AC 2011-2818: THE ROLE OF THE COLLEGE OF TECHNOLOGY IN THE NUCLEAR INDUSTRY

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Defining a Role for a College of Technology in Nuclear Education

Abstract

Ever-increasing energy demands, concerns over climate change, and an elusive chase for national energy independence are driving a quiet resurgence for increasing the use of nuclear power. Experts maintain however, that any nuclear power expansion will have to be both timely and at a scale that will provide the results intended. For this to happen, initiatives leading to the education and development of qualified nuclear personnel will have to be implemented. Because engineering technology programs feature plans of study that prepare graduates for occupational areas with a distinct "hands-on" reach, a College of Technology is in a unique position to participate and meaningfully contribute to any expansion of the domestic nuclear industry. The object of the paper is to define the role of a College of Technology as it seeks a first-time attempt to establish itself in nuclear power education. This is done using a two-part approach. The first part of the paper provides an overview of the global and domestic nuclear power industry, some of its challenges and accomplishments, and developments forming new and expanding directions for the future of this truly remarkable industry. The second part of the paper deals exclusively with nuclear engineering technology, a part of the academic enterprise that nurtures and sustains growth of the nuclear industry by providing it graduates with specialized work skills and a solid understanding of nuclear science basics. The paper examines course offerings of established nuclear educational programs including that at the U. S. Navy's Nuclear Power School. This information is used to develop the curriculum for a four-year Bachelor of Science degree program in Nuclear Engineering Technology. The template for the development of the proposed curriculum is the plan of study from an existing Mechanical Engineering Technology program. Because introduction of any new program can be a formidable task, the authors provide ideas for getting started by noting available resources that are sometimes overlooked.

Introduction

The United States is a monolithic, diverse country blest with vast and varied energy resources. The ever-changing make-up and scattered nature of these resources present a challenge for ensuring that demands for electrical power will be met through the middle of the 21st century. Net generation-by-source data[1] shows that coal and natural gas continue to lead the fossil fuels category which makes up almost 70% of total domestic electrical output. Nuclear leads the non-fossil category with a 20% make-up; renewables and other sources make up the remainder. More important, concern with the relentless growth in electric power in the last decade both globally and in the United States, has prompted a reevaluation of nuclear energy use despite its inherent issues involving economics, public perception of safety, waste management, and security. This activity is well documented in a landmark report dealing with the future of domestic nuclear power[2]. The study points out that concern with avoiding adverse consequences of climate change has increased significantly, that neither the U.S. nor emerging rapidly-growing economies have adopted curbs on greenhouse gas emissions, and that the emissions are projected to continue to increase. What follows is a brief overview of key industry developments that are shaping the scope and direction of what some experts call a "nuclear renaissance"[3], something the U. S. has not seen in decades. Of relevance is the impact on preparation and training of a nuclear workforce for an industry steeped in an inventory of unique and highly specialized skills cultivated in the advanced technical reaches of post-secondary education. Of particular interest is the response of one College of Technology to the ostensible nuclear expansion and how it proposes to address future educational demands, doing so for the first time.

Overview of Global Nuclear Power Development

In as much as the origins of nuclear power can be traced to familiar names in chemistry and physics, it was Enrico Fermi's development of a self-sustaining nuclear chain reaction that led to the launching of the nuclear industry as it is known today. In 2009 there were over 440 commercial nuclear power reactors operating in 30 countries including 104 in the United States. The first nuclear power plant to generate electric power commercially was in Obninsk, Russia in 1954. Today the Russian Federation ranks fourth in nuclear output[4]. See Figure 1. Of particular interest is mainland China's 23 plants currently under construction with another 27 units planned for construction to start within three years[5]. Fifteen other countries are planning to add nuclear reactors with a generating capacity of 150,000 MW. These include first-time developing nation users like Thailand, Turkey, and Vietnam[6].

Although tactical reasons behind growth in world nuclear usage vary, one expert[7] points out that the fundamental reasons for global nuclear power growth are linked to population growth, technological progress and its concomitant need for more energy, depletion of hydrocarbons, and a pure and simple desire for improvement and growth in living standards. As a result of robust growth beyond its borders, U. S. dominance as world leader in nuclear power generation is being challenged. On the other hand, this global expansion provides the U. S. with reassurance that nuclear energy indeed continues to be a viable and meaningful option for future power generation. Also, as world-wide nuclear operations expand, these contribute immeasurably to the knowledge and experience base of the entire nuclear community for dealing with approaches to safety and security issues that are different from those used in the U. S.

