Section 6:
THEORY

page

REACTOR THEORY:	192001 Neutrons	6-3
REACTOR THEORY:	192002 Neutron Life Cycle	6-4
REACTOR THEORY:	192003 Reactor Kinetics and Neutron Sources	6-5
REACTOR THEORY:	192004 Reactivity Coefficients	6-6
REACTOR THEORY:	192005 Control Rods (Full and/or Part Length)	6-7
REACTOR THEORY:	192006 Fission Product Poisons	6-8
REACTOR THEORY:	192007 Fuel Depletion and Burnable Poisons	6-10
REACTOR THEORY:	192008 Reactor Operational Physics	6-11
THERMODYNAMICS:	193001 Thermodynamic Units and Properties	6-13
THERMODYNAMICS:	193003 Steam	6-14
THERMODYNAMICS:	193004 Thermodynamic Processes	6-15
THERMODYNAMICS:	193005 Thermodynamic Cycles	6-16
THERMODYNAMICS:	193006 Fluid Statics and Dynamics	6-17
THERMODYNAMICS:	193007 Heat Transfer	6-18
THERMODYNAMICS:	193008 Thermal Hydraulics	6-19
THERMODYNAMICS:	193009 Core Thermal Limits	6-21
THERMODYNAMICS:	193010 Brittle Fracture/Vessel Thermal Stress	6-22

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K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Define fast, intermediate, and slow neutrons.	1.9	2.0
K1.02	Define prompt and delayed neutrons.	2.4	2.5
K1.03	Define thermal neutrons.	2.2	2.3
K1.04	Describe neutron moderation.	2.4	2.4
K1.05	Identify characteristics of good moderators.	2.0	2.1
K1.06	Define neutron lifetime.	1.6	1.6
K1.07	Define neutron generation time.	1.6	1.6
K1.08	Describe fast flux, thermal flux, and flux distribution.	1.9	2.0
K1.09	Describe sources of neutrons.	2.3	2.4

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
	Describe the neutron life cycle using the following terms:		
K1.01	--fast fission factor.	1.4	1.4
K1.02	--fast non-leakage probability factor.	1.4	1.6
K1.03	--resonance escape probability factor.	1.9	1.9
K1.04	--thermal non-leakage probability factor.	1.5	1.6
K1.05	--thermal utilization factor.	1.9	1.9
K1.06	--reproduction factor.	1.5	1.6
K1.07	Define critical, subcritical, and supercritical with respect to a reactor and in terms of the effective multiplication factor.	3.1	3.1
K1.08	Define effective multiplication factor and discuss its relationship to the state of a reactor.	2.6	2.6
K1.09	Define K-excess (excess reactivity).	2.5	2.7
K1.10	Define shutdown margin.	3.2	3.6
K1.11	Define reactivity.	2.9	3.0
K1.12	State the relationship between reactivity and effective multiplication factor.	2.4	2.5
K1.13	Calculate shutdown margin using procedures and given plant parameters.	3.5	3.7
K1.14	Evaluate change in shutdown margin due to changes in plant parameters.	3.8	3.9

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Explain the concept of subcritical multiplication.	2.7	2.8
K1.02	Given the simplified formula for subcritical multiplication, perform calculations involving steady state count rate and source count rate.	2.2	2.3
K1.03	Describe the production of delayed neutrons.	2.3	2.4
K1.04	Define delayed neutron fraction and effective delayed neutron fraction: state the reasons for variation.	2.4	2.4
K1.05	Define start-up rate.	2.7	2.8
K1.06	Describe the factors affecting start-up rate.	3.2	3.3
K1.07	Explain the effect of delayed neutrons on reactor control.	3.0	3.0
K1.08	Explain the prompt critical, prompt jump, and prompt drop.	2.8	2.9
K1.09	Given the power equation, solve problems for power changes.	2.3	2.3
K1.10	Define doubling time and calculate it using the power equation.	1.6	1.6
K1.11	Explain the necessity for installed neutron sources in a reactor core.	2.7	2.8

