APPENDIX A

TECHNICAL SPECIFICATIONS

Michigan State University

TRIGA Reactor

Revision 2

August, 1984

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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.

The dimensions, measurements and other numerical values given in these specifications may differ from measured values owing to normal construction and manufacturing tolerances, or normal accuracy of instrumentation.

1.0 DEFINITIONS

REACTOR OPERATING CONDITIONS

1.1 REACTOR SHUTDOWN

The reactor is shut down when the reactor is subcritical by at least 0.7% $\Delta K/K$ or $1.00.

1.2 REACTOR SECURED

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

a. The reactor is shut down;

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 50°C.

1.5 NONPULSING MODE

Nonpulsing mode operation shall mean operation of the reactor with the mode selector switch in the manual 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.

1.8 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.

1.9 REPORTABLE OCCURRENCE

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

a. Operation with any safety system setting less conservative that 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

1.10 EXPERIMENT

Any operation, hardware, 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 a part of their design. The MSU Reactor irradiations include exposure of samples to neutrons and/or gamma radiation in either the rotary specimen rack, central thimble or other experimental assembly.

1.11 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 forces 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.

1.12 MOVEABLE EXPERIMENT

A moveable 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.

1.13 EXPERIMENTAL FACILITIES

Experimental facilities shall mean in-core irradiation positions including the central thimble, the rotary sample rack, and in-pool irradiation facilities.

REACTOR COMPONENTS

1.14 SHIM ROD

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

1.15 SAFETY-TRANSIENT ROD

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

1.16 REGULATING ROD

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

1.17 FUEL ELEMENT

A fuel element is a single TRIGA fuel rod of standard type.

1.18 INSTRUMENTED ELEMENT

An instrumented element is a special fuel element in which a sheathed chromel-alumel or equivalert thermocouple is embedded in the fuel at the vertical center plane of the fuel element. More than one thermocouple may be located in each element.

1.19 STANDARD CORE

A standard core is an arrangement of standard and/or instrumented TRIGA fuel in the reactor grid plate. (Refer to Sec. 5.1)

1.20 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

1.21 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.

1.22 LIMITING SAFETY SYSTEM SETTING

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

1.23 OPERABLE

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

1.24 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.

1.25 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.

1.26 MEASURED VALUE

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

1.27 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.

1.28 SAFETY CHANNEL

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

1.29 CHANNEL CHECK

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

1.30 CHANNEL TEST

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

1.31 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 SAFETY SYSTEM SETTINGS

2.1 SAFETY LIMIT-FUEL ELEMENT TEMPERATURE

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 (Refer to Sec. 5.1) 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 specification 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 data, including the large mass of experimental evidence, obtained during high performance reactor tests on this fuel. These data 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 1830°F (1000°C) and the fuel cladding is water cooled.

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.

Specifications

The limiting safety system setting shall be 450°C as measured in an instrumented fuel element relative to the ambient temperature. Instrument element shall be located in the B or C ring of the core configuration.

Bases

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 500°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 fuel 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 would be no greater than 900°C providing a margin to the safety limit of at least 100°C for standard fuel elements. This margin is ample 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 nonpulsing 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 power 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 NONPULSING OPERATION

Applicability

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

Objective

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

Specifications

The reactor power level shall not exceed 275 kilowatts under any condition of operation. The reactor shall not be operated deliberately above 250 kw in the nonpulsing mode under any conditions.

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 convective 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

a. The reactor shall not be operated unless the shutdown margin provided by control rods shall be greater than 0.4% $\Delta K/K$ with:
   (1) the highest worth non-secured experiment in its most reactive state,
   (2) the highest worth control rod fully withdrawn; and
   (3) the reactor in the cold critical condition without Xenon.
b. The excess reactivity above cold critical, without Xenon, shall not exceed 2.25% $\Delta K/K$ with experiments in place.

c. The maximum rate of reactivity insertion associated with movement of a standard control rod shall be no greater than 0.2% $\Delta K/K$/sec.

