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TEXAS A&M UNIVERSITY

COLLEGE OF ENGINEERING

COLLEGE STATION TEXAS 77843-3133

CONF-840484--Absts.

DEPARTMENT OF NUCLEAR ENGINEERING
(409) 845-4161

12 March 84

4/5-7/84

Dear Attendees:

It is our pleasure to welcome you to the Spring 84 Texas A&M University Student/Professional Nuclear Science and Engineering Conference. While you are on campus we hope you will take the opportunity to visit more than just the nuclear related facilities (e.g. the Nuclear Science Center and the Cyclotron). Texas A&M does indeed have the largest college of engineering in the country, but we also have internationally renowned programs in chemistry, geosciences, agriculture, business, and several other areas.

In considering specific "things to see", we invite you to visit the University Center, which includes Rudder Tower, the Memorial Student Center, and the Regents Annex; the Academic Building; Sterling C. Evans Library; and the Agricultural Complex, including the Kleberg Center. For those of you not currently on a diet, a visit to the Creamery can be a satisfying experience.

We hope you will enjoy the conference as much as we enjoy having you visit us.

Yours truly,

Donald McDonald
Interim Dean of Engineering and
Associate Deputy Chancellor

Carl A. Erdman
Professor and Head
Nuclear Engineering

CAE/sgd

Tentative
Schedule of Events

All conference activities will be held in either the Memorial Student Center (MSC) or Rudder Tower (RT)

Thursday, April 5, 1984

5:00 - 10:00 pm	Conference registration and room assignments (Front Desk MSC)
7:00 - 10:00 pm	Snack and Soda Mixer (206 MSC)

Friday, April 6, 1984

6:00 - 9:00 am	Late registration (407 RT)
8:00 - 9:15 am	Plenary session, welcome and opening remarks (301 RT)
9:30 - 9:50 am	Judges briefing
10:00 - 12:00 am	Session I - Reactor Engineering (401 RT) Session II -Space Nuclear Power Systems (402 RT)
12:00 - 1:30 pm	Lunch Break
1:30 - 2:30 pm	Session III - Health Physics and Dosimetry (401 RT) Session IV - Fusion Engineering and Physics (402 RT)
2:45 - 3:45 pm	Session V - Experimentation (401 RT) Session VI -Reactor Physics and Theory (402 RT)
2:45 - 5:00 pm	Industrial Forum (301 RT) ← ?
4:00 - 5:00 pm	Tour of the Nuclear Science Center TRIGA Reactor (NSCR)
5:00 - 8:00 pm	Dinner Break
8:00 - ?	Social Function (Quonset Huts) Maps will be available

Saturday, April 7, 1984

11:00 - 1:00 pm	Closing brunch banquet (201 MSC) Speaker: Gen. Ernest G. Hardin

Notes: 1) Hotel checkout time is 2:00 pm Saturday
2) Special tours of the NSCR can be arranged for Saturday, April 7

Brunch Buffet Menu

Crisp Bacon, Grilled Ham, Savory Sausage
Scrambled Eggs
Hash-Browed Potatoes
Country Gravy or Creole Sauce
Fresh Fruit Tray
Frozen Peaches
Hot Fruit Compote
Biscuits
Cinnamon Nut Rolls
Butter and Jelly
Coffee

Texas A&M University Nuclear Science and Student/Professional Engineering Conference

Industrial Forum

FRIDAY, APRIL 6, 1984
2:30 - 5:00 pm

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PARTICIPATING COMPANIES :

CANBERRA
NATIONAL AMERICAN NUCLEAR SOCIETY
TEXAS UTILITIES (TUGCO)
MATSCO
GULF STATES UTILITIES
TEXAS A&M UNIVERSITY NUCLEAR ENGINEERING DEPT.
EBASCO
NAVY

Held in Rudder Tower room 301

SESSION I

REACTOR ENGINEERING
&
THERMAL HYDRAULICS

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: An Integrated Package for Reactor Analysis Support

Author(s): B. L. Rice Advisor:

Major Field: University:

Degree Program: Professional - North Texas Section ANS

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other x

ABSTRACT

Abstract not available at this time

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Advanced Carbide Fast Reactor Fuel Code Development

Author(s): Robert Greene

Advisor: K. L. Peddicord

Major Field: Nuclear Engineering

University: Texas A&M University

Degree Program: Ph.D.

Paper related to: Ph.D. Dissertation X M.S. Thesis

Term Paper Other

ABSTRACT

A main feature in establishing a fuel concept is the development of an extensive fuel performance code to account for the governing mechanisms that determine fuel behavior. This has been the case for the advanced carbide fuels for liquid metal fast breeder reactors. In the United States, the code which has been developed by the Argonne National Laboratory Westinghouse Advanced Reactor Division is the LIFE-IV-C code. This is a mechanistic code which is based on the earlier versions developed for oxide fuel. In the formation of a code, the models are established based on the physical processes. These are integrated into the overall computer program, and the results are compared with irradiation data. Another useful approach is that of an empirically based code. In this case, the models are developed on a statistical basis from the total accumulated database.

In this project, an empirically based code is being developed for the case of advanced carbides for fast reactors. The main database used is that from the US Department of Energy from irradiations by Westinghouse, Argonne, and Los Alamos National Laboratory. Models will be developed for the principle phenomena including fission gas release, clad strain, pin elongation, pellet restructuring, and other important effects, based on the data measured from post-irradiation examinations. This includes measurements of overall pin strain, gas composition and pressure, restructuring data and migration of fuel constituents. Two main advantages are realized in this approach. The first is that the total experimental experience is incorporated directly into the models. This is in contrast to the mechanistic approach in which the models are calibrated to the measurements. The second advantage is that the codes can be much smaller and run more efficiently than is the case for the large scale deterministic codes. In this project a small scale empirically based code is being developed for advanced carbide fuels for fast reactors.

