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March 11, 1983

Harold Bernard
Standardization & Special Projects Branch
Division of Licensing
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Bernard:

After discussions regarding the Safety Evaluation Report during the week March 1-4, several corrections to currently proposed Technical Specifications were indicated. Enclosed are 12 copies of the revised specifications. Please note that the changed pages and type of change are documented on an enclosed page. Some objection was made to the wording after specification 3.4.2 (page 11) regarding a potential channel failure. This wording has been changed.

Twelve copies of the rewritten Safety Analysis Report chapter are also enclosed as already provided for the Safety Evaluation Report developed by LANL personnel.

I hope that these items will resolve a few of the questions concerning R-92 license renewal.

Sincerely yours,

Thomas L. Bauer

Thomas L. Bauer
Reactor Supervisor
SOP# 3664

Enclosures

TLB:mgm

A020

UT Tech. Spec. Changes

March 1983

A. Page 8-9, section 3.2; format change of reactivity limitations.

B. Page 11, section 3.4.2; changed Integrated Pulse Power to Peak Pulse Power. Change comment regarding allowable failure of measuring of safety channel.

C. Page 11, section 3.4.3; changed Linear Power Scram to steady-state only and added a line to specify Peak Pulse Power Scram in pulse mode.

D. Page 30, section 5.7; changed ventilation specifications to original request removing parts c, d, and e.

E. New front page reflecting most recent date.

F. Typographical errors pages 14 and 22.

G. Changed metric units to English pages 24 and 25.

H. Page 22, section 4.2.3; clarification of weekly intervals.

6. INSTRUMENTATION AND CONTROL

6.1. GENERAL DESCRIPTION

The complete operating and protection system for the TRIGA reactor is contained in an operating console similar to that shown in Fig. 6-1 (original equipment installation). The console cabinet is 59 in. long by 22 in. deep by 50 in. high. Because of its profile, the console is positioned so that the operator can easily observe both the reactor experimental area and the console instruments. The electonic modules, logic systems, and relays are accessible by removal of individual panels or from swing doors at the rear of the console. All meters, rod controls, and recorder are placed for optimum readability and accessibility. The important parameters of log and linear power over the entire range are displayed on the same 10-in. chart paper of a dual-pen recorder. The log power record allows later determination of the range used for the linear power channel so that both accurate indication and recording of reactor power is obtained. Care has been used in the design of the console to display those variables and annunicate the conditions that are important and necessary for reactor operation and safety without confusing this information with nonessential auxiliary information.

A block diagram of neutron measurement components are shown in Fig. 6-2. Other auxiliary console instrumentation is shown in Fig. 6-3. Detectors, rod drives and other devices are shown to provide complete instrumentation diagrams of the safety, control, and measurement circuits.

Several modifications of the original console instrumentation system constructed in 1963 have occurred and are documented in facility files. The two most significant changes were a power increase from 10kw to 250kw

