L	N	--			--	--	--	--	--	2	--	--
VALVTECHNOLOGIES	M	N	2	2	2	--	--	--	--	--	--	--	--
Willbros Engineers, Inc.	M	N	3	5	5	--	--	--	--	--	--	--	--
Williams Pipe Line	M	N	2	1	2	--	--	1	--	--	--	--	2
Williams Technologies	S	N	1	1	2	--	--	1	--	--	1	--	--

(1) Faculty on Site at Industry
(2) Faculty Instruction to Industry
(3) Individual on Campus from Industry for More Than Just Advisory Board Meetings
(4) Joint Projects with Center Personnel
(5) Licensed Software
(6) Licensed Technology (Other Than Software)
(7) Graduate Hired by Industry
(8) Student on Site at industry
(9) Used Center's TestBed or Developed a Testbed to try Center-Developed Technology
(10) Developed Prototype of Application of Center-Developed Technology
(11) Other Technology Transfer (See Section 9 of this report)

The Center's interaction with industry representatives has been strong throughout its eight years of existence, entrenching its reputation as a strong research institution that knows how to bring positive results to the business table. Many industrial participants have been involved in the Center's RD&T activities. Some most important involvements are described briefly as follows:

The Williams Pipe Line Company (WPL) Company helped CPRC in designing and constructing both a CLP test loop at Rolla, and a larger loop in Columbia as part of the pilot plant. During Year 8, the Company sent a crew to Columbia, Missouri, to construct the outdoor portion of the pilot plant for CPRC as in-kind contribution, and will come back to construct the indoor portion later this year. WPL also arranged a demonstration of a special device to grind the interior of steel pipe for future CLP use. The device was demonstrated in Tulsa, Oklahoma, by its manufacturer (CUES) in Florida. Dr. Liu attended the Tulsa demonstration. Dr. Liu found the test to be potentially useful and suggested some modifications which may lead to future collaboration with the manufacturer. WPL also attended work sessions at CPRC on the design of the CLP Pilot Plant, and participated in a Professor-for-a-Day lecture in a pipeline engineering class.

The Williams Technologies, Inc., being the Center's Principal Consultant, reviewed the Center's R&D plans, budget priorities, and quarterly and annual reports. It provided both oral and written comments. It also helped the Center to develop a credible economic model to analyze the cost-effectiveness of coal log pipeline.

The Sumitomo Metal Industries, Ltd. (SMI) participated in the Center's PCP research by providing cost data for a hypothetical PCP system between Washington, D.C. and New York City. This enabled the Center to estimate the unit freight transportation cost of such a pipeline. The results suggest that such a pipeline can be quite cost competitive in comparison with train and truck. SMI pipeline manager Dr. Sanai Kosugi attended three meetings with CPRC researchers to discuss PCP research. He also reviewed three CPRC reports on PCP research, and provided detailed comments on each.

Another international company that collaborated with and helped the Center during Year 8 is Force Engineering in England. The company not only reviewed CPRC's design of linear induction motors (LIMs) for PCP, it also constructed and donated a LIM for testing by CPRC. This greatly boosted the PCP-LIM research at the Center.

Two engineers of the TDW Pigging Products participated in CPRC research aimed at developing a special electrode (probe) to sense coal logs in pipelines. They reviewed the CPRC design and provided both oral and written comments. Furthermore, they spent a day in Columbia, Missouri to discuss this sensor with CPRC researchers. Preliminary test results of this probe appear promising. Continued involvement of TDW Pigging Products in this project will be done during the next 12 months under a Supplementary Funding Request to NSF. This will insure TDW's continued interest in this sensor. TDW also donated several pipeline pigs and more than 50 special fittings to CPRC for special use.

CPRC has been collaborating with Nova Tech, a small business firm in Kansas that specializes in pipeline control systems, in research related to automatic controls of CLP systems. Nova Tech reviewed CPRC reports and theses in this area and provided valuable comments. The Company President also attended three work sessions in Columbia, and had extensive discussions with CPRC researchers in this area.

In 1994, CPRC collaborated with the MAPCO Pipeline Company, Williams Technologies, Inc., and T.D. Williamson Company, in testing coal logs in a 5-mile-long commercial pipeline in Conway, Kansas. The pipeline owner was MAPCO, which allowed the use of its pipeline for the test, free of charge to CPRC.

Note that prior to the establishment of the Center, there was little industry involvement in the RD&T of CLP. The Center has fostered industry interest in this new technology, as demonstrated by growing industry involvement. The Center encourages industry involvement in its work, especially in areas that companies have interest and expertise. The Center's policy encourages direct contact between faculty researchers in specific areas and companies with expertise in such areas. Such contacts have been frequent.

In addition to involving industry in research, the Center also transferred special technologies to its industrial sponsors. Examples include: the transfer of technology to the Gundlach Machine Company on the design of a hydraulic press to fabricate coal logs; transfer of software to Williams Technologies, Inc. to analyze coal log pipeline economics, transfer of a coal log sensor technology to TDW Pigging Products, and transfer of a special technique to Williams Pipe Line Company, to make smooth girth weld in the field.

C. IAB Activities

The Center being involved in mission-oriented research relied heavily on the guidance of its Industrial Advisory Board (IAB). The IAB consists of all the companies—large and small—that supported the Center during its 8-year operations. Since its beginning in 1991, CPRC has held two IAB meetings each year. At the meetings, the Center researchers reported semi-annual progress on R&D projects: the successes, problems and plans for the next six months.

The IAB contributed greatly to the Center's R&D progress, by providing the Center Director and researchers valuable input and advice. For CLP to succeed commercially, industrial concerns must be addressed in addition to the academic ones. The IAB allowed such concerns to be known and acted upon by the Center. The IAB meetings also helped to maintain the long-term interest of the IAB members in the Center's work. The adage, "Out of Sight, Out of Mind" can apply—even to sponsors, but the meetings kept them informed and positive about CPRC progress. Finally, IAB members also utilized this opportunity to discuss timely issues with each other, and with the Center Director. The IAB played a key role in advising the Center Director on all matters related to the Center's operation. Such advice was given not only at regular Board meetings, but in letters and phone calls throughout the year, and in e-mail recently. The Center Director gave serious consideration to all advice from the IAB and carried out the recommendations as much as practical.

The IAB and the semi-annual meetings were necessary for the success of the Center. They were a management tool that ensured communication between the Center and the IAB members to take place on a regular basis. More importantly, the input from the IAB members facilitated Center progress toward achievement of its goals. The degree of progress made in the past eight years would not have been possible without the IAB or the semi-annual meetings. The minutes of the latest IAB meeting is attached in Appendix 1.

D. Collaboration With Small Businesses

The Center has worked with small businesses in many capacities. For example, the Center has been a partner with a small business in an SBIR proposal for development of a portable compaction machine to use at coal mines for compacting coal fines. Small businesses have generously donated materials and services to construct the CLP pilot plant. They provided services such as trenching services, pipe bending and coatings and materials such as valves and pumps. The Center has used the technical expertise of its small business partners to help it validate and improve the large coal log machine design and to provide consultation and advice on control systems for the pilot plant system. Much of the research involvement and technology transfer activities discussed earlier pertain to small business.

7. MANAGEMENT AND STRUCTURE

The Center planning involves every researcher. Each week there is a meeting for each group such as the Hydraulics/Control group, and Coal Log Fabrication group. Besides reporting on the progress made each week, the meetings also involve planning. Each researcher is required to present his or her plan for the next week and for the more distant future, and each group leader is required to tell the others about the group plans. All such plans are discussed and debated at such weekly meetings. Then the Center Director advises the leaders on the action to be taken, and the responsible individuals carry out the plan according to decisions reached at these meetings.

The Center also has a carefully prepared written R&D plan which was revised periodically. The Industry Advisory Board (IAB) is closely consulted in preparing and formulating the plan.

Management issues are also discussed at weekly meetings with faculty and students and twice each year at the IAB meetings. The Center Director seeks advice on key management issues not only from the Center Business Manager but also from Center staff. For matters involving University of Missouri policies, the Center Director seeks guidance from the Dean of Engineering, the Engineering Research Director, the Vice Provost for Research, the Director of Sponsored Programs Administration (in matters about contracts and grants), and the Director of Patent and Licensing (in patent related matters). A CPRC university policy committee exists to guide the Center; the committee meets at least once each year.

The Center has used, basically, this system for managing and planning its work activities since its beginning in 1991 and continued to use it through year eight. There have been few changes made to this system because it works as evidenced by the CLP research results produced by CPRC. Keeping the management layers few, meeting weekly with the project teams, taking immediate remedial action and laying out a detailed, written plan of research have enabled the Center Director to produce significant results from the resources at his disposal. Had the Center been larger in terms of budget and projects to complete, the structure and procedures might have been inadequate. However, for CPRC they have worked for the past eight years.

A structural/personnel change during Year 8 is the appointment of a Business Manager (Terry Maynard) due to the increased need for contacting industry for donation and financial support, and the management of large projects such as the pilot plant construction and the new DOE project. The position of Associate Director was abolished in Year 8. These changes are reflected in the organizational chart (Fig. 1) on the next page. Table 5 contains personnel information required by NSF.

Table 5. STATE/IUCR Personnel for the Current year

		Sex		Minority Status [1]					Disabled	Disciplines
	#	M	F	1	2	3	4	5		
Faculty	8	8	0	0	3	0	1	4	1	*
Research Staff [2]	1	1	0	0	0	0	0	1	0	*
Visiting/Foreign Faculty [3]	1	0	0	1	0	0	0	0	0	*
Industry Researcher [4]	0	0	0	0	0	0	0	0	0	*
Post Doctoral	2	2	0	0	2	0	0	0	0	*
Management/Administration	1	1	0	0	0	0	0	1	0	
Technical Staff	1	1	0	0	0	0	0	0	0	
Students: UG										
Students: MS										
Students: PhD										

[1] 1: Native American; 2: Asian or Pacific Islander; 3: Black, not of Hispanic origin; 4: Hispanic; 5: White, not of Hispanic origin.

[2] Faculty Level Persons Employed Directly by State/IUCRC, Not on Regular Faculty.

