Facility License R-92

Technical Specifications

for the

TRIGA MARK I

University of Texas

Austin, Texas

Included in this document are the Technical Specifications and the "Bases" for the Technical Specifications. These bases, which provide the technical support for the individual technical specifications, are included for information purposes only. They are not part of the Technical Specifications, and they do not constitute limitations or requirements to which the licensee must adhere. Reference NRC Regulatory Guide 1.16 and ANSI N378-1974.

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1.0 DEFINITIONS

REACTOR OPERATING CONDITIONS

1.1 REACTOR SHUTDOWN

The reactor is shut down when the reactor is subcritical by at least one dollar (0.7% $\Delta k/k$) of reactivity.

1.2 REACTOR SECURED

The reactor is secured when all the following conditions are satisfied:

a. The reactor is shutdown,

b. The console key switch is in the "off" position and the key is removed from the console and under the control of a licensed operator or stored in a locked storage area, and

c. No work is in progress involving in-core fuel handling or refueling operations, maintenance of the reactor or its control mechanisms, or insertion or withdrawal of in-core experiments.

1.3 REACTOR OPERATION

Reactor operation is any condition wherein the reactor is not secured.

1.4 COLD CRITICAL

The reactor is in the cold critical condition when it is critical with the fuel and bulk water temperatures both below 40°C.

1.5 STEADY STATE MODE

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

1.6 PULSE MODE

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

1.7 SHUTDOWN MARGIN

Shutdown margin shall mean the minimum shutdown 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 conditions and that the reactor will remain subcritical without further operator action.

1.8a ABNORMAL OCCURRENCE

An "Abnormal Occurrence" is defined for the purposes of the reporting requirements of Section 208 of the Energy Reorganization Act of 1974 (P.L. 93-438) as an unscheduled incident or event which the Nuclear Regulatory Commission determines is significant from the standpoint of public health or safety.

1.8b REPORTABLE OCCURRENCE

A reportable occurrence is any of the following which occurs during reactor operation:

a. Operation with any safety system setting less conservative than specified in Section 2.2, Limiting Safety System Settings:

b. Operation in violation of a Limiting Condition for Operation;

c. Failure of a required reactor or experiment safety system component which could render the system incapable of performing its intended safety function;

d. Any unanticipated or uncontrolled change in reactivity greater than one dollar;

e. An observed inadequacy in the implementation of either administrative or procedural controls, such that the inadequacy could have caused the existence or development of a condition which could result in operation of the reactor outside the specified safety limits; and

f. Release of fission products from a fuel element.

REACTOR EXPERIMENTS

1.9 EXPERIMENT

Experiment shall mean (a) any apparatus, device, or material which is not a normal part of the core or experimental facilities, but which is inserted in these facilities or is in line with a beam of radiation originating from the reactor core; or (b) any operation designed to measure reactor parameters or characteristics.

1.10 EXPERIMENTAL FACILITIES

Experimental facilities shall mean rotary specimen rack, pneumatic transfer systems, in-pool irradiation facilities, central thimble, and vertical beam tubes.

REACTOR COMPONENTS

1.11 SHIM ROD

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

1.12 TRANSIENT ROD

The transient rod is a control rod with scram capabilities that can be ejected rapidly from the reactor core to produce a pulse.

1.13 REGULATING ROD

The regulating rod is a low worth control rod having an electric motor and scram capabilities.

1.14 FUEL ELEMENT

A fuel element is a single TRIGA fuel rod of standard type (i.e. stainless steel clad; 8.5 wt% U - $ZrH_{1.65}$; nominal 20% enriched).

1.15 INSTRUMENTED ELEMENT

An instrumented element is a special fuel element in which at least one thermocouple is embedded in the fuel near the horizontal center plane.

1.16 STANDARD CORE

A standard core is an arrangement of standard TRIGA fuel in the reactor grid plate.

1.17 OPERATIONAL CORE

An operational core is a standard core for which the core parameters of shutdown margin, fuel temperature, power calibration, and maximum allowable reactivity insertion have been determined to satisfy the requirements of the Technical Specifications.

REACTOR INSTRUMENTATION

1.18 SAFETY LIMIT

Safety limits are limits on important process variables which are found to be necessary to protect reasonably the integrity of certain of the physical barriers which guard against the uncontrolled release of radioactivity.

1.19 LIMITING SAFETY SYSTEM SETTING

Limiting safety systems setting is a setting for automatic protective devices related to those variables having significant safety functions.

1.20 OPERABLE

A system, device, or component shall be considered operable when it is capable of performing its intended functions in a normal manner.

1.21 REACTOR SAFETY SYSTEMS

Reactor safety systems are those systems, including their associated input circuits, which are designed to initiate a reactor scram for the primary purpose of protecting the reactor or to provide information which requires manual protective action to be initiated.

1.22 EXPERIMENT SAFETY SYSTEMS

Experiment safety systems are those systems, including their associated input circuits, which are designed to initiate a scram for the primary purpose of protecting an experiment or to provide information which requires manual protective action to be initiated.

1.23 MEASURED VALUE

The measured value is the magnitude of that variable as it appears on the output of a measuring channel.