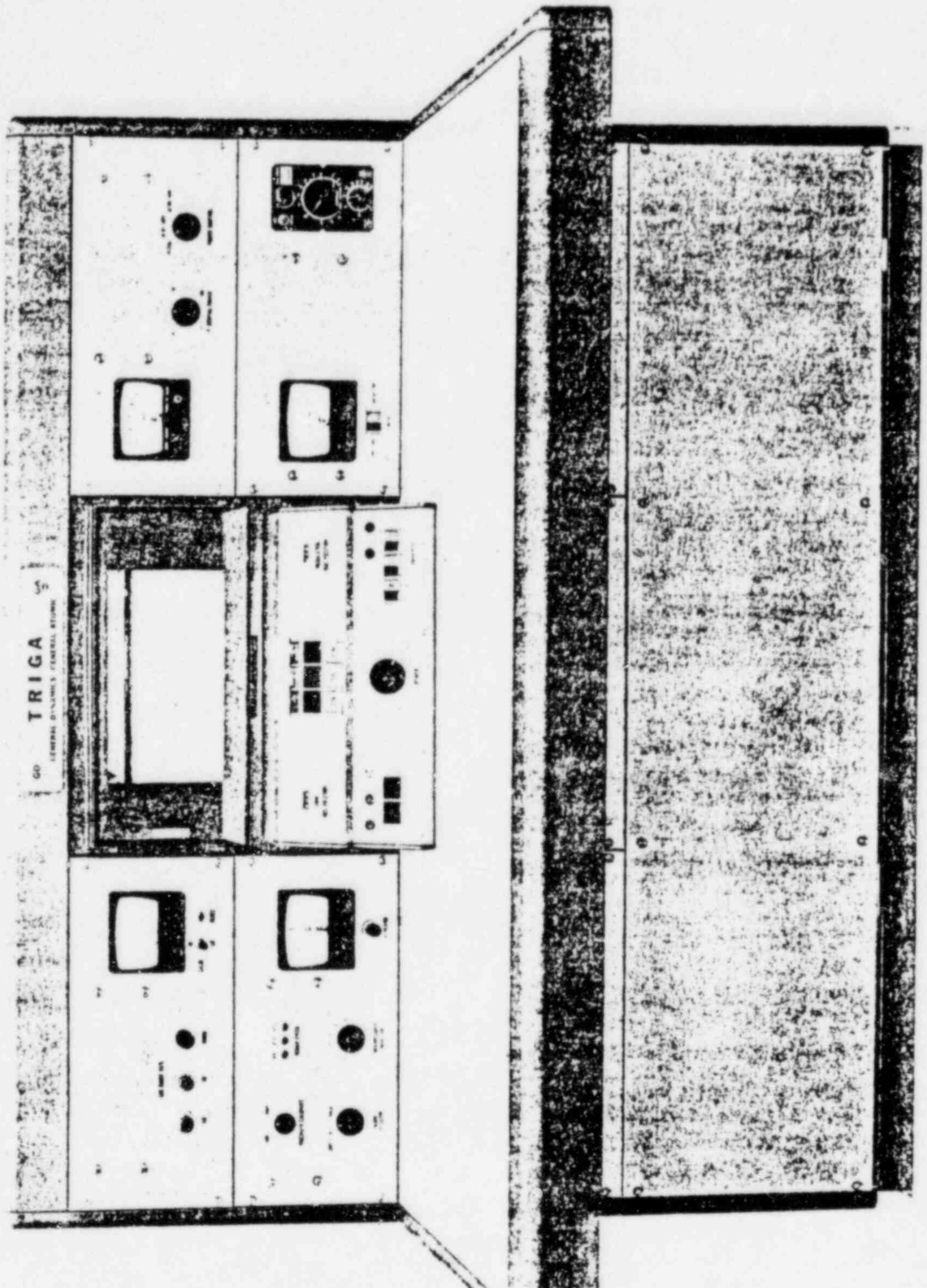

Fig. 6-1 TRIGA control console, front view

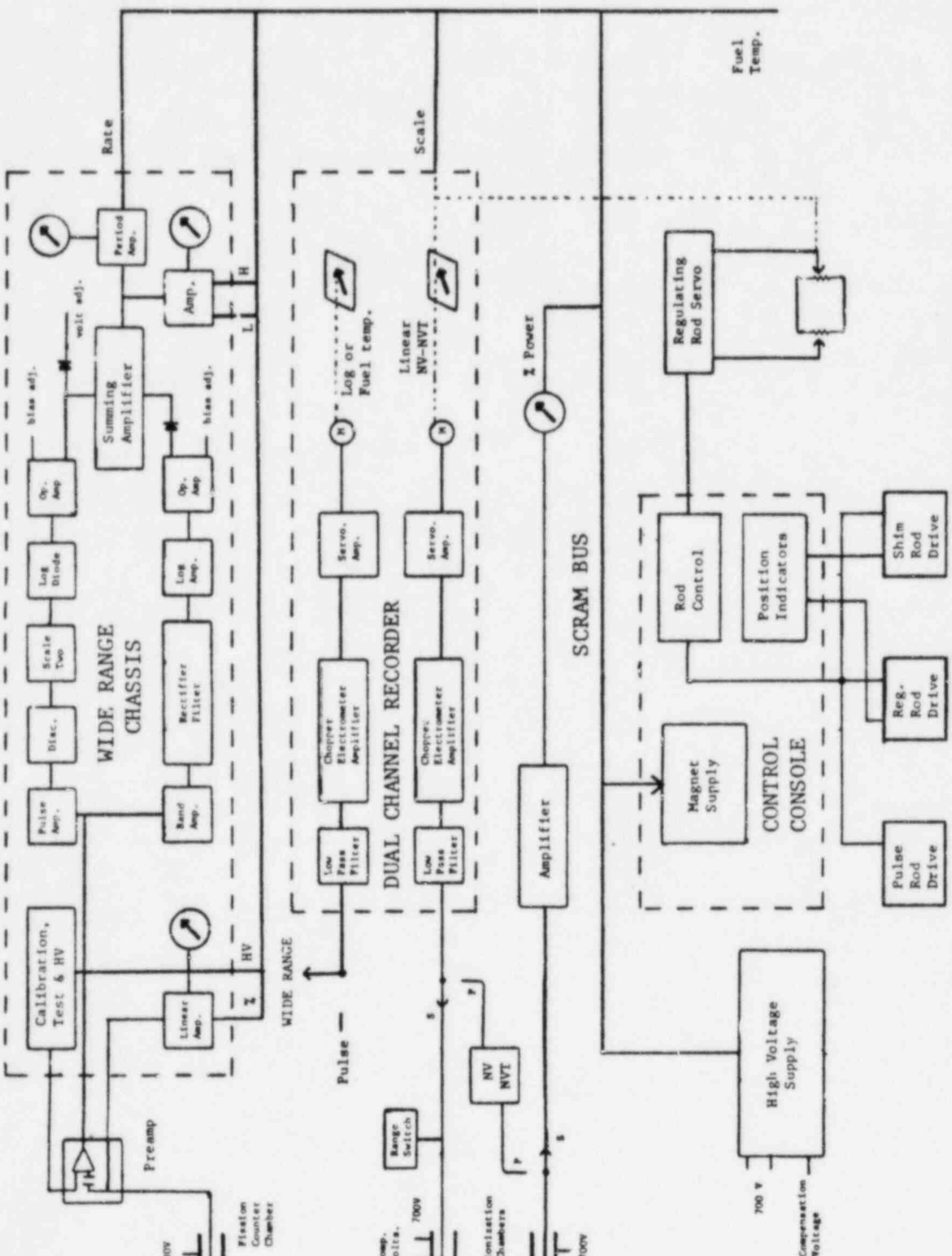

Fig. 6-2 Functional Block Diagram
Neutron Measurement Systems

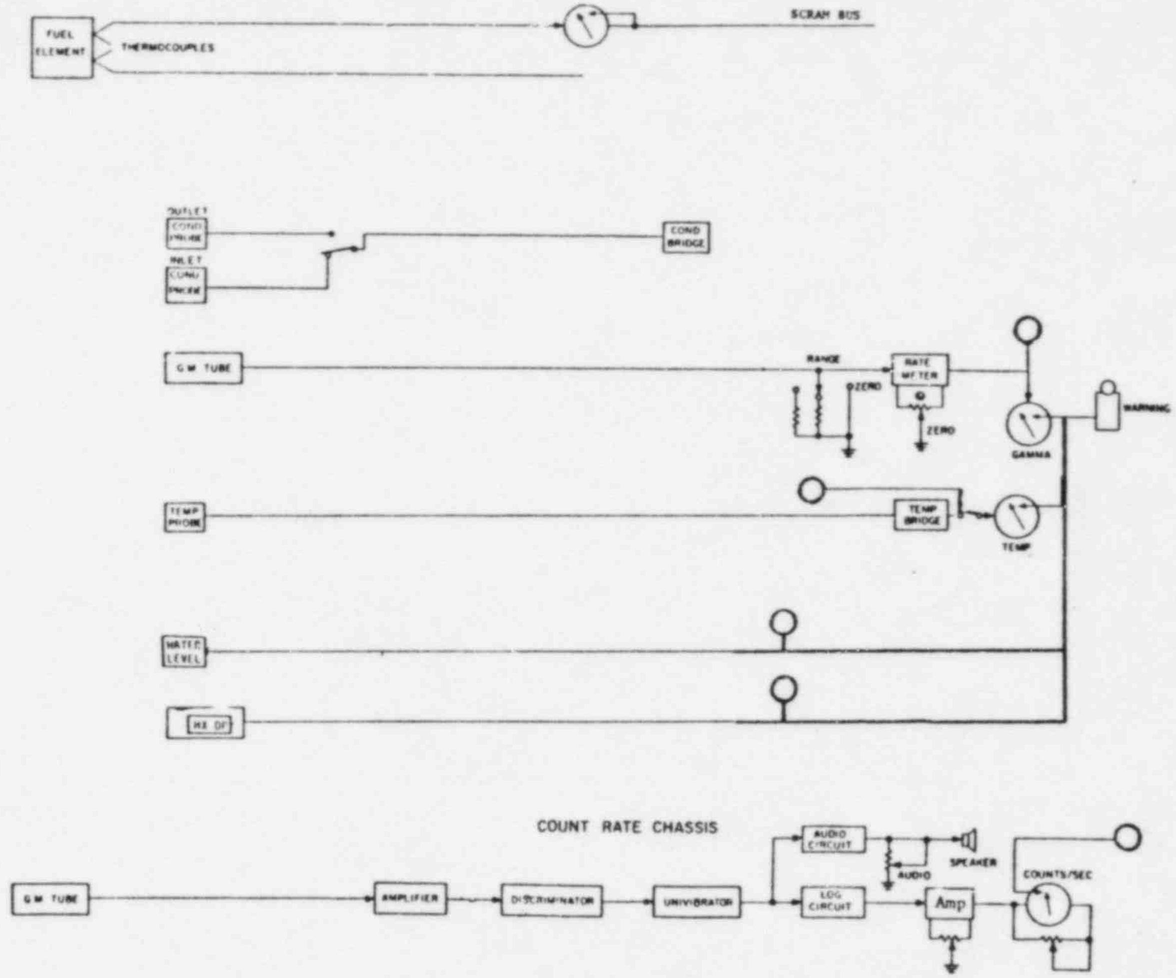

Fig. 6-3 Functional Block Diagram
Other Measurement Systems

in 1968 and installation of a wide range power measurement channel in 1982. Numerous minor changes occur on a continuous basis to replace component failures or improve component reliability. Minor changes include component changes, physical changes and auxiliary measurement systems that do not lessen the basic functions of the console instrumentation system. (Ref. 1 and 2)

6.2 NUCLEAR CHANNELS

The neutron monitoring channels consist of a wide-range power channel (including log count-rate source range, intermediate log range coverage and linear safety channel), a multirange linear power/safety channel used for accurate power measurement, and an additional linear safety channel.

The wide-range power channel consists of a 10-decade log range channel and linear range safety channel. It operates from a single fission chamber. This channel uses counting and Campbelling, or statistical techniques, to produce an accurate reading of log power over 10 decades, even in the presence of high gamma background of 10^6 R/hr. The output of the log power channel is displayed both on a meter and on one pen of the dual-pen recorder mounted on the front of the console. Period is also derived from the log power channel and is displayed on a meter. Linear power measurement is provided by chamber return current and is displayed on a front panel meter.

Bistable trips driven from the output of the wide-range channel provide a source interlock signal on the scram bus to prevent rod withdrawal unless the source level is above a preset level, or sufficient detection chamber high voltage is present. Scram signals are generated for excessive linear or log power indications, and a power rate of change scram is also available.