[3] Visits of 1 Week or More.

[4] Industry Researcher Working at Center

* Disciplines involved: Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical & Aerospace Engineering, and Mining Engineering

CAPSULE PIPELINE RESEARCH CENTER'S ORGANIZATIONAL CHART (Year 8)

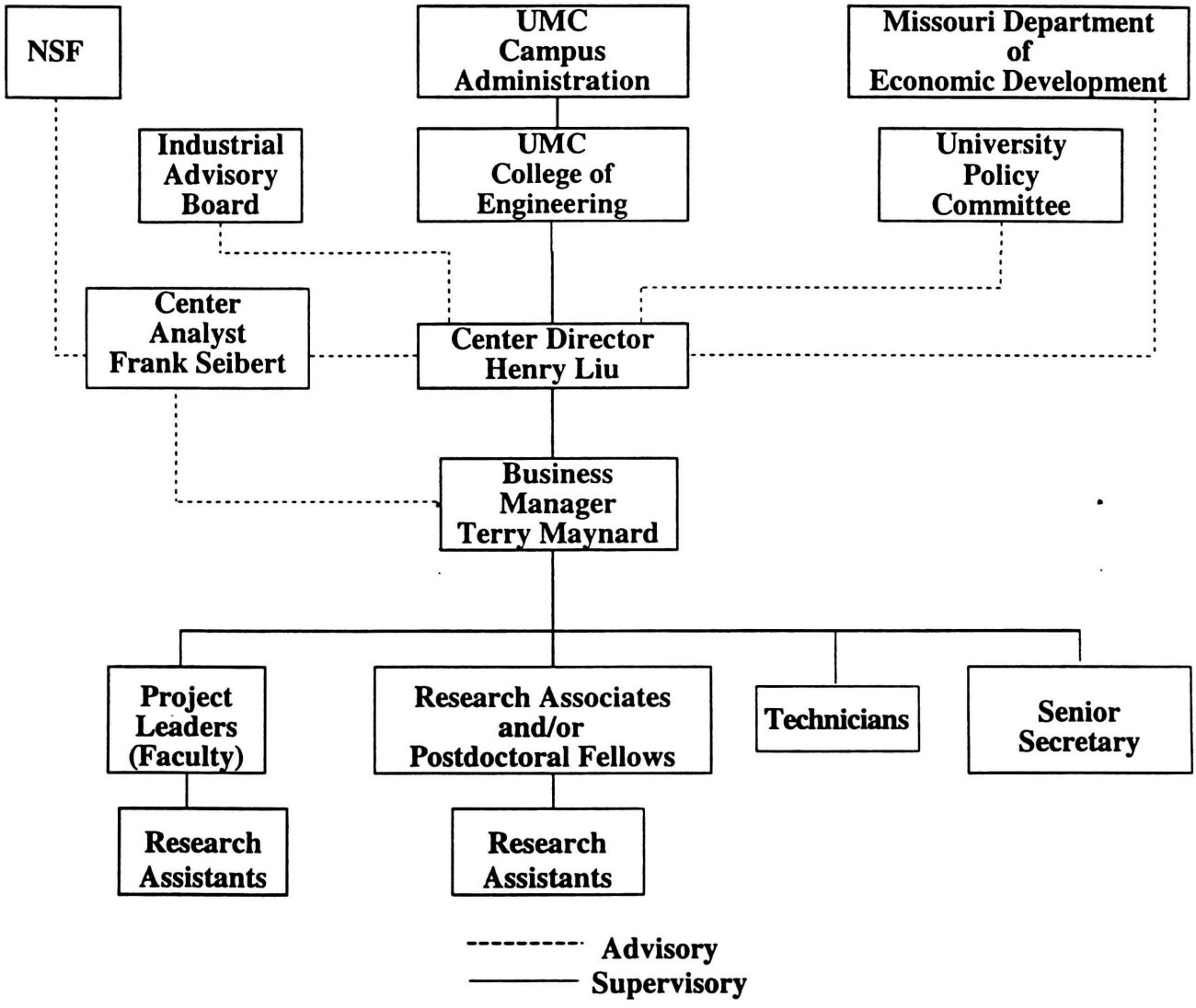

Fig. 1 Organizational Chart of Capsule Pipeline Research Center (CPRC)

8. CAPSULE PIPELINE RESEARCH CENTER ANALYST'S REPORT

by Frank Seibert, Director
with contributions by
Marilyn Lake, SBDC staff writer and Philly Anthony, MBA research assistant.
Small Business Development Center, University of Missouri-Columbia
September 1991-August 1999

INTRODUCTION

The Capsule Pipeline Research Center (CPRC) at the University of Missouri-Columbia has now completed its eighth and final year of the National Science Foundation (NSF) funding. By funding the CPRC for two, four-year periods, the NSF underscored the importance of the work conducted at the research center. The NSF's continued funding was pivotal in gaining University, state and industrial support. These eight years have culminated in building a solid foundation for the CPRC's continued existence, as well as for expansion into new areas of research and commercialization. The completion of the Coal Log Pipeline (CLP) pilot project plant construction in 1999 will coincide with the end of NSF and State of Missouri funding. The completed structure will stand as tangible evidence of the successful culmination of the original project's mission and goals, as well as, motivation to move forward with continued research and development on CLP technology's efficiency, cost effectiveness, and commercialization.

Sixteen Industrial Advisory Board (IAB) meetings have been conducted since the inception of the CPRC in 1991. These meetings have been variously attended by representatives from the following: the National Science Foundation (NSF), the Missouri Department of Economic Development, CPRC industrial board members, the Pittsburgh Energy Technology Center, engineers from China, the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI), the Missouri Department of Highways and Transportation, the Missouri Department of Natural Resources, and the Missouri Public Service Commission. Small business participants, potential industrial sponsors, the Dean of the College of Engineering (UMC), the Chief of Staff for the Chancellor (UMC), the Vice Provost of Extension (UMC), the Vice Provost of Research (UMC), the Dean of Mining (UMR), the Center Analyst, and the faculty, students and staff of the CPRC also attended these meetings. The IAB meetings focused on research activities, planning, field test results, potential commercial demonstration of CLP technology, funding and membership issues, patents and licensing issues, an economic study of CLP viability, and problems confronting center operations. Through these meetings and the director's dedication to frequent dissemination of information relating to the various applications of the CLP technology, the center has maintained a strong and healthy relationship with all stakeholders and interested parties.

FINANCIAL ISSUES

The CPRC has experienced financial challenges throughout the eight years. The most serious financial problem arose in 1995 when $250,000 of the matching funds from the State of Missouri were not approved by the Legislature, and hence, were not allocated and disbursed to the center. This represented not only a budget reduction of $250,000, but threatened the existence of the Center due to the matching fund nature of the state funding. Fortunately, both

NSF and the Missouri Department of Economic Development exercised great flexibility and patience until an effort to restore the funds was successful. Because of this concerted effort to educate the Missouri Legislature on the merits of CPRC and its benefits to Missouri, strong legislative support was obtained which solved the 1995 problem and paved the way for support of matching funds for the final three years, through 1999. Moreover, NSF's funding of the project for a second four-year period also had a positive impact on the Center's ability to recruit other funding and sponsors. This is seen in the receipt of funding from new members and increased funding from two founding members, Williams Pipe Line Company and Union Electric Company (AmerenUE). A strong market research and commercialization planning effort were begun in 1995 and have continued to bring positive results throughout the remaining years.

FACULTY ISSUES

Although a faculty promotion and tenure issue at the UMC College of Engineering had a negative impact on the CPRC, the center was able to maintain it's productivity for the full NSF funding period. In 1995 an external evaluation of the CPRC was commissioned by then president of the University of Missouri, George Russell, and administered by Foster Associates, with the help of J D Energy. The conclusion presented in the Foster Report had a positive impact on faculty issues and continuing support from the University of Missouri's highest leadership. Because of the CPRC's educational and research mission, the center director has continually assessed the needs of the Center and the availability of qualified researchers. Throughout the eight years he has had tremendous success in obtaining the dedicated services of some of the brightest minds available.

TECHNOLOGY TRANSFER

Technology transfer activities have been a high priority of the Center. Technological information has been disseminated at national and international meetings and during visits to other organizations and companies interested in capsule pipeline technology. Technology transfer information has been presented in center quarterly reports, shared at presentations with industry, presented at short courses, publicized through articles in national journals, and featured in the center newsletter and in video tapes produced by the center. The CPRC now has a web page, http://www.cclabs.missouri.edu/~cprc/. A new engineering course for graduates and undergraduates was developed and offered through the College of Engineering. The center's future plans continue to place a high priority on technology transfer issues.

FUTURE PLANNING

Future planning projects include technology transfer ventures and continuation of commercialization efforts. Even though great progress has been made in the development of CLP technology, the work will not be complete until the technology is fully realized for commercial use. The completion of the pilot plant pipeline test program, the production and testing of a coal log machine based on the rotary press concept, and the completion of a commercial CLP demonstration project remain to be done.

The pilot plant test facility which is nearing completion is a sheet metal building to house equipment and associated personnel, a coal log manufacturing machine, and a 3000 ft. long pipeline for testing coal logs and other capsules. When this CLP pilot project is completed and in use for demonstrating the application of capsule pipeline technology for transporting coal, agricultural products and other commodities, including waste materials, it will provide tangible evidence that this is a promising avenue for commercial use. Opportunities for small business ventures also are being pursued, such as those with the Gundlach Machine Company and the TDW Pigging Products.

The Center's commercialization strategy for promoting the acceptance and utilization of capsule pipeline technology in the industrial environment should yield significant positive results. The successful completion the CPL pilot project will greatly enhance the probability of the commercialization of this new technology and future research funding from industry.

SUMMARY

The center director has been able to rally the support of key industrial partners, governmental officials, the president and the vice president of the University of Missouri, the current chancellor, and certain distinguished alumni to assist with the necessary funding throughout the eight years of the CPRC project. The center director has been persistent in his dissemination of information about the significance of the CLP technology and promotion of the efforts of the CPRC. The director maintains a strong and healthy relationship with all members of the Industrial Advisory Board, representatives from state government, and the leadership of the University of Missouri. The Center continues to witness successes with its research activities. The most significant event to occur this year is the construction of the CLP pilot plant, which is in its final stage of completion.

