ETS-1

CONSOLE OPERATIONS MANUAL

LEAD REACTOR ENGINEER
LRE

MASTER

NTO-T-0010

NERVA Test Operations
Nuclear Rocket Development Station
Jackass Flats, Nevada

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LEAD REACTOR ENGINEER CONSOLE

CONTROL ROOM CONSOLE LAYOUT

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LIST OF ABBREVIATIONS

ATE	Assistant Test Engineer
BF ₃	Boron Trifluoride
CPS	Counts per Second
CROP	Control Room Operating Procedure
CTE	Chief Test Engineer
DVM	Digital Voltmeter
Eng Log	Engine Log System
EP	Experimental Plan
LRE	Lead Reactor Engineer
nv	Number of Neutrons per Square Centimeter per Second
pf	Picofarad 10^{-12} Farad
PIT	Power Increase Timer
R/hr	Roentgen per Hour
SUR	Startup Reset
TCB	Test Cell Building
TSCS	Test Stand Control System
T.S. Log	Test Stand Log System

I. INTRODUCTION

The Lead Reactor Engineer (LRE) console is one of five consoles in the Test Stand Control System (TSCS).

The LRE console is used to select and adjust nuclear instrumentation channels for reactor control and power indication. Controls are available to perform the following functions:

1. Select the log signal for reactor power control.
2. Set exponential and ramp settings for auto-startup.
3. Set fixed and floating power scram levels.
4. Set period trip.
5. Select sample time for the digital period circuit.
6. Select one linear channel for display on the CTE console.
7. Select one startup channel for display on ATE console.
8. Select one log channel for display on CTE console.
9. Measure power increase time.
10. Control the source drive system.
11. Switch the startup channels on/off.

II. PURPOSE

The purpose of this manual is to provide a current source of operational information about the Lead Reactor Engineer console. The various sub-systems controlled from this console are discussed in detail as well as some individual components. The operational methods for all of the Neutronics Systems are also discussed.

An operations manual of this type is subject to constant revision, both to increase the depth of coverage, and to reflect changes in equipment or operating procedures. Each of the LRE operators who qualify to operate this console will be required to up-date this manual and incorporate new information.

III. CONSOLE LAYOUT

The LRE console is located immediately to the left of the ATE console. It is on the left end of the five consoles which are under the direction of the CTE. Figure III-1 is the layout of the four instrumentation panels mounted on the face of the LRE console. The panels are as follows:

1. Pulse and Linear Power Panel- Upper Left. The pulse and linear power panel consists of controls and displays for the pulse (start-up) system and the linear power system.

Test Stand Pulse Channel No. 1 consists of the following:

- a. A total count digital readout. This is a six-digit gas ionization type with integral BCD to decimal decoder modules.
- b. A log count rate analog panel meter.
- c. A scaler power ON/OFF switch and indicator light.
- d. An ATE channel selector switch and indicator light electrically interlocked with the other pulse channels.
- e. An AUTO/HOLD switch and indicator light.
- f. A four-button mechanically interlocked time interval selector switch and indicator light.

Test Stand Pulse Channels 2 and 3 have controls and displays that are identical to Channel 1 above.

Test Stand Linear Power Channel No. 1 consists of the following:

- a. A linear power analog panel meter.
- b. A digital linear power range indicator. This is a one-digit gas ionization type with integral BCD to decimal decoder module.
- c. A CTE channel selector switch and indicator light electrically interlocked with the other two linear power channels.

Test Stand Linear Power Channels 2 and 3 have controls and displays that are identical to Channel No. 1 above.

2. Startup Panel-Lower Left. The startup panel consists of controls and displays for power increase time, auto startup, source drive, nuclear instrumentation, and printer.

Power Increase Time consists of the following:

- a. A power increase time digital display. This is a four-digit gas ionization type with external decoders.
- b. A three-button mechanically interlocked channel selector switch and indicator light.
- c. A three-button mechanically interlocked folding-time selection switch and indicator light.
- d. A power ON/OFF switch and indicator light.
- e. A RESET switch light.

The Source Drive consists of the following:

- a. An EXPOSED/SHIELDED light.
- b. A SOURCES NOT SHIELDED light.
- c. A key-operated 3-position switch for SHIELD/OFF/EXPOSE.

The Auto Startup consists of the following:

- a. A multiturn pot with vernier dial for setting the startup EXPONENTIAL rate.
- b. A multiturn pot with vernier dial for setting the startup RAMP rate.

The panel also includes a printer RUN/STOP switch light and a nuclear instrumentation CALIBRATION switch and indicator light.

3. Log Power Panel-Upper Right. The log power panel consists of controls and displays for the test stand log power and engine log power.

The Test Stand Log Power consists of the following:

- a. One log power analog panel meter for each of the three log channels.
- b. One ACTIVE/REJECT switch and indicator light for each of the three log channels.
- c. One INHIBIT switch and indicator light for each of the three log channels.
- d. An average log power analog panel meter.
- e. An average period analog panel meter.

- f. One average RESET switch and indicator light for average amplifier A and one for average amplifier B.

The Engine Log Power controls and displays are identical to the Test Stand Log Power channels above.

4. Reactor Setup Panel-Lower Right. The reactor setup panel consists of controls and displays for the nuclear power control and the reactor safety system.

The nuclear power control consists of the following:

- a. A nuclear power signal digital display. This is a four-digit gas ionization type with external decoders.
- b. A nine-position nuclear power rotary selector switch.
- c. A BF_3 power ON/OFF switch and indicator light.
- d. An LRE READY/HOLD switch and indicator light.
- e. A power control T.S. LOG/ENG. LOG switch and indicator light.
- f. A computed power analog panel meter.

The reactor safety system consists of the following:

- a. A FIXED power scram indicator light and an associated ACTIVE/BYPASS switch and indicator light.
- b. A FLOATING power scram indicator light and an associated ACTIVE/BYPASS switch and indicator light.

- c. A PERIOD scram indicator light and an associated ACTIVE/BYPASS switch and indicator light.
- d. A PROGRAMMED POWER/FIXED POWER scram mode select switch and indicator light.
- e. A four-button mechanically interlocked SAMPLE TIME selector switch and indicator light.
- f. A multiturn pot with vernier dial for setting the FIXED power scram.
- g. A multiturn pot with vernier dial for setting the FLOATING power scram.

The lower right panel also includes a LAMP VERIFY switch and indicator light.

IV. PURPOSE AND FUNCTION OF NEUTRONICS SYSTEM

A. Purpose

The Neutronics System has four functions:

1. Indicate reactor power level from source level to full power.
2. Furnish an analog signal which is the log of reactor power. This signal can be used for reactor power control.
3. Provide fixed power, programmed power, floating power and period scram signals to the safety system.
4. Provide period and e-folding signals which can be used for reactor control and analysis of reactor dynamics.