1.24 MEASURING CHANNEL

A measuring channel is the combination of sensor, interconnecting cables or lines, amplifiers, and output device which are connected for the purpose of measuring the value of a variable.

1.25 SAFETY CHANNEL

A safety channel is a measuring channel in the reactor safety system.

1.26 CHANNEL CHECK

A channel check is a qualitative verification of acceptable performance by observation of channel behavior.

1.27 CHANNEL TEST

A channel test is the introduction of a signal into the channel to verify that it is operable.

1.28 CHANNEL CALIBRATION

A channel calibration consists of comparing a measured value from the measuring channel with a corresponding known value of the parameter so that the measuring channel output can be adjusted to respond with acceptable accuracy to known values of the measured variable.

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.

Objective

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

Specifications

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

Bases

The important parameter for a TRIGA reactor is the fuel element temperature. This parameter is well suited as a single specificiation especially since it can be measured. 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. 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 1150°C and the fuel cladding is below 500°C. The 1000°C safety limit represents a conservative limit to maintain clad integrity for all operating conditions.

2.2 LIMITING SAFETY SYSTEM SETTINGS

Applicability

This specification applies to the scram settings which prevent the safety limit from being reached.

Objective

The objective is to prevent the safety limits from being reached.

Specification

The limiting safety system setting shall be 450°C as measured in an instrumented fuel element. The instrumented element shall be located in the B or C ring of the 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 450°C provides a safety margin of at least 550°C for standard TRIGA fuel elements. 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 at the mid-plane of the element and close to the anticipated hot spot. If the thermocouple element is located in a region of lower temperature, such as on the periphery of the core, the measured temperature will differ by a greater amount from that actually occurring at the core hot spot. Calculations indicate that, for this case, the true temperature at the hottest location in the core will differ from the measured temperature by no more than a factor of two. Thus, when the temperature in the thermocouple element reaches the trip setting of 450°C, the true temperature at the hottest location would be no greater than 900°C, providing a margin to the safety limit of at least 100°C for standard fuel elements. These margins are sufficient to account for the remaining uncertainty in the accuracy of the fuel temperature measurement channel and any overshoot in reactor power resulting from a reactor transient during steady state mode operation.

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 reduce the amount of energy generated in the entire pulse transient by cutting of the "tail" of the energy transient in the event the pulse rod remains stuck in the fully withdrawn position.

3.0 LIMITING CONDITIONS FOR OPERATION

3.1 STEADY STATE OPERATION

Applicability

This specification applies to the energy generated in the reactor during steady state operation.

Objective

The objective is to assure that the fuel temperature safety limit will not be exceeded during steady state operation.

Specifications

The reactor power level shall not exceed 275 kilowatts under any condition of operation. The normal steady state operating power level of the reactor shall be 250 kilowatts. However, for purposes of testing and calibration the reactor may be operated at higher power levels not to exceed 275 kilowatts during the testing period.

Bases

Thermal and hydraulic calculations indicate that TRIGA fuel may be safely operated up to power levels of at least 2.0 megawatts with natural convection cooling.

3.2 REACTIVITY LIMITATIONS

Applicability

These specifications apply to the reactivity condition of the reactor and the reactivity worths of control rods and experiments. They apply for all modes of operation.

Objective

The objective is to assure that the reactor can be shut down at all times and to assure that the fuel temperature safety limit will not be exceeded.

Specifications

3.2.1 Shutdown Margin

The reactor shall not be operated unless the shutdown margin provided by control rods shall be greater than 0.2% $\Delta k/k$ with:

a. the highest worth non-secured experiment in its most reactive state,

b. the most reactive control rod fully withdrawn,

c. the reactor in the cold critical condition without xenon.

3.2.2 Maximum excess reactivity shall be 2.25% $\Delta k/k$

3.2.3 Total worth of transient rod shall be limited to 1.8% $\Delta k/k$

3.2.4 Maximum insertion rate of standard control rod shall be 0.2% $\Delta k/k$ per second.

Bases

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. Maximum core reactivity above cold clean critical, the standard rod reactivity insertion rate, and transient rod total worth, establish available limits on the core power, rate of change of power, and pulse power levels. Each limiting parameter assures that the normally available reactivity and insertion rates cannot generate operating conditions that exceed fuel temperature safety limits.

3.3 PULSE MODE OPERATION

Applicability

This specification applies to the energy generated in the reactor as a result of a pulse insertion of reactivity.

Objective

The objective is to assure that the fuel temperature safety limit will not be exceeded.

Specification

The reactivity to be inserted for pulse operation shall be determined and limited by a mechanical block on the pulse rod, such that the reactivity insertion will not exceed 1.5% $\Delta k/k$, and shall be initiated from power levels less than 1 kilowatt.

Bases

Experiments with pulsed operation of TRIGA reactors indicate that insertions up to 3.5% $\Delta k/k$ have not exceeded the fuel temperature safety limit. For a 1.5% $\Delta k/k$ pulse the expected fuel temperature rise above ambient is approximately 400°C. Thus at an ambient temperature of 50°C a safety margin of 550°C is expected relative to the defined safety limit of 1000°C.

3.4 CONTROL AND SAFETY SYSTEM

3.4.1 Scram Time

Applicability

This specification applies to the time required for the scrammable control rods to be inserted fully from the instant that a safety channel variable reaches the Safety System Setting.

