PRNC 17 PUERTO RICO NUCLEAR CENTER PROGRAM OF INSTRUCTION FOR PRNC REACTOR OPERATORS (Academic Phase) ---Page Break--- PROGRAM OF INSTRUCTION FOR PUERTO RICO NUCLEAR CENTER REACTOR OPERATORS (Academic Phase) ---Page Break--- COURSE PURPOSE PREREQUISITES LABORS TRAINING LOCATION SECTION T - PREFACE PRNC REACTOR OPERATORS COURSE (Academic Phase) To provide reactor operator trainees with the academic preparation necessary for further technical instruction in the operation and maintenance of PRNC research reactors. Admission to the PRNC Reactor Operators Training Course: 6 months Puerto Rico Nuclear Center - Mayagüez ---Page Break--- SECTION I - SUMMARY PRNC REACTOR OPERATORS COURSE (Academic Phase) Time: Sub. Academic Subjects Mathematics and Slide Rule Physics Nuclear Engineering Electro-Mechanical Engineering Health Physics and Chemistry Plant Information Type of Instruction Lecture Demonstration Conference Practical Exercise Examination 6 months ---Page Break--- PRNC REACTOR OPERATORS COURSE (Academic Phase) SECTION III - ACADEMIC SUBJECTS Total: 356 hours SUBSECTIONS ANNEX HOURS PAGE MATHEMATICS PHYSICS NUCLEAR ENGINEERING ELECTRO-MECHANICAL ENGINEERING Algebraic operations; algebra; logarithms; exponentials; trigonometry and vectors; size and operators; examination Basic mechanics, work, power, and energy; atomic physics and radioactivity; basic radiation detection, nuclear physics; examination; lattice retort factor physics; steady state analysis; transient analysis; Basic fluid dynamics and power plant components, materials and practices; basic thermodynamics; examination; laboratories. Effects of conducting radiation; standards of radiological protection; applied health physics, chemistry and feedwater treatment; examination; laboratories. Introduction and general plant features; primary system, secondary systems; examination. ---Page Break--- PURPOSE: To give the student mathematical ability in basic arithmetic.

opers SECTION 1 - AMES ANNEX NOGER 1 Machentice and Slide Rule Time: 71 hours Hions, algebra, trigonometry, vectors, logarithms; 10 reach students slide rule operations required for the solution of applied problems in other academic subjects. HOURS AND subject SCORE TYPE core a course Introduction to subject; use of Introduction Liberal numbers; definition of algebraic terms and notations; terms and factors; signs of grouping. Arithmetic Review of methods in addition, subtraction, multiplication of arithmetic functions; simplification of complex fractions; operations with positive, negative numbers, with review. Introduction to the slide rule; Line Reading the "C" and "D" scales. Law of exponents multiplication, and division of numbers, subtraction, and Radicals Definitions; conversion from exponential to radical form; factoring and removal of factors from the radical; addition, subtraction, multiplication of radicals. Slide Rule 11 Simple multiplication on the "C" and "D" scales. "C" and "D" scales, Ratio and proportion involving "C" and "D" scales, Exponents and Practical exercises involving the radicals material covered in hours 4 and 5 ---Page Break--- HOURS AND subject SCORE, TE es score ee 8 Multiplication of positive and negative integers and numbers; multiplication of monomials and polynomials 9 Slide Rule TIT —Multiplication of numbers involving the use of powers of ten, 10 Multiplication of Practical exercises and review of the fundamentals and material covered in hour No. 3. polynomials Division of monomials and polynomials 12 Slide Rule Division involving use of "C", "D", "C" and "D" scales use of ratio and properties and power of ten. 13. Division of Practical exercises and review of material covered in hour No. 11. Polynomials 16 Special Products Squaring binomials; product of sums and factoring; sum and difference of two terms; product of any two binomials,