B. Function

The functions of the Neutronics System are: (1) accept current signals and pulses from various types of neutron detectors located in the S-2 side shield and on the reactor dome; (2) condition the pulses from the startup detectors for driving scalars and count rate meters; (3) convert the log detector current into a voltage which is proportional to the log of the detector current; (4) convert the current from the linear detectors into a linear voltage of ten decades with automatic range changing for each decade; (5) differentiate the log voltage to produce a signal which represents the period of the reactor; (6) compare the log power with demanded and selected levels to develop scram signals representing fixed power, floating power, and period scrams; (7) compare log power with a signal which is the maximum permissible nuclear power for the measured chamber pressure to develop a program power scram; (8) develop a scram signal when the drum roll-in exceeds a selected rate; (9) develop a scram signal when the drum position exceeds a selected maximum angle; (10) develop a scram signal when two out of three phases of neutronics ac power are lost; (11) electronically analyze the linear power signal to develop e-folding times in seconds.

All log and linear power are displayed by meters directly in watts of neutronic power. All period indications are displayed by meter in seconds. The power range in watts provided by the neutronics system is shown in Figure XVII-1.

V. STARTUP SYSTEM

Three independent startup channels are utilized in the testing of the NERVA engines. Neutron detection is accomplished using BF_3 (WL-6307) proportional counters. These startup channels incorporate a pulse amplifier, amplifier-discriminator, scaler and pulse to log current converters. The log count rate is displayed on count rate meters. A block diagram of the startup channels is shown in Figure V-1.

The startup channels will monitor the reactor power levels from source level to five decades above source level. The total counts in a preselected time interval from all three channels are displayed on the LRE Console. The three log count rates are also displayed on the LRE console, and any one of the log count rate channels can be selected for display on the Assistant Test Engineer console.

The individual units in the startup system are as follows:

1. Detector. A WL-6307 BF_3 proportional counter is used as the neutron detector. The detectors are discussed in detail in Section XIV.
2. High Voltage Supply. The high voltage power supplies for the startup channels are located in Rack 44 of the TCB. The front panel of one of these power supplies is shown in Figure V-2. A positive output polarity is used, and the voltage is adjustable from 0 to 3100 volts.

V-3

FIGURE V-2

FIGURE V-2

3. Pulse Amplifier. There are approximately 340 feet of coax cable (RG-59-U) between the detector and the current pulse amplifier. Impedance matching is done only at the input of the pulse amplifier since the detector does not have an amplifier-emitter follower built into its package. The three pulse amplifiers are located in Rack 44 of the Test Cell Building. The pulse amplifier is pictured in Figure V-3.

A block diagram of the pulse amplifier is shown in Figure V-4.

The pulse amplifier is an adjustable gain (100 to 1000) wide band, transistorized amplifier with integral power supplies for operation from a 117 vac power source. The input circuit is shown in Figure V-5.

The input accepts negative pulses from the detector and amplifies them before they are transmitted down the long lines to the control room. The output pulse is also negative and is impedance matched to the 75 ohm long line coax cable. During the setup procedure the gain is adjusted such that the output pulse amplitude is from 0.5 to 1 volt.

4. GE- TIC Amplifier-Discriminator-Timer. The General Electric Transistorized Integrated Counting system is located in Rack 03 in the Control Room. The pulses from the pulse amplifier, after being transmitted down approximately 1500 feet of coax cable, are amplified. A discriminator circuit rejects pulses with an amplitude less than that determined by setting of the discriminator. The output of the discriminator is a series of constant amplitude pulses which are fed to the

scaler circuit and to the pulse/log current converters. The scaler is a conventional decade scaler, and the output is by means of digital displays on the Pulse and Linear Power Panel (upper left) of the LRE console. The timer which controls the scaler operation is controlled from the same panel on the LRE console. The controls are:

- a. AUTO/HOLD switch to select mode of operation. In the AUTO mode the scaler counts for a preselected time and automatically resets after a period of time sufficient for the operator to read and record the indicated counts. In the HOLD mode the Scaler counts for a preselected time and then holds the count until reset by the SUR RESET switch located on the startup panel (lower left) of the LRE console.
- b. TIME INTERVAL SELECT. The LRE operator can select a counting time of 0.3, 10, 60 or 300 seconds.

The log count rate circuit output is displayed on meters on the Pulse and Linear Power Panel of the LRE console and ranged from 10^{-1} to 10^5 counts/sec.

TOP VIEW

FRONT VIEW

FIGURE V-3
PULSE AMPLIFIER
RACK 44
FOR TRAINING USE ONLY

V-7

FIGURE V-4

FIGURE V-5

VI. TEST STAND LOG POWER CHANNELS

The three test stand log power channels utilize WX-5362 compensated boron lined ionization chambers for neutron detection. The range is 7.5 decades below full power to 500 percent of full power. The log channels serve three functions:

1. Power level monitoring.
2. Input to the safety system for malfunction detection.
3. Power feedback signal for the Engine Control System.

The output currents from the log power detectors are fed to log microammeters. The output of each individual log channel is displayed on single range eight-decade log meters. Figure VI-1 is a block diagram of the log channels for the Test Stand Neutronics system. A more detailed block diagram of the log microammeter is shown in Figure VI-2. The amplifiers are located in Rack 46 in the Test Cell Building and are shown in Figure VI-3. One output of the log amplifier goes to the meters on the LRE console and to the data system with a buffer amplifier as isolation. The second output from each microammeter is connected to an averaging circuit. Normally, all three log channels are averaged, but an automatic circuit rejects from the average any one signal outside of a predetermined spread about the average. Controls at the LRE console permit inhibiting of the automatic reject circuit for each log power channel. Additional switches provide manual rejection of any of the channels from the averaging circuit. There are two averaging amplifiers as a reliability redundancy. The output of the two average amplifiers is auctioneered. If either one fails

high it will be rejected from the circuit. Because the outputs are auctioneered, a low failure will not affect the control signal. When an amplifier is rejected, it locks out until manually reset from the LRE console. The average reject circuit block diagram is shown in Figure VI-4. The average reject chassis is located in Rack 46 in the Test Cell Building, and one chassis is shown in Figure VI-5.

The average log power and the three log power channels are displayed on the LRE console and recorded by the Data Acquisition System.

The average log power signal is used to generate an average period signal. The average period is recorded by the Data Acquisition System and is displayed on a meter on the LRE console. The period circuit used for period display is shown in Figure VI-6 and is a conventional differentiating circuit.

