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September 12, 2016

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R-084

Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION REGARDING THE APPLICATION FOR LICENSE RENEWAL (TAC NO. ME1587)

Sir:

As part of the licensing review process, the Nuclear Regulatory Commission requested resubmittal of the Instrumentation and Control chapter of the SAR, a revision to the requalification plan, and a redacted copy of the Emergency Plan.

These documents are attached.

If you need further information, please contact Mr. Steve Miller at 301-295-9245 or stephen.miller@usuhs.edu.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge. Executed on 12 September, 2016.

Stephen Miller
Reactor Facility Director

AX45
A020
NRR

7 INSTRUMENTATION AND CONTROL SYSTEMS

7.1 SUMMARY DESCRIPTION

The reactor is operated from a Control System Console (CSC) located in the control room. The Data Acquisition Cabinet (DAC) is located in the reactor room along with cabinets that house the digital neutron linear/log power channel and the driver modules for the control rod stepping motors.

The operating mode of the reactor is determined by four mode selector switches on the console. In Automatic and Steady-State modes, the reactor can operate at demand power levels up to 1.0 MW. In Square Wave mode, a step insertion of reactivity rapidly raises reactor power to a steady-state a demand power level up to 1.0 MW. In the Pulse mode, a large-step insertion of reactivity results in a short duration reactor power pulse.

The reactor control system is all solid-state circuitry with a mixture of analog and digital instrumentation. .

7.2 DESIGN OF INSTRUMENTATION AND CONTROL SYSTEMS

Three independent power measuring channels provide for a continuous indication of power from the source level to peak power resulting from the maximum allowed pulse reactivity insertion. Trips are provided for over power and loss of detector high voltage on the two analog safety channels. Fuel temperature is measured for display as well. Other parameters not used by the reactor protection system are also monitored and displayed.

The instrumentation and control system is designed to provide the following:

- complete information on the status of the reactor and reactor-related systems
- a means for manually withdrawing or inserting control rods
- automatic control of reactor power level
- automatic scrams in response to over power, loss of detector high voltage, or high fuel temperatures
- automatic scrams in response to a loss of operability of the digital computer system
- monitoring of radiation and airborne radioactivity levels

7.2.1 Design-Basis Requirements

The primary design basis for the AFRRI Reactor is the safety limit on fuel temperature. To prevent exceeding the safety limit, design features, operating limitations, and automatic scrams are provided for over power conditions. Interlocks limit the magnitude of transient reactivity insertion.

7.2.1.1 Reactor Power Measurements

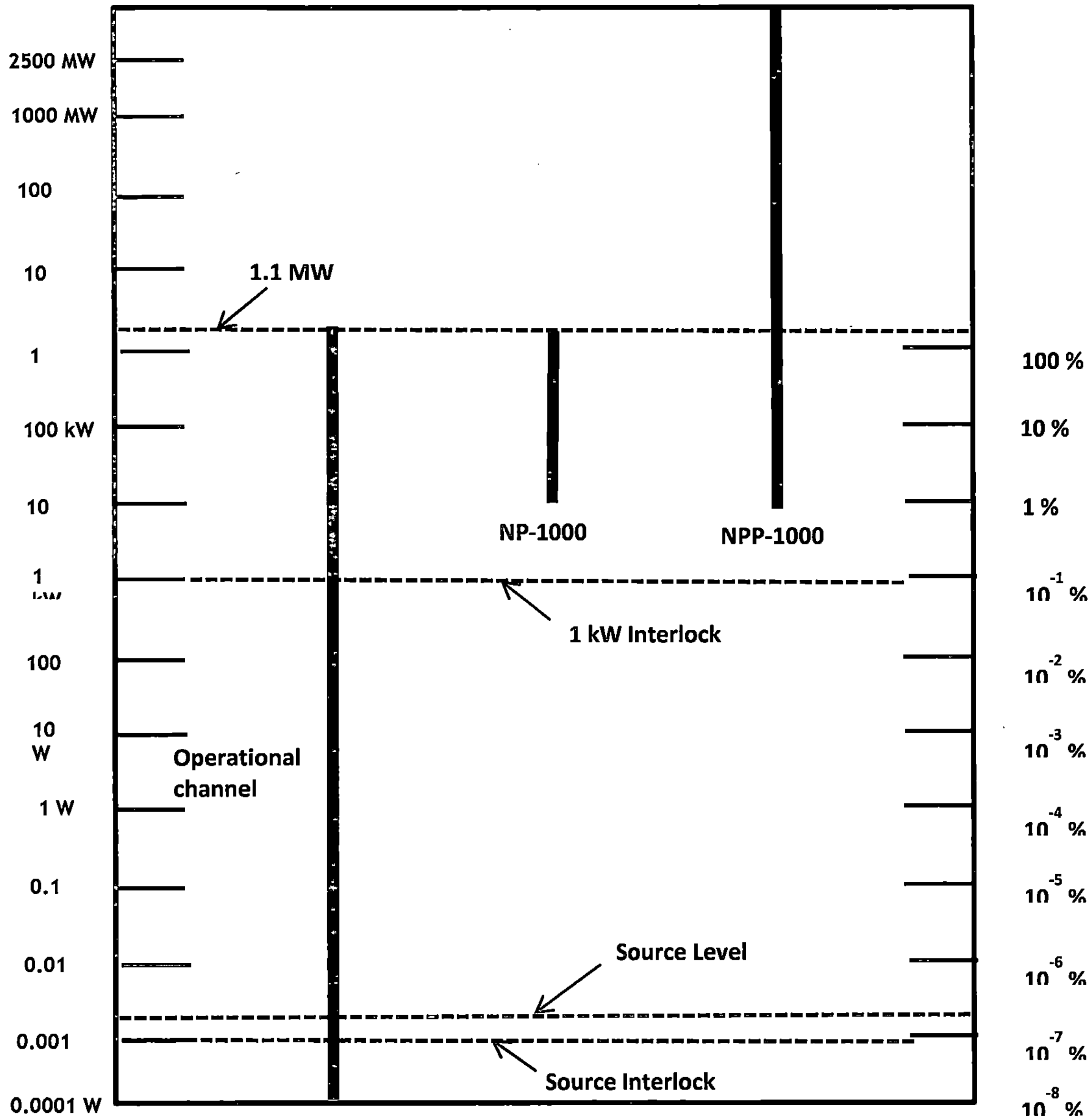
Reactor power is measured by three separate detectors; a fission or ion chamber serving the operational channel and either ion chambers or fission chambers serving the safety channels. The signal from the operational channel(s) provide wide range log power from 10^{-8} % to 100% reactor power and period indication from -30 seconds to +3 seconds. One ion chamber or fission chamber is connected to the NP-1000 safety channel. A second ion chamber or fission chamber is used by the NPP-1000 percent power and pulsing channel. Both the NP-1000 and NPP-1000 provide indication of linear reactor power from 0 % to 120 % steady state reactor power and the NPP-1000 also provides indication of reactor power for pulsing operations. Figure 7-1 shows the relative ranges of the channels and the detectors.