Center members have a clear sense of purpose and direction, as evidenced by attendance and discussions at weekly meetings and the other activities of the Center. The center director is an energetic and skillful leader. The activities of the Center are well documented in all areas which facilitate the tracking of its progress.

Some of the Center's other significant recent achievements include:

- technical success in making better coal logs by using back pressure,
- revision of the economic model,
- production of a hydraulic coal log manufacturing machine,
- completion of the design for a rotary based coal log manufacturing machine,
- acquisition of two patents, with three pending,
- use of coal log compaction technology to compact biomass waste material,
- acquiring a large DOE project on compacting biomass waste materials, and

- gaining support from Sumitomo Company and Mid-America Transportation Center to conduct research in using linear induction motors to power pneumatic capsule pipelines (PCP).

In evaluating the center's fulfillment of NSF's expectations, consider both the NSF guidelines and the center's own mission and goals. By these measures, the CPRC's accomplishments show that the Center both fulfilled and expanded its initial mission. The Center has been the main contributor to the advancement of capsule pipeline technology in the world. The technical accomplishments are accompanied by significant economic development and educational achievements. In today's educational and economic environment, it is very difficult to maintain a balance among the technical, economic and education goals. However, CPRC has managed successfully to maintain this balance and to achieve in each area.

Many diverse groups have an interest in the continuing success of the Capsule Pipeline Research Center. These groups include but are not limited to: small businesses, industries, local and state governments, as well as, the general public. The future use of coal log pipelines in Missouri will save enormous transportation costs for coal, which is becoming increasingly important to electric utilities. The CLP technology's potential use in transporting agricultural products, other commodities, and waste materials are areas that are being studied. An example of a spinoff of the Center's R&D program is the use of the methodology and machine designed for making coal logs for the low-cost compaction of coal fines and other solid wastes.

Recently initiated research on capsule pipelines at other universities (University of Minnesota and Texas A&M University, for example) is evidence of the interest that exists. The success of the September 2 & 3, 1999 International Symposia on Underground Transportation of Freight by Capsule Pipelines, held in Columbia, Missouri, also indicates a growing and active interest. Fifteen organizations, including the United States and Missouri Departments of Transportation co-sponsored this event. Development of a new pipeline industry in Missouri and elsewhere will generate thousands of new jobs and enrich the state and nation's economy. The potential for transporting other products and compacting industrial by-products underscores the tremendous value this new technology holds for the citizens of Missouri, the country, and the international community.

9. SUPPORT, FINANCIAL MANAGEMENT & BUDGET

(a) Data on industrial support for the current year (Year 8) are provided in Table 6(a), and for the entire period (8 years) are provided in Table 6(b). both tables are NSF forms. Table 6(a) is to be certified by the Sponsored Research Administration.

(b) Letter from University authority certifying that the Center has received its State matching fund of $250,000 during Year 8.

(c) The source of support for the current year (year 8) is listed in Table 7. The expenditures of the current year are listed in Table 8, Functional Budget.

Table 6 (a) Industrial Support and Characteristics for Current Year

Name/Company	Size L/M/S	Foreign Y/N	In-State Mfg. or R&D Site (Y/N)	"Core" Cash Support ($)	In-Kind Support ($)	Total Core Support ($)	Non-Core Cash Support ($)
Allen-Bradley Co. dba Rockwell Automation	L	N	N	0	46,402	46,402	0
Commercial Resins Co.	S	N	N	0	8,210	8,210	0
COMPACTCONSULT, Inc.	S	N	N	0	5,000*	5,000*	0
Dataforth--A Burr-Brown Company	M	N	N	0	3,865	3,865	0
Garney Companies, Inc.	S	N	N	0	5,250	5,250	0
GIW Industries, Inc.	M	N	N	0	14,397	14,397	0
Kistler Instrument Corporation	M	N	N	0	43,779	43,779	0
Krohne, Inc.	M	N	N	0	7,140	7,140	0
T. J. Gundlach Machine Co.	S	N	N	0	5,000*	5,000*	0
Maverick Tube Corporation	S	N	N	0	22,500	22,500	0
Rotork Controls, Inc.	M	N	N	0	43,766	43,766	0
Siemens Energy & Automation, Inc	M	N	N	0	4,640	4,640	0
Square D Company	L	N	N	0	19,660	19,660	0
Sumitomo Metal Ind., Ltd.	L	Y	N	30,000	0	30,000	0
Trans Metrics, Inc.	S	N	N		2,625	2,625	
Tulsa Tube Bending Co.	S	N	N	0	5,300	5,300	0
Tyco Flow Control	M	N	N	0	21,000	21,000	0
VALVTECHNOLOGIES	M	M	N	0	106,845	106,845	
Williams Pipe Line Co.	M	N	N	30,000	45,000*	75,000*	0
Williams Technologies, Inc.	S	N	N		5,000*	5,000*	0
T. D. Williamson, Inc. (T.D.W. Pigging Products)	M	N	N	0	9,161	9,161	0
Totals				**60,000**	**424,540**	**484,540**	**0**

*Amount estimated by CPRC; Company statements on in-kind contribution to CPRC for Year 8 have not yet been received.

UNIVERSITY ADMINISTRATION CERTIFICATION:

Deborah Caselman

Name and title of Authorized Institutional Official
Deborah Caselman, Associate Director

9/30/99

Date

Table 6 (b): Industrial Support and Characteristics Since Inception

Name/Company	Years of Member-ship	Size L/M/S	Foreign Y/N	In-State Mfg. or R&D Site (Y/N)	"Core" Cash Support ($)	In-Kind Support ($)	Total Core Support ($)	Non-Core Cash Support ($)
Allen-Bradley Co dba Rockwell Automation	8	L	N	N	0	46,402	46.402	0
Ameren (Union Electric)	1-6	L	N	Y	180,000	0	180,000	0
Arch Mineral Corporation	1-4	M	N	N	120,000	0	120,000	0
ARCO Pipeline	1	M	N	N	15,000	0	15,000	0
Associated Electric Cooperative, Inc.	1-7	M	N	Y	240,000	0	240,000	0
Bonnot Co.	1-4	S	N	Y		20,000	20,000	0
Commercial Resins Co.	8	S	N	N	0	8,210	8,210	0
COMPACTCONSULT, Inc.	6-8	S	N	N	0	15,000	15,000	0
Electric Power Research Inst.	1-2	M	N	N	0	0	0	50,000
Erie Press Systems	5	S			5,000	0	5,000	
Garney Companies, Inc.	8	S	N	N	0	5,250	5,250	0
Gifford-Hill-American	6	M	N	N	30,000	0	30,000	0
GIW Industries, Inc.	8	M	N	N	0	14,397	14,397	0
T. J. Gundlach Machine Co.	2-8	S	N	N	0	35,000	35,000	0
Illinois Clean Coal Inst. at UMR	4	--	N	Y	0	0	0	85,203
Illinois Clean Coal Inst. at UMR	5	--	N	Y	0	0	0	109,994
Illinois Clean Coal Inst. at UMR	6	--	N	Y	0	0	0	111,649
Kansas City Power & Light	1-2	M	N	Y	60,000	0	60,000	
Kistler Instrument Corporation	8	L	N	N	0	43,779	43,779	0
Krohne, Inc.	8	L	N	N	0	7,140	7,140	0
Loomis Products	4	S	N	N	0	17,000	17,000	0
MAPCO Transportation Co.	1-5	M	N	N	140,000	10,000	150,000	0
Maverick Tube Corporation	8	L	N	N	0	22,500	22,500	0
Mobil Oil	7	L	N	N		13,998	13,998	0
New Century Energies (Southwstn.Public Serv. Co.)	5-7	L	N	N	90,000	0	90,000	0
Nova Tech, Inc.	2-6	S	N	N	0	25,000	25,000	0
Peabody Holding Co. (Coal Services)	1-2	M	N	N	30,000	2,000	32,000	
PERMALOK	4-6	S	N	N	0	15,000	15,000	0
Pro-Mark Co.	2-4	S	N	N	0	15,000	15,000	0
James L. Ramer & Associates	1-3	S	N	N	0	15,000	15,000	0
Rotork Controls, Inc.	8	S	N	N	0	43,766	43,766	0
Siemens Energy & Automation, Inc	8	M	N	N	0	4,640	4,640	0
Square D Company	8	M	N	N	0	19,660	19,660	0
STI International Associates	6-8	S	N	N	0	15,000	15,000	0
Sumitomo Metal Ind., Ltd.	6-8	L	Y	N	90,000	8,460	98,460	0
Tulsa Tube Bending Co.	8	S	N	N	0	5,300	5,300	0
Tyco Flow Control	8	M	N	N	0	21,000	21,000	0
U.S. Dept. of Education (PHR Fel)	3-4	--	N	N	0	0	0	84,000
DOT (PCP-LIM Research)	7	L	N	N	0	0	0	49,365
DOE Energy Invention Program	1	--	N	N	0	0	0	40,000
DOE Lab Equipment Program	2	--	N	N	0	14,077	14,007	0
DOE Consortium Program	2-4	--	N	N	218,000	0	218,000	0
DOE Biomass Project	8	--	N	N	0	0	0	394,338
VALVTECHNOLOGIES, Inc.	8	M	N	N	0	106,845	106,845	0
Willbros Engineers, Inc.	3-5	M	N	N	0	45,000	45,000	0
Williams Pipe Line Co.	1-8	L	N	N	135,000	90,000	225,000	0
Williams Technologies, Inc.	1-8	M	N	N	0	120,000	120,000	0
T.D.W. Pigging Products (T.D. Williamson)	3-8	L	N	N	0	34,095	34,095	0
Total					**1,353,000**	**858,519**	**2,211,519**	**924,549**

MATCHING FUND CERTIFICATION

This is to certify that the Capsule Pipeline Research Center (CPRC) has received a total of $250,000 of matching fund from the State of Missouri for the 8th year of operation of the Center, covering the period 9/1/98-8/31/99.