The high voltage power supplies for the log channels are located in Rack 46 in the Test Cell Building and are shown in Figure VI-7. They are dual supplies with the positive voltage adjustable from 0 to 500 volts and the negative voltage adjustable from 0 to 300 volts. The nominal setting is +250 volts and -200 volts.

The ranging of the log power channels is for an eight-decade display of 55 watts to 5.5×10^9 watts. The amps per watt relationship is such that 1×10^{-10} amperes current output from the compensated ion chamber is 55

watts, or:

$$\frac{1 \times 10^{-10}}{55} = 1.818 \times 10^{-12} \text{ amps/watt}$$

In addition to the meter displays, the log power signal is displayed digitally on the LRE console and recorded on a printer located in Rack 01R in the Control Room. The display is in volts and the relationship of voltage to log power is as follows:

$$\frac{\text{Voltage Displayed}}{\text{Volts per Decade}} = \log \frac{\text{Reactor Power}}{55 \text{ watts}}$$

FIGURE VI-1

LOG SYSTEM
FOR TRAINING USE ONLY

FIGURE VI-2

**LOG MICROAMMETER
FUNCTIONAL BLOCK DIAGRAM
FOR TRAINING USE ONLY**

FIGURE VI-2

TOP VIEW

FRONT VIEW

FIGURE VI-3
LOG MICROAMMETER
RACKS 46 & 47
FOR TRAINING USE ONLY

FIGURE VI-4
AVERAGE AND REJECT CIRCUIT
FUNCTION BLOCK DIAGRAM
FOR TRAINING USE ONLY

FIGURE VI-5
AVERAGE & REJECT CHASSIS
RACKS 46 & 47
FOR TRAINING USE ONLY

NOTE:

- 1) INPUT: 0 TO +10 VOLTS
- 2) OUTPUT: 0 TO 10 VOLTS OUTPUT REPRESENTS
- 10 SEC. TO + 0.1 SEC. PERIOD.

FIGURE VI-6

VI-10

FIGURE VI-7

VII. ENGINE LOG POWER SYSTEM

The engine log power system consists of three log power channels. The detectors are located on the pressure vessel dome and are of the same type as the test stand log power channels except that the sensitivity is changed to match the desired amps/watt relationship. The electronics is identical with that used in the Test Stand log power instrumentation. Displays on the LRE console are also identical for both neutronics systems.

The normal mode of nuclear power control uses the signal from the Test Stand log averager, but the signal from the engine mounted system can be selected for control by the T.S. LOG/ENG. LOG switch light located on the Reactor Setup Panel (lower right).

The log amplifiers and power supplies for the engine log power system are located in Rack 47.

VIII. LINEAR SYSTEM

The linear power system consists of three redundant channels each of which indicates and records nuclear power in watts. The linear system block diagram is shown in Figure VIII-1. Three WX-5362 compensated ionization chambers are used as the detectors for the linear channels. The current output from the detectors is fed into an EG&G auto-ranging picoammeter, which is located in Rack 45 of the Test Cell Building. Figure VIII-2 is the picoammeter block diagram, and Figure VIII-3 is the front panel layout. The picoammeter display on the LRE console is ranged such that the 0-10 volt linear power output signal represents 0 to 2×10^{11} watts. The linear channels monitor the power level over eleven decades. The first decade is 0-2 watts and the eleventh decade is 0-20,000 megawatts. A range signal which gives the value of the exponent in the power decades is displayed as 0 through 9 plus an additional zero for eleven decades. An analog signal of the range indication is available for recording.

The picoammeter has an attenuation pot built into the circuit which allows the gain to be adjusted when the neutronics system is calibrated to the actual reactor power. This will be discussed in detail later in Section XVIII.

All three linear channels are displayed on the LRE console, and any one can be selected for display on the CTE console.

LINEAR SYSTEM M
FOR TRAINING USE ONLY

FIGURE VIII-1

AUTO-RANGING PICOAMMETER
FOR TRAINING USE ONLY

VIII-4

FIGURE VIII-3

NERVA
TRAINING
10170

AUTOMATIC RANGING PICOAMMETER
RACK 45
FOR TRAINING USE ONLY

FIGURE VIII-3

IX. POWER INCREASE TIMER

The ETS-1 Power Increase Timer uses the output voltage of a linear pico-ammeter to compute the reactor period. The period of reactor power is defined as the time required for the power to increase by a factor of e (2.718). Figure IX-1 is the block diagram of the Power Increase Timer.

The selected linear signal feeds the hold amplifier and comparator of the power increase timer. On command from the one-shot multivibrator the hold amplifier samples and holds the linear signal. The output of the hold amplifier is a voltage equal in magnitude and opposite in sign to the input voltage when the sample is taken. The comparator is set up so that when the linear signal increases a factor of e above the voltage output of the hold amplifier the comparator switches state. The comparator output goes through the relay driver and fires the one shot which resets the hold amplifier and starts a new measurements cycle. The time interval between cycles is the period of reactor power increase.

A clock generating a known frequency is fed through a gate to a scaler. The gate is closed when the hold circuit is set and opens when the comparator switches state. The clock frequency is selected so that the scaler displays the reactor period in seconds to a tenth of a second. The output of the scaler drives a NIXIE readout on the IRE console and a printer.

The power increments of $\epsilon \frac{1}{2}$ (1.648), $\epsilon \frac{1}{4}$ (1.284) and ϵ (2.718) are selected by changing the gain of the comparator inputs. Any of these increments can be selected at the LRE console. The clock frequency is changed with the selected power increments so that the scaler always indicates the period in seconds.

A linear range signal from the auto ranging picoammeter is connected to a Schmidt trigger in the Power Increase Timer. When the auto ranging picoammeter range changes, the Schmidt trigger resets the timing gate and the hold amplifier. This initiates a new measurement cycle. As the timing gate is reset the printer prints out the time indicated on the scaler. The Schmidt trigger signal is fed to the printer causing it to print out in red, indicating an erroneous number.

FIGURE IX-1

X. REACTOR SAFETY SYSTEM

The LRE console provides controls for setting parameters for automatic reactor scram. These parameters include:

1. Fixed Power
2. Floating Power
3. Programmed Power
4. Period

Other reactor safety scrams for which neutronics is responsible but does not have controls on the LRE console are:

1. Loss of Neutronics ac Power
2. Drum Roll-In
3. Maximum Drum Position

The average log signal from the Test Stand Log System is conditioned and compared with parameters determined by operating limits to develop the fixed power scram, floating power scram, and period scram. If an excessive power level is encountered or the period is too short, the reactor will be automatically scrammed. The loss of neutronics ac power, exceeding a selected maximum drum position, or roll-in of the drums at an excessive rate will also generate a scram signal. The reactor safety system block diagram is shown in Figure X-1.

