

# Final Report:

## U.C. Berkeley Nuclear Engineering

### Curriculum and Research Enhancement

Report for the period from  
February 14, 1993 to February 14, 1995  
DOE Contract DE-FG03-93ER75856

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## Contents

Executive Summary .....	3
Progress to Date.....	3
Continuation of the Program .....	4
Appendix A - Annual Budget - Department of Energy .....	5
Appendix B - Annual Budget - Pacific Gas and Electric .....	7
Appendix C - Letter of Continuing Commitment from PG&E.....	8
Appendix E - Course Report for NE-135.....	9
Appendix E - Course Description for NE-39.....	17

## Executive Summary

This is a report for the 2/14/93 to 2/14/95 period of the five-year program proposed and initiated in 1992, 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 DOE funds have supported scholarships and a novel educational program which includes summer coursework at the Diablo Canyon Nuclear Power Plant. The summer course provides an important introduction to reactor safety and operations to students who will in the future be responsible for running many of our existing nuclear power plants. The work was funded under DOE contract DE-FG03-93ER75856, with a matching gift to the Department from the Pacific Gas and Electric Company (PG&E). The work is currently continuing under DOE contract DE-FG03-94ER76010. PG&E has provided an additional matching gift in the amount of \$50,000 and renewed its pledge to continue its contributions.

## Progress to Date

The program described in the original grant proposal has been successfully implemented with an enthusiastic response from our students and faculty. The program consisted 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.

Concerning curriculum enhancement, the 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. The following section provides a detailed report on last summer's NE135 course at Diablo Canyon; what follows here is a brief synopsis.

NE 135 is a 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 just prior to the beginning of the Fall '93 semester, and the second prior to the beginning of the Fall '94 semester. 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, and '94 semesters as described in the previous grant proposal. This course, fully funded by the university, will be offered again in the Fall 1995 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 addition 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. The gifts have also supported activities of the new Center for Nuclear and Toxic Waste Management.

### **Program Continuation**

As stated in the original grant proposal, we propose to continue to apply DOE funds under this grant to provide scholarships for incoming freshmen and continuing students, and to support the new NE 135 course in 1996 and to initiate research projects on radioactive waste and materials management.

### **1994 NE-135 Course Report**

The NE-135 "Nuclear Facilities Operations" honors course was held for its second summer in July, 1994. 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 summer, the 1994 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. The class was particularly lucky because a shipment of fresh fuel was received the same week, so the students observed the inspection process and the transfer of the fresh fuel to the spent fuel pool for the Unit 2 refueling to come in September. They also 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 undergraduate and an Energy and Resources graduate student taking the course. Already other students are expressing interest in taking the course in the summer of 1995. 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 1994 NE-135 course and the continuing strong interest from students, we propose holding the course again in the summer of 1995.

## Introduction To NE-135

This section provides detailed information on the 1994 NE135 summer course on Nuclear Facility Operations, recently completed at U.C. Berkeley. In three weeks from July 5 to July 22, 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 a detailed report was issued following the 1993 course, 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. Unfortunately, changes in administration at the DOE resulted in the grant expiring prematurely in early 1994. A subsequent letter in April from the DOE indicated that 60% of the funding originally requested could be made available in FY94. Unfortunately, these funds also came into question, and shortly before the NE-135 course was to begin the Department was informed that the funds would not be available in time for the course. However, the College of Engineering and the Department of Nuclear provided the necessary funds, due to their strong commitment to this unique course. Future funding from the DOE can be applied for the 1995 summer, assuming that agreement is reached to repeat the course as is hoped.

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 1994 course considerably less effort was required, because much of the ground work had been 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 Steve Petrie of the D.C. and Jim Radford of the S.F. training departments, Dave Bahner of D.C. operations, and Ray Foster of D.C. engineering should be commended.

With co-instructors Per Peterson, Jay James, and Jasmina Vujic, the course started Monday, July 5. 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 4:00PM. On Sunday, July 17, 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 Friday, July 8 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 Friday, July 15 the students made their second field trip to PG&E's general office in San Francisco. There Jim Radford 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	Group 1	Group 2	Group 3
W	Operations	Training	Engineering
Th	Engineering	Operations	Training
F,	Training	Engineering	Operations
	Tu/W/Th groups alternate between activities (see below)		
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 (8/10-8/12)

#### 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.

## 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.