Objective

The objective is to achieve prompt shutdown of the reactor to prevent fuel damage.

Specification

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.

Basis

This specification assures that the reactor will be shut down promptly when a scram signal is initiated. Experiments and analysis have indicated that for the range of transients anticipated for a TRIGA reactor, the specified scram time is adequate to assure the safety of the reactor.

3.4.2 Reactor Control System

Applicability

This specification applies to the information which must be available to the reactor operator during reactor operation.

Objective

The objective is to require that sufficient information is available to the operator to assure safe operation of the reactor.

Specification

The reactor shall not be operated unless the measuring channels listed in the following table are operable.

Reactor Minimum Measuring Channels

Measuring Channel	Operable	Effective Mode	
		Steady State	Pulse
Fuel Element Temperature	1	X	X
Linear Power Level	1	X	
Percent Power Level	1	X	
Peak Pulse Power	1		X

The minimum measuring and safety channels are required to be operable prior to reactor startup. However, failure of any channel while the reactor is in operation is permissible, provided that an alternate channel is functional.

3.4.3 Reactor Safety System

Applicability

This specification applies to the reactor safety system channels.

Objective

The objective is to specify the minimum number of reactor safety system channels that must be operable for safe operation.

Specification

The reactor shall not be operated unless the safety channels described in the following table are operable.

Minimum Reactor Safety Channels

Safety Channel	Number Operable	Function	Effective Mode	
			Steady State	Pulse
Console Scram Button	1	Scram on operator demand	X	X
Fuel Element Temp.	1	Scram at 450°C	X	X
Linear Power Level	1	Scram at 110% of full scale	X	
Percent Power Level	1	Scram at 110% of full power	X	
Peak Pulse Power	1	Scram at 110% of full scale		X

Safety Channel	Number Operable	Function	Effective Mode Steady State	Pulse
High Voltage	1	Scram on loss of	X	X
Scram Relay Power	1	Scram on loss of	X	X
Magnet Current	1	Scram on loss of	X	X
Startup Channel	1	Interlock, prevent rod withdrawal with less than 2 neutron cps	X	
Rod Drive Control	1	Interlock, prevent simultaneous withdrawal of any two or more rods	X	
Rod Drive Control	1	Interlock, prevent transient rod withdrawal unless all rods are down	X	
Rod Drive Control	1	Interlock, prevent withdrawal of any rod except transient		X
Rod Drive Control	1	Timer, drop transient rod within 15 secs of pulse		X
Reactor Pool Level	1	Alarm at $\leq$ 4.5m	X	X
Pool Bulk Water Temp.	1	Alarm at $\geq$ 48°C	X	X
Heat Exchanger Pressure Difference	1	Alarm at $\leq$ 7kPa	X	X

Bases

The manual scram allows the operator to shut down the system is an unsafe or abnormal condition occurs. The fuel temperature and power level scrams provide protection to assure that the reactor can be shut down before the safety limit on the fuel element temperature will be exceeded. In the event of failure of the power supplies for high voltage, scram relays or magnet current, continued reactor operation is prevented without adequate measurement and control instrumentation.

The interlock to prevent startup of the reactor at power levels less than 4×10^{-3} watts, which corresponds to approximately 2 cps, assures that sufficient neutrons are available for proper startup. The interlock to prevent simultaneous withdrawal limits the maximum positive reactivity insertion rate available for steady state operation.

An interlock that prevents transient rod withdrawal during steady state operation protects against inadvertent pulse operation. The interlock to prevent withdrawal of the shim or regulating rod in the pulse mode is designed to prevent changing the critical state of the reactor just before pulsing. A preset timer insures that the reactor power level will reduce to a low level after pulsing.

3.5 RADIATION MONITORING SYSTEM

Applicability

This specification applies to the radiation monitoring information which must be available to the reactor operator during reactor operation.

Objective

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

Specification

The reactor shall not be operated unless the radiation monitoring channels listed in the following table are operable.

Radiation Monitoring Channels	Function	Number
Area Radiation Monitor	Monitor radiation levels within the reactor room	1
Continuous Air Radiation Monitor	"	1

During maintenance to the radiation monitoring channels, the intent of this specification will be satisfied by substitution of portable gamma sensitive instruments that are subject to visual observation or that provide audible alarms.

Bases

The radiation monitors provide information to operating personnel of any impending or existing danger from radiation so that there will be sufficient time to evacuate the facility and take the necessary steps to prevent the spread of radioactivity to the surroundings.

3.6 POOL WATER SYSTEMS

Applicability

This specification applies to the operating condition of the reactor pool and pool water systems.

Objective

The objective is to assure that coolant water is available to provide adequate cooling of the reactor core and adequate radiation shielding.

Specifications

Corrective action shall be taken or the reactor shall be shutdown if

a. less than 4.5 meters of water exists above the top grid plate,

b. the bulk pool temperature exceeds 48 °C, or

c. during heat exchanger operation, the chilled water outlet pressure is less than 7kPa greater than the pool water inlet pressure to the heat exchanger.