The major portion of the electronic circuitry is located in the Reactor Safety System chassis in Rack 63 of the Test Cell Building. This chassis is shown in Figure X-2.

FIGURE X-1

REACTOR SAFETY SYSTEM
FOR TRAINING USE ONLY

TOP VIEW

FRONT VIEW

FIGURE X-2
REACTOR SAFETY SYSTEM
RACK 63
FOR TRAINING USE ONLY

1. Fixed Power. The fixed power scram circuit compares the log power measured voltage (-) with a voltage (+) representing the reactor power level at which scram is desired. Whenever the two voltages are equal, the voltage output changes to a voltage which represents a scram condition.

2. Floating Power. The floating power scram circuit compares the log power measured voltage (-) with the log power demanded voltage (+) and a selectable factor voltage (+) by which the measured power can exceed the demanded power. The IRE operator selects this factor, and the usual setting is a factor of 2.0. Whenever the measured power equals the demanded plus the factor, the output voltage of the comparator changes to a scram condition.

3. Programmed Power Scram. In this scram mode, measured log power is compared with a signal which is the maximum permissible nuclear power for the measured chamber pressure. If measured log power exceeds this maximum permissible power a scram results. The maximum permissible nuclear power signal is the output of a log amplifier circuit which has as its input measured chamber pressure and is clamped at both ends. The upper clamp is determined by the setting of the fixed power scram potentiometer on the IRE console and is adjustable from 10% to 200% power. The lower clamp is adjusted at Rack 63 in the Test Cell Building. It is set up before a run series and not normally changed during a run.

4. Period. The period scram system at ETS-1 utilizes a new circuit called the Sample Data Period Limiter. It is designed to initiate a scram and provide an input to the safety system whenever the average reactor period is less than the trip circuit set level. The method of determining a period trip is basically a comparison of the actual level of power with a predetermined reference level. The reference level signal consists of two signals:

- a. The output of a sample and hold circuit which
 has as its input measured log power.
- b. A bias signal

The LRE operator can select one of four PERIOD TRIP pushbuttons marked 0.1, .25, .5 and 1.0 second and one of four INTERVAL SELECT pushbuttons marked 25%, 50%, 100% and 200% giving him 16 different combinations. The pushbuttons selected determine the sample and hold time and a bias to the summing junction of the comparator. Thus the bias level determines a specific reactor period by establishing the maximum value to which the measured log power may increase during the preset time interval. If the log power reaches the bias level before lapse of the time interval, the reactor period (time rate of change of log power) is shorter than desired and a scram is initiated. The reactor period trip set point is normally selected to coincide with planned operations and to provide adequate safety. The power interval is selected to provide the minimum sensitivity to noise present in the measured log power signal and still maintain adequate response time. Increasing the power interval will make the circuit less sensitive to noise but will also decrease the circuit response time to true reactor periods.

5. Loss of Neutronics AC Power. Each of the 3 phases of ac power is monitored by means of a power loss detector circuit. The output of each circuit feeds a relay logic circuit such that the loss of any two of the three phases produces a scram.

6. Maximum Drum Position Scram. The average drum position voltage is compared with the voltage from the Maximum Drum Position potentiometer on the ATE console. When the average drum position exceeds the selected value, the output of the comparator changes to a scram state and initiates a scram.

7. Drum Roll-In Scram. The drum roll-in detector protects the reactor from overcooling in the event a rapid inward excursion of the control drums should occur. The drum roll-in detector consists of a rate limited tracker and an error detecting circuit.

The average measured control drum position, θ_M , is tracked by the rate limited tracker with the constraint that the rate of change of the tracking signal, θ_T , cannot exceed a preset rate. The rate limit is adjustable from 1.0 to 5.0 deg/sec (nominally set for 1.50 deg/sec). The difference between the average measured drum position and the track drum position ($\theta_E = \theta_M - \theta_T$) is compared to a preset setpoint in an error detecting circuit. If the average measured drum position is less than the track drum position by an amount equal to or greater than the setpoint, a scram is initiated. The setpoint is adjustable from 0 to 20 degrees and nominally set at 12.5 degrees.

XI. NEUTRONICS CALIBRATION SYSTEM

The Neutronics Calibration System includes (1) range calibrator, shown in Figure XI-1, which provides signals for calibration and checkout of the log and linear channels, and (2) pulse calibrator, pictured in Figure XI-2, which provides pulse calibration of the startup channels.

1. Range Calibrator. The Range Calibrator includes separate voltage references for the log system and the linear system. Common switching functions place various resistors in series with the voltage references and the amplifiers. The resulting calibrated currents delivered to the amplifiers simulate the detector current and serve for setup, calibration, and checkout of the log and linear systems. In the LOCAL CALIBRATE mode the operator may select any current between 0.3×10^{-12} amperes and 1.0×10^{-2} amperes in steps of 1 or 3×10^{-n} amperes.

Other switching provides specified currents for use in data calibration. These current levels are 0, 25, 50, 75 and 100 percent of the full scale data channel. In the DATA CALIBRATE Mode the calibration currents sent to the log systems are 10^{-10} , 10^{-8} , 10^{-6} , 10^{-4} , and 10^{-2} amperes and to the linear systems are 0, 2×10^{-3} , 4×10^{-3} , 6×10^{-3} , 8×10^{-3} and 10×10^{-3} amperes.

A one point remote calibration of the log and linear systems can be initiated from the LRE console. This results in a 2×10^{-3} amp current from the Range Calibrator which is used for a quick check on system calibration.

FIGURE XI-1
 RANGE CALIBRATOR
 RACK 47
 FOR TRAINING USE ONLY

XI-3

FIGURE XI-2

The Range Calibrator is also used with the Test Simulation System. In this mode the reference voltage supplies are replaced with a simulate signal from the Test Simulation System, and the signal is sent through the range calibrator to various log and linear amplifiers.

2. Pulse Calibrator. A pulse generator is located in the Test Cell Building Electronics Room in Rack 44 near the startup pulse amplifiers. Both the pulse amplitude and pulse rate are adjustable, with the pulse repetition rate controllable from 0.01 to 100,000 pulses-per-second. The meters for the startup system are scaled from 10^{-1} to 10^5 counts-per-second on a log scale for a six decade operation.

A LOCAL/REMOTE switch allows the operator to select the mode of operation. In local operation the operator can select a calibration rate of 1, 10, 10^2 , 10^3 , 10^4 , 10^5 counts per second to check out the electronics system from end item to end item. In remote operation the pulse generator is set at 10^5 counts per second, and the LRE console operator, by depressing the NUCLEAR INST. CALIBRATE switch, obtains a single point full scale calibration check of the system.