A multirange safety channel provides a monitor of reactor power level on 13 power ranges. The channel consists of a compensated ionization chamber, calibrated range conversion switch, and output indication on one channel of a dual-pen recorder. Movement of the recorder pen provides a scram signal at approximately 110% of each power range scale. Pen motion on a dual slidewire also provides a correction signal for application of an automatic steady-state regulating rod control system.

The additional safety channel consists of an uncompensated ionization chamber, amplifier, and percent power meter indication that operates on a single range from 0 to 110% of full power. A meter relay provides a scram signal for a preset percent power level.

In the pulse mode, only one nuclear channel, the uncompensated ionization chamber is active. The output of the chamber is modified to measure peak power and total energy release which is recorded on one channel of the dual-pen recorder. A scram signal is provided by the recorder pen movement at full scale.

All the outputs of the nuclear measuring channels are at eye level to an operator at the console. The wide range channel and single range auxiliary safety channel are to the right and left, respectively, of the multirange linear and log outputs which are displayed on the dual channel recorder.

All nuclear channels include a means of calibrating and testing the channel and a means of testing the trip level. These calibrate and test circuits are built into the console as part of each channel.

The wide range power measurement unit replaces two channels of the original reactor control system. Both these channels remain available for supplementary use but are not routinely installed or calibrated. One channel is a log count-rate source channel consisting of fission counter, preamplifier, pulse amplifier, and log count-rate circuit. The output of the count-rate circuit is displayed on a meter calibrated from 1 to 10,000 counts per second. A meter relay provides an interlock signal at low source range counts. An audio speaker and recorder signal output are also generated by the channel. The second channel is an intermediate range power channel consisting of compensated ionization chamber with a commercial micro-microammeter. Output of the channel is a meter with 9 decades of sensitivity and scales of 0 to either 3 or 10. A meter relay provides for a signal interlock on high level power indication and an output signal for a recorder is available.

6.3. TEMPERATURE CHANNEL AND WATER MONITOR CHANNEL

A fuel temperature channel with a meter readout and scram is provided in both modes of reactor operation. The fuel temperature channel is mounted in the lower right panel of the console. The channel is provided with a TEST switch located on the front panel to allow checkout of the fuel temperature scram circuits. A second fuel temperature meter readout and supplemental scram are provided as part of the water monitor channel. The meter output is switch selectable and displayed on a front panel meter.

Several circuits with separate functions comprise the water monitor channel. Water conductivity at the deionizer inlet and outlet is measured by an ac bridge located in the lower left panel of the console. A temperature sensor in the purification loop supplements the conductivity measurement with a meter display on the front panel. Pool water activity is monitored by a GM tube in the purification system loop and activity displayed at the rear of the water unit panel. An excessive activity creates in audible alarm and visual indication on the control console panel.