Bases

a. Calculations and experiments at TRIGA facilities have shown that 4.5 meters of water above the reactor core is sufficient to provide reasonable radiation levels above the reactor pool.

b. The bulk water temperature constraint assures that sufficient core cooling exists under all anticipated operating conditions.

c. A pressure difference at the heat exchanger chilled water outlet and pool water inlet of 7kPa should be sufficient to prevent loss of pool water to the secondary chilled water system in the event of a leak between the two systems.

3.7 LIMITATIONS ON EXPERIMENTS

Applicability

This specification applies to experiments installed in the reactor and its experimental facilities.

Objective

The objective is to prevent damage to the reactor or excessive release of radioactive material in the event of an experiment failure.

Specifications

The reactor shall not be operated unless the following conditions governing experiments exist.

a. Non-secured experiments shall have reactivity worths less than 1 dollar.

b. The reactivity worth of any single experiment shall be less than 2.5 dollars.

c. The total reactivity worth of in-core experiments shall not exceed 3.00 dollars, including the potential reactivity which might result from experimental malfunction, experiment flooding or voiding, removal or insertion of experiments.

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

e. Explosive materials, such as gunpowder, TNT, PETN, or nitroglycerin, 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.

f. 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, or (3) possible accident conditions in the experiment shall be limited in activity such that if 100% of the gaseous activity or radioactive aerosols produced escaped to the reactor room or the atomsphere, the airborne concentration of radioactivity averaged over a year would not exceed the limit of Appendix B of 10 CFR Part 20.

g. In calculations pursuant to f. 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 0.3 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.

h. 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 curies and the maximum strontium inventory is no greater than 5 millicuries.

i. 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.

<u>Bases</u>

a. This specification is intended to provide assurance that the worth of a single unfastened experiment will be limited to a value such that the safety limit will not be exceeded if the positive worth of the experiment were to be inserted suddenly.

b. The maximum worth of a single experiment is limited so that its removal from the cold critical reactor will not result in the reactor achieving a power level high enough to exceed the core temperature safety limit. Since experiments of such worth must be fastened in place, its 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 high power levels from being attained.

c. The maximum worth of all experiments is also limited to a reactivity value such that the cold reactor will not achieve a power level high enough to exceed the core temperature safety limit if the experiments were removed.

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

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

f. This specification is intended to reduce the likelihood that airborne activities in excess of the limits of Appendix B of 10 CFR Part 20 will be released to the atmosphere outside the facility boundary.

g. This specification clarifies calculation conditions of part (f).

h. The 1.5-curie 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.

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

3.8 IRRADIATIONS

Applicability

This specification applies to irradiations performed in the irradiation facilities contained in the reactor pool as defined in Section 1.10. 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.

Specifications

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 4.2.5 for an experiment,

b. 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, otherwise it shall be classed as an experiment.

c. The device or material is encapsulated in a suitable container,

d. The reactivity worth of the device or material is 0.25 dollars or less, otherwise it shall be classed as an experiment, and

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.

Bases

This specification is intended to provide assurance that the special class of experiments called irradiations will be performed in a manner that will not permit any safety limit to be exceeded.

4.0 SURVEILLANCE REQUIREMENTS

4.1 GENERAL

Applicability

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

Objective

The objective is to verify the proper operation of any system related to reactor safety.

Specifications

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

Bases

This specification relates to changes in reactor systems which could affect the safety of the reactor. As long as changes or replacements to these systems continue to meet the original design specifications, then it can be assumed that they meet the presently accepted operating criteria.

4.2 LIMITING CONDITIONS FOR OPERATION

4.2.1 Reactivity Requirements

Applicability

These specifications apply to the surveillance requirements for reactivity control of experiments and systems.

Objective

The objective is to measure and verify the worth, performance, and operability of those systems affecting the reactivity of the reactor.

Specifications

a. The reactivity worth of each control rod and the shutdown margin shall be determined annually, but at intervals not to exceed 14 months.

b. The reactivity worth of an experiment shall be estimated or measured, as appropriate, before reactor operation with said experiment.

c. The control rods shall be inspected visually for deterioration at intervals not to exceed 2 years.

d. The transient rod drive cylinder and associated air supply system shall be inspected, cleaned, and lubricated semiannually, but at intervals not to exceed 8 months.

e. The reactor shall be pulsed semiannually to compare fuel temperature measurements and peak power levels with those of previous pulses of the same reactivity value or the reactor shall not be pulsed until such comparative pulse measurements are performed.

Bases

The reactivity worth of the control rods is measured to assure that the required shutdown margin is available and to provide an accurate means for determining the reactivity worths of experiments inserted in the core. Long term effects of TRIGA reactor operation are such that measurement of the reactivity worth on an annual basis is adequate to insure no significant changes in the shutdown margin. The visual inspection of the control rods is made to evaluate corrosion and wear characteristics caused by operation in the reactor. The reactor is pulsed at suitable intervals and a comparison made with previous similar pulses to determine if changes in fuel or core characteristics are taking place.

4.2.2 Control and Safety System

Applicability

These specifications apply to the surveillance requirements for measurements, tests, and calibrations of the control and safety systems.

Objective

The objective is to verify the performance and operability of those systems and components which are directly related to reactor safety.

