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STUDY OF ADVANCED PROFESSIONAL EDUCATIONAL REQUIREMENTS RELATIVE TO NUCLEAR FUEL CYCLE ENGINEERING IN INDUSTRY AND GOVERNMENT

FINAL REPORT

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DECEMBER, 1978

**Work Performed Under Contract EY-76-S-09-0947
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**UNIVERSITY OF SOUTH CAROLINA
COLLEGE OF ENGINEERING
COLUMBIA, S.C. 29208**

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SUMMARY

Under contract with the U. S. Department of Energy, the College of Engineering at the University of South Carolina has conducted an assessment of educational needs among engineers working in nuclear fuel cycle related areas. The study was initiated as a regional effort focusing on the concentration of nuclear industry in the Southeast. Educational needs addressed were those at the post-baccalaureate professional level. The project was envisioned as providing base line information for the eventual implementation of a program in line with the needs of the Southeast's nuclear community. Specific objectives were to establish the content of such a program and to determine those specialized features which would make the program most attractive and useful.

The study was conducted by an interdisciplinary faculty team, many of whom brought to the project considerable skill in various areas of nuclear related engineering. Off-campus, on-site interviews of practicing professionals were the primary mechanism used to obtain input to the study. Persons interviewed included top level management as well as many representatives of engineering management and front-line engineering from industry, the utilities and government throughout the Southeast.

As a result of the study, a list of subject areas has been compiled as best representing the current content of an educational program. The list is unique in that many of the subjects identified are not typical of a traditional university related curriculum. Briefly stated, the majority of engineers working in the region's nuclear industry have considerable experience and many are experts in their respective fields of endeavor. A typical university curriculum would simply not be at all well suited to

a clientele of experienced practicing engineers. The real need, as discovered while the study was in progress, is for an educational effort concentrating on what is identified in the report as "peripheral studies."

These are subjects which augment the day-to-day technological performance and which individuals identify with their performance and growth on the job.

In addition to identifying subject areas, a set of course descriptions and reference materials has been developed around each subject. Each course description contains information regarding objectives, anticipated audience, and prerequisites and offers a suggested course outline. Effort was taken to produce course descriptions which are also consistent with input received during the interview process. In many cases, experts from the region assisted in their preparation. Here again, many features of these course descriptions are not typical of subject material taught in a traditional engineering-science oriented curriculum at the graduate level.

A further result of the study has been the recognition of the importance of method as well as content in the development of the educational program. It is important that those responsible for implementing the program pay close attention to methods by which engineers (participants) learn and to the special interests of their employers. As the study progressed, considerable insight was gained into the special interests of the faculty, the engineers, and the engineering employers. One section of the report is devoted entirely to a condensed compilation of information regarding method obtained during the interview process.

Altogether, the information contained in the report provides a starting point for an educational program based on well defined needs. It is recommended, therefore, that implementation proceed as a natural follow on phase of the work already done. An initial modest program of implementation is

recommended which would continue to concentrate on the Southeast as a target area. The program should begin with the initiation of from 6 to 10 educational packages emphasizing quality as opposed to quantity. An active part of the agenda for implementation should include continued reassessment of the needs analysis initiated with this report. It should also be recognized that implementation of an educational program consistent with the needs of the Southeast nuclear community is a unique undertaking and serves as an experiment in the nation. If successful, then consideration should be given to similar such programs within other regional concentrations of industry.

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I. REVIEW OF THE PROJECT, PROJECT OBJECTIVES AND THE PROJECT PLAN

Under contract with the United States Department of Energy, the College of Engineering at the University of South Carolina has conducted a study to assess the educational needs of engineers who work in fuel cycle related areas. The study was initiated as a regional effort and focused on the relatively high concentration of nuclear industry located in the southeastern United States. The educational needs which have been addressed are those at the professional post-baccalaureate level. The clientele and virtually all those interviewed during the course of the study are practicing professionals who have completed their initial formal education.

From the onset, the project was envisioned as the starting point for a regional educational effort in line with the continued growth and development of the nuclear industry in the Southeast. The intent was to undertake a sound needs analysis and define an initial program content. Information would then be available as a basis for the development of a program which would be both attractive and useful to those working in the region's nuclear industry. As a regional effort, both the study and eventual developments based on the results of the study were expected to serve as an experiment for other parts of the nation. This section of the report explores the reasons for the project and also contains a statement of project objectives and a description of how the work of the project was carried out.

A. Reasons for the Project

1. Growing National Awareness of the Nuclear Fuel Cycle

The project was initiated at a time when the nation as a whole had begun to recognize a state of maturity within the nuclear industry. The

industry had reached a presence of size which had resulted in a general concern over such issues as safety, proliferation, and management of a growing inventory of waste materials. In the future, the nation's attention would be on all aspects of the fuel cycle rather than on just those areas directly related to fuel production and reactor operations. At least equivalent emphasis would be on post-reactor areas such as disposal, reprocessing, and reuse of fuels. The nuclear industry was due for some adjustments. Of interest to this project have been those adjustments anticipated in the areas of professional manpower requirements and, in particular, related educational requirements.

2. Concentration of Nuclear Industry in the Southeast

Throughout the Southeast occurs a relatively high concentration of nuclear industry. A list is given in Fig. 1. This industry includes power companies; commercial facilities involved in the production, processing, and disposal of nuclear materials; production facilities under supervision of the federal government; research laboratories; and various state and federal regulatory agencies. Nearly every aspect of the nuclear fuel cycle except mining and milling of uranium ore is represented. This project was undertaken recognizing that the numbers of engineers working in this industry was sufficiently concentrated to warrant educational experiences tailored to their needs.

3. Interaction of Engineering Faculty with the Surrounding Nuclear Industry

The University of South Carolina is situated almost at the geographic center of the Southeast nuclear community. Long before this project began, there had been considerable interaction between industry and the College of Engineering. Areas of interaction included research at the College, on-site faculty appointments, and a variety of other professional activities.

COMMERCIAL FACILITIES INVOLVED IN PRODUCING AND PROCESSING NUCLEAR MATERIALS

Westinghouse Fuel Fabrication Plant, Columbia, South Carolina
General Electric Fuel Fabrication Plant, Wilmington, North Carolina
Allied General Nuclear Services, Barnwell, South Carolina
Chem-Nuclear, Barnwell, South Carolina

POWER COMPANIES WITH NUCLEAR CAPABILITIES

Duke Power Company, Charlotte, North Carolina
South Carolina Electric & Gas Co., Columbia, South Carolina
Carolina Power and Light, Raleigh, North Carolina
TVA, Knoxville, Tennessee
Southern Company Services, Birmingham, Alabama
Florida Power and Light, Miami, Florida
Florida Power Corporation, St. Petersburg, Florida
Virginia Electric and Power Company, Richmond, Virginia

PRODUCTION FACILITIES UNDER SUPERVISION OF THE FEDERAL GOVERNMENT

Savannah River Plant, Aiken, South Carolina
Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee

RESEARCH LABORATORIES

Savannah River Laboratory, Aiken, South Carolina
Oak Ridge National Laboratory, Oak Ridge, Tennessee

GOVERNMENT AGENCIES

Savannah River Operations - DOE - Aiken, South Carolina
Nuclear Regulatory Regional Office, Atlanta, Georgia

Fig. 1. LIST OF LOCATIONS INCLUDED IN THE SOUTHEAST'S NUCLEAR INDUSTRY

The College has also had in operation a televised graduate program broadcast over part of the Southeast and a program of continuing engineering education also serving the Southeast. Users of both these programs have come from the surrounding nuclear industry. A variety of educational and professional activities, therefore, had been in process which placed the College in a favorable position to initiate an assessment of educational needs within the Southeast nuclear community.

4. Unique Nature of Educational Needs Within the Nuclear Industry

At the time the project was conceived, it was expected that the educational needs would be unique and would include many areas of technical knowhow not typically covered in formal education in engineering. During the course of the study, this original concept was reinforced many times. For the most part, engineers who work in the nuclear industry do not have nuclear backgrounds. Their backgrounds are largely chemical, electrical, and mechanical engineering. These individuals do not suddenly revert to becoming nuclear engineers. Rather, they continue to practice in their chosen field but apply what they know to objectives which are nuclear related. Nuclear related technology, however, is in itself unique. Working with a nuclear product often involves consideration of an additional set of technological rules as well as a requirement to pay attention to many government regulations specific to the industry. In addition, the very nature of the nuclear industry demands that all related technology be developed at a high level. The project was initiated, therefore, recognizing a set of circumstances which would favor the development of a post-baccalaureate educational effort.

An additional feature of the nation's and the region's nuclear industry is that a significant number of those engineers and scientists who

pioneered in post-reactor areas are now nearing retirement age. This point of fact was brought up many times by those interviewed during the course of the study. A situation has been developing in which a probable increased demand for professional talent is to be compounded by retirement and subsequent loss of technology. Here again existed a circumstance suggesting a potential need for advanced professional education.

The importance of recognizing that the area of need is at the post-baccalaureate professional level should be emphasized. Recent general awareness of the entire fuel cycle has stimulated a number of colleges and universities to initiate courses relative to the fuel cycle and re-processing. Almost exclusively, these courses are offered through departments of nuclear engineering to resident undergraduate and graduate students pursuing that discipline. It is important that nuclear engineering students be exposed to all aspects of the fuel cycle, and these educational efforts should be encouraged. These efforts, however, do not reach the great numbers of engineers who, as described above, enter the industry with a variety of non-nuclear backgrounds. The specific and unique nature of their needs is not realized until they are on the job and are best met by programs specifically designed for the post-baccalaureate professional level.

B. Project Objectives

The overall objective of the project was to provide a basis for further development of educational efforts which would be responsive to the growth and development of the Southeast nuclear community. The survey was initiated, therefore, to establish the content of a program which would

best meet the needs of engineers and scientists working in the nuclear industry in this region. The results of the survey in part resulted in the many course descriptions which are presented and described later on in the report. The study was also initiated with the objective of identifying the most effective ways of transmitting the educational program to would-be users. It was expected when the study began that both a large part of the content and also the characteristics of practicing professionals as learners would be unique and not typical of university modes of education. An important part of the study was, therefore, to determine those specialized features of the program which would make the program most attractive and useful.

C. Description of the Project Plan

An interdisciplinary faculty team from the College of Engineering was assembled to work on the study and included representation from chemical, electrical, and mechanical engineering. A number of these individuals brought with them a background of research and other professional activity which was nuclear related and which proved invaluable as the study progressed. One member of the team also possessed an extensive background in the development and management of educational programs for practicing engineers. This input to the project also proved invaluable.

As already stated, the objectives of the study were to determine the content of an education program and to determine those characteristic features other than content which would be important to the program's usefulness and success. Efforts on the part of the faculty involved in the study were based primarily on the following:

- (a) prior knowledge of the nuclear fuel cycle and of the various nuclear related engineering activities going on throughout the

Southeast.

- (b) independent research based largely on available literature.
- (c) information from past research at the College of Engineering
- (d) contact with professionals working in the nuclear industry.

Input from practicing professionals at work in the region's nuclear industry was considered to be the most significant part of the study. The entire project, therefore, was arranged so as to promote contact between members of the faculty team and persons from outside the university. A number of schemes were used including the following:

- (a) use of information obtained during visits made during other nuclear related research projects previously underway within the College.
- (b) arrangement of visits by practicing professionals to the College to consult with the faculty in their particular areas of expertise.
- (c) attendance on behalf of members of the project team at national meetings and symposiums generally attended by those working in the nuclear industry.
- (d) off-campus, on-site interviews of practicing professionals by members of the faculty team.

The off-campus, on-site interview was the vehicle used most extensively during the course of the study. A detailed list of visits made during the course of the study is contained in Appendix A. In general, the response was very good. Almost without exception, those persons interviewed were quick to grasp the purpose of the study and were encouraging and informative in their response.

The study followed a timetable shown in Fig. 2. The initial phase

FY-78

FY-79

. O . N . D . J . F . M . A . M . J . J . A . S . O . N . D .

1. Preliminary Visit to
Upper Management

x-----x

2. Survey Activity: Identification of
Educational Need and Key Subject Areas

x-----x

3. Survey Activity: Course Descriptions,
Reference Materials

x-----x

4. Final Report: Preparation and External
Review

x-----x

8

FIG. 2. TIMETABLE SHOWING THE RELATIONSHIP OF MAJOR PHASES OF THE STUDY

of the project involved visits to upper management at regional industry and government facilities. These visits were necessary in order to brief upper management regarding the project and to open the way for contact between the professional staff at each facility and members of the project team. The response of upper management was generally one of encouragement. Very little difficulty was experienced in gaining the cooperation necessary to complete the work of the survey.

The second phase of the study involved meeting with management and front-line engineers at facilities throughout the Southeast. The intention of this phase was to determine the nature of the educational need and to identify key subject areas which could then be arranged into an educational program. It was the information from these interviews which eventually resulted in the list of subjects described later in the report and shown in Fig. 5. With regard to specific subject areas, this part of the survey also involved determining the level, depth, and breadth of material, the level of interest, the most effective means of delivery, and potential resource persons who would later aid in the development of course descriptions and perhaps serve as adjunct faculty some time in the future.

The next phase of the project was concerned with the development of course content within individual subject areas and the identification of appropriate reference materials. For the majority of the subject areas, the project team was able to rely on its own resources and upon information obtained during previous interviews. In a number of areas, however, help in the preparation of course descriptions was obtained from experts outside the faculty. The results of this phase of the study, the course descriptions, and reference materials, are contained in

Appendices B and C respectively. The final phase of the project involved preparation of the final report and subjecting the report to a review by many of those from the surrounding nuclear community who were interviewed during the course of the survey.

At the onset of the project, it was originally intended to visit and interview persons at all locations making up the nuclear industry throughout the Southeast. The plan was to make contact initially at locations geographically close to the University and subsequently visit more remote locations. In so doing, it was realized that the faculty team would itself have to go through a learning process during the early stages of the project. As the series of interviews progressed, however, it became apparent that there existed considerable commonality of interests from one location to the next. It was decided, therefore to forego contact at all locations in favor of selectively interviewing at sites considered representative of the region's industry. These locations were for the most part a relatively short distance from the University. For example, as regards power companies serving the Southeast, the results of the survey are based on information obtained from Duke Power Company (a large company with in-house architectural-engineering capability) and South Carolina Electric and Gas Company (a company in the process of bringing a nuclear power plant on line). Some contact was also made with Carolina Power and Light and Southern Company Services, but visits to more remote locations were not undertaken. The results of the survey obtained at these locations indicated that little additional information would have been obtained through further interviews. A list of those places in the Southeast which were visited during the survey is given in

Fig. 3. The distinction is made between those locations at which contact was extensive and those locations at which only limited contact was made.