The fission chamber for the operational channel(s) wide range instrument is connected to analog circuitry in a NEMA Preamplifier box mounted on the wall of the reactor room. This box contains a high voltage power supply, low voltage power supplies, preamplifier, campbelling module, counter/transmitter module and other circuitry. The high voltage power supply also monitors the high voltage to the fission chamber. If a loss of high voltage to the operational channel's fission chamber is sensed, an interlock is generated. The analog output from the preamplifier and campbelling module box described above is sent to the counter/transmitter which digitizes the signal and communicates this signal to a NEMA Microprocessor box that is also mounted on the wall of the reactor room. This box contains low voltage power supplies and microprocessor circuitry to convert the detector signal to useable digital values and transmit that signal to the DAC computer system. The Microprocessor box also contains circuitry for trip setpoints that provide interlock functions and indications on the console.

The operational channel(s) log display provides a continuous indication from 10^{-8} % to 100% of full power for the console display, analog bar graph display, and the console chart recorder.

The reactor period signal is generated by the microprocessor assembly of the operational channel(s). Reactor period is displayed on the console display and analog bar graph display. A bistable circuit provides a visual warning and rod withdrawal interlock when the period is less than a predetermined limit. The period signal is also used by the AUTO control system.

The NP-1000 safety channel provides a linear power signal to the console display and analog bar graph display. These displays are scaled at 0 to 120% of full power. A bistable circuit provides scram and alarm functions if the high power setpoint is exceeded. The detector input to the NP-1000 safety channel is disabled during pulse mode operations. A separate bistable circuit provides a scram signal to the reactor protection system upon a loss of detector high voltage.



Operational channel(s) – Fission Chamber
NP-1000 – Uncompensated Ion Chamber
NPP-1000 – Uncompensated Ion chamber

Figure 7-1 AFRRI Power Instrument Ranges

The NPP-1000 power pulsing channel functions as a redundant NP-1000 safety channel during steady state operations. During pulsing operations, it displays peak power from a pulse on the scale of 0 to 3300 MW on the analog bar graph and a scale of 0 to 3300 MW on the console display. An analog bar graph display of integrated energy is also provided with a scale of 0 to 30 MW-s. A graphical display of a pulse is available on the console display, along with text information on the pulse number, pulse time and date, full-width at half-maximum power, peak power, integrated power, minimum period, and peak fuel temperature. These data are recorded and may be stored and recalled at a later date. The pulsing channel is enabled when the pulse mode switch is pressed, as long as all interlock conditions are met. The pulse data collection is performed by the DAC computer and begins when the pulse rod "Fire" button is depressed. This also enables the peak hold circuit and starts a one minute timer. The peak power and energy displays are reset at the end of the one minute period. The peak power is also recorded on the console data recorder.

The NPP-1000 channel contains bistable circuits that will produce a scram and alarm output for the conditions of the high power setpoint being exceeded and for loss of high voltage.

7.2.1.2 Temperature Measurements

As illustrated in Figure 7-2, fuel temperature is measured by a thermocouple embedded in an instrumented fuel element. There are two fuel temperature channels in the reactor instrumentation system, and therefore two thermocouples may be connected at one time. Fuel temperature is displayed on the console display and console analog bar graphs. A high temperature scram is sent to the reactor protective system for high power pulsing operations.

Temperature of the bulk pool water is measured by a resistance temperature detector (RTD). The RTD is mounted to the top of the reactor tank and the probe extends about 18 inches (45.72 cm) below the top of the tank. It sends a signal to the console that displays as the pool water temperature. A temperature alarm circuit on the pool water channel will annunciate an audible and visual alarm on the console if the water temperature exceeds a preset temperature. Two additional RTDs are located in the primary piping, one on the inlet to the heat exchanger and one on the outlet of the heat exchanger. The temperature signals from these detectors are sent to the console for display as the pool water outlet temperature and the pool water inlet temperature. These primary piping RTDs may not display accurate temperatures for the primary cooling water if the primary pump is not operating.