Bases

a. 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.

b. The value for maximum excess reactivity provides an adequate margin for experiment insertion while minimizing the possibility of exceeding the safety limits.

c. The limit on maximum rate of reactivity insertion assures that achieving super-criticality is dependent upon prompt and delayed neutrons rather than prompt neutrons alone.

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.

Specifications

a. 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 1.4% $\Delta K/K$.

b. Fuel temperature near the core midplane in either B or C ring of elements shall be continuously recorded during the pulse mode of operation using a standard instrumented fuel element. The reactor shall not be operated in a manner which would cause the measured fuel temperature to exceed 500°C.

c. Power levels during pulse mode operation that exceed 300 megawatts shall be cause for the reactor to be shut down pending an investigation by the reactor supervisor to determine the reason for the pulse power magnitude. His evaluation and conclusions as to the reason for the pulse magnitude shall be submitted to the Reactor Safety Committee for review. Pulse mode operation will not be resumed until approved by the Committee.

d. A pulse may be initiated only when the reactor is at a power level less than 1 kilowatt.

Bases

a. Measurements performed on the Puerto Rico Nuclear Center TRIGA-FLIP reactor indicated that a pulse insertion of reactivity of 1.4% $\Delta K/K$ resulted in a maximum temperature rise of approximately 400°C.

With an ambient water temperature of approximately 100°C, the maximum fuel temperature would be approximately 500°C resulting in a safety margin of 500°C for standard fuel. This margin allows amply for uncertainties due to the accuracy of measurement or location of the instrumented fuel element or due to the extrapolation of data from the PRNC reactor.

b. Continuous monitoring of the fuel temperature assures that the safety limit was not exceeded during a pulse.

c. Limiting the pulse power levels minimizes the possibility of fuel damage and the likelihood that the safety limit will be exceeded.

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 fully inserted 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.

Specifications

The scram time measured from the instant a simulated signal reaches the value of the LSSS to the instant that the control rod reaches its fully inserted position shall not exceed 2 seconds for the pulse (transient) rod and 1 second for the regular and shim rods.

Bases

This specification assures that the reactor will be promptly shut down when a scram signal is initiated. Experience 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 channels monitoring the reactor core, which must provide information 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.

Specifications

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

Measuring Channel	Min. No. Operable	Effective Mode N.P.	Effective Mode Pulsing
Fuel element Temperature	1	X	X
Linear Power Level	1	X	
% Power Level	1	X	
Integrated Pulse Power	1		X

Bases

Fuel temperature displayed at the control console gives continuous information on this parameter which has a specified safety limit. The power level monitors assure that the reactor power level is adequately monitored for both nonpulsing and pulsing modes of operation. The specifications on reactor power level indication are included in this section since the power level is related to the fuel temperature.

3.4.3 Reactor Safety System

Applicability

This specification applies to the reactor safety system channels.

TABLE 1

Minimum Reactor Safety Channels

Safety Channel	Number Operable	Function	Effective Mode N.P.	Effective Mode Pulse
Fuel Element Temperature	1	SCRAM @ LSSS	X	X
Linear (Power Level)	1	SCRAM @ 110% of scale	X	
% Power Level	1	SCRAM @ 110% of full power	X	
Console Scram Bar	1	SCRAM	X	X
Detector Power Supply (High Voltage)	1	SCRAM on loss of supply voltage	X	
Preset Timer	1	Transient rod scram 15 seconds or less after pulse		X
Shim & Regulating Rod Position	1	Prevent withdrawal		X
Start-up Channel	1	Prevent shim or regulating rod withdrawal with less than 2 neutron induced counts per second	X	
Shim & Regulating Rod Controls	1	Prevent simultaneous withdrawal	X	
NV/NVT SCRAM	1	Prevent excessive power during a pulse		X
Pulse Rod Interlock	1	Prevent withdrawal of pulse rod when shim and/or regulating rod are off the bottom	X	

Objective

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

Specifications

The reactor shall not be operated unless the safety channels described in Table 1 are operable.