LOCATIONS VISITED AS BASIS FOR SURVEY RESULTS

Westinghouse Fuel Fabrication Plant
Allied General Nuclear Services
Duke Power Company
South Carolina Electric and Gas Company
Oak Ridge National Laboratory
Savannah River Laboratory
Savannah River Plant

LOCATIONS AT WHICH LIMITED CONTACT WAS MADE

Carolina Power and Light
Southern Company Services
Oak Ridge Gaseous Diffusion Plant
Savannah River Operations - DOE
Nuclear Regulatory Commission

FIG. 3.. LIST OF LOCATIONS VISITED AS PART OF THE SURVEY

II. RESULTS-SUBJECT AREAS, COURSE DESCRIPTIONS, AND REFERENCE MATERIALS

A major objective of the study was to determine the content of an advanced education program which would be consistent with the needs of the region's nuclear industry. This section contains the results of that part of the study. Included are a discussion of special features relative to the program content which were realized during the study and a list of the subject areas which were identified.

A. Special Features Relative to Program Content

Throughout the duration of the study and as the interviews with practicing engineers progressed, a gradual but significant shift in thinking took place among members of the project team. At the time the project began, the faculty working on the project had collectively assembled a number of preconceived ideas regarding the educational program and what this program was to do for professionals working in the region's nuclear industry. To illustrate this point, reproduced in Fig. 4 is a list of subject areas which was assembled as a starting point for the investigation. It was correctly assumed at the time that this list would not remain static. Later in this section, Fig. 4 should be compared with Fig. 5. The latter is the actual list of subject areas identified during the course of the study.

Briefly stated, it appeared at the time that the project would be working toward the development of a program which would teach the principles of fuel cycle engineering and scientific technology to engineers and scientists engaged in fuel cycle work. The results of the study have shown that although there is a continuous number of entry level engineers

Nuclear Fundamentals
Manufacture of Nuclear Fuels
Alternative Nuclear Fuel Cycles
Reprocessing
Transport and Storage of Nuclear Fuel
Waste Management
Environmental Sampling and Monitoring
Control of Nuclear Processing
Component Design and Materials Applications

FIG. 4. LIST OF SUBJECT AREAS PUT TOGETHER AS A STARTING POINT FOR THE INVESTIGATION (FOR COMPARISON WITH FIG. 5).

who need to know more about fuel cycle principles, their numbers are small in relation to the total work force. The great majority of engineers working in the industry have considerable experience and, in effect, are the technology. As the study progressed, it became quite clear that the industry did not need an educational program set up exclusively to teach a technology to those in the process of developing that technology. The type of program anticipated at the start of the project would perhaps have worked well for engineering students in a traditional undergraduate/graduate curriculum. It was not, however, at all well suited to a clientele consisting of experienced practicing engineers.

There does exist, on the other hand, a real need for educational efforts concentrating on what is referred to here as "peripheral studies." The term peripheral studies applies to subject matter which serves to augment an individual's day-to-day performance and which the individual identifies with his or her own performance on the job. The concept is best described using a few examples.

Example:

Engineers at Duke Power Company, at other power companies, and those at Savannah River Laboratory in steam production who work with the ASME Boiler and Pressure Vessel Codes need to know more about the failure modes underlying the codes. (See Course Description No. 31a, Appendix B.)

Example:

Engineers working in the commercial nuclear industry need to know the basics of licensing requirements and features as they apply to their particular area of responsibility. (See Course Description No. 1, Appendix B.)

Example:

Non-electrical engineers responsible for system design, testing, and control need to know more about basic and practical electrical engineering. (See Course Description No. 19, Appendix B.)

Example:

Engineers responsible for selecting materials in radioactive environments have a need to know as much as possible about the effects of radiation on the mechanical and physical properties of an abundance of different materials. (See Course Description No. 24, Appendix B.)

These are examples typical of much of the input obtained from interviews during the study. A list of subject areas, therefore, has been identified for which there is a real educational need. In the majority of cases, these are areas which are in support of an engineering effort but which have not been pursued for various reasons such as lack of time, lack of direction, lack of awareness, lack of motivation, or lack of availability.

B. Subject Areas

Results of the study concerning program content are summarized in Fig. 5. Shown in the figure is a list of subject areas compiled as the result of interviews with engineers throughout the Southeast's nuclear industry. As such, the list represents the content of an educational program tailored to the needs of their particular industrial community.

It is a feature of Fig. 5 that relatively few of the subjects are typical of what might ordinarily be found in a traditional undergraduate/graduate curriculum. As stated previously in this report, the majority of the professionals working in the nuclear industry have considerable

NO.	SUBJECT AREAS	AGNS	WESTINGHOUSE	ORNL	SRP	SRL	SCE&G	DUKE POWER
1	LICENSING OF NUCLEAR FACILITIES	S	M	S	S	S	H	H
2	QUALITY ASSURANCE FOR NUCLEAR FACILITIES	S	H	M	M	M	M	H
3	SAFEGUARDS	M	S	M	S	S	S	S
4	NUCLEAR FUEL CYCLE	S	M	M	M	S	M	M
5	SHIELDING	H	H	H	H	S	S	S
6	CRITICALITY	H	H	H	H	S	S	S
7	HEALTH PHYSICS	H	H	H	H	S	S	S
8	FUEL HANDLING AND TRANSPORTATION	S	M	M	M	S	S	M
9	REMOTE HANDLING			H	H			
10	DECOMMISSIONING OF NUCLEAR POWER PLANTS			H	H	H	S	M
11	ENVIRONMENTAL ASPECTS OF THE FUEL CYCLE	M	M	S	S	S		
12	UPDATE OF ENERGY PROGRAMS	H	H	H	H	H	M	M
13	INTERACTION OF NUCLEAR TECHNOLOGY AND PUBLIC POLICY	H	H	H	H	H	H	H
14	REACTOR SAFETY							
	a. INTRODUCTION TO REACTOR SAFETY	H	H	H	H	H	H	H
	b. NUCLEAR POWER REACTOR SAFETY		M	H	H	M	S	H
15	FIRE PROTECTION FOR NUCLEAR REACTORS		M	H	H	M	M	H
16	NUCLEAR FUEL MANAGEMENT	S	S	M	S	S	S	H
17	POWER COMPANY ECONOMICS	S	S	S	S	S	M	M
18	ELECTRONIC INSTRUMENTATION FOR NUCLEAR APPLICATIONS	M	M		H	H	M	H
19	ELECTRICAL ENGINEERING FOR NON-ELECTRICAL ENGINEERS			H	H	M		
20	STRUCTURED DESIGN OF COMPUTER SOFTWARE	S	M		M	M	S	H
21	PRACTICAL STATISTICS FOR NUCLEAR ENGINEERS	M	H	H			S	M
22	SYSTEM RELIABILITY ANALYSIS APPLICATIONS	M		H				
23	FAULT TREE ANALYSIS	M		H				
24	RADIATION EFFECTS ON MATERIALS			H	H	H		M
25	BASIC CONCEPTS OF CORROSION	H	H	H	H		H	M
26	WELDING METALLURGY, INSPECTION, AND DEFECT CONTROL		H	H	H			M
27	WELDING PROCESSES AND WELDING DESIGN			H	H			M
28	DESIGN AGAINST MECHANICAL FAILURE							
	a. PROCEDURES FOR DESIGN AGAINST FATIGUE			H	H		H	H
	b. FRACTURE MECH. APPROACH TO DESIGN AGAINST FATIGUE			H	H		H	H
	c. ANALYSIS OF MECHANICAL FAILURES			H	H		H	H
	d. STRESS ANALYSIS USING FINITE ELEMENT METHODS			H	H			H
29	METALLURGY OF STAINLESS STEEL AND NICKEL-BASE ALLOYS		H	H	H		S	M
30	HYDRAULICS AND FLUID MACHINERY	S	S	H	H	S	H	H
31	PRESSURE VESSEL AND PIPING CODES							
	a. ASME CODES - FAILURE MODES			H	H		H	H
	b. PRESSURE VESSEL DESIGN			H	H		S	H
	c. PIPING ANALYSIS			H	M		S	H
32	PROJECT ENGINEERING	S	S	H	M	M	M	H
33	TECHNICAL MANAGEMENT	S	S	H	M	M	M	M
34	TECHNICAL COMMUNICATIONS	S	S	M	S	M	M	M
35	PROCESS DESIGN & ANALYSIS FOR NUCLEAR FUEL REPRO.	M	S	H	H	S	S	M
36	CHEMICAL PROCESS DESIGN AGAINST ACCIDENTS	S	S	M	S	S		
PROFESSIONAL STAFF		55	50	<1000	500	150	240	450

FIG. 5. SUBJECT AREAS IDENTIFIED DURING THE STUDY - LEVEL OF INTEREST AT VARIOUS LOCATIONS IDENTIFIED AS:

H - HIGH

M - MEDIUM

S - SPECIALIZED

experience. An educational effort, therefore, should be expected which does not place too much of an emphasis on the basic technology of the nuclear fuel cycle. Rather, the program content should reflect the needs of individuals who are already at the frontiers of their technology. The list in Fig. 5 also contains many subjects which are common to the needs of professional practice in engineering in general. However, the list has been compiled directly from survey results. Taken as a whole, it is unique to the region's nuclear industry.

Fig. 5 also contains information regarding the level of interest as a function of location. The designations used are H for high, M for medium, and S for specialized. A designation H indicates that a relatively large number of persons at that location have an interest in the subject. The designation M suggests that a somewhat smaller number of persons would have an interest. Likewise, the designation S indicates an interest level which is relatively small. The subject of criticality, for example, is expected to be of interest to a considerable number of the persons working at Oak Ridge National Laboratory and Savannah River Laboratory whereas considerably fewer persons would have an interest at the power companies. The designation S may be interpreted either as a small level of interest or reflect a highly specialized area of interest at a given location where only a few highly skilled individuals are involved. Safeguards is an example of a technology which is handled by a few select persons at each site.

Once again, the point should be made that the various locations identified in Fig. 5 are those at which extensive interviews were conducted during the course of the study. Contacts made at other locations indicate that the list of subject areas should be consistent throughout

the Southeast. In the last row of Fig. 5, information is provided which gives some indication of the size of the regional professional community which is involved in work which is nuclear related. The number of professionals given are only for those locations identified in the Figure. Additional professional manpower is also at work at other locations throughout the Southeast as identified in Fig. 1. The numbers in Fig. 5 do, however, show that a base population of professionals does exist in the Southeast which is of a size sufficient to support an educational program provided that the program is consistent with the needs of the region's industry.

C. Course Descriptions and Reference Materials

Course descriptions have been prepared relative to each of the subject areas identified in Fig. 5 and are included in Appendix B. These course descriptions were prepared as "free standing" documents and may be removed and used independent of the report. They are arranged in a common format and provide the following information:

Course Description

Course Objectives

Prerequisites

Course Outline

Course Format

The course descriptions are numbered and keyed to the subject areas listed in Fig. 5. Contained in Appendix C are lists of reference materials researched and considered to be appropriate background to the development of an educational effort within a particular subject area.

The course descriptions and lists of reference materials were developed

with considerable input from practicing engineers and scientists, many of whom are recognized experts in their respective fields. As a result, many of the course descriptions will show a departure from the traditional. Likewise, the suggested reference materials were, in most cases, not intended to be exhaustive lists. Rather these materials were selected to best support the specific objectives and course outlines of the individual course descriptions. The information provided in Appendices B and C together with Fig. 5 represents the interests and needs of engineers and scientists working in the Southeast's nuclear community as they themselves have expressed it.

III. ADVANCED PROFESSIONAL EDUCATION AND ENGINEERING IN THE NUCLEAR INDUSTRY

In looking at the educational needs of engineers in the nuclear industry, the utilities, and government, the impression is that not only is the content of an advanced educational program in engineering important, but so is the method. This relationship is interdependent and vital to the effectiveness of any advanced level program of education. Contained in this section is an overview of some findings and thoughts about engineering education gained from extensive interviews with a cross section of practicing engineers in the nation's Southeastern nuclear energy community.

Perhaps one of the most important findings (which is necessary for program implementation) is an attitudinal one gained by the faculty project team itself in realizing that the team's end purpose in this effort would be to build a unique educational program . . . "to help other adults (engineers) learn; and to help them learn what they want to learn in their field of engineering." Without this basic attitude, a program of advanced professional education would sooner or later falter through its own myopia. It would lay victim to the specialized teaching interests of a more research-oriented faculty, rather than grow in the educational interests of the participants (the advanced level engineer in the nuclear industry).

It has often been said that there are three types of people who are involved in post-baccalaureate engineering education . . . "the engineer (participant) who needs the education; the faculty member who facilitates the educational process; and the engineering employer who needs the engineer." All three of these people are key to the process, and any one of them can impede its occurrence. Much has been learned across the conference table during the survey, and interesting insight has been gained into all three groups. It is these findings

that are presented next.

A. The Practicing Engineer Viewpoint

While much has been written in the educational literature about practicing engineers and their preferences for continued education, there is perhaps no better way for a faculty project team to learn of these needs than to talk with practicing engineers on a "first hand" basis.

That is just what was done. Some typical thoughts and comments of practicing engineers are as follows:

- (a) Convenience and availability of the educational program will be a prime factor and will be key to the success and continuation of such an effort. Even though some post-baccalaureate courses presently exist, many are simply not available or convenient to the practicing engineer.
- (b) The educational method should try to overcome time, travel, and location limitations which might constrain participants.
- (c) The method should be conducive to how adults learn.
- (d) The courses should be presented in a clear and concise manner.
- (e) The faculty should be enthusiastic and know what they are talking about.
- (f) The courses must be current and at the state-of-the-art.
- (g) The courses should be repeatable, i.e., available to other participants at a future date.
- (h) Certain courses should be broad-brush, while others should be highly technical, dependent upon the level and interests of the participants. All courses should not try to cover the needs

of all types of participants, but they should be geared to the needs of specific participants. The method of education should also vary and should be dependent upon the specific levels and interests of the participants, e.g., the method should be relative to the participant's level, goals, and job roles.

- (i) Courses should run the spectrum from updating, to upgrading, to pushing the present state-of-the-art for both specialists and generalists.
- (j) Program participants must see ultimate and immediate benefits, and consequently the courses must extend the knowledge and skills that the participants already have.
- (k) The program should support the needs of the engineer in his or her present job. Engineers want to learn what they can apply immediately or in the near future.
- (l) There should be an adequate return versus effort ratio for the participants. Is the material relevant to the engineer's needs? Is the education important to the engineer? Is it considered to be important by management? What does the engineer get out of it? Will the participant get time off or at least given some time to attend or participate in the program? If the program is successful and the participants gain in professional development, would this eventually lead to promotions or salary increases?
- (m) Engineers are open to any methods of advanced professional education that will help them to learn and to continue their own individual development. This would include video-cassettes

with or without talk back; audio cassettes; traveling instructors (on-site instructions); short courses; seminars; semester length courses; self-study with books or lecture notes; workshops; etc. The packaging of course work into useable "chunks" or modules was encouraged, and the one-credit hour module idea received much enthusiasm. The pacing item is relevant education that produces results, i.e., effective learning and development on a convenient basis.

