MICHIGAN STATE UNIVERSITY

COLLEGE OF ENGINEERING · DIVISION OF ENGINEERING RESEARCH EAST LANSING · MICHIGAN · 48824

September 21, 1981

U. S. Nuclear Regulatory Commission
Division of Operating Reactors
Washington, D. C. 20555

RECEIVED SEP 24 1981 U.S. NUCLEAR REGULATORY COMMISSION

Docket No.: 50-294
Attention: Robert Carter
Reason: Renewal of Operating License R-114

Gentlemen:

When we last visited our beleaguered reactor supervisor, he was hopelessly trapped in a subterranean maze of Tech Specs, SAR's and Requal Programs. As he forced the Tech Specs to succumb to his courageous onslaught, our hero found himself faced with the two-headed monster, inflation-recession. At great personal peril, he slew the beast, forcing its master (the University), to let our hero sustain himself at the reactor pool for another year at the very least. As the financial Stygian darkness receeded, the SAR appeared and silently submitted to updating. The Requalification Program was found to be in good shape and willingly volunteered to be copied. With the prozed renewal in sight, our exhausted but dauntless hero respectfully offers 40 copies each of the updated Safety Analysis material and Requalification Program to his liege, the Nuclear Regulatory Commission. He awaits response, his anticipation exceeded only by his desire for further glorious victories.

Sincerely,

James Carrick

James Carrick
Reactor Supervisor

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B. SAFETY ANALYSIS

The following discussion pertains to the safety analysis required pursuant to Paragraph 50.34 of Part 50, 10 C.F.R. The letters and numbers refer to the proposed rules for this part dated 8/16/66.

50.34 (b) (1) Reactor Site Description

The proposed reactor site is located in the Engineering Building on the campus of Michigan State University. The campus is located in the southern area of the city of East Lansing, in Ingham County, in the state of Michigan. Reference to the floor plans (Figures 6, 7, 8, 9) of the Engineering Building will provide an adequate description of the building layout.

The proposed site within the Engineering Building is on the southern edge of the main campus. University farm lands and a few agricultural research laboratories occupy the area to the south to a distance of four to five miles. These areas are sparsely populated.

Classrooms, offices, and student residence halls lie to the north, east, and west of the site. Outside the campus area in a northerly direction is the city of East Lansing. Some areas of the city also lie to the east and west of the site. The city is approximately 3/4 to 1 mile from the site.

East Lansing is primarily a residential community composed of year around residents and students of the university. Most of the businesses are retail stores.

To the west and southwest of the main campus which is bounded on the west by Harrison Road are university apartments for married students.

The population of the city of East Lansing is approximately 51,000. This includes students who live as residents of the city. The number of students attending the university varies somewhat from season to season, but the peak student population is approximately 45,000. Of this number about 18,000 are on-campus residents in residence halls. A significant number of students commute to the campus from places of residence outside the East Lansing area.

A map of the East Lansing area (Figure 1) is included in this report in order to provide a physical representation of the area and to represent the resident population of the area. In the areas marked with heavy circular lines the population shown is that of students living on campus. There are no people residing within 1/4 mile of the site. There are approximately 3,300 people within the 1/4 to 1/2 mile boundary, 6,200 within the 1/2 to 3/4 mile boundary, and 1,000 people within the 3/4 to 1 mile boundary, as marked by the heavy circular lines. In other areas population is derived from voter registration data and is represented by voting precincts within the city.

In addition to the students living on campus there are approximately 6,500 people working 8 hours per day on the campus in such capacities as professors, administrative personnel, clerk-technical personnel, and labor people. The majority of these people work within 1 mile of the reactor site. The portion of the students of the university not residing on campus spend varying amounts of time per day on the campus. They are a highly mobile group and cannot be said to be in any one campus building for a significant amount of time. These people as well as the university employees could easily be moved from the area if a dangerous situation was caused by a reactor accident.

A map of the campus has been included in this report (Figure 2). It shows the location of the reactor site in relation to the rest of the campus. Campus buildings with appropriate identification are shown. In addition it shows new construction on the campus.

