TECHNICAL SPECIFICATIONS

ARKANSAS TECH UNIVERSITY

NUCLEAR REACTOR

(TRIGA MARK I)

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1.0 DEFINITIONS

1.1 GENERAL TERMS

1.1.1 Research Reactor

A research reactor is defined as a device designed to support a self-sustaining neutron chain reaction for research, development, training, educational, or experimental purposes, and which may have provisions for the production of radioisotopes.

1.1.2 Confinement

Confinement is the enclosure on the overall facility which controls the movement of air into it and out through a controlled path.

1.1.3 Operable

Operable means a system or component is capable of performing its intended function

1.1.4 Operating

Operating means a system or component is performing its intended function.

1.1.5 Safety Limit

Safety limits are limits on important process variables which are found to be necessary to reasonably protect the integrity of certain of the physical barriers which guard against the uncontrolled release of radioactivity. The principal barrier is the fuel element cladding.

1.1.6 Reactivity Limit

The reactivity limits are those limits imposed on the reactor core excess reactivity. Quantities are referenced to a Reference Core Condition. The reactivity worth of samarium in the core need not be included in excess reactivity limits.

1.1.7 Reference Core Condition

The condition of the core when it is at ambient temperature (cold) and the reactivity worth of xenon is negligible (< 0.30 dollars). The reference core condition will be known as the cold xenon free condition.

1.1.8 Excess Reactivity

Excess reactivity is that amount of reactivity that would exist if all the control rods (control, regulating, etc.) were moved to the maximum reactive condition from the point where the reactor is exactly critical ($k_{eff} = 1$).

1.1.9 Shutdown Margin

Shutdown margin is the minimum reactivity necessary to provide confidence that the reactor can be made subcritical by means of the control and safety systems starting from any permissible operating condition although the most reactive rod is in its most reactive position, and that the reactor will remain subcritical without further operator action.

1.1.10 Reactor Safety System

Reactor safety systems are those systems, including their associated input channels, which are designed to initiate automatic reactor protection or to provide information for initiation of manual protective action.

1.1.11 Protective Action

Protective action is the initiation of a signal or the operation of equipment within the reactor safety system in response to a variable or condition of the reactor facility having reached a specified limit.

a. **Channel level.** At the protective instrument channel level, protective action is the generation and transmission of a trip signal indicating that a reactor variable has reached the specified limit.

b. **Subsystem level.** At the protective instrument subsystem level, protective action is the generation and transmission of a trip signal indicating that a specified limit has been reached

c. **Instrument system level.** At the protective instrument system level, protective action is the generation and transmission of the command signal for the safety shutdown equipment to operate.

d. **Safety system channel.** At the reactor safety system level, protective action is the operation of sufficient equipment to immediately shut down the reactor.

1.1.12 Limiting Safety System Setting (LSSS)

Limiting safety system settings for nuclear reactors are settings for automatic protective devices related to those variables having significant safety functions. Where a limiting safety system setting is specified for a variable on which a safety limit has been placed, the setting shall be so chosen that automatic protective action will correct the abnormal situation before a safety limit is exceeded

1.1.13 Limiting Conditions for Operation (LCO)

Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the facility.

1.1.14 Scram Time

Scram time is the elapsed time between reaching a limiting safety system set point and a specified control rod movement

1.1.15 Shall, Should and May

The word "shall" is used to denote a requirement; the word "should" to denote a recommendation; and the word "may" to denote permission, neither a requirement nor a recommendation.

1.1.16 Delayed Neutron Fraction (β)

When converting between absolute and dollar value of reactivity units, a β of 0.007 is used. $\left[\$1.0 \equiv 0.7\ \%k \equiv 0.7\% \frac{\delta k}{k}\right]$.

1.2 REACTOR COMPONENTS

1.2.1 Control Rod

A control rod is a device fabricated from neutron absorbing material or fuel which is used to establish neutron flux changes and to compensate for routine reactivity loses. A control rod may be coupled to its drive unit allowing it to perform a safety function when the coupling is disengaged.

1.2.2 Safety Rod

A safety rod is a control rod having an electric motor drive and scram capabilities.

1.2.3 Shim Rod

A shim rod is a control rod having an electric motor drive and scram capabilities.

1.2.4 Regulating Rod

A regulating rod is a low-worth rod used primarily to maintain an intended power level and may be varied manually or by a servo-controller. The regulating rod may have scram capability.

1.2.5 Transient Rod

A transient rod is a control rod that is pneumatically driven and is capable of providing rapid reactivity insertion to produce a power pulse. The transient rod shall have scram capability.

1.2.6 Standard Control Rod

The safety, shim and regulating rods are standard control rods.

1.2.7 Standard Fuel Element

A fuel element is a single TRIGA fuel rod of standard type. Fuel is U-ZrH clad in stainless steel clad.

1.2.8 Instrumented Element

An instrumented element is a special fuel element fabricated for temperature measurement. The element shall have at least one thermocouple embedded in the fuel near the horizontal center plane.

1.2.9 Standard Core

A standard core is an arrangement of standard TRIGA fuel in the reactor grid plate and may include installed experiments.

1.2.10 Operational Core

An operational core is a standard core for which the core parameters of excess reactivity, shutdown margin, fuel temperature, power calibration, and reactivity worths of control rods and experiments have been determined to satisfy the requirements set forth in the Technical Specifications.

1.3 OPERATING CONDITIONS

1.3.1 Reactor Secured

The reactor is secured when:

1. It contains insufficient fissile material or moderator present in the reactor, control rods, or adjacent experiments, to attain critically under optimum available conditions of moderation and reflection, or
2. A combination of the following:
   a. The minimum number of neutron absorbing control rods are fully inserted or other safety devices are in shutdown position, as required by technical specifications, and
   b. The console key switch is in the off position and the key is removed from the lock, and
   c. No work is in progress involving core fuel, core structure, installed control rods, or control rod drives unless they are physically decoupled from the control rods, and
   d. No experiments in or near the reactor are being moved or serviced that have, on movement, a reactivity worth exceeding the maximum allowed for a single experiment or one dollar whichever is smaller.

1.3.2 Reactor Shutdown

The reactor is shut down if it is subcritical by at least one dollar in the Reference Core Condition and the reactivity worth of all experiments is accounted for.

1.3.3 Unscheduled Shutdown

An unscheduled shutdown is defined as any unplanned shutdown of the reactor caused by actuation of the reactor safety system, operator error, equipment malfunction, or a manual shutdown in response to conditions which could adversely affect safe operation, not including shutdowns which occur during testing or check-out operations.

1.3.4 Reactor Operating

The reactor is operating whenever it is not secured or shutdown.

1.3.5 Steady State Mode

Steady state mode operation shall mean operation of the reactor with the mode selector switch in the steady-state position.

1.3.6 Pulse Mode

Pulse mode operation shall mean any operation of the reactor with the mode selector switch in the pulse position.

1.4 REACTOR INSTRUMENTATION

1.4.1 Channel

A channel is the combination of sensor, line, amplifier, and output devices which are connected for the purpose of measuring the value of a parameter.

1.4.2 Channel Test

A channel test is the introduction of a signal into the channel for verification that it operates.

1.4.3 Channel Check

A channel check is a qualitative verification of acceptable performance by observation of channel behavior. This verification, where possible, shall include comparison of the channel with other independent channels or systems measuring the same variable.

1.4.4 Channel Calibration

A channel calibration is an adjustment of the channel such that its output corresponds with acceptable accuracy to known values of the parameter which the channel measures. Calibration shall encompass the entire channel, includinge equipment actuation, alarm, or trip and shall be deemed to include a Channel Test.

1.4.5 Measured Value

The measured value is the value of a parameter as it appears on the output of a channel.

1.4.6 True Value

The true value is the actual value of a parameter.

1.5 REACTOR EXPERIMENTS

1.5.1 Experiment

Any operation, equipment, or target (excluding devices such as detectors, foils, etc.), which is designed to investigate non-routine reactor characteristics or which is intended for irradiation within the pool, on or in a beamport or irradiation facility and which is not rigidly secured to a core or shield structure so as to be part of their design.

1.5.2 Movable Experiment

A movable experiment is one where it is intended that the entire experiment may be moved in or near the core, or into and out of the reactor while the reactor is operating.

1.5.3 Secured Experiment

A secured experiment is any experiment, experiment facility, or component of an experiment that is held in a stationary position relative to the reactor by mechanical means. The restraining force must be substantially greater than those to which the experiment might be subjected by hydraulic, pneumatic, buoyant, or other forces which are normal to the operating environment of the experiment, or by forces which can arise as a result of credible malfunctions.

1.5.4 Experimental Facilities

Experimental facilities shall mean rotary specimen rack, pneumatic transfer tube, central thimble, beam tubes, and irradiation facilities in the core or in the pool.