- (n) Most practicing engineers would not take courses just to get grades. However, credit for these courses would be important to many of them.
- (o) Many practicing engineers would be interested in a degree program if the educational method and content were improved. A degree means recognition and certification at that level.
- (p) The program should not be considered as a fringe benefit by management, but as an investment. This feeling must be extended to include released time for relevant education. Engineers feel that some managements do not back up all of their claims for professional development.
- (q) Practicing engineers would place more faith on an educational program if it included a mix of resident and adjunct professors from the university and industry rather than for a university to try to do all of it by itself. Such a program would utilize the practical industrial experience of the faculty and also real world case histories if needed.
- (r) Engineering-management is not placing as much emphasis as it should on professional growth and development. Not enough money

is invested for short courses and seminars. Engineering employees are presently reimbursed for graduate course work through tuition reimbursement policies which seldom extend to the same amount for short courses, etc.

- (s) Courses should be an opportunity to learn and not just be graded. Credit for courses should be optional.
- (t) The titles of course subjects should be livened up a bit, and they should not be misleading.
- (u) The availability of prepared course notes would be beneficial to learning.
- (v) Courses should be kept practical or aimed at the applied rather than merely in the theoretical realm.
- (w) Management's attitude is not to encourage or discourage advanced education. (This was unique to one group.) Employees must feel that management considers education to be worthwhile. Employees will always ask, "What will I get out of it?" Employers should arrange for either time off to take a course, or the course should be available at the work-site so that the employees can take the course after hours. At least some arrangements could be made to take courses on part employer's time and part employee's time.

B. The Faculty Viewpoint

Some typical comments and thoughts of the resident and adjunct faculty are as follows:

- (a) An advanced professional educational program would be an excellent way for the faculty to interact with industry. It

would reflect both in teaching and in industrial research opportunities.

- (b) A resident faculty cannot try to cover all of the material themselves, and it would be a good idea, therefore, to utilize the adjunct faculty concept. Some courses could be taught by resident faculty, some by adjunct faculty, and some by a team of adjunct and resident faculty.
- (c) Adjunct faculty, if handpicked, are just as good and sometimes better than resident faculty.
- (d) Just as with the practicing engineers, the faculty usually asks, "What will I get out of this program? What does the Dean, Provost, or President think of the concept? Will it count toward my tenure? Is it a worthwhile endeavor? Is it in my interest? Will the program help my own professional growth as an engineer-teacher and applied researcher?"
- (e) A part of the faculty is simply not interested in this concept and would rather do basic research rather than focus in engineering practice.

C. The Engineering Employer Viewpoint

Some typical viewpoints of several management groups are as follows:

- (a) Engineering-management would favor an educational endeavor that would help engineers to grow and develop to enable them to perform their present jobs better/to prepare them for increased responsibilities. Engineering-managers are also engineers and would look forward to a program that would also help them grow and develop.

- (b) Management is always searching for better ways (or should be) to help their employees grow and develop. They are not locked into existing in-house programs or to on-going university programs. They will always switch to a better opportunity.
- (c) There are many existing graduate programs that are not relevant to engineering practice and are, therefore, considered as fringe benefits.
- (d) Some existing continuing engineering programs that use video cassettes are too expensive, and the topics they cover are not relevant to work being done in industry. Many of these programs appear to be in the interest of the university faculty rather than in the interest of the participating students/employees.
- (e) The use of video cassettes is a good idea and certainly the direction of education in the near future. Audio cassettes may also be a useful method.
- (f) Engineering-management is interested in quality courses and not in the "traveling road show" type method that is occurring across the nation. They view "credit" as a matter of quality control on the part of the faculty to insure a high standard of educational content and method.
- (g) Engineering management does not want employees to abuse their educational policies. However, they will support employees to the hilt to take advantage of these policies if the employees are sincere in learning and want to participate in worthwhile programs.

- (h) Self-study should not be overlooked as an effective learning method.
- (i) Courses must be convenient for employees to learn, and must be supportive to the job's schedule and constraints. The job is first and education second, although there is an interdependence if the program is good.
- (j) There will be more participation in courses if engineers have easy access to the material and can avoid the inconvenience of traveling to distant classes, short courses, or seminars.
- (k) The feeling toward education is one and the same with the feeling toward professional growth. It should occur and should be supported. (This feeling was not unanimous, but it was in the majority.)
- (l) Engineering managers should play a strong role in diagnosing educational needs and formulating an educational program because they are also guiding and planning the organization's future technology and growth. Perhaps it is a dual responsibility of individual engineer and management to sit down together in the planning of professional development. (However, neither one of these two has adequate time to do this job properly.)
- (m) Teaching adults (practicing engineers) is different from teaching undergraduates. In general, any course involving usual presentation of material is less than effective if it does not involve a maximum of discussion (of the free and loose variety). This could occur between faculty and participants, or between participants and participants. It was suggested that a "rap" session could occur every three lectures.

- (n) Don't forget that learning also occurs on-the-job, and people don't necessarily stop learning after they have graduated from college.

IV. GUIDELINES FOR IMPLEMENTATION

Previous sections of this report have described the content of an educational program consistent with the needs of engineers who work in the nuclear industry throughout the southeastern United States. Features of such a program which would make it effectively more attractive and useful have also been described. Altogether, this information provides a starting point for an educational program based on well defined needs and in support of growth within the region's nuclear industry. In this section, recommendations are made regarding implementation of the program.

A. Program Implementation

Included in this report is sufficient information to initiate development of an educational program based largely on input from those who would be users of the program. The number of professionals working in the Southeast's nuclear industry has been described earlier in the report and is sufficient to support an educational program. It is recommended, therefore, that implementation of a program be initiated as a natural follow-on to the work which has already been done.

B. Level of Effort

Earlier in this report, more than 40 subject areas were presented as consistent with the educational needs of the region's nuclear community. It would be unwise, however, to undertake immediate implementation of the complete list. It is recommended instead that a modest effort of 6-10 educational packages be undertaken as an initial step toward implementation. Although there is a large number of professionals in nuclear related areas throughout the Southeast, it is unlikely that the numbers

are sufficient to support 40 or more subject areas per year. Even more important, however, is the potential for a loss of quality which might occur in a rush to implement a program which is too large. A program of from 6-10 educational packages is much more realistic and stands a much better chance of success.

C. Continued Assessment of Educational Needs

The nuclear industry as with any pioneering technology is constantly in a process of change and growth. From the standpoint of development of an education program focusing on the practicing professional, the industry presents a moving target. In this light, the list of subjects in Fig. 4 represents an assessment of needs as they exist right now. If the educational effort is to continue to be successful, these needs should be continuously scrutinized and reviewed from time to time. This aspect of updating the needs analysis goes hand-in-hand with implementation. The process of preparing and delivering an educational program involves repeated contact with engineers throughout the industry. An active part of the agenda should always be continued update of the needs analysis initiated with this report.

D. Experiment in the Nation

This study focused on the Southeast as a target area. It is recommended that the implementation phase continue the same focus. The success of the educational program will be greater if initially undertaken as a modest, low-key effort, reasonably available to those who would take part, and operated by a community of industry, government, and the university, all of whom have an awareness of each other's missions and roles. The intent would be to foster a spirit of cooperation based

on a mutual concern for technological growth and well-being. In a time of large nationwide programs, this concept is unique and serves as an experiment in the nation. If successful, then consideration should be given to similar such programs within other regional concentrations of industry.

APPENDIX A

RECORD OF VISITS UNDERTAKEN DURING THE PROJECT

1. Allied General Nuclear Services, Barnwell, South Carolina, on October 21, 1977. Huhns, M., Jur, T., Keating, D., and Stanford, T. To discuss program with representatives of plant management.
2. South Carolina Electric & Gas, Columbia, South Carolina, on October 26, 1977. Jur, T., Keating, D., and Orloff, D. To discuss program with upper management.
3. E. I. du Pont de Nemours & Company, Savannah River Laboratory on November 1, 1977. Jur, T., Keating, D., and Van Brunt, V. To review program plan with Mr. Paul Roggenkamp of the Advanced Operational Planning Division.
4. Duke Power Company, Charlotte, North Carolina, on Friday, November 4, 1977. Jur, T., Keating, D., Orloff, D., and Stanford, T. To discuss program with engineering management.
5. South Carolina Electric & Gas, Columbia, South Carolina, on November 8, 1977. Jur, T., Keating, D., and Orloff, D. To begin identifying areas of interaction with representatives of the engineering department.
6. DOE, Savannah River Operations Office, on November 15, 1977. Jur, T., Keating, D., Orloff, D., and Stephens, L. To discuss program with representatives of management.
7. E. I. du Pont de Nemours & Company, SRL and SRP on November 15, 1977. Jur, T., Keating, D., Orloff, D., and Stephens, L. To meet with representatives of the University Relations Office (SRL) and Personnel Office (SRP) and discuss the program.
8. Westinghouse Fuel Fabrication Plant, Columbia, South Carolina, on November 16, 1977. Jur, T. To discuss program with plant management.
9. South Carolina Electric & Gas, Columbia, South Carolina, on November 21, 1977. Stephens, L. To discuss licensing and regulation requirements.
10. E. I. du Pont de Nemours & Company, SRL and SRP on December 12, 1977. Jur, T., Keating, D., Orloff, D., and Stephens, L. To meet with representatives of the University Relations Office (SRL) and Personnel Office (SRP) to discuss mechanisms of contacting the professional staff at the Savannah River facilities.
11. Carolina Power & Light, Raleigh, North Carolina, on December 14, 1977. Jur, T., Keating, D., Orloff, D., and Rhodes, C. To discuss the program with upper management.

12. Westinghouse Fuel Fabrication Plant, Columbia, South Carolina, on December 15, 1977. Jur, T., Keating, D., Stephens, L., and Van Brunt, V. To further discuss the program and designated contact - the personnel manager.
13. Allied General Nuclear Services, Barnwell, South Carolina, on December 22, 1977. Stephens, L. To discuss licensing and regulation requirements.
14. Duke Power Company, Charlotte, North Carolina, on January 12, 1978. Jur, T., Huhns, M., Keating, D., Orloff, D., and Stephens, L. To meet with a large group of managers and engineers from design engineering and steam production.
15. Oak Ridge National Laboratory, Oak Ridge, Tennessee, on January 19, 1978. Jur, T., Keating, D., Stanford, T., and Van Brunt, V. To discuss program with representatives of lab management.
16. South Carolina Electric and Gas Company, Columbia, South Carolina, on January 26, 1978. Jur, T., Orloff, D., and Stephens, L. To meet with members of engineering staff to discuss educational needs and company organization.
17. Department of Energy, Savannah River Office, Aiken, South Carolina, on February 2, 1978. To discuss program with representatives of SRO management.
18. E. I. du Pont de Nemours & Company, SRL and SRP, on February 2, 1978. Huhns, M., Jur, T., Keating, D., Orloff, D., Stanford, T., Van Brunt, V. To meet with a large group of managers from SRL and SRP to discuss the program.
19. Duke Power Company, Charlotte, North Carolina, on February 9, 1978. Jur, T. To meet with engineering manager from the Mechanical Design Section of Design Engineering.
20. Duke Power Company, Charlotte, North Carolina, on February 9, 1978. Huhns, M., and Stephens, L. To meet with persons from Design Engineering (Electrical Division).
21. E. I. du Pont de Nemours & Company, SRL, on February 10, 1978. Orloff, D. To meet with representatives of Reactor Engineering and Environmental Effects to discuss educational needs and instructional expertise at SRL.
22. E. I. du Pont de Nemours & Company, SRP, on February 13, 1978. Keating, D. and Orloff, D. To identify educational needs and further contacts within SRP.
23. Westinghouse Fuel Fabrication Plant, Columbia, South Carolina, on February 15, 1978. Tatterson, G. and Van Brunt, V.

To discuss educational needs with representatives of Chemical Operations and Chemical Process Engineering.

24. Nuclear Regulatory Commission, Region II Office, Atlanta, Georgia, on February 16, 1978. Stephens, L. To discuss the project and to solicit NRC input in educational matters concerning regulatory activities.
25. Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, on February 16, 1978. Jur, T., Stanford, T. and Van Brunt, V. To introduce project to management.
26. South Carolina Electric and Gas Company, Columbia, South Carolina, on February 21. Stephens, L. To discuss in-core fuel management.
27. Duke Power Company, Charlotte, North Carolina, on February 22, 1978. Orloff, D. and Rhodes, C. To meet with persons from the Design Engineering (Fluid Systems and Environmental Sections) and Steam Production (Training Services).
28. Allied General Nuclear Services, Barnwell, South Carolina, on February 24, 1978. Stanford, T. and Tatterson, G. To discuss educational needs in the area of instrumentation and process control.
29. Southern Company Services, Birmingham, Alabama, on February 24, 1978. Jur, T. To discuss education needs in area of fuel procurement and management.
30. Duke Power Company, Charlotte, North Carolina, on March 4, 1978. Stephens, L. To meet with a member of the Design Engineering Division to discuss in-core fuel management.
31. Oak Ridge Associated Universities, Oak Ridge, Tennessee, on March 9, 1978. Keating, D. and Orloff, D. To explain the purpose and scope of project and to discuss areas of mutual interest and interaction.
32. Oak Ridge National Laboratory, Oak Ridge, Tennessee on March 9, 1978. Keating, D. and Orloff, D. To identify advanced professional needs within ORNL in mechanical engineering areas.
33. Georgia Tech Conference on Nuclear Power Safety March 14-16, 1978. Stephens, L.
34. Meeting - Back End of the LWR Fuel Cycle, Savannah Georgia, March 19-23. Orloff, D., Tatterson, G., Van Brunt, V.

35. E. I. du Pont de Nemours & Company, SRP on March 30, 1978. Jur, T. and Orloff, D. To meet with representatives of the Project Engineering Department to discuss education needs.
36. E. I. du Pont de Nemours & Company, SRL on March 30, 1978. Jur, T. and Orloff, D. To meet with representatives of Reactor Engineering to identify education needs and instructional expertise at SRL.
37. Carolina Power and Light, Raleigh, North Carolina on April 5, 1978. Keating, D., Orloff, D., and Rhodes, C. To discuss educational needs with representatives of engineering.
38. Oak Ridge National Laboratory, Oak Ridge, Tennessee, on April 11, 1978. Keating, D., Jur, T., Orloff, D., and Rhodes, C. To discuss project objectives with management of the Advanced Fuel Recycle Program.
39. Westinghouse Fuel Fabrication Plant, Columbia, South Carolina on April 17, 1978. Stephens, L. To discuss quality assurance educational requirements.
40. Oak Ridge National Laboratory, Oak Ridge, Tennessee on April 11, 1978. Stanford, T., Tatterson, G., and Van Brunt, V. To discuss educational needs with representatives of various chemical engineering departments.
41. Savannah River Plant, Aiken, South Carolina on April 27, 1978. Huhns, M. and Stephens, L. To discuss educational needs in the electrical engineering area.
42. Savannah River Laboratory, Aiken, South Carolina on May 16, 1978. Stanford, T., Tatterson, G., and Van Brunt, V. To discuss educational needs in chemical engineering related areas.
43. Savannah River Plant, Aiken, South Carolina on May 16, 1978. Stanford, T., Tatterson, G., and Van Brunt, V. To discuss educational needs in chemical engineering related areas.
44. Electric Power Research Institute, Palo Alto, California on May 23, 1978. Keating, D. and Orloff, D. To discuss the program and its objective with representatives of management.
45. Savannah River Laboratory, Aiken, South Carolina on May 24, 1978. Huhns, M. and Stephens, L. To discuss educational needs in the electrical engineering area.
46. Savannah River Laboratory, Aiken, South Carolina on May 30, 1978. Tatterson, G. To discuss educational needs in chemical engineering related areas.
47. Oak Ridge National Laboratory, Oak Ridge, Tennessee on June 1, 1978. Jur, T., Orloff, D., and Rhodes, C. To discuss educational needs with representatives of Engineering Technology Division.