XII. SOURCE DRIVE SYSTEM

The electronics part of the log and linear startup systems can be checked out end-to-end by means of the calibration system, but this does not provide a checkout of the neutron detectors. The source drive system enables end-to-end checkout of the S-2 shield mounted neutronics channels including the neutron detectors. The block diagram of the source drive system is included as Figure XII-1. The source drive system pneumatic diagram is shown in Figure XII-2.

Checkout is accomplished by pneumatically positioning a separate $^{238}\text{Pu} - \text{Be}$ neutron source close to the startup system neutron detectors located in each of three parts in the S-2 shield. The neutron flux increase produces an increase in the pulses from the W6307 BF_3 counter and an increase in the current from the WX 5362 detectors. The expected output level when the source is exposed is 4.5×10^2 counts per second for the startup detector and 0.42×10^{-10} amps for the log and linear detectors. This action is displayed on the IRE console as an increase in count rate on the startup channel, an increase in indicated power on the linear channels, and an increase in digital voltmeter reading on the log channels. The source drive system provides not only a continuity check of the systems but will also indicate troubles in the channels if an unexpected change in output level occurs.

When the source check is complete, the three sources are pneumatically driven to a position outside the S-2 shield where they are shielded from both the detectors and from personnel working in the area. With the sources

in this shielded position, solenoid driven pins lock them in place so that they cannot be inadvertently driven to an exposed position.

The source drive control system consists of a panel located in the Test Cell Building Electronics Room and a panel on the LRE console in the Control Room. A key is required to operate the source drive system from either location. Each source can be commanded individually, or all sources can be commanded simultaneously from the panel in the Test Cell Building. Individual source control from the LRE console is not possible. The key switch on the LRE console disables the control from the Test Cell Building and commands all sources simultaneously to the desired position. Limit switches in the exposed and shielded positions indicate the location of the sources by means of lights mounted on both panels.

A key and a special handling tool are required to insert or remove the ^{238}Pu - Be sources from the source drive system.

FIGURE XII-1
SOURCE DRIVE SYSTEM
BLOCK DIAGRAM
FOR TRAINING USE ONLY

FIGURE XII-2

XIII. FISSION CHANNEL

A pre-calibrated Fast Flux Fission Chamber Neutronic Power Calibrator System for initial XE-1 startup is required to:

1. Give a reasonably accurate indication of power level.
2. Obtain an initial calibration of the TSCS detectors and safety circuits.
3. Insure adequate exposure of the low power dosimeters.

1. Fission Channel Description. The detector used with the fission channel is a fission chamber containing uranium 238 and operated as a pulse chamber. The chamber used is a WX-30748 manufactured by Westinghouse Electric. Fast neutrons entering the fission chamber cause fission of the uranium, and the resulting fission fragments produce ionization which is easily detected electronically. The fission chamber dimensions are shown below.

Specifications of the fission chamber include:

MECHANICAL

Maximum Diameter	2 1/16 inches
Maximum Overall Length	11 11/16 inches
Approximate Sensitive Length	6 inches
Net Weight	1 3/4 pounds
Shipping Weight	12 pounds

MATERIALS

Outer Case	Aluminum
Electrodes	Aluminum
Insulation	Alumina Ceramic

NEUTRON SENSITIVE MATERIAL

Content	U_3O_8 depleted to 2 ppm in ^{235}U
Thickness	2 mg/cm ²
Total Quantity	1.72 grams
Gas Filling	Argon-Nitrogen Mixture
Gas Pressure	76 cm of Hg

IMPEDANCE

Resistance (minimum)	10 ⁹ ohms
Capacitance	190 pf

MAXIMUM RATINGS

Voltage Between Electrodes	1000 volts
Temperature	300°F
External Pressure (Note 1)	180 psi

TYPICAL OPERATION AS A COUNTER (Note 1)

Operating Voltage	300 volts
Operating Voltage Plateau	200 to 800 volts
Fast Neutron Flux Range	1.4×10^3 to 7×10^8 nv
Sensitivity (Note 2)	7×10^{-4} CPS/nv
Output Pulse Characteristics	
Amplitude (unloaded)	2×10^{-4} volts
Inherent Rise Time (average)	2×10^{-7} seconds

- Note: 1 The pressurizing atmosphere must be dry and non-corrosive.
- Note: 2 The sensitivity is 7×10^{-4} counts/neutron/cm² when the alpha background counting rate of the naturally radioactive uranium is adjusted to 5 counts/second. By varying the pulse height selector on the associated circuitry other sensitivities are available.

One advantage of the fission chamber is that the pulse produced by the fission fragments is so large that easy discrimination between neutron and gamma radiation is possible. By using uranium 238 the fission chamber is also made insensitive to slow neutrons.

2. Fission Channel Components. A block diagram of the Fission Channel is shown in Figure XIII-1.

The Fission Channel consists of the following components:

- a. Fast flux fission chamber installed at the nozzle throat of the XE-1 engine.
- b. Pre-amplifier close coupled to the detector.
- c. Amplifier/discriminator located in the Test Cell Building.
- d. Scaler and Timer located in the Test Cell Building.
- e. Amplifier/discriminator located in the Control Room.
- f. Scaler and Timer located in the Control Room.

The fast fission chamber produces pulses in a number proportional to the reactor power. The preamplifier amplifies the pulses and matches the

impedance of the coax cable which connects to the amplifier/discriminator located in the Test Cell Building. The discriminator rejects any pulses with an amplitude less than the setting of the discriminator. The output of the amplifier/discriminator is a series of constant amplitude pulses which can be fed either to the scaler and timer at the Test Cell Building, or at the Control Room. The scaler is a standard decade scaler which is turned on and off by means of settings on the timer unit. The total count displayed on the scaler is the counts per unit time as selected by the timer.

3. Fission Chamber Calibration. Calibration of the Fission Chamber requires portions of the calibration to be done at ETS-1 and portions accomplished at WANEF, Westinghouse Astronuclear Experimental Facility in Pittsburgh.

The Fission Chamber is first calibrated at NRDS using a ^{238}Pu - Be source. It is then shipped to WANEF where the source calibration is repeated to verify proper operation of the channel.

Next the detector is installed on the nozzle of a reactor mockup similar to the reactor which will be operated at ETS-1. The reactor is brought up to a known power level, and the Fission Channel counts-per-minute per watt relationship is established.

Completion of the calibration procedure is accomplished by shipping the Fission Channel back to NRDS and repeating the source calibration to guarantee that the unit is still functioning properly.

