APPENDIX A

TO LICENSE NO. R-62

TECHNICAL SPECIFICATIONS

FOR THE

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY REACTOR

DATED:

Change 4

1.0 Definitions

1.1 Reactor Shutdown - The reactor shall be considered shutdown whenever:

a. the coolant-moderator is dumped, and

b. the console switch is in the "off" position and the key withdrawn.

1.2 Reactor Operation - Reactor operation shall mean any condition wherein the reactor is not shutdown.

1.3 Operable - A system or component shall be considered operable when it is capable of performing its intended function in its normal manner.

1.4 Operating - A system or component shall be considered to be operating when it is performing its intended function in its normal manner.

1.5 Experiment - Experiment shall mean any apparatus, device, or material installed in the core or experimental facilities which is not a normal part of these facilities.

1.6 New Experiment - A "new experiment" is an experiment which, in the opinion of the Reactor Supervisor, differs from experiments previously carried out on the reactor facility.

1.7 Reactor Safety Channels - Reactor safety channels shall mean those circuits, including their associated input circuits, which are designed to initiate a reactor scram.

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

1.9 A Channel Calibration - A channel calibration is an adjustment of the channel such that its output responds, with acceptable range and accuracy, to known values of the parameter which the channel measures. Calibration shall encompass the entire channel, including equipment actuation, alarm, and trip.

1.10 Safety Limits - Safety limits are limits upon important reactor variables which are necessary to reasonably protect against the uncontrolled release of radioactivity.

1.11 Limiting Safety System Settings - Limiting safety system settings are maximum or minimum settings for automatic protective devices so chosen that automatic protective action will correct the most severe abnormal situation anticipated before a safety limit is exceeded.

2.0 <u>Site</u>

2.1 The reactor and associated equipment are housed in the northwest corner of the Physics Building on the campus of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

"2.2 The reactor room, the adjacent Room 6 and Room 108 (located directly above Room 6) and the roof of the Physics Building shall describe the exclusion area and the restricted area as defined in 10 CFR 20. Room 6 is subdivided into a radiochemistry laboratory, an anteroom and a storeroom. Room 108 shall contain the control room and laboratory-office space. Rooms 6 and 108 are connected by a circular stairway."

3.0 <u>Reactor Room</u>

3.1 The reactor room shall be of reinforced concrete construction. Air from the reactor room shall be discharged through a galvanized duct to the roof of the Physics Building by an exhaust fan on the roof. Control of any radioactive material released in the reactor room by normal operation or in an accident shall be provided by the ventilation system.

4.0 <u>Primary Coolant System</u>

4.1 The primary coolant system shall consist of piping, a storage tank, pump, hot side of heat exchanger, 2 core tanks, and a dump valve with demineralized water used as the primary coolant.

4.2 The maximum water temperature between the fuel plates of a fuel element shall be 170°F.

4.3 The components of the primary coolant system with the exception of the core tanks, heat exchanger, and associated connecting pipes shall be located in a process pit in the reactor room.

a. The process pit shall be large enough to contain the entire volume of primary coolant.

b. A drain into the process pit from beneath the core tanks shall be provided.

c. A sump pump which is normally shut off shall be the only means for draining the process pit.

d. A system of leakage control shall be employed to direct any potential leakage of primary coolant from the piping run to the heat exchanger to the process pit.

4.4 The primary coolant flow shall be provided by water pumped from the dump tank into a 6" dump-inlet line leading to the bottom of the core tanks. An overflow pipe near the top of each core tank shall return the coolant water to the dump tank by gravity. A scram condition shall open the dump valve connecting the 6" dump-inlet line to the dump tank, draining the core tanks and by-passing the core tanks in the coolant loop.

4.5 The reactor shall not be operated if the conductivity of the primary coolant exceeds 1.5 micromhos per cm.

5.0 Secondary Coolant System

5.1 The secondary coolant system shall consist of piping, a cooling tower, pump, cold side of heat exchanger and a flow throttle valve.

5.2 The secondary cooling system shall be maintained at a higher pressure than the primary coolant system during reactor operation.

5.3 Secondary coolant water shall utilize corrosion and organic growth inhibitors.

6.0 Reactor Core

6.1 Fuel:

6.1.1 Standard fuel elements shall be of the flat-plate type with twelve plates to each element. Each fully-loaded fuel plate shall be approximately 26-inches long by 3-inches wide by 0.080-inch thick, which includes 0.020-

inch aluminum cladding on each side, containing a nominal 22 grams of U-235 as uranium-aluminum alloy. The fuel plates shall be separated by 0.40 inch and mechanically joined at the top and bottom. Half and quarter-load fuel plates and aluminum dummy plates may be used to adjust the core loading.

