Pipeline Engineering Research and Education at Universities in the United States

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Abstract—*A national survey on pipeline engineering research and education at engineering and mining colleges of U.S. universities was conducted in 1996-97. It was found that only 12 schools offer pipeline related undergraduate courses, and 15 offer pipeline-related graduate courses. Only one university offers Pipeline Engineering or any other similar introductory course exclusively on pipelines. A strong need exists to have more of such courses offered at universities so that civil, chemical, mechanical, mining and other engineers who use pipelines to transport liquids, gases and solids will be better prepared to plan, design, construct and operate various types of pipelines in the future upon graduation from universities.*

While pipeline-related research covers a wide spectrum of subjects, only 25 schools reported to have pipeline-related research projects in the last five years. Only two existing research centers are focused on pipeline technologies: the Capsule Pipeline Research Center (CPRC) at the University of Missouri-Columbia, and the Trenchless Technology Center at Louisiana Tech University. A need exists to expand pipeline research at universities not only to generate new knowledge but also to provide opportunities for graduate training.

This paper will also discuss the experience learned in teaching ***"Pipeline Engineering"*** *at the University of Missouri-Columbia. The course has been taught by the first author for fourteen years, and much experience has been gained from this teaching involvement. During the past two years (1997-98), this course was taught using telecommunication equipment. Both ITV (Instructional Television) and ISDN (Integrated Services Digital Network) were used. This paper will also compare the two delivery systems with each other and with traditional classroom teaching.*

Justification of Survey

In the United States and throughout the world, pipelines are used extensively to transport many commodities: water, waste water, sewage, gas, petroleum products, chemicals, and many other products including solids. Recent (1995) statistics indicate that the total operating revenues of the oil- and gas-pipeline industries in the United States are $17 billion. These industries employ 200,000 people. Through more than one million miles of pipelines, 2 billion tons of oil and gas are transported each year in the United States [1].[*] The importance of pipelines for transporting water and sewage even surpasses that of oil and natural gas pipelines. The total amount of liquid and gas (including oil, natural gas, water, sewage and many other fluids and solids) transported by pipelines in the United States is estimated to be 2.7 trillion ton-miles. This is more than the freight transported by truck (0.9 trillion ton-miles) and railroad (1.2 trillion ton-miles) combined. Pipeline is also by far the safest mode of freight transportation, and is highly reliable and energy efficient. Since pipeline is critically important to any modern nation for the conveyance of critically needed materials such as water and oil, and since many industries use pipelines, it is legitimate to ask how are colleges and universities preparing today's and tomorrow's engineers and managers dealing with pipelines. Is there a course or option in pipeline engineering? What research is being conducted at universities to improve pipeline performance and to develop new pipeline technologies? This survey was conducted to answer these questions.

The Survey

The survey was conducted in November 1996 through December 1997 [2]. A survey form (questionnaire) was drawn up and sent to 225 deans of the engineering and mining colleges or schools in the United States. The cover letter asks the recipient—the Dean—to pass on the survey form to those faculty members in his (her) college who have pipeline-related research projects or educational activities. The survey form was intentionally made brief (a single page), in order to encourage responses. The form simply asks the respondent to list the research projects, courses (both graduate and undergraduate) and other activities related to pipeline by his (her) group or institution within the last five years. The respondents were requested to list only those research and educational activities <u>directly</u>

[*] Numerals in [ ] represent corresponding items in REFERENCES.

related to pipeline. They were told specifically <u>not</u> to list general courses in fluid mechanics, even though such courses usually cover pipe flow, pumps, flowmeters, etc. which are closely related to pipeline. It is the intent of this survey to determine from what courses other than general fluid mechanics do students learn about pipelines.

Of the 225 schools contacted, only 35 returned the form. They are presumed to be mostly from schools that have pipeline-related activities. Twenty-seven (27) of the 35 returns listed either pipeline-related courses or research projects, or both. The remaining 8 schools reported none of such activities. The survey result is based on the data provided by the 27 schools in the U.S. that have pipeline-related activities. They are listed in Table 1.

Survey Results

(a) Education

General courses in fluid mechanics in which pipe flow is covered are not counted as pipeline courses in this survey because they are generally known to exist at every engineering school. To list fluid mechanics will yield nothing new.