15 spectral Products Factoring polynomials with common iL factors, difference of two squares, various trinomials, sum and difference of the cubes. 16 Spectral Products Practice exercises and review of level and Factoring IIT material covered in hours 24 and 15. "Reduction of Literal fractions

and mixed expressions by lowest common denominator. 8 Addition, subtraction, multiplication, and division of Literal fractions; complex fractions. & Practical exercise in reduction of LPE Fractions. 20° Dimensional Analysis> Introduction to dimensions and in dimensional analysis both English and native. ---Page Break--- 6 HOURS AND subject SCORE, no EE score ve a 2 23 2% 2 2 8 30 2 33 Dimensional Analysis It Review Class Examination 7 Slide Rule ¥ Linear equations 7 Slide Rule 9 Graph of Square One 1 Graphs of Equations LL Slide Rule for Simultaneous Linear Equations = IT Equations = GEE Practical exercises and review of material covered in hours No. 20 and 21, Review of material covered in hours No. 1 to 21. Examination on material covered in hours No. 1 to 21. Combines operations of multiplication and division involving "Cc" "Ci" and "DI" scales and powers of ten, Definitions; equations, identities and conditional equations axioms in operations with equations; rules of transposition, cancelling, changing of signs Checking of equations, practical the solution of linear equations cd TAN, 8 and etc. video reel, sales on Principles of interest and slope, solutions of simultaneous equations. Practical exercises and review of material covered in hour No. 28 Raising any number to any power, Using LL and LEO scales. Comparison with MAM, "BM, and "R" scales. Algebraic solution by addition and subtraction. Solution of equations containing care unknowns. Lue Lor lz ae ak Le 1 ue ln 1 PE 1b iL lL Lee ---Page Break--- 3s 36 37 38 » 40 a 42 “3 46 Equations Radical Equations Literal Equations 13 Beautification of Trigonometry Definitions Trigonometric Tables Skills Rela rrr Shige Rote ax ‘traditional equations, Solution of radical equations. Solution of

quadrette squatioas. Practical exercise in the solution of fractional, radical and quadratic equations, Solution of literal equations similar to those encountered in other areas. Practical exercises and review of material covered in hour No. 28. Review of material covered in hours No. 24 to 39, Premination on material from No. 24 to 40. I covered an Introduction to trigonometry, definition of angle; coordinate system, angle of a right triangle; new trigonometric functions of the same angle; cofunctions of the complementary angle. Basic definitions of functions of any angle. Use of tables and slide rule to find the angle. Discussion of cosine, tangent varying through the use of the unit circle. Use of the slide rule involving the sine and cosine scaler. Use of the laws of sines involving the tangent in it. Let L be at the angle.

---Page Break---

subsection Score, my TE score was 86 50 82 33 82 63 Right Triangle: slide Rule x Periodic Functions 1 Periodic Functions 77 Review of Examination 121 arithmetics 1 Logarithms 11 Logarithms 131 Slide Rule x Logarithms Slide Rule x27 Exponential and Equations range of Functions. Review Class Examination 1 ton of the right angle, solution of the right triangle on slide rule. Rotation of the unit circle: graphs of the trigonometric functions. General sine wave equation; angular motion; oscillatory motion; rotary motion. Review of material covered in hours 42 to 51. Examination of material covered in hours 42 to 51. Definition of logarithm and its use in multiplication, division, and raising to power, Base 10 Logarithms; mantissa characteristics, and Practical exercises involving material covered in hours 54 and 55. Practical exercises in the use of the logarithm; finding natural logs writing "EL" scales on slide rule. Slide rule proficiency test Solution of logarithmic and exponential equations. Graphs of Logarithmic functions; solutions of growth and decay relationships. Advantages of semi-log and log-log graph paper and comparison to linear plot. “Plotting of equations.”