Bases

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. The manual scram allows the operator to shut down the system if an unsafe or abnormal condition occurs. In the event of failure of the power supply for the safety chambers, operation of the reactor without adequate instrumentation is prevented. The preset timer assures that the reactor power level will reduce to a low level after pulsing.

The interlock to prevent startup of the reactor at neutron count rates less than 2 cps, which corresponds to approximately 2.5×10^{-4} watts, assures that sufficient neutrons are available for proper startup.

The interlock to prevent withdrawal of the shim or regulating rod in the pulse mode is to prevent the reactor from being pulsed while on a positive period.

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.

Specifications

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

Radiation Monitoring Channels[1]	Function	No.
Area Radiation Monitor	Monitor radiation levels within the reactor room	1
Continuous Air Radiation Monitor	Monitor radiation levels within the reactor room and in exhaust stream	1

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 ARGON-41 DISCHARGE LIMIT

Applicability

This specification applies to the concentration of Argon-41 that may be discharged from the TRIGA reactor facility.

Objective

To insure that the health and safety of the public is not endangered by the discharge of Argon-41 from the TRIGA reactor facility.

Specifications

The concentration of Argon-41 in the effluent gas from the facility as diluted by atmospheric air in the lee of the facility due to the turbulent wake effect shall not exceed 4.8×10^{-8} µCi/ml averaged over one year.

Bases

The maximum allowable concentration of Argon-41 in air in unrestricted areas as specified in Appendix B, Table II of 10 CFR 20 is 4.8×10^{-8} µCi/ml.

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1 For periods of time for maintenance to the radiation monitoring channels, the intent of this specification will be satisfied if they are replaced with portable gamma sensitive instruments having their own alarms or which shall be kept under visual observation.

3.7 ENGINEERED SAFETY FEATURE - VENTILATION SYSTEM

Applicability

This specification applies to the operation of the facility ventilation system.

Objective

The objective is to assure that the ventilation system is in operation to mitigate the consequences of the possible release of radioactive materials resulting from reactor operation.

Specifications

The reactor shall not be operated unless the facility ventilation system is operable except for periods of time necessary to permit repair of the system. In the event of a substantial release of airborne radioactivity, the ventilation system will be secured automatically by a signal from an exhaust air radiation monitor.

Bases

During normal operation of the ventilation system, the concentration of AR-41 in unrestricted areas is below MPC. In the event of a clad rupture resulting in a substantial release of airborne particulate radioactivity, the ventilation system will be diverted through an absolute filter. Moreover, radiation monitors within the laboratory independent of those in the ventilation system will give warning of high levels of radiation that might occur during operation with the ventilation system secured.

3.8 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 materials 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 0.7% $\Delta K/K$.

b. The reactivity worth of any single experiment shall be less than 1.4% ΔK/K. The total reactivity worth of in-core experiments shall not exceed 2.1% ΔK/K.

c. Experiment materials, except fuel materials, which could off-gas, sublime, volatilize, or produce aerosols under (1) normal op ting 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 atmosphere, the airborne concentration of radioactivity averaged over a year would not exceed the limit of Appendix B of 10 CFR Part 20.

d. In calculations pursuant to (c) 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 lest 10% of these vapors can escape.

   (3) For materials whose boiling point is above 130°F and where vapors formed by boiling this material can escape only through an undisturbed column of water above this core, at least 10% of these vapors can escape.

e. 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.

f. If a capsule fails and releases material which could damage the reactor fuel or structure by corrosion or other means, removal and physical inspection of appropriate core components 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 Reactor

Safety Committee and the Reactor Supervisor or his designated alternate and determined to be satisfactory before operation of the reactor is resumed.

g. Experiments containing materials corrosive to reactor components, compounds highly reactive with water, or liquid fissionable materials shall be doubly encapsulated.

h. Explosive materials such as (but not limited to) dynamite, TNT, nitroglycerine or PETN shall not be irradiated in the reactor or experimental facilities.