Figure 1. **World Nuclear Plants – Operating and Under Construction**

	OPERATING PLANTS		UNDER CONSTRUCTION	
COUNTRY	**NUMBER**	**MW**	**NUMBER**	**MW**
U.S.A.	**104**	**100,683**	**1**	**1,165**
FRANCE	**58**	**63,130**	**1**	**1600**
JAPAN	**54**	**46,823**	**2**	**2,650**
RUSSIAN FED.	**32**	**22,693**	**11**	**9,153**
CHINA	**13**	**10,048**	**23**	**24,010**

Overview of Domestic Nuclear Power Development

Clearly, U.S. nuclear power growth pales in comparison with that of its global counterparts especially when one considers that no new plants have been put on line in over 30 years. Reasons for the domestic inactivity are both varied and complex. In the U. S., market-driven forces dictate that low cost energy will be generated. Despite their proclivity to pollute, coal-fired generating plants made economic sense because of relatively lower costs in their construction, start-up, and operation. For years, attempts to minimize environmental impact of coal-burning were made as evidenced by the introduction of clean-up devices such as scrubbers, electrostatic precipitators, and by the use of fluidized-bed boilers. Within the last decade, clean-energy concepts such as clean-coal technology, coal-gasification, a shift to greater use of natural gas, and use of renewables such as wind and solar, made their debut on the power generation horizon. Most recently, growing sensitivity about global warming and the need to generate electric power without releasing harmful CO_2 or other greenhouse gases, have taken on widespread proportion as evidenced by on-going crusader-type campaigns to get rid of dirty coal plants[8] and to replace these with costly, and quite often, publicly-subsidized solar and wind generation units. Experts maintain that despite their zero-fuel-cost status, solar and wind power systems have inherent shortcomings that render them unsuitable as primary supplier candidates of the nation's vast electrical power base. A much better choice for the latter is the expanded use of nuclear power.

Today, the climate for adopting the nuclear approach in the U. S. is more favorable than it has been for years. Factors contributing to the favorable nuclear outlook include:

1. A general public's reluctance to change a lifestyle that is and continues to be more electric-centered despite public awareness of the inherent risk of some damage to the environment.

2. Public insight that senses that claims about the potential of nuclear plant accidents and their inevitable meltdowns may have been overstated. In a recent Gallup Environmental Poll[9], public support for nuclear energy appears to be inching up.
3. Evidence of more than 30 years of domestic nuclear operations without a major incidence.
4. Encouragement from abroad that workable solutions for long-term disposal of nuclear waste can be successful.
5. Exponential growth in the development of new small nuclear reactors, capable of operating as stand-alone units buried at user sites without some of the safety and security shortcomings of their larger counterparts.[10]
6. Consideration for the use of fuel cycles other than uranium. Particular attention is being directed to the thorium fuel cycle.[11] Use of thorium is claimed to produce an energy conversion that is much safer and more efficient than that of uranium.
7. There is clear evidence that over the past 15 years, the U.S. nuclear industry has upheld an unheralded record of operational distinction for which it is often overlooked. For example, in a recent publication[12] the DOE cited that efficiency improvements and power uprates have added the equivalent of 5 to 6 new reactors to the electrical grid, and that plants, which were available to produce energy only 70 percent of the time in the early 1990s, are now producing power around 92 percent of the time.

In light of the above factors and considering the somewhat contentious history of nuclear energy in the U. S., public resistance to the use of nuclear power continues to exist. Notable factors worth citing here include:

1. Continued promotion of fear, the destructive power of nuclear energy, and zero-tolerance for any nuclear expansion. One study shows that these attributes can be traced to differences in the perception of risk by scientific and general public communities on complex projects.[13]

2. A financial community reluctant to help the nuclear industry which has been unable to reduce costs to license, build, and operate nuclear power plants. Simply stated, as an industry gains in operational knowledge and experience, its costs typically come down. This phenomenon apparently is not holding true for nuclear industry today. An excellent treatment of this complex subject is presented in a seminal report[14] that shows that relative costs of generation alternatives for coal, natural gas, nuclear to be 6.2, 6.5, and 8.4 cents/kWh. The report notes that mechanisms to reduce the cost of nuclear power and to make it competitive with coal and natural gas operations are possible. Potential cost-saving areas cited include changes in the logistics of new plant construction, standardization of plant design, and the cost of capital. The latter is especially challenging in an economic environment where costly enterprises such as nuclear power plants are not financed or owned by the government but must compete

with scarce resource dollars held in a private sector that is often beseiged with skepticism and mistrust of the nuclear power industry.