An approach in data analysis is the estimation of failure probability by linear regression onto cumulative damage functions, which would in turn be based on design and operational variables. The possibility of hysteretic and synergistic effects must also be considered.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Developing Superior Sorbers for Uranium & Strategic Elements Recovery from Seawate

Author(s): Jose G. Pina-Jordan

Advisor: Dr. F. R. Best

Major Field: Nuclear Engineering

University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis X

Term Paper_____ Other_____

ABSTRACT

The fact that there are about 4000 million tons of uranium in the world's oceans has become increasingly important internationally due to uncertainties in the supply of conventionally-mined uranium and the delay in the development of fuel recycle and breeder reactors. Several international institutions have worked on developing an economically viable process for the recovery of uranium and strategic elements from seawater. This report will concentrate on methods for testing, comparing, and improving sorber performance. Previous tests, in general, confirmed good performance for hydrous titanium oxide (HTO) and for anion exchanging resins employing an amidoxime functional group. Moreover, the resin performance is expected to improve when its properties are optimized. Thus, the present work, through fixed bed column experiments, not only will attempt to optimize and test different sorbers but also will study the effects of water temperature and salinity on the performance of the sorbers. Delayed fission neutron assay, fission track etch, and activation analysis will be used to study the elemental content in sorbers exposed to natural seawater. Recommendations for sorber improvements will also be made.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: *Characterization of Frictional Forces of a Packed Particle Bed in a Clad Tube*

Author(s): J.K. Thomas and R.O. Montgomery Advisor: Dr. K.L. Peddicord

Major Field: Thermal Hydraulics University: Texas A&M University

Degree Program:

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

Sphere-pac fuels have been considered for both light water reactors and liquid metal fast breeder applications. In measurements of well characterized tests, it has been observed that the packed particle bed of fuels spheres appears to relax along the clad tube. In this study an experiment has been carried out to measure this behavior within a simulated fuel pin. A packed particle bed of spheres is loaded into a clad tube. An axial load is placed on the bed of spheres and the frictional force is transmitted to the clad. The experimental design consists of measurements of both the static friction forces and the forces under a vibrational situation. It is determined that the packed bed efficiently transmits the axial forces to the clad wall by the use of frictional forces. For a sufficiently long bed of particles, the axial forces are such that a very large load is needed to overcome the friction forces at the wall.

A set of measurements were also made for the case in which the system is vibrated. In this situation it has been found that a well-defined velocity results which is a function of the bed load and the bed height.

The development of the data determined from these measurements will further serve to describe the overall behavior of sphere-pac fuel pins. When combined with an analytical description of this situation, a more complete picture of the mechanical behavior of pins will result.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Application of the FREY Transient Fuel Behavior Code to Design Basis Events in Light Water Reactor Fuel Pins

Author(s): R.O. Montgomery and C.V. De Vore Advisor: Dr. K. L. Peddicord

Major Field: Thermal Hydraulics University: Texas A&M University

Degree Program:

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other___X___

ABSTRACT

The FREY (Fuel Rod Evaluation sYstem) computer code is being developed under the sponsorship of the Electric Power Research Institute. The purpose of this code is to describe the time dependent behavior of light water reactor fuel pins under a variety of transient conditions. FREY is a best estimate code based on finite element analysis using state-of-the-art methodology.

In evaluating the FREY code, it is useful to determine its response to a number of well characterized Design Basis Events (DBE). These events are used for licensing analysis of fuel designs. The five transients that were considered were: the control rod drop event, the seized pump shaft, the control rod ejection accident, the excess load accident, and large break LOCA. The results from the FREY code were compared with two other transient codes, FRAP-T3 and FRAP-T6. The first four events where compared with the FRAP-T3 code and the design basis LOCA was compared with the FRAP-T6 code. Comparisons were made of fuel centerline temperature, clad surface temperature, pin clad stresses, clad strains, and internal gas pressure. FREY showed good capability in predicting these quantities compared to the two codes. FREY is generally considered to be a superior code in terms of its methodology than FRAP-T3. In specific cases it showed improved capability. For example, departure from nucleate boiling was predicted by FRAP-T3 for the seized pump shaft event. As was expected, this was not observed in FREY. FRAP-T6 is a more extensive code than FRAP-T3. Again FREY showed good capability in predicting the results of the large break LOCA.

The development of the FREY code as an analysis tool will be very useful in gaining operational flexibility and by determining the response of fuel pins to a variety of postulated transients.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Empirical Models for Sphere-Pac Mixed Carbide Fuel Pin Behavior

Author(s): R. Sartor and H. Giap

Advisor: Dr. Frederick Best

Major Field: Nuclear Engineering

University: Texas A&M University

Degree Program: BS

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

Sphere-pac fuels are being considered for fast reactor fuel pin development. It is useful to establish a computational capability to describe the behavior of these pins. An extensive mechanistic model has been developed in the form of the SPECKLE code. However, it is useful to have more efficient models based directly on fuel pin data. This is being developed in the form of the SPANGLE code (Sphere-Pac Analysis of Integrated Life-time Experience). The models for the SPANGLE code are developed from the sphere-pac mixed carbide database which consists of 21 pins irradiated in several reactors in Europe. A wide variety of irradiation conditions where utilized. Empirical models are being used to describe the overall gas release. This is based on a correlation of the data to burnup and temperature. The code utilizes a calculation of temperature profiles and restructuring within the sphere-pac bed.