(1) Meteorological, Geological, and Hydrological Data

(a) Meteorological Data

Meteorological Data for the site were obtained from the Department of Commerce's Agricultural Services Office at 1405 S. Harrison Road, East Lansing, Michigan. The data were recorded at Capitol City Airport which is located approximately 6 miles from the proposed reactor site. Since the terrain between the site and the airport is flat with no major hills or valleys, the data are expected to be representative of the site.

Figure 3 is a wind rose showing wind direction, speed and the percentage of time the wind blows in any one direction.

Temperature and precipitation data are given in Table 1.

Table 1. Temperature and Precipitation Data of the Reactor Site.

Annual average temperature	47.5°F
Coldest month	January
Hottest month	July
Annual total precipitation	30.80
Wettest month	June
Driest month	February

There is a history of tornados occurring in Michigan. According to the United States Weather Bureau, Office of the State Climatologist's bulletin "Michigan Tornado Fact Sheet," Michigan lies at the northeastern edge of the nation's maximum frequency belt for tornados. In Michigan for the 50-year period of 1916-1965, June has produced the greatest frequency of tornados, tornado days, and number of deaths due to tornados. The months of November, December, and January have never produced a verified tornado. February has produced only one. April has produced more tornado activity than any other month. Michigan, during the 1953-1977 period has averaged 15 tornados per year. Compare this with data for the surrounding states: Illinois 28, Indiana 23, Ohio 14, Wisconsin 17, and Minnesota 16. About 90 percent of the Michigan tornados occur in the southern one-half of the lower peninsula.

The general area around the site is also susceptible to damaging windstorms. A review of weather bureau data on damaging windstorms (excluding tornados) shows a total of 27 windstorms creating damage in excess of $500,000 since 1900. Of these storms, only 8 are listed as having winds in excess of 75 miles per hour. These windstorms had accompanying rain, freezing rain, hail, or snow.

(b) Geological Data

In the campus area of Michigan State University, the Saginaw group is the bedrock formation. The Saginaw group is over 300 feet thick in the area beneath the campus. The Saginaw group consists principally of alternating shale and sandstones. Well logs show the average thickness of the Pleistoceneglacial deposits in the campus area to be approximately 80 feet. Figure 4 shows the earth profile of the ground in the immediate area of the reactor site.

(c) Hydrological Data

From the same test boring that appears in Figure 4, campus engineers determined ground water level as a factor in designing the Engineering Building. The test boring was made at an elevation of 854.5 feet. It showed heavy ground water at 9 feet. The floor of the Engineering Building is 857 feet making a ground water level of 11.5 feet. There is a foundation drain tile around the entire perimeter of the Engineering Building. It is laid at an elevation of 843.17 feet.

Water moves very slowly through this moist clay and very little of the water reaching the drain tile is thought to come through the clay layer. The drain tile around the building footings tends to lower the ground water level. It is thought that the ground water level will not go below the sand-clay interface at approximately 12.5 feet referenced from the building floor because the clay is extremely moist and water movement is very slow (estimated to be 0.01 inch per hour).

Even if the reactor tank should rupture the water would not all drain out of the 25-foot deep tank because of the high ground water level. Approximately 12 feet of water would still remain in the tank.

The only source of flowing water in the area is the Red Cedar River which is located about one-quarter mile from the reactor site. It flows in a westerly direction to join the Grand River. It is not used as a source of water for human consumption.