Thirteen schools reported that they had both courses and research in pipeline engineering related topics in the last five years. The universities that offered courses related to pipeline engineering are presented in Table 2. At 12 universities, a total of 17 undergraduate courses were offered. Of all these undergraduate courses, only one course has a title that includes the word "pipe" or "pipeline." As to graduate courses, a total of 27 were taught at 15 schools. Three of these graduate courses have the word "pipe" or "pipeline" in their title; one has the term "closed conduits" which is the same as pipe. None of the schools reported any ***department, major***, ***minor, option*** or ***area*** in pipeline engineering.

(b) Research

The pipeline research topics at universities are quite varied—see Table 3. In addition to the 14 schools that had both research and courses, 9 schools had only research, but no pipeline engineering courses. The total number of studies (research projects) reported in the survey for the 5-year period preceding the survey is 58 at 25 universities. The number of projects listed (58) is somewhat an underestimate because some large projects (such as those at research centers) actually have several sub-projects under each having separate principal investigators and separate objectives. A majority of the reported studies are in the area of fluid dynamics. Sponsors of pipeline research are primarily federal agencies, most often the National Science Foundation (NSF). A number of projects were funded by industries and trade organizations such as Gas Research Institute (GRI) and American Water Works Association (AWWA).

Interpretation of Survey Results

As a result of this survey, the following interpretations are made:

1. The fact that only 35 of the 225 universities that have been contacted actually filled out and returned the survey form is an indication of the low level of pipeline-related research and educational activities at most universities, including many major universities in the United States. It is possible that some Deans who had received the survey form did not pass on the form to the proper individuals in his (her) college for response. However, if pipeline research and education at those schools were known to the Dean, most deans would have done their jobs and forwarded the form to the proper individuals for response. It is likely that most schools did not respond because they have little to report in pipeline-related activities. Some omissions are certainly inevitable.
2. Twenty-seven (27) universities have reported pipeline-related activities—either research or courses or both. Even if half of the schools with pipeline activities were omitted and did not respond, this would still be a rather low number. Considering the importance of pipelines to the nation and to many industries, it is clear that most universities are not paying due attention to providing students with adequate training in pipelines. Two reasons may explain for this inadequacy: (a) not knowing the need, and (b) lack of research funding opportunities. Many universities and faculty members do not pursue any field with limited funding opportunities. They seem to forget that such opportunities can be created if more attention is given to pipeline by more universities. Recently, the American Society of Civil Engineers has published a list of needed pipeline research topics [3].
3. Of all the pipeline-related undergraduate courses reported, only one has the word "pipe," or "pipeline" or "closed-conduits" in its title. It is clear that most of the courses listed are not solely on pipelines and hence do not serve as an introductory course in pipelines, even though they do address important aspects of pipelines. Given the importance of pipelines to many industries including petroleum, natural gas, water, sewer, public works, electric utilities, chemical, mining, etc., and given the fact that many students upon graduation work for these industries, it is not difficult to justify for an introductory course in pipeline

engineering, to be taken by students who have taken fluid mechanics. Such a course is highly desirable for students in civil, chemical, environmental, mechanical, nuclear, petroleum, mining and agricultural engineering.

4. Graduate students in certain disciplines should also be exposed to the introductory pipeline engineering course if they never had it during their undergraduate years. The fact that only 15 universities reported graduate courses in pipeline-related areas is also of concern. All major universities with graduate programs in engineering should have some graduate courses related to pipelines. Again, this is justified by the wide-spread application of pipelines in many industries.

In conclusion, it can be said that inadequate attention is being given to pipeline engineering at universities in the United States. The essential absence of pipeline engineering courses means that the training of pipeline engineers is done by industry on-the-job. This has been confirmed through discussion with industry representatives. This practice, though apparently effective in maintaining continuity and the status quo, it is ineffective in bringing new ideas and developing new types of pipelines and technologies for transporting materials and goods. To continue sending university graduates into the marketplace with little pipeline training does not serve the best interest of the society, the students, and many industries that use pipelines extensively.

Recommendations

On the basis of this pipeline engineering survey, the following recommendations are made:

(1) Promote more pipeline engineering courses in engineering; have at least one introductory course on pipeline engineering for civil, environmental, mechanical, chemical, nuclear, agricultural, petroleum and mining engineering undergraduate students, either as an elective or required.