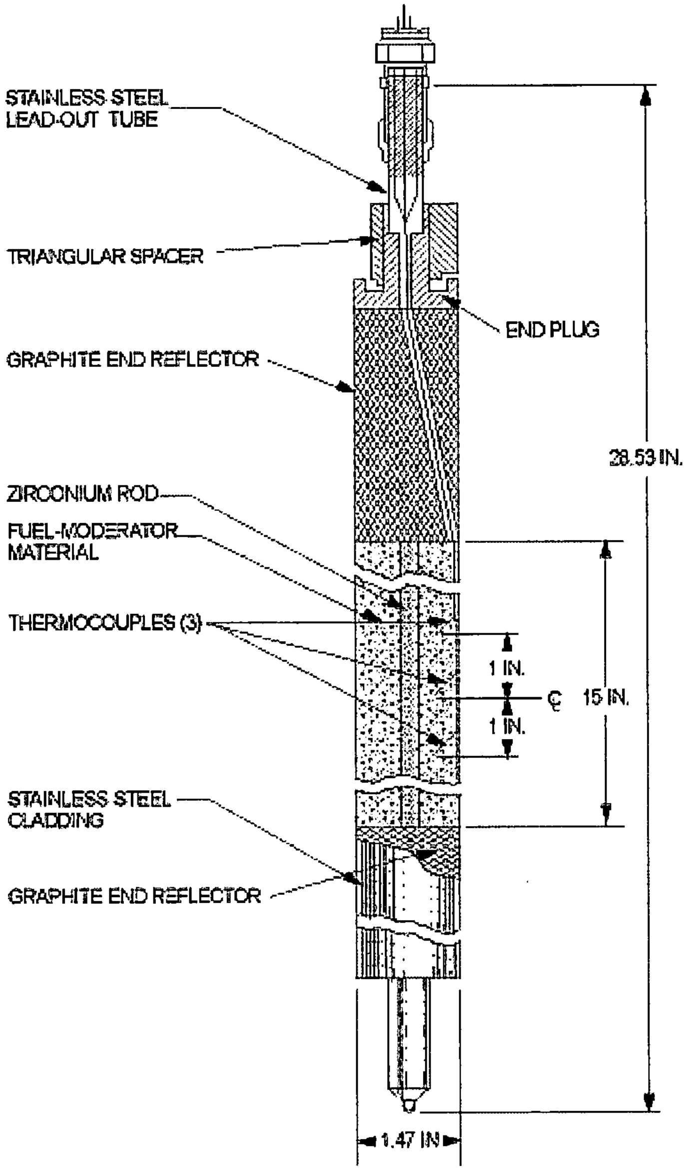


Figure 7-2

Instrumented Fuel Element

7.3 REACTOR CONTROL SYSTEM

7.3.1 Control Rod Drives

The four control rods are positioned by control rod drives mounted on the reactor top center channel.

As illustrated in Figure 7-3, the 3 standard control rod drives (Reg, Shim and Safe) rod drives are rack-and-pinion linear actuators. The regulating rod drive uses a stepper motor that is able to operate at variable speeds when operated by the servo system. The regulating rod drive operates at its maximum speed when controlled in the manual mode by the reactor operator. The shim rod drives use the same type stepping motor as the regulating rod drive but operate at a single speed. An electromagnet is secured to the bottom of the draw tube to which the rack is mounted. The magnet is moved up or down in response to rotation of the pinion shaft. The control rod is attached to the armature by a long connecting rod. When the magnet is energized, the armature is magnetically coupled to the draw tube. De-energizing the magnet causes the rod to drop. A dash pot is incorporated into the armature section to decelerate the rod near the bottom following a scram. Limit switches sense when the magnet is fully withdrawn, the magnet is fully down, and the armature (and thereby the rod) is fully down. A ten-turn potentiometer is coupled to the pinion shaft to provide for rod position indication. The pinion shafts are chain-and-sprocket coupled to a DC stepper motor.

The transient rod (also called the pulse rod) is operated by a pneumatic/electric drive. A connecting rod couples the transient rod to a piston rod assembly. As illustrated in Figure 7-4, the piston resides within an externally threaded cylinder. A ball screw nut acts on these external threads to raise or lower the cylinder. Rotation of the ball screw nut is accomplished by a worm gear coupled to a motor. A potentiometer is gear-driven by the worm gear shaft to provide rod position indication. A hydraulic shock absorber is incorporated into the top of the cylinder. Air from a compressor is connected to a normally-closed port of a three-way air solenoid valve. The common port is connected to the transient control rod drive cylinder below the piston. The normally-open port is vented. When the air solenoid valve is energized, air pressure is placed on the bottom of the piston causing the piston to be brought in contact with the shock absorber. The resulting reactivity insertion is dependent on the position of the cylinder prior to applying air. With air applied, energizing the motor in the up or down direction will cause the cylinder, piston, and control rod to move up or down as a unit. Scram of the transient rod is accomplished by de-energizing the air solenoid valve. This vents the air pressure under the piston and results in the control rod dropping. As illustrated in Figure 7-5, limit switches provide for sensing cylinder up, cylinder down, and rod down. A bracket extends over the top of the cylinder. A switch on the bracket opens a contact in the up circuitry when the shock absorber assembly contacts it. The bracket itself is substantial enough to stall the motor should the switch contact fail to open.