Table 2. Recorded Seismic Disturbances with Epicenters in Michigan*

Map No.	Approximate Epicenter Location	Calculated Latitude North	Epicenter Longitude West	Date of Seismic Disturbance	Intensity Modified Mercalli Scale
1.	Wenona	43°40'	83°54'	February 6, 1872	IV
2.	Adrian	41°53'	84°03'	January 27, 1876	----
3.	Detroit	42°22'	83°10'	February 27, 1876	----
		42°22'	83°10'	August 17, 1877	IV
		42°22'	83°10'	March 13, 1938	IV
4.	Southern Michigan	42.3°	85.6°	February 4, 1883	VI
5.	Niles	41°50'	86°16'	October 31, 1897	----
6.	St. Joseph	42°05'	86°31'	October 10, 1899	IV
7.	Menominee	45°05'	87°40'	March 13, 1905	V
		45°08'	87°40'	January 10, 1907	----
8.	Sault Ste. Marie	46°19'	84°22'	April 4, 1905	----
		46°29'	84°24'	January 23, 1930	III
9.	Calumet	47°16'	88°25'	July 26, 1905	VII-VIII
		47°16'	88°25'	March 3, 1915	IV-V
		47°16'	88°25'	October 1, 1918	III
		47°16'	88°25'	January 5, 1955	IV
10.	Houghton	47°07'	88°33'	February 9, 1906	----
		47°07'	88°33'	January 22-23, 1909	V
11.	Hancock	47°08'	88°37'	April 20, 1906	----
		47°08'	88°37'	January 6, 1955	V
12.	Grand Rapids	42°57'	85°41'	May 19, 1906	----
13.	Keweenaw Peninsula	47.3°	88.4°	May 26, 1906	VIII
14.	Morrice	42°51'	84°11'	February 22, 1918	IV
15	Port Huron	42°58'	82°28'	March 16, 1922	III
16.	Newberry	46°22'	85°31'	January 29, 1933	II
17.	Negaunee	46°30'	87°37'	October, 1935	II-III
18.	Escanaba	45°44'	87°05'	July 18, 1939	II-III
		45°44'	87°05'	August 1, 1939	II-III
		45°44'	87°05'	February 15, 1943	----
		45°44'	87°05'	November 16, 1944	II-IV
		45°44'	87°05'	December 10, 1944	II-IV
		45°44'	87°05'	May 18, 1945	II
19.	South Central Michigan	42°00'	85°00'	August 9, 1947	VI
20.	Lansing	42°45'	84°35'	February 2, 1967	IV

*Source: U.S. Dep't of Comm., N.O.A.A., Environmental Data Service and J. Docekal, 1970 (See references)

(Rev. 5/12/81)

The only recorded earthquake with Lansing as epicenter occurred February 2, 1967. It measured IV on the Modified Mercalli Scale which is an intensity just noticeable by some individuals. Since the installation of the reactor, there has been no noticeable earthquake activity in the State of Michigan. Table 2 gives the recorded earthquake activity in Michigan.

In considering possible earthquake or tornado damage to the reactor, it is concluded that neither of these events would lead to a significant safety hazard (see page C-12).

On these bases it is concluded that the proposed reactor site in the Engineering Building on the campus of Michigan State University in East Lansing, Michigan, is suitable for installation of the reactor.

50.34 (b) (2) Facility Description Summary

The Mark I Triga reactor is to be housed in Room 184 of the existing Michigan State University Engineering Building. This structure is a 3 floor concrete structure with block walls covered with brick veneer and was constructed in 1960-1962. (The attached photo (Figure 5) shows the building from a southwest direction.) The building is used for faculty and administrative offices, instruction and research and is of essentially fireproof construction. Room 184 is located on the first floor in the southeast corner of the building. The attached floor plans (Figure 6, 7, 8, and 9) show the room location with regard to the remainder of the building. Adjacent to the room are undergraduate teaching laboratories on the north and south sides: a hall separates the room from faculty offices on the west side and the east side of the room is an exterior wall which faces a parking lot and street. There is no basement beneath the north half of Room 184 and it is here that the reactor well will be located. The south end of the room covers a machine

50.34 (b) (3) (ii) Design Bases

(a) Reactor power: 250 KW steady state

250,000 KW (1.5% $\frac{\delta K}{K}$) pulsing.

(b) Reactor water temperature: 100°F.

(c) Restricted areas: Same as design criteria.

(d) Room ventilation 2 air changes per hour minimum.

(d) Shielding surrounding core and tank

(1) 1 1/2-foot concrete around tank to reduce ground activity to permissible levels

(2) 10-foot concrete (equivalent) from core to unrestricted access areas

(f) Emergency ventilation: doors and windows weather stripped. Capability of closing inlet air sources and diverting exhaust air through absolute filter in case of emergency. Air exhaust 150 cfm through this filter.

(g) Reactor fuel temperature: 500°C maximum.

