ENGINEERING FACULTY DOCUMENT NO. 30-04

February 23, 2005

TO: ENGINEERING FACULTY
FROM: FACULTY OF THE SCHOOL OF NUCLEAR ENGINEERING
DATE: FEBRUARY 23, 2005
SUBJECT: NEW DUAL LEVEL COURSE

The Faculty of the School of Nuclear Engineering has approved the following new dual level course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

NUCL 553 **Nano-Macro Scale Applications of Nuclear Technology**
Sem. 1, Class 3, cr. 3.
Prerequisite: Senior/Graduate student standing in science, engineering or technology or consent of instructor.

Introduce the principles of nuclear science and engineering for addressing industrial and scientific issues ranging from sub nano to macro scales. Areas to be covered will include propulsion, high energy density materials, supercooling, medical applications, sonoluminescence, novel detection systems for special nuclear and contraband materials, and advanced nuclear fusion power systems.

REASON: Nuclear engineering-based technology affects a wide range of disciplines. Yet, all existing courses relate primarily to applications involving nuclear fission power reactor systems. There is no coherent course that depicts the multifarious applications of nuclear technology affecting areas as wide as propulsion, to next generation clean power sources, to international security – involving sub femto to macro mass, length and time scales. The course has been offered twice on a trial basis with 7 students in Spring 2004, and 6 students during Fall 2004. This course can be taken as a technical elective course. A condensed version was also offered to the 2004 Freshman class ENGR103.

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NUCL 553
Nano-Macro Scale Applications of Nuclear Technology

1. **Course Title for Official Student Ledger:** NANO-MACRO NUCL TECH Technology

2. **Justification:** Nuclear technology impacts various facets of life for which an enormous technology base has been developed over 100 years of R&D. A course is needed that elevates awareness of this technology base to then intentionally focus, search for opportunities and apply this knowledge base to the non-nuclear industrial world and for resolving grand challenges of today. No such course is taught at present.

3. **Course Level:** Dual level Engineering Course

4. **Pre-requisite:** Graduate or senior standing in science, engineering or technology or consent of instructor.

5. **Course Instructor:** School of Nuclear Engineering faculty.

6. **Course Outline:**

Course Objectives:

- To provide students with practical insights on inter-disciplinary applications of nuclear technology and theories to address grand-challenges of life and to prepare them for a life-long learning experience.
- To provide principles of nuclear technology theory (reactor, medical, safety, thermal-hydraulics) and overview of research knowledge developed over the past 50 years;
- To enable students to apply the vast knowledge base of technology for application to national security, industrial safety (e.g., metals casting), powder production, variable-thrust propulsion, space power applications, food safety, medicine (cancer cell destruction), novel high energy density power source development.

Text:

Class notes, along with materials consisting of research articles, reports and materials from a wide variety of sources. No formal text exists but is under preparation; Professor Taleyarkhan has been preparing one such text.

OUTLINE OF CLASS LECTURE SERIES

Lecture Series **Content**

1

General Introduction to Nuclear Technology and Related R&D Enterprise

- Nuclear scales (force levels relative to gravity,etc., particle types and their features)
- Nuclear reaction fundamentals (interaction of photons, neutrons, betas/alphas with matter)
- Biological effects of nuclear particles and their penetrating prowess along with signatures
- Type of nuclear reactors (power producing, production types, research/test)
- Sources of nuclear particles (industrial and research; isotopes, reactors, accelerators)
- Nuclear particle transport and interaction modeling and analyses tools and technology
- Thermal-hydraulics modeling and analyses bases – including that for assessing Thermal attack of structures, aerosol formation/transport in complex geometries, atmospheric transport and probabilistic risk estimation for health effects.
- Nuclear safety research technology bases
  - Thermal hydraulics related (CHF, stability, transients) technology for application to non-nuclear areas
  - Nuclear reactor accident related technology and applications to non-nuclear system
  - Severe accidents related technology developed for nuclear power reactor systems including aerosol-gas generation/transport and health effects and relationships to the world of homeland security (e.g., dirty bombs, chem.-bio agent transport, radiological threats, accident management and mitigation).
  - Energetics of nuclear interactions vs chemical interactions and technologies developed for containment of loads from missles, overpressurization.

2 Energetic Fluid-Fluid Interactions

- Nuclear Technology bases developed for addressing melt-water steam explosion safety
  - Physics of steam explosions (mixing, propagation,triggering, expansion);
  - Modeling and analyses of mixing, triggering, propagation and expansion; along with Missile-structure impact dynamics)
  - Spontaneous triggering versus external triggering
  - Energetics of chemically-charged explosive interactions and potential applications for Naval warfare systems

-Relationships to volcanology, metals casting, supercooled powders, novel explosives / propellants, LNG safety

- Metals industry safety (application of principles for prevention of molten metal-water explosions)
- Application of principles for generating supercooled powders (vastly enhanced ductility, super-plasticity.

- Controlled Energy Release propulsion (variable velocity guns, ship board propulsion,…)

3 National Security & Other Industrial Applications

-- Insights and tools from nuclear sci./tech.

-- Scenarios, needs (Bio(anthrax), Contraband, Explosives, SNMs, OilWell, Concrete,..)

-- Tools used (TRIGA, Electron accel., PNGs, Isotope Sources)

-- PNFA method

-- Detection methods (NaI, HPGe, Pl./Liq-Scint., SDDs) - conventional

4 Metastable fluid technology based futuristic applications
-- Motivations (insights/tools from nuclear sciences and technologies)
-- Cavitation of Liquids & Sonoluminescence (SL, SBSL/MBSL)
-- Superheat vs Tension of Liquids -- Limits of superheat (pulse, static)
-- Nucletion theory (variation of rate of nucleii formation with Tsup, pneg)
-- Theoretical approx. for nano-scale nucleation in positive/negative pressures
-- SDDs (mini-explosives; detection of sub-nano particles)
-- Tensioned metastability for revoluationary nuclear particle detection for homeland security
-- Advanced applications for next generation propulsion and launch systems.
-- Nanofluidics

5 -- Advanced and Novel Nuclear Fusion Energy
-- Current thrusts (ITER, ICF, AICF/Bubble fusion)
-- Bubble nuclear fusion -- allure/applications for novel, clean energy sources
-- Nucleation, chamber design/mfg., operations
-- Expts. Conducted and results (n,g,T)
-- Theoretical modeling (EOSs, Model framework, Results of computation)
-- Rayleigh Plesset gas-vapor bubble dynamics
-- Shock transport modeling/simulations; dissociation, ionization and plasma formation
-- Bubble nuclear fusion based space power/propulsion

6 -- Medicinal / Health Applications of Nuclear Technology
-- Diagnosis with gamma and X-rays
-- Therapy (PET, SPECT, Brachytherapy, BNCT)
-- Advanced on-demand cavitation induced therapy and cancer defeat and lithotripsy

7 Miscellaneous Applications of Nuclear Technology
-- Neutron activation based dating
-- Gemstone coloration
-- Neutron radiography for multi-phase flow distribution

8 Insights into Advanced Research Applications of Neutron Sources
-- SNS; TRIGA, ILL/HFIR
- Semiconductors, Drugs, Magnetism, Materials, Engines, Corrosion Sciences Research

Topical Coverage	
Topic	Weeks
Introduction to nuclear R&D technology	2
Energetic fluid-fluid safety technology applications	3
National security applications	1
Tensioned fluid metastability applications	3
Advanced/novel nuclear fusion energy applications	3
Medicinal / health applications	1
Miscellaneous applications	1
Advanced research applications with neutrons	1