48. Oak Ridge National Laboratories, Oak Ridge, Tennessee on June 1, 1978. Jur, T., Orloff, D., and Rhodes, C. To discuss in-house educational programs at ORNL with George Moore who heads that activity.
49. Oak Ridge National Laboratory, Oak Ridge, Tennessee on June 1, 1978. Jur, T., Orloff, D., and Rhodes, C. To discuss educational needs in Materials and Ceramics Division with J. Cunningham, Associate Director.
50. South Carolina Electric & Gas, Columbia, South Carolina on June 1, 1978. Stephens, L. and Huhns, M. To discuss instrumentation and structured computer programming interests.
51. Savannah River Plant, Aiken, South Carolina on June 8, 1978. Huhns, M. and Stephens, L. To discuss educational needs in electrical engineering related areas.
52. Savannah River Laboratory, Aiken, South Carolina on June 14, 1978. Jur, T. To discuss content of courses in system reliability and fault tree analysis with E. Nomm.
53. Oak Ridge National Laboratory, Oak Ridge, Tennessee on June 16, 1978. Jur, T. To discuss content of courses in pressure vessel and piping design with J. Corum of the Engineering & Technology Division.
54. Southern Company Services, Atlanta, Georgia on June 26, 1978. Jur, T. To discuss project objectives and educational needs with representatives of the professional development department.
55. Visit by consultant and seminar speaker to Columbia, South Carolina on June 28, 1978. Professor Thomas Eaton from the University of Kentucky to speak on the subject of fuel management and to consult on same subject with L. Stephens.
56. South Carolina Electric & Gas Company, Columbia, South Carolina on July 7, 1978. Stephens, L. To discuss quality assurance educational requirements.
57. Tennessee Valley Authority, Knoxville, Tennessee on July 19, 1978. Jur, T. To discuss extension of current USC course offerings to engineers at TVA.
58. Oak Ridge National Laboratory, Oak Ridge, Tennessee on July 19, 1978. Jur, T. To discuss extension of current USC course offerings to staff at ORNL.
59. Radiation Safety in Non-Destructive Testing Topical Conference, San Francisco, California, July 30 - August 3, 1978. Stanford, T. and Tatterson, G.
60. 15th DOE Air Cleaning Conference, Boston, Massachusetts on August 7-11, 1978. Van Brunt, V. To assess educational needs in area of off-gas processing.

61. Oak Ridge National Laboratory, Oak Ridge, Tennessee on September 6, 1978. Van Brunt, V. To discuss course content and educational needs in areas of radiation effects on solid materials and quality assurance.
62. Visit by consultant to Columbia, South Carolina on September 9, 1978. Karl Seidle to consult with T. Jur on subject of ASME Boiler and Pressure Vessel Codes.
63. Joint Power Generation Conference, Dallas, Texas, September 11-14, 1978. Orloff, D. and Rhodes C.

APPENDIX B
COURSE DESCRIPTIONS

1. LICENSING OF NUCLEAR FACILITIES

- I. Course Description: An overview of the procedures and regulations required for licensing nuclear facilities with emphasis on licensing of commercial power plants.
- II. Course Objectives: The course will provide the engineer with a basic understanding of the complex licensing process.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Regulatory requirements
 - 1. Brief history of the regulatory process and agencies (Atomic Energy Act, Price-Anderson Act, Atomic Energy Commission, Nuclear Regulatory Commission, Department of Energy, Environmental Protection Agency, etc.)
 - 2. Differences between licensing requirements for nuclear vs. coal plants
 - 3. Code of federal regulations
 - 4. NRC regulatory guides
 - 5. Other NRC documents
 - 6. Difference between federal and state laws
 - B. Role and function of regulatory agencies
 - 1. Nuclear regulatory commission
 - a. standards setting and rule making
 - b. technical reviews and studies
 - c. action on license applications
 - d. surveillance and enforcement
 - e. evaluation of operation experience
 - f. confirmatory research
 - 2. Environmental protection agency
 - 3. State and local agencies
 - C. The licensing process for nuclear power plants
 - 1. Review process for construction permit or limited work authorization
 - a. safety aspects
 - i. preliminary safety analysis report (licensee)
 - ii. safety evaluation report (NRC)
 - iii. review by advisory committee on reactor safeguards (NRC)

- iv. public hearings conducted by Atomic Safety and Licensing Board
 - v. intervenor actions and consequences
 - b. environmental aspects
 - i. environmental report (licensee)
 - ii. draft environmental statement (regulatory agencies)
 - iii. public hearing conducted by Atomic Safety Licensing Board
 - iv. final environmental statement
 - 2. Operating license review process (similar to construction permit process)
 - a. final safety analysis report (licensee)
 - b. safety evaluation report for operation (regulatory agencies)
 - D. Generic licensing
 - E. Case study of the entire licensing process for a given plant
- V. Course Format: This material could be presented as part of an introductory course in nuclear engineering or as a one day seminar. Prepared course notes could be used.

2. QUALITY ASSURANCE FOR NUCLEAR FACILITIES

- I. Course Description: This course presents an overview of quality assurance requirements for nuclear power plants. This will be discussed primarily in the framework of the requirements of Appendix B, Code of Federal Legislation, Title 10, Part 50, and ANSI N45.2. ASME, IEEE and other standards can be covered as required.
- II. Course Objectives: This course will provide an introductory level understanding of quality assurance requirements and is intended for all engineers working in nuclear related areas.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Quality assurance for major design/construction phases
 - 1. Difference between quality assurance and quality control
 - 2. Design and procurement stage
 - 3. Construction stage
 - 4. Pre-operational and initial startup stage
 - 5. Operational stage
 - B. Federal regulations for quality assurance (Appendix B)
 - 1. Organization
 - 2. Quality assurance program
 - 3. Design control
 - 4. Procurement document control
 - 5. Instruction procedures and drawings
 - 6. Document control
 - 7. Control of purchased material, equipment, and services
 - 8. Identification and control of materials, parts, and components
 - 9. Control of special processes
 - 10. Inspection
 - 11. Test control
 - 12. Control of measuring and test equipment
 - 13. Handling, storage, and shipping
 - 14. Inspection, test, and operating status
 - 15. Non-conforming materials, parts, or components
 - 16. Corrective action

17. Quality assurance records

18. Audits

C. Reporting deficiencies to NRC

D. Role and function of NRC in quality assurance

E. Implementation of quality assurance programs

F. Current controversial issues

V. Course Format: This course could best be presented as a one day short course using prepared course notes.

3. SAFEGUARDS

- I. Course Description: A review of the measures that may be employed to prevent theft and diversion of special nuclear materials and the sabotage of nuclear facilities.
- II. Course Objectives: Familiarize those working in the nuclear industry with the safeguard problems, regulations, and licensing requirements.
- III. Prerequisite: An undergraduate degree
- IV. Course Outline:
 - A. Physical security measures at fixed sites
 - 1. Physical barriers and alarm systems
 - 2. Access control and admittance systems
 - 3. Containment mechanisms
 - 4. Active delaying systems
 - 5. Guard forces
 - 6. Communications
 - B. Security for special strategic nuclear materials (SSNM) in transit
 - 1. Transport vehicles
 - 2. Special material containers
 - 3. Escorts and convoys
 - 4. Shipment planning and control
 - 5. Response to attacks
 - C. Material control, accounting, and accountability
 - 1. Management control
 - 2. Custodial control
 - 3. Inventory control
 - 4. Accounting systems
 - 5. Personnel screening
 - 6. Collocation
 - 7. Modification of SSNM
 - a. spiking
 - b. blending
 - D. Current requirements for safeguarding SSNM
 - 1. Physical protection of fuel cycle facilities
 - 2. Physical protection of SSNM in transit
 - 3. Material control and accounting
 - 4. Implementation of safeguards requirements

- a. licensing
- b. inspection and enforcement
- c. experience in safeguarding SSNM

V. Course Format: This material could best be presented as a two day short course using prepared notes.

4. NUCLEAR FUEL CYCLE

- I. Course Description: An overview of the entire nuclear fuel cycle from mining to waste management including alternative process technologies. Discussion will include alternate fuel cycles, the effect of alternate fuels on process technology and process chemistry.
- II. Course Objectives: Familiarize the student with the chemistry and the process technology of the nuclear fuel cycle. He will be able to understand the overall fuel cycle and the relationship between each subprocess step to the overall cycle.
- III. Prerequisites: An undergraduate degree
- IV. Course Outline:
 - A. Introduction
 - 1. Resources - availability and limitations
 - 2. Alternate reactor cycles
 - a. LWR
 - b. gas cooled convertors HTGE
 - c. breeder reactor
 - i. LMFBR
 - ii. gas cooled breeders GCFBR
 - iii. LWBR
 - d. Heavy water reactors (i.e. CANDU)
 - 3. Alternate fuel cycles with and without recycle
 - a. U-Pu
 - b. U-Th
 - B. Mining and Milling
 - 1. Mining
 - 2. Milling
 - a. extraction
 - b. concentration and purification
 - c. product preparation
 - 3. Radioactivity released
 - 4. Low-grade ores
 - 5. Costs of reducing radiation doses

- C. Conversion of uranium concentrate to UF_6
 - 1. Processes
 - a. dry process
 - b. wet process
 - 2. Radioactivity released
 - a. dry process
 - b. wet process
 - 3. Costs of reducing radiation doses
- D. Uranium isotope separation
 - 1. Separation processes
 - a. gaseous diffusion
 - b. gas centrifugation
 - c. other methods
 - 2. Radioactivity released
 - 3. Doses to the public
- E. Fuel fabrication
 - 1. Processes
 - a. processes for enriched uranium
 - b. recycle fuel
 - c. cladding
 - 2. Radioactivity released
 - a. enriched uranium processes
 - b. recycle fuel
 - 3. Costs of reducing radiation doses
 - a. enriched uranium processes
 - b. recycle fuel processes
- F. Nuclear reactor technology
 - 1. LWR
 - a. PWR
 - b. BWR
 - 2. LMFBR
 - 3. HTGE
 - 4. Heavy water reactors
- G. Fuel reprocessing
 - 1. Nature of LWR fuel

2. Separations process
 - a. purex process
 - b. waste treatment
 - c. advanced method for specific isotopes
3. Fuel reprocessing plant
4. Radioactivity released
5. Costs of reducing radiation doses
- H. Transportation
 1. Uranium concentrate
 2. UF_6 to and from enrichment plants
 3. Fabricated fuel
 4. Spent fuel and reprocessing wastes
 - a. spent fuel
 - b. reprocessing wastes
 5. Relationship of shipping to siting
 6. Transportation accidents
- I. Waste management
 1. Sources of radioactive wastes
 - a. mills
 - b. fabrication plants
 - c. reprocessing plants
 - d. nuclear reactors
 2. Waste treatment
 - a. decay
 - b. solidification
 - c. partitioning of actinides
 3. Geologic isolation
 4. Other disposal options
 5. Radioactive release
 - a. dose levels
 - b. costs of reducing dose
- J. Licensing and safeguards
 1. Standards for release of radioactive materials from nuclear fuel cycles
 2. Standards for licensing non-irradiated fuel facilities
 3. Standards for licensing radiated fuel facilities

V. Course Format: This material can be presented as a three credit hour graduate/undergraduate course.

VI. Comments:

- A. A discussion will be given under each topic indicating the present and future adequacy of each particular area in view of anticipated expansion of nuclear power.
- B. This course material content is very ambitious even for a three hour credit course. Much discretion must be used in choosing the depth of treatment in each case.

5. SHIELDING

- I. Course Description: An overview of shielding including nuclear decay, radiation attenuation, dosimetry, shielding calculations and types.
- II. Course Objectives: The course is designed to provide the practicing engineer with an understanding of shielding design.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Design requirements and philosophy
 - B. Decay of nuclides
 - C. Kinds of radiation and energy levels
 - D. Penetration depths and range
 - E. Attenuation of gamma rays by distance and material
 - 1. Linear or mass attenuation coefficient
 - 2. Energy absorption linear attenuation
 - F. High gamma energies, Compton scattering and build-up
 - G. Geometry and strength of source
 - 1. Sample calculations
 - H. Physical radiation dose and relative biological effectiveness
 - I. Health physics terms
 - J. Approximate shielding calculations
 - 1. Point source
 - 2. Distributed source
 - K. Detailed shielding calculations (overview)
 - 1. Boltzmann equation
 - 2. Monte Carlo method
 - 3. method of moments
 - 4. method of successive scattering
 - L. Shield types
 - 1. Homogeneous
 - 2. Laminated shields
 - M. Shield quality
 - N. Shield heating
 - O. Shield contamination and decontamination

P. Other considerations

1. Bremsstrahlung radiation
2. Skyshine and air shine
3. Self-shielding or absorption

Q. Undertainties in shielding calculations

R. Shielding problems, engineering decisions, and case histories

S. NRC Regulatory Guide 8.8 and "As Low As Reasonably Achievable" (ALARA)

T. Shield Design

1. Cost versus benefit
2. Regulations
3. Maintenance considerations

- V. Course Format: If treated as a survey course only, the course could be delivered in three full days. For more intensive coverage, five days with some time between days for individual study would be required. Prepared course notes would be used to present the material.

6. CRITICALITY

- I. Course Description: An overview of the aspects of Criticality including Reaction Theory, Shielding, Criticality Measurements and Experiments, Criticality Prevention, Accident Scenarios, Dose Modeling, and Case Histories.
- II. Course Objectives: The course will provide the practicing design and operations engineer with the aspects of criticality, criticality prevention, and application of criticality applications.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Chain reactor theory and neutron generation
 - B. Available experimental data
 - C. Experiments in simulated process vessels and materials
 - D. Shielding and other neutron absorption
 - E. Heat release and supercriticality
 - F. Criticality measurements
 - G. Design revision due to criticality
 - H. Factors affecting criticality
 - 1. Neutron number produced per fission
 - 2. Critical mass and mass size
 - 3. Size and shape of fissionable material
 - 4. Moderation
 - 5. Neutron reflection
 - 6. Poisoning
 - 7. Dilution
 - I. Process vessel interaction
 - J. Criticality control and prevention
 - 1. Procedural or administrative control
 - 2. Mass limitations
 - 3. Geometry limitations
 - 4. Concentration limitations
 - 5. Poisoning criteria
 - 6. Combinations of limitations
 - K. Development of accident scenarios
 - L. Safety limits and allowances factors

- M. Standards and nuclear regulatory guides
- N. Practical considerations in criticality design
- O. Practical operating procedures in criticality processing
- P. Dose modeling
- Q. Detailed criticality calculation techniques
- R. Hand criticality calculations techniques
 - 1. Solid angle array calculations
 - 2. Surface density and critical thickness calculations
 - 3. Density analog calculations
- S. Interpretation and application of criticality calculations in the plant
- T. Case histories of criticality accidents

- V. Course Format: If survey only, the course could be delivered in three full days. For more intensive coverage, allow five days with some time between days for individual study. Most information will be contained in prepared course notes.