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Define moderator temperature coefficient of reactivity.	3.1	3.2
K1.02	Define fuel temperature coefficient of reactivity.	3.0	3.2
K1.03	Describe the effect on the magnitude of the temperature coefficient of reactivity from changes in moderator temperature and core age.	2.9	3.1
K1.04	Explain resonance absorption.	2.4	2.4
K1.05	Explain doppler broadening and self-shielding.	2.3	2.4
K1.06	Describe time effects of core age, moderator temperature, and boron concentration on moderator temperature coefficients.	3.1	3.1
K1.07	Describe the effects of core age, fuel temperature, and moderator temperature on fuel temperature (doppler) coefficient.	2.9	2.9
K1.08	Describe the components of power coefficient.	3.1	3.1
K1.09	Compare boron reactivity worth vs. boron concentration.	2.8	2.9
K1.10	Compare boron reactivity worth vs. moderator temperature.	2.9	2.9
K1.11	Explain the change in reactivity addition rate due to boration/dilution over core life.	2.9	3.1
K1.12	Explain differences between reactivity coefficients and reactivity defects.	2.7	2.7
K1.13	Explain and describe the effect of power defect and doppler defect on reactivity.	2.9	2.9

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Name the material used for thermal neutron absorption in control rods.	1.8	1.9
K1.02	Describe nuclear properties of active neutron absorber material in the control rod.	1.9	2.0
K1.03	Predict direction of change in reactor power for a change in control rod position.	3.5	3.6
K1.04	Define reactor scram/trip.	3.2	3.2
K1.05	Define control rod worth, differential control rod worth, and integral control rod worth.	2.8	3.1
K1.06	Explain the shape of curves for differential and integral new versus rod position.	2.6	2.9
K1.07	Explain direction of change in magnitude of CRW for a change in moderator temperature, boron concentration, and fission product poisons.	2.5	2.8
K1.08	State the purpose of flux shaping.	2.7	2.9
K1.09	State the purpose of rod sequencing and overlap.	2.8	3.0
K1.10	Describe axial flux imbalance, including long-range effects.	3.0	3.3
K1.11	Describe the effects of quadrant power tilt (symmetric offset), including long-range effects.	2.8	3.2
K1.12	Describe power peaking or hot-channel factors.	2.9	3.1
K1.13	Define and calculate quadrant tilt (symmetric offset) ratio.	2.9	3.3
K1.14	Explain the effects of full and/or part length rods on Delta I (flux distribution).	3.2	3.6
K1.15	Discuss rod insertion limits.	3.4	3.9
K1.16	Describe the effects of control rods on power peaking or hot-channel factors.	2.8	3.1

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Define fission product poison.	2.5	2.6
K1.02	State the characteristics of Xenon-135 as a fission product poison.	3.0	1.1
K1.03	Describe the production of Xenon-135.	2.7	2.8
K1.04	Describe the removal of Xenon-135.	2.8	2.8
	Describe the following processes and state their effect on reactor operations		
K1.05	--Equilibrium Xenon	3.1	3.1
K1.06	--Transient Xenon	3.2	3.4
K1.07	--Xenon following a scram	3.4	3.4
K1.08	Describe the effects that Xenon concentration has on flux shape and control rod patterns.	3.3	3.4
	Plot the curve and explain the reasoning for the reactivity insertion by Xenon-124 versus time for the following:		
K1.09	--Initial reactor startup and ascension to rated power.	3.0	3.1
K1.10	--Reactor startup with Xenon-135 already present in the core.	3.1	3.2
K1.11	--Power changes from steady-state power to another.	3.1	3.1
K1.12	--Reactor scram.	3.1	3.1
K1.13	--Reactor shutdown.	2.9	3.0
K1.14	Explain the methods and reasons for the operator to compensate for the time dependent behavior of Xenon 135 concentration in the reactor.	3.2	3.3
K1.15	State the characteristics of Samarium-149 as a fission product poison.	1.9	1.9
K1.16	Describe the production of Samarium-149.	1.8	1.8
K1.17	Describe the removal of Samarium-14.	1.8	1.8
K1.18	Define equilibrium samarium.	1.8	1.8
	Plot the curve and explain the reasoning for reactivity insertion by Samarium-149 versus time for the following		
K1.19	--Initial reactor startup and ascension to rated power.	1.8	1.9
K1.20	--Reactor shutdown.	1.7	1.8
K1.21	Describe the effects of power changes on samarium concentration.	1.7	1.8

K1.22	Compare effects of Samarium-149 on reactor operation with those of Xenon-135.	1.8	1.8