1.5.5 Reactivity Worth of an Experiment

The reactivity worth of an experiment is the maximum absolute value of the reactivity change that would occur as a result of intended or anticipated changes or credible malfunctions that alter experiment position or configuration.

1.6 REACTOR OPERATORS

1.6.1 Certified Operators

An individual authorized by the chartering or licensing organization to carry out the duties and responsibilities associated with the position requiring the certification.

1.6.2 Class A Reactor Operator

An individual who is certified to direct the activities of Class B reactor operators. Such an individual is also a reactor operator and is commonly referred to as a Senior Reactor Operator (SRO).

1.6.3 Class B Reactor Operator

An individual who is certified to manipulate the controls of a reactor. Such an individual is commonly referred to as a Reactor Operator (RO).

1.7 SURVEILLANCE INTERVALS

1.7.1 Surveillance Intervals

Maximum intervals are to provide operational flexibility and not to reduce frequency. Established frequencies shall be maintained over the long term. Allowable surveillance intervals shall not exceed the following:

a. 5 years (interval not to exceed 6 years).

b. 2 years (interval not to exceed 2-1/2 years).

c. Annual (interval not to exceed 15 months).

d. Semiannual (interval not to exceed 7-1/2 months).

e. Quarterly (interval not to exceed 4 months).

f. Monthly (interval not to exceed 6 weeks).

g. Weekly (interval not to exceed 10 days).

h. Daily (must be done during the calendar day).

1.7.2 Surveillance Activities

Surveillance activities, (except those specifically required for safety when the reactor is shut down) may be deferred during reactor shutdown, however they must be completed prior to reactor startup. Surveillance activities scheduled to occur during an operating cycle which cannot be performed with the reactor operating may be deferred to the end of the cycle.

In general, two types of surveillance activities are specified, operability checks and calibrations. Operability checks are generally specified as monthly to quarterly. Calibrations are generally specified as annually to biennially.

2.0 SAFETY LIMITS AND LIMITING SYSTEM SETTINGS

2.1 FUEL ELEMENT TEMPERATURE SAFETY LIMIT

Applicability

This specification applies to the temperature of the reactor fuel in a standard TRIGA fuel element.

Objective

The objective is to define the maximum temperature that can be permitted with confidence that no damage to the fuel element cladding will result.

Specification(s)

The maximum temperature in a standard TRIGA fuel element shall not exceed 1000 C under any conditions of operation.

Basis

The important parameter for a TRIGA reactor is the fuel element temperature. This parameter is well suited as a single specification since it can be measured directly. A loss in the integrity of the fuel element cladding could arise from a build-up of excessive pressure between the fuel-moderator and the cladding if the fuel temperature exceeds the safety limit. The pressure is caused by the presence of air, fission product gases, and hydrogen from the dissociation of the hydrogen and zirconium in the fuel-moderator. Hydrogen pressure is the most significant component. The magnitude of this pressure is determined by the fuel-moderator temperature and the ratio of hydrogen to zirconium in the alloy.

The safety limit for the standard TRIGA fuel is based on calculations and experimental evidence. The results indicate that the stress in the cladding due to hydrogen pressure from the dissociation of zirconium hydride will remain below the ultimate stress provided that the temperature of the fuel does not exceed 1000 C and the fuel cladding is water cooled.

2.2 LIMITING SAFETY SYSTEM SETTINGS

2.2.1 Fuel Temperature

Applicability

This specification applies to the protective action for the reactor fuel element temperature.

Objective

The objective is to prevent the fuel element temperature safety limit from being reached.

Specification(s)

The limiting safety system setting shall be 500 C as measured in an instrumented fuel element. The instrumented element shall be located in the B or C ring of the reactor core configuration.

Basis

The limiting safety system setting is a temperature which, if exceeded, shall cause a reactor scram to be initiated preventing the safety limit from being exceeded. A setting of 500 C provides a safety margin at the point of measurement of at least 500 C for standard TRIGA fuel elements in any condition of operation. A part of the safety margin is used to account for the difference between the true and measured temperatures resulting from the actual location of the thermocouple. If the thermocouple element is located in the hottest position in the core, the difference between the true and measured temperatures will be only a few degrees since the thermocouple junction is near the center and the mid-plane of the fuel element close to the anticipated hot spot. If the thermocouple element is located in a region of lower temperature, such as the periphery of the core, the measured temperature will differ by a greater amount from that actually occuring at the core hot spot. Calculations indicate that the actual temperature at the hottest location will not be greater than 900 C in such a case. This provides a 100 C margin to the safety limit which is more than sufficient to account for any uncertainties.

In the pulse mode of operation, the same limiting safety system setting will apply. However, the temperature channel will have no effect on limiting the peak powers generated because of its relatively long time constant (seconds) as compared with the width of the pulse (milliseconds). In this mode, however, the temperature trip will act to limit the energy release after the pulse if the transient rod should not reinsert and the fuel temperature continues to increase.

2.2.2 Operating Power Level

Applicability

This specification applies to the protective action for power generated in the reactor during continuous operation.

Objective

The objective is to prevent the fuel element temperature safety limit from being reached.

Specification(s)

The normal steady state operating power level of the reactor shall be 250 kW. The reactor may be operated at power levels not to exceed 275 kW during short periods for test or calibration.

Basis

Thermal and hydraulic calculations indicate that standard TRIGA fuel elements may be safely operated at power levels in excess of 1500 kW with natural convection cooling.

3.0 LIMITING CONDITIONS FOR OPERATION

3.1 REACTOR CORE PARAMETERS

3.1.1 Shutdown Margin

Applicability

This specification applies to the reactivity margin by which the reactor core will be considered shutdown when the reactor is not operating.

Objective

The objective is to assure that the reactor can be shut down safely by a margin that is sufficient to compensate for the failure of a control rod or the movement of an experiment.

Specification(s)

The reactor shall not be operated unless the shutdown margin provided by control rods is greater than 0.4 %k with:

a. The reactor in the cold xenon free condition,
b. The most reactive control rod fully withdrawn,
c. The highest worth non-secured experiment in its most reactive state.

Basis

The value of the shutdown margin assures that the reactor can be shut down from any operating condition even if the highest worth control rod should remain in the fully withdrawn position and an unsecured experiment is in a high reactivity state.

3.1.2 Excess Reactivity

Applicability

This specification applies to the reactivity condition of the reactor core in terms of the available excess above the cold xenon free, critical condition.

Objective

The objective is to prevent the fuel element temperature safety limit from being reached by limiting the potential reactivity available in the reactor for any condition of operation

Specification(s)

Maximum excess reactivity shall be 2.25 %k [2.25% δk/k].

Basis

Maximum excess core reactivity is sufficient to provide the core rated power, xenon compensation and reactivity for shutdown. Analysis of the reactor core demonstrates that no single component represents sufficient potential reactivity to reach the fuel element temperature safety limit during any condition of operation.

3.1.3 Transient Insertions

Applicability

This specification applies to the total potential worth of the transient rod and the allowable reactivity insertion for reactor pulse operation.

Objective

The objective is to limit the reactivity available for pulse insertion to a value that will not cause the fuel temperature safety limit to be exceeded.

Specification(s)

Total worth of transient rod shall be limited to 2.25 %k, and

a. The reactivity to be inserted for pulse operation shall be initiated from power levels less than 1 kW.

b. The pulse reactivity insertion shall not exceed 1.4 %k, and shall be limited by a mechanical block on the pulse rod.

Basis

Experiments with pulsed operation of TRIGA reactors indicate that insertion up to 3.5 %k have not exceeded the fuel temperature safety limit. Calculations demonstrate that the total insertion of all the transient rod worth will not exceed the fuel temperature safety limit. Thus for a 1.4 %k pulse a substantial safety margin exists between the fuel element safety limit and the rise of peak fuel temperature above the ambient temperature of 50 C.

3.2 CONTROL AND SAFETY SYSTEM

3.2.1 Operable Control Rods

Applicability

This specification applies to the function of the control rods.

Objective

The objective is to determine the operability of the control rods by specification of the scram times for scrammable control rods and reactivity insertion rates for standard control rods.

Specification(s)

The reactor shall not be operated unless the control rods are operable, and

a. The scram time measured from the instant a simulated signal reaches the value of a limiting safety system setting to the instant that the slowest scrammable control rod reaches its fully inserted position shall not exceed 2 seconds.

b. Maximum reactivity insertion rate of a standard control rod shall be less than 0.2 %k/s.