7. HEALTH PHYSICS

- I. Course Description: An overview of health physics including radiation detection, biological and environment aspects, dosimetry, and nuclear medicine.
- II. Course Objectives: The course is designed for the practicing engineer and is to provide him with an understanding of health physics in general.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Radioactivity and decay mechanisms
 - B. Radiation and detection instrumentation with statistics
 - C. Biological effects and models
 - D. Environmental effects and models
 - E. Radiation dosimetry and exposure evaluation
 - F. Toxicology of radioactive materials
 - G. Nuclear medicine and body protection
 - H. Radiation injury and case histories
 - I. Radiation protection guides
 - J. Dose Reduction
 - 1. Simple methods of shielding
 - 2. Cost and benefits
 - K. Health studies and surveys
 - L. ALARA "As Low As Reasonably Achievable"
 - M. Education of general public
- V. Course Format: The course could be delivered in three full days. Prepared course notes are suggested.

8. FUEL HANDLING AND TRANSPORTATION

- I. Course Description: A review of spent fuel shipping cask design, spent fuel handling, and government regulations applicable to the handling and transportation of spent fuel.
- II. Course Objective: This course is intended to present the current studies of the equipment and regulations used in the handling and transportation of spent nuclear fuel.
- III. Prerequisite: An undergraduate engineering degree
- IV. Course Outline:
 - A. Light water reactor spent fuel shipping casks
 - 1. Structural requirements
 - 2. Shielding requirements
 - 3. Cooling systems
 - 4. NRC and DOT design regulations
 - 5. Description of available shipping containers
 - B. Fuel handling
 - 1. Loading and unloading fuel elements
 - 2. Radiation monitoring
 - 3. Decontamination of shipping cask
 - 4. Safety inspection
 - C. Transportation
 - 1. Transportation modes
 - a. trucks
 - b. railway
 - c. barge
 - 2. NRC and DOT regulations
 - 3. State and local regulations
 - 4. Security of transport vehicle
 - D. Environmental impact
 - 1. Radioactive emission
 - 2. Accident analysis
- V. Course Format: This course could best be presented as a two day short course using prepared course notes.

9. REMOTE HANDLING

- I. Course Description: A state-of-the-art overview of capabilities and advances in remote handling, involving visual sensors, tactile sensors, mechanical arms, automated assemblers, and robots.
- II. Course Objectives: To acquaint the practicing engineer with the capabilities of current remote handling technology.
- III. Prerequisites: A degree in electrical, nuclear, mechanical, or computer engineering.
- IV. Course Outline:
 - A. Introduction
 - B. Visual systems for remote handling
 - 1. Imaging devices
 - a. television cameras
 - b. X-ray scanners
 - c. gamma-ray scanners
 - d. infrared and ultraviolet cameras
 - 2. Stereo imaging
 - 3. Image enhancement
 - 4. Image analysis
 - a. object detection
 - b. object recognition
 - C. Tactile sensors for remote handling
 - D. Mechanical remote handlers
 - 1. Dynamics and linkages
 - 2. Control
 - E. Automated remote handling systems
 - 1. Artificial intelligence and computer control
 - 2. Software
- V. Course Format: The material could be best presented as a one-day short course.

10. DECOMMISSIONING OF NUCLEAR POWER PLANTS

- I. Course Description: This course will present environmental, economic, and technical issues relating to nuclear power plant decommissioning.
- II. Course Objectives: The course will acquaint engineers and engineering managers with the issues currently under review by the NRC which affect the licensing, planning, and cost estimation associated with plant decommissioning.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Current and projected decommissioning regulations
 - 1. Effect on current operation of existing reactors
 - 2. Status of current plans of utilities for decommissioning
 - B. Economics of decommissioning
 - 1. Cost estimation techniques
 - 2. Financing options
 - C. Plant design for decommissioning
 - 1. Documentation of reactor plant needed for decommissioning
 - 2. Design criteria for facilitating the decommissioning of nuclear facilities
 - D. Decommissioning technology/State of the art
 - 1. Cutting techniques and compatibility with reactor materials
 - 2. Fire safety during decommissioning
 - 3. Environmental safety during decommissioning
- V. Course Format: A workshop format consisting of invited papers, case studies, and discussion sessions is recommended.

11. ENVIRONMENTAL ASPECTS OF THE FUEL CYCLE

- I. Course Description: The radiological and toxicological effects of material at nuclear facilities is studied. The course includes the emission, monitoring, instrumentation, and environmental transport of hazardous materials.
- II. Course Objectives: This course is intended to present the practicing engineer or scientist with an overview of the environmental consideration in the nuclear fuel cycle.
- III. Prerequisites: An undergraduate engineering or science degree.
- IV. Course Outline:
 - A. Review of health physics
 - 1. Radiological hazards
 - a. types of radiation
 - b. dose level terms
 - c. biological effects of ionizing radiation
 - (1) whole body
 - (2) critical organs
 - 2. Toxicity
 - a. exposure limits
 - b. biological effects
 - B. Limits and isotopic emission from nuclear facilities
 - 1. Mining
 - 2. Enrichment
 - 3. Fuel fabrication plants
 - 4. Reactor plants
 - 5. Reprocessing plants
 - 6. Low and high level waste storage facilities
 - C. Transport of radioactive and toxic materials in the environment
 - 1. Atomospheric dispersion of discharges
 - a. meteorological effects
 - b. gaussian plume diffusion model
 - c. the K-theory of diffusion
 - d. meteorological measurements
 - e. precipitation scavenging of particulates

- 2. Transport of radioactive and toxic materials in rivers and lakes
 - a. diffusion
 - b. ecological transport
- 3. Transport of radioactive and toxic materials in plants and soil
- D. Radiation monitoring instrumentation
 - 1. Electromagnetic radiation detection
 - a. phototubes
 - b. photodiodes and phototransistors
 - c. photoconductive cells
 - 2. Particle detectors
 - a. Geiger-Muller tubes
 - b. scintillation counters
 - c. solid state detectors
- E. Radiation monitoring program
 - 1. Sampling and analysis
 - a. baseline
 - b. operations
 - 2. NRC reporting procedures

V. Course Format: This material could best be presented as a three day short course or three hour course using prepared course notes.

12. UPDATE ON ENERGY PROGRAMS

- I. Course Description: A review of the state of technology of the energy conversion techniques including fossil, nuclear, and solar energy sources. Environmental impact, economics comparison, and availability of resources are reviewed in the course.
- II. Course Objective: This course will provide the practicing engineer with a broad overview of current energy conversion techniques.
- III. Prerequisite: An undergraduate engineering degree.
- IV. Course Outline:
- A. Fossil fuel electric power plants
 - 1. Steam power generating systems
 - 2. Thermodynamics and efficiency
 - 3. Fuels
 - 4. Combustion
 - 5. Environmental impact
 - a. effluents
 - b. waste heat
 - 6. Economics of fossil fuel plants
 - 7. Fuel resources
 - B. Nuclear electric power plants
 - 1. Fundamentals of nuclear reactors
 - 2. Commercial nuclear reactors
 - 3. Nuclear power and the environment
 - 4. Waste management
 - 5. Economics of nuclear power
 - 6. Fuel resources
 - C. Solar energy
 - 1. Space heating and cooling
 - a. collectors
 - b. cooling systems
 - i. absorption refrigeration
 - ii. Rankine cycle

2. Solar electric
 - a. photovoltaic
 - b. solar furnace
 - c. ocean thermal energy conversion
 - d. wind energy
 - e. biomass
3. State of technology
4. Economics of solar energy
5. Environmental impact
- D. Alternative electric power generating techniques
 1. Hydroelectric
 2. Magnetohydrodynamics
 3. Nuclear fusion
 4. LMFBR and LWBR
 5. Geothermal
 6. Fuel cells
 7. State of technology and economic potential of alternative generating techniques

V. Course Format: This material can be presented as a two day short course using prepared course notes

13. INTERACTION OF NUCLEAR TECHNOLOGY AND PUBLIC POLICY

- I. Course Description: This course is a workshop to discuss the relationship between nuclear technology and public policy.
- II. Course Objective: The course is intended to open a dialogue among engineers and allow them to explore pathways of interaction between technology and public policy.
- III. Prerequisites: None
- IV. Course Outline:
 - A. The evolution of public policies
 - 1. Who is involved?
 - 2. What is the procedure?
 - B. Pathways of interaction of the engineering profession with the public sector.
 - 1. Responsibility as a profession
 - 2. Modes of thinking of policy makers, technical and non-technical (industry, government, press, and public)
 - 3. Missions and roles
 - C. The antitechnologists
 - 1. Do they exist and who are they?
 - 2. What is their ultimate purpose?
 - 3. What are their methods?
 - D. Internal and external issues of the engineering profession
 - 1. Present posture
 - 2. Areas for improvement
 - 3. Bringing about change
- V. Course Format: This course could be presented as a professional seminar on six consecutive Fridays with selected readings, round table discussion, and external speakers resulting in a proceedings of the workshop.

14a. INTRODUCTION TO REACTOR SAFETY AND
THE DESIGN OF SAFETY SYSTEMS

- I. Course Description: This course presents an overview of such topics as reactor hardware, reactor systems, postulated accidents and their consequences, along with case histories as related to reactor safety.
- II. Course Objective: This course is intended to provide an overview of reactor safety technology and a basic understanding of reactor safety terminology. In addition, the course may serve as a prerequisite to subsequent more detailed courses in the reactor safety area.
- III. Prerequisite: An undergraduate engineering degree.
- IV. Course Outline:
- A. Description of reactor hardware and systems
 - 1. Primary system
 - 2. Secondary system (in support of primary system)
 - 3. Balance of the plant
 - B. Description of postulated accidents and their consequences on the reactor and the environment
 - C. Systems design of safety systems
 - 1. Probabilistic design technique
 - a. defining risks
 - b. fault tree analysis
 - 2. Determination of safety factors
 - a. accelerated life testing of components
 - 3. Diversity
 - D. Case histories of safety related design and management errors
 - E. Regulation and reactor safety
 - 1. Licensing procedure and overview
 - 2. Safety assessment in licensing (PSAR, SAR)
 - 3. Current problems
 - F. Introduction to safety computer codes
 - G. Economic aspects of reactor safety
- V. Course Format: The course can be structured as a 3-5 day short course using prepared course notes.

14b. NUCLEAR POWER REACTOR SAFETY

- I. Course Description: This course will present a basic understanding of reactor safety technology as it relates to piping core, steam generator, and the control system in terms of the design base accidents.
- II. Course Objectives: The objectives of this course is to enable the student to read and understand Preliminary Safety Analysis Reports (SAR).
- III. Prerequisites: An undergraduate engineering degree; a general knowledge of heat transfer, fluid mechanics, and thermodynamics; and introductory knowledge of reactor safety and the design of safety systems.
- IV. Course Outline:
 - A. Primary system integrity
 - 1. Pressure vessel
 - 2. Piping systems
 - 3. Steam generators and pumps
 - B. Loss of coolant accident
 - 1. Emergency core cooling
 - 2. Blowdown transients
 - 3. Reflood transients
 - C. Power transients
 - 1. Reactor kinetics
 - 2. Reactivity feedback and control
 - 3. Reactivity accidents
 - 4. Recriticality potential
 - D. Fuel element behavior
 - 1. Influence of operating history
 - 2. Transient behavior
 - 3. Failure mechanisms
 - 4. Failure propagation, local to whole core
 - 5. Fuel behavior modeling
 - E. Containment systems
 - 1. Environmental and accident loads
 - 2. Fission product control
 - 3. Current containment designs
 - F. Fission product release and transport
 - 1. Biological effects of radiation

- 2. Atmospheric dispersion
- 3. Critical exposure pathways
- G. Cooling failure transients
 - 1. Flow failures
 - 2. Loss of heat sink accident
- H. Human reliability
 - 1. Factors influencing performance
 - 2. Error identification
 - 3. Reliability analysis

- V. Course Format: A minimum of 45 hours including direct contact with the instructor and independent study and problem solving will be required. Prepared course notes will be used.

15. FIRE PROTECTION FOR NUCLEAR REACTORS

- I. Course Description: This course will present practical applications of fire protection for nuclear power reactors by stressing a sound understanding of the fundamental techniques.
- II. Course Objectives: Currently, there exist few individuals with expertise both in the area of nuclear power plant design and fire protection. It is the objective of this course to help bridge the gap between these two separate engineering disciplines. Emphasis on practical applications based on a sound understanding of the fundamentals will be stressed.
- III. Prerequisites: An undergraduate engineering degree.
- IV. Course Outline:
 - A. Fundamentals of combustion
 - 1. Thermochemistry
 - 2. Kinetics
 - 3. Ignition
 - 4. Flame propagation
 - 5. Explosions and detonations
 - B. Reactor safety considerations
 - 1. Fire control problems due to radiation effects
 - 2. Accidents involving fissionable materials
 - 3. Fire in control systems
 - 4. Electrical circuits and wiring
 - 5. Incompatible materials
 - C. Review of fire protection regulations
 - 1. NFPA regulations
 - 2. NRC regulations
 - D. Design for fire protection
 - 1. Location and construction
 - 2. Ventilation and access
 - 3. Electrical equipment
 - 4. Flammable liquids and gases
 - 5. Extinguishing systems
 - 6. Fire detection systems
 - 7. Alarm systems

8. Analysis of fire potential
9. Special problems
- E. Fire fighting methodology
 1. Plant organization for fire protection
 2. Self inspection program
 3. Planning for handling emergencies
 4. Interfacing local and plant fire departments
 5. Security aspects

- V. Course Format: The course would best be implemented as a 3-5 day short course with time between days for individual study. Prepared course notes can be used to present this material.