6.1.2 (deleted)

6.1.3 Twelve fuel elements, loaded six to each core tank, shall make up a core loading. Maximum excess reactivity above cold clean critical shall be limited to 0.6% delta k/k including positive reactivity from experiments.

6.1.4 The moderator temperature coefficient of reactivity shall be negative and have a minimum absolute reactivity value of 6.8×10^{-5} delta K/K°C at any operating temperature. The moderator void coefficient of reactivity shall be negative and have a core averaged value of 0.184% delta k/k per 1% void.

6.2 Control Rods:

6.2.1 Four 1/8" thick boral control rods, 2 safety, 1 shim and 1 regulating of the windowshade type shall be positioned in slots machined in the graphite external reflector adjacent to the outside face and near each outside corner of the core. All control rods shall be inspected for cracks and deformations at least once a year.

6.2.2 The two safety rods and the shim rod shall each have a reactivity worth of approximately 0.55% delta k/k. The safety rods must be withdrawn sequentially prior to withdrawal of the shim or regulating rods. The maximum time for insertion of the safety and shim rods following initiation of a SCRAM signal shall not exceed 0.8 seconds. The maximum reactivity input rate of the safety and shim rods shall not exceed 0.02% delta k/k/sec. This reactivity input rate (0.02% delta k/k/sec) is not applicable when the core is devoid of water moderator.

6.2.3 The regulating rod reactivity worth shall be approximately 0.15% delta k/k. Automatic control shall be provided by a servo system driving the regulating rod.

6.2.4 The reactor shall be subcritical by a minimum margin of 0.5% delta k/k when the safety or shim rod of maximum reactivity worth and the regulating rod are fully withdrawn from the core.

6.3 Control Rod Drives:

6.3.1 The two safety rod drives shall have limit switches with console indicators showing full withdrawal and full insertion.

6.3.2 The shim rod position shall be displayed on the console to an accuracy of $\pm$ 0.1 in.

6.3.3 The regulating rod position shall be displayed on the console to an accuracy of $\pm$ 0.1 in.

6.4 Neutron Sources:

The neutron source shall provide a minimum of 10^6 neutrons per second and shall be positioned during reactor startup in the central graphite reflector region.

7.0 Reactor Safety Systems

7.1 The instrumentation, safety, and control systems shall provide the (a) information, (b) automatic and manual shutdown capabilities, and (c) automatic and manual control capabilities required to assure safe reactor operation through all power ranges. The reactor safety system shall include instrumentation and associated circuits which manually or automatically actuate interlocks, energize alarms and/or scram the reactor when certain preset limits are reached as listed in Table I.

7.2 The safety system shall be constructed such that no single electrical fault which partially or completely disables the automatic scram function can, in any manner, impair or disable the manual scram function, and vice-versa.

7.3 All reactor safety channels shall be capable of initiating reactor shutdown independent of one another. The reactor safety channels shall be fail safe.

" 7.4 The channels of nuclear instrumentation listed below with their operating ranges shall be operating and connected to the safety system as noted in Table I:

Safety Channel	Operating Range
(a) Startup Channel	$1-10^6$ cps
(b) Log N-Period Channel	0.0001 - 1000% Power, -30 to +3 seconds
(c) Safety Channel #1	0 - 150% Power
(d) Safety Channel #2	0 - 150% Power

A minimum of two channels of nuclear instrumentation shall be operating on scale through all power ranges (0.1 watt to 120 kW)."

7.5 Process instrumentation shall provide continuous indication at the console of primary coolant inlet and outlet temperatures and primary coolant flow rate. Annunciators shall be provided at the console to indicate high outlet primary coolant temperature and loss of coolant flow.

7.6 Radiation monitors shall provide adequate safety action to protect the general public and operating personnel against excessive radiation levels. At least the following reas shall be monitored by radiation monitors having a minimum range of 0.1 to 10^4 millirem per hour.

a. East and west walls of reactor room, and

b. Exhaust duct (stack) to roof.

A fission product monitor shall be located in or near the process pit to monitor the primary coolant before it returns to the dump tank. This monitor shall have a minimum range of 0.1 to 10^4 millirem/hr.