Since the code is being developed for use on small scale personal computers, it is extremely flexible and can be used in an efficient way by experimenters. The development of the code and its models will be useful in evaluating a wide variety of potential situations such as reactor startup and postulated off normal transients.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Loss of Sphere-Pac Fuel from a Breached Fuel Pin

Author(s): Dion J. Sunderland

Advisor: Dr. K. L. Peddicord

Major Field: Nuclear Engineering

University: Texas A&M University

Degree Program: Master of Science

Paper related to: Ph.D. Dissertation_____ M.S. Thesis ✓

Term Paper_____ Other_____

ABSTRACT

Sphere-pac fuel is being considered as one of the possible candidates for fast reactor fuel pin designs. A pricipal safety question that arises with respect to sphere-pac fuel is the possible egress of fuel material in the case of a breach of the clad, especially with respect to early failure. An evaluation is being made of the potential for fuel particle loss upon clad failure, using a scale fast reactor fuel pin model consisting of two size-fractions of simulated fuel spheres. A number of clad breaches are being considered. In addition, a variety of other situations within the fuel pin are examined; these include restructuring of the central region of the fuel, which will retard the loss of fuel material.

Under the conditions of time and temperature, sintering will take place between fuel spheres. This phenomenon will also be accounted for and its effect on fuel egress evaluated.

By combining an experimental measurement with modeling of the fuel loss mechanisms, a more complete picture will be gained of the potential loss of fuel particles from a sphere-pac fuel pin.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Behavior of the Coolant Flow in the PBF Severe Fuel Damage Scoping Test

Author(s): Chul-Hyung Kang

Advisor: Dr. Robert W. Albrecht

Major Field: Nuclear Engineering

University: Univ. of Washington

Degree Program: M.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis X

Term Paper_____ Other_____

ABSTRACT

The Severe Fuel Damage research program, which is to be performed in the Power Burst Fcility at the Idaho National Engineering Laboratory, consists of a series of tests investigating fuel rod and core response, and the release and transport of fission product and hydrogen during a loss-of-coolant accident.

In the relatively initial stages of the test, the inlet flow to the bundle was reduced or the power was increased to force the water level to decrease, leaving the bundle cooled by steam.

Twelve fission chambers were installed external to the fuel bundle assembly in the two strings on opposite sides of the shroud. The primary objective of these detector is to measure neutron flux and fluence and the two-phase level (steam-steam/water interface). Other objectives were two-phase velocity measurement and fuel motion analysis.

This thesis focuses on the two-phase velocity measurements only.

The signals from neutron detectors in the bypass flow region of the train were examined to determine the extent to which coolant characteristics in the two phase region could be characterized by the available signals. It was found that two phase velocities can be resolved at elevations near the liquid level. The measured velocities are not always simple rise velocities. when the level is low in the test train, the velocities are upward. When the level is near the top of the test train, the velocities are indicative of a considerable degree of vertical rotational motion (swirling) of the two phase coolant below the model.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Evaluation of the Steady-State Initialization Capability of the FREY Code

Author(s): C.V. De Vore, R.O. Montgomery Advisor: Dr. K.L. Peddicord

Major Field: Nuclear Engineering University: Texas A&M University

Degree Program: Bachelor of Science

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

The FREY (Fuel Rod Evaluation sYstem) computer code is being developed under the sponsorship of the Electric Power Research Institute. The purpose of this code is to describe the time dependent behavior of light water reactor fuel pins under a variety of transient conditions. FREY is a best estimate code based on finite element analysis using state-of-the-art methodology.

It is important to establish the self-initialization capability of the FREY code so that proper initial conditions can be established for a transient which might occur at any time during the life of a fuel pin. To assess the steady-state initialization of the FREY code, comparisons were made with the F-Code also developed by EPRI. F-Code is meant to be a mechanistic code specifically designed to handle long term steady-state calculations. Comparisons were made of fission gas release and clad strain for F-Code and FREY. The capabilities of FREY showed good results in comparisons with F-Code. FREY was also compared with a number of well characterized irradiated fuel pins which were examined after removal from their respective reactors. After considering pins from eight different reactors, FREY again showed good capability in predicting the measured results for the actual irradiated fuel pins. In comparison with F-Code, FREY typically showed a smaller gas release and somewhat more physically justifiable release rates, particularly at low burnup.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Fast Flux Reduction Techniques in PWR's

Author(s): Jeff Fint

Advisor:

Major Field: Nuclear Engineering

University: University of California
Santa Barbara

Degree Program:

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other x

ABSTRACT

In recent years, several pressurized water reactors, (PWR's) have been identified as being susceptible to a hypothetical accident that could lead to a catastropic failure of the reactor vessel. Events of particular concern combine rapid cooling of the vessel wall with substantial system over-pressure. These types of events have been named "over-cooling transients" or "pressurized thermal shock," PTS.

Primary concern is over plants built during the late 1960's and early 1970's, before a significant body of data was available on radiation embrittlement.

Examination shows that although plant-specific analysis is essential, a general class of solutions proves to be very effective. The solution centers around fuel management, and has the potential to reduce fast flux at the vessel wall by 77% while not affecting overall plant performance.