Specifications

a. The scram time shall be measured annually, but at intervals not to exceed 14 months.

b. A channel test of each of the reactor safety scram channels for the intended mode of operation shall be performed prior to each day's operation or prior to each operation extending more than one day.

c. A functional check of all safety channels listed in section 3.4.3 shall be performed semiannually, but at intervals not to exceed 8 months.

d. A Channel Calibration shall be made of the power level monitoring channels by the calorimetric method annually, but at intervals not to exceed 14 months.

e. A test of the power level safety circuits shall be performed semiannually, but at intervals not to exceed 8 months.

Bases

Measurement of the scram time on an annual basis is a check not only of the scram system electronics, but also is an indication of the capability of the control rods to perform properly. The channel tests will assure that the safety system channels are operable on a daily basis or prior to an extended run. The power level channel calibration will assure that the reactor will be operated at the proper power levels. Transient control rod checks and semiannual maintenance insure proper operation of this control rod.

4.2.3 Radiation Monitoring System

Applicability

This specification applies to the surveillance requirements for the area radiation monitoring equipment and the continuous air monitoring system.

Objective

The objective is to assure that the radiation monitoring equipment is operating and to verify the appropriate alarm settings.

Specification

The area radiation monitoring system, the continuous air monitoring system, and the exhaust monitoring system shall be calibrated semi-annually, but at intervals not to exceed 8 months, and shall be verified to be operable at weekly intervals not to exceed 9 operating days.

Basis

Frequent inspection by weekly verification of area radiation and an air monitoring system set points, in conjunction with semi-annual calibration is adequate to correct for any variation in the system due to a change of operating characteristics over a long time span.

4.2.4 Pool Water Systems

Applicability

This specification applies to the reactor pool water tank, heat exchanger cooling system and purification system.

Objective

The objective is to maintain pool water level and quality to assure adequate core cooling, core radiation shielding, and control of water corrosion and activation properties.

Specification

a. Pool water conductivity shall be sampled at least weekly. The conductivity shall not exceed 6 micromhos per centimeter averaged over a month.

b. The reactor normal pool level shall be verified daily when the heat exchanger chilled water inlet and outlet block valves are open.

c. During periods when operators are not present in the laboratory, the heat exchanger primary pump will be shut down and the chilled water inlet and outlet block valves closed.

Bases

The specification for pool water conductivity assures that potential corrosion products and water activation are controlled at acceptable levels.

The specifications on heat exchanger operation establish that reactor pool level conditions are monitored by qualified personnel to detect abnormal operation.

4.2.5 Experiment and Irradiation Limits

Applicability

This specification applies to the surveillance requirements for experiments installed in the reactor and its experimental facilities and for irradiations performed in the irradiation facilities.

Objective

The objective is to prevent the conduct of experiments or irradiations which may damage the reactor or release excessive amounts of radioactive materials as a result of failure.

Specifications

a. A new experiment shall not be installed in the reactor or its experimental facilities until a hazards analysis has been performed and reviewed for compliance with the Limitations on Experiments, Section 3.7, by the Reactor Committee. Minor modifications to a reviewed and approved experiment may be made at the discretion of the senior reactor operator responsible for the operation provided that the hazards associated with the modifications have been reviewed and a determination made and documented that the modifications do not create a significantly different, a new, or a greater hazard than the original approved experiment.

b. An irradiation of a new type of device or material shall not be performed until an analysis of the irradiation has been performed and reviewed for compliance with the Limitations on Irradiations, Section 3.7, by the Reactor Supervisor.

Bases

The procedure of administrative review of experiments and irradiations by the reactor staff and reactor committee as appropriate, monitors reactor utilization so that reactor operation is conducted without endangering the safety of the reactor or exceeding the limits of the Technical Specifications.

4.3 REACTOR FUEL ELEMENTS

Applicability

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

Objective

The objective is to verify the continuing integrity of the fuel element cladding.

Specifications

All fuel elements shall be inspected visually for damage or deterioration and measured for length and bend after the first 100 pulses and then after each 500 pulses thereafter. The maximum interval between inspections of fuel elements shall be no greater than two years. The reactor shall not be operated with damaged fuel. A fuel element shall be considered damaged and must be removed from the core if:

a. In measuring the tranverse bend, the bend exceeds the original bend by 1/16 inch, or

b. In measuring the elongation, its length exceeds the original length by 1/10 inch, or

c. A clad defect exists as indicated by release of fission products.

Bases

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.

5.0 DESIGN FEATURES

5.1 REACTOR FUEL

Applicability

This specificiation 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.

Specifications

Standard TRIGA fuel

The individual unirradiated standard TRIGA fuel elements shall have the following characteristics:

(1) Uranium content: 8.5 Wt-% uranium enriched to a nominal 20% Uranium-235.

(2) Zirconium hydride atom ratio: nominal 1.6 hydrogen-to-zirconium, ZrH_x.

(3) Cladding: 304 stainless steel, nominal .020 inches thick.

Bases

The Design basis of the standard TRIGA core demonstrates that 250 kilowatt steady or 20 megawatt-sec pulse operation presents a conservative limitation with respect to safety limits for the maximum temperature generated in the fuel. The fuel temperatures are not expected to exceed 450°C during any condition of normal operation.

5.2 REACTOR CORE

Applicability

This specification applies to the configuration of fuel and in-core experiments.

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.