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Define burnable poison and state its use in the reactor.	2.1	2.5
K1.02	Describe and explain distribution of burnable poisons in the core.	2.0*	2.2
K1.03	Given a curve of K-effective versus core age, state the reasons for maximum, minimum, and inflection points.	1.7*	2.1
K1.04	Describe how and why boron concentration changes over core life.	3.1	3.4
K1.05	Describe the effects of boration/dilution on reactivity during forced-flow and natural circulation conditions.	3.0	3.2

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	List parameters which should be monitored and controlled during the approach to criticality.	3.4	3.5
K1.02	List reactivity control mechanisms which exist for plant conditions during the approach to criticality.	2.8	3.1
K1.03	Describe count rate and instrument response which should be observed for rod withdrawal during the approach to criticality.	3.9	4.0
K1.04	Relate the concept of subcritical multiplication to predicted count rate response for control rod withdrawal during the approach to critical.	3.8	3.8
K1.05	Explain characteristics to be observed when the reactor is very close to criticality.	3.8	3.9
K1.06	Calculate ECP using a 1/M plot.	2.9	3.1
K1.07	Calculate ECP using procedures and given plant procedures.	3.5	3.6
K1.08	List parameters which should be monitored and controlled upon reaching criticality.	3.5	3.7
K1.09	Define criticality as related to a reactor startup.	3.2	3.3
K1.10	Describe reactor power response once criticality is reached.	3.3	3.4
K1.11	Describe how to determine if a reactor is critical.	3.8	3.8
K1.12	List parameters which should be monitored and controlled during the intermediate phase of startup (from criticality to POAH).	3.5	3.6
K1.13	Discuss the concept of the point of adding heat (POAH) and its impact on reactor power.	3.4	3.6
K1.14	Describe reactor power response prior to reaching the POAH.	3.1	3.1
K1.15	Explain characteristics to look for when the POAH is reached.	3.4	3.4
K1.16	Describe monitoring and control of reactor power and primary temperature during 0% to 15% (B & W).	3.2	3.3
K1.17	Describe reactor power response after reaching the point of adding heat.	3.3	3.4
K1.18	Describe the monitoring and control of T-ave, T-ref, and power during power operation.	3.6	3.5
K1.19	Describe means by which reactor power will be increased to rated power.	3.5	3.6
K1.20	Explain the effects of control rod motion or boration/dilution on reactor power.	3.8	3.9
K1.21	Explain the relationship between steam flow and reactor power given specific conditions.	3.6	3.8
K1.22	Explain how boron concentration affects core life.	2.6	3.8

K1.23	Explain the shape of a curve of reactor power versus time after a scram.	2.9	3.1
K1.24	Explain reactor power response to a control rod insertion.	3.5	3.6
K1.25	Explain the necessity for inserting control rods in a predetermined sequence during normal shutdown.	2.9	3.1
K1.26	Define decay heat.	3.1	3.2
K1.27	Explain the relationship between decay heat generation and: a) power level history, b) power production, and c) time since reactor shutdown.	3.1	3.4

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Convert between absolute and gauge pressure and vacuum scales.	2.5	2.7
K1.02	Recognize the difference between absolute and relative (Kelvin) temperature scales.	1.9	2.0
K1.03	Describe how pressure and level sensing instruments work.	2.6	2.6
K1.04	Explain relationships between work, power, and energy.	2.2	2.3
K1.05	Explain the law of conservation of energy.	2.1	2.1

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Define energy and work.	1.9	2.0
K1.02	Describe effects of pressure and temperature on density or specific volume of a liquid.	2.4	2.5
K1.03	Describe the effects of pressure and temperature on density or specific volume of a gas.	2.3	2.4
	Define the following terms:		
K1.04	--Latent heat of vaporization	2.3	2.3
K1.05	--Vaporization line	1.9	1.9
K1.06	--Critical point	1.9	1.9
K1.07	--Vapor dome	1.8	1.8
K1.08	--Saturated liquid	2.8	2.8
K1.09	--Wet vapor	2.1	2.1
K1.10	--Saturated vapor	2.3	2.3
K1.11	--Vapor pressure	1.7	1.8
K1.12	--Moisture content	2.8	2.3
K1.13	--Quality	2.3	2.3
K1.14	--Superheated vapor	2.4	2.5
K1.15	--Supersaturated vapor	1.8	1.9
K1.16	--Subcooled and compressed liquids	2.6	2.7
K1.17	--Subcooling	3.0	3.2
K1.18	--Specific heat	2.3	2.3
K1.19	- -Enthalpy	2.3	2.4
	Identify the following terms on a T-s diagram:		
K1.20	--Critical point	1.9	2.0
K1.21	--Saturated liquid line	2.1	2.1
K1.22	--Saturated vapor line	2.0	2.1
K1.23	--Solid, liquid, gas, vapor, and fluid regions	1.9	1.9
K1.24	Explain the usefulness of steam tables to the Control Room operator.	2.8	3.1
K1.25	Explain and use saturated and superheated steam tables.	3.3	3.4
K1.26	Apply specific heat in solving heat transfer problems.	1.9	2.0