50.34 (b) (3) (iii) Design Details

(a) Reactor

(1) Introduction

The TRIGA* reactor was developed by General Atomic Division of General Dynamics Corporation for use by universities and research institutions as a general-purpose research and training facility. Using U-$ZrH_{1.0}$ or U-$ZrH_{1.7}$ fuel, the reactor is designed for

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*TRIGA trademark registered in U. S. Patent Office.

steady-state operation at a power level of 250 kw (thermal) and for routine pulsed operation. The total loading of this TRIGA reactor core will be a maximum of 2.25% $\delta k/k$ (\$3.00) excess reactivity above a cold, critical, compact condition. Pulsed operation will be limited to rapid insertions of up to 1.5% $\delta k/k$. As used in this document, a pulse is defined as a step insertion of an amount of excess reactivity between 0.75% and 1.5% $\delta k/k$. A 1.5% $\delta k/k$ pulse yields a burse having a prompt energy release of about 8 Mw-sec, a peak power of about 250,000 kw, and a pulse width at half maximum of about 30 msec.

The safety of the TRIGA reactor lies in the large prompt negative temperature coefficient that is an inherent characteristic of the uranium-zirconium hydride fuel-moderator material. Thus, even when large sudden reactivity insertions are made and the reactor power rises in a short period, the excess reactivity is compensated for automatically because the fuel temperature rises simultaneously so that the system returns quickly to a normal power level before any heat is transferred to the cooling water.

The inherent prompt shutdown mechanism of TRIGA reactors has been demonstrated extensively during many thousands of transient tests conducted at the two prototype TRIGA reactors in General Atomic's laboratories in San Diego. These tests, using aluminum-clad, $U\text{-}ZrH_{1.0}$ elements, involved step insertions of reactivity of up to 3.1% $\delta k/k$. This demonstrated safety has permitted to location of TRIGA reactors in urban areas in buildings without the pressure-type containment usually required for other research reactors of similar power level and excess reactivity.

The reactor core consists of a lattice of cylindrical aluminum-clad $U\text{-}ZrH_{1.0}$ or stainless steel clad $U\text{-}ZrH_{1.7}$ fuel-moderator elements and graphite (dummy) elements. Twenty percent enriched uranium is used. A 1-foot-thick graphite radial reflector surrounds the core and is supported on an aluminum stand at the bottom of the tank. Water occupies about one-third of the core volume.

The power level of the pulsing TRIGA reactor is accurately controlled with three control rods: a regulating rod, a shim rod, and a safety-transient rod.

to-zirconium atom ratio is approximately 1 in aluminum clad elements and 1.7 in stainless steel clad elements. Each element contains about 36 grams of U^{235}. Since the aluminum clad elements are obtained from the University of Illinois, they contain a samarium burnable poison disc at each end.

Each element is sealed in a 0.030-inch-thick aluminum can, and all closures are made by heliarc welding. Two 4-inch sections of graphite are inserted in the can, one above, and one below the fuel, to serve as top and bottom reflectors for the core. Aluminum end fixtures are attached to both ends of the can, making the overall length of the fuel-moderator element approximately 28.5 inches. The fuel element cladding is anodized to retard wear and corrosion. The stainless steel clad elements are similarly constructed except the cladding is 0.020 inch thick Type 304 stainless steel.

The lower end fixture supports the fuel-moderator element on the bottom grid plate. The upper end fixture consists of a knob for attachment of the fuel-handling tool and a triangular spacer, which permits cooling water to flow through the upper grid plate. The weight of a fuel element is about 6.5 pounds.

2.2.2.1. Instrumented fuel-moderator elements

Instrumented fuel-moderator elements, shown in Figure 13, are provided with the core of each TRIGA pulsing reactor. These instrumented elements have the same dimensions and fuel material as standard elements, but they contain three chromel-alumel thermocouples embedded halfway between the outer edge of the element and its vertical centerline. They are located 1 inch above, and 1 inch below and at the horizontal center-line of the fuel. The tube that leads from the fuel element is sealed with an aluminum plug containing holes for the thermocouple wires. Soft solder flowed in on top of the plug seals the holes around the wires and between the plug and the tube. The wires lead from the fuel element to the surface of the water in aluminum tubing (one of the elements to be obtained from the University of Illinois has seven thermocouples versus the three mentioned above).

2.2.3. Graphite Dummy Elements

Graphite dummy elements may be used to fill grid positions not filled by the fuel-moderator elements or other core components. They are of the same general dimensions and construction as the fuel-moderator elements, but are filled entirely with graphite.