(2) Schools with strong research programs in pipeline should not only offer pipeline-related courses, but also allow students to choose pipeline engineering as a "minor," "option," or "area" under civil, mechanical and chemical engineering departments. This will enhance the employment opportunities for students enrolled in such programs.

(3) Provide more federal programs for supporting graduate students and research in pipeline engineering. Pipeline engineering is a critically needed area with insufficient number of highly-trained engineers to enter the workplace each year.

(4) Related industries should do more to support universities in pipeline education and research.

Pipeline Engineering: An Introductory Course

To be discussed next is an introductory course in pipeline engineering taught at the University of Missouri-Columbia (UMC), by the first author of this paper. It is discussed herein with the hope that other universities will develop a similar course to serve their students.

(a) Course Description

The course at UMC is CE/MAE 345 PIPELINE ENGINEERING. It is a 3-credit course serving as an elective for students in engineering. The course is co-sponsored by CE (Civil Engineering Department) and MAE (Mechanical & Aerospace Engineering Department). It is taken normally by seniors and graduate students in CE, MAE and some other departments. The purpose of the course is to provide a broad coverage in pipeline engineering so that the students will have a good background in pipelines for a variety of applications. The prerequisites of the course is CE/MAE 251 Fluid Mechanics.

(b) Contents

The course is divided into two parts. Part 1 is Pipe Flows, and Part 2 is Pipeline Technology. The part on Pipe Flows covers six chapters:

(1) Incompressible pipe flow—steady and unsteady, single pipe and pipe network.

(2) Compressible pipe flow—constant temperature, adiabatic, with friction and frictionless, for both ideal gas and real gas.

(3) Non-Newtonian Fluids—power-law fluids, Bingham plastic fluid, yield stress, laminar-turbulent transition, pressure drops, etc.

(4) Hydraulic transport of solids—pseudo-homogenous, heterogeneous, moving-bed and stationary-bed regimes, limit-deposit velocity, etc.

(5) Pneumatic Conveying—positive and negative pressure systems, dilute and dense phase transport, pressure gradient, electrokinetic effect on safety, etc.

(6) Capsule Transport—hydraulic capsule pipeline, pneumatic capsule pipeline, coal log pipeline, etc.

Part 2, Pipeline Technology, covers the following topics (chapters):

(1) Pipe Materials, Valves and Other Fittings—Comparison of various pipe materials including steel, other metals, plastic (especially PVC and PE), concrete (both low and high pressure types), clay, corrugated, etc.; nominal pipe size, schedule and strength; types of valves and pressure regulators, etc.
(2) Pipeline Planning and Construction—route selection and ditching, microtunneling, directional drilling, river crossing, pipe bending, welding, flanges, etc.
(3) Pipeline Protection and Safety—coating, lining, insulation, corrosion, cathodic protection, soil resistivity, pipe-to-ground potential, third-party damage, pipeline leak detection, integrity monitoring, pigging, etc.
(4) Design Considerations—internal load (hoop tension), external load (buckling), soil pressure on buried pipe, thermal stresses, etc.

(c) Textbook

There is no suitable textbook at present for this introductory course. However, through fourteen years of teaching this course, the writer has developed a rather detailed set of notes, homework problems, and exam problems. The notes and homework problems are printed and given to the students before they are discussed in the class. Eventually, the notes will be expanded into a textbook for publication by a commercial publisher. Prior to publication, arrangements can be made to use the notes for teaching at other universities. Those interested in doing that should contact the first author.

(d) Course Evaluation

Student response to the course, judged from student evaluation conducted near the end of each semester, appears favorable. Students seem to feel the course to be highly relevant.

(e) Distance Learning

Since 1997, the course was taught simultaneously to students both in Columbia, Missouri and Kansas City, Missouri, via telecommunications. Two different systems of telecommunications were used for delivery of the lectures: ITV (Instructional Television) System, and the ISDN (Integrated Services Digital Network). This created an opportunity to compare the two systems.