Bases

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 suddenly inserted.

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. 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.

d. 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 exhaust vent will be less than that allowed by 10 CFR Part 20 for an unrestricted area.

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

f. Double encapsulation minimizes the chance of contaminating the irradiation facilities or causing structural damage to the irradiation facilities.

g. Explosive material will not be irradiated in order to prevent the possibility of an explosion which might damage the core components.

3.9 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. The surveillance requirements for irradiations are given in Section 4.3.5.b.

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 3.8 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 0.175% $\Delta K/K$ 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 Safety Committee. A system shall not be considered operable until after it is successfully tested. A licensed reactor operator shall be present during maintenance of the reactor control and safety system.

Bases

This specification relates to changes in reactor systems which could directly 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 SAFETY LIMIT - FUEL ELEMENT TEMPERATURE

Applicability

This specification applies to the surveillance requirements of the fuel element temperature measuring channel.

Objective

The objective is to assure that the fuel element temperatures are properly monitored.

Specifications

a. Whenever a reactor scram caused by high fuel element temperature occurs, an evaluation shall be conducted to determine whether the fuel element temperature safety limit was exceeded.

b. A Channel Check of the fuel element temperature measuring channel shall be made quarterly whenever the reactor is operated by recording a measured value of a meaningful temperature indication.

Bases

Operational experience with the TRIGA system gives assurance that the thermocouple measurements of fuel element temperatures have been sufficiently reliable to assure accurate indication of this parameter.

4.3 LIMITING CONDITIONS FOR OPERATION

4.3.1 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 an experiment shall be estimated or measured, as appropriate, before reactor operation with said experiment.

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

c. The transient rod drive cylinder and associated air supply system shall be inspected, cleaned and lubricated as necessary semi-annually at intervals not to exceed 8 months.

d. The reactor shall be pulsed semi-annually at intervals not to exceed 8 months 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 for any other purpose until such comparative pulse measurements are performed.

Bases

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. Transient control rod checks and semi-annual maintenance insure proper operation of this control rod.

4.3.2 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 system 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 Channel Calibration shall be made of the power level monitoring channels by the calorimetric method annually but at intervals not to exceed 14 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 levels.

4.3.3 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.

Specifications

The area radiation monitoring system and the continuous air monitoring system shall be calibrated annually but at intervals not to exceed 14 months and shall be verified to be operable at weekly intervals.

Bases

Experience has shown that weekly verification of area radiation and air monitoring system set points in conjunction with annual calibration is adequate to correct for any variation in the system due to a change of operating characteristics over a long time span.

4.3.4 Ventilation System

Applicability

This specification applies to the building confinement ventilation system.

Objective

The objective is to assure the proper operation of the ventilation system in controlling releases of radioactive material to the uncontrolled environment.

Specifications

It shall be verified weekly that the ventilation system is operable in both normal and emergency conditions.

Bases

Experience accumulated over several years of operation has demonstrated that the tests of the ventilation system on a weekly basis are sufficient to assure the proper operation of the system and control of the release of radioactive material.

4.3.5 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 radiative 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 3.8, by the Reactor Safety 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 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 3.9, by a licensed senior operator qualified in health physics, or a licensed senior operator and a person qualified in health physics.

Bases

It has been demonstrated over a number of years of experience that experiments and irradiations reviewed by the Reactor Staff and the Reactor Safety Committee as appropriate can be conducted without endangering the safety of the reactor or exceeding the limits in the Technical Specifications.

4.4 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 in the reactor core (except instrumented) shall be measured for length and bend at intervals not to exceed the sum of 25% ΔK/K in pulse reactivity or 3 years, whichever comes first. 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 transverse bend, the bend exceeds 0.125 inch over the length of the cladding;
b. In measuring the elongation, its length exceeds its original length by 0.25 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 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.