SESSION II

NUCLEAR SPACE REACTORS AND SYSTEMS

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Design Requirements and Problems of a Space Nuclear Reactor

Author(s): Christine Cockey Advisor: Dr. Gene Lucas

Major Field: Nuclear Engineering/Physics University: U.C. Santa Barbara

Degree Program: B.S. / B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other___x___

ABSTRACT

An important element in space exploration is a reliable and high density source of power. As more power is needed, research has been directed to a space nuclear reactor. Special problems exist which must be surmounted. The areas focused on in most research are environment, reliability, and mission requirements. At the present time, all work is in the design phase.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Evaluation of Uranium Oxide Fuel for the SP-100

Author(s): David C. Carpenter Advisor: Dr. K.L. Peddicord

Major Field: Nuclear Engineering University: Texas A&M University

Degree Program: Masters

Paper related to: Ph.D. Dissertation_____ M.S. Thesis XX

Term Paper_____ Other_____

ABSTRACT

The initial core designs for the SP-100 space reactor will utilize the extensive experience that has been accumulated with uranium oxide fuel. Much of the data has obtained from irradiations in commercial nuclear power plants. However, the conditions in the SP-100 will be that of a compact fast reactor.

In an effort to determine the behavior of UO_2 fuel for SP-100, a project is underway to model the fuel pin response in a fast reactor environment. This typically consists of power densities and clad temperatures which are higher than in commercial reactors. A computer code is under development which will simulate this situation. The temperature profile within the fuel pin drives the other important mechanisms. Calculations indicate that the temperatures in the SP-100 pins will range from 1400 to 1700 K. This can result in redistribution of internal porosity, swelling of the fuel, formation of a central void, and the release of oxygen and potentially corrosive fission products from the fuel matrix. Fission products such as cesium and iodine will diffuse from the fuel to the clad inner surface. At the clad, these constituents can combine with the available oxygen and, under conditions of stress loads from the swelling fuel, lead to clad failure.

The goal of the study is to assess these phenomena to determine if the integrity of the clad can be assured for the design lifetime of the SP-100 fuel pins.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: High Temperature Gas Space Power Reactor

Author(s): E. Chaffee, P. Huynh, J. Peery, D. Smith and J. Travers
Advisor: F. Best and K. Peddicord
Major Field: Nuclear Engineering
University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

Evaluating all considerations for electrical generation in a space environment, nuclear power has been deemed most feasible. A high temperature gas reactor would be able to provide 1MW of electricity for a ten year period without core maintenance. Calculations were made based on nuclear reactor theory and thermodynamics to prove that these specifications could be met. It will be shown that this reactor system can be transported to the space station via the space shuttle. Design considerations include fuel, core configuration, core vessel, shielding, and power conversion systems and devices. The HTGR will employ highly enriched uranium fuel, will be graphite moderated, helium cooled, and will generate electrical energy through a Brayton cycle.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: A Liquid-Metal Cooled Fast Space Reactor

Author(s): K. Seager, M. Blumberg, J. Osborn
K. Thomas and T. Nguyen
Advisor: F. Best and K. L. Peddicord
Major Field: Nuclear Engineering
University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

This paper presents the design of a liquid-metal cooled fast-spectrum compact space reactor. The requirements of this reactor are to provide a continuous power of 1 MW(e), operate for ten years without refueling, have restart capabilities, and be transportable by the space shuttle.

Lithium-7 will be used as the reactor coolant, with potassium as the working fluid in a Rankine power conversion cycle. The fuel consists of cylindrical elements in a square lattice, composed of UN with Nb-1% Zr cladding. Beryllium-B_4C drums along with moveable Be shielding will be used for reactivity control. Electromagnetic pumps will be used to drive the coolant through the systems. A molybdenum direct condensor-radiator will be used to reject waste heat to space.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Space Nuclear Reactor

Author(s): D. Carpenter, H. Giap, J. Gunn, Advisor: F. Best and K. L. Peddicord
R. Williams, C. Gamache, J. Rubio

Major Field: Nuclear Engineering University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

The HP-1 is a heat-pipe space power reactor that is designed to supply 1MWe to a low earth orbiting space station. The power conversion is to be by Brayton cycle with regeneration and intercooling. The HP-1 is a fast reactor using 93% enriched UO_2 fuel fabricated into plates separated by thin layers of Mo. Preliminary calculations suggested core dimensions of approximately 46 cm diameter and 50 cm in height. The reactor will be controlled using rotating drums composed of Be reflector and B_4C absorber material. Also incorporated in the design is the capability to restart the reactor if necessary.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Space Nuclear Advanced Fuel Unit (SNAFU)

Author(s): M. DeHart, A. De La Paz, K. Knipple, C. Lochrie, R. Sartor
Advisor: F. Best, K. L. Peddicord
Major Field: Nuclear Engineering
University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

Recent developments in national policy have called for the establishment of a permanent space station within the next ten years. This group has been asked to design a nuclear reactor for this station. This reactor must be able to supply a continuous one megawatt of electrical power for a ten year period without refueling. Additional design specifications are shutdown and restart capabilities, and the ability of the components of the design to be deliverable by the space shuttle; i.e., the dimensions and weights of the components are limited to the space and weight limits of the shuttle cargo bay. The solution proposed is a high temperature, helium cooled fast reactor.