Review of material covered in hours 5 to 61, Examination on material covered in hours 4 to 61. ---Page Break--- OURS AND THE score ee “ 6 Co 70 Plane vectors 1 Plane Vectors II Plane

Vectors III Operator J Operators it J Gparstor 12r Review Class Examination ¥ Equations; emphasis on notations Vector subtraction; components of a vector, addition of rectangular components. "of vector problems, Real and imaginary numbers, complex numbers; graphical representation of numbers affected by 3 fundamental operations with complex numbers, Graphical representation of addition subtraction, multiplication and division of complex numbers; polar form of complex numbers, multiplication and division of complex numbers in polar form Practical exercise involving material covered in hours 67 and 62 Review of material covered as hours Examination on material covered in hours 4 e090, ts tL tn rE tL in 1 Pe l@ le ---Page Break--- PURPOSE: OURS AND subject TYPE Introduction and physics necessary for o detail ANNEX SINGER 2 Pages Time: 61 hours Page ae ag fiestets « Denis understanding of the classics and nuclear study of nuclear reactor engineering and health physics CGS system Linear Motion Rotary Motion Force, work and power Energy 1 Energy 12 Energy 1t Energy 1¥ Examination 1 Matter and Molecules Importance, objectives process: G5 unste Of ease Length, time, force, work, and power, Velocity-time-distance relationship, velocity, momentum and radiation, angular velocity, and acceleration. Review motion, force, work, power, units, equivalence of work and energy change, Heat energy and temperature, theory, watts, temperature scales and electrical energy, electrostatic force and potential, reference to EE, electron chest and nuclear energy, comparison of energy release, reaction equations, and magnitudes All materials from 1 to 8, Properties of water including states, density, composition, division of Water into molecules, compounds and mixtures, 10 an tL 1b iL an Le an ---Page Break--- 1“ 1s 16 v Fr » 20 Models of the Atom: Atomic Number sel

Mess Mase Equivalent of Energy, Mase Defect and Bincing Energy Examination 12 Radioactivity T Radionuclide 11 Radioactive Decay Chart of the Nuclides Radioactive Decay Series Alpha and Beta Particles Gamma Rays and Neutrino Interactions of Particles Interaction of Radiation with Matter Identification of elements, chemical symbols and periodic table; electrons, protons and neutrons; electrostatic forces Models of Thompson, Rutherford, Bohr, Sommerfeld, Hyperfine, and Modern, relationship to number of protons, electrons 2 x 4 mass of natural atoms, isotopes, lepton, isomers nuclear reaction equation. Einstein's equation, calculations amu to @ conversion, nuclear reaction equations. Mass of constituents, mass of result relationship of ALL materials from 11 to 16, Introduction to radioactivity, both Natural and artificial; properties of waste ten, Demonstration of physical phenomena. Statistics of radioactive decay, half-life, decay constant, laws of exponential decay. Use of Chart of Nuclides in radioactive decay and nuclear reactions. Parent-daughter decay series, natural and artificial series Charge and mass; typical alpha and beta decay; range in air; equation; energy; Charge and mass; other electromagnetic radiation; range; wavelength; frequency, Planck's constant, energy. Total electrostatic attraction and repulsion; specific ionization vs. path length; Photoelectric effect, Compton scattering, Pair production; annihilation radiation. ---Page Break--- 2 HOURS AND SUPER SCORE THE 26 detection 1 Principles of operation of ionization chamber, proportional counter. 27 detection 11 Principles of operation of UIC, CRC, and BF detector, and ion chamber- 28 Radiation Attenuation and distance; radioactive decay, all function I inverse square Law, 2 Attenuation by Material effect on attenuation, all Materials attenuation coefficient; energy and material dependence; half thickness. 30 Review ALL material from 19 to 29 le ‘SL Examination TIT All material from 19 to 29 is Review properties of neutrons;

absorption, 11. scattering, Easton, 33. Flux Beam flux; reactor flux; concept, unite, at relation to intensity 34 Reaction Dependence of cross section on projectile energy; target nucleus, and specific reactions, 35 Reaction Microscopic and Macroscopic cross sections 26 Reaction Rate Dependence on flux and microscopic cross section; sample calculation 37 Fission Conditions leading to non-fission absorption; absorption of activation; applicability to reactors 38 Neutron