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Explain the relationship between real and ideal processes.	1.8	1.9
K1.02	Explain the shape of the T-s diagram process line for a typical secondary system.	1.7	1.9
	Nozzles:		
K1.03	Describe the functions of nozzles in flow restrictors.	1.9	1.9
K1.04	Describe the functions of nozzles in air ejectors.	2.0	2.0
	Turbines:		
K1.05	Explain the function of nozzles fixed blading and moving blading in the turbine.	1.6	1.7
K1.06	Explain the reason turbines are multistages.	1.5	1.7
K1.07	Define turbine efficiency.	1.6	1.6
K1.08	Explain the difference between real and ideal turbine efficiency.	1.6	1.7
	Pumps:		
K1.09	Define pump efficiency.	1.3	1.3
K1.10	Explain the difference between ideal and real pumping processes.	1.3	1.3
	Condensers:		
K1.11	Describe the process of condensate depression and its effect on plant operation.	2.4	2.5
K1.12	Explain vacuum formation in condenser processes.	2.2	2.3
K1.13	Explain the condensing process.	2.2	2.3
	Throttling and the Throttling Process:		
K1.14	Explain the reduction of process pressure from throttling.	2.1	2.3
K1.15	Determine the exit conditions for a throttling process based on the use of steam and/or water.	2.8	2.8

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Define thermodynamic cycle.	1.6	1.7
K1.02	Define thermodynamic cycle efficiency in terms of net work produced and energy applied.	1.6	1.8
K1.03	Describe how changes in secondary system parameter affect thermodynamic efficiency.	2.5	2.6
K1.04	Describe the moisture effects on turbine integrity and efficiency.	2.1	2.3
K1.05	State the advantages of moisture separators/repeaters and feedwater heaters for a typical steam cycle.	1.9	1.9

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Distinguish between static pressure, dynamic pressure, and total pressure.	2.2	2.3
K1.02	Define head loss.	2.3	1.4
K1.03	Discuss operational considerations of viscosity as related to head loss.	1.7	1.8
K1.04	Explain operational implications of water hammer.	3.4	3.6
	Define or explain the following terms and concepts:		
K1.05	--Mass flow rate	2.9	3.0
K1.06	--Two-phase flow	2.8	2.9
K1.07	--Pressure spike	2.7	2.7
K1.08	--Gas binding	2.8	1.8
K1.09	--Recirculation ratio	1.9	1.9
K1.10	--Water hammer	3.3	3.4
K1.11	--Cavitation	3.1	3.3
K1.12	Explain why flow measurements must be corrected for density changes.	2.5	2.6
K1.13	Explain the relationship between pressure head and velocity head in a fluid system.	2.2	2.3
K1.14	Discuss the velocity profiles for laminar flow and turbulent flow.	1.8	1.9
K1.15	Describe the methods of controlling system flow rates.	3.1	3.3

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
	Heat Transfer		
K1.01	Describe three mechanisms of heat transfer.	2.5	2.5
K1.02	Define thermal conductivity.	2.0	2.2
K1.03	Explain the manner in which fluid films affect heat transfer.	2.2	2.4
K1.04	Describe how the presence of gases or steam can affect heat transfer and fluid flow in heat exchangers.	2.8	3.0
	Core Thermal Power		
K1.05	Define core thermal power.	2.7	2.9
K1.06	Explain methods of calculating core thermal power.	3.1	3.3
K1.07	Define percent reactor power.	2.7	2.8
K1.08	Calculate core thermal power using a simplified heat balance.	3.1	3.4