7.7 A building evacuation alarm system consisting of radiation monitors described in paragraph 7.6 and warning horns in the corridors on each floor of the Physics Building shall be operable under shutdown conditions. The stack monitor and the area monitor located on the west wall of the reactor room shall actuate an alarm at the console, sound the warning horns, and shut off the reactor room ventilation system when pre-set radiation levels are reached. The alarm shall be reset by a key-operated switch when the Health Physicist or his designated alternate, with the concurrence of the Reactor Supervisor, verifies that the alarm condition is cleared. The room ventilation unit shall require manual restarting.

7.8 The gaseous radioactive waste shall be released through the facility stack. An air monitor located in the stack near the exhaust end shall monitor radioactive gases whenever the reactor is in operation.

7.9 The maximum release rate of Ar-41 from the stack shall not exceed 1×10^{-4} curies/sec. The release of Ar-41 shall not exceed 315 curies per calendar year.

7.10 The rector exhaust system shall maintain a stack flow rate, whenever the reactor is in operation, such that a negative pressure is maintained in the reactor room with respect to the surrounding area. All doors to the reactor room shall be closed during reactor operation.

7.11 Operable portable survey instruments shall be available at the facility for measuring beta-gamma exposure rates in the range of 0.0 to 20 rem per hour and neutron dose rates from 0.0 to 0.5 rem per hour.

8.0 Administrative Requirements

8.1 The Virginia Polytechnic Institute and State University Reactor Safety Committee shall review reactor operation and safety. The Committee shall include the following members; and additional members may be appointed as deemed appropriate by the Vice President for Administration and Operations of Virginia Polytechnic Institute and State University.

Dean or Department Head (Science or Engineering), Chairman
Faculty Representative from Arts and Sciences
Faculty Representative from Engineering
Faculty Representative from Agriculture
Outside Representative (Consultant)
Reactor Supervisor, Ex-Officio
University Health Physicist, Ex-Officio

Members of the Committee, other than ex-officio, shall be appointed by the Virginia Polytechnic Institute and State University Vice President for Administration and Operations on recommendation of the Chairman of the Committee.

The Reactor Safety Committee shall meet at least quarterly and upon call of the chairman.

Committee actions must be supported by a majority vote of its members.

Committee findings shall be reported in writing to the Vice President for Administration and Operations on a timely basis.

8.2 The Reactor Safety Committee shall be responsible for the review and approval of:

8.2.1 Operation of the nuclear reactor.

8.2.2 Conformity of operations with the Technical Specifications.

8.2.3 Unusual incidents and occurrences.

8.2.4 Any additions, modifications, or maintenance to the core and its associated support structure, the coolant system, the rod drive mechanism, or the reactor safety system to determine that they are 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.

8.2.5 Changes in the facility or procedures to determine if they constitute (1) unreviewed safety questions, (2) changes in Technical Specifications, or (3) are reportable under paragraph 50.50 of 10 CFR 50.

8.3 The Reactor Safety Committee shall review and approve written procedures for:

8.3.1 Testing and calbiration of reactor operating instrumentation and controls, control rod drives, and area radiation monitors.

8.3.2 Reactor start-up, routine operation, and reactor shutdown.

8.3.3 Fuel loading or unloading.

8.3.4 Preventive or corrective maintenance operations which could have an effect on the safety of the reactor.

8.3.5 Emergency conditions involving potential or actual release of radioactivity including personnel evacuation.

8.3.6 New experiments.

8.4 The reactor shall be under the direction of the Reactor Supervisor who shall be a licensed Senior Operator. The Reactor Supervisor shall have overall responsibility for the safe operation of the reactor facilities. In all matters pertaining to reactor operations and to these Technical Specifications, the Reactor Supervisor shall be responsible to the Nuclear Laboratory Director and to the Reactor Safety Committee.

8.4.1 The Reactor Supervisor shall have the following minimum qualifications:

(1) Bachelor's degree in Engineering or Physical Science and a minimum of 2 years experience in the operation of a nuclear facility during which he shall have demonstrated competence in supervision and reactor operations, or

(2) In lieu of a Bachelor's degree, an additional 4 years of reactor operating experience is acceptable. Credit for 1 years experience for each

year of applicable undergraduate college level engineering or scientific work may be applied in such cases.

8.5 The Radiological Safety Officer shall review and approve all procedures and experiments involving radiological safety. He shall enforce rules, regulations and procedures relating to radiological safety, and conduct routine radiation surveys.