Other factors that raise concerns about the near-term direction that development in U. S. nuclear power may take include:

1. Elimination of federal funding for a nuclear waste repository at Nevada's Yucca Mountain leaving the nation with no solution to the permanent storage of nuclear waste.

2. Lack of adequate safeguards to manage the proliferation of nuclear materials in an environment of rapidly expanding global growth.

3. Lack of federal government directives and policy for energy growth

4. Aging facilities.[15] Operation of reactor plant components beyond 60 years is being considered.

5. Aging workforce.[16] The Nuclear Energy Institute 2010 Work Force Report indicates that by 2015, the industry will need to hire approximately 25,000 more workers.

The subject of an aging worforce and the state of readiness of the U. S. nuclear workforce for the 21ST century industry is also documented in the American Physical Society's 2008 Nuclear Readiness Report[17]. The report provides an excellent overview of challenges facing the nuclear industry and the nuclear engineering sector of academia. Resolution of these challenges and recommendations to ensure that future technology and employment needs will be met, including the role of the federal government in this activity, are explored.

To ensure that vibrant innovation and growth is maintained in the nuclear industry through the middle of the 21st century will require planning and preparation at the grass-roots level of the industry namely, its people. Because of the inherent technical nature of the nuclear industry, focused dialog between the industry and the numerous agencies that train and develop its people will be required. In anticipation of such dialog and any collaborative efforts that may evolve, the authors of this paper set forth to describe how one College of Technology, currently offering no nuclear coursework, would expand and modify its teaching and research mission to meet the highly specialized needs of the nuclear industry. Before examining how transformation to a nuclear-based curriculum can be made, the authors would like to note that no attempt to gauge the present strength or sentiment of the nuclear industry, particularly as it could or would affect the timing of new nuclear plant licensing, construction, etc. This paper is truly both time-and-event-independent. Its prime intent is to define an educational role for an upstart nuclear engineering technology program within existing constraints of the industry regardless of developments that would favor or inhibit any transformation to increased use of nuclear power.

To start, an overview of several established nuclear education programs that prepare students for the nuclear industry is presented.

Current Programs in Nuclear Education

Nuclear education in U. S. colleges and universities resides primarily in "nuclear engineering" programs. One source lists over 30 such schools, most of which have both undergraduate and graduate offerings[18]. At the undergraduate level, the programs focus on basics of nuclear physics and reactor kinetics leading to reactor design and plant operation. The goal of these programs is to prepare students for careers in engineering design with emphasis on reactor hardware, plant operating systems, and related areas including safety, fuel disposal, licensing of commercial reactors, and medical and military applications. Like other engineering disciplines, opportunities for advanced engineering education and research are available in these programs.
For individuals interested in a nuclear -based education with emphasis on post-design activities such as equipment operation, maintenance, or personnel training, the academic community offers two and four-year programs in engineering technology. Currently only three schools offer four-year B. S. degree programs in the Nuclear Technology or Nuclear Engineering Technology areas. These are Excelsior College, Thomas Edison State College, and the University of North Texas. A list of core and elective courses offered at the three colleges is presented in Table 1.0 of the Appendix. The list shows that the three programs have the following nuclear core topics in common:

Nuclear Materials
Health Physics/Radiation Protection
Radiation Measurement
Plant Systems Overview
Reactor Core Fundamentals
Reactor Theory
Reactor Design & Operation
Reactor Kinetics and Transient Analysis

Students also have to take a series of basic math, science, social science, communications, and computer courses including selections from prescribed elective courses. Successful program completions qualify graduates for career opportunities in positions with titles such as Reactor Operators, Health Physics Technologists, or Technicians dealing with quality assurance, chemistry, instrumentation and controls, and plant electrical andmechanical operations. Table 2.0 in the Appendix lists curriculum course requirements for a B. S. in Nuclear Engineering Technology at Thomas Edison State College with a total credit hour requirement of 126 hours, 58% of which involve required technical subjects. Table 3.0 in the Appendix provides a sample list of course titles in two-year nuclear A.A.S. degree programs at seven institutions. Average total credit hours for these programs are 69. The common thread of nuclear core courses in the Associates programs are:

Reactor Plant Systems
Nuclear Instrumentation and Controls
Fundamentals of Health Physics/Radiation Detection and Protection
Radiation Physics
Basic Nuclear Engineering
Reactor Theory, Safety and Design

It is interesting to note the similarity of the nuclear course offerings between the two and four year institutions. This is not unexpected considering that graduates from both programs are required to perform their respective assignments along with engineering graduates in plant environments that call for knowledge of and adherence to strict radiation protection and safety measures.