Specifications

a. The core shall be an arrangement of TRIGA uranium-zirconium hydride fuel-moderator elements positioned in the reactor grid plate.

b. The TRIGA core assembly shall be the standard TRIGA fuel.

c. Single positions may be occupied by control rods, neutron startup source, ionization chamber, voids, in-core experimental facilities, or graphite reflector elements.

Bases

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

5.3 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 or reliability with respect to their physical and nuclear characteristics.

Specification

a. The shim control rod shall have scram capability and 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 regulating control rod shall have scram capability and contain the materials as specified for the shim control rod.

c. The transient control rod shall have scram capability and contain borated graphite or boron and its compounds in a solid form as a poison in an aluminum or stainless steel clad. The transient rod shall have an adjustable upper 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.

5.4 RADIATION MONITORING SYSTEM

Applicability

This specification describes the functions 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

The radiation monitoring equipment listed in the following table will be available for reactor operation.

Radiation Monitoring Channel and Function

Area Radiation Monitor (gamma sensitive instruments)
Function - Monitor radiation fields in key locations with alarm and readout at control console

Continuous Air Radiation Monitor (beta, gamma sensitive detector with air particulate collection capability)
Function - Monitor concentration of radioactive particulate activity in the reactor room with alarm and readout available to operator.

Basis

The radiation monitoring system is intended to provide information to operating personnel of any impending or existing danger from radiation so that there will be sufficient time to evacuate the facility and take the necessary steps to prevent the spread of radioactivity to the surroundings.

5.5 FUEL 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 which is being stored will not become critical and will not reach an unsafe temperature.

Specifications

a. All fuel elements shall be stored in a geometrical array where the k-effective is less than 0.8 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.

Basis

The limits imposed by Specifications 5.5a and 5.5b are conservative and assure safe storage.

5.6 REACTOR POOL WATER SYSTEMS

Applicability

This specification applies to the pool containing the reactor and to the cooling of the core by the pool water.

Objective

The objective is to assure that coolant water shall be available to provide adequate cooling of the reactor core and adequate radiation shielding.

Specifications

a. The reactor core shall be cooled by natural convective water flow.

b. The pool water inlet and outlet pipes to the water purification system shall not extend more than 4.5 meters below the top of the reactor pool when fuel is in the core.

c. Pool water inlet and outlet pipes to the heat exchanger shall not extend more than 4.5 meters below the top of the reactor pool when fuel is in the core.

Bases

a. This specification is based on thermal and hydraulic calculations which show that a standard 63 element TRIGA core can operate in a safe manner at power levels up to 1,700 kW with natural convection flow of the coolant water.

b. In the event of accidental pumping with no return of pool water through inlet and outlet pipes of the purification system, the pool water level will drop no more than 4.5 meters from the top of the pool.

c. In the event of accidental pumping with no return of pool water through the heat exchanger water system, the pool water level will drop no more than 4.5 meters from the top of the pool.

5.7 REACTOR FACILITY VENTILATION SYSTEM

Applicability

This specification applies to the room which houses the reactor.

Objective

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

Specifications

a. The reactor shall be housed in a closed room which has been modified to restrict leakage. The minimum volume in the reactor room shall be approximately 680 cubic meters.

b. The laboratory air ventilating system shall be contained and shall circulate air within the confines of the reactor room. Air and exhaust gases from the reactor room shall be released to the environment only as a result of leakage through doors, etc.

c. The pneumatic transfer system shall be a closed loop carbon dioxide filled system.

Bases

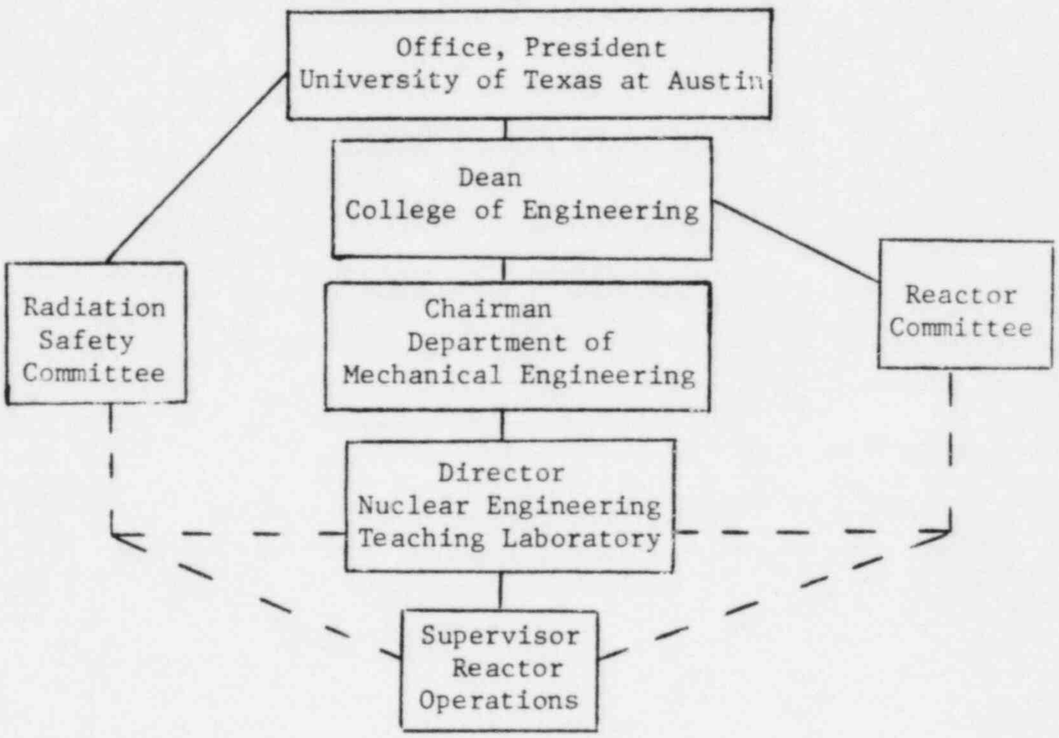
The facility is designed such that the ventilation system in the event that excessive airborne radioactivity is detected the ventilation system shall be shutdown to minimize transport of airborne materials. Analysis indicates that in the event of a major fuel element failure personnel would have sufficient time to evacuate the facility before the 40 hour week occupational dose is exceeded.

