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December 11, 1990

Mr. Theodore S. Michaels
USNRC
PDNP
M.S. 11-B-20
Washington, D.C. 20555

Dear Mr. Michaels:

This letter is in response to the incident involving the operation of the Worcester Polytechnic Institute's Nuclear Reactor Facility on Tuesday December 4, 1990 and reported to NRC by myself that same evening. The enclosed report details the events surrounding the incident, subsequent analyses and actions discussed with and approved by this facility's oversight committee, and th conclusions drawn.

To summarize, while shutdown on Tuesday afternoon maintenance was performed on the Log-N/Period Amplifier which required its being de-energized and removed from the control console. Following the maintenance, the log amplifier portion of Log-N/Period Amplifier was calibrated and the safety system scram was observed operable for a 7.5 second indicated period. During power ascension to 900 watts, the console operator surmised the actual rate of power change was faster than was indicated by the period meter. The operator then took immediate action to shutdown the reactor.

Subsequent analyses indicate that when the log amplifier portion of the Log-N/Period Amplifier was calibrated,the Log-N/Period Amplifier met the Technical Specification requirements for the safety system settings. During operations that calibration drifted. Tests performed on the Log-N/Period Amplifier indicate the cause of the drift to be due to inadequate "warmup" time once the Amplifier was re-energized. By de-energizing and re-energizing the Amplifier, the drift during warmup has been reproduced and recorded on the Log-N Power recorder. The drift stabilizes after approximately 45 minutes. A complete calibration of the Log-N/Period Amplifier was performed on December 10. The calibration was then checked 24 hours later on December 11 and no adjustments were necessary.

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The drifting during operation could then be considered a component malfunction, that if allowed to continue could have made the system incapable of performing its safety function by not providing automatic shutdown at the limits specified in the Technical Specifications. We therefore categorize this incident as a Reportable Occurence as defined by item 3 for reportable occurences in our Technical Specifications. We do not consider this incident reportable as defined in item 1 since the safety system setting had not changed; but rather, it was the processing of the compensated ion chamber signal that had changed.

The Facility's oversight committee and I believe we have established adequate controls to ensure the problem will not reoccur. Those controls are delineated in the enclosed report. Lastly, we conclude that the problem which affected the period indication would not also occur in the safety system channels which measure power. The controls currently in place require that if maintenance is performed on one of these channels, it is functionally tested and its calibration checked against the other two. In addition, power is calibrated semi-annually via foil activation method. These channels are then always adjusted conservatively when compared to the foil results.

If you should require additonal information, please do not hesitate to contact me. We thank you for your assistance and attention to this matter.

Sincerely,

Leo M. Bobek,
Director

cc Mr. T.F. Dragoun,
Region I

DESCRIPTION OF CIRCUMSTANCES

On Tuesday December 4, 1990 at 1235 a reactor start-up was initiated for routine irradiation of student experiments. One experiment required an irradiation while subcritcal and the other required an operation of 900 watts.

At 1257 a reactor scram occured with the reactor subcritical (one control blade withdrawn and a second blade partially withdrawn), due to an electronically erratic period meter.

The Log-N/Period Amplifier was de-energized and removed from the control console for diagnostic testing. A vacuum tube (designated as V1 by the G.E. supplied technical manual) was replaced in the power supply portion of the Log-N/Period Amplifier by the SRO. The Amplifier was then replaced in the control console and re-energized. At 1328, the log amplifier portion of the Log-N/Period Amplifier (see block diagram) was then re-calibrated on the high (100kw) end and on the low (1.0 watt) end. At 1340, the channel was then functionally checked by placing the neutron source along side the Log-N detector and observing that the meter responded and that the safety system scram occured at a 7.5 second indicated period. The technical manual (see attached portions) for the Log-N/Period amplifier states that replacement of tubes designated as V20, V21, V22, or V25 requires readjustment of the instrument and that replacement of all other tubes will not effect calibration. Permission was then given to re-start the reactor by the SRO. At 1401, with all control blades withdrawn and the regulating blade at 10 inches, a subcritical irradiation was performed for one minute. The regulating blade height was then increased to bring the reactor critical. At 1407, the neutron source and B-10 detector were removed from the core. The operator then raised the reg. blade height to 20 inches to obtain an indicated 50 second period. At approximately 300 watts the operator began to stabilize power by inserting the reg blade. Power continued to increase and at 500 watts the operator manually drove in the control blades in an effort not to exceed the requested 900 watts. These actions reduced the indicated period to greater than 100 seconds. When the linear power indicators passed the 800 watt level, the operator surmised power was increasing more rapidly than indicated and decided to initiate a manual scram.