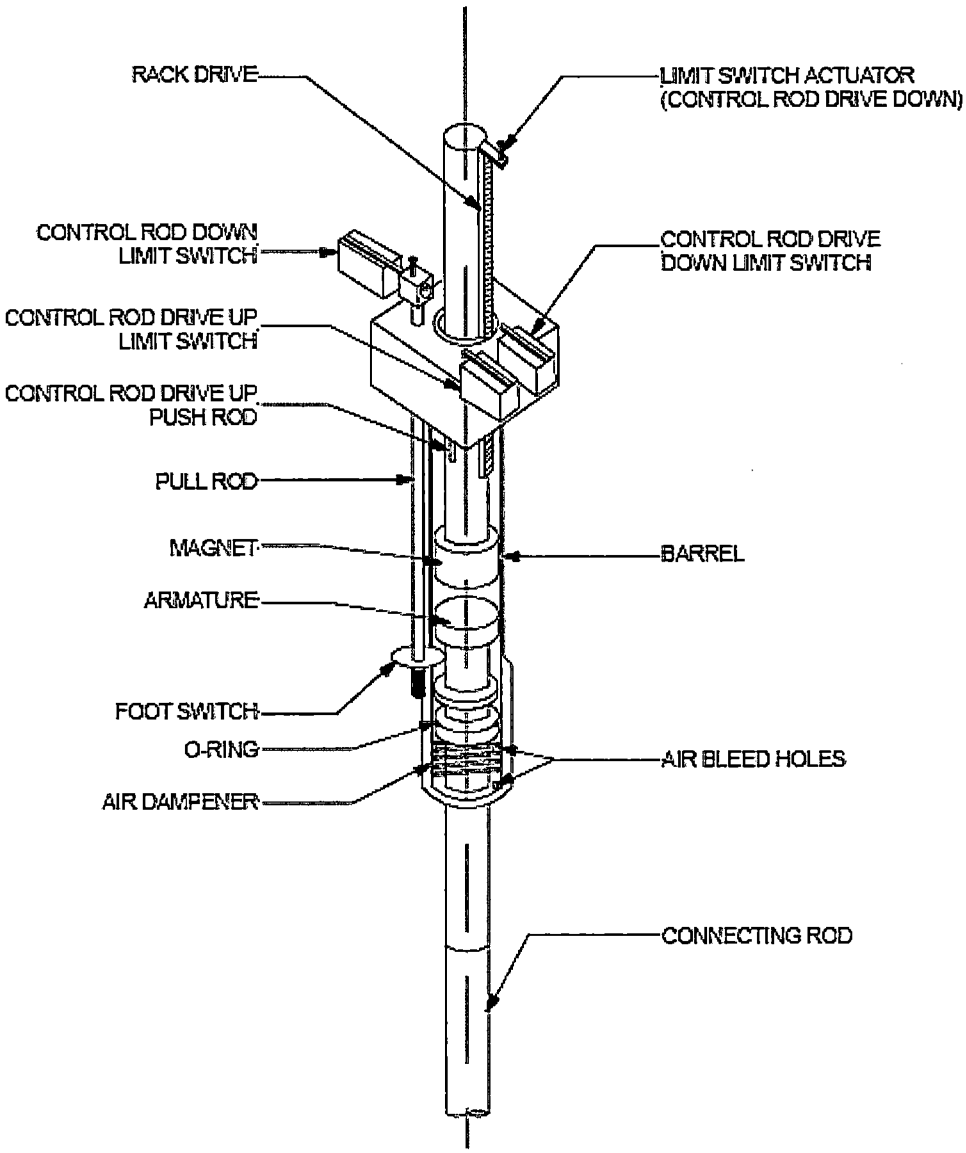


Figure 7-3

Standard Control Rod Drive and Limit Switches

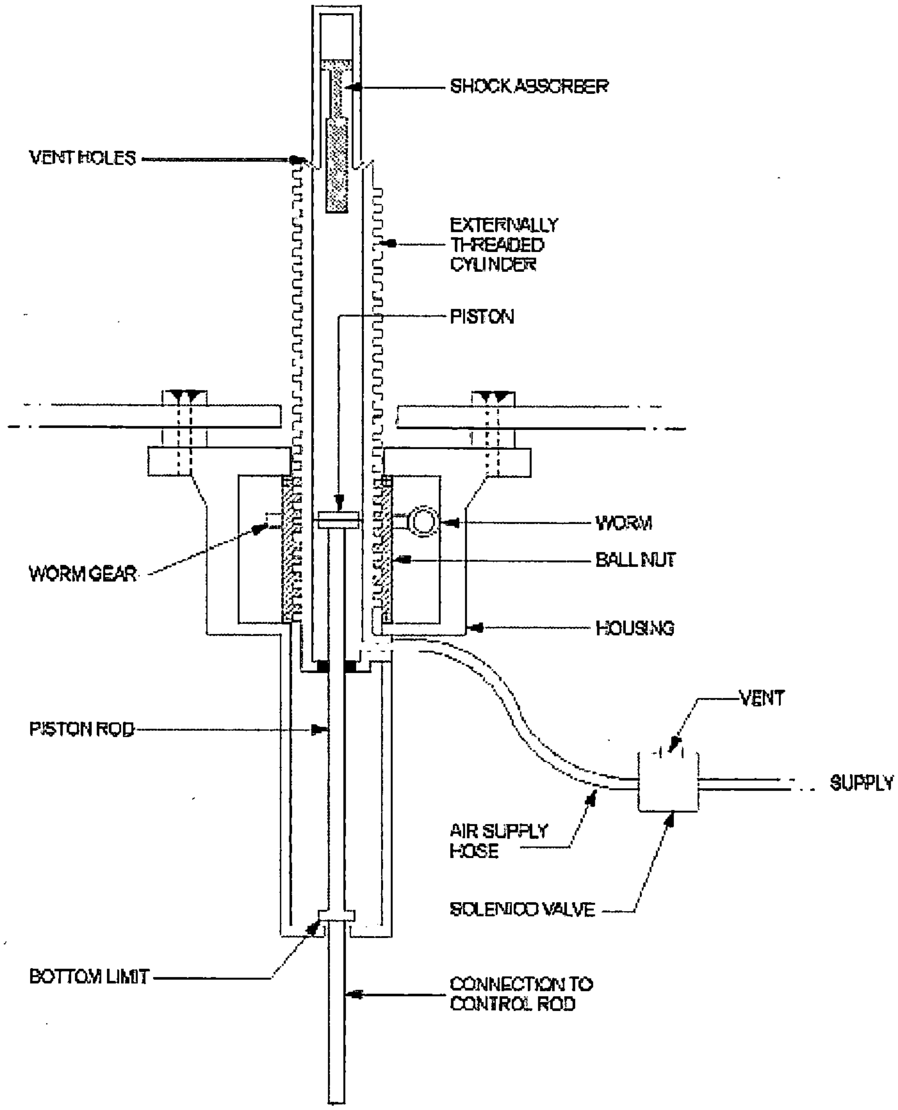


Figure 7-4

Transient Rod Drive

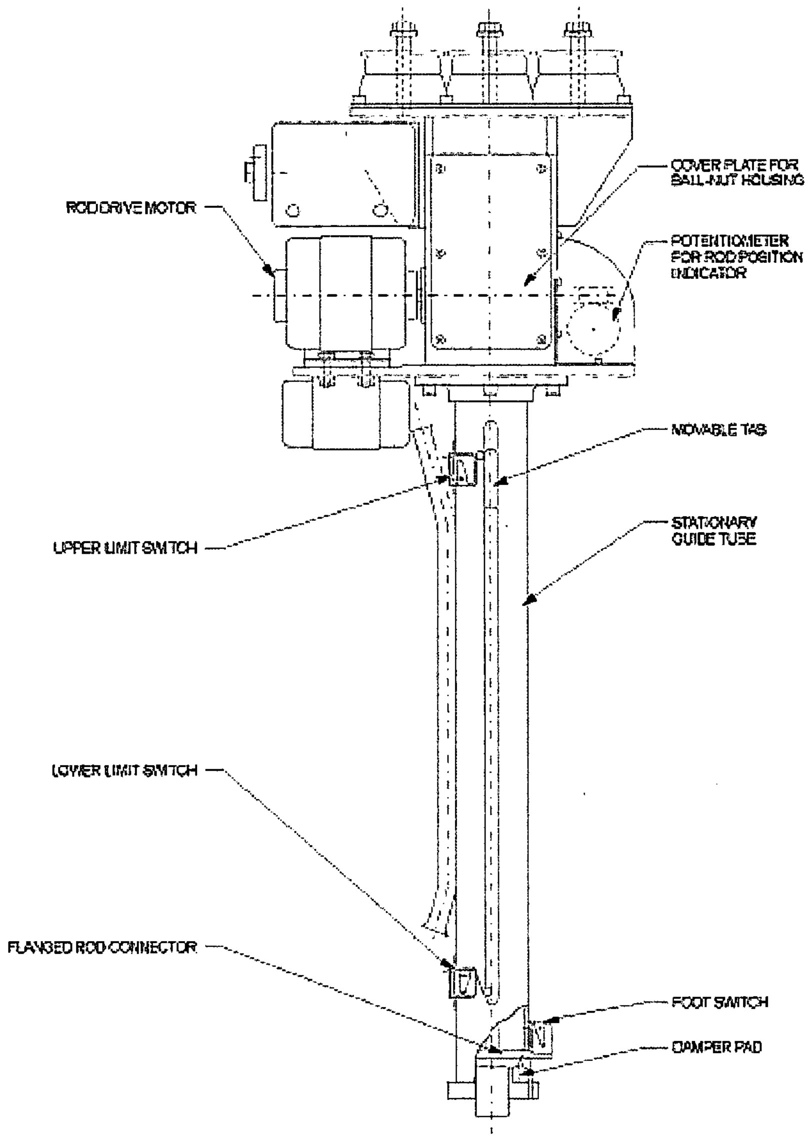


Figure 7-5

Transient Rod Drive Limit Switches

7.3.2 Servo System

In the Automatic and Square-Wave modes of operation, the regulating rod is controlled by the servo system to control reactor power based on input signals from a power channel, the reactor period signal, and the power demand control.

