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ABSTRACT

Several areas that are lacking in undergraduate nuclear engineering programs are discussed. Although most programs provide adequate theoretical knowledge in nuclear science, the nuclear engineer must have a working knowledge with the complete nuclear power plant, and be acquainted with the functions and responsibilities of the various segments of the nuclear industry and of the federal and state agencies under whose regulation the entire industry must operate. Suggestions are given for means of incorporating these practical aspects into nuclear engineering programs. (MLH)

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AN INDUSTRIAL VIEW OF UNDERGRADUATE PROGRAMS

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It is generally recognized that the nuclear industry has undergone rapid and profound changes in the last decade. It has evolved from principally a research and development program directed towards many new and often exotic concepts to a mature effort primarily involved with a limited number of well-developed concepts ultimately serving and responsive to the needs of a single industry - the electric utility industry. Because it primarily serves a single industry, nuclear engineering education must be guided by the needs of that industry. The nature of the electric utility industry today is such that nuclear engineering graduates, if they are to become productive with a minimum of additional training, must be both more specialized and more practically oriented than their counterparts in the traditional engineering disciplines.

Far too many present day nuclear engineering graduates lack even a rudimentary practical understanding of the nature and problems of the industry they will ultimately serve. They generally have sufficient background in basic engineering science and in nuclear fundamentals but are not familiar with the practical aspects of the machines, the interrelationships, and the procedures upon which the industry is based. They must now learn these things on the job and this significantly delays the time when they become productive members of the team. The nuclear engineering programs in the universities can and should do more to give their students more practical and immediately useful knowledge about the industry they will serve. The remainder of this paper details some of the more critical deficiencies encountered by the author and presents some suggestions as to what the universities might do to help.

Many if not most nuclear engineering programs give their students a respectable understanding of the physics of nuclear reactors, shielding, health physics, and nuclear heat transfer but appear to stop there. Little or nothing seems to be formally included in the programs about the rest of the systems found in a nuclear power plant. Today's nuclear engineer needs to be familiar not only with the reactor core but with the entire nuclear steam supply system as well as the peripheral systems commonly referred to as balance-of-plant. He should understand the differences between the various types of nuclear steam supply systems and the advantages and disadvantages of each. Examples of some balance of plant systems whose function and basic design features should be better understood are the steam and power conversion systems, the radioactive waste system; heating, ventilating, and air conditioning systems; in-plant electrical systems, and the engineered safeguards systems. In addition to a basic idea of the criteria governing the design of these systems and how they operate, the nuclear engineer must appreciate the interrelationships between them and how they affect the design of the entire plant. The ultimate goal of the nuclear industry today is to design and build safe, reliable, and economical nuclear power plants. Consequently nuclear engineering educational programs ought to instill in their students an understanding of the principles of the design and operation of the complete nuclear power plant. Many do not.

In addition to a working familiarity with the complete nuclear power plant, the nuclear engineer needs as well to be aquainted with the functions and responsibilities of the various segments of the nuclear industry and of the federal and state agencies under whose regulations the entire industry must operate. He must understand how each of these are related one to another and to the nuclear power plant project itself. The role in a nuclear power plant project of the utility, the architect-engineer, the constructor, the major equipment supplier, and the various consultants should be made clear to the student before he graduates. He should be at least aquainted with the essential steps in the licensing process and with the content and purpose of the major documents required. It is desirable but perhaps not as crucial, except for those immediately involved with nuclear fuel, for a nuclear engineer to have an appreciation of what is involved in each of the steps of the nuclear fuel cycle.

The design, construction, and operation of a nuclear power plant is probably the most highly regulated of any major industrial or commercial activity. Each and every step which is safety related must be performed in absolute conformity with the requirements of state or federal regulations or both and this conformance must be adequately documented. In fact if a recently proposed amendment to the Code of Federal Regulations is adopted, it will be a crime punishable by a large personal fine for a responsible engineer to fail to report noncompliance with safety related regulations and it will be illegal for that engineer's company to reimburse or otherwise compensate him for the fine. It is, therefore, absolutely essential for the nuclear engineer to be intimately familiar with the regulations governing the design, construction, and operation of a nuclear power plant. These regulations are promulgated in a variety of different forms including the Code of Federal Regulations, design guides, and a myriad of codes and standards.

It is not reasonable to expect any academic program to instill in its students a thorough understanding and competence in the application of all or even most of the areas mentioned above. That takes years of practice. It is, however, not unreasonable to expect graduate nuclear engineers to know that these things exist and to understand their relative importance and how they fit into the overall picture. In the author's opinion a single course in nuclear power plant design, if properly structured and taught by one intimately familiar with modern nuclear engineering practice could go a long way toward filling this need. Such a course would logically but not necessarily follow a course in nuclear reactor design and should be required of all students who intend to become involved with the practical aspects of nuclear power.

A suggested way to structure such a nuclear power plant design course would be to follow and study from a utility point of view a typical nuclear power plant project from its inception through commercial operation. The major problem areas and the interrelationships between the various segments of the nuclear industry could be illustrated in this way along with the important features of the plant design. Let's briefly look at a project and consider how this might be accomplished.

The project begins with the identification of the need for additional generating capacity on the system. The first question to be answered, other than can we afford any kind of new power plant at all, is whether the new plant will be fossil or nuclear. At this point, the capital cost, fuel cost, availability of the various fuels, operating and maintenance expense, environmental effects, and system power requirements must be considered among other things. This can be gone through rather quickly but it will graphically demonstrate the magnitude of the costs involved, point out the significant advantages of nuclear power, and introduce the student to the concepts of comparative economic analysis.