2.2.4. Neutron Source

The neutron source consists of a mixture of americium and beryllium, double encapsulated to ensure leak-tightness. Its initial strength at manufacture is 3 curies. This source has a nominal outside diameter of

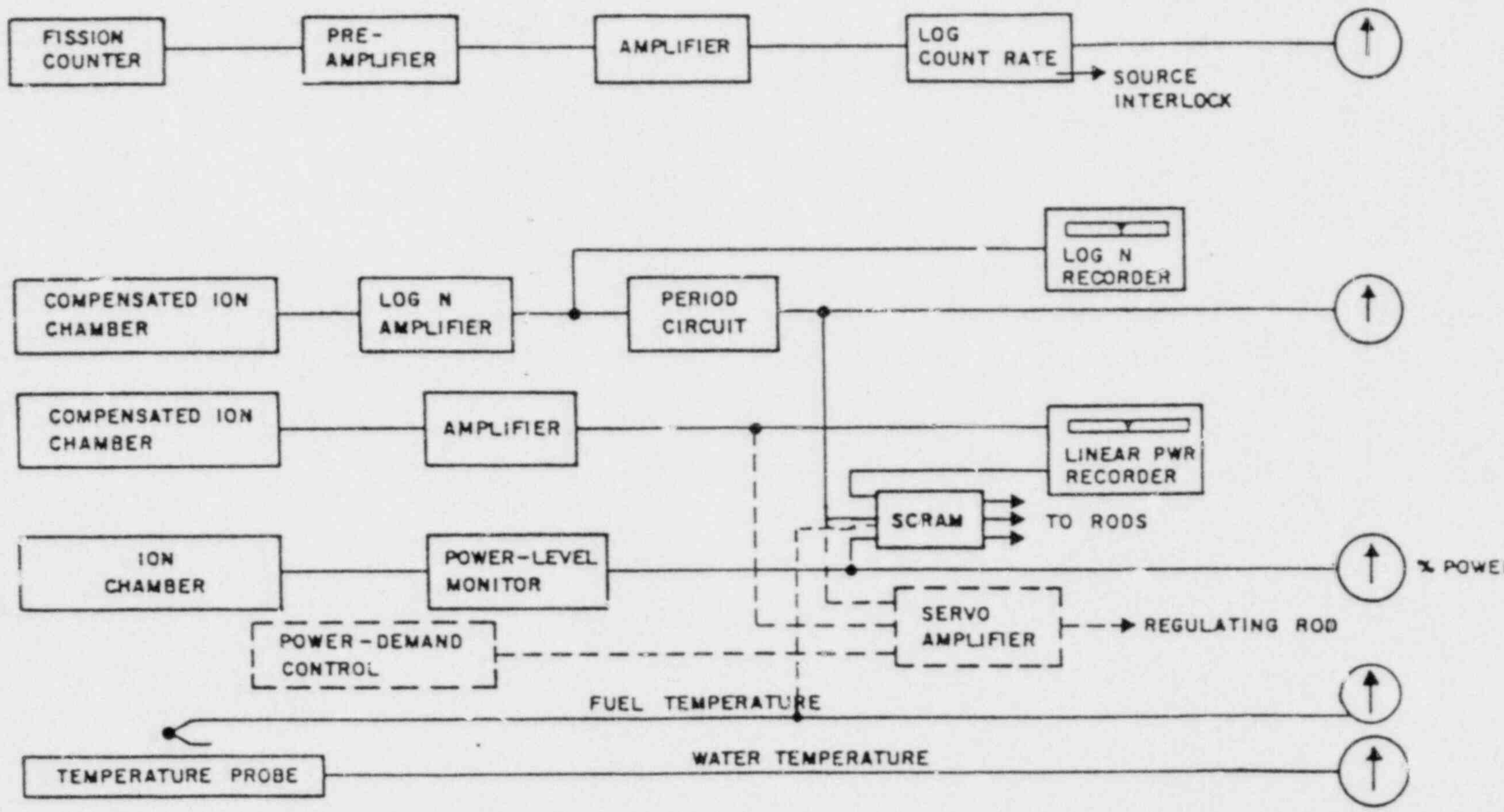

Figure 20. Block Diagram of Reactor Instrumentation for Steady-State Operation (Pulsing Rector Only)

The count-rate channel, using a fission counter and log count-rate chassis, provides power indication over 4 decades from below source level. This channel is provided with a source interlock that prevents rod withdrawal unless source level is above a preset level.