Nuclear Education Programs in the U.S. Navy

Another prominent source of nuclear education is the U. S. Navy. Its flagship program is offered at the Naval Nuclear Power Training Command's Nuclear Power School where enlisted sailors, officers, and civilians are trained in shipboard power operations and maintenance of submarines and surface ships. Discussions with an Officer-graduate from the Nuclear Power School indicate that officers assume an intense workload that focuses on both tactical and operational aspects of the naval vessel. Unlike land-based reactor systems, naval reactors are uniquely designed to function in dynamic modes that feature rapid ramp-ups of power not available on land-based units. The specialized training needed to operate and command nuclear vessels is offered to qualified individuals, many, but not all of whom, are engineers.

Although curriculum offerings to various attendees of the School vary, the following topics are provided to all program attendees[19]:

Mathematics
Nuclear physics
Electrical power theory and generating equipment
Nuclear reactor technology
Thermodynamics
Chemistry
Materials science and metallurgy
Health physics
Reactor principles

The U. S. Navy also maintains articulation with four public colleges and universities where graduates from the Nuclear Power School can earn college credit and a degree in either nuclear engineering technology or nuclear engineering. Two of those institutions include the previously-mentioned Excelsior College and Thomas Edison State College. The Navy also has its own Naval Postgraduate School for research and advanced technology development. Because large parts of the Navy Nuclear Power curriculum are classified, details of course offerings are not available. In fact, classified materials are restricted from leaving training buildings at the School, so that students cannot use classware to study outside of the classroom. Suffice to say that the preparation of naval personnel for careers involving nuclear propulsion has and continues to be highly specialized and characterized by the stringent academic standards. The nuclear fleet's record of zero-reactor[20] accidents continues to set the benchmark for safe and reliable operation of nuclear plants. Hence it is not surprising to note that many power plant postings, especially those for Reactor Operators, are filled by individuals with U. S. Navy experience. However, the nature of that resource is expected to change as the naval workforce ages and as the size of the fleet undergoes reduction.

<u>Proposed Program of Nuclear Education</u>

Academic education at the university level strives to meet multiple objectives. These objectives include equipping students with the ability to solve problems and the skills necessary for lifetime learning. Attainment of these objectives will allow them to face a multitude of challenges and adapt to the changing needs of their profession throughout their career. Another objective of academic education is to provide students with practical skills that reflect the current state-of-the-practice. These practical skills will allow them to make immediate contributions to their employer upon graduation. A College of Technology with its prime mission and charter focused more on applications and practices rather than discovery and the sciences, is ideally positioned to educate a workforce that understands and is capable of operating power plants. Cursory checks of power generating plants show that graduates from technology programs nationwide occupy a wide spectrum of positions, many with assignments ranging from equipment testing, data acquisition and analysis, to supervision of plant operation and maintenance, safety and security, quality control, and purchasing. Many of these individuals were hired because of their broad-based computer and communication skills and their comfort with, and preference for, hands-on assignments that allow them to build the knowledge and skills that nuclear employers value.

With concerns about aging equipment, an aging workforce, and the perceived notion that the answer to the future generation of electric power without CO_2 falls within the realm of nuclear industry and its people, the authors have developed a program of study within the academic mission and scope of a College of Technology. The program is based on:

(a) Existing Nuclear Engineering and Technology education models.

(b) Campus access Nuclear Engineering and Health Sciences programs that already specialize in the radiation sciences.

The proposed program is presented in curriculum format as a list of courses and credit-hour requirements for a Bachelor of Science degree in Nuclear Engineering Technology. See Figure 2.0. A brief overview of the proposed Nuclear Engineering Technology (NET) curriculum is presented:

1. Basis for development of the curriculum is the plan of study from the Mechanical Engineering Technology (MET) program. Selection of the MET plan aligns with existing mandates of the power generation industry in terms of relevancy and the right mix of technical disciplines.

2. The total number of credit hours required to complete the 4-year NET program is 125, of which roughly 75% is made up of required technical subjects.