Waters - Elastic and inelastic scattering; conservation of momentum and KE; necessity of moderation, properties of moderator Physical events during moderation, H Conditions Leading to fission; liquid drop model; threshold energy; the fissionable nuclei used in reactor 40 Neutron Physics Review physical events during moderation; Introduction to Neutron Lifetime, fermi phase diffusion Length, migration area. ---Page Break--- OURS AND Success Score, mu Score 41 Examination ALL material covered in 1 co 40 2 42 Boyle's Law and Behavior of gases under varying conditions; Charles' Law Introduction to lab procedures and graphing experimental results, 43 Statistical wa- Use of scalers, and determination of design- 4 PE. ture of Radioactive decay probabilities of radioactive sources, 46 Radiation Use of G.M., proportional counters, actinide Measurements Estimation and BF detectors. Voltage plateau determination. 43 Radioactive Decay Determination of half-life and decay constant 46 Gamma Shielding Shield effectiveness of various materials; attenuation coefficients ---Page Break--- PURPOSE: To give the student an understanding of theory and related fundamental ANNEX NUMBER 3 NUCLEAR ENGINEERING ‘Time; 66 hours study of plant operations. Reasonable Materials 2 Fission Process and Chain Reaction 3 Neutron Cross Sections and Reaction Rate 4 Neutron Cross Sections and Reaction Rate 11 3 Fission Neutrons Neutron Generation Time and Lifetime 7 Neutron Travel 8 Effective Multiplication

Introduction. Names and symbols of prime fissionable materials, fuel enrichment. Liquid-drop nuclear model; conditions required for fission; release of energy in fission; fission product distribution. Chain reaction: non-sustaining, sustaining, multiplying. Evaluate fission and capture cross sections of reactor materials, practical exercise in the use of reaction probabilities and cross sections. Neutron energy spectrum; prompt and delayed neutrons; decay of delayed neutron precursors. Definition of beta, the delayed neutron fraction, neutron lifetime; effective neutron the effect of neutrons upon overall reaction time; influence upon reactor control. Derivation of average logarithmic energy decrement; moderator slowing down power, moderating ratio; ferroi age, slowing down length; diffusion length; migration areas, migration length. Definition of keff, the multiplication factor. Introduction to the four factor formula, calculation of four terms from the neutron cycle, understanding of the basic nuclear reactor procedures essential for a detailed ‘HOURS. AND lL ib aL 1 PE aL tL iL ---Page Break--- 10 a a Bb 4 1s 36 sus, Neutron Production and Fast Piston Resonance Escape and Thermal Utilization Fast and Thermal Leakage Geometric Buckling Exanteatton 1 multiplication 1 Multiplication 11 Multiplication G27 Reactivity coefficients T Score, Definition and derivation of reproduction dependence of eta upon fuel enrichment; definition of fast fission factor; dependence of epsilon upon enrichment, ratio of fuel to moderator, and other reactor parameters. Definition of resonance escape probability; control of p through moderator/fuel ratios, fuel absorption cross section, average logarithmic energy decrement of moderator, enrichment; definition and derivation of thermal utilization factor, influence of moderator/fuel ratio. For finite reactor; definition of keff. Definition and mathematical expression of fast and thermal neutron non-leakage probabilities; solution of materials buckling, geometric buckling; relationship between

materials and geometric buckling; sample calculation of core criticality, Examination on material covered from Teo 12, Review of multiplication factor. Derivation of neutron multiplication equation; sample calculations. Derivation of neutron multiplication situation; discussion of equation assumptions and limitations; review of effective neutron generation time. Definition of reactor period. Derivation of neutron multiplication equation defines the concept of reactivity; graph of reactivity vs. period; relationship between reactivity and effective neutron generation time, Temperature coefficients of reactivity; nuclear coefficients due to changes in diffusion length, fermi age: cross sections, and Doppler density coefficients due to changes in microscopic cross sections,