Basis

The specification for rod scram time assures that the reactor will shut down promptly when a scram signal is initiated. The specification for rod reactivity insertion rates assures that the reactor will start up controllably when rods are withdrawn. Analysis has indicated that for the range of transients anticipated for a TRIGA reactor the specified scram time and insertion rate is adequate to assure the safety of the reactor.

3.2.2 Reactor Control System

Applicability

These specifications apply to logic of the reactor control system.

Objective

The objective is to determine the minimum control system interlocks operable for operation of the reactor.

Specification(s)

The reactor shall not be operable unless the minimum safety interlocks are operable. The following control system safety interlocks shall be operable:

	Interlocks on Control Rod Drive	Number Operable	Function	Effective Mode Steady-State	Pulse
1.	All Control Rods Startup Withdrawal	1	prevent for less than 2 counts per sec	X	
2.	All Control Rods Simultaneous Withdrawal	1	prevent for two or more rods	X	
4.	Safety-Transient Rod Withdrawal	1	prevent unless safety-transient cylinder is down	X	
5.	Safety-Transient Rod Withdrawal	1	prevent for power > 1 kW		X
6.	All rods except Safety-Transient Rod Withdrawal	1	prevent during pulsing		X
7.	Safety-Transient Rod	1	reinsert rod within 15 seconds		X

Basis

Interlocks are specified to prevent operation of the control rod drives unless certain specific conditions exist. The interlock to prevent startup of the reactor at power levels less than 2 neutron cps, which corresponds to approximately 4×10^{-3} Watts, assures that sufficient neutrons are available for controlled reactor startup. Simultaneous withdrawal of more than one control rod is prevented by an interlock to limit the maximum positive reactivity insertion rate available for steady state operation. Several interlocks applied to the transient rod determine the proper rod operation during pulse operation and protect against inadvertent pulse operation. The interlock to prevent withdrawal of the motor driven rods in the pulse mode is designed to prevent changing the critical state of the reactor prior to the pulse. A preset timer insures that the transient rod will not remain in the pulse position for an extended time after the pulse.

3.2.3 Reactor Safety System

Applicability

These specifications apply to operation of the reactor safety system.

Objective

The objective is to determine the minimum safety system scrams operable for the operation of the reactor.

Specification(s)

The reactor shall not be operable unless the minimun safety channels are operable. The following control rod scram safety channels shall be operable:

Safety Channel	Number Operable	Function	Effective Mode Steady-State	Effective Mode Pulse
1. Manual Scram Bar	1	Scram on operator demand	X	X
2. Fuel Temperature	2	Scram at 500 C	X	X
3. Percent Power Level	2	Scram at 110% of full power	X	
4. Percent Power Level (Peak Pulse Power)	1	Scram at 110% of full power		X
5. High Voltage	1	Scram on loss of	X	X
6. Magnet Current	1	Scram on loss of	X	X

Basis

Manual operation of the reactor safety system is considered part of the protective action of the reactor safety system. Signals for control rod insertion and reactor shutdown provide scrams on excessive fuel temperature and power level that is short of the fuel element temperature safety limit. Operation without adequate control and safety system power supplies is prevented by scrams on neutron detector high voltage and control rod magnet current.

3.2.4 Reactor Instrument System

Applicability

These specifications apply to measurements of reactor operating parameters.

Objective

The objective is to determine the minimum instrument system channels to be operable for continued operation of the reactor.

Specification(s)

A minimum configuration of measuring channels shall be operable. The following minimum reactor parameter measuring channels shall be operable:

Measuring Channel	Number Operable	Effective Mode Steady-State	Effective Mode Pulse
1. Fuel Temperature	2	X	X
2. Percent Power Level	2	X	
3. Percent Power Level (Peak Pulse Power)	1		X

Basis

The minimum measuring channels are sufficient to provide signals for automatic safety system operation. Signals from the measuring system provide information to the control and safety system for a protective action. Measurements of the same or different parameters provide redundancy.

3.3 OPERATIONAL SUPPORT SYSTEMS

3.3.1 Reactor Coolant Conditions

Applicability

This specification applies to the operating conditions for the reactor pool and coolant water systems.

Objective

The objective is to assure that adequate conditions are maintained to provide shielding of the reactor radiation, protection against corrosion of the reactor components, cooling of the reactor fuel, and prevent leakage of the primary coolant.

Specification(s)

Corrective action shall be taken or the reactor shall be shutdown if the following reactor coolant water conditions are observed:

a. The water conductivity, averaged for periods of one month, is greater than 5.0 μmho/cm, or
b. The bulk pool water temperature exceeds 50 C, or
c. The water depth, measured from the top grid plate to the pool water surface, is less than 5.0 meters, or
d. The water level is not within 0.5 ft of normal operating level during operation,
e. The pressure difference during heat exchanger operation, measured between the chilled water outlet pressure and the pool water inlet pressure to the heat exchanger, is less than 7kPa (1 psi).

Basis

The specifications for conditions of the pool water coolant system provide controls that are to control radiation exposures and radioactive releases associated with the reactor fission product inventory.

a. Average measurements of pool coolant water conductivity 5.0 μmho/cm provide sufficient information to control the effects of corrosion and activation of coolant water impurities.

b. The bulk water temperature constraint assures that sufficient core cooling exists under all anticipated operating conditions and protects the water purification system resin from deterioration.

c. Calculations and experience at TRIGA facilities have shown that 5.0 meters of water above the reactor core is sufficient to provide reasonable radiation levels above the reactor pool.

d. The pool water level is an indirect indication of leak into or out of the primary during operation.

e. A pressure difference at the heat exchanger chilled water outlet and pool water inlet of 7 kPa should be sufficient to prevent loss of pool water to the secondary chilled water system from the primary reactor coolant system in the event of a leak in the heat exchanger.

3.3.2 Air Ventilation Conditions

Applicability

This specification applies to the air ventilation conditions in the reactor area during reactor operation.

Objective

The objective is to control the air flow from experimental facilities and the reactor room by isolation or controlled release of the ventilation exhaust.

Specification(s)

The reactor shall not be operated unless minimum conditions for air confinement are functional. The following minimum conditions shall exist:

a. Equipment shall be operable to isolate the reactor room by closure of access doors and ventilation dampers manually or automatically by a signal from exhaust air monitor.

b. Air from experimental facilities and the reactor room shall be exhausted above the reactor room roof line at a minimum of 10 m from ground level.

c. Total argon-41 released from the facility shall be limited to an annual average of 4.8×10^{-8} μCi/cm^3.

Basis

The specifications for exhaust ventilation and isolation of the reactor room provide control for radioactive releases by both routine and non routine operating conditions. The maximum allowable concentration of argon-41 in air in unrestricted areas as specified in Appendix B, Table II of 10 CFR 20 is $4.8 \times 10^{-8}\ \mu Ci/cm^3$.

3.3.3 Radiation Monitoring Conditions

Applicability

This specification applies to the radiation monitoring conditions in the reactor area during reactor operation.

Objective

The objective is to monitor the radiation and radioactivity conditions in the area of the reactor for indication of a radioactive release.

Specification(s)

The reactor shall not be operated unless minimum conditions for radiation measurement are functional. The following minimum conditions shall exist:

a. A continuous air monitor (particulate) shall be operable with readout and audible alarm.
b. An area radiation monitor (gamma) shall be operable with readout and audible alarm.
c. A portable radiation monitoring device shall be available. The portable monitor may be substituted for the installed monitors during short periods of inoperability.

Basis

The radiation monitors provide information to operating personnel of impending or existing hazards from radiation so that there will be sufficient time to evacuate the facility or take the necessary steps to control the exposure of personnel and release of radioactivity.

3.4 LIMITATIONS ON EXPERIMENTS

3.4.1 Reactivity

Applicability

This specification applies to the reactivity associated with experiments located in the reactor core.

Objective

The objective is to control the amount of reactivity associated with experiments to values that will not endanger the reactor safety limit.

Specification(s)

The reactor shall not be operated unless the following conditions governing experiment reactivity exist:

a. Non-secured experiments shall have reactivity worths less than 0.7 %k (1 dollar).

b. The reactivity worth of any single experiment shall be less than 1.4 %k (2.0 dollars).

c. The total reactivity worth of in-core experiments shall not exceed 2.1 %k (3.0 dollars), including the potential reactivity which might result from malfunction, flooding, voiding, or removal and insertion of the experiments.

Basis

a. The worth of single moveable experiment is limited so that sudden removal of the experiment will not cause prompt criticality. Worth of a single unsecured experiment will not cause a reactivity insertion that would exceed the core temperature safety limit.

b. The maximum worth of a single experiment is limited so that the fuel element temperature safety limit will not be exceeded by removal of the experiments. Since experiments of such worth must be secured in place, removal from the reactor operating at full power would result in a relatively slow power increase such that the reactor protective systems would act to prevent excessive power levels from being attained.

c. The maximum worth of all experiments is limited so that removal of the total worth of all experiments will not exceed the fuel element temperature safety limit.