8.5.1 The Radiological Safety Officer shall have the following minimum qualifications:

(1) Bachelor's degree in Biological or Physical Science and a minimum of 2 years experience in personnel and environmental radiation monitoring programs at a nuclear facility.

(2) In lieu of a Bachelor's degree, an additional 4 years experience in personnel and environmental monitoring programs at a nuclear facility is acceptable.

(3) Certification as a Health Physicist by the Health Physics Society is acceptable in lieu of the education and experience requirements given above.

8.6 When operating, the reactor shall be under the direct control of the Reactor Supervisor or other licensed reactor operators. Students may manipulate the reactor controls only under the direct supervision of a licensed reactor operator.

8.6.1 The person exercising control of the reactor shall be aware of the status of operation at all times. Whenever the reactor is operating or work which could possibly affect the reactivity status of the reactor is being performed, there shall be, in addition to the licensed reactor operator, a second person in the building immediately available by telephone or intercom.

8.6.2 The reactor shall not be operated when there are significant defects in fuel elements, control rods, or reactor instrumentation and control. Abnormal operation of the reactor controls, safety systems or auxiliary systems shall require immediate action to secure the safety of the facility and determine the cause of the abnormal behaviour.

9.0 Experiments

9.1 Experimental Facilities:

9.1.1 Facilities for the insertion of experiments shall be limited to:

(1) Graphite thermal column (west face)

(2) Shield tank experiment facility (east face)

(3) Removable graphite pieces in central graphite reflector region (between core tanks)

(4) Two beam ports (north and south faces)

(5) Pneumatic Rabbit Systems

The thermal column door shall be normally locked and an annunciator on the console shall alarm when the door is open. Three pneumatic rabbit systems may be installed. These shall be operated with N_2 gas and shall be vented through an absolute filter to the exhaust stack.

9.2 Experiment Limitations:

9.2.1 "New experiments" shall be submitted to the Reactor Safety Committee in writing and approved before insertion in the reactor. The documentation of new experiments, which shall be reviewed and approved by the reactor supervisor or his designated alternate, shall include:

(1) the purpose of the experiment,

(2) a description of the experiment, and

(3) an analysis of the possible hazards associated with the performance of the experiment.

9.2.2 The reactivity worth of any single movable experiment in the reactor core or experimental facilities shall not exceed 0.3% delta k/k. Movable experiments are defined as experiments which could conceivably be expelled during operation, accidentally or intentionally moved during operation, or flooded or collapsed in such a way as to affect reactivity.

9.2.3 Experiments having moving parts shall have reactivity insertion rates less than 0.05% delta k/k per sec except that components whose movements results in a reactivity change of less than 0.05% delta k/k may be oscillated at higher frequencies.

9.2.4 No experiment shall be installed in the reactor in such a manner that:

(1) it could shadow the nuclear instrumentation system monitors,

(2) failure of the experiment could interfere with the insertion of a control rod, or

(3) failure of the experiment could credibly result in fuel element damage.

9.2.5 No experiment shall be performed involving materials which could:

(1) credibly contaminate the reactor coolant system causing corrosive action on reactor components or experiments,

(2) cause excessive production of airborne radioactivity, or

(3) produce a violent chemical reaction.

9.2.6 The amount of special nuclear material contained in an experiment shall be limited to 5 grams in the form of solid samples.

9.2.7 Explosive materials such as gunpowder, dynamite, TNT or nitroglycerine shall not be irradiated in the reactor irradiation facilties.

10.0 Fuel Storage and Transfer

10.1 Two fuel storage pits shall be located in the reactor room floor and each shall be capable of storing 16 fully-loaded fuel elements. Each fuel element shall be stored in a separate cylindrical hole in the storage pit with appropriate shielding.

10.2 When each pit is fully-loaded and flooded with water, the K_{inf} shall not exceed a calculated value of 0.52.

10.3 A fuel transfer cask shall be utilized to transfer single fuel elements to and from core and storage positions.

10.4 All fuel transfers shall be conducted, with the reactor shutdown, by a minimum staff of three men which shall include a licensed senior operator. The staff members shall monitor the operation using appropriate radiation monitoring instrumentation. All fuel transfers shall be entered in the reactor log.

11.0 Surveillance Requirements

11.1 Prior to each day's operation (with the exception of those experiments which require the reactor to be operated for more than one full day) a reactor checkout shall be performed. This checkout shall be appropriately documented in the reactor log and shall include:

a. A visual inspection of the shield penetrations and experimental facilities.

b. A front panel test of the instrumentation and area radiation monitoring systems, and

c. A functional check on primary coolant flow and temperature, operation of the annunciator system, and conductivity devices.