buckling, and reactor dimensions. tL ie iL aL iL ---Page Break--- 8 w 20 aL 2 23 2% 25 successor Reactivity coefficients Tr Poisons T Poisons 11 Control Rod Effects ‘Transient Effects Examination 11 Fix control Reactor instrumentation 28 Reactivity Coefficient Reactor Fuel Elements Pressure, void and poison coefficients of reactivity; effects upon reactor operation; fuel loading requirements to compensate for negative reactivity effects, Origin of fission product poisons; qualitative and mathematical description of the rate of buildup and removal of xenon Poison; equilibrium concentration. Mathematical derivation of the reactivity equivalent of reactor poison from the influence of poisons upon thermal utilization factor. Sample calculations. Effect of control rods; perturbation of reactor flux; use of control rods to mitigate negative reactivity effects, and changes in power; shadowing effect introduction to rod worth. Review of transient analysis: multiplication equations, reactor period, reactivity and reactivity coefficients, flux Perturbation; delayed neutron transients, Examination of material covered from 16 to 22, Types of control rods; general features of reactor control; alarms, interlocks; function of the operator. Types and ranges

of reactor flux monitor - Seg instruments; uses during operation startup; linear power, log n, ported and power channels, principles of design. Review of principles of Control rod worth; experimental procedure for worth determination; sample calculations. Experimental procedure for determination of temperature and poison coefficient ‘sample’ calculations, Types and Functions of reactor fuel elements; Fabrication principles; burnable poisons, 16 lb tL Lt Le Lt iL ib iL ---Page Break--- v OURS AND subcritical SCOPE, Tue 29 Heat Transfer 1 of heat transfer; conduction, convection, radiation; temperature versus heat transfer curves; nucleate boiling 30 Heat Transfer II Reactor heat sources; dependence upon flux, hot spots; shutdown heat sources, removal of decay heat. 31 Reactor accident conditions; scram parameters and bypasses; design considerations; maximum credible accident; radiation hazards in plant location and safety. 32 Examination II Examination on material covered from le 2% to 31. 33 Reactor Shielding Review of particle and ray attenuation; all types and effectiveness of shielding materials; removal of heat from shield. 34 Reactor Materials Types of reactor coolants; characteristics of various coolants; selection criteria; moderating and reflecting materials. 935 Reactor Materials Reactor structural materials; other materials associated with reactor components; corrosion, mass transport 36 Reactor Regulation effects upon reactor materials, Materials activation; nil-ductility transition temperatures; curves of operating limits. 37 Reactor Loop Components peculiar to reactor systems; Components Piping requirements zero Leakage pumps and valves; leakage control systems; purification systems. 38 Subcritical Derivation of mathematical expression for Multiplication neutron subcritical multiplication; significance of multiplication, reactor neutron sources; startup procedures 2 Core Loading Core loading procedures; traverse multi- multiplication curves, significance,

application to loading of fuel storage areas 40 startup Approach to criticality; startup procedures; 1 1. Operations hazards involved in improper operation. ---Page Break--- HOURS AND SUBJECT Score Tre 41 Power operation Reactor operation at power; important iL and Shutdown system parameters; shutdown conditions review of nuclear reactor engineering, 42 Examination IV Examination on material covered from 28 to 41. 43 Neutron Phenomena Demonstration covering moderation, some reflection, diffusion, and other neutron phenomena. 44 Introduction to General introduction to nuclear simulator, 3 PE Nuclear Simulator operation of simulator, and description of components. 43 Reactor Startup Familiarization with reactor startup procedures and transient Behavior during startup, 46 Reactivity Effects of radioactivity changes on 3 re Period reactor period, graphing reactivity vs period curves, 47 Control Rod Reactivity worth calibration of control 3 PE calibration rod. 48 Poison Effects Effects of Xenon and other poisons on Reactivity. 49 Core Loading Core loading procedures, adverse 3 Re multiplication. 50 Automatic Requirements for