The best part of the ISDN system, from the student/instructor standpoint, is the electronic chalkboard. It allows the instructor to write or mark on the board with colors, and draw perfect circles and straight lines. Erasing a whole page can be done instantly by the touch of a button. However, the image is transmitted by Internet whose access is not guaranteed at all times. Therefore, two backup systems are used in the event the board is not functional. Furthermore, lecture notes and view graphs must be entered into a computer prior to the class by a technician. This requires early preparation of class materials, and is more demanding on the instructor's time than when he (she) uses the ITV system. Also, the resolution of the electronic chalk board is marginal, and there is a one-second delay (approx.) for writings to appear on the board. These two problems can be solved by using better equipment or a faster computer. An advantage of the ISDN System is that the equipment is portable. It can be rolled into and used in any room that has electrical and phone outlets.

The ITV system is less flexible but more reliable and easy to use. Instructors must sit or stand in a fixed place and write on a paper placed under an overhead camera. Equipment is attached to the room (permanently mounted) and hence not portable.

Both systems enable distance learning to take place with students and instructors being able to see each other and talk to each other via a TV set. Both systems should not be used unless distance learning is involved. Without distance learning, traditional teaching with an overhead projector is more convenient and just as effective.

(f) Conclusion

An introductory course, Pipeline Engineering, has been tried out successfully in the last 14 years at the University of Missouri-Columbia. It is recommended for students in engineering, especially civil, chemical and mechanical engineering, both undergraduates (seniors) and beginning graduate students. The course provides a sound background in pipeline engineering to students, and prepares the students for success in employment with many industries that use pipelines extensively, not just the pipeline industry. More universities need to seriously consider offering such a course to benefit their students. The course can be taught either in the traditional class-room lecture manner, or with ITV or ISDN for distance learning.

References

1) Gross, M. and Feldman, R.N., 1997, "National Transportation Statistics 1997," U.S. Department of Transportation/Bureau of Transportation Statistics, DOT-VNTSC-BTS-96-4, pp. 244-246.

2) Liu, H., Letter dated November 22, 1996, "National Survey on Pipeline Research and Education at Universities.
3) Pipeline Research Needs, American Society of Civil Engineers, Reston, Virginia, 1997, 153 pages.

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TABLE 1. NAMES OF U.S. UNIVERSITIES THAT OFFER COURSES AND/OR CONDUCT RESEARCH RELATED TO PIPELINE ENGINEERING.*

UNIVERSITY OF ALABAMA-BIRMINGHAM	NEW JERSEY INSTITUTE OF TECHNOLOGY
COLORADO SCHOOL OF MINES	NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY
COLORADO STATE UNIVERSITY	OAKLAND UNIVERSITY
UNIVERSITY OF FLORIDA	UNIVERSITY OF OKLAHOMA
GEORGIA INSTITUTE OF TECHNOLOGY	PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY OF IDAHO	UNIVERSITY OF PITTSBURGH
UNIVERSITY OF KENTUCKY	RENSSELAER POLYTECHNIC INSTITUTE
LOUISIANA TECH UNIVERSITY	TEXAS A&M UNIVERSITY
MARQUETTE UNIVERSITY	TULANE UNIVERSITY
UNIVERSITY OF MICHIGAN	UNIVERSITY OF TULSA
UNIVERSITY OF MINNESOTA	UNIVERSITY OF WASHINGTON
UNIVERSITY OF MISSOURI-COLUMBIA	WAYNE STATE UNIVERSITY
UNIVERSITY OF MISSOURI-ROLLA	UNIVERSITY OF WYOMING
MONTANA STATE UNIVERSITY	

* Respondents to survey (Liu, 1996).

Table 2. Undergraduate and Graduate Pipeline Courses at U.S. Universities (1991-96).

