Nuclear Engineering Education in 21st Century

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Abstract: Nuclear engineering is concerned with the practical applications of nuclear energy. A nuclear engineer should be able to comprehend the basics of nuclear reactors, commercial nuclear power plant design, advanced or future nuclear systems, and application of nuclear energy. Nuclear engineering in general includes activities in virtually every branch of engineering and that if offers an unusual challenge to those who are interested in the new fields of professional activity. The next decade will focus on trying to resolve the "three dimensional problem" of energy, the environment and economy. It is very desirable to develop inherently safe reactors whose safety in inherent and easily demonstrable, and does not depend on the interference of safety devices which have some probability of failing, or on operator skills and good judgement, which could vary considerably. True inherent safety exist when no mechanical or human intervention is required to shut down the reactor safely. The opportunities for service are great in utilization science at the service of humanity. There are important contributions to be made in research and development through inventions and developments of new ideas and new nuclear reactor concepts. It is gratifying to contribute to the progress of high technology and the advancement of the civilization

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1. The Energy Problem

Energy and economy may be considered as synonymous concepts since there is no economy without energy. The solution to the ever-increasing for energy to satisfy the needs of the growing world population and improve of living lies in the combined utilization of all forms of energy. None of the energy resources by itself is a panacea. Nuclear energy when generated safely and used in suitable applications have an important role in solving the world energy problem. Nuclear engineer deals with the generation and utilization of nuclear energy among others.

2. What's Nuclear Engineering?

Engineering is defined as "the art and science involved in the utilization of the forces and materials of nature for the benefit of mankind." Nuclear engineering, thus may be defined as "the art and science involved in the utilization of the forces and materials associated with nuclear transformations for the benefit of mankind." Nuclear engineering is concerned with the practical applications of nuclear energy, that is the energy that emanates from the nucleus of an atom. It consists in the development and application of the principles, the processes, the materials, and the equipments involved in the controlled utilization of nuclear reactions.

The applications include the production of power by nuclear fission or fusion, the technology associated with nuclear fuel production and nuclear waste handling, industrial process control, and materials processing.

The use of radioactive materials in research, industry, medicine, and agriculture is closely associated with nuclear engineering application. Foe example, nuclear radiation is used for food preservation. The spoilage of foodstuffs is caused by various microorganisms which are present in the foodstuffs at the time they are packed or shipped. Such spoilage can be inhibited by exposing these materials to large fields of radiation, sufficient to annihilate or otherwise render harmless the offending organisms. In a related area, various medical supplies, such as surgical instruments can be sterilized after packaging by placing them in radiation fields from radioactive isotopes or in beam of charged particles from accelerators. Another application is chemical processing. When radiation interacts with matter, a variety of ions and molecules are formed that some cases are capable of catalyzing chemical reactions. Several new products have been developed with this unique processing technique.

Nuclear engineering deals mainly with the design, construction and operation of nuclear reactors. Nuclear reactor is a device capable of maintaining and self-sustaining, controlled nuclear fission or fusion reaction.

Nuclear fission is the splitting of a heavy atomic nucleus into two or more fragments. Nuclear fusion is the formation of on atomic nucleus by the union of two other nuclei of lighter mass. Both processes are accompanied by the release of an enormous amount of energy.

The existing nuclear reactors are of fission type since still the fusion reactors have not come into existence. Most nuclear engineers today involved in the research and development of nuclear power installations, either stationary power plants for generation of electricity or propulsion of mobile systems. The fact that nuclear fuels have a high specific energy; that is, they release a large amount of energy per unit weight of fuel, and the fact that they do not consume oxygen for such processes, they are used to fuel submarine propulsion reactors and can be used in the reactors for space travelling. It appears that nuclear power rockets will be necessary in order to carry out manned missions to other planets in the solar system when such missions are undertaken. The desirability of nuclear rockets stems from the fact that the total vehicular mass required for a long distance mission is considerably less if the vehicle is powered by a nuclear rocket rather than by a conventional chemical rocket.