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
	Departure from Nucleate Boiling		
K1.01	Distinguish between boiling processes and other heat transfer mechanisms.	2.8	3.0
K1.02	Describe means by which boiling affects convection heat transfer.	2.8	3.0
K1.03	Describe the processes of nucleate boiling, subcooled nucleate boiling, and bulk boiling.	2.8	3.1
K1.04	Describe DNB (departure from nucleate boiling).	3.1	3.3
K1.05	List the parameters that affect DNR and DNBR and describe their effect(s).	3.4	3.6
K1.06	Describe CHF (critical heat flux).	2.8	2.9
K1.07	Describe transition (partial film) boiling.	2.6	2.6
K1.08	Describe film boiling.	2.6	2.6
K1.09	Describe burnout and burnout heat flux.	2.3	2.4
K1.10	Define DNBR.	2.9	3.1
	Two Phase Flow		
K1.11	Classify slug flow region along a fuel pin, experiencing two phase flow.	1.9	2.1
K1.12	Describe annular flow region along a hypothetical fuel pin, experiencing two phase flow.	1.8	1.9
K1.13	Describe dryout region or mist flow region along a hypothetical fuel pin, experiencing two phase flow.	1.9	2.1
K1.14	Describe effects of flowrate and phase change on the heat transfer coefficient.	2.6	2.7
K1.15	Define and describe subcooling margin (SCM).	3.6	3.8
K1.16	Draw the temperature profile from the centerline of a fuel pellet to the centerline of the flow channel.	2.4	2.6
K1.17	Explain the necessity of determining core coolant flow.	2.9	3.2
K1.18	Describe the factors affecting single- and two-phase flow resistance.	2.3	2.5
K1.19	Describe core bypass flow.	2.5	2.8
K1.20	Explain the need for adequate core bypass flow.	2.9	2.9

	Natural Circulation		
K1.21	Explain the conditions which Must exist to establish natural circulation.	3.9	4.2
K1.22	Describe means to determine if natural circulation flow exists.	4.2	4.2
K1.23	Describe means by which natural circulation can be enhanced.	3.9	4.1
K1.24	Describe the process of reflux boiling (boiler condenser process).	2.7	3.1
K1.25	Describe how gas binding affects natural circulation.	3.3	3.4
	Sketch the axial temperature and enthalpy profiles for a typical-reactor coolant channel and describe how they are affected by the following:		
K1.26	--Onset of nucleate boiling	2.2	2.4
K1.27	--Axial core flux	2.2	2.4
K1.28	--Inlet temperature	2.2	2.4
K1.29	--Heat generation rate	2.2	2.4
K1.30	--Flow rate in the channel	2.3	2.4

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	Explain radial peaking factor (RPF)	2.3	2.8
K1.02	Explain axial peaking factor (APF)	2.3	2.8
K1.03	Explain local peaking factor (LPF)	2.2	2.7
K1.04	Explain total peaking factor (TPF)	2.3	2.7
K1.05	State the reason thermal limits are necessary.	3.1	3.5
K1.06	Describe the function of the core protection calculator (thermal margin calculator).	2.8	3.7
K1.07	Describe factors that affect peaking and hot channel factors.	2.9	3.3

K/A NO.	KNOWLEDGE	IMPORTANCE RO	IMPORTANCE SRO
K1.01	State the brittle fracture made of failure.	2.8	3.2
K1.02	State the definition of Nil-Ductility Transition Temperature.	2.4	2.5
K1.03	Define reference temperature.	2.0	2.4
K1.04	State how the possibility of brittle fracture is minimized by operating limitations.	3.3	3.7
K1.05	State the effect of fast neutron irradiation on reactor vessel metals.	2.9	3.0
K1.06	Define pressurized thermal shock (PTS)	3.6	3.8
K1.07	State the operational concerns of uncontrolled cooldown.	3.8	4.1

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11. ABSTRACT *(200 words or less)*

This document provides the basis for development of content-valid licensing examinations for reactor operators and senior reactor operators. The examinations developed using this document will cover those topics listed under 10 CFR 55, "Operators' Licenses." The PWR catalog contains approximately 7,000 knowledge and ability (K/A) statements for reactor operators and senior reactor operators. Each K/A statement has been rated for its importance to safety.

Supplement 1 to Revision 2 of NUREG-1122 reworded and reorganized Section 2, "Generic Knowledge and Abilities," added a new K/A topic to Section 4, “Emergency/Abnormal Plant Evolutions,” to address generator voltage and electric grid disturbances, and corrected other minor typographical errors.

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