The core design incorporates a new concept, unclad metal fuel pins. The fuel pins consist of U-15 w/o Pu-10 w/o Ti alloy. Metal fuels are more suitable than oxide or carbide fuels for fast reactors because metal fuels do not "soften" (moderate) the neutron flux as extensively. The chosen fuel alloy has enough strength to support the fuel rod structurally; this eliminates the primary function of cladding. Without cladding, heat transfer is enhanced and PCI (Pellet Clad Interaction) are eliminated; and fission gases will be released into the coolant. The fuel pins will be packed in a hexagonal lattice.

The turbine temperature limit of 1000°C sets the system limit. This temperature limit will determine the radiator operating temperature. The radiator is to be constructed of a titanium alloy.

This design will satisfy all of the imposed criteria as a viable solution to the space nuclear reactor power system.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: The Design of a 1 MWe Space Power Station

Author(s): P. Bellmore, F. Davis, S. Hensel, D. Horn, V. Le, D. Rhodes
Advisor: F. Best and K. L. Peddicord
Major Field: Nuclear Engineering
University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

The manned space stations that are now being planned will require a high power, long lived, power source. The combustion of fossil fuels is not possible in space and current space power generation systems would be too large for the power required. The proposed power generation system would include a nuclear reactor with a conventional turbine, compressor, and generator set.

The design of a 1MWe nuclear powered, HTGR, space power station with a 10 year lifetime will be discussed. Topics to be included will be:

1. Nuclear Reactor Physics
2. Plant Thermal Hydraulics
3. Physical Design
4. Transportation, and
5. Assembly

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Low Orbit Reactor Device

Author(s): C. Steen, R. Montgomery, M. Moore, G. Sjoden, C. De Vore
Advisor: F. Best and K. L. Peddicord
Major Field: Nuclear Engineering
University: Texas A&M University

Degree Program:B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

The low orbit reactor device (LORD-I) will be a high temperature gas cooled fast reactor (HTGFR). The reactor has been designed to operate with minimal maintenance for 10 years. In the event of a shutdown, the reactor will have a restart capability. LORD-I is designed to continuously supply 1MW of electric power.

This design will utilize a direct loop gas cycle using helium as both the working fluid and the coolant. The core of the reactor will consist of highly enriched (93%) uranium oxide (UO_2) fuel arranged in a close packed array of elements. The fuel cladding material is made of a vanadium alloy. The reactor thermal power output will be approximately 8 MWth. Control of the core will be achieved through the use of cylindrical berylium boron-carbide reflector/absorber positioned along the outer perimeter of the core. Several reactor safety features have been included. Safety shutdown rods made of boron carbide will be inserted throughout the core to ensure complete shutdown in case of an accident. In addition, a high pressure helium injection system will be used in the event of a minor coolant loss.

The production of power will be based on the use of a Brayton gas cycle system incorporating a heat regenerator, allowing for efficiencies greater than thirty percent. Using both high and low pressure turbines, the resulting shaft work will drive a network of compressors and generators. The excess heat will be rejected to space using radiative heat pipe assemblies.

Radiation exposure will be minimized by suspendng the reactor on a boom extending from the space station. In addition, a physical shield will be constructed between the reactor and the space station to provide additional radiation protection.

The LORD-I reactor system should prove to be a reliable reactor device for future space power applications.

SESSION III

HEALTH PHYSICS AND DOSIMETRY

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Data Reduction Network for Environmental Surveillance

Author(s): Thomas Hjellming

Advisor:

Major Field:

University: Arizona State

Degree Program:

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other_____

ABSTRACT

The data reduction network for environmental surveillance is a system of software programs capable of analyzing dose measurements taken at various environmental stations using Thermoluminescent Dosimeters (TLDs), portable micro R meters, and Pressurized Ion Chambers (PICs). The network was designed to compile and reduce data from sixty-five sites surrounding the Palo Verde Nuclear Generating Station as part of an environmental surveillance program setup by the Radiation Measurements Facility at Arizona State University (ASU). ASU is under contract with the Arizona Public Service Company to provide environmental assessment of the Palo Verde Nuclear Generating Station.

Site dose measurements are taken on a monthly basis using TLDs and portable micro R meters. Quarterly readings are taken with TLDs and PICs. The TLDs used are Panasonic UD-812 badges, which are read on a Panasonic UD-710A Automatic TLD reader. Raw TLD data is transmitted directly to the host computer for analysis.

After the site doses have been calculated using TLDs, comparisons are made with TLD, micro R and PIC readings for the past six months (or two quarters), to check for readings deviating more than 25%. Increases or decreases in measured doses are immediately brought to the attention of the system operator for further interpretation.

At the end of the year, an annual environmental report is printed out which displays all the site results in graphic and tabular form. The annual report is then submitted to Arizona Public Service.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: THERMOLUMINESCENT DOSIMETRY ENVIRONMENTAL MONITORING PROGRAM FOR PALO VERDE NUCLEAR GENERATING STATION.

Author(s): Robert S. Blanton, G.W. Klingler, Brian Ramey, B. Stewart Advisor: Dr. John W. McKlveen

Major Field: University: Arizona State University

Degree Program:

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other x

ABSTRACT

The NRC requires that the environment surrounding a nuclear generating station be radiologically monitored for measurable levels of radiation. To meet the direct radiation monitoring portion of the regulatory requirements a preoperational thermoluminescent dosimetry (TLD) environmental monitoring program has been established by Arizona State University for the Palo Verde Nuclear Generating Station. A portion of the TLD program consists of familiarization with the operational characteristics of the Panasonic UD-710A automatic TLD reader and quantification of the response characteristics of the Panasonic UD-812 dosimeter badge along with the calibration of both to provide a low level radiation measurements system. Finally, the TLD system is applied to environmental monitoring through sixty three TLD stations located around the power plant in accordance with the NRC Branch Technical Position dated November 1979. Data collected during the past nine months has established an average radiation background between 95 and 110 mR per year. The TLD measurements are compared against micro-R and pressurized ion chamber measurements made at the same locations.