In Automatic mode, the reactor power is compared against the power demand setting to obtain power error. The period signal is monitored by the controller to limit the reactor period to a minimum of +8 seconds when power is being increased. To reduce hunting of the regulating rod, a deadband is incorporated in the system. The power error signal is used by the DAC computer to determine which direction (if any) the regulating rod needs to move to correct the power error. The regulating rod speed is variable and it will move slowly for small errors and it will move fast for large errors. The regulating rod speed cannot exceed the travel speed that is used in manual control. The variable speed ability of the servo system reduces power overshoot during transients.

To perform a Square Wave, the reactor must be configured in Steady-State mode. First, the reactor power is raised to some nominal low power (less than 1000 W) with the air to the transient rod off. Second, the transient rod cylinder is raised to the position corresponding to the desired reactivity insertion. Finally, the square wave mode switch is depressed to change the console mode from Steady-State to Square Wave and the transient rod fire button pressed. Reactor power will increase to the desired power level and then switch to the Automatic mode to maintain a constant power level.

7.3.3 Interlocks

The following are the interlocks utilized by the reactor console:

- The 1-kW permissive interlock to prevent pulsing when wide range log power is above 1 kW
- Interlock to prevent the shim, safety and regulating rods from being withdrawn in pulse mode
- Interlock to ensure that only one control rod can be manually withdrawn at a time in the steady state mode
- Rod withdrawal prevent (RWP) interlock, activated by a low count rate on the operational channel(s)when the log power is not greater than 10^{-7} % power. An indication is provided on the console low resolution monitor to indicate when a source level rod withdrawal interlock is present
- Interlock to prevent the application of air to the transient rod drive mechanism in the steady state mode unless the drive cylinder is fully inserted;
- Interlock to ensure that only one control rod can be manually withdrawn at a time in the square wave mode, excluding the transient rod.

7.4 REACTOR PROTECTION SYSTEM

The scram circuits function to shut down the reactor by dropping all four control rods to their fully inserted positions. Scram is accomplished by de-energizing the magnets for the safety, shim, regulating rods and by de-energizing the air solenoid valve for the transient rod.
A reactor scram will result under any of the following conditions:

- Operator-initiated manual scram
- Fuel element temperature in excess of the setpoint
- Safety channels measuring power in excess of the setpoint
- Loss of high voltage to the safety channels
- Drop in pool level below setpoint
- Activation of emergency stop circuit
- Pulse timer initiated scram
- DAC-to-CSC Watchdog failure scram

7.5 ENGINEERED SAFETY FEATURES ACTUATION SYSTEMS

There are no engineered safety feature actuation systems.

7.6 CONTROL CONSOLE AND DISPLAY INSTRUMENTS

7.6.1 High Resolution Monitor Display

The high resolution graphic monitor displays the following reactor parameters:

- Reactor wide range linear power from operational channel(s)
- Reactor wide range log power from operational channel(s)
- Reactor period from operational channel(s)
- Reactor linear power from NP-1000 and NPP-1000
- Reactor fuel temperatures
- Reactor pool temperature
- Rod position and reactor graphic

7.6.2 Reactor Status Display

The reactor status display monitors parameters in text format for reactor power channels, temperatures, interlock status, etc. The items displayed are determined by the facility management. This display also can be changed to the SCRAM and WARNING window display by depressing the computer keyboard SPACE bar, and will display any items in a SCRAM or WARNING trip mode.

7.6.3 Hardwired Analog Bargraph Displays

Analog bargraphs on the control console are hardwired separately from the computer system. In the event of a computer malfunction, this allows observance of reactor conditions. These bargraphs include indications of:

- NP-1000 linear power level
- NPP-1000 linear power level
- operational channel(s)log power level
- operational channel(s)period
- Fuel Temperature channel 1
- Fuel Temperature channel 2
- NVT for pulsing operations
- NV peak power for pulsing operations

7.6.4 Reactor Mode Control Panel

The Mode Control Panel has switches the operator uses to select various modes of operation, test functions, automatic mode demand power level, and main power on/off.

7.6.5 Console Chart Recorder

The console chart recorder records and displays wide-range log power.

7.6.6 Annunciator Function

When an alarm or warning is received at the control console, an audible signal will sound and a message will be displayed on the monitor. When the operator presses the acknowledge button, the audible signal will be silenced and the message display will remain until the alarm or warning has cleared. If the alarm or warning condition has cleared, the message will clear.

7.7 RADIATION MONITORING SYSTEMS

The radiation monitoring systems associated with reactor operations at AFRRI are maintained as a means of ensuring compliance with radiation limits established under 10 CFR 20. These systems consist of remote area monitors, continuous air monitors, reactor stack monitors, and AFRRI perimeter monitoring. Detailed information (such as alarm setpoints for the various monitors, appropriate reactor operator responses to radiation alarms, and procedures involving monitor data evaluation and archiving) can be found in References 7-1 and 7-2.

The radiation monitoring systems associated with AFRRI reactor operations provide readouts and radiation alarms at key locations in the AFRRI complex. These locations are:

- Reactor Room (Room 3161)
- Reactor Control Room (Room 3160)
- Emergency Response Center (Room 3430)
- Annunciator panel in Hallway 3101

The radiation alarms in the reactor room and the radiation alarm readouts in the reactor control room provide the reactor operators with information necessary for the safe operation of the AFRRI-TRIGA reactor. The audible and visual alarms on the annunciator panel in Hallway

3101 alert the Security Watchman (during nonduty hours) of unusual reactor conditions when the reactor is secured. When reactor personnel are present in the reactor administration/control area, the audible alarm on the annunciator panel in Hallway 3101 is turned off.