3.4.2 Irradiations

Applicability

This specification applies to irradiations performed in the installed irradiation facilities contained in the reactor pool. Irradiations are a subclass of experiments that fall within the specifications hereinafter stated in this section.

Objective

The objective is to prevent damage to the reactor, excessive release of radioactive materials, or excessive personnel radiation exposure during the performance of an irradiation.

Specification(s)

A device or material shall not be irradiated in an irradiation facility under the classification of an irradiation unless the following conditions exist:

a. The irradiation meets all the specifications of Section 3.4 for an experiment,
b. The device or material is encapsulated in a suitable container,
c. The reactivity worth of the device or material is 0.175 %k (0.25 dollars) or less, otherwise it shall be classed as an experiment,
d. The expected radiation field produced by the device or sample upon removal from the reactor is not more than 10 rem/hr at one foot after 10 min., otherwise it shall be classed as an experiment,
e. The device or material does not remain in the reactor for a period of over 15 days, otherwise it shall be classed as an experiment.

Basis

This specification is intended to provide assurance that the special class of experiments called irradiations will be performed in a safe manner.

3.4.3 Materials

Applicability

These specifications apply to experiments installed in the reactor and its experimental facilities.

Objective

The objective is to prevent the release of radioactive material in the event of an experiment failure, either by failure of the experiment or subsequent damage to the reactor components.

Specification(s)

The reactor shall not be operated unless the following conditions governing experiment materials exist:

a. Experiments containing materials corrosive to reactor components, compounds highly reactive with water, potentially explosive materials, and liquid fissionable materials shall be doubly encapsulated.

b. If a capsule fails and releases material which could damage the reactor fuel or structure by corrosion or other means, removal and physical inspection shall be performed to determine the consequences and need for corrective action. The results of the inspection and any corrective action taken shall be reviewed by the Director, or his designated alternate, and determined to be satisfactory before operation of the reactor is resumed.

c. Each fueled experiment shall be controlled such that the total inventory of iodine isotopes 131 through 135 in the experiment is no greater than 1.5 millicuries and the maximum strontium inventory is no greater than 5 millicuries.

d. Explosive materials, such as gunpowder, nitroglycerin, trinitrotoluene, or pentaerythritol tetranitrate in quantities greater than 25 milligrams shall not be irradiated in the reactor or experimental facilities. Explosive materials in quantities less than 25 milligrams may be irradiated provided the pressure produced upon detonation of the explosive has been calculated and/or experimentally demonstrated to be less than the design pressure of the container.

e. Experiment materials, except fuel materials, which could off-gas, sublime, volatilize, or produce aerosols under (1) normal operating conditions of the experiment or reactor, (2) credible accident conditions in the reactor, (3) possible accident conditions in the experiment shall be limited in activity such that if 100% of the gaseous activity or radioactive aerosols produced, escape into the reactor room or the atmosphere, the airborne concentration of radioactivity averaged over a year would not exceed the occupational limits for maximum permissible concentration.

f. In calculations pursuant to e. above, the following assumptions shall be used: (1) If the effluent from an experimental facility exhausts through a holdup tank which closes automatically on high radiation level, at least 10% of the gaseous activity or aerosols produced will escape. (2) If the effluent from an experimental facility exhausts through a filter installation designed for greater than 99% efficiency for 0.25 micron particles, at least 10% of these vapors can escape. (3) For materials whose boiling point is above 55 C and where vapors formed by boiling this material can escape only through an undisturbed column of water above the core, at least 10% of these vapors can escape.

Basis

a. Double encapsulation is required to lessen the experimental hazards of some types of materials.

b. Operation of the reactor with the reactor fuel or structure damaged is prohibited to avoid release of fission products.

c. The 1.5-millicurie limitation on iodine 131 through 135 assures that in the event of failure of a fueled experiment leading to total release of the iodine, the exposure dose at the exclusion area boundary will be less than that allowed by 10 CFR Part 20 for an unrestricted area.

d. This especification is intended to prevent damage to reactor components resulting from failure of an experiment involving explosive materials.

e. This specification is intended to reduce the likelihood that airborne activities in excess of the maximum allowable limits will be released to the atmosphere outside the facility boundary.

f. This especification provides guidance for the calculation of conditions in part (e).

4.0 SURVEILLANCE REQUIREMENTS

4.1 REACTOR CORE PARAMETERS

4.1.1 Shutdown Margin

Applicability

This specification applies to the measurement of reactor shutdown margin.

Objective

The objective is to periodically determine the core shutdown reactivity available for reactor shutdown.

Specification(s)

Shutdown margin shall be determined annually, or after significant core or control rod changes.

Basis

Annual determination of shutdown margin and measurements after reactor core or control rod changes are sufficient to monitor significant changes in the core shutdown margin.

4.1.2 Excess Reactivity

Applicability

This specification applies to the measurement of reactor excess reactivity.

Objective

The objective is to periodically determine the changes in core excess reactivity available for power generation.

Specification(s)

Excess reactivity shall be determined annually, or after significant reactor core or control rod changes.

Basis

Annual determination of excess reactivity and measurements after reactor core or control rod changes are sufficient to monitor significant changes in the core excess reactivity.

4.1.3 Transient Insertion

Applicability

This specification applies to surveillance of the transient rod mechanism and to observation of the reactor transient response.

Objective

The objective is to assure the function of the transient rod drive and to compare the reactor pulse insertion parameters.

Specification(s)

The transient rod drive cylinder and associated air supply shall be inspected, cleaned, and lubricated annually, and

a. A reactor pulse shall be performed annually to compare fuel temperature, peak power, and energy measurements with those of previous pulses.
b. The reactor shall not be pulsed routinely until such comparative measurements have been made.

Basis

Annual inspections of the pulse rod drive system should be sufficient to detect and correct changes in the system that could impair operability. The annual measurement of pulse parameters provides data to monitor changes in the reactor core transient characteristics.

4.2 CONTROL AND SAFETY SYSTEM

4.2.1 Operable Control Rods

Applicability

This specification applies to the surveillance of the control rods.

Objective

The objective is to assure the operability of the control rods by periodic measurement of the scram times and insertion rates.

Specification(s)

Control rod worths shall be determined annually or after significant core or control rod changes, and

a. The scram time of a scrammable control rod shall be measured annually or whenever any work is done on the rods or rod drive system.
b. The reactivity insertion rate of a standard control rod shall be measured annually.
c. The operability of the standard control rods shall be tested daily when the reactor is operating.

Basis

Annual determination of control rod worths or measurements after significant core changes provide information about changes in reactor total reactivity and individual rod worths. The specification intervals for scram time and insertion rate assure operable performance of the rods. Specification c. verifies operability requirements during each day of operation. Deviations that are significant from acceptable standards will be promptly corrected.

4.2.2 Reactor Control System

Applicability

This specification applies to the tests of the logic of the reactor control system.

Objective

The objective is to specify intervals for test, check, or calibration of the minimum control system interlocks.

Specification(s)

The minimum safety interlocks shall be tested at semiannual intervals.

Basis

The periodic test of the interlock logic at semiannual intervals provides adequate information that the control system interlocks are functional. Checks or calibrations of the control system logic are not considered applicable functions.

4.2.3 Reactor Safety System

Applicability

This specification applies to tests of the function of the reactor safety system.

Objective

The objective is to specify intervals for test, check, or calibration of the minimum safety system scrams.

Specification(s)

The minimum safety channels shall be calibrated annually and tested prior to each days operation or prior to each extended period of operation following a period when the reactor is secured in excess of 24 hours.

Basis

The periodic calibration at annual intervals provides adequate information that the setpoints of the safety system scrams are functional. Tests of the safety system prior to each planned operation assure that each intended scram function is operable.

4.2.4 Reactor Instrument System

Applicability

These specifications apply to calibrations, checks, and tests of reactor measurement channels.

Objective

The objective is to specify intervals for test, check, or calibration of the minimum instrument channels.

Specification(s)

The minimum instrument channels shall be calibrated annually. Calibration of the power measuring channels shall be by the calorimetric method. A check and test of each channel shall be made prior to each days operation or prior to each extended period of operation following a period when the reactor is secured in excess of 24 hours.

Basis

Annual calibration of instrument channels are scheduled to allow adjustments for changes in reactor and instrumentation parameters. Checks and tests are applied prior to system operation to verify function of the system.

4.3 OPERATIONAL SUPPORT SYSTEMS

4.3.1 Reactor Coolant Conditions

Applicability

This specification applies to surveillance conditions for the reactor pool and coolant water systems.