Signature: Deborah Caselman

Name: Deborah Caselman

Title: Associate Director
Sponsored Programs Administration

Date: 9/30/99

Table 7: Functional Budget and Sources of Support for the Current Year

Functional Category	State	Industry	NSF	University	Other Support	Total Support
Core Research	80,000	40,000	220,000	100,000	0	440,000
Non-Core Research	0	0	0	0	204,338	204,338
Total Research	80,000	40,000	220,000	100,000	204,338	644,338
Equipment	0	80,000	0	0	0	80,000
Facilities	100,000	344,540	0	98,780	0	543,320
Industrial Collaboration & Technology Transfer	20,000	5,000	0	0	0	25,000
Management	50,000	15,000	30,000	0	20,000	115,000
Indirect Cost	0	0	0	225,000	170,000	395,000
Total	**250,000**	**484,540**	**250,000**	**423,780**	**394,338**	**1,802,658**

Table 8. State/IUCRC Functional Budget (Expenditures) Current Year

	SOURCES OF SUPPORT					
	State	Industry (1)	NSF	University (2)	Other (3)	Total
"Core" Research Salaries (4), Supplies & Services/Other (5)	80,000	20,000	180,000	100,000	0	380,000
Non "Core" Research	0	0	0	0	204,338	204,338
Total Research	**80,000**	**20,000**	**180,000**	**100,000**	**204,338**	**584,338**
Equipment(6)	0	80,000	0	0	0	80,000
Facilities	100,000	200,000	0	98,780	0	398,780
Industrial Collaboration and Technology Transfer (7)	20,000	5,000	0	0	0	25,000
Management (8)	50,000	15,000	30,000	0	20,000	115,000
Indirect Cost	0	0	0	225,000	170,000	395,000
GRAND TOTAL(9)	**250,000**	**320,000**	**210,000**	**423,780**	**394,338**	**1,598,118**

(1) Industrial Membership Fees Plus Industry Augmented "Core" Funds.
(2) Cash and In-Kind.
(3) Federal Agencies, Foundations, gGfts, etc.
(4) Include Fringe Benefits.
(5) Travel, Consultant, Publications.
(6) No More Than 10% of Total "Core" Funds.
(7) No More Than 30% of Total "Core" Funds of State and Industry. To Support Costs For Workshops, Training Courses, Experimental Tests.
(8) Center Director's Time in Management, Administrative Costs, Travel, etc.

10. UPDATE OF CONTACT INFORMATION FOR CENTER

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APPENDICES

(1) Latest IAB Meeting Minutes

(2) Press Coverage of Current-Year Activities

(3) International Symposium on Capsule Pipelines: Program

(4) University New Initiatives for Commercializing CLP Technology

(5) Center Publication List

(6) No-Cost Extension and Supplemental Funding Requests to NSF

Appendix 1:
Latest IAB Meeting Minutes

MEETING OF THE INDUSTRIAL ADVISORY BOARD (IAB)
CAPSULE PIPELINE RESEARCH CENTER
Columbia, Missouri
April 15, 1999

MINUTES

1. Mr. Hank Brolick, IAB Chair and CEO of Williams Technologies, Inc., chaired the meeting. He called the meeting to order and welcomed all the participants.

2. Dr. Jack Burns, UMC Vice Provost for Research, welcomed the participants on behalf of the Chancellor of the University of Missouri-Columbia. He then announced a major initiative planned by the University of Missouri-Columbia to help facilitate the commercialization of CLP. The initiative is in two parts. The first part deals with raising 1.5 million-dollars from industry or investment groups. The money raised is to be used for testing the CLP pilot plant currently under construction, and for completing the CLP development work so that the CLP technology can be commercialized in the next two to three years. The pilot plant is now in its final phase of construction. According to this initiative, companies investing in this $1.5 million project will be entitled to collect 50 percent of all royalties received from future use of CLP. Current CLP sponsors will get the first rights to accept or refuse the opportunity to invest in this project. The second part of the initiative is an offer of reduced royalties for the first commercial CLP project. The guaranteed low royalty for the first project (demo project) is no more than five cents per ton of coal transported by CLP, over the life span of this first project.

   Dr. Burns emphasized the timeliness of these opportunities in the CLP development cycle, and that the University of Missouri-Columbia is serious about building the necessary industry partnerships to get the CLP commercialized.

3. Dr. Andy Blanchard, Director of Research, College of Engineering, welcomed the participants on behalf of the Dean of the College of Engineering – who came to the meeting later in the morning. Dr. Blanchard thanked the industrial representatives for

the support that their companies had provided to CPRC. He also thanked the faculty and students for their contributions and hard work.

4. Dr. Mike Chippendale, Associate Director, Missouri Agricultural Experiment Station, mentioned his College's interest in CPRC research both in compaction of biomass and in transport of grain by capsule pipelines. He pointed out his College's help to CPRC by providing land on the Holstein Farm for the Field Station and the pilot plant pipeline currently under construction. Dr. Henry Liu, CPRC Director, thanked Dr. Chippendale and his College for excellent cooperation with the College of Engineering and CPRC. Liu anticipated collaboration with Ag College in future research in biomass compaction and grain pipeline areas.

5. There was a self-introduction of all participants and brief description of their organizational interest in CPRC's work.

6. Dr. Liu reviewed briefly the missions of the Center. He then reviewed the key accomplishments made by CPRC since its beginning in 1991.

7. Research assistants and faculty members presented the results of their work since the last IAB meeting. The presentations included:

   - Kevin York and Chai Plodpradista explained the use of linear induction motors (LIM) for powering pneumatic capsule pipelines (PCP) and the design and equations that they would be testing in laboratory in the upcoming months.

   - Dr. Yuyi Lin explained the modifications being made to the coal log compaction machine so that more accurate readings of back pressure generated by the coal log machine can be taken. He also showed the designs of the second generation coal log machine, based on the principle of rotary presses used for manufacturing medicine tablets. Special features learned from coal log research such as the back pressure control, will be incorporated in this machine. The machine has a rotary table holding many molds. The rotation of the table guided by a cam produces compression using upper and lower pistons. This second generation machine will

be capable of producing one coal log per second. It will be strictly mechanical in operation and not use hydraulic systems which are more expensive.

- Dr. Jerry Tien, Associate Professor of Mining Engineering at the University of Missouri-Rolla, brought the audience up-to-date on the work being done by the research team at the University of Missouri-Rolla. They confirmed the scale-up predictability--being able to predict the strength of large logs from data taken from small coal logs. The result shows that the strength of the coal logs compacted by a large (5.4-inch diameter) mold appears to be the same as that by a small (1.94-inch diameter) mold, provided that compaction conditions (binder amount, pressure, etc.) are the same for the large as for the small logs.

- Mr. Bill Burkett, Senior Research Associate, reviewed the progress made in the pilot plant construction. He showed that Phase 1 (outdoor) construction is almost completed, and Phase 2 will be completed by August 1.

- Dr. Yadong Li, Post Doctoral Fellow, gave a progress report of the DOE project on biomass compaction which started on December 1, 1998. He showed that good-quality biomass logs can be compacted at room temperature without binder.

8. Dr. Jim Thompson, Dean, College of Engineering, greeted the participants. He complimented Dr. Liu and the CPRC team on their hard work and accomplishments. He pointed out that their work would enable the College to get more involved in interesting and significant areas in the future. He also thanked industry for their patience in supporting CPRC for eight years. He said that the jet engine was developed separately in Germany and England, over a time span of 20 years, before it was finally used. (Moral of the story: Major technologies take time to develop and perfect.)

9. Dr. Liu wrapped up the morning session by going over the tasks to be completed by September 1, 1999. Besides finishing the pilot plant, the coal log machine will undergo further testing; the design of the second generation machine (rotary press) will be completed; the 1995 CLP economic model will be revised to incorporate the new coal log manufacturing parameters and both current and second generation coal log machines; the manual of practice will be revised;

CPRC will conduct a second national survey of possible CLP projects/sites for commercial demonstration; University of Missouri-Rolla team will complete the scale-up study; Liu's student, Gao, will complete the research on the effects of bends and slopes on CLP.

10. Liu finished by explaining the experiment program to be conducted at the new CLP pilot plant. He also explained the new University policy and initiative for CLP. Industry participants asked questions and discussed the University plan. Liu clarified some issues such as: the 30-day response time will not start until the University sends a formal notice to all CPRC industrial partners; the right to 50% of royalty is intended to be transferable as in the case of the other property rights; and the 5 cents per ton of royalty mentioned for the first commercial project is the maximum. In the event that the first project is not financially attractive, the University will consider to further reduce the rate or wave it entirely in order to encourage the first commercial project to take place soon.

APPENDIX 2:

Press Coverage of Current-Year Activities

THE KANSAS CITY STAR

Saturday, September 4, 1999

Professor pushes underground freighting

By OSCAR AVILA
The Kansas City Star

Every day, Henry Liu watches the freight trucks hauling their goods, adding to the congestion on Interstate 70. He says he knows a better way.

Liu and other professors at the University of Missouri-Columbia are studying a system to transport freight through underground tubes.

And Liu insists this is no pipe dream.

"There are all sorts of people in this world. Some will be skeptical that this is possible," said Liu, director of the Capsule Pipeline Research Center. "I know it will take time for people to accept it."

The state thinks it is worth studying. Legislators have approved almost $2 million for the center since 1991, matching private donations and a grant from the National Science Foundation.

Liu was the host of an international symposium on the subject this week.

Here is how a pipeline system would work:

Planners would build steel pipelines, several feet in diameter, and bury them at least 3 feet underground. The pipelines could run along highways or railroad tracks, between cities or industrial facilities.

Steel capsules on wheels, propelled through the pipelines by air, would carry freight. Other pipelines would contain electromagnetic material or water to move the capsules along.