7.7.1 Remote Area Monitors

The remote area monitors (RAMs) in the remote area monitoring system of primary concern to the reactor are R-1, R-2, E-3, and E-6. These units are placed in various areas of the reactor building where potential radiation hazards may exist due to reactor operation.

The monitors utilize scintillation detectors which measure gamma radiation with energies greater than 20 keV. The units have a range of 1 mrem/hr to 10^5 mrem/hr and a nominal accuracy of ±15 percent at all levels. The units have a time constant of 2 seconds and a meter and alarm response time of less than 1 second. The monitors activate radiation alarms at various locations within AFRRI; the alarm set points are variable. The monitors also activate visual alarms in the control room and the Emergency Response Center (room 3430).

The RAMs are calibrated at regular intervals using a radiation source of known intensity. The locations of the RAMs, the readouts, and the audible and visual radiation alarms are given in

Table 7-1 and Figures 7-6 through 7-8. The alarm setpoints can be found in AFRRI internal documents (References 7-1 and 7-2).

7.7.2 Continuous Air Monitors

The continuous air monitors (CAMs) of primary importance to the reactor are two CAMs located in the reactor room. Three additional CAMs, which monitor the exposure rooms and the prep area, are discussed in Section 10. The CAMs provide continuous air sampling and monitoring (gross beta-gamma activity) primarily of airborne particulate matter.

The CAMs draw air with an air pump (~7 cfm) through a shielded filter assembly, which traps any particulate matter greater than 0.3 microns in diameter. A G-M detector measures any radioactive particulates trapped by the filter. The count rate (counts per minute) is recorded by a three-cycle, logarithmic, strip-chart recorder mounted on the CAM itself. The units have a sensitivity range of 50 cpm to 50×10^3 cpm and a nominal accuracy of ± 10 percent. The units have a time constant which is inversely proportional to the count rate, being 200 seconds at 50 cpm and 1 second at 50,000 cpm. The units have the capability of actuating alarms at two adjustable radiation levels.

Table 7-1 Reactor Remote Area Monitors

RAM	Location	Readout	Radiation alarm
R-1	Approximately 7 feet above the floor on the reactor room east wall	Meter in reactor control room and Emergency Response Center (Room 3430)	Activates audible and visual alarm in the reactor room and in the reactor control room; activates visual alarm in the Emergency Response Center (Room 3030); activates visual and optional audible alarm on annunciator panel in Hallway 3101
R-2	Approximately 7 feet above the floor on the reactor room west wall	Same as R-1	Activates visual alarm in the reactor control room and in the Emergency Response Center (Room 3430)
E-3	6 feet above the floor on the west wall prep area opposite ER #1 plug door	Same as R-1	Same as R-2. In addition, there are a visual and audible local alarm in the prep area near ER #1, and a red light at the front desk.
E-6	6 feet above the floor on the west wall prep area opposite ER #2 plug door	Same as R-1	Same as E-3, except the visual and audible local alarm is in the prep area near ER #2

The primary reactor room CAM is located in the southwest corner of the reactor room and is visible from Room 3156. The air sampled by this CAM is taken from approximately 36 inches above the reactor pool surface inside the core support structure. The air is passed through a hose to the CAM. The air is exhausted by the CAM back to the reactor room. The reactor room CAMs form an integral part of the reactor room containment capability, in that when either CAM's high-level alarm is activated, the supply and exhaust dampers to the reactor room in the ventilation system are automatically closed to isolate the reactor room air volume.

The backup reactor room CAM is located along the west wall of the reactor room and its alarms are visible from the control room and Room 3158. The air sampled by this CAM is taken from a point near the warm drain located along the west side of the reactor pool. The air is exhausted by the backup CAM back to the reactor room.

A description of the CAMs' alarms, locations and read-out is given in Table 7-2 and Figures 7-6 through 7-8. The alarm setpoints can be found in the appropriate AFRRI internal documents (Reference 7-2). Additionally a flashing visual light on the reactor auxiliary instrumentation console in the reactor control room will be illuminated when either reactor room CAM is set in the TEST mode during testing.