The paper will describe the environmental monitoring program, badge calibration and the computer methodology used to process the results.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: THERMOLUMINESCENCE ALBEDO NEUTRON DOSIMETRY

Author(s): Mohamed S. Salem

Advisor: Dr. John W. McKlveen

Major Field: Nuclear Engineering

University: Arizona State University

Degree Program: M.S. Program

Paper related to: Ph.D. Dissertation_____ M.S. Thesis X X

Term Paper_____ Other_____

ABSTRACT

The thermoluminescence albedo neutron dosimeter is considered the best personal neutron dosimeter available today, however, it does not satisfy all requirements for being satisfactory for universal application and usage in a wide variety of radiation environments.

A commercially available thermoluminescent neutron dosimeter (Panasonic UD-809AQ) was used for this albedo neutron research. The dosimeter is good for thermal and epithermal neutrons, but very poor for fast neutrons, due to the high energy dependence response. The uncertainty associated with the thermal neutron dose equivalent ranges from 2% to 24% and for the epithermal neutrons is 2% to 47%. The response is dependent on the beam direction.

Distance between the dosimeter and the body should be very small (0-1 cm). For dosimeters placed more than 1 cm the measured dose equivalent will be underestimated by 24%. The dosimeter sould be worn carefully because if it is reversed the dose equivalent will be underestimated by 65%. The fading rate at 24°C is 12% after 3 days, 37% after 3 weeks and increases with the temperature.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: The Effect of the HOSGER Albedo Neutron Dosimeter Orientation on Neutron Dose Estimates

Author(s): Noreen D. Poor

Advisor: Dr. Nolan Hertel

Major Field: Health Physics

University: The University of Texas at Austin

Degree Program: Nuclear & Biomedical Engineering

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other Summer Research Project, at Argonne National Lab

ABSTRACT

Neutron dose estimates made from a phantom-mounted HOSGER albedo neutron dosimeter are dependent upon the relative orientation of the dosimeter to the source, and may vary as much as 60%. An 80-gram Plutonium-Beryllium neutron source was used to irradiate the HOSGER dosimeter mounted on a 30cmx30cmx15cm Lucite slab at one meter, as the slab, or phantom, was rotated 360 degrees about both horizontal and vertical axes.

SESSION IV

FUSION ENGINEERING

AND PLASMA PHYSICS

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Deuteron Injection D-T Fusion Device Analysis

Author(s): Kenneth Washington and D. Allison Advisor: Dr. T. A. Parish

Major Field: Nuclear Engineering University: Texas A&M University

Degree Program: B.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other X

ABSTRACT

In order to obtain useful electrical energy from fusion devices, it has been suggested that an interesting reactor could result if D-T fusion were to be driven by injecting a deuteron beam into a plasma of cold tritium targets. The major motivation of this option is the existing technological difficulties in achieving the high temperatures needed for a thermonuclear D-T plasma. Under the deuterium injection mode of operation, the tritium field particles serve as fusion targets moving with a Maxwellian distribution. The fusion device would act as an energy multiplier with fusions taking place as the deuterium beam loses energy to the cold tritium plasma. The purpose of this research is to perform preliminary calculations to predict the ratio of the fusion energy produced to the deuterium energy injected as the temperature of the background tritium, the temperature of the background electrons, and the injected deuteron energy are varied. The model developed assumes slowing down of the deuterium injection particles by coulombic interaction with the field electrons and tritium particles. The reaction rates are calculated using current fusion cross-section data and a high order gauss-legendre integration technique. Results obtained for various tritium temperatures are compared to literature values obtained using alternate methods and conclusions are derived to relate these results to the performance of a reactor based on this mode of operation.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Ignition Conditions for Reversed Field Pinches

Author(s): Erfan Ibrahim

Advisor: Dr. Dale Klein

Major Field: Nuclear Engineering

University: University of Texas at Austin

Degree Program: Mechanical Engineering

Paper related to: Ph.D. Dissertation_____ M.S. Thesis__x__

Term Paper_____ Other_____

ABSTRACT

The RFP is an axially symmetric toroidal shaped device that holds a plasma by the simultaneous presence of a toroidal field B_ϕ and a poloidal field B_θ. The current I_ϕ sustains the poloidal field B_θ and the toroidal field is maintained by electric currents through external poloidal coils. A study of Magnetohydrodynamic (MHD) instabilities gives certain plasma physics criteria that have to be satisfied for an MHD stable plasma in the RFP configuration. These are pressure balance equation, Suydam criterion, instabilities with wavelength greater than the radius of the toroid have to be overcome, and the RFP Taylor criterion has to be satisfied, i.e. the Fθ values have to lie in the region of minimum energy with negative F values and θ values ranging between 1.2 and 1.6.