Three additional water system parameters create visual indication on the front panel of the control console and audible alarm indication. Two signals are pool measurement conditions on pool water level and pool bulk temperature. The third parameter that provides alarm indication is differential pressure in the heat exchanger unit between secondary outlet and primary inlet.

6.4 REACTOR OPERATING MODES

During reactor operation, the individual control and safety channels are intimately related. There are three operating modes: manual, automatic, and pulse. The manual and automatic modes are steady-state power modes. The manual mode is accomplished by setting the MODE SELECTOR switch to the MANUAL position. The automatic mode is not currently installed.

Fig. 6-4 shows the approximate channel and detector operating ranges as a function of reactor power level.

The manual and automatic reactor control modes are used for reactor operation from source level to 100 percent power (250 kW). These two modes are used for manual reactor startup, change in power level, and steady-state operation. The pulse mode generates high power levels for short periods of time (max 250 MW).

6.4.1. Manual Mode

The manual mode can be used to control the reactor power level from source level to the full rated power of 250 kW. The wide range channel displays the neutron flux level from below the source level to greater than the 100% (250 kW) flux level. The output of the channel log indication is displayed by the red pen of the strip chart recorder located in the center of the console. To withdraw control rods, the

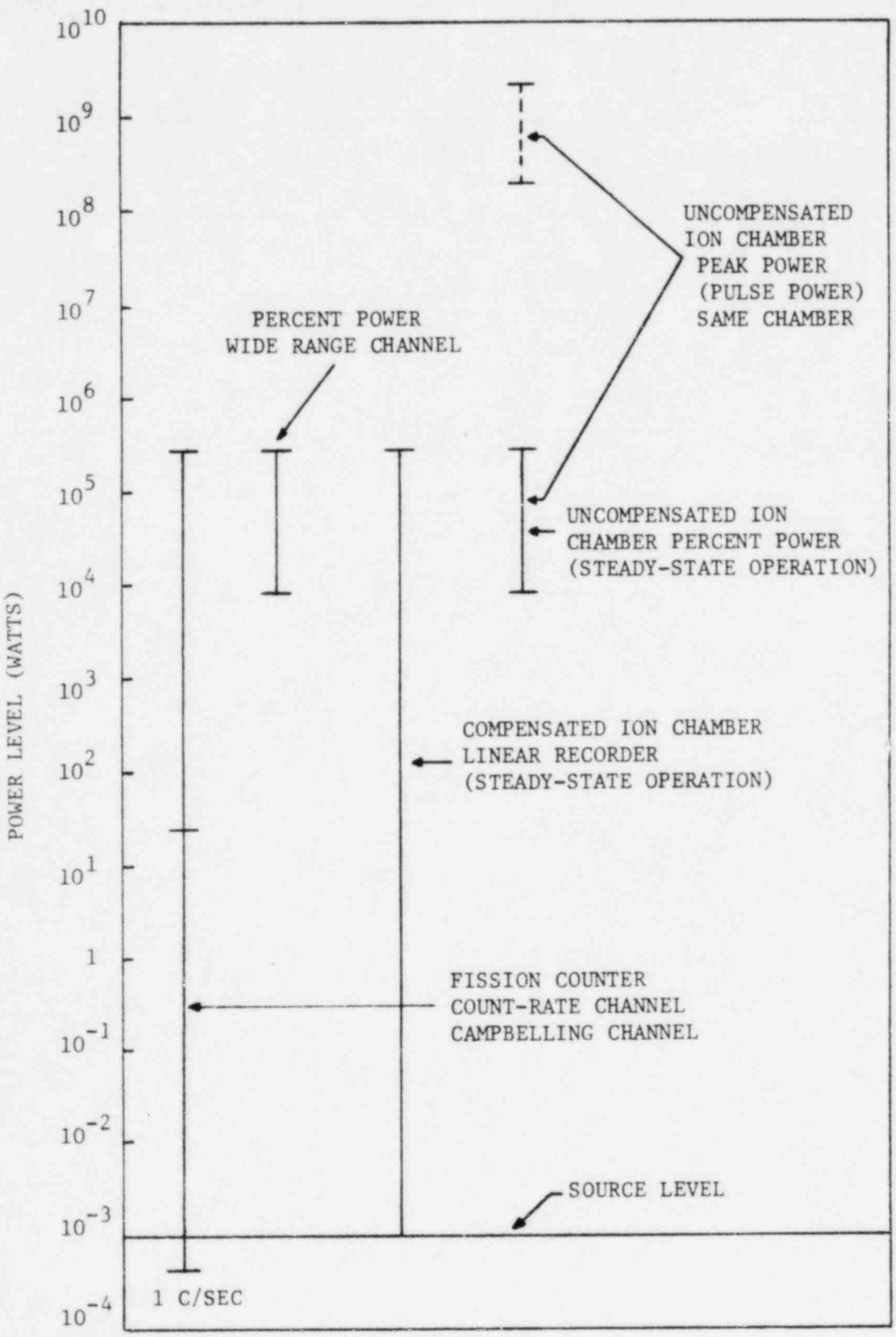

Fig. 6-4 Operating ranges of TRIGA Mark I pulsing reactor neutron detectors

high voltage condition and minimum source level rod withdrawal interlock requirement of the wide range channel must be satisfied (about 10 nv at the detector which corresponds to 2 counts per second). At approximately 10^{-8} percent power, depending on the gamma flux level, the multirange linear channel can detect the neutron flux and the blue pen of the recorder will respond. As the power level is increased, the operator advances the linear multirange channel range switch to keep the channel sensitivity compatible with the operating flux level.

The instrument system provided for manual operation consists of an NLL-2 log/linear channel operating from one fission chamber. The output of the NLL-2 provides input signals for calibration and test of linear, log, and period measurements. The 10-decade log power output is displayed on a meter, and one pen of a dual-pen recorder. Period information over the full ten decades of log power is read out on a meter calibrated from -30 seconds to infinity to +3 seconds. Linear power is displayed on a meter calibrated from 0 to 125% of full power. Indicators identify bistable trip conditions for high voltage, source level, period, linear and log power.

A multirange linear output from a compensated ionization chamber is displayed on the other channel of the dual channel recorder. Thirteen overlapped ranges provide linear power indication from 25 mW to 275 kW. A signal to the scram bus is created on overrange of any scale by 110%.

A second safety channel consists of uncompensated ionization chamber, amplifier and meter calibrated output of percent power (0-110%). A scram signal is provided through meter relay contacts.