3. Who is a Nuclear Engineer?

Nuclear engineering involves elements of physics, mechanical, chemical, and electrical engineering. A nuclear engineer should be able to comprehend the basics of nuclear reactors, commercial nuclear power plant design, advanced or future nuclear systems, and application of nuclear energy. Knowledge about nuclear systems includes design, control, operation, and impact on environment. Thus, basic familiarity with fuel cycles, materials, thermal design, systems dynamics and control, instrumentation, radiation and radioisotopes, and other nuclear processes is essential. In addition to the basic knowledge, a nuclear engineer must be able to assume the role of an electrical engineer, mechanical engineer, chemical engineer, structural engineer, and material engineer in areas related to nuclear systems.

Health physics would also be an important subject, so to describe the connection between biology and the different radiations associated with nuclear energy.

The other fields related to nuclear engineering is the uses of radioisotopes and radiations for medical and industrial purposes and for food conservation. The nuclear engineer must have a scientific background strong enough to allow them to understand and to use efficiently and quickly the new technologies.

4. Relationship of Nuclear Engineering to other Fields of Engineering

Nuclear engineering, concerned with the application of principles, processes, materials, and equipment in the controlled utilization of nuclear reactions, is closely related to several other fields of engineering and science. Although the execution of a nuclear engineering project may include the application of physics, chemistry, mathematics, and engineering sciences such as mechanics of solids, mechanics of fluids, nature and properties of materials, electrical theory, thermodynamics, and transfer processes, as do other fields of engineering, the distinctive feature of nuclear engineering is the fact that the applications involve nuclear transformations and principles of nuclear particle behavior.

Rigorous design conditions are imposed on nuclear engineering projects. Unusual requirements for the purity of materials to be used in reactors have challenged the chemical engineer, metallurgist, the ceramic engineer, and the chemist. Many materials utilized in nuclear engineering projects are not conventional engineering materials and had and will have to be developed.

The problems of instrumentation are challenging. Wide ranges of sensitivity are required, and response must be rapid and reliable.

The temperatures well above the usual operating range are necessary in some applications. This fact brings in problems of structural design, including resistance to creep and resistance to thermal shock. Heat transfer problems tend to be complex as unusual geometries are involved with extremely high heat transfer rates, and in some cases liquid metals instead of conventional fluids are used as coolants.

The effect of radiation in changing the properties of materials is an ever present problem. The waste radioactive materials cannot be disposed of in the usual manner and special provision must be made for its handling and storage.

It is evident that nuclear engineering in general includes activities in virtually every branch of engineering and that if offers an unusual challenge to those who are interested in the new fields of professional activity.

5. Nuclear Energy and The New Era

The energy available from nuclear fission using uranium is very large. The potential energy from fusion is even higher but fusion is unlikely to be applied practically during the next couple of decades. Nuclear safety and handling of nuclear waste are challenges for nuclear engineers. The environmental issue in using fossil fuel that has attracted most attention is the potential of global warning due to the accumulation of "greenhouse gases", notably carbon dioxide. Some 50% of the greenhouse effect is traced to the increase in carbon dioxide which results from the burning of fossil fuels and deforestation. Not all alternate and renewable energy sources are environmentally benign. Energy efficiency or conservation is an important issue, but their contributions are limited and must be achieved on an economic basis.

The next decade will focus on trying to resolve the "three dimensional problem" of energy, the environment and economy.

The question that is always raised is which supply mixes of energy resources would best respond to our needs for energy, account being taken of the environment and economic?

6. The Problems of Nuclear Energy

One of the reasons behind the difficulties of public acceptance of nuclear energy is the psychological implications of its origin. Unfortunately nuclear power grew out of the military uses of nuclear fission, namely as the result of construction of the types of nuclear reactors suitable for nuclear weapons material production and to power nuclear submarines. Following electricity production from a test nuclear reactor in 1951 and the launching of the Atoms for Peace Program by United States in 1954, industries involved in military efforts found an opportunity to use the declassified technologies for civilian nuclear power production. This is how the nuclear industry was born.

As time has evolved and deficiencies in the existing nuclear reactor concepts appeared, new safety systems were added to them. Today's nuclear reactors possess numerous expensive and complex active safety systems, but still have not eliminated the possibility of a reactor accident. As a result, the public has lost confidence in nuclear energy.

Today, there exist in fact a world-wide moratorium on nuclear energy. The public objections to nuclear energy most often expressed are reactor safety, cost and nuclear waste disposal.