Assuming all the scaling laws used in RFP experiments were to hold at all temperatures up to ignition a power balance equation has been derived for RFPs and the plasma can be ohmically heated to ignition. There is no proof that these laws will be significantly altered as ignition is approached, at least present plasma physics knowledge does not call for any further limitations or loss mechanisms. The only limitation at the moment would be an engineering one where current density limit, first wall neutron loading limit, magnetic field strength at magnet limit, or setting up a Bessel function Model $\vec{B}$ configuration could pose as a problem. As far as the pessimism with using present laws to scale an ignited plasma is concerned only experimentation at the energy level will set it aside or voice it with stronger arguments.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Thermal Neutron Driven, Fast Neutron Source

Author(s): S. Na, T. Tran, D. Sunderland Advisor: Dr. T. A. Parish

Major Field: Nuclear Engineering University: Texas A&M University

Degree Program:

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other ✓

ABSTRACT

Shielding, tritium breeding, and radiation damage calculations for D-T fusion reactors must be verified. The results of numerical calculations show that it may be possible to use a thermal neutron source (fission reactor) to produce a useful number of 14.1 Mev neutrons. Neutrons impinging upon a region of Li^6D can produce 14.1 Mev neutrons by the following reactions: $^6Li(n_{th},T)^4He$ and $D(T,n_{fast})^4He$.

The 14.1 Mev neutron yield factor and triton range in LiD were determined using a variety of numerical integration techniques. Applying a 16-pt. Gauss-Legendre quadrature, on 100-Kev energy ranges, from 1 Kev to 2.73 Mev, the fast neutron yield was determined to be 1.8×10^{-4} 14.1 Mev n per thermal neutron. This result agrees with previous results in the literature.

Based on this yield factor, the special irradiation cell of the TAMU TRIGA reactor, with a steady-state thermal flux of @10^{12}n cm^2/sec, could yield a 14.1 Mev neutron source of 10^{12}n/sec from a LiD target of area 60x60 cm^2. A source of this size is comparable to that obtained with accelerators. Therefore a LiD neutron source at the TAMU facility could be useful for shielding and neutronics analyses related to fusion reactors.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Neutronics and Photonics Performance of Inertial Confinement Fusion Pellets with Internal Tritium and He^3 Breeding.

Authors: Doug Haseltine (A&M) Advisor: Ted Parish
Magdi Ragheb (UI)

Major Field: Nuclear Engineering University: Texas A&M

Degree Program: M.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____
Term Paper_____ Other work done at University of Illinois

ABSTRACT

The neutronics and photonics performance of a pellet with a small DT core trigger, surrounded by a larger volume of D to enable tritium and He^3 breeding, is examined. The response to a 70% DD with 30% DT composite neutron spectrum is calculated using either W, Be, or Pb as structural materials at core density radius products ranging from 9.42 to 94.2 kg/m^2.

The percentage of energy leakage from the pellet in the form of escaped neutrons is 42% of the source energy for the DT source and 29% for the DD source. The gamma-ray energy percentage deposited in the pellet is 27% for the DT source and 10% for the DD source. For the pellet with the composite source, the energy multiplication factor is 1.27.

Thus the large DD contribution to the composite neutron source results in the pellet performing many of the functions normally reserved for the blanket such as spectral softening, breeding, and neutron and energy multiplication. The neutron energy leakage is 38% of the source energy for the composite source. It is estimated that the neutron energy leakage amounts to 11% of the fusion energy, compared with 70% as neutron energy in a DT pellet.

These results are significantly different from those encountered in conventional DT inertial confinement designs, and thus lower tritium inventories, higher power densities, reduced radiation damage and materials activation of the reactor coolant and structure may be achievable.

SESSION V

EXPERIMENTATION

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: PWR Low Power Physics Test Program Requirements

Author(s): W. Nixon and J. Seawright Advisor:

Major Field: University:

Degree Program: Professional - Texas Utilities

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other x

ABSTRACT

PWR Low Power Physics Test Programs are required by the Nuclear Regulatory Commission (NRC) to be implemented following each reactor fueling/refueling operation. These programs not only ensure that the reactor conforms to design specifications, but also establish the operating characteristics of the reactor. In addition, cycle specific technical data and curves utilized during subsequent reactor operations are developed.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Preconcentration Method for the Determination of Uranium, Thorium and Transition Elements Using X-Ray Flourescence and Activation Analysis

Author(s): Mohammed Ally

Advisor: Dr. Dale Klein

Major Field: Nuclear Engineering

University: University of Texas at Austin

Degree Program: Mechanical Engineering

Paper related to: Ph.D. Dissertation_____ M.S. Thesis X

Term Paper_____ Other_____

ABSTRACT

Analyzing trace concentrations of uranium, thorium and other pathfinder elements in natural waters can provide useful information for uranium deposits. Also, environmental information for the water supply may be deduced from this trace analysis. Preconcentration of natural water is generally necessary for the trace characterization. This study details a search for preconcentration techniques using different organic compounds as the precipitating reagents and an inorganic carrier. The final recipes for each reagent as applied to produce samples are presented. Energy Dispersive X-Ray Flourescence Spectroscopy and Instrumental Neutron Activation Analysis methods are used as the analyzing part. Comparison of data using the two methods are also presented.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL
NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Irradiation Cell Flux Determination with the Bonner Sphere Detectors.

Authors: Doug Haseltine, Mike Vasquez
Advisors: Gerald Schlapper, Richard Neff
Major Field: Nuclear Engineering
University: Texas A&M

Degree Program: M.S.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____
Term Paper_____ Other X

ABSTRACT

A study was performed to more precisely determine the neutron flux levels and energy dependence of the irradiation cell beam port at the A&M Nuclear Science Center reactor. Data was obtained using the Bonner multisphere detector system utilizing a $Li^6I(Eu)$ scintillator for both pure beams and neutron output modified by a variety of beam port filters. The results were then unfolded using an updated revision of the BON31G code to obtain the magnitude and energy of the various neutron spectrum peaks, as well as a fractional dose from thermal to 15 MeV neutrons.