A log-n channel using a compensated ion chamber covers the power range from less than 10 watts to above full power, and is read and recorded by one pen of the 11-inch, dual-channel recorder. A period circuit indicates reactor period from -40 to ∞ to +7 seconds with a scram level adjustable throughout the range from ∞ to +7 seconds.

A linear micromicroammeter channel provides a power level measurement from about 0.001 watt to full power, with a range switch having two ranges per decade so that measurement of the compensated ion chamber current may be made accurately. The output is indicated and recorded by the second pen of the recorder. A linear channel scram at 110% of full scale is provided on all ranges.

A percent-power-level channel operating from an ion chamber indicates power in the range from a few percent to 110% of full power. This circuit provides for an adjustable-level scram within this range.

Fuel temperature and cooling water outlet temperatures are metered, as shown in Figure 20. A manually operated water conductivity bridge is provided with two probes to read conductivity at the demineralizer inlet and outlet; the bridge is located on the console.

2.3.2.2. Pulsing Operation. After a power level of less than 1000 watts in the steady-state operating mode is reached, the mode switch is changed to the pulse mode so that the reactor can be pulsed. When the switch is turned to the pulse mode, the normal neutron channels are disconnected and a high-level pulsing chamber is connected to read out the peak power of the pulse. The pe[illegible]r is then displayed on the recorder several seconds after the pulse is completed. Also, changing the mode switch to pulse removes an interlock that prevents application of air to the safety-transient rod unless the safety-transient rod cylinder is in the full "in" position and thus allows pulsing to take