3. 35 of a total of 38 courses listed in the proposed curriculum are available and already being offered. Descriptions of these pre-numbered courses are available the Internet. Of particular note are the MET 317 Machine Diagnostics course…a course that features vibration signal capture and analysis involving large high speed rotating equipment, and MET 422 Power Plants and Energy Conversion where students receive a first-time exposure to nuclear reactor basics. Nuclear Engineering courses NUCL 200 Introduction to Nuclear Engineering and NUCL 205 Nuclear Engineering Laboratory I deal with fundamentals leading to the understanding of nuclear basics and development of proficiency in the measurement of nuclear radiation.

4. Three new courses are proposed in the nuclear core. These are:

    (a) Nuclear Reactors and Plant Systems. While traditional nuclear engineering courses focus on the design of systems models i.e., emergency core cooling system model, the courses offer little in dealing with the operation and maintenance of individual components that make up the models. Thus, the prime focus of the proposed course is directed at individual components including their performance, operation, upkeep, and their eventual replacement. The course is structured to handle PWR and BWR thermal fission reactors, their control, and performance. Related components such as feedwater heaters, turbines, condensers, cooling towers, and pumps are examined using a holistic approach leading to overall performance measures such as heat rate and thermal efficiency. Resources to develop course content are currently available.

Figure 2.0

Proposed Curriculum for Bachelor of Science in Nuclear Engineering Technology

Category & Courses	**Credits**		
General Education Requirements:			
Communications			
English Composition (ENGL 106)	3		
Fundamentals of Speech Communication (COM 114)	3		
Graphics Communications (CGT 110)	3		
Production Design and Specifications (MET 102)	3		
Computer Analysis Tools (MET 163)	3		
Visual Programming (CNIT 175)	3		
Technical Writing (ENGL 421)	3		
TOTAL		**21**	
Humanities and Social Sciences			
Social Science Elective	3		
TOTAL		**3**	
Natural Science and Mathematics			
Precalculus (MA 159)	5		
Calculus for Technology I (MA221)	3		
Calculus for Technology II (MA 222)	3		
Elementary Statistical Methods (STAT 301)	3		
General Physics I (PHYS 220)	4		
General Physics II (PHYS 221)	4		
General Chemistry (CHEM 111)	3		
TOTAL		**25**	**49**
Areas of Study:			
Mechanical Core			
Applied Statics (MET 111)	3		
Materials and Processes I (MET 143)	3		
Materials and Processes II (MET 144)	3		
Applied Strength of Materials (MET 211)	4		
Dynamics (MET 213)	3		
Machine Diagnostics (MET 317)	3		
TOTAL		**19**	**68**

Figure 2.0 (Continued)

Electrical Core			
Electricity Fundamentals (ECET 214)	3		
Controls and Instrumentation (MET 284)	3		
TOTAL		**6**	**74**
Thermal/Fluids Core			
Heat/Power (MET 220)	3		
Applied Thermodynamics (MET 320)	3		
Fluid Power (MET 230)	3		
Applied Fluid Mechanics (MET 313)	3		
TOTAL		**12**	**86**
Nuclear Core			
Introduction to Nuclear Engineering (NUCL 200)	3		
Nuclear Reactors and Plant Systems (new)	3		
Radiological Engineering Fundamentals (new)	4		
Nuclear Engineering Laboratory I (NUCL 205)	4		
Selected Topics in Applied Nuclear Energy (new)	3		
		17	**103**
Capstone Project	4		
TOTAL		**4**	**107**
Electives: Technical/Interdis..select any 6…4 must be technical electives			
Electrical Power and Controls (ECET 231)	4		
Generation & Transmission of Elec. Powr (ECET 331)	4		
Mechanical Constructio (BCM 215)	3		
Mech. & Elec. Construction Management (BCM 317)	3		
Heavy Industrial Construction (BCM 481)	3		
Total Productive Maintenance (IT 381)	3		
Monetary Analysis (IET 451)	3		
Power Plants and Energy Conversion (MET 422)	3		
Advanced Fluid Power (MET 334)	3		
Radiation Science Fundamentals (HSCI 312)	3		
Hydraulic Motion Control (MET 432)	3		
Pneumatic Motion Control (MET 436)	3		
Applied Computational Methods (MET 581)	3		
Applied Optimization (MET 503)	3		
Management/Supervision Elective	3		
Global Elective	3		
TOTAL		**18**	
Total Credits For Degree			**125**

(b) Radiological Engineering Fundamentals. In addition to lectures, primary course focus is on measurements, sensors, instruments, their calibration and use. In as much as radiation science methods and procedures are treated in courses dealing with health physics, present offerings lack the applied reach of learning objectives envisioned by the authors. The proposed course would have laboratory exercises that feature calibration of radioactive sources and pocket ionization chambers, calibration and use of automatic sample changers, proportional counters and the Geiger-Mueller tube, radiation surveys including air sampling for radon, and whole body counting, to name a few. Development of these exercises shall be made in conjunction with resources available at the authors' university Radiological and Environmental organization. The latter monitors campus-wide radiation activity in departments such as Chemistry, Physics, Nursing, Pharmacy, etc. Because radiation exposure of personnel is a major concern on a university campus, many universities have similar organizations equipped with trained personnel and appropriate devices to control radiological activity. These organizations can be an invaluable resource for development of radiation-based laboratory exercises of the type mentioned above.