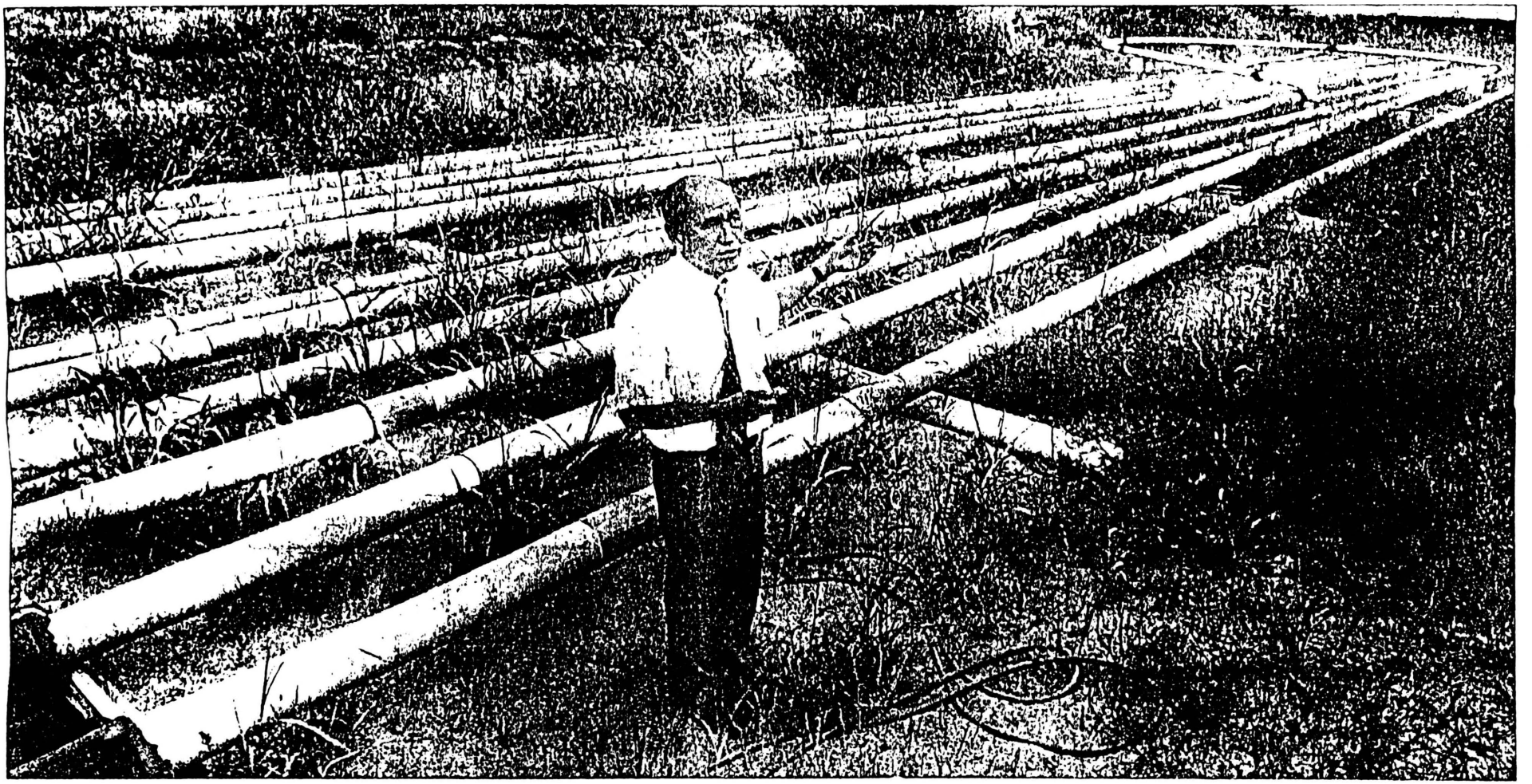
Some pipelines are larger versions of the pneumatic tubes that move material from the drive-up lanes at banks.

Liu acknowledged that some Missouri legislators and representatives of trucking and rail industries considered the idea a waste of money.

George Round, an engineering professor at McMaster University in Hamilton, Ontario, said he had seen the same resistance in Cana-

See TUBES, B-2

Tubular transport



L.G. PATTERSON/Special to The Star

Researchers at the University of Missouri-Columbia are studying ways to move freight in underground tubes. Professor Henry Liu on Friday showed pipes that are being constructed just west of Columbia. The pipes will be covered with dirt later. The study has been funded partly by the state and the National Science Foundation.

TUBES: 'The technology is there'

Continued from B-1

da.

"They are very, very powerful lobbies really, and they don't want to rock the boat," he said. "But the technology is there. The economics are fantastic. But I certainly think there are strong political overtones."

Liu said he also defended the center against critics who say the new technology only will benefit a small group of companies.

Joe Driskill, director of the Missouri Department of Economic Development, said pipelines could help utilities by lowering the cost of transporting coal. He said consumers then could benefit through lower utility rates.

Driskill, whose department helped fund the center, said he did not expect his department to contribute any more money. He said he was confident the pipeline technology was feasible.

"But we are getting close to the point where we need to see some results," Driskill said.

MU researchers also are studying coal-log pipelines, which compact coal into foot-long cylinders and send them floating on water.

The center is building a $1.5 million pipeline simulator that is expected to be finished by the end of the year.

Liu predicts that some type of extensive capsule pipeline system will be developed in the next 10 years, probably by a private company.

Liu said pipelines were being used on a limited basis in Japan and other countries. Some researchers think pipelines could be used to move mail. A Dutch researcher wants to ship flowers.

L.G. PATTERSON/Special to The Star

University of Missouri-Columbia researchers are studying coal-log pipelines, which compact coal into cylinders and send them floating on water. Professor Henry Liu (right) showed the compressed coal Friday.

At the Texas Transportation Institute in College Station, researchers are studying a freight pipeline to ease increased trucking traffic caused by the North American Free Trade Agreement.

Stephen Roop, the institute's director of rail research, said the study would determine the feasibility of a pipeline.

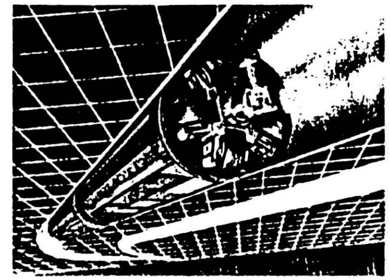
"It would be a big undertaking," said Roop, who was scheduled to present a paper at the MU conference. "That's not to say it would be any less big than adding a lane to an interstate highway.

"I realize we live in a very political world and we need to show that this would be beneficial to everyone."

To reach Oscar Avila, Missouri correspondent for The Star, call (816) 234-4902 or send e-mail to oavila@kcstar.com

Appendix 3:

International Symposium on Capsule Pipelines: Program

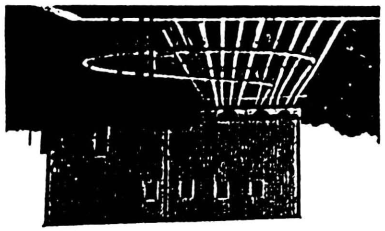


The Pneumatic Tube—A Brighter Future for Freight Transportation
(Photo Courtesy of Sumitomo Metal Industries, Ltd.)

This is Your Invitation—

Please come and explore with us how the world's freight transportation problems can be solved—Underground!

Capsule Pipeline Research Center



The University of Missouri's New Coal Log Pipeline Pilot Plant Preparing for Commercialization

You Don't Want to Miss the—

International Symposium on Underground Transportation of Freight by Capsule Pipelines and Other Tube/Tunnel Systems

September 2-4, 1999 Columbia, Missouri, U.S.A.

Short Course Also Available (Sept. 1) at the—

International Symposium on Underground Transportation of Freight by Capsule Pipelines and Other Tube/Tunnel Systems, September 2-4, 1999
To be held at the Holiday Inn East (Holidome) in Columbia, Missouri

Sponsor: Capsule Pipeline Research Center, University of Missouri-Columbia

Co-Sponsors:
American Society of Civil Engineers (Pipeline Research Committee)
Chinese Mechanical Engineering Society
Civil Engineering Research Foundation (CERF)
Delft University of Technology (OTB Research Institute for Housing, Urban and Mobility Studies)
Florida Institute of Phosphate Research
International Freight Pipeline Society

Co-Sponsors (Cont.):
Mid-America Transportation Center
Minnesota Department of Transportation
Missouri Department of Transportation
National Science Foundation (Engineering Education and Centers Division)
National Institute of Standards and Technology (Building & Fire Research Laboratory
Sumitomo Metal Industries, Ltd. Japan
Texas Transportation Institute (Texas A&M University)
U.S. Department of Energy
U.S. Department of Transportation

Purpose of Symposium:

To bring international experts, researchers, government officials and planners together to exchange information on research and planning in any type of capsule pipelines or tube/tunnel systems for underground transportation of freight in the 21st century.

Who Should Attend:

Transportation systems planners, consulting engineers, researchers, pipeline equipment suppliers, shippers of coal, minerals, grain, ag products, mail, parcels, solid wastes and factory products, and engineers of pipeline companies and construction firms. This is an opportunity for **anyone** concerned about the economic, environmental, and physical limitations of our current transportation systems. Experts from around the world will show how underground freight transportation can create a safer, more efficient way of shipping in the 21st century.

Added Bonus-September 1, 1999 One-Day Short Course on Capsule Pipelines

Continuing Education Credit will be awarded to all who attend. Dr. Henry Liu, Professor and Director of Capsule Pipeline Research Center, will teach basic concepts and design of hydraulic capsule, pneumatic capsule, and coal log pipelines. He will also cover the economics of transporting coal and grain by capsule pipelines, and compare it with transportation by train and trucks.

Program

1st Day, September 2, 1999 (Thursday)

Holiday Inn East (Ivy A Room)

AM

Registration (7:30-8:30)

Session 1: Opening Session (8:30-10:00)

1. Introduction (Henry Liu, Conference Chair)
2. Welcome (Speakers to be announced)

Keynote Speech:

"Selling the Underground Pipe Dream"
Dr. Marshall Lih, Director
Engineering Education & Centers Division
National Science Foundation, U.S.A.

Session 2: Technology Review (10:20-12:00)

Luncheon (Missouri Room) Noon

"Black Mesa Coal Slurry Pipeline—A Success Story,"
Henry Brolick, President & CEO
Williams Technologies, Inc., U.S.A.

P.M.