Objective

The objective is to maintain the reactor coolant conditions within acceptable specifications.

Specification(s)

The following measurements shall monitor the reactor coolant conditions:

a. The water conductivity sensor shall be checked annually and pool water conductivity measured monthly.
b. The water temperature sensor shall be checked annually, tested monthly and monitored continuously during reactor operation.
c. The water depth sensor shall be checked annually, tested monthly and monitored continuously during operation of the reactor.
d. The sensors measuring pressure on the primary and secondary sides shall be checked and tested annually and monitored continuously during operation.

Basis

Conditions for the reactor coolant are monitored by visual observation of measurements or automatic action of sensors. Periodic checks and tests of measurement devices for the reactor coolant system parameters assure that the coolant system will perform its intended function.

4.3.2 Air Ventilation Conditions

Applicability

This specification applies to surveillance conditions for the air ventilation in the reactor area.

Objective

The objective is to demonstrate the function of confinement and release of air from the reactor bay.

Specification(s)

The following actions shall demonstrate the air confinement conditions:

a. Annual examination of door seals and isolation dampers.
b. Monthly functional tests of air confinement isolation.
c. Calibration of argon-41 measurements shall be made annually and measurements or calculations performed monthly.

Basis

Periodic evaluations of air confinement criteria are determined by examination, test, and calibration of the appropriate ventilation functions. The reactor room ventilation system provides control for radioactive releases during both routine and non routine operating conditions.

4.3.3 Radiation Monitoring Conditions

Applicability

This specification applies to the surveillance conditions of the radiation monitoring channels.

Objective

The objective is to assure the radiation monitors are functional.

Specification(s)

The minimum radiation monitors specified to be operable during reactor operation shall be

a. Calibrated at semiannual intervals.
b. Checked at monthly intervals.

Basis

Periodic calibrations and frequent checks are specified to maintain reliable performance of the radiation monitoring instruments.

4.4 LIMITATIONS ON EXPERIMENTS

4.4.1 Reactivity

Applicability

This specification applies to surveillance of the reactivity of experiments.

Objective

The objective is assure the reactivity of an experiment does not exceed the allowable specification.

Specification(s)

The reactivity of an experiment shall be measured before an experiment is considered functional.

Basis

The measured reactivity or determination that the reactivity is not significant will provide assurance that configuration of the experiment or experiments is allowable.

4.4.2 Irradiations

Applicability

This specification applies to the surveillance requirements for reactor irradiations.

Objective

The objective is to provide a record of experiments inserted in the reactor as irradiations.

Specification(s)

Experiments classified as irradiations shall be identified and a log or other record maintained while the sample is in the reactor.

Basis

Experiments performed as irradiations are monitored by data on the sample location, identification, and other pertinent information.

4.4.3 Materials

Applicability

This specification applies to the surveillance requirements for materials inserted into the reactor.

Objective

The objective is to prevent the introduction of materials that could damage the reactor or its components.

Specification(s)

Any surveillance conditions or special requirements shall be specified as a part of the experiment approval.

Basis

A careful evaluation of all experiments is performed to classify the experiment as an approved experiment.

4.5 QUALITY CONTROL

4.5.1 Safety Related Systems

Applicability

This specification applies to the requirements of any system related to reactor safety.

Objective

The objective is to assure the proper function of any system related to reactor safety.

Specifications

Any modifications or maintenance to the reactor shield, the pool or its penetrations, the pool coolant system, the core and its associated support structure, the rod drive mechanisms, the reactor safety system, or the air ventilation system shall be made and tested in accordance with the specifications to which the systems were originally designed and fabricated. Alternate specifications may be approved by the reactor operations committee. A system shall not be considered operable until after it is tested successfully.

Basis

This specification relates to changes in reactor systems which could affect the safety of the reactor operation. Changes or substitutions to these systems that meet or exceed the original design specifications are assumed also to meet the presently accepted operating criteria. Questions that may include an unreviewed safety question are referred to the reactor operations committee.

4.5.2 Fuel Element Inspections

Applicability

This specification applies to the inspection requirements for the fuel elements.

Objective

The objective is to inspect the physical condition of the fuel element cladding.

Specification(s)

The reactor shall not be operated with damaged fuel and a visual inspection of the fuel elements shall be made at biennial intervals. A fuel element shall be considered damaged and must be removed from the core if:

a. In measuring the transverse bend, the bend exceeds the original bend by 1/16 inch or,
b. In measuring the elongation, the length exceeds the original length by 1/10 inch or,
c. A clad defect exists as indicated by release of fission products.

Basis

The frequency of inspection and measurement schedule is based on the parameters most likely to affect the fuel cladding of a pulsing reactor operated at moderate pulsing levels and utilizing fuel elements whose characteristics are well known.

The limit of transverse bend has been shown to result in no difficulty in disassembling the core. Analysis of the removal of heat from touching fuel elements shows that there will be no hot spots resulting in damage to the fuel caused by this touching. Experience with TRIGA reactors has shown that fuel element bowing that could result in touching has occurred without deleterious effects. The elongation limit has been specified to assure that the cladding material will not be subjected to stresses that could cause a loss of integrity in the fuel containment and to assure adequate coolant flow.

4.5.3 Control Rod Inspections

Applicability

This specification applies to the inspection requirements for the control rods.

Objective

The objective is to inspect the physical condition of the reactor control rods.

Specification(s)

The reactor shall not be operated with damaged control rods and a visual inspection of the rods shall be made at biennial intervals.

Basis

The frequency of inspection for the control rods will provide periodic verification of the condition of the control rod linkages and the control rod clad.

5.0 DESIGN FEATURES

5.1 REACTOR CORE

5.1.1 Configuration

Applicability

This specification applies to the configuration of fuel elements, control rods, incore experiments, and other reactor components.

Objective

The objective is to assure that provisions are made to restrict the arrangement of fuel elements and experiments so as to provide assurance that excessive power densities will not be produced.

Specification(s)

The reactor shall be an arrangement of core grid positions occupied by standard fuel elements, control rods, and graphite elements. Single element positions may be occupied by voids, water or experiment facilities. Special multielement positions or single element positions may be occupied by approved experiments.

Basis

Standard TRIGA cores have been in use for years and their characteristics are well documented.

5.1.2 Standard Fuel Elements

Applicability

This specification applies to the fuel elements used in the reactor core.

Objective

The objective is to assure that the fuel elements are of such a design and fabricated in such a manner as to permit their use with a high degree of reliability with respect to their physical and nuclear characteristics.

Specification(s)

The standard TRIGA fuel element at fabrication shall have the following characteristics:

a. Uranium content: 8.5 wt% uranium enriched to a nominal 19.7% Uranium-235;
b. Zirconium hydride atom ratio: nominal 1.6 hydrogen to zirconium, ZrH_x;
c. Cladding: 304 stainless steel, nominal .020 inches thick.

Basis

The Design basis of the standard TRIGA core demonstrates that 1.5 MW steady or 36 MW–s pulse operation presents a conservative limitation with respect to safety limits for the maximum temperature generated in the fuel. For this case, the fuel temperatures are not expected to exceed 550 C during any condition of normal operation. The maximum power for this reactor is 250 kW, and during pulsing total energy produced is about 8.2 MW–s. The maximum fuel temperature during normal operation will not exceed 350 C.

5.1.3 Control Rods

Applicability

This specification applies to the control rods used in the reactor core.

Objective

The objective is to assure that the control rods are of such a design as to permit their use with a high degree of reliability with respect to their physical and nuclear characteristics.

Specification(s)

The safety-transient, safety-shim, and regulating, control rods shall have scram capability, and

a. Contain borated graphite, B_4C powder, or boron and its compounds in solid form as a poison in aluminum or stainless steel cladding.
b. The safety-transient rod shall have an adjustable limit to allow a variation of reactivity insertions.

Bases

The poison requirements for the control rods are satisfied by using neutron absorbing borated graphite, B_4C powder, or boron and its compounds. These materials must be contained in a suitable clad material, such as aluminum or stainless steel, to insure mechanical stability during movement and to isolate the poison from the pool water environment. Scram capabilities are provided for rapid insertion of the control rods which is the primary safety feature of the reactor. The transient control rod is designed for a reactor pulse.

5.2 FACILITY DESIGN

5.2.1 Reactor Shield, Pool and Coolant

Applicability

This specification applies to the reactor pool and the cooling water system.

Objective

The objective is to assure that adequate radiation shielding and cooling water are available for reactor operation.

Specification(s)

a. Pool water level shall be protected by holes for siphon breaks in coolant pipe lines no more than 0.5 m below the top of the reactor pool.

b. The reactor core shall be cooled by natura[illegible]ective water flow.

