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U.C. Berkeley Nuclear Engineering Curriculum and Research Enhancement

Final Report

Progress report for the period from
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Report to:

U.S. Department of Energy
Office of Nuclear Energy, Science and Technology
Office of Resource Management, NE-10
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DISCLAIMER

Introduction

This report discusses the progress achieved during the first three years funding of our multi-year program for curriculum and research enhancement for the Department of Nuclear Engineering at the University of California, Berkeley. The program is designed to strengthen the departmental academic infrastructure and improve the education breadth of nuclear engineering students. The work discussed here was supported under DOE contracts DE-FG03-93ER75856 and DE-FG03-94ER76010, and DE-FG03-95NE38105, with matching funding by gifts to the Department from the Pacific Gas and Electric Company (PG&E). PG&E provided matching gifts each in the amount of $50,000 and renewed its pledge to continue its contributions.

The awards from the DOE and PG&E have provided crucial support for our department's educational mission. PG&E's support has funded distinguished lecturers for our courses and seminars, and has provided critical startup funds for the new Junior faculty we have brought in during the last four years. Forty percent of the support from DOE has provided scholarships for our most outstanding undergraduate students during a period of large increases in student fees. The remainder of the DOE support has been invested in curriculum enhancement, resulting in a new Freshman seminar program and a new summer honors course on nuclear facilities operations.

Due to its declining utility for research, six years ago our department decommissioned our TRIGA research reactor, to make the space available for an accelerator-driven rotating target neutron source for fusion studies. The DOE has traditionally supported these university reactors, in part because they provide a vital educational experience for undergraduate students in reactor operations. Thus in 1993 we were determined to use our DOE award to replace the undergraduate education that our research reactor formerly provided with an equal or superior educational experience. As this progress report indicates, we can now make a compelling argument that our effort has been successful. Under our curriculum enhancement program, our students now have the opportunity to spent a full week at the Diablo Canyon Nuclear Power Plant, after spending two weeks full time at Berkeley studying plant operations. PG&E and its plant personnel have provided outstanding support for this effort, support which our department sincerely appreciates. The students spend a full day operating the plant using the full-scale simulator, spend a day each individually and in small groups with operations and engineering personnel, and by the end of the week are intimately familiar with the basics of nuclear power plant operations, at a depth that can not be achieved with a university research reactor.

A primary mission for nuclear engineering departments will remain the education of the engineers who will be responsible for the safe operation of our nation's existing nuclear power plants. In the past, university research reactors have provided a crucial element in that education. As more research reactors are decommissioned in response to evolving research needs, the program we have developed with PG&E may serve as a useful model for other nuclear engineering departments. Certainly, as our report indicates, the ongoing support of the DOE, and the commitment the PG&E has provided to our educational efforts, has had a strong influence on our students. We sincerely hope to continue this program, to help ensure the quality and background of our nuclear engineering graduates remains commiserate with the task of ensuring the safety and reliability of our nation's nuclear power plants.

Progress to Date

Now in its fourth year, the program described in the original grant proposal has been successfully implemented with an enthusiastic response from our students and faculty. The program consists of two parts, one for innovative additions to our curriculum funded by the DOE, and the other for distinguished lectureships and support for basic research funded by gifts from PG&E. In particular, the program related to curriculum provides entirely novel experiences for undergraduate students and has proven to be an outstanding innovation in undergraduate education.

Our proposed DOE Undergraduate Honors Program was put in place for the Fall '93 semester. We awarded scholarships to incoming freshmen and continuing students, as described in the previous grant proposals, and a new course was initiated, "Nuclear Facility Operations," NE 135, which included instruction on site at the Diablo Canyon Nuclear Power Plant,. Appendix E provides a detailed report on last summer's NE135 course at Diablo Canyon; what follows here is a brief synopsis.

NE 135, "Nuclear Power Operations," is a novel summer honors program on the operation of nuclear fission power plants and other nuclear facilities. The course provides classroom and hands-on training in nuclear power plant operation and maintenance. The course is conducted both at U.C. Berkeley (2 weeks) and at the Diablo Canyon Nuclear Power Plant (1 week). The students work and study in teams of 5. The first offering of NE 135 was in the summer of 1993, and the course has been offered annually since then, most recently in the summer of 1996. NE 135 proved to be popular as anticipated, with double the number of applications that could be accommodated with the maximum space available (15 students, a number set by the limited group sizes permitted inside the Diablo Canyon facility and one-on-one training with the plant engineers, operators, and maintenance personnel). PG&E management and personnel at Diablo Canyon and the San Francisco office deserve special recognition, as they have made exceptional contributions to the course, providing reading materials, photographs, and arrangements for activities at the plant. In addition to NE 135, targeted mainly for juniors and seniors, we initiated the new introductory course for freshmen, NE 39, in the Fall '92, '93, '94, and '95 semesters as described in the previous grant proposal. This course, fully funded by the university, will be offered again in the Fall 1996 semester. The freshman course proved quite successful, both with larger than expected enrollment, and with an excellent array of speakers, including several from industry, the medical profession, and Nobel Laureate Glen Seaborg.