Both the multirange linear channel and second percent power safety channel contain signals to test channel and scram functions. Protective trips to the reactor scram control system have light indications located on the wide range unit (5) and control console (6).

Thermocouples embedded in the fuel elements sense fuel temperature with a meter that displays 0-600°C. A meter relay provides a protective input signal to the reactor control system. Multiple thermocouples (6) may be switch selected and a secondary thermocouple, temperature display, and protective trip are switchable to the water temperature meter (0-600°C, fuel; 0-60°C, water).

In addition to water temperature indication from the purification system, the water activity is sensed and diplayed on a meter (0-1 ma; not visible from the console front panel). Lights on the control console panel indicate trips of alarm set points for pool water temperature, activity, level, and heat exchanger differential pressure.

6.4.2. Automatic Mode

The automatic mode is identical to the manual mode except that the regulating rod position is controlled by a feedback control system to regulate the reactor power level as detected by the multirange linear channel. Automatic operation can be initiated at any power level detectable by the linear multirange channel, but a level above 50 W is preferred. The setpoint for the regulator is determined by operator adjustment of the DEMAND control located to the left of the chart recorder. The period signal is also connected to the flux regulator to provide a constant logarithmic rate of change of power when a large change in power level is demanded.

The regulating rod is now controlled automatically in response to a power level and period signal by means of a servo amplifier. Reactor power level is compared with the demand level set by the operator and is used to bring the reactor power to the demand level in a fixed preset period. The demand level is determined by the range switch position and the percent demand potentiometer. The period control signal, which is fed into the servo amplifier, allows power level changes to be made automatically on a constant period, usually set for 30 or 60 seconds.

6.4.3. Pulse Mode

Pulse mode is used to generate high peak fluxes or power levels for short periods of time. The maximum peak pulse power, nv, is 250 MW, but its limited duration makes the total energy release less than 16 MW-seconds, nvt, per pulse.

To initiate the pulse mode of operation the reactor condition is set at a steady-state power level below 1 kW. It is also necessary to position the transient rod and cylinder to produce the desired reactivity change when air is applied to the cylinder.

6.4.3.1. Monitoring Channels. Two reactor parameters are measured during pulsing operation: fuel temperature and neutron flux. Flux is measured in two different terms: the peak flux achieved (nv), and the total (nvt,) or time integral, of the flux during the pulse. Since the pulse duration is extremely short, this information is stored and then recorded. The fuel temperature and flux monitoring channels provide the necessary alarms and shutdown mechanisms to help ensure that the reactor is operated safely.