6.0 ADMINISTRATIVE CONTROLS

6.1 ORGANIZATION

a. The facility shall be under the direct control of the Director or a licensed senior operator designated by him to be in direct control. The Director shall be responsible to the Dean of the College of Engineering and the Chairman of the Department of Mechanical 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. He shall enforce rules for the protection of personnel from radiation.

b. The safety of operation of the Nuclear Engineering Teaching Laboratory shall be related to the University Administration as shown in the following chart.



6.2 REVIEW AND AUDIT

a. A Reactor Committee of at least three (3) members knowledgeable in fields which relate to Nuclear Safety shall review, evaluate, and approve safety standards associated with the operation and use of the facility. The University Radiological Safety Officer shall be an ex-officio member of the Reactor Committee. The jurisdiction of the Committee shall include all nuclear operations in the facility and general safety standards.

b. The operations of the Reactor Committee shall be in accordance with a written charter, including provisions for:

(1) Meeting frequency,

(2) Voting rules,

(3) Quorums,

(4) Method of submission and content of presentation to the Committee,

(5) Use of subcommittees, and

(6) Review, approval, and dissemination of minutes.

c. The Committee thereof shall audit reactor operations at least quarterly, but at intervals not to exceed four months.

d. The responsibilities of the Committee thereof include, but are not limited to, the following:

(1) Review and approval of experiments utilizing the reactor facilities;

(2) Review and approval of all proposed changes to the facility, procedures, and Technical Specifications;

(3) Review of the operation and operational records of the facility;

(4) Review of unusual or abnormal occurrences and incidents which are reportable under 10 CFR Part 20 and 10 CFR Part 50;

(5) Determination of whether a proposed change, test, or experiment would constitute an unreviewed safety question or a change in the Technical Specifications; and

(6) Review of abnormal performance of facility equipment and operating anomalies.

6.3 ACTION TO BE TAKEN IN THE EVENT A SAFETY LIMIT IS EXCEEDED

In the event a safety limit is exceeded:

a. The reactor shall be shut down and reactor operation shall not be resumed until authorized by the NRC;

b. An immediate report of the occurrence shall be made to the Chairman, Reactor Committee, and reports shall be made to the NRC in accordance with Section 6.7 of these specifications; and

c. A report shall be prepared which shall include an analysis of the causes and extent of possible resultant damage, efficacy of corrective action, and recommendations for measures to prevent or reduce the probability of recurrence. This report shall be submitted to the Reactor Committee for review and then submitted to the NRC when authorization is sought to resume operation of the reactor.

6.4 ACTION TO BE TAKEN IN THE EVENT OF A REPORTABLE OCCURRENCE

In the event of a reportable occurrence, the following action shall be taken:

a. The Director or his designated alternate shall be notified and corrective action taken with respect to the operations involved;

b. The Director or his designated alternate shall notify the Chairman of the Reactor Committee;

c. A report shall be made to the Reactor Committee which shall include an analysis of the cause of the occurrence, efficacy of corrective action, and recommendations for measures to prevent or reduce the probability of recurrence; and

d. A report shall be made to the NRC in accordance with Section 6.7 of these specifications.

6.5 OPERATING PROCEDURES

Written operating procedures shall be adequate to assure the safety of operation of the reactor, but shall not preclude the use of independent judgement and action should the situation require such. Operating procedures shall be in effect for the following items:

a. Testing and calibration of reactor operating instrumentation and controls, control rod drives, area radiation monitors, and air particulate monitors;

b. Reactor startup, operation, and shutdown;

c. Emergency and abnormal conditions, including provisions for evacuation, reentry, recovery, and medical support;

d. Fuel element and experiment loading or unloading;

e. Control rod removal or replacement;

f. Routine maintenance of the control rod drives and reactor safety and interlock systems or other routine maintenance that could have an effect on reactor safety;

g. Actions to be taken to correct specific and foreseen potential malfunctions of systems or components, including responses to alarms and abnormal reactivity changes; and

h. Civil disturbances on or near the facility site.