Course	Cr.	School	Instructor	Dept.
UNDERGRADUATE				
Hydraulic Engineering	3	Colorado State University	Skinner	CE
Hydraulics	3	University of Idaho	Liou	CE
Applied Stress Analysis	3	Marquette University	Widera	ME/IE
Hydraulics	3	University of Michigan	Wright	CE
Hydraulic Design	3	"	"	CE
Pipeline Engineering	3	University of Missouri-Columbia	Liu	CE
Applied Fluid Mechanics	3	"	Lenau	CE
Advanced Hydraulic Engineering	3	Montana State University	Williams	CE
Production Engineering	3	New Mexico Inst. Mining & Tech.	Rajtar	PNGE
Production Process Engineering	3	Pennsylvania State University	Adewumi	PNGE
Solids Processing	3	University of Pittsburgh	Klinzing/Chiang	ChE
Infrastructure Engineering	3	Rensselaer Polytechnic Institute	Grivas	CE
Water & Wastewater Infrastructure	3	"	Esler/Smith	EE
Corrosion	3	"	"	MSE
Welding Processes & Metallurgy	3	"	"	MSE
Production Design	3	University of Tulsa	Brill	PE
Fluid Mechanics (focused on pipelines)	4	University of Washington	Finlayson	ChE
GRADUATE				
Introduction to Offshore Technology	3	Colorado School of Mines	Chung	E
Marine Mining Systems	3	"	"	E
Operation of Hydraulic Systems	3	Colorado State University	Ruff	CE
Hydraulic Structures/Systems	3	"	Skinner	CE
Hydraulics of Closed Conduits	3	"	Rugg	CE
Hydromachinery	3	"	Skinner	CE

Table 2. . Undergraduate and Graduate Pipeline Courses at U.S. Universities (Continued)

Transport Phenomena in 2-Phase Flow	3	Georgia Institute of Technology	Ghiaasiaan	ME
Nuclear Reactor Technology II	3	"	"	ME
Biofluid Mechanics	3	"	Ku	ME
Fluid Transients	3	University of Idaho	Liou	CE
Mechanics of Liquid Flow in Pipes	3	University of Kentucky	Wood	CE
Stormwater Modeling	3	"	Ormsbee	CE
Design & Manuf. of Composite Materials	3	Marquette University	Widera	ME/IE
Hydraulic Transient	3	University of Michigan	Wylie	CE
Hydraulic Transport of Solids	3	University of Missouri-Columbia	Round	CE/MAE
Pipeline Engineering	3	"	Liu	CE/MAE
Advanced Hydraulics (Water Hammer)	3	"	Lenau	CE
Advanced Production Engineering	3	New Mexico Inst. Mining & Tech.	Rajtar	PNGE
Non-Newtonian Fluid Mechanics	3	University of Oklahoma	Shah	PNGE
Natural Gas Engineering	3	Pennsylvania State University	Adewumi	PNGE
Solids Processing	3	University of Pittsburgh	Klinzing/Chiang	ChE
Earthquake Processing	3	Rensselaer Polytechnic Institute	Papageorgiou	CE
Infrastructure Engineering	3	"	Grivas	CE
Advanced Production	3	University of Tulsa	Brill	PE
Two-Phase Modeling	3	"	Sarrca	PE
Transient Two-Phase Flow	3	"	Shoham	PE
Multi-phase Flow in Pipes	3	University of Wyoming	Sharma	CPE

Note: Acronyms for departments of engineering:
CE = Civil; ChE = Chemical; CPE = Chemical & Petroleum; E = Engineering; EE = Environmental;
IE = Industrial; ME = Mechanical; MSE = Material Science & Engineering; PE = Petroleum Engineering;
PNGE = Petroleum and Natural Gas.

Table 3. Research in Pipeline Engineering at U.S. Universities (1991-96).

Title	School	Investigator (PI)	Sponsor
High Performance Concrete Pipes	University of Alabama-Birmingham	Fouad	Industry
Cement Lined Ductile Iron Pipe	"	"	"
Deep-Ocean Pipe Dynamics	Colorado School of Mines	Chung	NSF
Impact on Offshore Pipelines	"	"	SAUDI ARAMCO
Two Phase Flows	"	"	Multi-National
Three Phase Flows	"	"	Multi-National
Hydromachinery	Colorado State University	Skinner	TVA/USBR
Valve Tests	"	Brisbane	Industry
Flow Meter Studies	"	Abt	Industry
User Friendly Models for Cathode Protection of Trans-Alaska Pipeline	University of Florida	Orazem	Alyeska
User-Friendly Models for Cathodic Protection of Pipelines	"	"	Industry
Fluid Dynamics of a Pressurizer Surgeline in a Reactor Pipeline System	Georgia Institute of Technology	Desai	--
Pipeline Leak Detection	University of Idaho	Liou	API
Leak Detectability	"	"	GRI
Modeling Dynamic Check Valves	"	"	Industry
Neural Networks Applied to Transients	"	"	--

Table 3. Research in Pipeline Engineering at U.S. Universities (1991-96) Cont.