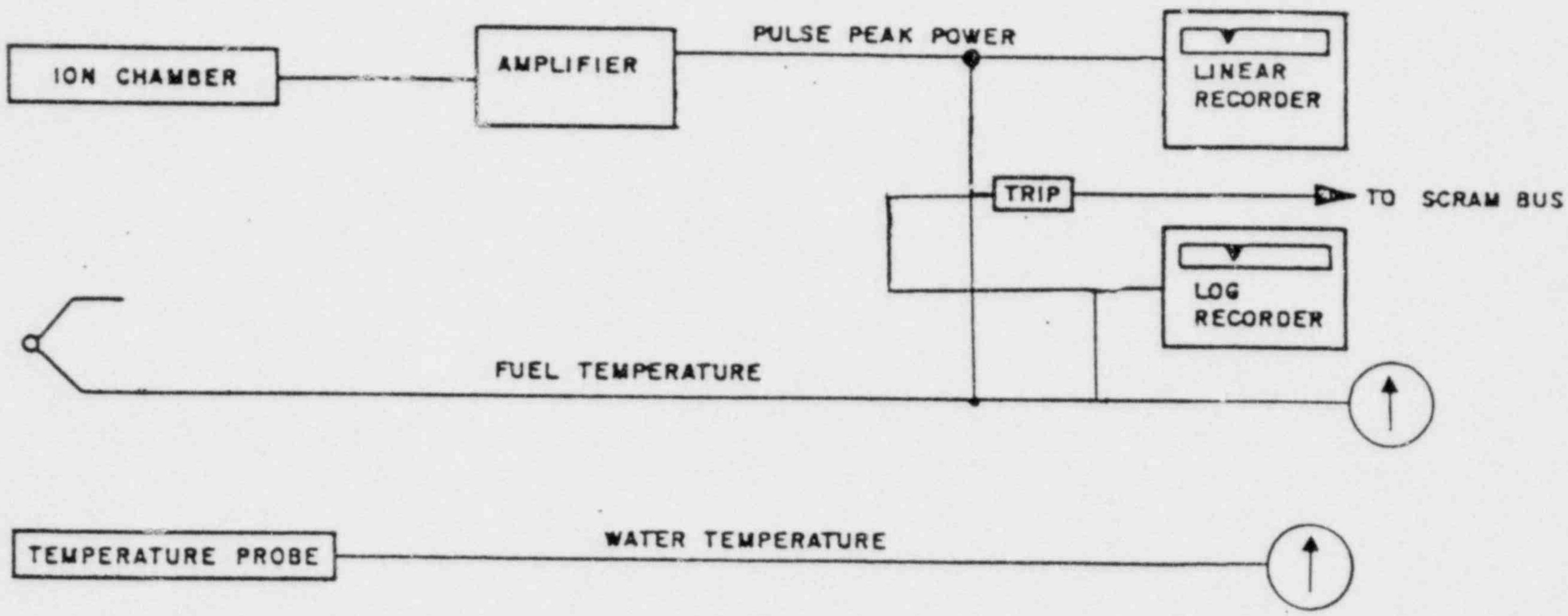

Figure 21. Block Diagram of Reactor Instrumentation for Pulsing Operation

(2) Radiation Dose Rates Around Reactor

Complete gamma dose measurements have been taken around the MSU TRIGA reactor during 250-kw steady-state operation. Typical measurements are listed in Table 3. No neutron leakage has been detected from operating TRIGA reactors except for a thermal neutron dose of 0.03 mrem/hr (15 neutrons/cm^2-sec) measured above the rotary specimen rack drive shaft tube during 100-kw operation.

As indicated in Table 3, the measured radiation dose rates are low enough to allow operating personnel to perform experiments at the edge of the reactor tank during full power operation.

The maximum permissible dose rate in restricted areas established by the U.S. Nuclear Regulatory Commission, for persons whose previous radiation history is unknown, is 1.25 roentgens per quarter calendar year (approximately 100 mrem per week). Furthermore, the NRC guidelines state that exposure levels should be as low as reasonably achievable. The International Commission on radiation Protection (ICRP) recommends that the average external occupational exposure should not exceed 5 rem per year. Dose rates inside the restricted area clearly fall within these regulations and guidelines during normal operations.

Table 3. Gamma Dose Rates Around Triga Reactor During 250-KW Steady-State Operation

Location of Instrument	Dose Rate (mr/hr) Measured 250-kw Steady-State Operation
Surface of actor tank water	1.3
At handrail adjacent to reactor tank	<0.1
At top of reactor structure, beside tank	0.2

Dose rates apply when the reactor cooling system is in operation. These doses are given in milliroentgens (mr). Since only gamma radiation was measurable, mr is the same as mrem in this case. The roentgen equivalent, man (rem) is defined as the dose of any ionizing radiation that will produce the same biological effect as that produced by 1 roentgen of X-ray or gamma-radiation.

The radiation levels produced at the floor level in the classroom over the reactor are less than the permissible levels for non-radiation workers as specified in Title 10, CFR Part 20 as measured by film badges located in the classroom and on the ceiling of the reactor room.

(3) Loss of Shielding and Cooling Water

Loss of water can occur by only two means: the tank may be pumped dry, or a tank failure may allow the water to drain.

The tank outlet and inlet water lines each have a 1/2-inch diameter hole drilled a foot below the normal water level. The purpose of these holes is to break pump suction or accidental siphoning if the tank water level drops below this hole. Also the tank outlet pipe extends only about 3 feet below normal water level. Therefore, even if the water system was operated carelessly, for example, when the pump discharge line was disconnected for repairs, the tank could not be pumped dry accidentally. The tank can be pumped dry only by deliberate action of the operating crew. In the unlikely event that the tank must be drained for repairs, the fuel will first be removed from the reactor and stored in shielded casks, or in the fuel storage pits provided.

Even though the possibility of the loss of shielding water is believed to be exceedingly remote, a calculation has been performed to evaluate the radiological hazards associated with this type of accident under the condition that the reactor has been operating for a long period of time at 250 kw prior to losing all of the shielding water. The radiation dose rates were determined for the two different locations given in Table 4. The first location, above the unshielded reactor core at the top of the reactor tank, receives direct radiation. The second location, at the top of the reactor shield, is shielded from the direct radiation by the concrete reactor structure, but is subject to scattered radiation. The assumption is made that a thick concrete ceiling 9 feet above the top of the reactor shield will maximize the reflected radiation dose. Time is measured from the conclusion of 250-kw operation. Dose rates assume no water in the tank.