Concerning the PG&E funded program, we have brought two Distinguished Lecturers in the field of Nuclear Waste Management (Prof. Kiyosi from Tokai University in Japan and Professor Ivars Neretnieks from the Royal Institute Of Technology in Sweden), and we have provided partial support for a distinguished Professor in Residence to teach advanced courses in fusion technology and neutronics (Dr. Ehud Greenspan). These gifts also funded about one-third of the cost of a new student/faculty computer laboratory being established by our most recent additions to the faculty, Assistant Professor Jasmina Vujic, who is an expert in computational modeling of neutron transport and author of the highly-successful GTRAN-2 code at Argonne National Laboratory, and Assistant Professor Joon-hong Ahn, an expert in radioactive waste management and geologic repository characterization. The gifts have also supported activities of the new Center for Nuclear and Toxic Waste Management.

Appendix A - Course Report for NE-135

1996 NE-135 Course Report

The NE-135 "Nuclear Facilities Operations" honors course was held for its fourth summer in July, 1996. Once again the students' reaction to the course was enthusiastic. After two weeks of intensive study of reactor systems and fundamentals at U.C. Berkeley, the students and instructors spent the third week at the PG&E Diablo Canyon Nuclear Power Plant. There the students once again participated in a broad array of activities, described in this report.

With the experience gained from our previous summers, the 1996 course required less preparation by the UC and PG&E participants, yet resulted in a course of even higher quality. Again the participation of PG&E personnel was outstanding. The students spent time with plant operators walking through the turbine and auxiliary buildings. There they saw equipment they had studied during the first two weeks, from the safety injection pumps to the main turbines and condensers.

This summer the class arrived the day after a system-wide blackout had taken both of the Diablo Canyon units down. This provided an unusual education experience for the students, as they had the opportunity to observe the plant personnel work to return the units on line. During this period, which included near record electrical demand due to unusually hot weather, PG&E experienced rolling blackouts and purchased outside power at over 12 cents per kWh. However, the class observed that the plant made very conservative decisions about safety, delaying startup for five days to test all of the plant's main steam safety relief valves rather than a smaller sample, because one of the valves had opened at a pressure outside it's expected range during the plant shutdown.

During the previous two summers, shipments of fresh fuel were received during the week of the class, so the students observed the inspection process and the transfer of the fresh fuel to the spent fuel pool.

The students spent part of the day in Diablo's control room. Traveling in the plant the students became familiar with procedures for entering and leaving radiological control areas. The students also spent time one-on-one with engineers, both in their offices learning about the wide range of the engineers' jobs, and out in the plant examining systems the engineers have responsibility for. From plant training personnel they received instruction on instrumentation and plant procedures in Diablo Canyon's control room simulator. In teams of five, the students "ran" the plant, performing a full plant startup from hot standby to 30% power, and then responding to several accident scenarios including a large break loss of coolant, steam generator tube rupture, and a small break loss of coolant accident. The students also went on tours, including trips to the maintenance training facility, automated warehouse, 500kV switchyard, and ocean biology laboratory.

NE-135 provided a unique and valuable experience for the students that participated in the course. This summer NE-135 was opened to students outside of Nuclear Engineering, with an Environmental Science and Mechanical Engineering undergraduate students taking the course. Already other students are expressing interest in taking the course in the summer of 1997. We believe that continuation of the course will provide large benefits to the field of nuclear engineering, and that extending the course enrollment to include students in other energy-related disciplines will provide additional long-term benefits.

Based on the excellent results of the 1996 NE-135 course and the continuing strong interest from students, we propose holding the course again in the summer of 1997.

Introduction

This report provides detailed information on the 1995 NE 135 summer course on Nuclear Facility Operations, recently completed at U.C. Berkeley. In three weeks from July 17 to August 4, the course provided an exceptional opportunity for 15 students to study engineering, systems, and operating procedures at one of the nation's top ranked nuclear power plants. The experience this summer was even better than the first year the course was offered. Because detailed reports were issued following the 1993 and 1994 courses, this report is shorter.