automatic controls, 2 PE Controls demonstration of ---Page Break--- 8 APPENDIX NUMBER 4 ELECTRO-MECHANICAL ENGINEERING Time: 26 hours PURPOSE: To give the students an understanding of electric circuits found in electrical and electronics fields and to provide the students with some understanding of fluid flow and heat transfer and of components found in nuclear reactors HOURS AND SUBJECT Score TYPE met _____room ve 1 The Simple Outline of course; Ohm's Law, power, and Electric sample problems. charges 2 Series Kirchhoff's voltage law, application of Ohm's and Kirchhoff's laws to DC series circuits. 3 DC Parallel Kirchhoff's current law, application of Ohm's and Kirchhoff's laws to DC parallel circuits: 4 D.C. Compound Series-parallel combinations, simplification and solution of compound circuits, voltage dividers, 3 DC circuits Student

solution in class of DC circuit 1 PE Problems problems. 6 Electrical Wire measurement, resistivity, insulation, = 11 Conductors protection. 7 Review of DC Examination on material covered from the Theory Vite 6, 8 Alternating AC definitions, vectors, sine wave iL Current. characteristics 9 Reducers Self inductance, induced emf, mutual inductance, phase relations, time 29° Capacitance Capacitor construction, dielectrics, all time constant, phase relations 11 Inductive and Phase relations between voltage current in Capacitive and reactive circuits, vector problems; Real impedance ---Page Break--- 2 a 4 1s 16 v 18 » 20 2 2 23 % 25 suspect AC Power AC Series Circuits ‘AC Parallel Circuits AC Composite Circuits Ag circuit. Problems Basic Electrical Indicating Instruments Review of AC Theory Beam Instantiation IE Tubes and Current Conduction Unidirectional Devices Power Supplies Power supply Waveforms Amplification in Vacuum 3254 Gas-Filled Tubes + synchros Review Examination 11 Transformer COPE ‘True power, reactive power, apparent power, power factor, power triangle, Solution of series circuits containing resistance, inductance, and capacitance. Solution of parallel circuits containing resistance, inductance, and capacitance. Solution of compound circuits with complex branches, Students solve AC problems in class, D'Arsonval galvanometer, ammeter, volt meter, shunts and multipliers, electro- dynamometer. Review of all material covered in 8 to 17, Examination on material covered in 8 to 17. ‘Tube types; electron emission, Vacuum diodes, crystal diodes rectifiers. ary disk Purpose, components, filters, waveforms. Demonstration of half and full wave rectification with various filters Fundamentals of vacuum triode amplifiers Gas diodes, thyratrons, phototubes, application of synchro devices to rod drive Indicators. Review of electronics from 20 to 25. Examination on material covered from 20 to 25. Theory of separation, construction, efficiency. 20 HOURS AND TE all ---Page Break--- a HOURS. AND suspect Score I’ve 29 Transformer

Instrument transformers, power distribution transformers, autotransformers. 30. Transformer single and three-phase hookups polarity, connections polyphase windings. 31 Low voltage short circuits, overcurrents, fuses, and protective switches circuit breakers, distribution switching equipment systems. 22 Review of EE review of all material covered from 1 to 31. 1. 33 Classification IV examination in material covered from 1 to 31. 2 8 34 Fundamental outline of course; symbols and English system of units; force, work, energy, power, efficiency, and torque, physics of liquids and gases. 35. Pressure; definition, absolute, atmospheric, vacuum and concept of psi. 26 Pressure measuring devices; open manometer, differential manometer, barometer, Bourdon gauge. 37 Mass flow description and calculation of flow, velocity, head, 28 Bernoulli's pressure, velocity, and flow measuring equation, Bernoulli's equation. Pump and friction heads. 39 Application of Bernoulli's equation to solve practical problems by students in 40 Fluid friction in pipes; laminar flow; in Reynolds number. Friction losses on valves and fittings. 41 Evaluation of determination of pump horsepower required for various piping systems. Practical problems. 42 Pumps classification of pumps by types and groups. Head and flow relations in pumps. ---Page Break--- HOURS. AND

SUBJECT SCORE, PE score 43. Review review of material covered in 34 to 42. 46 Examination all material covered in periods 34 to 42. 45 Temperature review temperature heat relationship; Celsius, Fahrenheit, Kelvin temperature scales and conversion, nature of heat. Linear, differential area and volume expansion and contraction of liquids and solids. 46 Heat measurement definitions; British thermal unit, thermal capacity.