Substantive changes to the above procedures shall be made only with the approval of the Reactor Committee. Temporary changes to the procedures that do not change their original intent may be made by the Director or his designated alternate. All such temporary changes shall be documented and subsequently reviewed by the Reactor Committee.

6.6 FACILITY OPERATING RECORDS

In addition to the requirements of applicable regulations, and in no way substituting therefore, records and logs shall be prepared of at least the following items and retained for a period of at least five years for items a through f and indefinitely for items g through k.

a. Normal reactor operation,

b. Principal maintenance activities,

c. Reportable occurrences,

d. Equipment and component surveillance activities required by the Technical Specifications,

e. Experiments performed with the reactor,

f. Gaseous and liquid radioactive effluents released to the environs,

g. Any offsite environmental monitoring surveys,

h. Fuel inventories and transfers,

i. Facility radiation and contamination surveys,

j. Radiation exposures for all personnel, and

k. Updated, corrected, and as-built drawings of the facility.

6.7 REPORTING REQUIREMENTS

In addition to the requirements of applicable regulations, and in no way substituting therefor, reports shall be made to the NRC Region IV, Office of Inspection and Enforcement as follows.

a. A report within 24 hours by telephone and telegraph of:

(1) Any accidental release of radioactivity above permissible limits in unrestricted areas whether or not the release resulted in property damage, personal injury, or exposure;

(2) Any violation of the safety limit; and

(3) Any reportable occurrences as defined in Section 1.8 of these specificiations.

b. A report within 10 days in writing of:

(1) Any accidental release of radioactivity above permissible limits in unrestricted areas whether or not the release resulted in property damage, personal injury, or exposure. The written report (and, to the extent possible, the preliminary telephone or telegraph report) shall describe, analyze, and evaluate safety implications, and outline the corrective measures taken or planned to prevent reoccurrence of the event;

(2) Any violation of a safety limit; and

(3) Any reportable occurrence as defined in Section 1.8 of these specifications.

c. A report within 30 days in writing of:

(1) Any significant variation of measured values from a corresponding predicted or previously measured value of safety-connected operating characteristics occurring during operation of the reactor;

(2) Any significant change in the transient or accident analysis as described in the Safety Analysis Report;

(3) Any changes in facility organization; and

(4) Any observed inadequacies in the implementation of administrative or procedural controls.

6.7.1 A report within 90 days after completion 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.

6.7.2 An annual report covering the operation of the unit during the previous calendar year submitted prior to March 31 of each year providing the following information.

a. A brief narrative summary of: (1) operating experience (including experiments performed), (2) changes in facility design, performance characteristics, and operating procedures related to reactor safety and occurring during the reporting period, and (3) results of surveillance tests and inspections;

b. Tabulation of the energy output (in megawatt days) of the reactor hours the reactor was critical, and the cumulative total energy output since initial criticality;

c. The number of emergency shutdowns and inadvertent scrams, including reasons therefore;

d. Discussion of the major maintenance operations performed during the period, including the effect, if any, on the safety of the operation of the reactor and the reasons for any corrective maintenance required;

e. A brief description, including a summary of the safety evaluations of changes in the facility or in procedures and of tests and experiments carried out pursuant to Section 50.59 of 10 CFR Part 50;

f. A summary of the nature and amount of radioactive effluents released or discharged to the environs beyond the effective control of the licensee as calculated or measured at or prior to the point of such release or discharge.

Liquid Waste(summarized on a monthly basis)

(1) Radioactivity discharged during the reporting period.

(a) Total radioactivity released (in curies).

(b) The MPC used and the isotopic composition if greater than 1×10^{-7} microcuries/cc for fission and activation products.

(c) Average concentration at point of release (in microcuries/cc) during the reporting period.

(2) Total volume (in gallons) of effluent water (including diluent) released during each period of release.

Gaseous Waste (summarized on a monthly basis)

Radioactivity discharged during the reporting period (in curies):

(a) Total estimated quantity of radioactivity released (in curies);

(b) Total estimated quantity of Argon-41 released (in curies) during the reporting period;

(c) Estimated average atmospheric-diluted concentration of Argon-41 released during the reporting period in terms of microcuries/cc and fraction of the applicable MPC value;

(d) Total estimated quantity of radioactivity in particulate form with half lives greater than eight days (in curies) released during the reporting period;

(e) Average concentration of radioactive particulates with half lives greater than eight days released in microcuries/cc during the reporting period; and

(f) An estimate of the average concentration of other significant radionuclides present in the gaseous waste discharge in terms of microcuries/cc and fraction of the applicable MPC value for the reporting period if the estimated release is greater than 20% of the applicable MPC.

Solid Waste(summarized on an annual basis)

(1) Total amount of solid waste packaged (in cubic feet)

(2) Total activity in solid waste (in curies)

(3) The dates of shipment and disposition (if shipped off site).

g. An annual summary of the radiation exposure received by facility personnel and visitors in terms of the average radiation exposure per individual and greatest exposure per individual in the two groups. Each significant exposure in excess of the limits of 10 CFR 20 should be reported including the time and date of the exposure as well as the name of the individual and the circumstances leading up to the exposure;

h. An annual summary of the radiation levels and levels of contamination observed during routine surveys performed at the facility in terms of the average and highest levels; and

i. An annual summary of any environmental surveys performed outside the facility.