(c) Selected Topics in Applied Nuclear Energy. Using assigned readings, seminars, and outside experts in the nuclear field, faculty challenge students beyond traditional classroom content by exploring developments in areas such as long-term disposal of used nuclear fuel, nuclear security and proliferation, small modular reactors, national energy policy, global nuclear power, developments of the Nuclear Regulatory Commission, ASME Nuclear Component Certification (N-type Codes), nuclear medicine, military applications of nuclear energy, and on-going campus research involving reactors, fuels, and cycles.

Thus it can be seen that the list of courses in the proposed curriculum compares reasonably well with existing Nuclear Engineering Technology offerings and serves as an excellent starting point for the formal design of a program of study leading to a degree in Nuclear Engineering Technology. Moreover, the College of Technology at the authors' main campus is ideally positioned to undertake such an initiative because of the availability of a 1000 watt nuclear reactor in the Nuclear Engineering department. The reactor is used as a training reactor for classroom instruction and features activities such as critical/initial start-up, neutron activation, and safety shutdown, to name a few. The department also has laboratory facilities equipped with radiation detection and measurement capability that the College of Technology would benefit from. Whereas a campus nuclear reactor is an outstanding educational resource, its availability should not preclude consideration for the development of a 4-year nuclear engineering technology program. Today's power plant and nuclear reactor simulators are making inroads into the classroom and can initially serve as substitutes for their full-scale counterparts. The availability of external funding for these types of educational tools is worth pursuing.

Conclusion

The authors set out to define a role of a College of Technology in nuclear education by considering the status of the nuclear power industry in light of experts' claims that expansion of the domestic nuclear power industry, if not already in the making, is inevitable. The authors focus on educational needs to satisfy future workforce demands that the expansion will create. This is done through the development of a curriculum for a four-year Bachelor of Science degree in Nuclear Engineering Technology. Details of the proposed curriculum are presented. It is the expressed wish of the authors that the proposed curriculum serve as a starting-step for any College of Technology considering an active role in nuclear education.

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APPENDIX

Table 1.0

General Course Requirements for Degree Programs
Nuclear Engineering Technology

Institution	Course Titles	Core course	Elective	
Excelsior College	Electrical Theory	X		
Nuclear Engineering Technology (BS)	Computer Applications	X		
124 credits	Materials	X		
	Nuclear Materials	X		
	Health Physics/Radiation protection	X		
	Radiation Measurement Lab	X		
	Plant Systems Overview	X		
	Reactor Core Fundamentals	X		
	Fluids	X		
	Heat Transfer	X		
	Integrated Technology Assessment Requirement	X		
Reactor Operator	Advanced Reactor Theory		X	
	Control Systems (electromechanical)		X	
	Instrumentals and Controls		X	
	Nondestructive Testing		X	
	Nuclear Testing		X	
	Print Reading		X	
	Radio Chemistry		X	
	Reactor Safety: Mitigating Core Damage		X	
	Reactor Kinetics		X	
	Reactor Control Systems		X	
	Shielding		X	
	Simulator Training		X	
	Systems (BWR, PWR)		X	
	Transient Analysis		X	
Quality Assurance Tech.	Codes and Standards		X	
	Computer Systems		X	
	Computer Programming		X	
	Database Management		X	
	Engineering Drawing/Blueprint Reading		X	