Session 3: Existing Projects (1:20-3:00)

Session 4: Other Projects/Analyses (3:20-5:00)

2nd Day, September 3 (Friday)

Holiday Inn East (Ivy A Room)

A.M.

Session 5: Other Projects/Analyses (8:00-9:20)

Session 6: Panel Discussion on Need for Freight Pipelines in the U.S. (9:40-10:40)

Session 7: Panel Discussion on Need for Freight Pipeline in Other Nations (11:00-12:00)

Luncheon (Missouri Room) Noon
Speaker and Topic To Be Announced

Session 8: Workshop for Planning Freight Pipelines for the 21st Century (1:20-2:20)
Session 8A: United States
Session 8B: Other Nations
Session 8C: R&D Needs

Session 9: Workshop Report (2:40-3:40)

Session 10: Tour—Capsule Pipeline Lab (4:00-5:00)

3rd Day, September 4 (Saturday)

Tour of the Lake of the Ozarks
Bus leaves at 8 a.m. and returns at 5 p .m.

To Register On-Line

http://www.ecn.missouri.edu/centers/cprc/

General Information

Location and Lodging

All sessions of the symposium will be held at the Holiday Inn East (Holidome), I-70 & Providence Road, Columbia, Missouri, U.S.A. Anyone arriving at the Columbia airport may take advantage of the Holiday Inn's free van transportation service. Simply check the van service option on the Hotel Registration Form provided in this brochure and indicate your time of arrival. The Holidome features 142 spacious rooms including suites, king and double bedded rooms. Rooms are offered with an exterior or interior entrance, and have telephones with data ports, on-command video and Nintendo, and in-room coffeemakers. A restaurant, indoor pool, whirlpool, sauna, exercise room, and game room are all made available during your stay. Ask for the special guest rate of $58 per night for participants of the CPRC International Symposium. This special rate is guaranteed until August 10, 1999. The hotel needs your credit card number and expiration date at the time of reservation. To make a reservation, call 1-800-465-4329 or use the Hotel Registration Form in this brochure. It can be mailed or copied and faxed.

Transportation to and from Columbia

Columbia, Missouri is located between two large cities—Kansas City and St. Louis. However, Columbia Airport has flights (TWA Express) to and from St. Louis, not Kansas City. So, if you fly into Kansas City, you need to rent a car or take a van (Tiger Air Express) for a 2-and-one-half hour ride to Columbia. If you fly into St. Louis, you may take the TWA Express, rent a car, or van (Tiger Air Express); the ride by car or van is 2 hours. Tiger Air Express (van) is available daily beginning at 9 a.m. from St. Louis and at 9:30 a.m. from Kansas City. The van's final departure from St. Louis is at 9:30 p.m. and from Kansas City, at 9:00 p.m. For this van, call 1-800-333-3026.

Saturday's Trip to The Lake of the Ozarks

Please check our web site at:
http://www.ecn.missouri.edu/centers/cprc/
for a complete presentation on all the attractions of this beautiful part of the United States. We have a Riverboat Cruise planned with a bus leaving Columbia at 8 a.m. and returning at 5 p.m. If you wish to stay longer, you may want to rent a car and make other travel arrangements.

More About— Capsule Pipeline Research Center

Capsule Pipeline Research Center (CPRC) is the host organization sponsoring this Symposium. CPRC has just completed 8 years of R&D in capsule pipeline technologies for transporting coal (the coal log pipeline or CLP), solid wastes, grain and many other products. This was accomplished under the sponsorship of the National Science Foundation, State of Missouri, and an industry consortium. Funding for R&D in CLP was also received from the U.S. Department of Energy and Electric Power Research Institute.

The last lap of a race for CLP commercialization revolves around a newly constructed pilot plant. This facility not only will demonstrate the capabilities of the new coal log pipeline, but will also be used in testing other types of capsule pipelines for transporting grain, solid wastes and other cargoes. Furthermore, the coal log compaction technology is being used to compact biomass solid wastes for power generation in a research project funded by the U.S. Department of Energy.

Another project, sponsored by Sumitomo Metal Industries, Ltd. and the Mid-America Transportation Center, focuses on the use of the linear induction motor (LIM) to power pneumatic capsule pipeline (PCP) systems.

Capsule Pipeline Research Center is pleased to host the Symposium and expects to gain much from the interchange of information and ideas for future underground freight transport.

Symposium Papers/Speakers

Session 1: Opening Session

Keynote: **Selling the Underground Pipeline Dream,** Dr. Marshall Lih, Director, Engineering Education & Centers Division, National Science Foundation, U.S.A.

Session 2: Technology Review

2.1 **Capsule Pipeline Technologies: Current Status and Potential Future Use,** Henry Liu, Capsule Pipeline Research Center, University of Missouri, U.S.A.

2.2 **Recent Developments in Coal Log Pipeline Technology,** J. W. Wilson, University of Missouri-Rolla, and T. R. Marrero, University of Missouri-Columbia, U.S.A.

2.3 **Electrical Capsule Pipeline System for Freight Transportation,** Y. J. Zhao and Thomas S. Lundgren, University of Minnesota, and John Sampson, Minnesota Department of Transportation, U.S.A.

2.4 **Tube Transportation,** Larry Vance, Volpe National Transportation Systems Center, U.S. Department of Transportation, U.S.A.

2.5 **Review of Past and Current Research and Use of Capsule Pipelines in Japan,** Katsuya Yanaida, Kyushu Sangyo University, and Yuji Tomita, Kyushu Institute of Technology, Japan

Session 3: Existing Projects

3.1 **Sumitomo Pneumatic Capsule Pipelines in Japan and Future Developments,** Sanai Kosugi, Pipeline & Thermal Plant Engineering Department, Sumitomo Metal Industries, Ltd., Japan

3.2 **Electromagnetic Pipeline Transport Systems for the Phosphate Industry,** D. Bruce Montgomery, Magplane Technology, Bedford, MA, U.S.A.

3.3 **Use of Linear Induction Motors for Pumping Capsules in PCP,** Henry Liu, Robert O'Connell, W. Plodpradista, and Kevin York, University of Missouri-Columbia, U.S.A., and Alan Foster, Force Engineering, United Kingdom

3.4 **Feasibility and Design Considerations of Pipelines for Freight Transport along Selected Corridors — A TEA-21 Study,** Steve Roop and Christine Jerko, Texas Transportation Institute, Texas A & M University, U.S.A.

3.5 **Underground Freight Transport in Urban Areas,** Johan Visser, Delft University of Technology, and Martin Muller, Interdepartmental Underground Transport Task Force, Government of the Netherlands

Session 4: Other Projects/Analyses

4.1 **OLS-Schiphol, a Pilot Study for Automated Underground Freight Transport in the Netherlands,** B.A. Pielage, Mechanical Engineering Department, Delft University of Technology, The Netherlands

4.2 **Potential for Pneumatic Capsule Pipeline Systems in North America,** P. Brink Weaver, Pneumatic Systems Ltd., and George F. Round, McMaster University, Canada

4.3 **Transportation of Goods through Pipelines — A Comprehensive Study,** Dietrich Stein, Robert Stein and Britta Schoessen, Ruhr-University of Bochum, Germany

4.4 **Megaships, Megaports and Landside Access Problems In the U.S. Port Industry — An Opportunity for Freight Pipelines,** Arthur P. James, Ph.D., Texas Transportation Institute, Texas A&M University, Galveston, Texas, U.S.A.

4.5 **Tubular Freight Transportaton System Risk Assessment,** C. S. "Rocky" Shih, Bill Ingersoll and Albert Arroyo, University of Texas at San Antonio, Texas, U.S.A.

Session 5: Other Projects/Analyses

5.1 **Feasibility of Underground Pipeline Transport of Freight in the City of Leiden,** A. J. van Binsbergen, Faculty of Civil Engineering and Geosciences, Transportation Section, Delft Universitiy of Technology, the Netherlands

5.2 **Benefits and Capabilities of Medium to Long Distance Tube Transportation Systems,** Steve Catha and Carl Peterson, Cross Roads Technology, New Orleans, Louisiana, U.S.A.

5.3 **Appropriate Cost Estimates for Capsule Pipeline Installation,** Richard Mueller, CEO, TubeFreight, LLC, Dallas, Texas, U.S.A.

5.4 **Analysis of Pneumatic Capsule Pipeline Systems with Branches,** Yuji Tomita, Kyushu Institute of Technology, Japan

Luncheon Speakers

September 2: *(See program)*

September 3: *(See program)*

Dinner Speaker

September 2: *(See program)*

A One-Day Short Course on Capsule Pipelines

Holiday Inn East (Holidome)—ECR Room
Columbia, Missouri—September 1, 1999

a.m.	Subject
8:00 - 8:50	Basic Concepts & Design of HCP
8:50 - 9:00	Break
9:00 - 9:50	Hydrodynamics of HCP
9:50 - 10:00	Break
10:00 - 10:50	Coal Log Pipeline (CLP) Technology
10:50 - 11:00	Break
11:00 - 11:50	Economics of Transporting Coal and Grain by Capsule Pipeline
12:00 - 1:00	Luncheon
p.m.	
1:00 - 1:50	Basic Concepts and Design of PCP
1:50 - 2:00	Break
2:00 - 2:50	Fluid Mechanics of PCP (Part 1: Short Pipelines-Incompressible)
2:50 - 3:00	Break
3:00 - 3:50	Fluid Mechanics of PCP (Part 2: Long Pipelines-Compressible)
3:50 - 4:00	Break
4:00 - 4:50	Questions, Answers and Discussion
4:50	End of Short Course

(Note: A set of Lecture Notes will be provided.)

The Purpose:
This short course in capsule pipelines is for anyone interested in learning the basics and details of capsule pipelines, including HCP, PCP and CLP (Coal Log Pipeline).

Registration Fee:
$200 (U.S. currency)—Includes morning pastries at 7:30, beverages throughout the day, and a luncheon. Please use registration form in this brochure to mail or FAX registration—or—Register online: http://www.ecn.missouri.edu/centers/cprc/

Short Course Instructor & Symposium Chair

Henry Liu is Professor of Civil Engineering and Director of Capsule Pipeline Research Center, College of Engineering, University of Missouri-Columbia (MU). Liu is an expert in hydraulics, fluid mechanics, and pipeline engineering. He has received both national and international awards for his contributions to the field of capsule pipelines.