FISSION CHANNEL BLOCK DIAGRAM
FOR TRAINING USE ONLY

FIGURE XIII-1

4. Calibration of Neutronics to Reactor Power Level. Prior to use with the reactor, the source calibration check of the fission chamber is repeated at ETS-1.

The Fission Chamber detector is then installed on the nozzle in the same position as at WANEF. The reactor is brought up to a power level such that a statistically acceptable count rate is registered on the scaler. A series of timed counts are recorded to establish a counts-per-minute relationship. By correlation with the counts-per-minute per watt relationship established at WANEF the reactor power in watts is calculated.

The Neutronics channels are then electronically adjusted to agree with the calculated power determined from the fission channel. The log amplifiers used with the log channels are adjusted by means of an offset adjustment, and the auto-ranging picoammeters used with the linear channels are adjusted by means of a gain adjustment. The accuracy of this preliminary power calibration is expected to be within a factor of 2. This is sufficient for the initial setting of the power for low power dosimetry and the settings for fixed and floating power scrams.

XIV. NEUTRON DETECTORS

The Test Stand Nuclear Instrumentation and the Engine Nuclear Instrumentation systems utilize two different types of neutron detectors: BF_3 detectors and compensated ionization chambers.

1. WL-6307 BF_3 Detectors. These detectors are used in the start-up channels. The WL-6307 proportional counter is designed to detect neutrons of thermal energy in the range from 10^{-1} to 10^5 neutrons/cm²/sec. The use of boron trifluoride, BF_3 , proportional counters for the detection of thermal neutrons depends upon the nuclear reaction $^{10}\text{B} (n, \alpha) ^7\text{Li}$. The ionization, resulting from the energy loss of the alpha particle and lithium nucleus in boron trifluoride gas, is collected and produces a charge at the collecting electrode for each boron disintegration occurring in the counter. This counter is extremely rugged, meeting military specifications for shock and vibration, and will operate in any position at temperatures up to 250°F. The materials used have been selected for low activation properties. The thermal neutron sensitivity of the WL-6307 is approximately 4.5 counts/neutron/cm² at an operating voltage of 2000 volts. Construction of the WL-6307 is shown below.

Specifications of the BF_3 detector include:

MECHANICAL

Maximum Diameter	1 1/32 inches
Maximum Overall Length	12 1/8 inches
Approximate Sensitive Length	8 5/8 inches
Net Weight	6 ounces
Shipping Weight	3 pounds

MATERIALS

Body	Aluminum
Electrode	0.001 inch dia. Tungsten
Connector	Magnesium
Insulation:	
Electrode Supports	Alumina Ceramic
Connector	Polystyrene
Neutron Sensitive Material:	
Content	Boron trifluoride enriched to 96% in Boron-10
Pressure	55 Cm of Hg

IMPEDANCE

Resistance (minimum)	10^{11} ohms
Capacitance (approx.)	10 pf

MAXIMUM RATINGS

Voltage between Electrodes	2500 volts
Temperature	250° F
External Pressure (Note 3)	180 psi
Operating:	
Thermal Neutron Flux	10^5 nv
Non-Operating:	
Thermal Neutron Flux (Note 1)	10^{10} nv
Gamma Flux (Note 1)	10^5 R/hr

TYPICAL OPERATION (Note 2)

Operating Voltage	2000 volts
Thermal Neutron Flux Range:	
With Conventional Circuitry	2.2×10^{-1} to 2.2×10^4 nv
With Special Circuitry (Note 4)	10^{-1} to 10^5 nv
Sensitivity	4.5 CPS/nv
Plateau Characteristics:	
Length (minimum)	200 volts
Overall Slope (maximum)	4 percent
Output Pulse Characteristics:	
Amplitude (approx. unloaded)	60 Millivolts
Inherent Rise Time (Average)	10^{-7} seconds
Inherent Background (Note 5) (approx.)	0.2 Counts/second

- Note 1: When in flux levels exceeding the maximum operating level the high voltage should be removed, and the tube shorted through a maximum of 3 megohms.
- Note 2: These characteristics will vary depending upon the associated circuitry.
- Note 3: The pressurizing atmosphere must be dry and non-corrosive.
- Note 4: With low-noise, high resolution circuitry.
- Note 5: In radiation-free areas, and with low-noise circuitry, values of the order of 4 to 6 counts-per-minute have been observed. High humidity environments should be avoided since they may impair performance.

Figure XIV-1 gives the characteristic curves of the WL-6307 detector.

2. Compensated Ion Chamber WX-5362. The compensated ionization chamber has two volumes. One volume is coated with ^{10}B which has a high thermal neutron cross section for the $^{10}\text{B} (n, \alpha) ^7\text{Li}$ reaction. The current

VOLTAGE CURVE FOR BF_3 COUNTER

INTEGRAL BIAS CURVE FOR BF_3 COUNTER

MULTIPLICATION CURVE FOR BF_3 COUNTER

CHARACTERISTICS OF BF_3 COUNTER UNDER
 ^{60}Co GAMMA IRRADIATION

from this volume is due to the neutron flux plus the gamma. The other volume is sensitive to gamma only. The neutron sensitive volume has a positive high voltage, while the other volume has negative high voltage resulting in a net current due to neutrons only.

The WX-5362 is used for all log and linear channels. It is an electrically compensated ion chamber designed for operation with a fixed, applied compensating voltage. The chamber is of guard-ring construction utilizing high-purity alumina ceramics throughout. The outer shell and support structures are titanium; the electrodes and electrode support structures are beryllium to reduce low energy photon response and internal gamma heating. The gas fill is nitrogen to maximize the plateau length. The thermal neutron sensitivity with a 19.5 cm nitrogen fill is 5×10^{-15} amps/nv. The term nv is the number of neutrons/second incident on 1.0 cm^2 of target material. The uncompensated gamma sensitivity is about 2×10^{-13} amps/R/hr. The compensated ionization chamber dimensions are shown below:

Specifications of the WX-5362 detector include:

MECHANICAL

Maximum Diameter	3 1/32 inches
Maximum Overall Length	7 1/2 inches
Approximate Sensitive Length	2 5/16 inches
Collector Area	75 cm ²
Net Weight	3 pounds
Shipping Weight	12 pounds

MATERIALS

Outer Case	Titanium
Electrodes	Beryllium
Insulation	Alumina
Neutron Sensitive Material:	
Content	Boron enriched in B-10
Thickness	0.5 mg/cm ²
Gas Filling	Nitrogen