The instrument system contains one safety channel monitoring the core flux and two thermocouple channels monitoring fuel temperature.

In the pulse mode the uncompensated ionization chamber is switched to the input of the peak reading (nv) and flux integrating (nvt) circuits. The output of the peak and integrated flux is indicated on one pen of the dual-pen recorder. Also, a peak flux scram is provided by the same scale overrange signal used in the steady-state mode. The output of the nvt circuit is automatically recorded following the recording of the nv circuit. The scale is calibrated in both MWs and MW-seconds. The thermocouple channel located in the lower right panel is displayed on the second pen of the recorder, and the second thermocouple channel is displayed on the other panel meter. Either will provide an automatic shutdown for excessive temperature.

6.5. REACTOR CONTROL SYSTEM

The control of reactor flux is accomplished by use of the three control rods. The control rod circuit consists of the three horizontal rows of lighted pushbuttons located on the center of the rod control panel.

6.5.1. Manual Rod Control Circuit

Manual rod control is accomplished by the lighted pushbuttons on the rod control panel, similar to Fig. 6-5. The top row of annunicators, when illuminated, indicates magnet contact with the armature and magnet current. Depressing any one of the CONT/ON pushbuttons will interrupt the current to that magnet and extinguish the magnet current ON indicator. If the rod is above the down limit, the rod will fall back into the core and the CONT light will be extinguished until the magnet is driven to the down limit where it again contacts the armature.

The annunciators in the middle row, when illuminated, indicate the upper (UP) and the bottom row indicate the lower (DOWN) limit positions of the rods. By depressing the indicators the control rod will move in the direction indicated. Several interlocks prevent the movement of the rods in the UP direction:

1. Two UP switches depressed at the same time
2. Scrams not reset
3. Magnet not coupled to armature
4. Mode switch in AUTOMATIC position (regulating rod only)
5. Mode switch is in the PULSE position (all rods except the transient rod)
6. Mode switch in STEADY-STATE (all rods not down transient rod only)

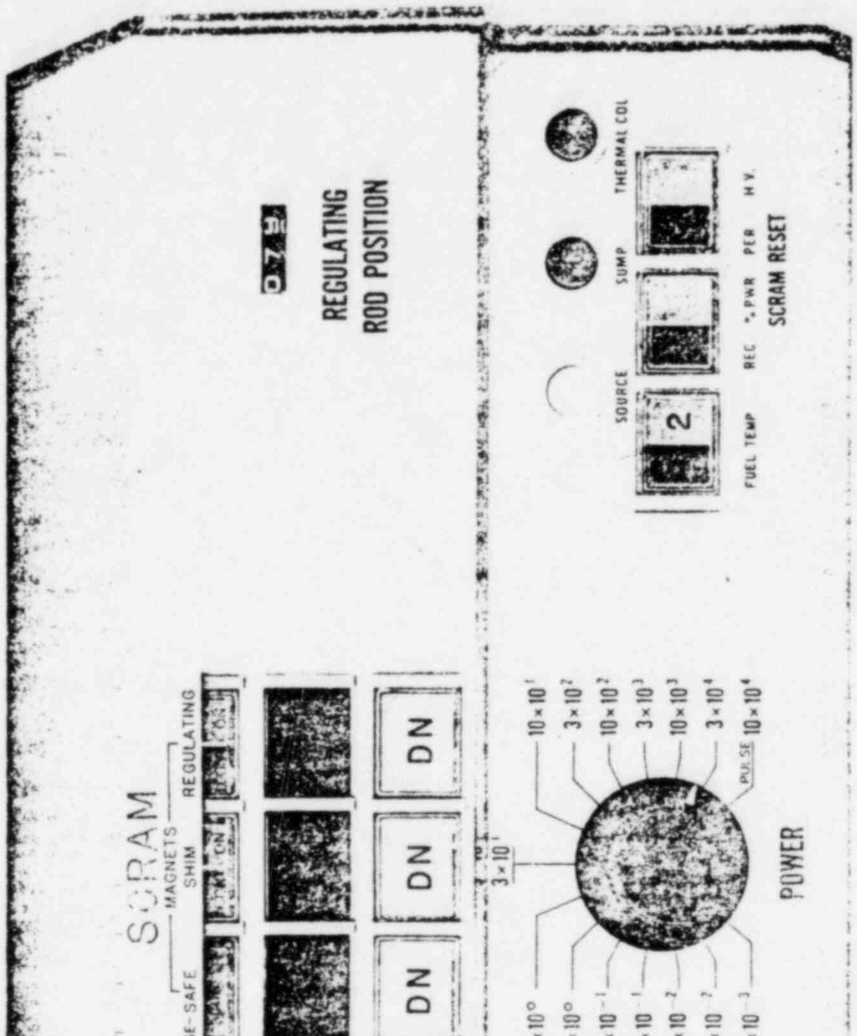

Fig. 6-5 --Control panel

There is no interlock inhibiting the DOWN direction of the control rods except in the case of the regulating rod while in the AUTOMATIC mode.