Following the shutdown of the reactor, the safety system instrument indications and operator actions were discussed with the operator by the SRO and the Facility Director. Following the discussion, a decision was made to calculate the actual reactor period from the regulating blade excess reactivity calibration data, given the reactor critical regulating blade height of 12.5" and the maximum height during the evolution being 20". A "rule of thumb" formula was employed and the

calculation indicated an expected period of approximately 8 seconds.

Following that determination of reactor period, an evaluation of the Log/Period Amplifier performance was started at approximately 1600. The evaluation consisted of checking the Log-N/Period Amplifier calibration according to the manufacturer supplied technical manual. The technical manual (see attached portions) specifically stated that calibration of the period amplifier should not be attempted unless the log amplifier had first been calibrated. The decision was made not to first calibrate the log amplifier portion of the Log-N/Period Amplifier as required because it was believed the entire amplifier should be checked in an "as is state". The remainder of the calibration procedure included using a formula to calculate the voltage ramp required to produce a desired period. The formula also requires the value for a voltage measurement obtained from the calibrated log amplifier. Using this voltage value obtained, and calculating the voltage ramp required to produce a 3 second period, the calculated voltage ramp was then input into the Log-N/Period Amplifier. The results were as follows:

Expected Period	Actual Period
3 sec.	6.5 sec.
5 sec.	12 sec.

These measurements concluded at approximately 1730.

Based on these measurements and the estimate of the expected period, the Director decided to inform the NRC. The Technical Specification 5.7(1) for the WPI Reactor requires that the NRC be notified promptly of a condition that could prevent a reactor safety system from performing its intended function. With concurrence of the Director and SRO, this call was made at 1755.

On Wednesday morning, December 5, a meeting of the the Radiation, Health, and Safeguards Committee (RHSC) was called for 1300 and in the interim, discussions were held to: develop a chronological order of events, develop a plan to further analyze and correct the amplifier problem, and develop a plan to prevent recurrence.

To help analyze the amplifier problem, it was decided to recheck the period amplifier calibration by performing the log amplifier calibration first. This accomplished, the ramp voltage required for an expected period of 3 seconds was input. The resutls were:

Expected Period	Actual Period

3 sec. 5.2 sec.

In addition, the amplifier trip setpoints were also verified at actual meter readings of 7.5 seconds for the relay scram and 5.2 seconds for the electronic. The Technical Specifications require a relay scram for a true reactor period of 5 seconds or greater and an electronic scram for a true reactor period of 3 seconds greater.

At this time, the recorder tracings from the log and linear power strip chart recorders were used to make an estimate of the reactor period. From the log power tracing an estimated period of 38 seconds was obtained and from the linear power tracing an estimate of 32 seconds was obtained.

At 1300 the RHSC convened to assess the situation. Subsequent to the discussion on the analysis and proposed action, it was suggested the reactor period estimate calculation performed the previous evening would be re-evaluated. Following the meeting, the more accurate Inhour equation was solved for reactor period using a numerical technique. This solution was then employed to calculate reactor period using the same value of reactivity addition from the reg. blade height of 12.5" to 20". The calculation performed in this fashion provided an expected period of 34 seconds. This result closely matched the results obtained from the strip chart traces but was still faster than the 50 second period observed by the operator. Review of the previous night's calculation showed an error using the "rule of thumb" formula.

Actions Submitted And Approved By The RHSC December 7, 1990

A) Immediate Log-N/Period Amplifier Corrective Actions:
1. Replace all vacuum tubes and allow a 24 hour "burn in" period.
2. Perform an amplifier calibration according to the technical manual, meeting all required specifications.
3. This calibration report will be given to the RHSC for review at the next scheduled meeting.