Assuming that the choice is nuclear, the next problem is often the selection of the major members of the project team: the architect-engineer, the constructor, and the environmental consultant. Again this should not take much time but through consideration of which firms have been associated with other nuclear projects the student can be introduced to the names, functions, and areas of specialization of the major firms involved in these segments of the industry and the part each will play in the total project.

Next, a suitable site must be found. By consideration of the site selection process the student will become familiar with the essential requirements of a nuclear power plant site. Geology, seismology, demography, possible transmission corridors and the availability of adequate cooling water are some of the more important ones.

The bid specifications for the nuclear steam supply system, the initial nuclear fuel supply, and the turbine generator are prepared as the initial step in the evaluation process. Here is a good place to introduce the student to the essential characteristics of each of these and how they must fit together to meet the requirements of the utility system.

After the bids are received, the detailed process of comparative evaluation begins. It is at this point that the details and characteristics of all of the different nuclear steam supply systems including fuel and turbine generators should be examined. Advantages and disadvantages of each of the different systems should be considered. This can be done quite well by assigning small groups of students to the system supplied by each major vendor and requiring each group to produce a written report detailing the features and advantages of their particular system. Sufficient material to accomplish this is available from the vendors and at least some of them are willing to supply their "standard" proposal consisting of several volumes of detailed descriptions and advantages of their systems at no cost to universities for continued use. These "standard" proposals contain a wealth of information and provide invaluable references for the students. Each of the groups should give a rather detailed oral presentation of their finding to the class and attempt to sell the class on their particular system. One system can then be chosen for the project. It has been the author's experience that this procedure generates a high degree of student interest and does a surprisingly good job of aquainting the students with all of the different systems.

Following the final selection of the nuclear steam supply system and turbine generator vendors, the plant design and licensing activities begin and proceed essentially in parallel. In fact, the main documents required in the application for a construction permit; the preliminary safety analysis report (PSAR) and the environmental report (ER), are required to contain so much detail that the essential characteristics and major design features of all of the important systems in the entire plant must be fixed and described therein. Consequently the PSAR and ER, particularly the PSAR are excellent documents upon which to base a practical study of nuclear power plant design. Additionally, complete sets of these documents can be obtained for use by universities

Because of the limited time available, it would not be practical to consider the detailed design of all of the systems. However in addition to the nuclear steam supply system, a few major systems such as the steam and power conversion system, the radioactive waste management system, the heating, ventilating, and air conditioning system; and the engineered safety systems should be studied in sufficient depth to generate a basic understanding of their function, principle design features, and interrelationships with other systems. It is extremely important for these studies to be done in a way that illustrates how the design of these systems is governed by the appropriate codes, standards, and design guides.

The licensing process, proceeding in parallel with the plant design, does not lend itself as readily to classroom study partly because it is governed by a myriad of federal, state, and local regulations which are constantly changing and often difficult to interpret. Nevertheless it is critically important. The largest part of the delays and cost overruns experienced by nuclear power plant projects in recent years can be attributed to licensing difficulties. The essentials of the licensing process should therefore be discussed, perhaps in a purely expository manner. The principal governmental agencies involved, the permits and licenses required, the necessary documents, and a chronological description of the process should all be included.

The construction phase of the plant along with the remaining activities necessary to reach commercial operation can be studied and related to the preceding project phases by utilizing a detailed major milestone schedule as a guide. This can serve as a useful review and is a good place to tie down any remaining loose ends.

In the author's opinion, a nuclear power plant design course such as this, taught by an instructor who has been broadly involved in a practical way with a nuclear power plant project, would give the student a basic practical familiarity with not only the entire plant but also the major segments of the nuclear industry. Such a familiarity would significantly reduce the time he now spends on his first job learning enought to become a productive member of the team. Those of us who must now bear with new graduates during their first few months on the job would be eternally grateful.

In addition to those most critical areas discussed above, there are two others where a large percentage of engineering graduates are seriously deficient: communication skills and engineering economics. Many of todays' engineering graduates are unable to write an acceptable report, give an acceptable oral presentation, or read a print. The first two of these can, in this author's opinion, be corrected by requiring the students to give as many oral and written reports as possible within the context of existing courses. Laboratory courses are ideally suited to this. In such courses, the student's grade should depend as much on the quality of his oral and written reports as on his knowledge of the subject. Technical knowledge without the ability to communicate it is worthless! The ability to read a print is usually taught in a course in engineering drawing. It is astonishing but true that more than a few engineering curricula require no engineering drawing at all. This is a most serious deficiency and must be corrected where it exists. No person should be allowed to graduate from an engineering school who cannot read a print.

In the practice of nuclear engineering with which this author is familiar, engineering economic analysis plays a vital role in virtually every project. Particularly in these times, capital is a scarce commodity and the best possible use must be made of it. Minimizing the cost of or maximizing the return from a project is constantly on the engineer's mind. Further, the advantages and disadvantages of a particular project must often be couched in financial jargon easily understood by management. For these reasons, it would appear that a course in engineering economic analysis ought to be required in modern engineering curricula. It seldom is.

All of the preceding comments are based on the author's view of undergraduate programs from the standpoint of an electric utility involved in several nuclear power plant projects. From that standpoint, nuclear engineering graduates need to have a greater practical knowledge of the complete nuclear power plant and of the nuclear industry. They need to understand the principles of engineering economic analysis and they must be able to communicate their knowledge effectively. The methods suggested herein for filling these needs have worked well in the author's experience. It is hoped that others as well may find them useful.