Rod position may be determined by a digital position indicator for each drive. Position readout is within 0.2%. By pushing the scram bar all rods may be inserted simultaneously in a manual scram.

6.5.2. Automatic Operation

Automatic power control can be obtained by switching from manual operation to automatic operation. All of the instrumentation, safety, and interlock circuitry described above applies and is in operation in this mode. However, the regulating rod is now controlled automatically in response to a power level and period signal by means of a servo amplifier. Reactor power level is compared with the demand level set by the operator and is used to bring the reactor power to the demand level on a fixed preset period. The demand level is determined by the range switch position and the percent demand potentiometer. The period control signal which is fed into the servo amplifier allows power level changes within the reactivity limits of the regulating rod to be made automatically on a constant period. The purpose of this feature is to automatically maintain the preset power level during long-term power runs. Limit switches on the regulating rod interlock the servo amplifier control when the regulating rod reaches the down limit.

6.5.3. Pulsing Operation

Reactor control in the pulsing mode consists of establishing a critical reactor at a flux level below 1 kW in the steady-state mode. This is accomplished by the use of the two control rods, leaving the transient rod fully inserted. The MODE SELECTOR switch is then placed in the pulse range (selected to give an on-scale reading for the flux level of the pulse to be produced). The MODE SELECTOR switch automatically connects the pulsing chamber to the safety channel input, the dual-pen recorder inputs to the flux and fuel temperature channels, and removes the high voltage supply to the compensated ionization chamber.

The adjustable transient rod up position is raised to a preselected position for the desired total reactivity insertion, depending on the peak flux levels desired. When the MODE switch is placed in the pulse position thus arming the transient rod air solenoid circuit and, when all transient operation conditions have been met, air may be applied to the transient rod cylinder whenever the TRANSIENT ROD UP bottom is depressed. From the time the TRANSIENT ROD button is depressed, the operation of the reactor and control console is automatic. The reactor flux and fuel temperature will increase to a peak value and decrease rapidly. After a preset time (less the 15 secs) the transient rod will be released and fall back into the core. The timer which controls the transient rod release is located inside the console. The peak flux, integrated flux, and fuel temperature attained during the pulse will be indicated on the dual-pen recorder.

Fuel temperature is monitored by chromel-alumel thermocouples embedded in the fuel elements. Two thermocouples are connected to the right and left front panel meters, respectively. The right channel fuel temperature is automatically switched to one pen of the dual-pen recorder in the pulse mode.

6.6. REACTOR SAFETY

A reactor protective action interrupts the magnet current and results in the immediate insertion of all rods under any of the following conditions:

1. High neutron flux on safety channels (110%),
    a. uncompensated ionization chamber percent power,
    b. fission chamber linear power output,
    c. compensated ionization chamber overrange of scale,
    d. overrange wide range log power (not used)
2. Power supply failure
    a. ionization chambers high voltage
    b. fission chamber high voltage
    c. scram relay power
3. High fuel temperature (400°C)
    a. steady-state 1 of 1
    b. pulse 1 of 2
4. Low neutron source count rate
5. High rate of change of power (3 secs)
6. Peak flux (NV) in pulse mode
7. Manual initiation

All scram conditions are automatically indicated by the annunciators. A manual scram will also insert the control rods and may be used for a normal fast shutdown of the reactor. The annunciators are located in two different locations. A set of 5 bistable trip operated circuits are located on the wide range panel. Another set of 6 relay operated annunciators are located on the control console panel

Console instrumentation power is divided into four functional systems. The wide range channel operates directly from a line power source and is continuously active. Power through a rear panel console switch maintains line power to alarms, water measurement systems, ionization chamber, high voltage supplies, routinely maintained active. A front control panel switch provides power to indicator lamps and remaining instrumentation units excluding the rod magnet supply.

The rod drive magnet power can be obtained only with the key switch mounted on the front of the console. The key operation prevents unauthorized operation of the reactor and yet allows checkout and calibration of instrument channels by maintenance technicians, or rapid and continuous surveillance of specific system functions.

Chapter 6

References

1. TRIGA MARK II Instrumentation and Maintenance Manual, GA 4175, The University of Texas.

2. Log-Linear Safety Channel Mode 1 NLL-2F Instruction Manual, Gulf EL-102 June 10, 1971.