If maintenance or recalibration is required, it shall be performed before reactor startup proceeds.

11.2 Routine maintenance on all control and process system components shall be performed in accordance with written schedules and written procedures.

11.3 All reactor instrument channels and radiation monitors shall be calibrated according to written procedures, based where appropriate on manufacturer's recommendations. Calibrations shall be made at intervals of not more than 180 days.

11.4 A drop test of the control rods shall be performed at approximately 90-day intervals. This test shall verify that the total scram time is within the specified limits.

11.5 Reactivity insertion rates shall be verified annually.

11.6 Building evacuation drills shall be carried out at approximately 90-day intervals.

TABLE I

SAFETY SYSTEM FUNCTIONS

Item No.	Condition	Detector	Set Point	Action	Bypass Provisions
1	Neutron Count Rate < Set Point	Fission Chamber in Start-up Channel	$\geq$ 3 cps	Dump valve cannot be closed. If dump valve already closed, rod drive motors are inoperable until condition corrected.	May be bypassed by senior operator provided the Servo Channel is fully operative in the same range (> .1 watt)
2	Coolant-Moderator Temperature < Set Point	Sensor in Process Pit	$\geq 70^{o}F$	Same as (1)	May be bypassed for a specific experiment with approval of Reactor Safety Committee
3	Coolant-Moderator Flow < Set Point	Flow detector, 1% accuracy minimum, over the full scale range measured	$\geq$ 3 gpm	Same as (1); Annunciation	Same as (2)
4	Reactor Room Ventilation Fan Off	Relay	--	Same as (1)	None
5	Moderator-Coolant Operating Level < Set Point	Pressure Sensor in Process Pit	Not less than overflow pipe level in core tanks	All control rod drives inoperable	May be bypassed by senior operator for control rod tests with moderator coolant dumped

Item No.	Condition	Detector	Set Point	Action	Bypass Provisions
6	Safety Rod #1 not fully withdrawn	Limit Switch on Rod Drive	--	#2 Safety Rod, Shim-Safety Rod and Reg. Rod inoperable	May be bypassed by senior operator for control rod tests, such as drop tests
	Safety Rod #2 not fully withdrwan	Limit Switch on Rod Drive	--	Shim-Safety Rod and Reg. Rod inoperable	Same as above for Safety Rod #1
7	Reactor Period < Set Point	Compensated Ion Chamber in Log-N-Period Channel	$\geq$ 10 sec.	Annunciation	None
			$\geq$ 5 sec.	Scram	None
8	Reactor Power > Set Point	2 Uncompensated Ion Chambers in Level Safety Channels #1 and #2	$\leq$ 125% Full Power	Scram	None
9	Automatic Control Servo Set-Point deviation $\pm$ 15%	Servo-Control Circuit	$\leq \pm$ 15%	Annunciation. Preclude Servo Operation and revert to Manual Control	None
10	Reg. Rod at Upper or Lower Limit	Limit Switches at each end position	--	Annunciation. Preclude Servo Operation and revert to Manual Control	None
11	Activation of Manual Scram Switch on Console or at Remote Position	Contacts within Switch	--	Scram	None

Item No.	Condition	Detector	Set Point	Action	Bypass Provisions
12	Moderator Temperature > Set Point	Sensor in Process Pit	$\leq$ 170°F	Annunciation	None
13	Level in Shield Tank < Set Point	Pressure Sensor in Process Pit	$\leq$ 2′ below top of shield tank	Annunciation	May be bypassed for specific experiments by Senior Operator
14	Moderator Level in Core Tanks > Set Point	Pressure Sensor in Process Pit	$\geq$ 1" be[illegible] top of core boxes	Scram	None
15	Earthquake > Set Point	Velocity type Seismograph	0.14 g equivalent to #3 Richter Scale	Scram; alarm	None
16	Radiation Level > Set Point	Stack Monitor and Two Areas Radiation Monitors	$\leq$ 15 mr/hr	Annunciation and, in case of building evaluation area monitor, a building evacuation alarm and reactor room ventilation system shut off	None
17	Radiation Level Fission Product Monitor > Set Point	Monitor on Moderator-Coolant from Core	$\leq$ 10X Normal Reading	Annunciation	None
18	Loss of Secondary Flow	Flow sensor, minimum of 1% Accuracy, in secondary piping	> 50 GPM	Annunciation	May be bypassed for operation below a Power Level of 1 KW