The NE-135 course began as a proposal for curriculum enhancement to the Department of Energy in May of 1992. The proposal was accepted, and Pacific Gas and Electric Company provided matching funding. The original course development in 1993 required detailed planning and extensive participation of PG&E personnel, both at Diablo Canyon and at their San Francisco general office. For the 1995 course considerably less effort was required, because much of the ground work had be laid out the previous year. Still, the considerable efforts of the PG&E personnel, and the strong support of their management, deserve recognition. In particular, the organizational efforts of Bruce Terrell of the Diablo Canyon training department should be commended.

With co-instructors Per Peterson and Jay James, the course started Monday, July 29. The first two weeks consisted of intensive instruction at U.C. Berkeley, with lectures, group activities, hands-on activities, and field trips filling each day from 9:00AM to 3:00PM. On Sunday, August 11, the students and instructors traveled to San Luis Obispo, staying at the dorms at Cal Poly. The following week was spent out at the plant, participating in a broad range of learning activities.

Weeks 1 and 2: U.C. Berkeley

The first two weeks of the NE-135 course were devoted to intensive instruction on PWR reactor systems, instrumentation, and operations. Typically, each day included three one-hour lectures, two group activities (team problem solving and studies), and a hands-on activity such as disassembly and reassembly of a centrifugal pump.

The UCB instruction also included two field trips. On Monday, August 5 the students visited the UCB cogeneration plant, where Joe Cusumano showed the students the equipment used to generate campus heating steam (60,000 to 160,000lb/hr) and simultaneously generate electricity (around 20MW) using a natural gas-fired turbine with a steam bottoming cycle. This gave the students both an introduction to one of the major growing sources of electrical generation capacity and a preliminary view of major equipment components shared by nuclear power plants. With their following visit to Diablo Canyon, the students also had the opportunity to compare and contrast the equipment, regulatory, and safety requirements of nuclear and non-nuclear power plants.

On Thursday, August 8 the students made their second field trip to PG&E's general office in San Francisco. There Tien Lee had arranged a program where the three student teams rotated through visits to engineering, licensing, and quality assurance engineers.

The students also participated in daily "Hands On" activities, which included a visit to the NE shop where they were shown the operation and capabilities of a variety of machine shop tools and welding equipment. The students also tore down and reconstructed a centrifugal pump, visited research laboratories, toured the Hesse Hall steam turbine laboratory, studied video and text material on the TMI and Chernobyl accidents, and built a 1/4 scale mockup of the D.C. control room control panels to aid in their studies of the plant operation

The lectures and group activities were designed to give the students an in-depth understanding of all the major plant systems and instrumentation at the Diablo Canyon Nuclear Power Plant. The topics were covered in sufficient detail so the students could

understand the purpose and know the location of all the major plant equipment they would see at Diablo Canyon, and so they knew the major plant control parameters and operating procedures, such that they could operate the plant using the control room simulator after a brief introduction by PG&E training personnel. The following list summarizes the topics studied in the lectures.

Week 3: Diablo Canyon

The third week of NE-135 was spent at the Diablo Canyon Nuclear Power Plant. PG&E plant personnel were outstanding in providing an introduction to their jobs and the plant operations and equipment, working hard to insure that the students understood the most important aspects of their jobs.

The tables below give the detailed activities the students participated in. As the list shows, the activities were diverse and provided a detailed introduction to the plant systems and operations, and the day-to-day tasks the plant engineers and operators perform.

Day	Activity		
Su	Travel to San Luis Obispo		
M	GET (short-term employee training for access to radiological control areas), whole body count (9:00a-11:30a). Observation of crew on simulator (12:00a-1:00p, 5:00p-7:00p). Operations introduction and PIMS orientation (1:00p-5:00p).		
	Tu/W/Th groups alternate between activities (see below)		
	Group 1	Group 2	Group 3
Tu	Operations	Training	Engineering
W	Engineering	Operations	Training
Th	Training	Engineering	Operations
F,	Tour of 500kV switchyard (8:30a-9:00a). Tour biology laboratory (9:15a-10:00a). Tour automated warehouse facility (10:00a-12:00a). Final Exam/Whole body count (1:00p-2:30p). Return to Berkeley		

Group Activities (8/12-8/14)

Engineering

Student	7-10	10-11:30	11:30-1	1-3	3-4	4-5
1	Sys. Eng.	RX Eng.	lunch	Reg. Com.	DCN	STP/PRO
2	"	"	"	"	"	"
3	"	"	"	"	"	"
4	"	"	"	"	"	"
5	"	Reg. Com.	"	RX Eng.	STP/PRO	DCN
Instr.	"	"	"	"	"	"