B) Procedural Actions:
1. Establish an electronic calibration procedure for the G.E. Log-N/Period Amplifier based on the G.E. manual.
2. Draft and implement a Standing Order requiring this calibration be performed on a semi-annual basis.
3. Draft and implement a standing order requiring the operator to verify period meter performance using doubling time.
4. Draft and implement a standing order requiring a complete calibration for any maintenance performed on the G.E. Log-N Amplifier. Replacement of vacuum tubes will require pre-testing before installation. After re-energizing the Amplifier, it shall be given a minimum 1 hour "warm up" period.

All such maintenance will be reviewed at the next scheduled RHSC meeting.

C) Administrative Actions:
1. Provide and document additional training to all operators emphasizing reactor kinetics applicable to the WPI Reactor. This training will be reviewed by the RHSC at the next scheduled meeting.
2. While maintaining a strict requirement for prompt notification of the Commission for a Reportable Occurrence, an effort should be made to provide independent review of the circumstances and analyses leading to such a conclusion.
3. The RHSC, without preclusion of NRC required changes, approves the above actions and will review those actions applicable to review at the next scheduled meeting.

Actions Taken As Of December 7

Between December 6 and December 7, all vacuum tubes in the Log-N/Period Amplifier were replaced. On the morning of December 7, the Amplifier was replaced in the console and energized for testing and calibration. When a calibration was performed, the Log-N/Period Amplifier exhibited the same behavior as during operations on Tuesday. There was the same apparent drifting of the log portion of the amplifier. After approximately one hour, the Log-N/Period Amplifier began exhibit normal behavior with no apparent drift following re-calibration of the log amplifier.

SUMMARY AND CONCLUSIONS

The incident and analysis work performed on the Log-N/Period Amplifier post reactor shutdown can be summarized as follows:

1) Following the vacuum tube replacement in the Log-N/Period Amplifier power supply early Tuesday afternoon, the calibration performed on the log amplifier portion and subsequent functional tests of the period amplifier scram both indicated the Log-N/Period Amplifier was operable.
2) When it was realized the system was not behaving normally, the operator took immediate action to shut down the reactor.
3) Late Tuesday afternoon, a calibration check was performed on the Log-N/Period Amplifier. A calibration check of the log amplifier portion indicated it had drifted significantly from the calibration performed 2 and 1/2 hours earlier, directly prior to start up.
4) A calibration check was next performed on the period amplifier portion of the Log-N/Period Amplifier. This was done without strictly following the technical manual procedure which requires calibration of the log amplifier portion prior to proceeding. The period amplifier calibration check performed in this way would indicate it was out of calibration such that its safety system