IMPEDANCE

Resistance (minimum) at 20°C:	
Signal to case	10 ¹³ ohms
H.V. to case	10 ¹² ohms
Compensating to case	10 ¹² ohms
Capacitance (approx.):	
Signal to case	175 pf
H.V. to case	135 pf
Compensation Chamber to case	80 pf

MAXIMUM RATINGS (19.5 cm N₂ fill)

Voltage between electrodes, dc	500 volts
Temperature	350° C
External Pressure	180 psi
Thermal Neutron Flux	10 ¹³ nv

TYPICAL OPERATION (19.5 cm N₂ fill)

Operating Voltage (Notes 1 & 2)	See Figure XIV-2
Compensating Voltage	See Figure XIV-2
Thermal Neutron Flux Range	10^4 to 1.5×10^{12}
Thermal Neutron Sensitivity (Figure XIV-2)	1×10^{-15} A/nv
Gamma Sensitivity:	
Uncompensated (See Figure XIV-2)	2.4×10^{-13} A/R/hr
Compensated (95%)	1.2×10^{-14} A/R/hr

Note 1: The saturation voltage for a saturation current density of 2×10^{-5} amp/cm² of collector area is shown in Figure XIV-2 for a 19.5 cm N₂ fill. The device may be operated at higher current densities with a corresponding increase in saturation voltage. For additional information consult the manufacturer. Increased sensitivity with pressure will result in an increase in saturation voltage requirements as may be seen in Figure XIV-2. Again the data shown are for a collector current density of 2×10^{-5} amp/cm² and a further increase will result if this value is exceeded. For purposes of computing current density, the collector area is listed under "MECHANICAL". Increases in pressure will result in an increase in voltage breakdown ratings.

Note 2: In Figure XIV-2, $V_{0.9}$ is the voltage at which the current is 90% (0.9) of the saturated value at that flux level.

3. Detector Locations.

a. Test Stand S-2 Shield. Figure XIV-3 shows the general layout of the S-2 shield detector retainer installation. There are three

COMPENSATED ION CHAMBER CHARACTERISTIC CURVES FOR TRAINING USE ONLY

FIGURE XIV-2

**SOURCE DRIVE AND
DETECTOR LOCATION
FOR TRAINING USE ONLY**

FIGURE XIV-3

detector retainers each of which contain three detectors: one log, one linear and one startup. The detector retainer assembly is pictured in Figure XIV-4. Each detector is contained in a separate tube as shown in Figure XIV-5. When the neutron source is in the exposed position, water circulates between the source and each detector and acts as a moderator/attenuator. The position of the detector in the tube is selected to give the desired amps/watt relationship. This position is calculated from the flux distribution through the S-2 shield and the neutron sensitivity of the detector. Positioning of the detector is made possible by inserting aluminum blocks ahead of the detector. Streaming behind the detector is limited by inserting right solid cylinders of borated polyethelene in the tube. One WX-5362 in each detector retainer is instrumented with thermocouples to monitor gamma heating. The shell of each detector is coated with an insulating material to isolate signal common from test stand ground.

b. Engine Mounted Nuclear Detectors. Figure XIV-6 shows the layout of the three WX-5362 detectors. Figure XIV-7 illustrates the method of assembling the detectors to beryllium mounting brackets, which are bolted to the thrust ring adapter flange on the dome end of the pressure vessel. Two of the three detectors are instrumented with three thermocouples each to monitor gamma heating. These detectors are insulated from the pressure vessel to isolate the signal common from test stand ground. There is also a calorimeter installed on the thrust ring adapter flange. The neutron flux per watt will be greater at the thrust ring adapter flange detectors than at the detectors mounted in the S-2 shield, so the sensitivity must be less for similar ranging.

XIV-11

FIGURE XIV-4

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10290

DETECTOR RETAINER ASSEMBLY

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FIGURE XIV-4

XIV-12

WX-5362
COMPENSATED
ION CHAMBER

SOURCE
DRIVE

WX-5362
COMPENSATED
ION CHAMBER

WL-6307
BF₃ DETECTOR

FIGURE XIV-5

NERVA
TRAINING
10300

CROSS-SECTIONAL VIEW OF DETECTOR RETAINER
FOR TRAINING USE ONLY

FIGURE XIV-5

B. DETECTOR ASSEMBLY

A. BERYLLIUM BRACKET ASSEMBLY

XV. SOURCES

Several different neutron sources of varying yields are required for adequate checkout of the neutronics systems. As described in Section XII, a source drive system is required to check the shield mounted nuclear detectors. Three ^{238}Pu - Be sources of approximately one curie were procured for this use. A one-curie ^{238}Pu - Be source was also procured for use as a reactor startup source. Two other ^{238}Pu - Be sources were transferred to ETS-1 from TCA to be used as checkout sources for general detector checks and laboratory use. There are also ^{238}Pu - Be sources with yields of $1.76 \times 10^7 \text{ n/cm}^2/\text{sec}$ and $2.12 \times 10^6 \text{ n/cm}^2/\text{sec}$. The $1.76 \times 10^7 \text{ n/cm}^2/\text{sec}$ source is used for calibration of the fast fission electronics.

All sources are stored in the ETS-1 Source Storage Vault during non-test periods. Prior to a test the sources are placed in the S-2 shield source drive units for detector calibration, and are mounted on the reactor as a startup source. Handling and use of all sources at ETS-1 is governed by NTO-I-0391.

XVI. CONSOLE SETUP PROCEDURE

The normal procedure for setting up the neutronics system for an EP will be as follows:

1. R-2 Day. All units of each system will be set up as per the proper procedure (NTO-I or SOP) and each system checked end-to-end. Each parameter which is recorded as data will be channelized for proper recording channel, zero, and span. A source check will be done to verify proper operation of each detector.
2. R-1 Day. All discrepancies found on R-2 day will be corrected. And a source check made to insure continued proper performance of the system.
3. R-0 Day. Final adjustments to each system will be made according to the appropriate procedures. Starting time for this function is determined by Control Room run time for the EP. This setup is completed prior to start of control room operations, and a final source check of all channels is made.
4. Setup Checklist. Before the LRE operator performs his console setup checklist, he should have in his possession all neutronics checklists which note any discrepancies found which have not been corrected by this time. At the time that the operator begins his setup the console will be active and all systems checked out. The LRE checklist will include all units in the Test Cell Building as well as the Control Room. The LRE

must verify that every Neutronic System switch in the Test Cell Building is in the proper position and all units conform to his checklist before beginning his check of the LRE console.