Specific heat. Application of fundamental heat equation, 47 Heat Transfer - Heat transfer by conduction. Principle of conduction and the influencing factors. Practical problems, 48 Convection Heat transfer by forced and natural convection and influencing factors, 49 Radiation Heat transfer by radiation and influencing factors, 50 Thermodynamics The mechanical equivalent of heat. The laws of thermodynamics. Thermodynamic systems. Introduction to general energy equation. General Energy General energy equation; potential and kinetic energy, transferred heat, external work. Application of the equation. Examination All material covered in periods 48 to 53. Feedwater Classification of heat exchangers, purposes, Equipment Types and construction of deaerators and evaporators. Avarsery Purpose, ration and construction of valves; Equipment types, globe, check, safety, characteristics of piping and fittings. Nuclear Power General requirements and features of water-cooled nuclear reactors. Pump Piping and heat exchangers, valve corrosion and Definition, types, causes and prevention. Course Review Specific application in reactors, Review of entire course, ---Page Break--- 7 38 39 © 6 2 6 6 6 ECT Examination 121 Introduction Measuring Resistance and Power in DC circuits, DC Circuits Single Phase AC circuits Power in A.C. circuits Rectification Transformers Introduction to ME Laboratory, Fluid Flow Characteristics Pump Curves HOURS AND SOFE, ALL material covered in ME course Identification, safe handling, connections of equipment and instruments, Measurement of resistance and power using voltmeter, ammeter, Wheatstone bridge, ohmmeter, Battneter. Series and parallel DC circuits, verification of Kirchhoff's current and voltage laws, Additional practice in interpreting and hooking up electrical circuits, Demonstration on oscilloscope lagging and leading currents as inductance and capacitance are varied in an RCL network. Measurement of effect of

inductance and capacitance independently on current voltage relationship. Impedance measurement. Measurement of power in AC circuits using Wattmeters, Determine power factor in AC circuits, Draw vector relationships Investigation of the characteristics of dualwave and fullwave rectifiers, Comparison of filter networks Read and interpret wiring diagrams of single, parallel transformer connection, Polarity check of transformers. Three phase laboratory techniques; basic computations in density, specific gravity, pressure vacuum and fluid flow rates. Use of mercury differential manometer; determination of resistance to flow in gate and globe valve: Nature, importance, and note of characteristic curves; obtaining head vs. flow, efficiency and horse power curves. Comparison of pump types: centrifugal and rotary, ---Page Break--- ANNEX NUMBER 5 HEALTH PHYSICS AND CHEMISTRY Time: 39 hours 2% PURPOSE: To give the students background in the principles and purpose of Health Physics and Water Chemistry; a working knowledge of personnel protection, monitoring equipment, biochemistry, feedwater treatment and related analysis, and general procedures followed in research reactors, HOURS AND SUBJECT SCOPE, TYPE etc 1 Introduction introduction to health physics; early discovery and experience with radiation; development of health physics; comparison and application to nuclear field, 2 monitoring Review of atomic structure and composition; 11 Radiation 3) Radiation units 7 4 Radiation units 1 5 Biology 6 Biological Effects 7 Maximum (external) Permissible Concentrations 8 MP. (external) 5 mre Internal, origin of radiation emission; interaction of particles with matter; effects of contamination from various types of radiation. Radioactive decay-physical and biological Definitions of roentgen, curie, rep, rad, rem, and R-BLE, curies, rep, 4 nonograph Characteristics of