Specifications

Standard TRIGA fuel

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

a. Uranium content: maximum of 12.0 Wt% enriched to a nominal 19.9% Uranium 235.

b. Hydrogen-to-zirconium atom ratio (in the ZrH_x): maximum 1.7 H atoms.

c. Cladding: 304 stainless steel, nominal 0.020 inch thick.

Bases

A maximum uranium content of 12 Wt% in a standard TRIGA element is about 41% greater than the design value of 8.5 Wt%. Such an increase in loading results in an increase in local power density of approximately 41%. An increase in local power density of 41% reduces the safety margin by at most 15%. The maximum hydrogen-to-zirconium ratio of 1.7 will produce a maximum pressure within the clad during an accident well below the rupture strength of the clad.

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 reactor shall not be operated with a core lattice position vacant except for

   (1) replacement of single individual elements with in-core irradiation facilities of control rods;

   (2) two separated experiment positions in the D through E rings, each occupying a maximum of three fuel element positions; or

   (3) positions on the periphery of the core assembly.

c. The reflector, excluding experiments and experimental facilities, shall be a combination of graphite and water.

Bases

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

b. Vacant core lattice positions will contain experiments or an experimental facility to prevent accidental fuel additions to the reactor core. They will be permitted only on the periphery of the core to prevent power perturbations in regions of high power density.

c. The core will be assembled in the reactor grid plate which is located in a pool of light water. Water in combination with graphite reflectors can be used for neutron economy and the enhancement of experimental facility radiation requirements.

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 of reliability with respect to their physical and nuclear characteristics.

Specifications

a. The shim and regulating control rods 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 safety-transient rod shall have scram capability and contain borated graphite or boron and its compounds in a solid form as a poison in aluminum or stainless steel clad. The safety-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 safety-transient 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.

Specifications

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, alarm and readout at control console.

Continuous Air Radiation Monitor (beta, gamma sensitive detector with air collection capability)

Function - Monitor concentration of radioactive particulate activity in building, alarm and readout at control console.

Gas (Ar^{41}) Radiation Monitor (gamma sensitive detector with air collection capability)

Function - Monitor concentration of radioactive gases in building exhaust, readout at control console.

Bases

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.

Bases

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

5.6 REACTOR BUILDING AND VENTILATION SYSTEM

Applicability

This specification applies to the building 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 facility designed to restrict leakage. The minimum free volume in the facility shall be 2×10^8 cubic centimeters.

b. The reactor laboratory shall be equipped with a ventilation system designed to filter and exhaust air or other gases from the reactor laboratory and release them from a stack at a minimum of 13.7 meters from ground level. The filter shall be used during emergency situations specified by the continuous air monitor or by the operator.

c. Emergency filtering controls for the ventilation system shall be located in the control room and the system shall be designed to filter in the event of a substantial release of fission products.

Bases

The facility is designed such that the ventilation system will normally maintain a negative pressure with respect to the atmosphere so that there will be no uncontrolled leakage to the environment. The free air volume within the reactor laboratory is confined when emergency filtering is being performed. Controls for emergency filtering and normal operation of the ventilation system are located in the control room. Proper handling of airborne radioactive materials (in emergency situations) can be conducted from the control room with a minimum of exposure to operating personnel.

5.7 REACTOR POOL WATER SYSTEM

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 pipe to the demineralizer and heat exchanger 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 to the demineralizer and heat exchanger shall have vacuum breaker holes machined into the pipe no more than one meter below the top of the reactor pool, in case of pool water loss due to external pipe system failure.
d. The reactor shall not be operated if the pool water level is less than 5.48 meters above the top grid plate of the core.
e. The bulk pool temperature shall be monitored while the reactor is in operation and the reactor shall be shut down if the temperature exceeds 50°C.
f. The pool water shall be sampled for conductivity at least weekly. Conductivity averaged over a month shall not exceed 5 micromhos per centimeter.