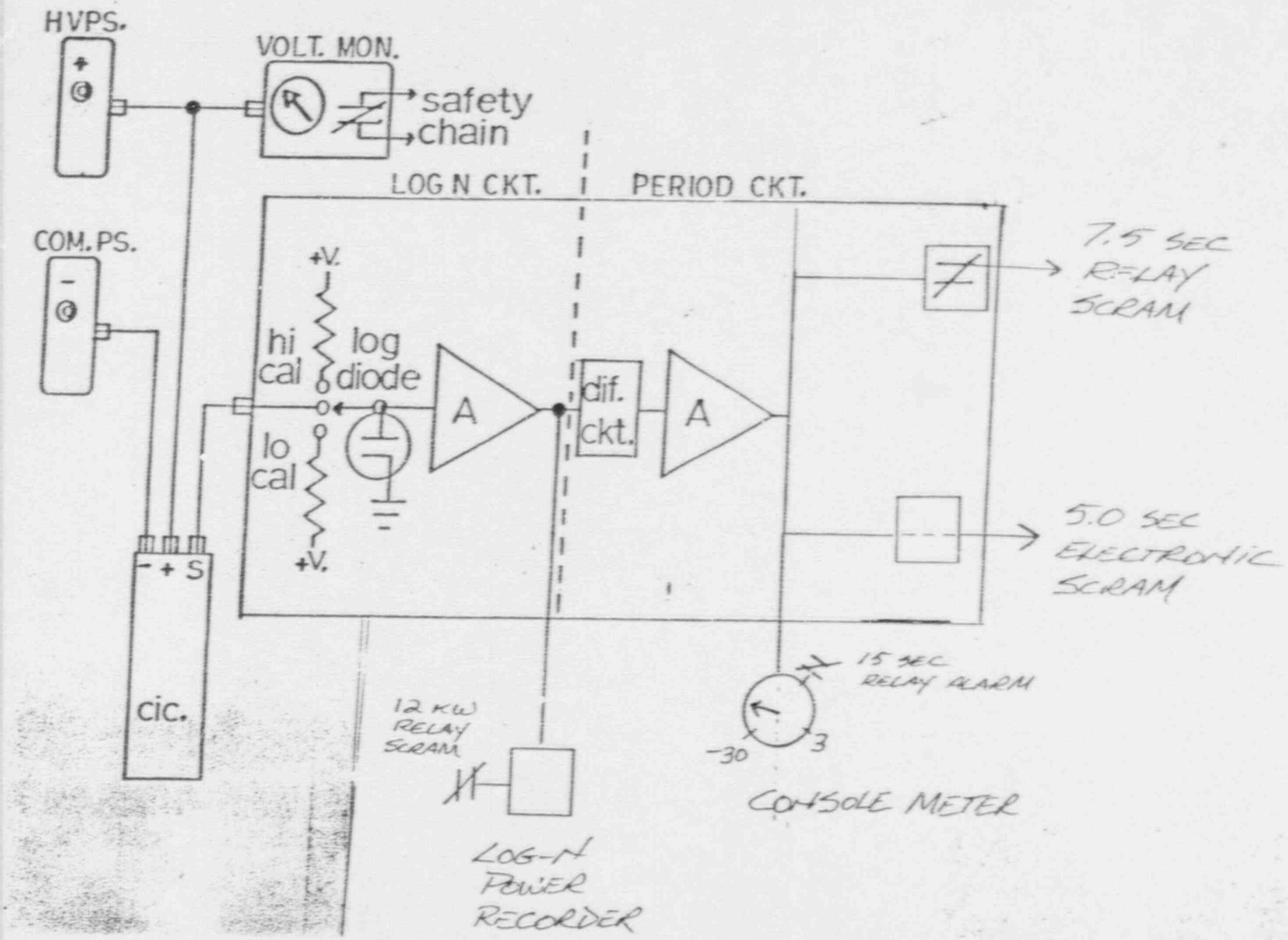
settings were less conservative than required by the Technical Specifications.

5) A calibration check of the period amplifier portion of the Log-N/Period Amplifier was performed again on Wednesday morning, this time strictly following the technical manual procedure by first calibrating the log amplifier portion (as was the done directly prior to start up on Tuesday). The results indicated the Log-N/Period Amplifier met the Technical Specification limit for the safety system settings at the time of start up.
6) Based on observations made when all the vacuum tubes were replaced and subsequent observations made when the Amplifier was de-energized and re-energized, the period amplifier behavior which caused the operator to manually shut down the reactor was most likely due to not allowing the Log-N/Period Amplifier adequate "warm up" time after the vacuum tube was replaced and the Amplifier re-energized.

Again, it must be emphasized that when the maintenance was performed and checks made according to Facility License requirements and manufacturers recommendations, there was no indication the unit could malfunction.

This incident does however provide us the opportunity to improve administrative controls on safety system related maintenance and to provide improved operator training.

Lastly, as of November 15,1990, a new Log-N/Period Amplifier was ordered from Gamma-Metrics of San Diego, California. The unit is expected to arrive at the end of February or early March. This unit will replace what is the last original neutron measuring channel for the reactor. Until the new unit arrives, administrative and procedural actions taken will provide reasonable assurance that the current unit will be capable of performing its intended safety function.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SECTION IV

MAINTENANCE INSTRUCTIONS

4.1 General

The General Electric Log N and Period Amplifier is designed to operate with a minimum of maintenance and adjustment. The unit is balanced and calibrated at the factory and should not require additional adjustment (except for the 10^{-6} - 10^{-1} built-in calibration) unless tubes are replaced. If V20, V21, V22, or V25 are replaced, the instrument should be readjusted. Other tubes can be replaced without any effect on the calibration.

4.2 Periodic Maintenance

Routine periodic maintenance will serve to keep the General Electric Log N Period Amplifier in operation for long periods of time. If the unit is in continuous service, it should be checked every 5,000 hours. If it is in casual use only, it should be checked every 1,000 hours of operation, or at least annually.