Optimal Operation of Water Distribution Systems	University of Kentucky	Ormsbee	NSF
An Optimization Model for Rural Water Distribution Systems	"	Lingireddy	KWRRI
Trenchless Technologies Center (Various Projects)	Louisiana Tech University	Sterling	Industries Consortium
Internal Pressure Testing of Plastic Pipe	Marquette University	Widera	PVRC
External Pressure Testing of Plastic Pipe	"	"	PVRC
Analysis of Shell Intersections	"	"	PVRC
Unsteady Flow in Pipe	University of Michigan	Wylie	NSF & Other Sources
Surging During Surcharging of Storm Sewers	"	Wright	--
Metering of Flow in Storm Sewers	"	"	--
Lubricated Flows	University of Minnesota	Joseph	NSF & Oil Industry
Pneumatic Capsule Pipeline System Design	"	Zhao/Lundgren	Minnesota DOT
Hydraulic Capsule Pipeline R&D	University of Missouri-Columbia	Liu/Marrero/Others	NSF/State/Industry
Coal Log Pipeline R&D	"	"	"
Pneumatic Capsule Pipeline R&D	"	Liu/O'Connell	NSF/MATC/Industry
Coal Log Pipeline	University of Missouri-Rolla	Wilson	NSF/State/Industry
Factors Limiting Microbial Growth on the Distribution System	Montana State University	Camper	AWWA
Investigation of Biological Stability of Water in Treatment Plants & Distrbtn. Systems	"	"	AWWA
Interactions Between Pipe Materials, Corrosion Inhibitors, Disinfectants, Organics, & Distrbution System Biofilms	"	"	NWRI
Microbial Souring in Oil Formations (& Pipelines)	"	Sears	NSF/Industry
Pipeline Infrastructure Study	New Jersey Institute of Technology	Pignataro	U.S. DOT
Pipeline Leak Detection System for Oil and Gas Gathering Lines	New Mexico Inst. of Mining & Tech.	Rajtar	WERC
Develpmnt. of Non-Intrusive Laser Diagnostics for Measurements in Sediment-Laden Flows	University of Oklahoma	Parthasarathy	NSF
LDV Measurements in Fully-Developed Channel Flows of Non-Newtonian Liquids	"	Shah	GRI/DOE
Fracturing Fluid Characterization Facility	"	"	"
Transient Flow Surges & Low Frequency Flow Instabilities in Parallel-Tube	Oakland University	Wedekind/Blatt	NSF
Modeling PCB/Condensate Distribution in Gas Pipelines	Pennsylvania State University	Adewumi	Consortium of Agencies
Modeling Hydrate Deposition and Slury Transport in Pipelines	"	"	"
Pneumatic Conveying and Neural Network Analysis	University of Pittsburgh	Klinzing	NSF
Flow-Economizer for Long Distance Conveying	"	"	DOE
Lifeline Earthquake Engineering	Rensselaer Polytechnic Institute	O'Rourke	NSF/NCEER
Pipeline Monitoring Technologies	"	Savic	Industry
Pipeline Safety	Texas A&M	Mamora	DOT Ofc. of Pipeline Safety

Table 3. Research in Pipeline Engineering at U.S. Universities (1991-96) Cont.

Evaluation U-Liner Technology for Trenchless Sewer Rehabilitation	Tulane University	Bakeer/Barber	Louisiana EQSF
Test for Fluid Migration Between Host Pipe and Pile Liners	"	Bakeer/Guice	City of Baton Rouge
Paraffin Deposit in Pipelines	University of Tulsa	Brill/Volk	DOE, GRI and Industry Consortium
Oil Water Flow in Pipelines	"	Trullero	Consortium
Low Liquid Holdup Two-Phase Flow	"	Meng	"
Slug Characteristics in Pipeline	"	Marcano	"
SMARTE Enrichment Project	Wayne State University	Rathod	NSF
Tech-Prep 2000	"	"	Michigan
King-Chavez-Parks Program	"	Robinson	WSU
Summer Academy	"	Green	WSU