Bases

a. This specification is based on thermal and hydraulic calculations which show that the TRIGA core can operate in a safe manner at power levels up to 2,700 kW with natural convection flow of the coolant water.

b. In the event of accidental siphoning of pool water through inlet and outlet pipes of the demineralizer and heat exchanger system, the pool water level will drop no more than 4.5 meters from the top of the pool.

c. In the event of external pipe system failure, the vacuum breaker holes machined into the pipe will cause the cessation of water pumping after the loss of not more than one meter of water.

d. This specification assures that adequate shielding is provided by the pool water while the reactor is operated.

e. The water conductivity is an indicator of the water purity and can be used to monitor for the leakage of ground water into the tank. Maintaining low conductivity readings should allow early detection of leaks of this type. Another reason to maintain low conductivity is to insure low ion or mineral concentration in the water. Thus there is only a small likelihood of inducing activity in the mineral ions which are in the solution. The result is to limit the radiation levels experienced in the reactor room.

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6.0 ADMINISTRATIVE CONTROLS

6.1 ORGANIZATION

a. The facility shall be under the direct control of the Reactor Supervisor or a licensed senior operator designated by him to be in direct control. The Supervisor shall be responsible to the Dean of the College of Engineering and the Associate Dean for Graduate Studies and Research for safe operation and maintenance of the reactor and its associated equipment. The Supervisor 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 against radiation.

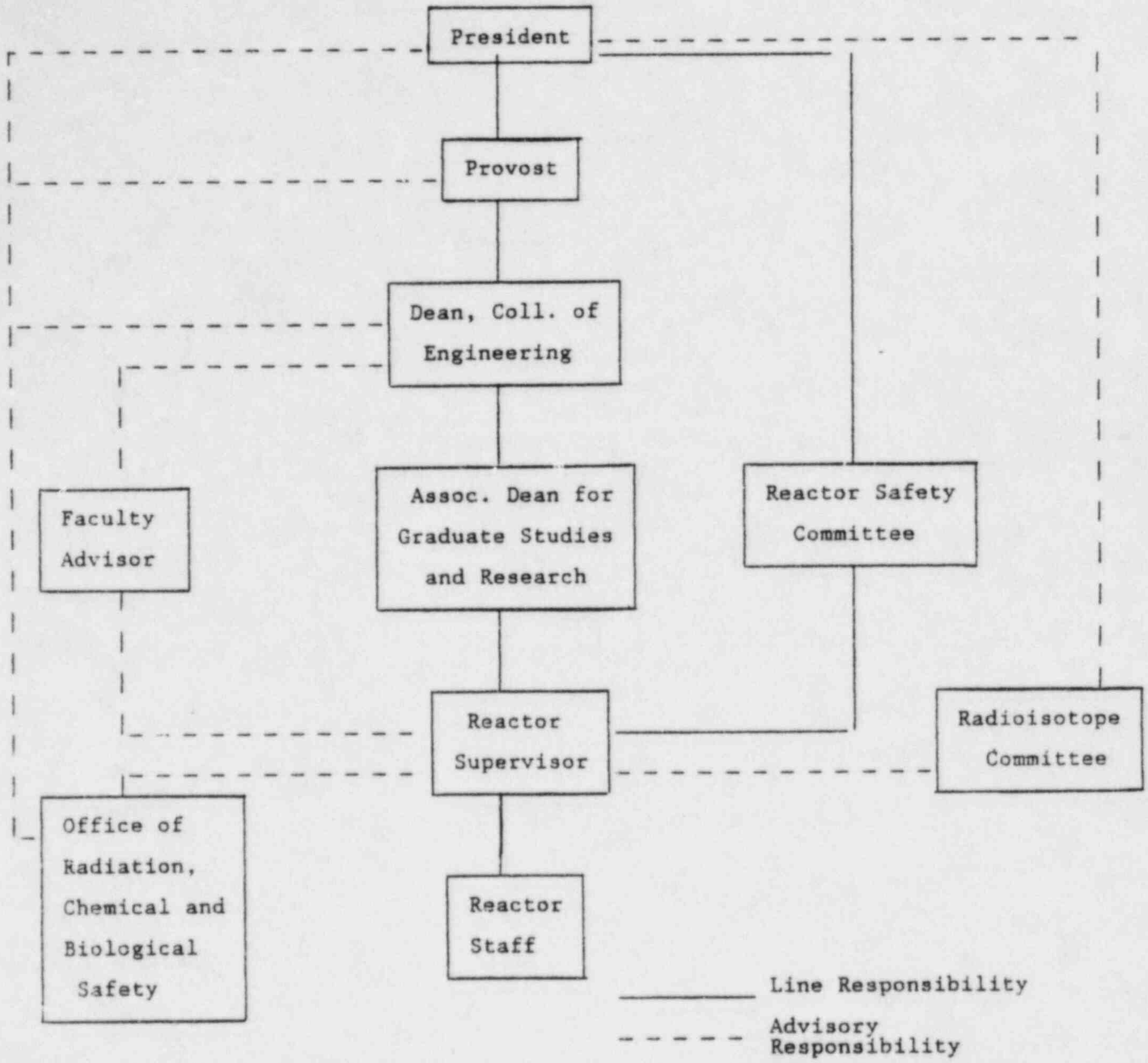
b. The safety of operation of the MSU TRIGA Nuclear Reactor shall be related to the University Administration as shown in the following chart.