5. Setup. The setup of the LRE console will be as follows:

- a. Depress the LAMP VERIFY button.
Replace all burned out bulbs.
- b. Test Stand Pulse Channels.
 - (1) Verify that the scaler power is ON.
 - (2) Select the channel to be displayed on the ATE console.
 - (3) Select the desired TIME INTERVAL.
 - (4) Set the scaler operating mode to AUTO.
- c. Test Stand Linear Power
Select the linear channel to be displayed on the CTE console.
- d. Test Stand Log Power
 - (1) Verify that all channels are ACTIVE.
 - (2) Verify that all INHIBITS are OFF.
 - (3) Verify that the averaging amplifiers are ACTIVE.
- e. Engine Log Power
 - (1) Verify that all channels are ACTIVE.
 - (2) Verify that all INHIBITS are OFF.
 - (3) Verify that the averaging amplifiers are ACTIVE.
- f. Power Increase Timer
 - (1) Verify that the power is ON.

- (2) Depress the PIT RESET button.
 - (3) Select the linear channel to be used for power increase time.
 - (4) Select the desired power increase time.
- g. Depress the SUR RESET button.
- h. Source Drive System
 - (1) Verify that the command is OFF. Remove key.
 - (2) Verify that the source is SHIELDED.
 - (3) Verify that the SOURCES NOT SHIELDED light is OFF.
- i. Auto Startup
 - (1) Set the EXPONENTIAL pot to the setting called for in the Control Room Operating Procedure (CROP) for the first AUTO-STARTUP.
 - (2) Set the RAMP pot to the setting called for in the CROP for first AUTO-STARTUP.
- j. Verify that the Printer is OFF.
- k. Verify that the BF_3 power is ON.
- l. LRE Status should be in HOLD.
- m. Select POWER CONTROL mode called for by CROP.
- n. Switch NUCLEAR POWER SIGNAL-DVM to each position and verify that the leakage current of each log detector is less than 10^{-8} amperes.
- o. Scram Alarm and Bypass
 - (1) FIXED POWER SCRAM POT. Set to the setting called for by the first fixed power scram check in the CROP.

- (2) FLOATING POWER SCRAM POT. Set to the setting called for by the first fixed power scram check in the CROP.
- (3) PERIOD TRIP. Select the period which will be used for the first run of the EP.
- (4) SAMPLE TIME. Select the sample time to be used for the first run of the EP.
- (5) FIXED POWER, FLOATING POWER AND PERIOD. Set scrams to ACTIVE mode.
- (6) FIXED/PROGRAM POWER mode. Select proper mode as per CROP.

p. Neutronics Calibration

Depress the calibration pushbutton and check for following:

- (1) Each startup channel should read 10^5 counts/sec.
- (2) Each log channel should read 1.1×10^9 watts. After the calibration of the neutronics system to real reactor power, this reading will be changed by the amount of the correction factor. See Section XVIII.
- (3) Each linear channel should read 1.1×10^9 watts. After the calibration of the neutronics system to real reactor power, this reading will be changed by the amount of the correction factor. See Section XVIII.

6. Ready. When the checklist has been completed to this point, the LRE should be ready to operate for an EP, and when requested to do so by the TD, should depress his LRE READY button.

XVII. POWER COVERAGE

The BF_3 proportional detectors are used for startup of the NERVA engine. These detectors give count rate data at very low power levels below the operating range of the linear channels. The neutronics power coverage for each channel type is included in Figure XVII-1. The startup channels cover the range from approximately 0.1 milliwatt to 100 watts.

The linear channels detect the neutron level during the engine power run. These channels are used for display and data recording purposes and e-fold measurements. These channels cover the power range from approximately 100 milliwatts to 20,000 megawatts.

The log power channels are used by the Engine Control System to control the reactor power level and by the Reactor Safety System to limit a nuclear excursion. Either the Test Stand log power channels or the engine log power channels can be selected for control functions. Both log power systems cover the power range from 55 watts to 5500 megawatts. During the preliminary testing of NERVA engines the Test Stand log power channels will be used. As the program advances toward flight oriented hardware and controls, the engine log power channels will be used.

The Lead Reactor Engineer console is primarily a neutronics console which consists of the displays and controls for both the Test Stand Neutronics System and the Engine Neutronics System.

The Assistant Test Engineer console is used for reactor physics tests and includes reactor drum controls, period meter indication and startup log count rate.

The Chief Test Engineer console contains the manual controls for engine operation; both linear and log power are displayed on this console to aid the operator during engine power runs.

APPROXIMATELY
0.1 Milliwatt

100 Watts

START - UP

APPROXIMATELY
100 Milliwatts

20 KMW

LINEAR SYSTEM

55 Watts

5.5 KMW

LOG - TSCS

55 Watts

5.5 KMW

LOG - ECS

FIGURE XVII-1

NERVA
TRAINING

10330

XE-1 NEUTRONICS POWER COVERAGE
FOR TRAINING USE ONLY

FIGURE XVII-1

XVIII. REACTOR CALIBRATION

Prior to the activation of ETS-1, the scaling of the neutronics system was agreed on as outlined in Section VI. The value 1.818×10^{-12} amps/watt has been used to set up meter scaling, amplifier gains, offsets, etc. therefore it is important that the detectors be located in such a position that their current output during reactor operation gives this relationship.

Section XIV shows the location of all of the detectors. However, this location is based on a calculated neutron flux in the water tank and above the reactor dome, and on the vendor's sensitivity of the detector. The sensitivity of each detector is different and the flux calculations have a relatively large uncertainty. This means that once absolute reactor power is established the neutronics must be shifted to agree with it. As the program progresses through a series of runs there are several calibration steps that must be made. As was pointed out in Sections VI, VII and VIII, the log amplifiers have an offset pot which is used for this adjustment, and the linear autoranging picoammeters have an attenuation pot for the same purpose. Absolute values in the startup system are not important, so an adjustment is not necessary in this system. Four of the calibration procedures are described.

1. Fast Fission Calibration. During initial criticality the first calibration is accomplished as outlined in Section XIII.
2. Low Power Dosimetry. An analysis of the dosimetry gives an

actual reactor power which is compared with the indicated power during the low power dosimetry exposure. An adjustment of the log and linear system is made to correspond with the indicated correction factor.

3. Heat Capacity Method. At an intermediate power (100 kilowatts) the reactor is held at a constant power over a period of time. During this time the core temperatures are recorded. The $\frac{dT}{dt}$ is proportional to the reactor power. The expression $\frac{dT}{dt}$ is the derivative of temperature with respect to time. This calculated power is compared with the indicated power and an adjustment made if necessary.

4. Thermal vs Nuclear. At approximately 50% power, during a hold, thermal power is calculated and compared with indicated neutronics power. An adjustment of the log and linear systems is not done at this time, but the FIXED POWER scram point may be adjusted if the TD feels it is necessary in order to comply with test requirements.