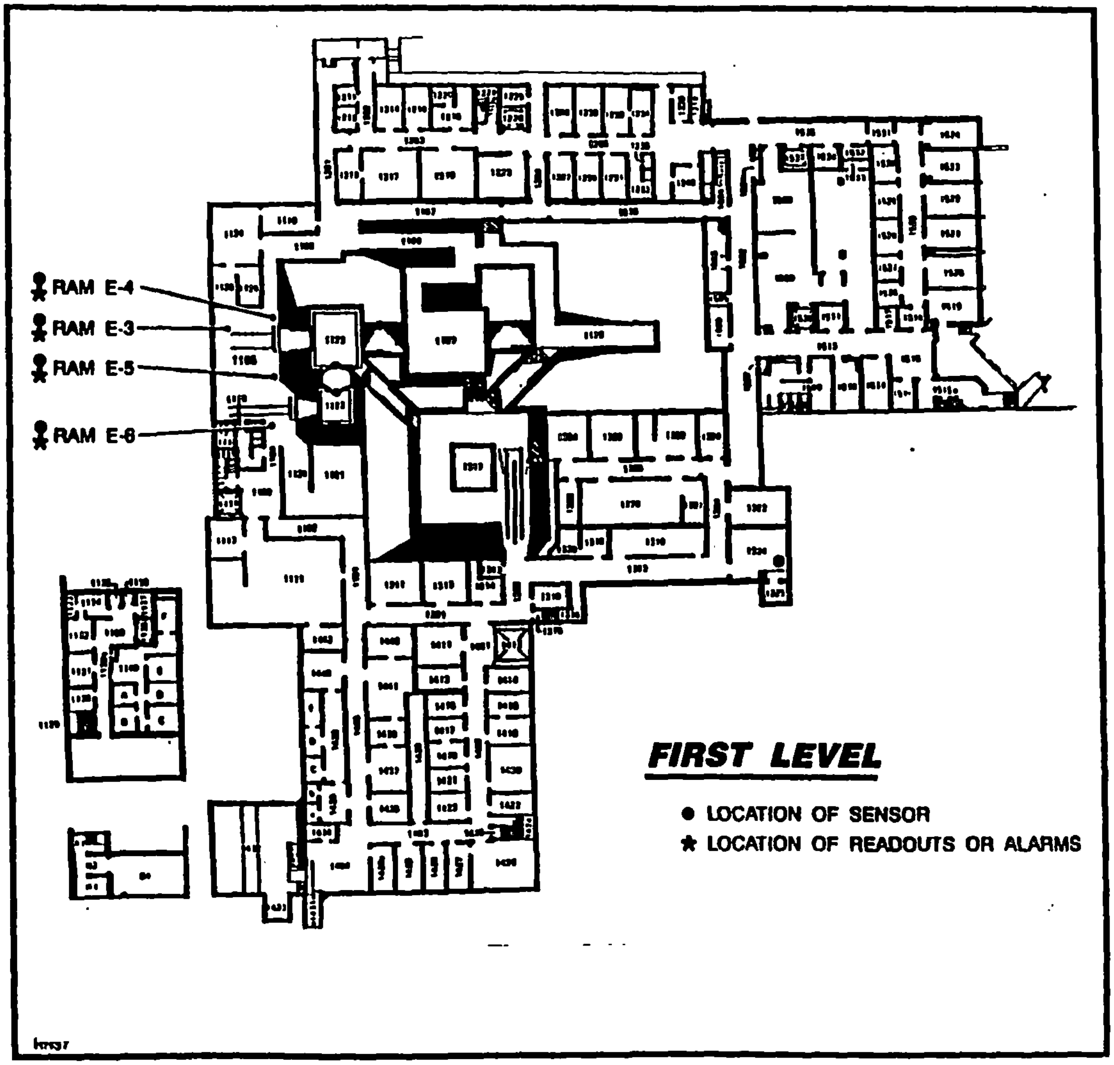


Figure 7-6

AFRRI Radiation Monitors Associated with AFRRI-TRIGA Reactor First Level

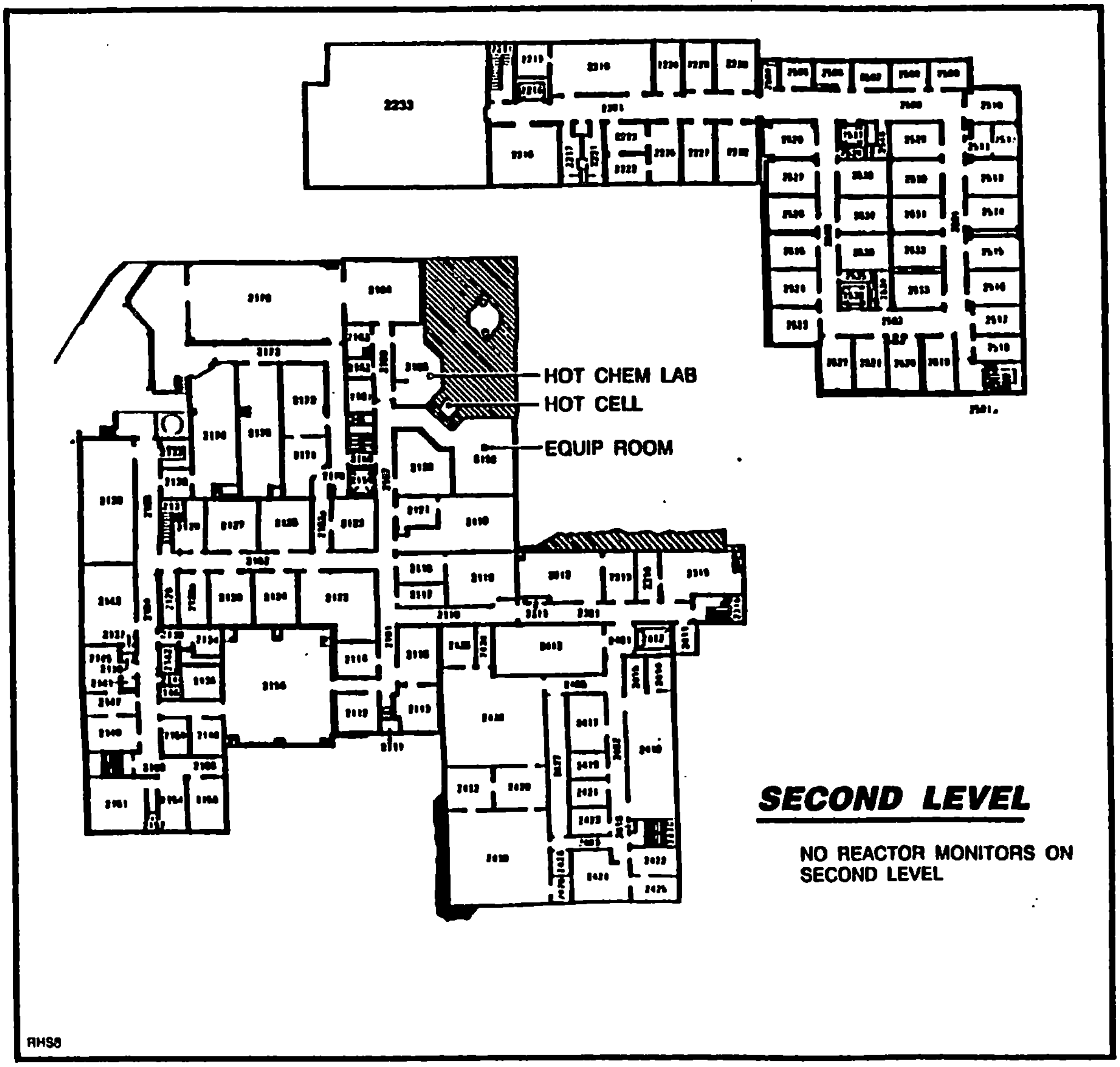


Figure 7-7

AFRRI Radiation Monitors Associated with AFRRI Reactor Second Level

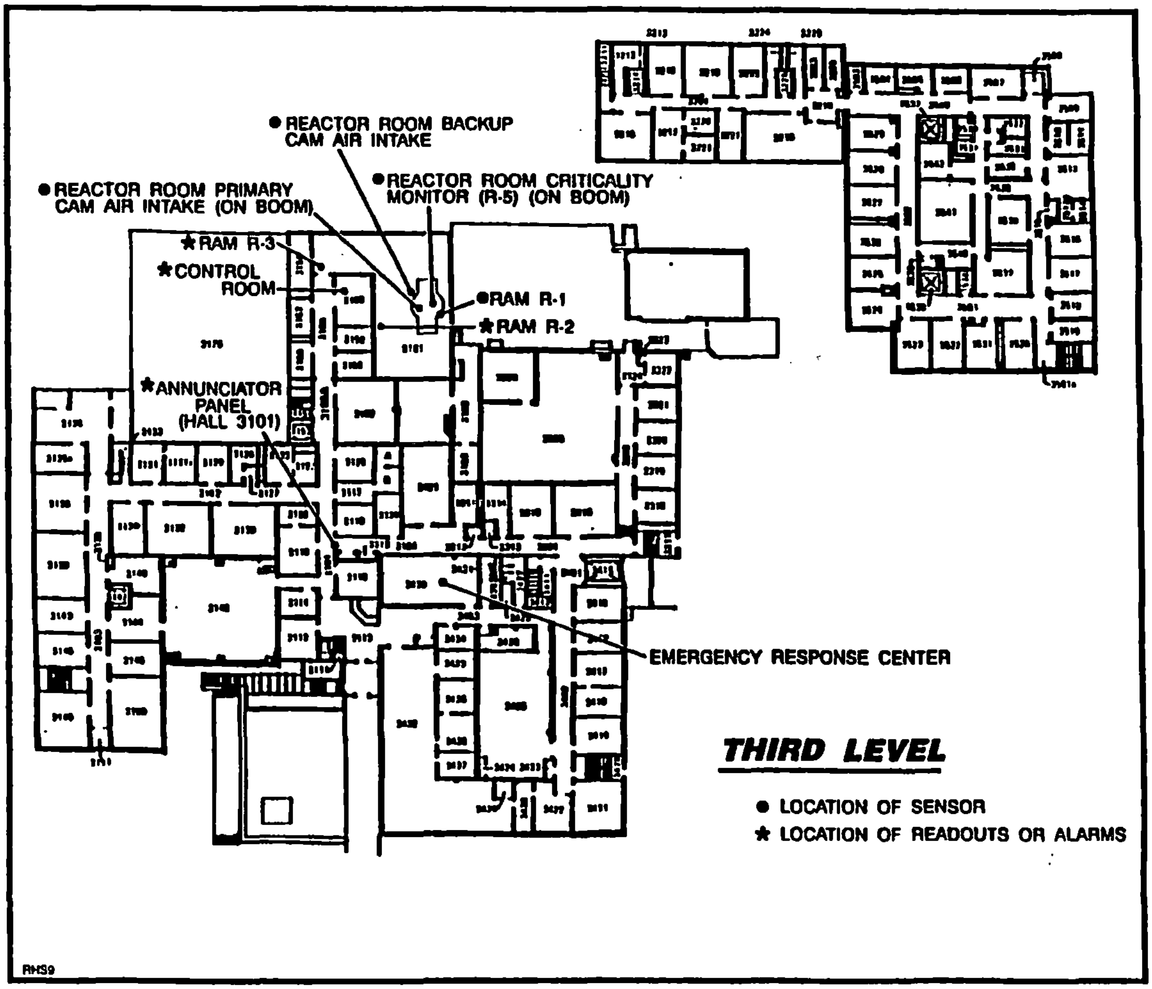


Figure 7-8

AFRRI Radiation Monitors Associated with AFRRI Reactor Third Level

Table 7-2 Reactor Room Continuous Area Monitors

CAM	Location of air intake	Readouts	High-level alarm	Low-level Alarm[(1)]
Primary	Approximately 36 inches above reactor pool inside core carriage	Meter in reactor control room	Activates audible and visual alarm on unit itself	Activates visual alarm on the unit itself
		Strip chart recorder located on the unit itself	Activates audible and visual alarm on reactor control room annunciator panel	
			Activates visual alarm on reactor room wall panel	
			Activates audible and visual alarm on annunciator panel in Hallway 3101	
			Causes the reactor room ventilation dampers to close	
Alternate Backup	Near the warm drain along the west side of the reactor tank	Strip chart recorder located on the unit itself and meter in reactor control room	Identical to primary CAM alarm indications, when connected	Activates visual alarm on the unit itself

(1) If the low-level alarm is being used

7.7.3 Stack Monitoring Systems

The stack monitoring systems consist of the stack flow monitor and the stack gas monitor. These systems provide data about the radioactive effluents discharged through the reactor stack. The stack flow monitor measurements are recorded by a strip chart recorder. Stack gas monitor measurements of Ar-41 emissions are recorded on a strip chart recorder and can be viewed at the end of each day by an operator to verify that no unusual Ar-41 releases have occurred.

7.7.3.1 Stack Flow Monitoring System