6.2 REVIEW AND AUDIT

a. A Reactor Safety Committee (RSC) of at least five (5) 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 Radiation Safety Officer and the Reactor Supervisor shall be members of the Reactor Safety Committee. The jurisdiction of the RSC shall include all nuclear operations in the facility and general safety standards.

b. The operations of the Reactor Safety 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, and
   (5) Use of subcommittees.

c. The RSC or a Subcommittee thereof shall audit reactor operations at least quarterly, but at intervals not to exceed four months.


President
Provost
Dean, Coll. of Engineering
Assoc. Dean for Graduate Studies and Research
Reactor Safety Committee
Faculty Advisor
Reactor Supervisor
Radioisotope Committee
Office of Radiation, Chemical and Biological Safety
Reactor Staff
Line Responsibility
Advisory Responsibility

d. The responsibilities of the Committee or designated Subcommittee 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 Safety 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 Safety 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 Supervisor or his designated alternate shall be notified and corrective action taken with respect to the operations involved;
b. The Supervisor or his designated alternate shall notify the Chairman of the Reactor Safety Committee;
c. A report shall be made to the Reactor Safety 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 adequa 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, and medical support;
d. Fuel element 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 Safety Committee. Temporary changes to the procedures that do not change their original intent

may be made by the Supervisor or his designated alternate. All such temporary changes shall be documented and subsequently reviewed by the Reactor Safety Committee.

6.6 FACILITY OPERATING RECORDS

In addition to the requirements of applicable regulations, and in no way substituting therefor, records and logs shall be prepared of at lest 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. 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 III, Office of Inspection and Enforcement as follows:

a. A report within 24 hours by telephone or telegraph.
   (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.
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 1.9 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 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 of 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 and the hours the reactor was critical;

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 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) Total radioactivity (in curies), released by nuclide, during the reporting period based on representative iostopic analysis.

(d) Average concentration at point of release (in microcuries/cc) during the reporting period. (2)

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

Gaseous Waste (summarized on an annual basis)

(1) Radioactivity discharged during the reporting period (in curies)

(a) Total estimated quantity of radioactivity released (in curies) determined by an appropriate sampling and counting method.

(b) Total estimated quantity of Argon-41 released (in curies) during the reporting period based on data from an appropriate monitoring system.

(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 values.

(d) Total estimated quantity of radioactivity in particulate form with half lives greater than eight days (in curies) released during the reporting period as determined by an appropriate particulate monitoring system.

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

(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.

(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.

(i) A description of any environmental surveys performed outside the facility.