Bases

a. Siphon breaks set the subsequent level for loss of coolant by the prevention of inadvertant pumping of water from the pool or accidental loss of water by siphon without the associated return of coolant water.

b. This specification is based on thermal and hydraulic calculations which show that a standard 85 element TRIGA core can operate in a safe manner at power levels up to 1,900 kW with natural convection flow of the coolant water.

5.2.2 Air Confinement

Applicability

This specification applies to the boundary for control of air in the area of the reactor.

Objective

The objective is to assure that provisions are made to restrict the amount of release of radioactivity into the environment.

Specification(s)

a. The reactor room shall be designed to restrict leakage and will have a minimum enclosed air volume of 394 m^3.

b. The ventilation system will maintain a negative pressure compared to ambient air conditions.

c. Ventilation system shall isolate reactor room air upon detection of a radiation limit signal.

Basis

a. Calculations for dilution of radioactivity associated with safety of reactor operation and release of effluents depends on the available air volume. Nominal activities are calculated for the specified volume.

b. Air leakage from the reactor room during operation is restricted to the exhaust stack by control of the pressure difference relative to the external ambient pressure.

c. The isolation dampers and fan motors for the reactor room supply and exhaust air are controlled by a logic signal from a radiation sensor to provide automatic air isolation.

5.2.3 Radiation Monitoring

Applicability

This specification describes the function and essential components of the area radiation monitoring equipment and the system for continuously monitoring airborne radioactivity.

Objective

The objective is to describe the radiation monitoring equipment that is available to the operator to assure safe operation of the reactor.

Specification(s)

Air radiation monitoring equipment (gamma sensitive) shall consist of fixed and portable instruments. Geiger tube type detectors are common but other types of radiation sensors may be applied to specific measurements. An air particulate radiation monitor (beta and gamma sensitive with air collection capability) will monitor material deposited on filters.

Basis

Radiation measurement is necessary to provide information for routine operation or during the occurrence of a design basis accident. Multiple or different radiation sensors are provided for duplication of radiation measurements and for identification of radioactivity conditions.

5.3 REACTOR FUEL ELEMENT STORAGE

Applicability

This specification applies to the storage of reactor fuel at times when it is not in the reactor core.

Objective

The objective is to assure that fuel storage will not become critical and will not exceed design temperatures.

Specification(s)

a. All fuel elements and fueled devices shall be stored in a geometrical array where the effective multiplication is less than 0.9 for all conditions of moderation.

b. Irradiated fuel elements and fueled devices shall be stored in an array which will permit sufficient natural convection cooling by water or air such that the fuel element or fueled device temperature will not exceed design values.

Bases

The limits imposed by these specifications are considered sufficient to provide conservative fuel storage and assure safe storage.

6.0 ADMINISTRATIVE CONTROLS

6.1 ORGANIZATION

6.1.1 Structure

The facility shall be under the direct control of the Director or a licensed senior operator designated to be in direct control. The management for operation of the facility shall consist of the organizational structure (Figure 6-1) established as follows:

6.1.2 Responsibility

The Director shall be responsible to the Dean of the School of Systems Science and the Head of the Department of Engineering for safe operation and maintenance of the reactor and its associated equipment. The Director or his appointee shall review and approve all experiments and experimental procedures prior to their use in the reactor. Individuals of the management organization shall be responsible for the policies and operation of the facility, and shall be responsible for safeguarding the public and facility personnel from undue radiation exposures and for adhering to the operating license and technical specifications.

6.1.3 Staffing

1. The minimum staffing when the reactor is not secured shall be:
    a. A certified operator in the control room.
    b. A second person in the facility complex able to carry out prescribed written instructions. Unexpected absence of the second person for as long as two hours to accommodate a personal emergency will be acceptable provided immediate action is taken to obtain an alternate person.
    c. A designated Class A (senior) operator readily available on call. The available operator should be within thirty minutes of the facility and reachable by telephone.

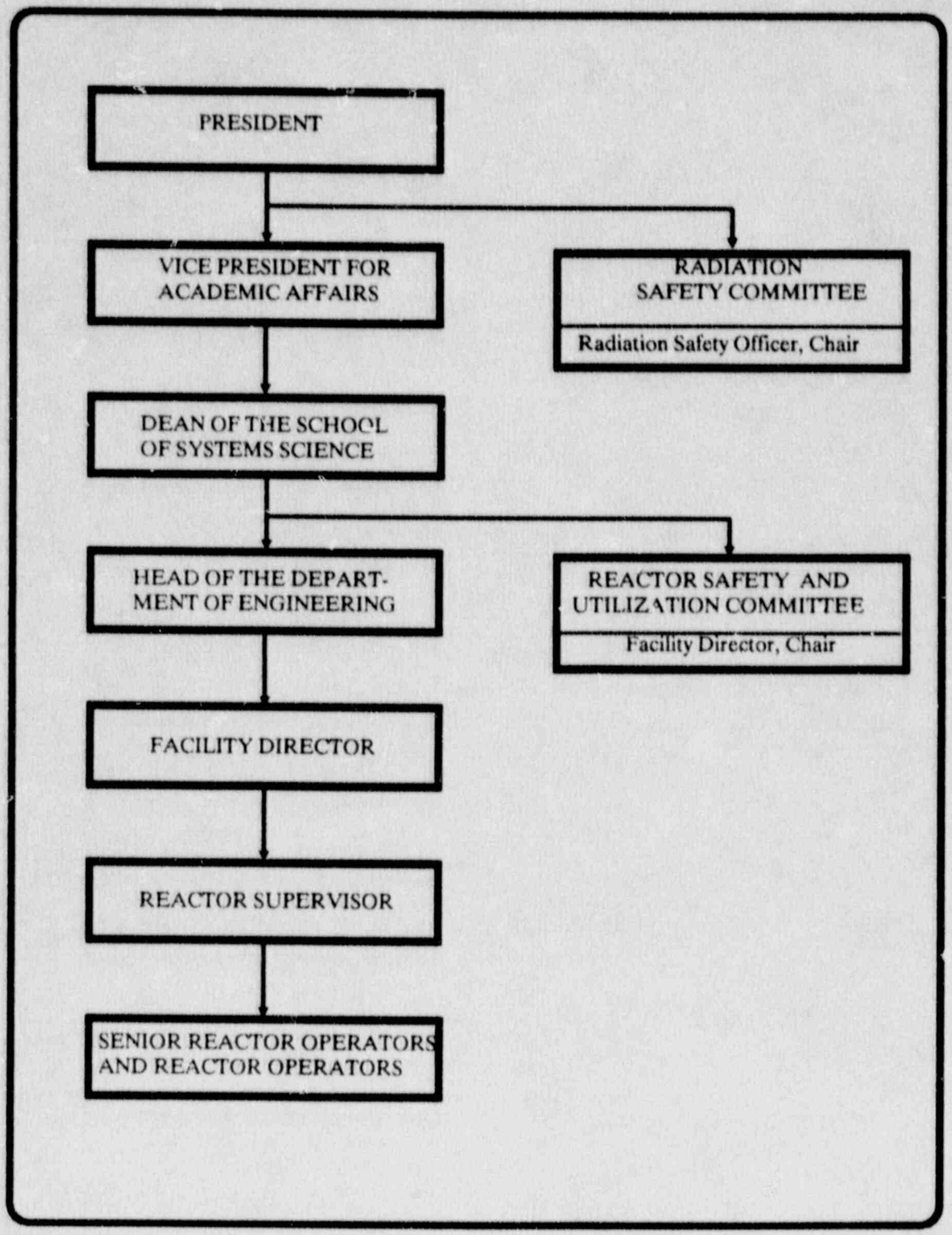

Figure 6-1 Organization for the management and Operation of the Arkansas Tech University Reactor Facility

d. A health physics-qualified (knowledgeable in radiation control procedures) individual readily available on call.

2. A list of reactor facility personnel by name and telephone number shall be available to the operator in the control room. The list shall include:

   a. Management personnel.

   b. Radiation safety personnel.

   c. Other operations personnel.

3. Events requiring the direction of a Class A operator shall be:

   a. All fuel element or control-rod relocations within the reactor core region.

   b. Relocation of any experiment with a reactivity worth of greater than one dollar.

   c. Recovery from an unscheduled shutdown will require documented verbal concurrence if the cause is unknown.

(4) Events requiring the presense of a health physics-qualified individual:

a. Fuel transfer operations

b. Installation, changing locations, or removal of an experiment.

c. Any maintenance activity involving the reactor safety system that could cause an abnormal release of radioactive materials.

6.1.4 Selection and Training of Personnel

The selection, training, and requalification of operations personnel shall meet or exceed the requirements of American National Standard for Selection and Training of Personnel for Research Reactors, ANSI/ANS-15.4-1977, or its successor, and be in accordance with Requalification Plan approved by the Nuclear Regulatory Commission.