7. Ideal Nuclear Reactors

It is very desirable to develop inherently safe reactors whose safety in inherent and easily demonstrable, and does not depend on the interference of safety devices which have some probability of failing, or on operator skills and good judgement, which could vary considerably. True inherent safety exist when no mechanical or human intervention is required to shut down the reactor safely.

A great effort wold-wide is being made to develop new nuclear reactor concepts with inherent safety, which is believed to be a requisite for the public acceptance of the nuclear energy, to contribute to the solution of the world energy problem[1].

All current reactors must include safety systems to remove decay heat that threatens to produce after the chain reaction in a reactor has ceased. It is this decay heat that threatens to produce the most frightening of nuclear accidents- the core melt. The inherently safe reactors are transparently incapable of producing a core melt. They are "forgiving" reactors, able to tolerate human and mechanical mal functions without endangering public health. Also they are called "walk way" reactors as the key feature of these reactors is their reliance upon passive or non-mechanical, safety systems.

The nuclear engineers are left with the challenge of providing the new era with adequate nuclear rectors to serve as clean and safe energy sources.

The Universal House of Justice declares that, "The scientific and technological advances occurring in this unusually blessed century portend a great surge forward in the social evolution of the planet, and indicate the means by which the practical problems of humanity many be solved. They provide, indeed, the very means for the administration of the complex life of a unite world."

8. How to Enter Nuclear Engineering Studies

Today exist throughout the world numerous universities who offer undergraduate but mostly graduate degrees in the field of nuclear engineering. Many of them still make part of the traditional engineering departments.

The first formal university nuclear engineering education program was established in 1950 by Clifford Beck at North Carolina State University in the United States. The first university training/research reactor was put into operation there in 1953. Historically, most of the nuclear engineering programs were at the graduate level on the belief that nuclear engineering was too specialized and difficult for undergraduates. Later on many undergraduate programs in nuclear engineering have came into existence.

For undergraduate studies, one needs to have a good solid background in basic sciences, and for graduate studies it is preferred that one has completed a degree in physics, mechanical, chemical or electrical engineering.

9. What are the Opportunities for Service?

The future for nuclear engineering education will be exciting and filled with new opportunities born of change, crises, and challenge. Looking beyond the year 2000, one can be sure only that entire technical and engineering communities will endure both great evolution and certain revolutions.

Traditionally, most nuclear engineering programs have emphasized either reactor physics or thermal hydraulics. Electives in health physics, shielding and metallurgy are used to round out the programs. The problems of space reactors and particle beams involve space physics and material and solid state sciences, are subjects not yet found in many traditional nuclear engineering programs.

Furthermore, if commercial fusion reactors are ever to become a reality, there will be, in addition to plasma physics problems, many material-related problems to be resolved. Engineers working on such problems will need experience in solid-state science as well as metallurgy to cope with the rising technology.

The coming decades appear to be especially crucial for all of the nuclear–related technologies. Radioactive waste management is becoming an urgent need. Breeder technology is maturing for commercial utilization. Controlled fusion is reaching for ignition. Their development depends heavily on the quality of people will be the products of nuclear engineering education. On the other hand, the need for high-quality nuclear engineering education in the future is apparent. Nuclear engineering is more demanding than other engineering because the price of failure is greater.

The opportunities for service are great in utilization science at the service of humanity. There are important contributions to be made in research and development through inventions and developments of new ideas and new nuclear reactor concepts. It is gratifying to contribute to the progress of high technology and the advancement of the civilization. As Baha' u' llah said, "All men have been created to carry forward an ever-advancing civilization."[2]

In the coming years when the goal of disarmament is accomplished, all of the intellectual and material resources in the nuclear field will be dedicated to the production of energy for improving the standard of the living of the humanity. There are great opportunities to develop ideas of how to transform existing nuclear weapons materials into the peaceful uses for the service of mankind; namely, as promised in the Bible, "They shall beat their swords into plowshares, and their spears into pruning hooks." There are needs to develop new nuclear reactor concepts which offer total safety and whose nuclear waste will not be a menacing waste but serve as a useful source of radiation for application in the fields of agriculture, industry and medicine.

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