Living cells, tissues, organs, organ systems; components of cells-(genes and chromosomes)= principal organs of interest in humans, Physical, chemical,

biological and physiological effects of radiation; acute and chronic exposures; external and internal hazards; radio-sensitivity of body organs, limits for external radiation exposure; limiting exposure by time, distance, and shielding, calculation of working times in external radiation fields with and without shielding. Limits for internal radiation hazards, critical organs; air and water activity limits. Examination I activity, analysis 1 Activity Analyst 1 Radiation Hazards and Control in Reactor Personnel Monitoring and Control External: Plant Control Responsibilities of Individuals to Nuclear Plants Relative to HP Decontamination IT Basic C4 Feedwater Treatment and Analysis Material Balance Estimation Score, Examination of Lessons 1 to 8 Sampling procedures; air, water, sampling preparations; counting techniques. Activity determinations, counting statistics (interpretation of), sources of radiation hazards; concept of control-delineation of areas; radiation work permit; personnel and equipment decontamination, requirements for film badges and pocket dosimeters, survey and personnel monitoring equipment; protective clothing-use and availability. Responsibility for use of this equipment. Control of radiation areas; monitoring of areas and effluents; area radiation monitoring systems; control of sources and radioactive materials, concepts of environmental monitoring radioactive waste storage and disposal; shipment of radioactive materials definition of accidents and incidents, general procedures Responsibilities of Health Physicist, supervisors, and individuals; the Health Physicist in the chain of command; reports and records. Examination of Lessons 1 to 17. Principles, theory, treatment, acids and water and its impurities, aeration, coagulation, filtration, demineralization; pH, conductivity. Theory of material balance and problems. Feedwater treatment, chemistry, material balance.

---Page Break--- 23 % 25 Area Survey, Teedvater Treatment, 2% OURS AND Score, Type of operation of detectors and some survey instruments used for alpha, beta, gamma and neutron detection; point and area surveys. Calibration of instruments, Construction of calibration curves, Use of previously calibrated instruments to survey a radiation area. Setting up of access controls and determination of working times at specified locations for the area, Demonstration and practical exercise on water aeration, handouts, coagulation, filtration, demineralization, pH, conductivity, Cl, SO3 and O2 analysis, ---Page Break--- a” ANE NUMBER 6 PLANT INFORMATION Time: 21 hours PURPOSE: To familiarize students with the design and function of the system, components, general hardware and safety of nuclear plants as groundwork in preparing the student for Plant Operations Training. “It is intended that this course will show the students how the theory they have learned in other academic subjects ties in with actual plant operations. AND subsequent Score, Type of Instrumentation General description of primary instrumentation, nuclear instrumentation, and where located, method of control by control rod drives, and primary system temperature. Primary System system and components used to measure temperature, flow and level. Nuclear Instrumentation Problems encountered in detection, types of detectors, and the source range, power range channels. Control Rod Drive Functions, design considerations, construction of control rod drive mechanisms; together with the sources of power, interlocks and associated instrumentation, Reactor Protective Ways of controlling a reactor during operation, design requirements of a control rod system, types of control rods (shim and safety), conditions which could cause damage (loss of coolant, loss of flow and reactivity addition). Operational Aspects Sampling of primary and secondary water, what aspects of Water Chemistry are analyzed for, what to expect or

require Limite and what corrective action is used. Methods of chemical addition blowdown, various

methods of water chemistry control. Shielding discussion of primary and secondary shielding construction, materials, shadow shielding using plant components and shield water cooling system. ---Page Break--- 8 HOURS AND SUBJECT Score rd 8 Refueling discussion of general refueling procedures, tools and precautions 9 Examination examination of material covered from to 8. 12 10 Reactor Safety AEC regulations and organization analysis 1 Requirements of hazards evaluation and what may be found therein, 11 Core Design discussion of what data is available from the reports and core design reports from contractors and history of discussed incidents personnel. 12 Tour of EXC tour of the FRNC swimming pool reactor to point out important system components. 13 PaNC tour detailed tour of the FRNC swimming pool reactor pointing out details of systems and instrumentation, ---Page Break---