16. NUCLEAR FUEL MANAGEMENT

- I. Course Description: This course will concentrate on in-core and refueling aspects of fuel management for pressurized water reactors. Pre-purchase and disposal considerations in fuel management will be treated lightly.
- II. Course Objectives: This course will provide the practicing engineer with the background and techniques needed to understand the principle of in-core nuclear fuel management.
- III. Prerequisites: A strong background in nuclear reactor analysis (nuclear physics, transport and diffusion theory, reactor kinetics, flux and power distributions, thermal-hydraulic analysis, fuel depletion analysis).
- IV. Course Outline:
 - A. Fuel management concepts and relation to overall power plant economics
 - B. In-core fuel and poison management objectives
 - 1. Maintain reactor power
 - 2. Shape reactor power distribution
 - 3. Maximize heat release from nuclear fuel
 - 4. Operate reactor with specified safety limits
 - 5. Optimize fuel cycle costs
 - C. Review of nuclear reactor analysis
 - 1. Criticality
 - 2. Reactor kinetics
 - 3. Flux and power distribution
 - 4. Thermal-hydraulics
 - 5. Fuel depletion
 - D. PWR fuel management variables
 - 1. Operational stage
 - a. control rod position
 - b. soluble poison concentration
 - c. power level
 - 2. Reload stage
 - a. fuel assembly types (batch fraction, fuel enrichment)
 - b. fuel assembly pattern
 - 3. Deviation of actual operation from planned operation

E. Constraints on in-core fuel management

1. Utility system consideration
 - a. energy output
 - b. refueling schedule and optimizing fuel cycle length
 - c. costs minimization
2. Reactor considerations
 - a. status of core reactivity
 - b. thermal-hydraulic limits
 - c. mechanical design
 - d. fuel physical limits
3. Economic and supplies factors
 - a. cost of money
 - b. cost of uranium
 - c. cost of all processing steps
 - d. lead time for procurement
 - e. contracts and warranties

F. Computer codes for fuel management

1. Thermal neutron cross section calculations
2. Intermediate and fast neutron cross-section calculations
3. Diffusion calculations (reactivity, power distribution, control, rod worth, reactivity coefficients)
4. Diffusion-depletion calculations (reactivity, poison work, power distribution vs. burn-up, predicted core lifetime, Xenon effects.
5. Overall fuel-management costs

V. Course Format:

This course could be preceded as a workshop of at least one week. If it is decided to include "hands-on" experience with manipulating the various fuel management computer codes, the course needs to be conducted in a location where computing facilities with access to the codes are available. This would involve considerable effort for anyone not currently involved deeply in this work.

17. POWER COMPANY ECONOMICS

- I. Course Description: An overview of the concepts of power company economics as they relate to engineering in the power industry and utilities.
- II. Course Objectives: The objectives of the course are to help the practicing engineer gain a solid background and working understanding of real world economics in engineering practice.
- III. Prerequisites: An engineering degree
- IV. Course Outline:
 - A. Basic accounting concepts
 - B. Utility accounting and the Uniform System of Accounts
 - C. Internal and external financing
 - D. Financial mathematics
 - E. Capital costs vs. operating costs
 - F. Capital repayment and depreciation
 - G. Rate of return
 - H. Federal income taxes
 - I. Identification and comparison of alternatives
 - J. Comparison of various methods of economic analysis
 - K. Special topics
 - 1. Allowance for funds used during construction owning vs. leasing (capital, operating, leveredged)
public vs. private financing
 - L. Computer programs for utility economics
 - M. Analysis of present day alternatives
 - N. Federal and state regulatory agencies and their effects on utility financing
- V. Course Format: This course could be a professional workshop meeting on several consecutive Thursdays or Fridays. Course notes, video cassettes, and audio cassettes would be used to present this material with discussions.

18. ELECTRONIC INSTRUMENTATION FOR NUCLEAR APPLICATIONS

- I. Course Description: A presentation of instrumentation and measurement techniques needed for nuclear applications. The course stresses the physical principles upon which measurements are made and covers the processing of signals from the point of measurement to their interpretation.
- II. Course Objectives: The course is designed for the practicing instrumentation engineer in the nuclear industry who wishes to further his understanding of measurement principles and applications.
- III. Prerequisite: An undergraduate engineering degree
- IV. Course Outline:
 - A. General overview of measurement techniques
 - B. Fundamental quantities for transducer operation
 - 1. Electrical
 - a. voltage
 - b. current
 - c. charge
 - d. resistance
 - e. capacitance
 - f. inductance
 - 2. Mechanical
 - a. pressure
 - b. temperature
 - c. size
 - d. number
 - e. velocity and acceleration
 - f. weight or mass
 - g. time and frequency
 - C. Types and characteristics of transducers
 - 1. Electrical
 - a. voltmeters, ammeters, ohmmeters
 - b. probes
 - c. fluxmeters
 - 2. Mechanical
 - a. velocimeters

- b. accelerometers
 - c. counters
 - d. strain gauges
 - e. thermocouples
 - f. flowmeters and viscosity meters
 - g. level indicators
 - h. densitometers
- D. Chemical composition measurements
 - 1. Gas chromatography
 - 2. Infrared and ultraviolet spectroscopy
 - 3. pH-meters for hydrogen ion concentration
- E. Electromagnetic radiation detection
 - 1. Phototubes
 - 2. Photodiodes and phototransistors
 - 3. Photoconductive cells
- F. Particle detection
 - 1. Geiger - Muller tubes
 - 2. Scintillation counters
 - 3. Solid-state detectors
- G. Isotope concentration measurements
 - 1. Disintegration energies and decay rates
 - 2. Spectrum analysis
- H. Signal processing
 - 1. Noise reduction techniques
 - 2. Data transmission methods
 - 3. Data storage methods
 - 4. Data reduction techniques
- I. Commercial instrumentation
 - 1. Capabilities
 - 2. Limitations
 - 3. Instrument decontamination
- V. Course Format: The material would be presented as a five-day short course.

19. ELECTRICAL ENGINEERING FOR NON-ELECTRICAL ENGINEERS

- I. Course Description: An overview of electrical engineering is presented covering aspects of electromagnetic machinery, electric power, and analog and digital electronic circuits.
- II. Course Objectives: This course is designed for non-electrical engineers in the nuclear industry who wish to understand the fundamentals of practical electrical engineering.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Introduction
 - 1. Review of circuit theory fundamentals
 - B. AC power fundamentals
 - 1. Single-phase systems
 - 2. Three-phase systems
 - 3. Power measurements
 - 4. Power transmission
 - C. Electromagnetic machinery
 - 1. DC motors and generators
 - 2. AC motors and generators
 - 3. Stepping motors
 - D. Electronics fundamentals
 - 1. Electronic components and component selection
 - 2. Power supplies
 - 3. Interference and filtering
 - 4. Operational amplifiers
 - 5. Digital-analog and analog-digital converters
 - 6. Digital integrated circuits.
 - a. counters
 - b. shift registers
 - c. multiplexers
 - d. adders
 - 7. Microprocessors
 - E. Electrical control systems
 - 1. Feedback concepts
 - 2. Stability criteria

- V. Course Format: This material could be best presented as a one week workshop using prepared notes.

20. STRUCTURED DESIGN OF COMPUTER SOFTWARE

- I. Course Description: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing the design of computer software. Presentations cover principles and applications in structured programming and software engineering, including top-down system development, program correctness, and stepwise refinement. The course provides practical programming experience on remote computer terminals.
- II. Course Objective: This course provides engineers and managers in the nuclear industry with the ability to design and manage structured computer software systems.
- III. Prerequisites: The examples and terminology used would be technical in nature, so the participants should have a knowledge of scientific computing systems and should be conversant in at least one computer language.
- IV. Course Outline:
- A. Introduction
 - 1. Fundamentals of software engineering
 - 2. Systems approach to software design
 - B. Top-down program design
 - 1. Hierarchical design
 - 2. Program stubs
 - 3. Program testing with program coding
 - C. Modular programming
 - 1. Organizing programs into modules
 - 2. Independent modules
 - D. Management of large software development efforts
 - 1. Programmer teams
 - 2. Structured walk-throughs
 - E. Structured programming fundamentals
 - 1. Choice of programming language
 - 2. Control formats in programs

F. Advanced programming concepts

1. Decision tables
2. Program decomposition
 - a. flow charts
 - b. Warnier-Orr diagrams
3. Converting nonstructured programs to structured programs

G. Case study

1. An advanced programming design example utilizing structured techniques

- V. Course Format: Material on structured programming techniques could best be presented to engineers in the nuclear industry as a two-day short course. The course could be offered either at or near major nuclear engineering installations such as Duke Power Company, ORNL, and SRL-SRP. The course ideally would involve strong interactions between the instructors and the participants, as well as practical programming experience on remote computer terminals. It would therefore be unsuitable for taped or television presentation.

21. PRACTICAL STATISTICS FOR NUCLEAR ENGINEERS

- I. Course Description: The course will consist of a review of probability theory followed by an intermediate treatment of mathematical statistics. This course will be similar to an upper level undergraduate course in mathematical statistics but would emphasize practical and pertinent aspects of the use of statistics in the nuclear industry (e.g. sampling in quality control and quality assurance plans).
- II. Course Objective: This course will provide the engineer working in the nuclear industry with the ability to solve problems which are statistical in nature.
- III. Prerequisites: Differential and integral calculus
- IV. Course Outline
 - A. Review of probability theory
 1. Sample description space, outcomes
 2. Combinational mathematics
 3. Discrete and continuous variables
 4. Probability density and frequency function of a single variable
 5. Probability distribution functions
 6. Examples of probability distribution functions
 - a. Bernoulli
 - b. Binomial
 - c. Poisson
 - d. Gaussian
 7. Joint, conditional, and marginal probabilities
 8. Independence of random variables
 9. Bayes' Theorem
 10. Expectation and Moments
 11. Law of Large Numbers
 12. Central Limit Theorem
 - B. Mathematical statistics
 1. Sampling
 2. Correlation
 3. Regression
 - a. linear

- b. multilinear
- c. curvilinear
- 4. Significance testing
- 5. Hypothesis testing
- 6. Estimation techniques
 - a. maximum likelihood
 - b. minimum near square error
- 7. Small sample distributions
 - a. chi square testing
 - b. student's "t" distribution
 - c. "F" distribution

V. Course Format: This course would require a full semester treatment and use a standard text supplemented by prepared notes for topics specifically related to the nuclear industry.

22. SYSTEM RELIABILITY ANALYSIS APPLICATIONS IN THE NUCLEAR INDUSTRY

- I. Course Description: This course presents a variety of methods which have been developed to analyze the reliability and/or hazards of engineering systems and facilities. Application of these methods is becoming increasingly commonplace throughout the nuclear industry. Licensing of nuclear facilities requires the use of system reliability techniques as an assessment of safety. Moreover, the use of such techniques during the design of a facility or subsystem has come to be recognized as technical and economic good sense.
- II. Course Objectives: This course will provide those persons in technical areas throughout the nuclear industry with a knowledge of the basic methods of system reliability analysis.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Initial study of a system
 1. How to obtain the necessary familiarization with the system.
 2. Identification of potential hazards
 - a. preliminary hazards analysis
 - b. fault hazards analysis
 - c. failure modes and effects analysis
 3. Tabular/graphical representations of hazard analysis
 - a. reliability diagram
 - b. fault tree
 - B. Qualitative analysis techniques
 1. Single failure analysis
 2. Common mode failure
 3. Identification of critical paths and components in fault tree
 4. Examples of application in nuclear areas
 - C. Obtaining necessary probability data
 1. Data banks
 2. Rule-of-thumb
 3. Life testing
 4. Failure rates and failure rate curves
 5. Introduction to derivation of distribution functions

- D. Basic mathematic procedures
 - 1. Boolean algebra
- E. Procedures for qualitative analysis
 - 1. Cut set algorithm
 - 2. Boolean reduction
 - 3. Pitfalls
 - 4. Computer codes
 - 5. Examples of applications in nuclear areas

V. Course Format: If taught as a survey only, the course could be delivered in two full days. For more realistic and useful coverage, allow 3-5 days with some time between days for individual study. Prepared course notes could be used.

23. FAULT TREE ANALYSIS

- I. Course Description: This course presents the concept of fault tree analysis, the major technique now being used as both a qualitative and quantitative tool in determining the reliability of engineering systems and facilities. The technique provides a systemized detailed approach leading to the identification and control of potentially high risk events. In general, once a decision is made to assess system reliability, fault tree analysis is the technique which is employed.
- II. Course Objectives: This course will introduce the techniques and methods of applications of fault tree analysis to engineers and scientists having responsibility for assessment of the reliability of systems or facilities.
- III. Prerequisites: A basic knowledge of probability and statistics and an introductory level understanding of system reliability analysis.
- IV. Course Outline:
- A. Introduction topics
 - 1. FTA in relation to other system reliability schemes
 - 2. Application of FTA to nuclear and nuclear related systems
 - B. FTA - description of the technique
 - 1. Construction rules
 - 2. Definition of terms
 - 3. Symbols
 - 4. Examples
 - C. Qualitative applications
 - 1. Minimum cut sets
 - 2. Common mode failure
 - 3. Available computer codes for qualitative analysis - sources of codes
 - 4. Examples
 - D. Quantitative applications
 - 1. Necessary background in statistics and Boolean Algebra
 - 2. Method of computing top event probability
 - 3. Failure rates, failure times, component unavailability
 - 4. Available computer codes for quantitative analysis
 - 5. Examples

E. Recent and expected future developments in FTA

F. Guidelines for future study

V. Course Format:

A minimum of 45 hours total involvement broken down between (a) direct contact with instructor, (b) independent study. If, for example, the course is run for three or more days, some time between days should be set aside for independent study. It would be unrealistic to attempt to adequately cover the content in a one day or two consecutive day format. Prepared course notes could be used.

24. THE EFFECT OF RADIATION ON MATERIALS PROPERTIES

- I. Course Description: The effects of radiation on electrical, mechanical, thermochemical and thermophysical properties of materials; radiolytic decomposition and radiochemistry.
- II. Course Objectives: The course is designed for the practicing engineer to learn how to determine extent of radiolytic decomposition; to understand the basics of radiochemistry and to understand the effects of radiation on material properties.
- III. Course Outline:
 - A. Introduction to radiochemistry
 - B. Radiochemical reactions
 - C. Effect of radiation on properties of materials
 - 1. Electrical properties
 - 2. Mechanical properties
 - 3. Thermophysical properties
 - 4. Thermochemical properties
- IV. Comments:
 - A. The course should survey materials presently available and discuss limitations in radiation environment as a function of specific material.
 - B. The course should also include the types of material testing required and presently in use for nuclear applications and typical radiation environments that materials are expected to be subject to.