6.2 REVIEW AND AUDIT

The Reactor Safety and Utilization Committee shall perform independent review and audit of the safety aspects of reactor facility operations.

6.2.1 Composition and Qualifications

A Reactor Safety and Utilization Committee shall consist of at least three (3) members appointed by the Dean of the School of Systems Science. The members shall collctively represent a broad spectrum of expertise appropriate to nuclear reactor technology and safety. The Facility Director and university Radiation Safety Officer shall be ex-officio members of the Committee. Individuals may be either from within or outside the operating organization. Qualified and approved alternates may serve in the absence of regular members

6.2.2 Charter and Rules

The operations of the Reactor Safety and Utilization Committee shall be in accordance with an established charter, including provisions for:

1. Meeting frequency – not less than once per calendar year and more frequently as circumstances warrant, consistent with effective monitoring of facility activities.
2. Quorums – a quorum shall be three members. Members of the operations staff shall not be a voting majority.
3. Use of subcommittees – the committee may appoint one or more qualified individuals to perform the audit function.
4. Dissemination, review, and approval of minutes – written records of the meetings shall be kept, and copies forwarded to the Dean of the School of Systems Science in a timely manner.

6.2.3 Review Function

The review function shall include facility operations related to reactor and radiological safety. The following items shall be reviewed:

1. Determinations that proposed changes in equipment, systems, tests, experiments, or procedures do not involve an unreviewed safety question.
2. All new procedures and major revisions thereto having safety significance, proposed changes in reactor facility equipment, or systems having safety significance.

3. All new experiments or classes of experiments that could affect reactivity or result in the release of radioactivity.
4. Proposed changes in technical specifications or the license.
5. Violations of technical specifications or license. Violations of internal procedures or instructions having safety significance.
6. Operating abnormalities having safety significance.
7. Other reportable occurrences.
8. Audit reports.

A written report or minutes of the findings and recommendations of the review group shall be submitted to the Dean of the School of Systems Science and the Reactor Safety and Utilization Committee members in a timely manner after the review has been completed.

6.2.4 Audit Function

The audit function shall include selective (but comprehensive) examination of operating records, logs, or other documents. An area will be audited by a person not directly responsible for the records and may include discussions with cognizant personnel or observation of operations. The following items shall be audited:

1. Facility operations for conformance to the technical specifications and applicable license conditions, at least once per calendar year (interval between audits not to exceed 15 months).
2. The retraining and requalification program for the operating staff, at least once every other calendar year (interval between audits not to exceed 30 months).
3. The results of action taken to correct those deficiencies that may occur in reactor facility equipment, systems, structures, or methods of operation that affect reactor safety, at least once per calendar year (interval between audits not to exceed 15 months).
4. The reactor facility emergency plan and physical security plan, and implementing procedures, at least once every other year (interval between audits not to exceed 30 months).

Deficiencies uncovered that affect reactor safety shall immediately be reported to the Dean of the School of Systems Science. A written report of the findings of the audit shall be submitted to the Dean of the School of Systems Science and the Reactor Safety and Utilization Committee members within three months after the audit has been completed.

6.3 OPERATING PROCEDURES

Written operating procedures shall be prepared, reviewed, and approved prior to initiating any of the activities listed in this section. The procedures shall be reviewed by the Reactor Safety and Utilization Committee and approved by the Facility Director or a designated alternate. These reviews and approvals shall be documented in a timely manner. Several of the following activities may be included in a single manual or set of procedures or divided among various manuals or procedures:

1. Startup, operation, and shutdown of the reactor.
2. Fuel loading, unloading and movement within the reactor.
3. Routine maintenance of major components of systems that could have an effect on reactor safety.
4. Surveillance tests and calibrations required by the technical specifications or those that could have an effect on reactor safety.
5. Personnel radiation protection, consistent with applicable regulations.
6. Administrative controls for operations and maintenance and for the conduct of irradiations and experiments that could affect reactor safety or core reactivity.
7. Implementation of required plans such as the emergency plan or physical security plan.

Substantive changes to the above procedure shall be made effective only after documented review by the Reactor Safety and Utilization Committee and approval by the Facility Director or a designated alternate. Minor modifications to the original procedures which do not change their original intent may be made by the Reactor Supervisor, but the modifications must be approved by the Facility Director or a designated alternate within 14 days. Temporary deviations from the procedures may be made by the responsible Senior (Class A) operator or higher individual present, in order to deal with special or unusual circumstances or conditions. Such deviations shall be documented and reported to the Facility Director or the designated alternate.

6.4 EXPERIMENT REVIEW AND APPROVAL

Approved experiments shall be carried out in accordance with established and approved procedures.

1. All new experiments or class of experiments shall be reviewed by the Reactor Safety and Utilization Committee and approved in writing by the Facility Director or designated alternate prior to initiation.
2. Substantive changes to previously approved experiments shall be made only after they are reviewed by the Reactor Safety and Utilization Committee and approved in writing by the Facility Director or designated alternate. Minor changes that do not significantly alter the experiment may be approved by the Reactor Supervisor.

6.5 REQUIRED ACTIONS

6.5.1 Action to be Taken in Case of a Safety Limit Violation

1. The reactor shall be shut down and reactor operations shall not be resumed until authorized by the licensing agency, Nuclear Regulatory Commission(NRC).
2. The safety limit violation shall be promptly reported to the Facility Director or a designated alternate.
3. The safety limit violation shall be reported to the licensing agency (NRC).
4. A safety limit violation report shall be prepared. The report, and any follow-up report, shall be reviewed by the Reactor Safety and Utilization Committee and shall be submitted to the licensing agency (NRC) when authorization is sought to resume opearation of the reactor. The report shall describe the following:
   a. Applicable circumstances leading to the violation including, when known, the cause and contributing factors.
   b. Effect of the violation upon reactor facility components, systems, or structures and on the health and safety of personnel and the public.
   c. Corrective action to be taken to prevent recurrence.

6.5.2 Action to be Taken in the Event of an Occurrence of the Type identified in 6.6.2(1)b., and 6.6.2(1)c.

1. Reactor conditions shall be returned to normal or the reactor shall be shutdown. If it is necessary to shutdown the reactor to correct the occurrence, operations shall not be resumed unless authorized by the Facility Director or a designated alternate.
2. The occurrence shall be reported to the Facility Director or a designated alternate and to licensing authorities as required.
3. The occurrence shall be reviewed by the Reactor Safety and Utilization Committee at the next scheduled meeting.

6.6 REPORTS

6.6.1 Operating Reports

Routine annual reports covering the activities of the reactor facility during the previous calendar year shall be submitted to licensing authorities within three months following the end of each prescribed year. Each annual operating report shall include the following information:

1. A narrative summary of reactor operating experience including the energy produced by the reactor or the hours the reactor was critical, or both.
2. The unscheduled shutdowns including, where applicable, corrective action taken to preclude recurrence.
3. Tabulation of major preventive and corrective maintenance operations having safety significance.
4. Tabulation of major changes in the reactor facility and procedures, and tabulation of new tests or experiments, or both, that are significantly different from those performed previously and are not described in the Safety Analysis Report, including conclusions that no unreviewed safety questions were involved.
5. A summary of the nature and amount of radioactive effluents released or discharged to the environs beyond the effective control of the owner-operator as determined at or before the point of such release or discharge. The summary shall include to the extent practicable an estimate of individual radionuclides present in the effluent. If the estimated average release after dilution or diffusion is less than 25% of the concentration allowed or recommended, a statement to this effect is sufficient.
6. A summarized result of environmental surveys performed outside the facility.
7. A summary of exposures received by facility personnel and visitors where such exposures are greater than 25% of that allowed or recommended.

6.6.2 Special Reports

1. There shall be a report not later than the following working day by telephone and confirmed in writing by telegraph or similar conveyance to the licensing authorities to be followed by a written report within 14 days that describes the circumstances of the event of any of the following:
   a. Violation of fuel element temperature safety limit (see 6.5.1).

b. Release of radioactivity from the site above allowable limits (see 6.5.2)

c. Any of the following (see 6.5.2):

i. Operation with actual safety-system settings for required systems less conservative than the limiting safety-system settings specified in the technical specifications.

ii. Operation in violation of limiting conditions for operation established in the technical specifications unless prompt remedial action is taken.

iii. A reactor safety system component malfunction which renders or could render the reactor safety system incapable of performing its intended safety function unless the malfunction or condition is discovered during maintenance tests or periods of reactor shutdowns.

iv. An unanticipated or uncontrolled change in reactivity greater than 0.07 %k (1 dollar). Reactor trips resulting from a known cause are excluded.

v. Abnormal and significant degradation in reactor fuel, or cladding, or both, coolant boundary, or confinement boundary (excluding minor leaks) where applicable which could result in exceeding prescribed radiation exposure limits of personnel or environment, or both.

vi. An observed inadequacy in the implementation of administrative or procedural controls such that the inadequacy causes or could have caused the existence or development of an unsafe condition with regard to reactor operations.