	Measurements		X	
	Probabilistic Reliability Analysis		X	
	Quality Assurance/Quality Control		X	
	Regulations		X	
	Technical Specifications		X	
Health Physics Technologist	Advanced Instrumentation		X	
	Emergency Planning		X	
	Instrument calibration		X	
	Radiation Biology		X	
	Radiation Effects/Interaction with Matter		X	
Chemistry Technician	Analytical Chemistry		X	
	Advanced Computer Analysis (Chemistry)		X	
	Corrosion Chemistry		X	
	Instrumental Analysis		X	
	Physical Chemistry		X	
	Radio Chemistry		X	Repeated
	Water Chemistry		X	
Instrumentation and Controls Tech.	Advanced Electronics		X	
	Computer Languages		X	
	Computer Systems		X	Repeated
	Data Base Concepts		X	
	Digital Electronics		X	
	Electronics		X	
	Industrial Electronics		X	
	Metrology (instrument calibration)		X	
	Microprocessor Programming		X	
	Microprocessor Systems		X	
	Process Control Theory		X	
	Scaling (mathematical)		X	
	Digital Process Control		X	
Mechanical Tech.				
	Filters and Resin Beds		X	
	Heat Exchangers		X	
	Machinery Alignment		X	
	Pipe Erosion/Corrosion		X	
	Pipe Supports/Constraints		X	
	Precision Machine Tools and		X	

	Instrumentation			
	Pressure Vessels and Piping		X	
	Pumps and Valves		X	
	Steam Generators		X	
	Tool Calibration		X	
	Tube Inspection and Repair		X	
	Valve Operators		X	
	Waste Processing (Rad and/or industrial)		X	
Thomas Edison State College	Nuclear Physics-Radiation Physics/Atomic Physics			
Nuclear Engineering Technology (BS Applied Sciences and Technology)	Thermodynamics or Heat Transfer			
120 Total credits	Fluid Mechanics-Hydraulics			
Reactors and Systems				
	Reactor Engineering/Reactor Theory			
	Elements of Nuclear Energy or Introduction to Nuclear Power Systems			
	Reactor Analysis and Design/Nuclear Reactor Physics			
	Reactor Heat Transfer/Reactor Core Damage and Transient Analysis			
	Primary Reactor Systems/Secondary Plant Systems			
	Reactor Systems/Reactor Operations			
	BWR/PWR Systems			
Instrumentation				
	Nuclear Power Plant Instrumsntation/Instrumentation and Controls			
Radiation Effects	Radiation and Reactor Systems/Nuclear Reactor Materials			
	Radiation Biology/Radiation Biophysics			
Safety and Protection	Radiation Safety			
	Radiological, Reactor Environmental Safety			

	Radiation Protection and Control			
Nuclear Electives	Nuclear Reactor Safety/Applied Health Physics/ALARA Principles			
	Fuel Cycles/Industrial Safety/Quality Assurance and Non-destructive Testing			
	Radiation or Reactor Physics			
	Nuclear Radiation Fundamentals/Radiation Biology			
University of North Texas				
Engineering Technology Nuclear Concentration (BS)	Calculus 1&2			
125 Total credits	Technological Systems			
	Mechanics/Mechanics Laboratory			
	Statics			
	Elementary Probability and Statistics			
	Electronics and Magnatism/Electronics and Magnatism Laboratory			
	Fundamentals of Electrical Engineering			
	Quality Assurance			
	Electronic Devices and Controls			
	Applied Thermodynamics			
	Nuclear Inst. & Measurement			
	Electric Power Generation & Transmission			
	Fluid Mechanics Applications			
	Radiation Biology & Safety			
	Nuclear Reactor Theory			
	Engineering Ethics			
	Reactor Engineering Design & Operation			

Table 2.0

Bachelors of Science in Applied Science and Technology
General Requirements
Nuclear Engineering Technology

Category & Courses	Credits		
General Education Requirements			**60**
English Composition		6	
English Composition I (ENC 101)	3		
English Composition II (ENC 102)	3		
Humanities		12	
Technical Report Writing (ENG 201)	3		
Ethics and the Business Professional (PHI-384)	3		
Electives *Must include at least two subject areas*	6		
Social Sciences		12	
Psychology and Sociology	3		
Electives *Must include at least two subject areas*	9		
Natural Science and Mathematics		21	
Calculus I & Calculus II	6		
Statistics	3		
Physics I with laboratory Physics II	6		
General Chemistry	3		
Computer Programming Requirement or Programmable Logic Controller (CRT-212)	3		
General Education Electives		9	
Area of Study:			51
Nuclear Physics for Technology (NUC-303)	3		
Thermodynamics	3		
Heat Transfer	3		
Fluid Mechanics	3		
Reactors and Plant Systems Reactor Fundamentals Primary Reactor Systems (NUC-331) Nuclear Instrumentation and Control (NUC-351)	 3 3 3	 9	
Radiation Effects Radiation Biophysics (NUC-412) Radiation Interaction (NUC-413) or Radiological, Reactor, Environmental Safety (NUC-342)	 3 3 3	 6	
Electrical Theory	3	3	
Nuclear Materials (NUC-420)	3	3	
Radiation Analysis Laboratory	1	1	
Nuclear Electives		13	