The stack flow monitoring system measures the average flow rate of air exhausted through the reactor stack. The system consists of a pair of pitot tubes and Magnehelic pressure gauges which mechanically measure the dynamic pressure in the stack and produce a proportional electrical signal. A strip chart recorder located in the reactor control room records the stack flow. There are no level alarms associated with this system, except when exhaust fan EF5 fails, in which case a visual alarm is activated in the reactor control room.

7.7.3.2 Stack Gas Monitoring System

The stack gas monitor (SGM) system is a NaI scintillation detection system which samples exhaust air from the reactor stack. The air is passed through a filter to remove particulates before being analyzed. This system will detect those effluents which have been released into the reactor stack, and are set to alarm at the limit currently specified in the AFRRI Reactor Emergency Plan.

The stack gas monitor system is capable of activating alarms at two levels. Additionally, a flashing visual light on the reactor auxiliary instrumentation console in the reactor control room will be illuminated when the stack gas monitoring system pump motor is turned off. The locations of the system readouts and alarms are listed in Table 7-3. The setpoints for the radiation alarms can be found in the appropriate AFRRI internal documents.

Table 7-3 Stack Monitoring Systems

System	**Readout**	**Radiation Alarm**
Stack Flow Monitoring System	Strip chart recorder in reactor control room	(Not applicable) However, EF5 failure gives a visual alarm in reactor control room
Stack Gas Monitoring System	Meter in reactor control room	Activates audible and visual alarm in reactor control room

7.7.4 Perimeter Monitoring

An environmental monitoring program is conducted by AFRRI primarily to measure environmental doses received from radionuclides produced by the AFRRI-TRIGA reactor, particularly Ar-41. The environmental monitoring program shall consist of an NRC/EPA approved reporting method.

7.8 REFERENCES

7-1. Armed Forces Radiobiology Research Institute, Health Physics Procedures (HPPS), Safety and Health Department.

7-2. Armed Forces Radiobiology Research Institute, Reactor Operational and Administrative Procedures, Radiation Sciences Department, Reactor Division.