A Personal Note from Dr. Henry Liu . . .

This Symposium will show that underground freight transportation by capsule pipelines and other similar underground tube freight technologies can provide positive solutions to the world's transportation dilemma. These technologies are expected to play a major role in freight transportation in the 21st century, resulting in greater prosperity, improved transportation safety, and reduction in air and noise pollution on highways and streets.

The media and the general public have been captivated by advancements in capsule pipeline technology. At the University of Missouri's Capsule Pipeline Research Center in Columbia, we have received hundreds of inquiries from reporters, the general public and industry, wanting to know when the coal log pipeline, and other types of capsule pipelines will be ready for commercial use. With government, scientific community and industry working together, we can achieve our goals in the very near future. That is why it is imperative to bring transportation planners, shippers, researchers and policy makers together at this symposium to assess the state-of-the-technology and plan future programs on capsule pipelines for the 21st century.

Hotel Registration Form

HOLIDAY INN COLUMBIA-EAST (HOLIDOME)

Name _____

Organization or Company represented:

_____

Mailing Address: _____

_____

Phone: _____ FAX: _____

E-Mail Address: _____

Date of Arrival: _____

Date of Departure: _____

Please check your choice of the following:

- ☐ Double Beds—Non Smoking
- ☐ Double Beds—Smoking
- ☐ King-Size Bed—Non Smoking
- ☐ King Size Bed—Smoking
- ☐ Roll-Away Bed ($8.00 Extra)
- ☐ Van Service From Airport—Please provide time of arrival of your flight:

_____

- ☐ Special Dietary Needs (If Any): _____

_____

_____

If you wish to pay **the pre-approved special rate of $58,** please complete the following and FAX or mail to the address below by August 10:

Credit Card # _____

Name of Credit Card Co.: _____

Expiration Date: _____

Card Holder Signature: _____

If you wish to pay by check, draft or money order, please mail with this form by August 10 to:

HOLIDAY INN COLUMBIA-EAST
1612 N. PROVIDENCE RD., COLUMBIA, MO 65202
PHONE: 573-449-2491; FAX: 573-874-6720
TOLL FREE PHONE: 1-800-HOLIDAY

SYMPOSIUM/SHORT COURSE REGISTRATION FORM

INTERNATIONAL SYMPOSIUM ON UNDERGROUND TRANSPORTATION OF FREIGHT BY CAPSULE PIPELINES AND OTHER TUBE/TUNNEL SYSTEMS
Columbia, Missouri, U.S.A.
SEPTEMBER 2-4, 1999

Name: _____

Organization or Company: _____

Mailing Address: _____

_____

_____

Phone: _____ FAX: _____

E-Mail Address: _____

Events I plan to attend:

- ☐ The Symposium, Sept. 2-3—$300
- ☐ Post Symposium Tour, Sept. 4—$50
- ☐ Spouse Program $50
- ☐ One Day Short Course, Sept. 1—$200

(Note: Fees Quoted are in U.S. dollars for registration received before August 10, 1999. A 10% increase in fees will be assessed to late registration after August 10.)

If you wish to pay by Credit Card, please complete the following:

I am paying a total of $ _____ for the events checked above, using my:

Name of Credit Card Co.: _____

Credit Card #: _____

Expiration Date: _____

Card Holder Signature: _____

If you wish to pay by check, draft, or money order, please make it payable to **"University of Missouri."**

Mail or Fax all payments to Diana Wyatt, MU Conference Office, 348 Hearnes Center, Columbia, MO 65211. Phone: (573) 882-4349; FAX: (573) 882-1953.

For Office Use Only: 2313 55/62 Core Mail ID_____ Receipt #_____

Appendix 4:

University New Initiatives for Commercializing CLP Technology

Announcement on a University New Policy on Patent-Royalty Sharing and Fund-Raising for Coal Log Pipeline Project

1. **Purpose:** The Capsule Pipeline Research Center (CPRC) needs money for two more years to test the coal log pipeline (CLP) pilot plant currently under construction. Upon successful completion of the two-year tests, the CLP technology can then be used in the first commercial project—the demonstration (demo) project. University of Missouri is providing patent incentives to companies willing to invest in the further development of the CLP technology through the pilot plant test, and to companies wanting to demonstrate the first commercial project.

2. **Money Needed for Pilot Plant Tests in Two Years:**
   Direct Cost for Completing Pilot Plant Test: $1,000,000
   Indirect Cost (46% of Direct Cost): $460,000
   Patent Application/Maintenance Fees
   (including both U.S. and foreign patents) $40,000
   Total: $1.5 Million

3. **Patent Benefit for Contribution to Pilot Plant Project:** Companies contributing to the $1.5 million for the pilot plant test together will share 50% of future royalty received by University of Missouri from licensing the coal log pipeline technology to users. The sharing will be prorated. For instance, if a company contributes or invests $150,000, it will get 10% of the 50% of the industry share of the royalty.

4. **Maximum and Minimum Offers and Selection of Offerers:** The total allowable investment under this plan is $1.5 million, to be divided in ten equal shares of $150,000 each. The maximum offer that can be accepted from any company or individual is ten shares; the minimum is one share. Selection of offerers is on a first-come basis. After all ten shares have been bought by investors, no more offers will be accepted.

5. **Letter of Intent:** Offers should be made in a letter of intent addressed to Henry Liu, CPRC Director. The letter of intent should specify the amount of investment that the company is willing to make. All those who indicated an intent to invest a minimum of $150,000 (one share) will receive a draft Agreement, specifying detailed conditions of the deal. Companies that have expressed an interest through the letter of intent will be allowed to comment on the draft Agreement. The University will consider all the received comments, if any, and issue a final Agreement for signature by all those interested within 30 days. Then the companies will have another 30 days to sign the Agreement. So, a total of two months are needed to complete the Agreement.

6. **Commercial Demo Project:** Any company that wishes to construct the first commercial coal log pipeline (CLP) for use in the future is guaranteed by the University of Missouri that the Company will not need to pay the University more than 5 cents per ton of coal transported through the pipeline, throughout the life of

that particular pipeline. This is compared to the 50 cents (approx.) per ton of coal transported that must be paid for non-sponsors in future commercial projects. For existing CLP Consortium members, the rate is between 1¢ and 15¢, depending on financial contribution made to CPRC as specified in original Agreements. Note that this offer on commercial demo project is independent of the offer on the $1.5 million investment for pilot plant tests. Companies investing in the pilot plant project may or may not have a suitable demo project.

7. **Use of the Money Raised:** Other than the $460,000 indirect cost and the $40,000 for patent applications/maintenance, the remaining $1,000,000 will be used for carrying out an R&D program using the CLP pilot plant, a program aimed at readying the CLP technology for commercial use.

8. **Pilot Plant Research, Development and Demonstration Program (2-Years):**

   1) Test the abrasion resistance of coal logs manufactured by different processes, using both bituminous and subbitumious coals.
   2) Test the performance of the pump bypass in pumping coal log trains. Test different valve stroking strategies.
   3) Test the performance of capsule injection/ejection system.
   4) Test the adequacy of the instrumentation system (pressure transducers, flow meters, coal log sensors, PLC, and SCADA) for use in CLP.
   5) Test the degradation rate of using Polyox for drag reduction in the pipe with coal logs. Also test the new Polyox injection method (vacuum injection method) invented by CPRC.
   6) Demonstrate the whole pilot plant system to potential users and investors.
   7) Update the economic model and the manual of practice based on the results of the pilot plant test.
   8) Prepare a final report documenting the pilot plant test results.
   9) Apply for at least one foreign patent (in China) and one or more U.S. patents.

Appendix 5:

Center Publication List

CAPSULE PIPELINE RESEARCH CENTER (CPRC)
University of Missouri-Columbia
Publications List
(1991-1998)

A. Theses/Dissertations and Student Papers:

Bahr, M., Rapid Compaction of Bituminous Coal Logs, M.S. Thesis, Department of Chemical Engineering, May 1996, 126 pages, (Adviser: Richard Luecke).

Bennett, J., EPRI Water Absorption Tests, B.S. Chemical Engineering, University of Missouri-Columbia, July 1992, 12 pages, (Adviser: Thomas R. Marrero).

Berg, D.M., Hot Extrusion of Coal Logs, M.S. Thesis, Department of Chemical Engineering, University of Missouri-Columbia, August 1993, 187 pages, (Adviser: Thomas R. Marrero).

Carney, D., Water Impervious Coatings for Coal Logs, M.S. Thesis, Department of Chemical Engineering, December 1996, 106 pages, (Adviser: Richard Luecke).

Chen, F., Advances in Coal Log Fabrication for Coal Log Pipelines, M.S. Thesis, Department of Civil Engineering, University of Missouri-Columbia, May 1995, 106 pages, (Adviser: Brett W. Gunnink).

Chen, S.H., Effects of Particle Size, Binder Concentration and Compaction Pressure on Selected Properties of Coal Logs, M.S. Thesis, Department of Chemical Engineering, University of Missouri-Columbia, August 1993, 102 pages, (Adviser: Thomas R. Marrero).

Cheng, C.C. Wear and Damage of Coal Logs in Pipeline, Ph.D. Dissertation, Department of Civil Engineering, University of Missouri-Columbia, December 1994, 347 pages, (Adviser: Henry Liu).

Chiao, Victor Kuo-Ping, Internal Corrosion Control of Steel Pipeline For Transporting Coal Logs, M.S. Thesis, Department of Civil Engineering, University of Missouri-Columbia, July, 1991, 78 pages, (Adviser: Dr. Shankha K. Banerji)

Deng, Q., Analysis of Coal Log Extrusion, M.S. Thesis, Department of Civil Engineering, University of Missouri-Columbia, December 1995, 184 pages, (Adviser: Henry Liu).

Ding, Y., Characterization of Pyrite Surface and Evaluation of Effect of Absorbed Depressants on Pyrite Floatation Ph.D. Dissertation, Department of Mining Engineering, University of Missouri-Rolla, May 1992, 180 pages, (Adviser: John Wilson).