2. A report within 30 days to the licensing authorities of:

   a. Permanent changes in the facility organization involving the Dean of the School of Systems Science, Head of the Department of Engineering, or the Facility Director.

   b. Significant changes in the transient or accident analysis as described in the Safety Analysis Report.

3. A report within 90 days after completion of startup testing of the reactor upon receipt of a new facility license or an amendment to the license authorizing an increase in reactor power level describing the measured values of the operating conditions or characteristics of the reactor under the new conditions including:

   a. An evaluation of facility performance to date in comparison with design predictions and specifications; and

   b. A reassessment of the safety analysis submitted with the license application in light of measured operating characteristics when such measurements indicate that there may be substantial variance from prior analysis.

6.7 RECORDS

The records may be in the form of logs, data sheets, or other suitable forms. The required information may be contained in single, or multiple records, or a combination thereof.

6.7.1 Records to be Retained for a Period of at Least Five Years or for the Life of the Component Involved if Less than Five Years

1. Normal reactor facility operation (but not including supporting documents such as checklists, log sheets, etc., which shall be maintained for a period of at least one year).
2. Principal maintenance operations.
3. Reportable occurrences.
4. Surveillance activities required by technical specifications.
5. Reactor facility radiation and contamination surveys where required by applicable regulations.
6. Experiments performed with the reactor.
7. Fuel inventories, receipts, and shipments.
8. Approved changes in operating procedures.
9. Records of meeting and audit reports of the review and audit group.

6.7.2 Records to be Retained for at Least One Training Cycle

Retraining and requalifications of certified operations personnel: Records of the most recent complete cycle shall be maintained at all times the individual is employed.

6.7.3 Records to be Retained for the Lifetime of the Reactor Facility

(Note: Applicable annual reports, if they contain all of the required information, may be used as records in this section.)

1. Gaseous and liquid radioactive effluents released to the environs.
2. Off-site environmental monitoring surveys required by technical specifications.
3. Radiation exposure for all personnel monitored.
4. Drawings of the reactor facility.

ENVIRONMENTAL IMPACT

ARKANSAS TECH UNIVERSITY

NUCLEAR REACTOR

(TRIGA MARK I)

September, 1989

Table of Contents

ENVIRONMENTAL IMPACT

This document deals with the environmental effects that are expected from the operation of a TRIGA Mark I research reactor at Arkansas Tech University. The reactor is part of the Center for Energy Studies.

A. Environmental Effects of Facility Construction

The TRIGA reactor will be located in the Center for Energy Studies at Arkansas Tech University. Design of the building is intended for the reactor facility and other laboratories and offices associated with applications and research in nuclear technology. Approximately 36% of the 700 square meter facility is designated for the reactor facility.

Utility construction projects such as chilled water, heated water, electricity, road construction, and other support facilities for the Center are provided and proposed. Utility requirements and construction activities for the Center and its related facilities including the reactor facility will not be different substantially from those required during standard construction projects. Construction activities of the facility should have no impact on areas beyond the Center site.

Utilities required by the facility are communications, electricity, chilled water, domestic water and sanitary sewer. Some utilities such as hot water, chilled warer, and compressed air are generated at the reactor facility. All utilities at the Center are maintained by the University.

B. Environmental Effects of Facility Operation

The TRIGA reactor facility is designed for 250 kW(thermal) steady-state operation. Environmental effects of the operation will include waste heat disposal, production of liquid and gas radioactive effluents, and the generation of liquid and solid radioactive wastes. None of these waste items are considered significant with respect to environmental impact although each is treated appropriately. No resources for the facility are considered significant to the environment.

Heat disposal from the reactor pool is provided by heat exchange with a central chilled water supply. Estimated chilled water requirements for dissipation of the peak facility heat load is 275 kW for the reactor and 66 kW for the building. A chilled water facility with a capacity of about 350 kW will provide the ultimate heat rejection source.

Radioactive gas effluents produced by the reactor are argon-41 and nitrogen-16. Production and release of these gases are controlled so that the short half-life of each product will further diminish the radiological impact. Release of argon-41 is a function of the reactor power level, operation time and quantity of air exposed to the reactor with some contribution from dissolved air in the coolant. Release of nitrogen-16 is related primarily to the reactor power level and coolant flow through the reactor. The respective argon-41 and nitrogen-16 half-lives of 109 minutes and 7 seconds respectively, affect the type of control applied to the release. Controls on both gases are applied to limit occupational exposures, although the short half-life of nitrogen-16 eliminates any significant environmental release compared to the longer half-life of argon-41 that is released to the environment. The upper limit for release of argon-41 from continuous single shift operation at full power for one year is 50 Curies. The actual value will be lower substantially and should be less than 20 Curies as indicated by the conservative estimate and data available from other facilities.

Production of activation products in the coolant water consists of activation of impurities and small quantities of deuterium and tritium. Activation of short-lived gaseous products of oxygen and nitrogen are not considered significant environmental effects. Releases of radioactive hydrogen products to the environment would occur through the evaporation of pool water. These releases are projected to be a small fraction of the allowable concentrations for the hydrogen isotopes. Liquid waste releases typical of similar facilities are less than 0.01 Curies per year and should be less substantially for this facility.

Solid wastes released for waste burial and liquid waste released to sanitary sewer systems are expected to represent a fraction of the total University release amounts. Most of the waste activity is short-lived isotopes such as Na^{24}, Mg^{27}, Al^{28}, C^{l38}, Cr^{51}, Mn^{56}, Ni^{65}, As^{76}, and others. A few longer-lived radioisotopes such as Co60 and small amounts of Cs^{137} are also created and disposed. Waste disposal includes gloves, paper, containers, samples, and resin. Activation products are accumulated in an ion exchange resin and removed on a periodic basis. The annual volume of resin required to control pool water quality is less than 0.1 cubic meters. Dose rates at the surface of the resin volume are typically 10-20 mrem/hr with intermediate and long half-life activation products present. Total volume of solid wastes is projected to be 1 to 2 cubic meters per year. Sanitary sewer disposal of liquid waste should also be a fraction of the disposal constraints specified in 10 CFR Part 20.

Storage, processing and disposal of fuel elements is not considered a significant activity of this facility. Projections from the operation schedules of similar types of reactor facilities indicate that less than 750 MW-days of burnup would be accumulated after 40 years. Ultimate disposal and processing of the fuel is a function of the Department of Energy.

Studies such as NUREG CR-1756 contain detailed information for the radionuclide inventories expected after operation of a typical research reactor facility. Major isotopes of concern identified are Co^{60}, Zn^{65}, and C^{14}, although several other isotopes and such rare earth radionuclides as Eu^{152} are expected to be present in reactor materials and shield concrete.

C. Environmental Effects of Accidents

Accidents ranging from failure of experiments to the largest core damage and fission product release considered possible result in doses of only a small fraction of 10 CFR Part 20 guidelines and are considered negligible with respect to the environment. Credible accident analysis for TRIGA and TRIGA fueled reactors are presented in NUREG CR-2387 (PNL-4028).

D. Unavoidable Effects of Facility Construction and Operation

The unavoidable effects of construction and operation involves the materials used in construction that cannot be recovered and the fissionable material used in the reactor. No adverse impact on the environment is expected from either of the unavoidable effects.

E. Alternatives to Construction and Operation of the Facility

There are no suitable or more economical alternatives which can accomplish both the educational and the research objectives of this facility. These objectives include the training of engineering students and power plant operators in the operation of nuclear reactors, the operation as a source of neutrons for neutron activation analysis or neutron radiography and other activities related to education and radioisotope applications.

F. Long-Term Effects of Facility Construction and Operation

The long-term effects of a research facility such as the Center for Energy and Environmental Studies are considered to be beneficial as a result of the contribution to scientific knowledge and training. The impact on the environment associated with this facility is minimal.

G. Cost and Benefits of Facility and Alternatives

The cost for this facility is projected at $1.25 million with a minimum environmental impact from the operation of the facility. The benefits include, but are not limited to: the applications of neutron activation analyses, production of neutron beams for research and or application, production of short-lived radioisotopes, education of students and public, and training of operating personnel. Some of these activities could be conducted using particle accelerators or radioactive sources, but these alternatives are also costly and less effective and in some cases not applicable. There is no reasonable alternative to a nuclear research reactor of this type for conducting the broad spectrum of activities previously mentioned.