Upon placing four inches of iron in the beam path, the thermal neutron flux was attenuated two to three orders of magnitude and a peak in the range of hundreds of keV was discovered. Addition of differing thicknesses of iron, aluminum, or sulfer apparently served to reduce the strength of the beam without significantly altering the characteristics of the main peak. As the filter was increased, however, more scatterings to the walls of the cell were encountered, which had a tendency of softening the spectrum and increasing the width of the flux peak. But even with the cell scattering and some potential detector saturation on some of the less filtered beams, the resolved flux spectrum varied less than a half order of magnitude in the area of the average energy of the beam.

SESSION VI

REACTOR THEORY AND PHYSICS

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: TRIGA Reactor Dynamics Above Prompt Critical

Author(s): Mr. James Johnson Advisor: Dr. George Nelson

Major Field: Nuclear Engineering University: University of Arizona

Degree Program: B.S. Nuclear Engineering

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other xx

ABSTRACT

The object of this experiment is to use pulsing techniques with the TRIGA to determine the ratio β/l and the energy coefficient of feeback reactivity.

Six power bursts were pulsed for input reactivities between \$1.25 and \$2.45. The initial inverse period was calculated in three different ways: FWHM, energy generated up to time of peak power, and by the superleast program.

The ratio β/l (where β =delayed neutron fraction and l is the neutron generation time). The ratio β/l is a key parameter of the TRIGA reactor when performing pulsing techniques. The ratio of β/l was found to be 128.7 sec^{-1}. The energy coefficient of feedback reactivity was found to be 0.1928 \$/Mw-sec.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Computational Model for Commercial Reactor Core Analysis

Author(s): C. Willingham and J. Boatwright
Advisor:
Major Field:
University:

Degree Program: Professional - North Texas Section ANS

Paper related to: Ph.D. Dissertation_____ M.S. Thesis_____

Term Paper_____ Other x

ABSTRACT

Abstract not available at this time

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: (see below)

Author(s): Bruce C. Wilson

Advisor: Dr. Clarence Lee

Major Field: Nuclear Engineering

University: Texas A&M University

Degree Program: Ph.D.

Paper related to: Ph.D. Dissertation_____ M.S. Thesis__x__

Term Paper_____ Other_____

ABSTRACT

SOLUTION OF THE TIME-DEPENDENT DIFFUSION EQUATION USING A CONSERVATION VARIATIONAL METHOD AND ANALYTIC OPERATOR TECHNIQUES

by

Bruce C. Wilson
Department of Nuclear Engineering
Texas A&M University

The time-dependent concentration diffusion equation with radioactive decay was solved using a conservation variational method and analytic exponential operator technique. The conservation variational method used Lagrange multipliers to minimize the time-dependent diffusion equation functional subject to the physical constraint of conservation. The resulting set of coupled differential equations was solved using an analytic exponential operator technique. The results obtained, using the conservation variational method, were compared with analytic and finite difference solutions in order to determine the validity and accuracy of the method. The conservation variational method obtained analytic accuracy for the case of pure diffusion in one and two region spheres, using the minimum number of equations necessary to define the problem. The results also tend to indicate that the conservation variational method can obtain more accurate solutions (with possible analytic accuracy) than comparable finite difference methods while using approximately one-half the total number of equations.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Inverse Kinetics on Treat

Author(s): Jeffrey A. Benjamin Advisor:

Major Field: Nuclear Engineering University: Oregon State Univ.

Degree Program: B.S.

Paper related to: Ph.D. Dissertation _____ M.S. Thesis _____

Term Paper _____ Other Summer Research

ABSTRACT

This report deals with the application of rod-drop inverse kinetics techniques on Argonne National Laboratory Transient Reactor Test facility (TREAT). The theory of inverse kinetics is discussed as well as the experimental set-up and applications to TREAT. Special emphasis is placed on changing detector efficiencies during the rod drop. These changes in efficiency are utilized to yield a digital computer solution to the point kinetics equations. Results as well as the feasibility of application are also discussed.

TEXAS A&M UNIVERSITY STUDENT/PROFESSIONAL

NUCLEAR SCIENCE and ENGINEERING CONFERENCE

Title: Solution of Neutron Transport Equation Using Spherical Harmonics

Author(s): Wesley C. Fan & Clarence E. Lee

Advisor: Clarence E. Lee

Major Field: N.E.

University: Texas A&M Univeristy

Degree Program: Doctor of Philosophy

Paper related to: Ph.D. Dissertation X M.S. Thesis_____

Term Paper_____ Other_____

ABSTRACT

Analytical solutions of the one-dimensional steady-state neutron transport problems have been investigated. The energy and angular dependence in the transport equation are treated by using multigroup approximation and spherical harmonics expansion. The spatial-dependent angular moments are determined from the multigroup P_N equations using eigenfunction expansion technique. These eigenfunctions are the exponential function, the modified Bessel function, and the spherical Bessel function for infinite slab, cylinder, and symmetric sphere, respectively.

The proposed solution technique has been employed to determine the critical dimensions, the effective multiplication factors, and neutron angular flux distribution for selected transport problems. The numerical results indicate excellent agreements with the S_N method and other benchmark calculations even with low-order angular approximations.