Du, H., Issues Related to Reliable Operation of Pump Bypass System for Capsule Pipeline,, Ph.D. Report, Department of Mechanical Engineering, University of Missouri-Columbia, August 1996, 219 pages, (Adviser: Satish Nair).

El-Bayya, Majed, Unsteady Flow of Capsules in a Hydraulic Pipeline: Theory and Experiment, Ph.D. Dissertation, Department of Civil Engineering, University of Missouri-Columbia, May 1994, 189 pages, (Adviser: Charles W. Lenau).

El-Bayya, Majed, Transient Flow in Hydraulic Capsule Pipeline, M.S. Thesis, Department of Civil Engineering, University of Missouri, May, 1991, 113 pages, (Adviser Charles W. Lenau).

Gao, Xiang, Hydrodynamics of HCP with Slopes and Bends, Ph.D. Dissertation, Department of Civil Engineering, University of Missouri-Columbia, December 1999, 249 pages

Garber, L., Water Quality Effects of Drag Reduction Polymers, M.S. Thesis, Department of Civil Engineering, University of Missouri-Columbia, May 1995, (Adviser: Shanka Banerji).

Hjelmfelt, A., Water Quality and Treatment of Coal Log Pipeline Effluent, M.S. Thesis, Department of Civil Engineering, University of Missouri-Columbia, May 1995, (Adviser: Shanka Banerji).

Huang, X., Polymer Drag Reduction in Hydraulic Capsule Pipeline (HCP), M.S. Thesis Department of Civil Engineering, University of Missouri-Columbia, August 1994, 137 pages, (Adviser: H. Liu).

Ji, G., Research and Design of Coal Log Fabrication Machine, M.S. Thesis, Department of Mechanical & Aerospace Engineering, University of Missouri-Columbia, May 1995, 142 pages, (Adviser: Yuyi Lin).

Kananur, J.J., Compaction of High Strength Binderless Coal Logs for Pipeline Transportation, M.S. Thesis, Department of Civil Engineering, University of Missouri-Columbia, May 1994, 106 pages, (Adviser: Brett W. Gunnink).

Kuhlman, G.S., Polymer Slurry Drag Reduction in Hydraulic Capsule Pipeline, M.S. Thesis, Department of Chemical Engineering, May 1999, 180 pages, (Adviser: Thomas R. Marrero).

*Student

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*Student

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*Student

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*Student

D. Patents and Invention Disclosure:

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*Student
**Visiting Scholar

Appendix 6:

No-Cost Extension and Supplemental Funding Requests to NSF

Capsule Pipeline Research Center
University of Missouri-Columbia
College of Engineering

E2421 Engineering Building East
Columbia, MO 65211-2200

PHONE (573) 882-1810
FAX (573) 884-4888
E-MAIL liuh@missouri.edu
OR marrerot@missouri.edu

June 22, 1999

Dr. Joy Pauschke
Program Director
Engineering Education and Center Division
National Science Foundation
4201 Wilson Blvd., Rm. 585
Arlington, VA 22230

Dear Joy:

The purpose of this letter is to request for a no-cost extension of the current (amended) NSF Cooperative Agreement ECD 9108841, Capsule Pipeline Research Center. If possible, we request that the extension be granted for two years for the following purposes:

1. To complete the coal log pipeline (CLP) pilot plant study which will take two years. The pilot plant is being built using industry donated equipment and labor, and using some funds from the State and the University. Support of the pilot plant study for the next two years is expected to come from industry. Since the pilot plant study is the final step of R&D in coal log pipeline, and since coal log pipeline has been the main focus of CPRC under NSF sponsorship, it makes sense to extend the NSF Agreement for two years to complete what we set out to do eight years ago when the Center was first funded by NSF.
2. To allow three Ph.D. and two M.S. students to complete their research currently funded by CPRC. By granting a no-cost extension, NSF will get credit for helping to complete their work in the next two years. I will use the remaining funds to support them to complete their work.
3. Spend the unspent amount of funds, estimated at $60,000 approximately, for supporting students who have started their work but have not yet completed it. See attachment for the latest account projection.

Through a copy of this letter, I am asking our Sponsored Programs Administration to send you the necessary papers and signatures for extending the Cooperative Agreement.

Sincerely yours,

Henry

Henry Liu, Director
Capsule Pipeline Research Center

cc: Dr. Win Aung, NSF
Mr. Mike Warnock, SPA
Mrs. Susan Jones, Engineering Fiscal Office
Mr. Pete Dohm, Engineering Fiscal Office

ACCOUNT SUMMARY

Period Covered 9/1/98-8/31/99

Dr. Liu & Marrero
Account Name: NSF Center Account #: C-5-34044 22-Jun-99

Allocation: 9/1/98-8/31/99	250000.00	Prepared by: Pete Dohm
Balance Forward + Committments: 9/1/98	71504.59	Based on 5/31/99 FBMO
Total Projected Expenditures	257359.80	
Projected Balance Available 6/22/99	64144.79	

CLASS	DESCRIPTION	Budget	Expenditures to Date 9/1/98-8/31/99	Committed Items	Total Projected Expenditures	Balance Available
2100	DR. LIU	25404.00	0.00	12460.66	12460.66	12943.34
2101	DR. MARRERO	17232.00	0.00	17168.88	17168.88	63.12
2102	DR. Lenau	7146.00	0.00	14023.00	14023.00	-6877.00
2103	DR. Gunnink	0.00	0.00	7251.00	7251.00	-7251.00
2104	Dr. Y. Lin	6663.00	0.00	6599.50	6599.50	63.50
2105		0.00	0.00	0.00	0.00	0.00
2106	Terry Maynard	0.00	13585.00	13551.00	27136.00	-27136.00
2170	RES. ASSISTANTS	60936.00	23084.33	23839.72	46924.05	14011.95
2200	PROFESSIONAL - Post Doc.	20000.00	0.00	5000.01	5000.01	14999.99
2300	TECHNICAL	25000.00	1666.68	1188.52	2855.20	22144.80
2400	SECRETARIAL	9500.00	15079.24	4545.60	19624.84	-10124.84
2710	STUDENT HOURLY	7500.00	489.00	6000.00	6489.00	1011.00
2800	STAFF BENEFITS	32611.00	8033.86	19181.72	27215.58	5395.42
2915	TUITION	15120.00	4670.95	0.00	4670.95	10449.05
3100	TRAVEL	8000.00	5616.62	4395.09	10011.71	-2011.71
3600	POSTAGE & BASIC PHONE	0.00	1737.81	525.20	2263.01	-2263.01
3800	WATS	0.00	308.61	500.00	808.61	-808.61
4400	RENT/LEASE	0.00	43.50	0.00	43.50	-43.50
4800	COPY SERVICE & Publications	5888.00	922.25	604.75	1527.00	4361.00
5100	SUPPLIES	5000.00	11624.50	1801.74	13426.24	-8426.24
5500	CONSULTING	4000.00	0.00	2000.00	2000.00	2000.00
6400	Center Evaluation ***	0.00	0.00	4000.00	4000.00	-4000.00
7000	OTHER/MISC & Rolla	0.00	2137.37	15750.00	17887.37	-17887.37
7700	EQUIPMENT	0.00	1990.00	0.00	1990.00	-1990.00
9600	Patent Application		983.69	5000.00	5983.69	-5983.69
	Balance Forward 9/1/8	71504.59				71504.59
	TOTAL DIRECT	321504.59	91973.41	$165,386.39	257359.80	64144.79

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College of Engineering

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July 20, 1999

Dr. Win Aung
Program Coordinator
State/IUCRC
Engineering Education and Center Division
National Science Foundation
4201 Wilson Blvd.
Arlington, VA 22230

Dear Dr. Aung:

I am applying for a Supplemental Request under current Cooperative Agreement No. ECD-9108841. The request is for $53,729 as shown in the attached budget. The work proposed is for performing research (both theoretical analysis and laboratory experiments) on a new type of pipeline sensor invented recently by our Center. This new sensor can detect not only coal logs but also other types of capsules and pipeline "pigs"--scrappers. It is an innovative new concept that may be used in the future not only for coal-log and capsule pipelines, but also for ordinary liquid or gas pipelines.

However, before the concept can be used in practice, it must be studied thoroughly including developing a theoretical framework to predict the sensor behavior under various conditions. Experiments also are needed to verify the theoretical predictive model and determine the model parameters before the sensor can be used. Furthermore, the sensor must be tested not only for coal logs and capsules, but also for "pigs" (scrapers) used in commercial pipelines.

The research is of great interest to our Center which must have a simple reliable sensor to detect the coal logs and capsules in pipelines at various places such as near valves, pumps and so on. It is also of interest to companies that manufacture and supply measuring equipment and sensors for pipeline companies. We have contacted the TDW Pigging Products Company in Tulsa, Oklahoma, and the company is interested in collaborating with us in this research.

As shown in the enclosed proposal, I have proposed both theoretical and experimental programs for studying this kind of sensor. While the theoretical work will be conducted at our university, the laboratory tests will be conducted both at our Center and at TDW. The experiments at our Center will use the newly-built coal log pipeline

pilot plant--a 3,000-ft-long pipeline test facility. The experiments at TDW will use pigs and will be conducted in Tulsa using TDW's pig testing facilities.

The proposed work will not only benefit our coal log and capsule pipeline research, it also has the potential of development into a sensor for pig detection in all types of pipelines for transporting water, crude oil, petroleum products, natural gas, slurry, capsules and coal logs. With the success of this project, TDW Pigging will further develop the sensor to the point that it can become a standard commercial product for pig detection far superior to current systems.

I hope that you will be able to approve this Supplemental Request so that this very worthwhile research can be pursued. Thanks!

Sincerely yours,

Henry Liu

Henry Liu, Director
Capsule Pipeline Research Center

FOR THE CURATORS OF THE UNIVERSITY
OF MISSOURI

Joyce M. Pfaff 7/26/99

Joyce M. Pfaff — Date
Interim Associate Director
Office of Sponsored Program Administration

University Proposal No. EG-0010098-1