25. BASIC CONCEPTS OF CORROSION

- I. Course Description: An overview of corrosion as applied to the nuclear industry.
- II. Course Objectives: The course is designed for practicing engineers to provide them with an understanding of corrosion.
- III. Prerequisites: An undergraduate engineering degree
- IV. Course Outline:
 - A. Basic principles
 - 1. Material environment
 - 2. Electrochemical aspects
 - B. Types of corrosion
 - 1. Stress corrosion
 - 2. Galvanic
 - 3. Pitting
 - 4. Intergranular
 - 5. Leaching
 - 6. Erosion
 - 7. Uniform attack
 - 8. Hydrogen damage
 - 9. Fretting corrosion
 - C. Materials
 - 1. Metals
 - a. zircalloys
 - b. stainless steel
 - c. Inconel
 - d. etc.
 - 2. Acids
 - a. nitric acids
 - b. sulfuric
 - c. hydrofluoric
 - 3. Liquid metals
 - 4. Fused salts
 - 5. Plastic, rubbers, and ceramics
 - D. Types of liquid metal corrosion
 - 1. diffusion

- 2. solution
- 3. intermetallic compound formation
- 4. mass transfer by composition on thermal gradients
- E. Corrosion data
- F. Corrosion testing
- G. Corrosion prevention
- H. Inhibitors and chemical treatment
- I. Specific corrosion problems in the nuclear industry
 - 1. Effect of contained moisture on fuel rod performance
 - 2. Prefilming
 - 3. Effect of scratches on protected surfaces
- J. Case histories

- V. Course Format: If survey only, the course could be delivered in three days. For more intensive coverage, allow five days with some time between days for individual study. Most information will be contained in course notes.

26. WELDING METALLURGY, INSPECTION METHODS, & DEFECT CONTROL

- I. Course Description: This course examines and explains some of the metallurgical factors involved in the welding process. Also considered are weld defects and methods of inspecting for weld quality and integrity.
- II. Course Objectives: Faced with demands for increased quality, reliability, and integrity, engineers responsible for designing and specifying welds are compelled to give attention to the metallurgical factors involved. Quite often, however, these same engineers have had little formal training in metallurgical principles. This course is intended to fill this gap.
- III. Prerequisites: An undergraduate degree in engineering; preferably some experience in basic welding principles and welding design.
- IV. Course Outline:
 - A. Metallurgical principles
 1. Structure of metals
 2. Phase diagrams
 3. Equilibrium and non-equilibrium transformations
 - B. Metallurgy and welding of steel
 1. Phase transformations in steel
 2. Heat treatment
 3. Hardenability
 4. The metallurgy of the heat affected zone
 - C. Metallurgy and welding of aluminum alloys
 1. Non-heat treatable alloys
 2. Heat treatable alloys - precipitation hardening
 3. The metallurgy of the heat affected zone
 - D. Metallurgy and welding of stainless steels
 1. Non-heat treatable grades - austenitic and ferritic
 2. Heat treatable grades - martensitic and precipitation hardenable
 3. The metallurgy of the heat affected zone
 - E. Weld defects
 1. Types of defects
 2. Effects of defects on weld properties

3. Process control to minimize defects

F. Inspection of welds

1. Destructive methods
2. Non-destructive methods
3. Welding inspection codes and standards - an overview

V. Course Format:

A course of 3-5 days duration should be adequate to cover the above material. Instruction time would best be spread over a number of weeks to allow time between instruction for independent study. It would also be feasible to divide the above content into two courses of shorter duration. The first of these would cover the metallurgy of welding (2-3 days) and the second would cover weld defects and inspection procedures. Course material can be obtained from Introductory Welding Metallurgy (American Welding Society, most recent edition), Welding Inspection (American Welding Society, most recent edition), and prepared course notes.

27. WELDING PROCESSES AND WELDING DESIGN

- I. Course Description: This course describes the process of designing a welded product in terms of the weld process, joint design, and weld size.
- II. Course Objectives: This course seeks to enable the design engineers to better design weldment and select appropriate welding procedures. The emphasis is on the design application of welding rather than on metallurgical considerations.
- III. Prerequisites: An undergraduate degree in mechanical or civil engineering, particularly a working knowledge of basic mechanics of materials.
- IV. Course Outline:
- A. Welding processes and selection
 - 1. Shielded metal arc welding
 - 2. Gas shielded arc welding
 - 3. Submerged arc welding
 - 4. Other processes - an overview
 - 5. When to use which process and why
 - B. Joint design
 - 1. Edge preparation
 - 2. Types of joints
 - 3. When to use which joint and why
 - C. Determination of weld size
 - 1. Weld strength
 - 2. Determination of weld loads
 - 3. Consideration of stress concentration in welds
 - 4. Consideration of residual stress
 - D. Control of shrinkage and distortion
 - E. Weld failure
 - 1. Failure behavior in the weld zone
 - 2. Failure of bimetallic joints
 - 3. Review of in-service failures
- V. Course Format: The course could be handled in review form as a one day seminar. However, the depth and breadth of coverage necessary for a lasting learning experience would better involve a series of from 3 to 5 days. Preferably, the instruction time would be spread out over a number of weeks to allow time between instruction for independent study. Course material could be obtained from Current Welding Processes (edited by Arthur L. Phillips, American Welding Society) and prepared course notes.

28a. PROCEDURES FOR DESIGN AGAINST FATIGUE

- I. Course Description: This course presents the nature of fatigue failure and design methods which minimize fatigue.
- II. Course Objectives: This course provides a detailed view of fatigue design and is intended for engineers engaged in the activities of designing, testing, inspecting, or maintaining mechanical components and structures.
- III. Prerequisites: An undergraduate degree in mechanical or civil engineering. A working knowledge of basic mechanics of materials is required.
- IV. Course Outline:
 - A. The nature of fatigue failure
 - 1. Service conditions leading to fatigue failure
 - 2. Typical appearance of fatigue failure
 - 3. The mechanisms of fatigue failure
 - B. Traditional design approach - high cycle fatigue
 - 1. Service conditions suggesting application of high cycle fatigue approach
 - 2. Stress amplitude testing and determination of fatigue strength
 - 3. S-N curve, fatigue limit, endurance ratio
 - 4. Effect of load type, part size, and surface finish
 - 5. Effect of mean plus alternating stress
 - 6. Effect of stress concentration
 - 7. Effect of combined loading
 - 8. Variations in behavior of different materials
 - C. Design based on fatigue crack growth
 - 1. Service conditions suggesting application of a crack growth based design approach
 - 2. Introduction to linear elastic fracture mechanics
 - 3. Fracture mechanics based techniques for predicting fatigue crack growth
 - 4. Threshold effects in fatigue crack growth
 - 5. Factors affecting fatigue crack growth
 - D. Design approach in the low cycle regime
 - 1. Service conditions suggesting application of a low cycle fatigue design approach

2. Cyclic stress controlled material response
3. Strain amplitude testing
 - a. strain-life curves
 - b. estimating strain life curves from static properties
4. Effect of mean plus alternating stress
5. Effect of stress concentration
- E. Fatigue under various amplitude - cumulative damage
- F. Statistical nature of fatigue data and its effect on design

V. Course Format:

The above list of content covers a great deal of material and would best be treated in a full semester graduate level course. A scaled down version of the same material could be covered in a minimum of five full days. It would be highly advisory that the instruction time be spaced rather than run consecutively in order to allow some time for independent study.

The above list of content could also be broken down to allow for quite useful courses of duration shorter than five days. For example, Parts A & B together provide an introduction to fatigue design concepts and could be covered in approximately two days. Part C could also be offered as a one day short course.

For a full semester length course, the recommended course materials are Metal Fatigue (Woods, Wittrich, and Cullen) and supplementary course notes. For a short course presentation, prepared course notes would be sufficient.

28b. FRACTURE MECHANICS APPROACH TO DESIGN AGAINST FRACTURE

- I. Course Description: During the past decade, fracture mechanics has developed to the point where it is now a useful design tool for engineers involved in the design of mechanical components and structures. Fracture mechanics based design procedures are not complicated and can readily be put to use without having an extensive background in theoretical mechanics. As a result, design and inspection procedures based on fracture mechanics principles are becoming increasingly commonplace. This course will present those design procedures based on fracture mechanics which are used to prevent low stress fracture. For example, a number of published design codes such as Section III of the ASME Boiler and Pressure Vessel Code (which covers nuclear components) contain specifications based on fracture mechanics.
- II. Course Objective: The typical undergraduate curriculum in mechanical and civil engineering traditionally do not cover fracture mechanics. This course is intended to fill that gap.
- III. Prerequisites: An undergraduate degree in mechanical or civil engineering. A working knowledge of the basic mechanics of materials at the undergraduate level is required.
- IV. Course Outline:
- A. Overview of the problem of fracture
 - 1. Characteristics of low stress fracture
 - 2. Noteworthy historical failures due to low stress fracture
 - 3. Temperature and strength transition characteristics of materials
 - B. Linear elastic fracture mechanics
 - 1. Stress intensity factor
 - 2. Stress intensity factor equations
 - 3. Relation between stress intensity factor and fracture toughness
 - C. Experimental determination of fracture toughness
 - D. Fracture mechanics design
 - 1. Examples
 - 2. Case studies and failure analyses
 - E. Fracture mechanics approach to design against fatigue
 - F. Fracture mechanics bases for published design codes

V. Course Format:

A 1½-2 day traditional short course format should be adequate. The subject could also be covered in one day at the expense of perhaps dropping Parts E and F and de-emphasizing Part C of the above proposed course contents. Prepared course notes would be used.

28c. ANALYSIS OF MECHANICAL FAILURES

- I. Course Description: This course presents methods for examination of mechanical failures and discusses the characteristics of different types of mechanical failures.
- II. Course Objectives: This course will provide the engineer with the capability of analyzing the causes of mechanical and structural component failure. The use of this knowledge will yield more intelligent, more confident, and more failure resistant designs. The content of this course is seldom found in undergraduate engineering curricula and must typically, therefore, be obtained through post-baccalaureate experience of one sort or another. This course is intended to fill that need.
- III. Prerequisites: An undergraduate degree in engineering and, in particular, a knowledge of both elementary materials science and mechanics of materials.
- IV. Course Outline:
 - A. Failure examination techniques
 - 1. Assembling background information
 - 2. Visual examination techniques
 - a. macroscopic
 - b. microscopic
 - 3. Chemical analysis techniques
 - 4. Determining material properties
 - 5. Determining service load and environmental conditions
 - 6. Reporting
 - B. Fractographic and metallographic techniques
 - 1. Techniques for fractographic examination at low magnification
 - 2. Metallographic techniques
 - 3. Electron microscopy and fractography
 - C. Characteristics of different types of failures
 - 1. Brittle vs. ductile fracture
 - 2. Fatigue
 - 3. Corrosion and stress corrosion
 - 4. Hydrogen damage
 - 5. Elevated service temperature failure
 - 6. Failure attributed to welding and heat treatment

V. Course Format:

The content could be covered in condensed survey form in one day short course format. However, more adequate coverage could easily be obtained using a three day format with time between days for independent study. The kind of material covered in a course of this sort is particularly applicable to a videotaped-televised format. The large number of fractographs, micrographs, and fractured parts to be examined and described are easily displayed and viewed using a television monitor. Materials for this course can be obtained from Analysis of Metallurgical Failures (V. J. Colongelo and F. A. Heiser, Wiley, 1974), prepared course notes, and example fractographs, micrographs, and fractured parts.

28d. STRESS ANALYSIS USING FINITE ELEMENT METHODS

- I. Course Description: This course gives an introduction to the basic principles of the use of finite elements in stress analysis application. Application problems are presented using one or more of the available prepared computer programs. STRUDL is used in developing the content below since it is perhaps the most convenient and economical of the various programs available. It should be kept in mind that once the philosophy of any one particular program is learned, it is not difficult to move to another.
- II. Course Objectives: The finite element method is an extremely valuable approach to stress analysis. Instruction in the method, however, is typically not undertaken at the undergraduate level. As a result, there are a great number of engineers who regularly design structural and mechanical hardware who have little or no experience in finite element application. This course is intended to provide this knowledge.
- III. Prerequisites: Undergraduate degree in aeronautical, civil, or mechanical engineering or engineering mechanics; in particular, a basic understanding of the principles of mechanics of materials.
- IV. Course Outline:
- A. Basic concepts of finite element methods
 - 1. Review of the stiffness method of analysis
 - B. The STRUDL language
 - 1. Introduction to STRUDL
 - 2. STRUDL language convention
 - 3. Commands to the STRUDL system
 - 4. Examples
 - C. Application to articulated structures
 - 1. Line elements
 - 2. Elementary applications involving beams and simple trusses using STRUDL
 - 3. General applications involving trusses and frames using STRUDL
 - D. Applications to plane stress problems
 - 1. Plane stress formulation using triangular and rectangular elements
 - 2. Applications using STRUDL

- E. Applications to plate flexure problems
 - 1. Plate flexure formulations
 - 2. General applications involving plate bending using STRUDL
 - 3. General applications involving shell structures using STRUDL
 - 4. General applications involving axially symmetric structures
- F. Applications to arbitrarily shaped solids
 - 1. Isoparametric elements
 - 2. General applications using STRUDL

V. Course Format: The above content is extensive and it is unlikely to be covered in less than a five day effort. As such, coverage of all the subtopics listed represents an ideal. Courses of shorter duration might easily be arranged by considering only topics A through D. Material for this course can be obtained from prepared course notes and ICES STRUDL - II Engineering User's Manual, Dept. of Civil Engr., Massachusetts Institute of Technology (most recent edition).

VI. Comment: Finite element short courses are widely available. However, few if any of these courses seldom present the practicing engineer with an appreciation for the limits of the method including information on how to check the results. As a particularly useful and distinguishing feature, this course should contain (at appropriate points during delivery) discussion elements on the accuracy of finite element methods, checks for accuracy, and information on what to expect from the analysis.

29. METALLURGY OF STAINLESS STEEL AND NICKEL-BASE ALLOYS

- I. Course Description: This course presents the classification, strengthening mechanisms, mechanical properties, corrosion properties, and irradiation effects of both stainless steels and Nickel-base alloys. These materials are widely used in nuclear related applications when elevated temperatures or corrosion resistance are important.
- II. Course Objectives: This course is intended to provide a better understanding of these materials in service applications, material selection, control of mechanical and physical properties, fabrication, and design.
- III. Prerequisites: Undergraduate degree in engineering with at least one course in basic materials science.
- IV. Course Outline:
- A. Stainless steels
 - 1. Classification
 - 2. Strengthening mechanisms, heat treatment, and microstructure
 - 3. Mechanical properties
 - 4. Corrosion properties
 - 5. Irradiation effects
 - B. Nickel-based alloys
 - 1. Range of alloys
 - 2. Strengthening mechanisms, heat treatment, and microstructure
 - 3. Mechanical properties
 - 4. Corrosion properties
 - 5. Irradiation effects
 - C. Considerations in welding stainless steels and nickel-base alloys
- V. Course Format: The one to two day traditional course format should be adequate. If greater depth of coverage is to be considered, the course could also be extended over a 3-5 day schedule. Following this latter format, the course would preferably be spread out over a series of weeks to allow time between instruction for independent study. Course material could be selected from manufacturers product literature for stainless steel and nickel-base alloys.