Activities involve spending time with engineers who work with:

DCN - Design Change Notice
Reg. Com. - Regulatory Compliance
RX Eng. - Reactor Engineering (shadow a reactor engineer)
STP/PRO - System Test Procedure/
Sys. Eng. - System Engineering

Operations

Student	8-8:30	8:30-10:30	10:30-11:30	11:30-1	1-3	3-4	4-5
1	Crew Brief	Aux Bldg	SFM (1)	lunch	Turb Bldg	CO (1)	SCO (1)
2	"	"	SFM (2)	"	"	CO (2)	SCO (2)
3	"	"	CO (1)	"	"	SFM	SFM (1)
4	"	"	CO (2)	"	"	SCO (1)	SFM (2)
5	"	"	SCO	"	"	SCO (2)	CO

The activities involve spending time with operators to:

Crew Brief	- Sit in on morning crew briefing (students bring donuts).
Aux. Bldg.	- Travel with operator through auxiliary building
CO	- Shadow a Control Room Operator
SCO	- Shadow a Senior Control Room Operator
SFM	- Shadow a Shift Foreman
Turb Bldg	- Travel with an operator through the turbine building

Training

Student	7-10:30	10:30-11:30	11:30-12	12-5
1	Maint. Training	Proc. Overview	Lunch	Simulator
2	"	"	"	"
3	"	"	"	"
4	"	"	"	"
5	"	"	"	"

Activities involve:

Maint. Training.	- Examine plant equipment (pumps/steam generator bottom head/etc.)
Proc. Overview	- Discussion of Operations and Procedures
Simulator	- Students first perform control manipulations: turbine load changes, generator control, rod control, main feedwater flow, charging and letdown flow changes, makeup controls, and electrical bus transfers. Then perform a controlled load reduction and manual reactor trip, then plant start up to 30% power from hot standby. Run through several accident scenarios on simulator: large break loss of coolant accident following small leak, steam generator tube rupture, loss of all offsite power. Discuss methods for diagnosing accident cause and use of emergency procedures.

Appendix B - Course Description for NE-39

INTRODUCTION TO NUCLEAR ENGINEERING

NE 39

Nuclear Engineering Faculty and Staff

Fall Term

2 Units
2 hours lecture per week (two one-hour lectures per week)

Description: Introduction to topics and issues in nuclear engineering: nuclear reactions and radiation, radiation protection and control, energy production and utilization, nuclear fuel cycle, reactor theory, nuclear power engineering, reactor operation, controlled fusion, nuclear waste, medical and other application of radiation, advanced research topics.

Content: This course is intended to provide incoming students with an overview of the array of topics and applications in nuclear engineering. This overview provides a framework and motivation for lower division course work. The topics to be introduced include:

1) **Nuclear reactions and radiation:** A general introduction to radioactive decay, interaction of radiation with matter, properties of fission products, radiation protection and control, effects of radiation on man, biological pathways and dispersion in the environment.

2) **Energy production and utilization:** A comparison of energy sources including fossil, nuclear, and renewable. Global energy flows, environmental impacts, economic evaluation and externalities, and technical issues.

3) **Fission reactors:** The nuclear fuel cycle front end, nuclear fission and chain reacting systems, criticality, fission reactor types, energy transport and conversion in reactor systems, reactor safety and accident scenarios, advanced reactor concepts, reactor operation.

4) **Controlled fusion:** nuclear fusion reactions; fusion reactor concepts, magnetic and inertial confinement; plasma physics; tritium handling.

5) **Nuclear waste:** high, medium, and low level wastes, transuranic waste; waste sources, power, defense, medical; geologic repositories; waste transport mechanisms and dispersion; economic and political issues; future directions for waste disposal.

6) **Additional topics:** history of nuclear engineering, medical and other applications of radiation, tours of laboratories and research facilities on campus and at LBL and LLNL.

Prerequisites: none

Course Work: Lectures, reading, term paper, and examinations.

Course Grading: The grading will be based on classroom participation, examinations (midterm and final), and the term paper.

Course Reference Materials: The course text will be "Nuclear Energy," Raymond L. Murray, Pergamon Press, 1988.

Course Objective: This course is intended to provide incoming lower division students with an overview of the array of topics and applications of current importance in nuclear engineering. This overview will provide a framework and motivation for lower division studies, optimizing student preparation for upper division nuclear engineering courses. Outside lecturers from industry and the national laboratories will provide a broader perspective of work in the nuclear engineering field.