During the routine periodic maintenance, all plug-in type tubes should be removed and checked. Do not remove or attempt to test electrometer tubes V21, V22, and V25 unless there is substantial evidence that they are causing trouble. These tubes have a long life and seldom need to be replaced unless abused. Replace all tubes that are weak or faulty with new tubes as listed in the Replaceable Parts List, Section V.

Visually inspect for any signs of loose terminals, corroded joints, or overheated parts, and brush accumulated dust from circuit boards. Be sure to replace all cover plates and all tube shields properly.

4.3 Calibration Procedure

4.3.1 Log N Amplifier

The following procedure should be used to calibrate the Log N Amplifier:

1. With the power turned off, adjust the mechanical zero on the Log N meter to read 10^{-7} and on the period meter to read infinity.

2. Turn power on and adjust R2 on power supply to indicate +20 ±0.1 volts d-c at point F.

3. Turn the OPERATE-CALIBRATE switch to calibrate 10^{-6}.

4. Adjust R263 so that the period meter again reads infinity.

5. Adjust R208 so that the Log N meter reads 10^{-6}. (R208 is on the front of the panel behind the port hole.)

6. Turn OPERATE-CALIBRATE switch to Calibrate 10^{-1}.

7. Adjust R220 so that the Log N meter reads 10^{-1}. (R220 is or the front panel.)

8. Repeat (5) and (7) until both points calibrate. If calibration cannot be achieved at this point due to running out of adjustment on the potentiometers, proceed as follows:

   a.) Return R208 to about the center of its travel.

   b.) With the OPERATE-CALIBRATE switch on 10^{-6}, adjust R209 so that the Log N meter reads 10^{-6}.

   c.) With the OPERATE-CALIBRATE switch on 10^{-1}, adjust R220 to 10^{-1}.

   d.) Repeat b.) and c.) until both points calibrate. Now R208 is in its center position ready for routine calibration.

9. Return the OPERATE-CALIBRATE switch to OPERATE. The Log N meter should read down-scale below 10^{-7} with no input current. If not, check for one of the troubles listed in 4.5.2.

4.3.2 Period Amplifier

The following procedure should be used to calibrate the period amplifier. Do not attempt to calibrate the period amplifier until the Log N Amplifier has been calibrated.

1. With the Log N meter on 10^{-1} calib., measure the voltage at point AA.

2. With the Log N meter on 10^{-6} calib., measure the voltage at point AA.

3. Subtract the voltage measured at (2) from that measured at (1) and refer to the difference as V.

4. Connect a negative going voltage ramp at point AA with its output calculated by the following formula:

$$\text{ramp (volts/sec.)} = \frac{V}{\text{Period (sec.)} \times 16.2}$$

Where V is the voltage in (3) above.

< USE 3 SEC. PERIOD (NOT VALID FOR OTHERS)

5. With a 3-second period ramp applied, adjust R226 so that the period meter reads 3 seconds.

Note: The period alarm and period trip adjustments are roughly calibrated by the marks on the back panel. If an exact calibration is required, continue with the following procedure:

6. Apply a ramp as in (4) equivalent to the period at which an alarm is desired. Adjust the period alarm (on back panel) so that the circuit just trips.

7. Apply a ramp as in (4) equivalent to the period at which a trip is desired. Adjust the period trip (on back panel) so that the circuit just trips.

4.4 Calibration Instruments

The following instruments are recommended to accomplish the calibration and trouble shooting procedures:

1. Function Generator, Hewlett-Packard Model HP 202A.

2. Vacuum Tube Voltmeter, Hewlett-Packard, Model HP 410B.

3. D-C Amplifier and Electrometer, General Radio, Model 1230-A.

4.5 Trouble Shooting

4.5.1 General

If the Log N and Period Amplifier does not function properly, the following procedures should be followed to localize the source of trouble:

1. Check to see that the line cord is connected to a live circuit. Verify proper power source regulation.

2. Check for a blown fuse. If a fuse is blown, determine the cause and correct any improper condition that may exist before energizing the equipment.

3. Check the unit for faulty tubes utilizing the Voltage Chart, Table 4-1, to isolate probable faulty tubes.

4. Inspect the unit for faulty parts utilizing the Voltage Chart, Table 4-1, and the etched-circuit board illustrations shown in Figures 1-3 through 1-6 for parts location.

4.5.2 Leakage Current

If the general trouble shooting procedures do not locate the circuit