30. HYDRAULICS AND FLUID MACHINERY

- I. Course Description: A course in fluid hydraulics designed to cover subjects pertaining to nuclear facilities. The course covers the analysis of fluid flow in hydraulic systems and fluid machinery.
- II. Course Objectives: The course will provide the practicing design and operations engineer with an appreciation for hydraulics and fluid machinery as applied to the nuclear industry.
- III. Prerequisites: An undergraduate engineering degree and a basic course in fluid mechanics
- IV. Course Outline:
 - A. Steady-state pressure losses in hydraulics systems
 - 1. Friction losses in pipes, valves, and fittings
 - 2. Flow in closed circuits
 - 3. Pipe networks
 - 4. Flow cavitation
 - 5. Flow induced vibrations
 - 6. Natural convection in piping systems
 - 7. Computer codes
 - B. Unsteady flow
 - 1. Transient flow of incompressible fluids
 - 2. Water hammer
 - a. liquid water
 - b. steam
 - C. Two-phase flow
 - 1. Flow regimes in two-phase flow in pipes
 - a. bubble flow
 - b. slug flow
 - c. annular flow
 - d. mist flow
 - e. other
 - 2. Prediction of flow regimes
 - 3. Pressure losses in pipe flow
 - a. Lockhart-Martinelli correlation
 - b. Martinelli-Nelson correlation
 - c. other two-phase pressure loss models
 - d. critical flow phenomenon

4. Two-phase phenomenon with heat transfer
 - a. regimes of boiling
 - b. nucleation
 - c. pool boiling heat transfer
 - d. boiling in forced convection
 - e. critical heat flux
5. Two-phase hammer
- D. Fluid machinery - applications and limitations
 1. Pumps
 - a. centrifugal
 - b. axial flow
 - c. positive displacement
 - i. piston
 - ii. gear
 - iii. vane
 - d. diaphragm
 - e. jet
 - f. electromagnetic
 2. Compressor and fans
 - a. centrifugal
 - b. axial flow
 - c. rotary
 - d. reciprocating compressors
 3. Mixers
 4. Bearings and seals
 - a. lubricants
 - b. bearings
 - c. seals
 5. Hydraulic systems

V. Course Format: This course could be delivered in five full days. Prepared course notes could be used.

31a. ASME BOILER AND PRESSURE VESSEL CODES, SECTION III, DIVISION I
FAILURE MODES AND THEIR RELATION TO CODE DESIGN PROCEDURES

- I. Course Description: and Course Objectives: A sizable number of engineers working in the nuclear industry are involved in the design of equipment which falls under the jurisdiction of the ASME Boiler and Pressure Vessel Codes. That portion of the Code which concerns the design and specification of nuclear power components is Section III. Metal components such as vessels, piping, valves, and related equipment are covered by Division I of Section III. The basis of Section III, Division I, is a recognition of various modes of failure and the application of design procedures to avoid failure. It is the intention of this course to provide a background in the various failure modes, a review of accepted design procedures to avoid failure, and a presentation of design procedures as specified in the codes.
- II. Prerequisite: Undergraduate degree in mechanical or civil engineering, particularly with an emphasis on mechanics of materials and mechanical behavior of materials.
- III. Course Outline:
- A. Introduction to the codes
 - 1. Historical notes
 - 2. Makeup of the codes, design criteria, and specification preparation
 - 3. Design by rule versus design by analysis
 - B. Static failure
 - 1. Failure criteria in general
 - 2. Failure criteria as specified in subsections NB, NC, and ND of Section III
 - C. High cycle fatigue
 - 1. High cycle fatigue design techniques in general
 - 2. High cycle fatigue design methods as specified in subsections NB, NC, and ND of Section III
 - 3. Criteria for exemptions from fatigue analysis
 - D. Low cycle fatigue
 - 1. Low cycle fatigue design techniques in general
 - 2. Low cycle fatigue design methods as specified in subsections NB, NC, and ND of Section III
 - E. Low stress fracture
 - 1. Fracture mechanics approach
 - 2. Transition temperature approach

3. Low stress fracture design methods as specified in NB, NC, and non-mandatory appendix G of Section III

- F. Stress corrosion failure
- G. Hydrogen degradation
- H. Creep

- V. Course Format: The above course description contains a great deal of material even if only covered in survey fashion. An intensive short course, minimum duration 4-5 days, would be required. Some time period between days would be useful for independent study on behalf of the participants. The above content could also be offered as a full semester or full quarter graduate course. Such a course would be offered either with or without the emphasis on ASME code design procedures. Recommended course materials are Design Methods for Power Plant Structures (Burgreen) and supplementary course notes.

31b. PRESSURE VESSEL DESIGN IN RELATION TO THE ASME BOILER
AND PRESSURE VESSEL CODE, SECTION III, DIVISION I

- I. Course Description: and Course Objectives: Section III, Division I of the ASME Boiler and Pressure Vessel Code covers in part design procedures for situations involving nuclear applications. Design engineers working in this area must have a knowledge of the ASME codes. The course described herein is concerned with the overall organization and application of ASME Section III with particular emphasis on subarticles of key interest to engineers involved in any way in the design of pressure vessels which fall under the jurisdiction of the ASME Boiler and Pressure Vessel Code, Section III.
- II. Prerequisites: Undergraduate degree in mechanical or civil engineering particularly with an emphasis on mechanics of materials and mechanical behavior of materials.
- III. Course Outline:
- A. Introduction to the codes
 - 1. Historical notes with emphasis on that part of the code applicable to vessels
 - 2. Makeup of the codes, design criteria, and specification preparation
 - 3. Breakdown of Section III with emphasis on subsections applicable to vessels
 - B. Class 2 and 3 - pressure vessels
 - 1. Failure theories versus ASME code limits for class 2 and 3 vessels
 - 2. Class 2 and 3 - vessel analysis
 - 3. Fatigue methods - class 2 and 3 vessels
 - 4. Special analysis considerations
 - a. nozzles
 - b. skirts
 - c. welded attachments
 - d. portals
 - 5. Example design
 - C. Class 1 pressure vessels
 - 1. Modes of failure versus class 1 vessel analysis
 - a. static failure
 - b. fatigue failure
 - 2. Thermal analysis

3. Special analysis consideration
 - a. nozzles
 - b. skirts
 - c. welded attachments
 - d. portals
4. Example design

V. Course Format: Approximately five (5) days should be allowed to adequately cover all of the above material. Time between days should be allowed for independent study. The material would be best presented using prepared course notes.

31c. PIPING ANALYSIS AND ITS RELATION TO THE ASME BOILER
AND PRESSURE VESSEL CODE, SECTION III, DIVISION I

- I. Course Description: Section III, Division I, of the ASME Boiler and Pressure Vessel Code covers in part piping analysis for situations involving nuclear application. It is imperative that, to do a proper job, the piping analyst have a working knowledge of the ASME codes and their relationship to other codes and standards. The course described herein is concerned with the overall organization and application of ASME Section III with particular emphasis on subarticles of key interest to the piping analyst.
- II. Prerequisites: Undergraduate degree in mechanical or civil engineering, particularly with an emphasis on mechanics of materials and mechanical behavior of materials.
- III. Course Outline:
- A. Introduction to the codes
 - 1. Historical notes with emphasis on evolution of that part of the code applicable to piping
 - 2. Makeup of the codes, design criteria, and specification preparation
 - 3. Breakdown of section III with emphasis on subsections applicable to piping
 - B. Class 2 and 3 piping
 - 1. Failure theories versus ASME code limits for class 2 and 3 piping
 - 2. Class 2 and 3 piping analysis
 - 3. Class 2 and 3 stress intensification factors
 - 4. Fatigue methods for class 2 and 3 piping
 - 5. Example analysis
 - C. Class 1 piping
 - 1. Modes of failure versus ASME class 1 piping and analysis equations
 - 2. Piping analyses fatigue evaluation
 - 3. Class 1 stress indices
 - 4. Thermal analyses
 - 5. Example analysis

- IV. Course Format: This course could adequately be covered in a 2-3 day short course format. Material would best be presented using prepared course notes.
- V. Comments: At appropriate points in the course, comparisons should be made between ASME Section III requirements and requirements of other codes such as ANSI B31.1 and B31.2. Such a comparison should reflect the relative concern for nuclear piping.

32. PROJECT ENGINEERING

- I. Course Description: An overview of the concepts of project engineering as they relate to the power industry and utilities.
- II. Course Objectives: The objectives of the course are to help the practicing engineer develop his professional skills in the administrative side of engineering. Emphasis will be placed on engineering practice.
- III. Prerequisites: An engineering degree
- IV. Course Outline:
 - A. Introduction to project engineering
 - *B. Specifications and engineering design
 - *C. Cost and manpower estimating
 - *D. Design evaluation and review
 - *E. Special topics
 - 1. Engineering economic/Cost-benefit analysis
 - 2. Measuring and evaluating rate of return in engineering design
 - 3. Systems cost-effectiveness
 - F. Contract administration
 - *G. Scheduling, PERT/CPM
 - *H. Project monitoring, communication, and follow-up
- V. Course Format: This course could be a professional workshop meeting on six consecutive Thursdays or Fridays. Study notes, video cassettes, audio cassettes, and computer practice sessions would be used in presenting this course.

*These topics would be given special emphasis. The course would be primarily oriented toward the development of practical skills of getting-the-job-done.

33. TECHNICAL MANAGEMENT

- I. Course Description: An overview of the concepts of technical management as they relate to engineering in the power industry and utilities.
- II. Course Objectives: The objectives of the course are to help the engineering manager improve and develop his professional skills in the human enterprise of engineering practice.
- III. Prerequisites: An engineering degree and current or future responsibility of engineering management.
- IV. Course Outline:
 - A. Introduction to systems engineering management
 - B. Role of the technical manager
 - C. Technical planning
 - D. Systems cost effectiveness
 - E. Program scheduling and control
 - F. Organizing and staffing
 - G. Motivating engineers
 - H. Effective utilization and development of the engineering staff
 - I. Special topics
 - 1. Management roles and techniques in problem solving and handling conflict
 - J. Technology and policy
- V. Course Format: This course could be a professional workshop meeting on six consecutive Thursdays or Fridays. Course notes, video cassettes, and audio cassettes would be the method of presenting this topic along with significant class discussion. Use of real world situations would be emphasized.

34. TECHNICAL COMMUNICATIONS

- I. Course Description: An overview of the concepts of technical communications from technical correspondence through report writing and oral presentations.
- II. Course Objectives: The objectives of the course are to help the practicing engineer improve and develop his or her skills in clear and effective written and oral communications.
- III. Prerequisites: An engineering degree
- IV. Course Outline:
 - A. Introduction to technical communications
 - B. Understanding the communication process
 - C. Principles and styles of technical correspondence
 - D. Mechanics of correspondence
 - E. Reports
 - F. Letters and inter-office memoranda
 - G. Special topics
 - 1. Effective use of time and use of dictation/recording equipment
 - H. Effective oral presentation
 - I. Listening skills
 - J. Conducting meetings
- V. Course Format: This course could be a professional workshop meeting on six consecutive Thursdays or Fridays. Material could be presented by prepared course notes, video cassettes, and audio cassettes with discussion. The course would also emphasize actual examples of letters, reports, etc. involved in day-to-day engineering work.

35. PROCESS DESIGN AND ANALYSIS FOR NUCLEAR APPLICATIONS

- I. Course Description: This course covers those areas of process design which are specific to the nuclear fuel cycle. Special emphasis is placed on the design considerations which result from the processing of radioactive materials.
- II. Course Objective: The objective of the course is to provide both the student and the practicing engineer with the skills required to solve design problems which are unique to the nuclear fuel cycle.
- III. Prerequisite: An engineering degree.
- IV. Course Outline:
 - A. Overview of nuclear fuel reprocessing and its place in the nuclear fuel cycle
 - B. Special considerations in radiochemical processing
 - C. Separation processes
 - D. Spent fuel dissolution
 - E. Mechanical operations
 - F. Fluid flow
 - G. Heat transfer
 - H. Solvent extraction
 - I. Other mass-transfer operations
 - J. Instrumentation
 - K. Material accountability
 - L. Auxiliary equipment
 - M. Radiochemical plant design
 - N. Material safeguards
 - O. Plant management and operations
 - P. Radiochemical-processing costs
- V. Course Format: This course could be offered as a one semester course. The level of the material presented is within the grasp of either a senior or a first year graduate student. Suggested course materials include Long, J. T., Engineering for Nuclear Reprocessing, ANS, LaGrange Park, Illinois, 1977, and prepared class notes.
- VI. Comments: Because of the political and highly emotional influences upon the nuclear industry, it would be difficult to discuss the design of nuclear facilities without discussing how it is affected by society. How these topics are included and to what extent they are included in this course would depend upon the social situation at the time of its offering.

36. CHEMICAL PROCESS DESIGN AGAINST ACCIDENTS

- I. Course Description: Accident analysis as applied to the nuclear industry. Coverage will include accident criteria, reliability analysis, safety specifications, and regulations and process design considerations.
- II. Course Objectives: The student will be made aware of failure modes, fault tree, reliability and availability analysis, common cause failure analysis, and safety standards. He will consider equipment redundancy and layout to minimize potential process failures as well as become familiar with applicable EPA, NRC, and OSHA regulations.
- III. Course Outline:
- A. Criteria for accidents
 - 1. Flamability (explosion/fire)
 - 2. Leakage (radiation/spills (liquid, gas, powders))
 - 3. External (airplane crash/earthquake)
 - 4. Safeguards (intruder attack)
 - B. Description of system reliability/availability methods
 - 1. Failure modes/statistics - Monte Carlo Analysis
 - 2. Fault tree analysis
 - 3. Reliability/availability
 - 4. Common cause failure analysis
 - 5. Reliability analysis programs and codes
 - 6. Reliability analysis data bases
 - C. Safety specifications/regulations
 - 1. OSHA requirements
 - 2. EPA, NRC requirements
 - 3. Emission dose rates
 - D. Process design considerations
 - 1. Redundancy
 - 2. Layout
 - 3. Safety features of equipment
 - 4. Safety equipment
- IV. Comments:
- A. Course outline should address requirement for acceptable data base of equipment reliability data and present availability of such a data base.
 - B. Should also include examples of valid successful application of this type analysis for additional study by the serious student.

APPENDIX C

REFERENCES

1. LICENSING OF NUCLEAR FACILITIES

1. "Licensing of Production and Utilization Facilities," Title 10, Code of Federal Regulations, Part 50.
2. "Reactor Site Criteria," Title 10, Code of Federal Regulations, Part 100.
3. "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," USNRC Regulatory Guide 1.70, Revision 2 (September 1975).
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5. "Numerical Guides for Design Objectives and Limiting Condition Conditions for Operation to Meet the Criterion 'As Low As Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," Appendix I, Title 10, Code of Federal Regulations, Part 50, Licensing and Production Utilization Facilities.
6. "Preparation of Environmental Reports for Nuclear Power Stations," USNRC Regulatory Guide 4.2, Revision 1 (January 1975)
7. "ECCS Evaluation Models," Appendix K, Title 10, Code of Federal Regulations, Part 50, Licensing and Production Utilization Facilities.
8. "Seismic and Geologic Siting Criteria for Nuclear Power Plants," Appendix A, Title 10, Code of Federal Regulations, Part 100, Reactor Site Criteria.
9. "Operators' Licenses," Title 10, Code of Federal Regulations, Part 55.

2. QUALITY ASSURANCE FOR NUCLEAR FACILITIES

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