Military/INPO Discipline Specific Training including Laboratory/Practicum – 1 to 13 credits Occupational Health & Safety (APS-400) – 3 credits Applied Quality Management (APS-300) – 3 credits Regulatory Policy and Procedures (EUT-401) – 3 credits Applied Economic Analysis (EUT-402) – 3 credits *Required credits from academically reviewed training/experience or above listed courses*			
Nuclear Engineering Technology Capstone (APS-405)	4	4	
Free Electives			15
Total Credits for Degree			**126**

09-09-2010

Table 3.0

General Education Requirements for Degree Courses
Nuclear Engineering Technology

Institution	Course	Core course	Elective	
Luzerne County Community College				
AAS Nuclear Engineering Technology	D. C. Electricity			
67 total credits	Introduction to Reactor Plant Systems			
	A. C. Electricity			
	Nuclear Instrumentation & Controls			
	Technical Physics I			
	Atomic & Nuclear Physics			
	Automatic Process Control			
	Technical Physics II			
	Fundamentals of Health Physics			

	Reactor Core Fundamentals			
	Human Performance Technology/Error Avoidance			
Salem Community College				
AAS Nuclear Energy Technology	Mechanical Sciences			
62 Total credits	Applied Physics and Chemistry			
	Nuclear Industry Fundamental Concepts			
	Heat Transfer and Fluid Flow			
	Instrumentation and Control I			
	Basic Nuclear Systems			
	Nuclear Science			
	Reactor Plant Protection and Safety			
	Instrumentation and Control II			
Arkansas Tech University				
AS Nuclear Technology	Engineering Materials			
69 Total credits	Statics			
	Basic Nuclear Engineering			
	Thermodynamics I			
	Radiation Health Physics			
	Radiation Detection Lab			
Chattanooga State				
Nuclear Power Engineering Technology Concentration AAS	Electrical Circuits I			
65 Total Credits	Power Plant Components			
	Concepts of Physics			
	Introduction to Power Plant Instrumentation			
	Power Generating			

	Systems I			
	Statics and Strength of Materials			
	Thermodynamics I			
	Technical Reports			
	Power Generating Systems II			
	Power Plant Chemistry			
	Statistics and Quality Control for Engineering Technology			
	CAD Engineering Drawing I & II			
Lakeland Community College				
Nuclear Engineering Technology (AAS)	Introduction to Technology	X		
70 Total Credits	Nuclear Industry Fundamental Concepts	X		
	Radiation Detection and Protection	X		
	Applied Physics I	X		
	D. C. Circuit Analysis	X		
	Nuclear Plant Drawings	X		
	Power Plant Components	X		
	Applied Physics II	X		
	A. C. Circuit Analysis	X		
	Reactor Plant Materials	X		
	Thermo-Fluid Sciences	X		
	Sensors and Actuators	X		
	Reactor Theory, Safety and Design	X		
	Capstone and Case Studies in Nuclear Engineering Technology	X		
	Training Skills and Techniques		X	
	Manufacturing Processes I		X	
	Computer Numerical Control Part Programming (CNC)		X	
	Digital Systems Fundamentals		X	
	Linear and Switch-Mode		X	

	Power Supplies			
	Motor Control and Servo Systems		X	
	Current Local and National Electrical Codes		X	
	Programmable Logic Controllers		X	
	Statistics		X	
	Nuclear Field Experience		X	
	Applied Physics III		X	
Terra Community College				
AAS Nuclear Power Technology	Electricity			
64 Total Credits	Instrumentation and Process Control			
	Hand and Power Tools			
	Safety			
	Nuclear Industry Fundamental Concepts			
	Nuclear Plant Drawings			
	Reactor Plant Materials			
	Thermo-Fluid Sciences			
	Radiation Detection and Protection			
	Reactor Theory, Safety and Design			
	Nuclear Field Experience			
Brazosport College				
Nuclear Power Technology (AAS)SUM	Process Instrumentation I			
86 Total Credits	Process Technology I			
	Safety, Health, and Environment I			
	Applied Instrumental Analysis I			
	Statistics			
	Cooperative Education I - Chemical Technology/Technician or Principles of Quality Organic Chemistry I			
	Applied Instrumental Analysis II			

	Applied Petrochemical Technology (Technical Physics)			
	Organic Chemistry II			