EPRI

TESTS OF NNC WATER LEVEL INDICATOR AT ALAMBAMA POWER COMPANY'S FARLEY ONE NUCLEAR PLANT FOLLOWING UNIT ONE SHUTDOWN - NOVEMBER 7, 1980

RESEARCH PROJECT 1611

KEY PHASE REPORT, MAY 1981

Prepared by

NATIONAL NUCLEAR CORPORATION
1904 Colony Street
Mountain View, California 94303

Principal Investigators and Authors

Samuel Untermyer
Lester Kornblith
David Kahn

ELECTRIC POWER RESEARCH INSTITUTE

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EPRI Contract RP1611-1

Prepared for

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

EPRI Project Manager

Dr. Patrick G. Bailey
Analysis and Testing Program
Nuclear Power Division

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Prepared by
National Nuclear Corporation
Mountain View, California

EPRI PERSPECTIVE

PROJECT DESCRIPTION

Following the accident at Three Mile Island, considerable attention has been directed toward instrumentation systems capable of measuring water in PWR vessels during normal operation, shutdown, and transient condition. As a result of the need for reactor operators to be aware of the plant conditions that may result in inadequate core cooling, the USNRC has recently issued guidelines in NUREG 0737 that require each utility to commit to a choice of and begin plans to install a water level measurement system before January 1, 1982. The purpose of RP1611 is to review such proposed instrumentation systems and perform limited development, testing, and analyses of alternative and promising concepts.

PROJECT OBJECTIVE

The objective of this work has been to develop, test, and analyze the results of a proposed non-intrusive water level detection system. This system consists of neutron radiation detectors placed both above and below the vessel. The potential advantages of such a system are its relative very low cost, ease of installation, modification, and parts replacement.

PROJECT RESULTS

Four separate top detector assemblies and one large bottom assembly, each containing BF-3 neutron detectors, have been constructed for measuring the neutron count rate above and below, respectively, the PWR vessel after shutdown. Tests using only the top detector assemblies were conducted at the Farley Unit One nuclear plant during a normal plant refueling shutdown during November 1980. A number of draindown and refill tests were performed that allowed the water level to reach as low as the core nozzle midplanes.

The results of the measured count rate vs. measured water level indicate that the detection system tested may be able to be used to indicate water level variations below approximately six feet above the top of the reactor core. Additional analyses are being conducted under seperate contract in this project to model the theoretical response of this non-intrusive system concept. Additional tests of the complete system are being planned to be conducted on the Farley Unit Two plant in 1982.

ABSTRACT

Following the TMI incident, EPRI asked National Nuclear Corporation (NNC) to develop a non-invasive coolant level monitor (NICLM) that could be installed on existing reactors without penetrating the pressure system. The NICLM system measures mass of water per unit area above the reactor core. The detected reaction radiation consists of photoneutrons created by interaction of energetic gammas from ^{140}La fission product and deuterium in the coolant water. Tests at Farley I indicated that the neutron count rate above the core was affected by water level but that count rates were low. Since the core had been shut down for several days before the measurements were made, this did not conclusively indicate the applicability of the NICLM system soon after shutdown.

CONTENTS

SUMMARY

Following the TMI incident, Dr. Edwin Zebroski, now Director of NSAC, asked NNC to develop a Non-Invasive Coolant Level Monitor (NICLM); one that could be installed without penetrating the pressure system. NNC proposed a system consisting of radiation detectors mounted above the vessel. Comparing readings of these detectors with a normalizing reading from other detectors on the side or bottom of the vessel provides an indication of reactor water level.

The NICLM system measures mass of water per unit area above the reactor core, therefore it provides a warning of either low water or boiling. Unlike other level indicators, however, circulation rate or water turbulence will not effect the readings.

In practice, it has been found that after shutdown the detected radiations consist of energetic fission product gamma rays, such as those from ^{140}La. These gammas have energies higher than activation gammas such as ^{60}Co which are abundant near the top of the vessel. Energetic gammas are detected (in the presence of ^{60}Co) by measuring photoneutron emission from deuterium in the coolant. Neutrons from beryllium are then detected by BF_3 neutron counters, which are insensitive to gamma rays.*

Relative gamma attenuation between the top and side (or bottom) detectors provides the basis for the water level measurement in the shutdown reactor whenever the core is submerged under more than three feet of water. When the core is submerged by less than three feet of water, neutrons produced in the core are able to pass through the water and reach the top detectors directly; thus resulting in extremely high count rates, giving the operator a clear indication of imminent core uncovery. This counting "spike" which occurs just before uncovery is one of the safety features of the NICLM system.

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*Gamma ray detectors cannot be used because they cannot distinguish between ^{60}Co sum gammas (total 2.5 MeV) from the energetic fission gammas.

The top detectors count until they accumulate a fixed number (typically 100 or 1000) counts. They then repeat the cycle. The reference side detectors are gated to count during the period when the top detectors count, and recycle when the top detectors recycle. The counts then displayed by the reference detector scalers at the end of each cycle are proportional to:

$$\frac{\text{Side detector counts}}{\text{Top detector counts}}$$

This quotient is related to water level.

BWR measurements indicate that the attenuation length of neutrons in cold water is between 4 inches and 6 inches of water at operating temperature. Thus, the operating detector readings should increase by a factor of 14 or more when the level falls 16 inches. Consequently, the neutron detectors used during reactor operation will increase rapidly should a void form. This gives the timely indication needed for early reactor shutdown.

Section 1

INTRODUCTION

THEORY OF NON-INVASIVE WATER LEVEL INDICATOR

Following the TMI incident, EPRI indicated the desirability of measuring reactor water level after shutdown without penetrating the pressure system.

NNC proposed a system consisting of sensitive neutron detectors mounted above the reactor vessel. Readings of these detectors would then be compared with count rates either from existing startup detectors or new detectors installed under the vessel. The ratio of these counts would then provide an indication of reactor water level.

In the course of the resultant EPRI funded investigation, two different theories evolved as to the way neutrons reach the top of the vessel through large thicknesses of water. Through shorter water thicknesses (up to three feet of room-temperature water) there is little question but that neutrons from the reactor diffuse through this water in the conventional fashion. For higher water levels, however, there is a difference of opinion on the mechanisms involved.

Photoneutron Production in Water

Les Oakes' (EPRI) suggestion, based on an ORNL test, postulated that energetic gammas from the reactor core may react with isotopes such as deuterium in water to produce neutrons at considerable heights above the reactor. If this is true, then following shutdown, neutrons produced far from the core would reflect gamma levels in the core (hence preshutdown power) and to water geometry near the detectors, but would be insensitive to the core neutron source and core multiplication (boron).

Streaming of Neutrons Around Reactor Vessel

During a meeting at SAI in October, 1980, Dr. Tom Albert explained that extensive calculation on other reactors using computer codes demonstrated that at least 90% of the neutrons reaching the top of the reactor vessel arrived there from the core

through clearance between the shield and the vessel, or by other streaming paths between the core and the outside of the shield.

If this theory is correct, then the neutrons above the vessel should depend on post-shutdown neutron production. Past shutdown neutron production in turn depends on source strength and core multiplication. Since core multiplication (boron) affects neutron production of this theory were valid, it would seem that boron content would have an effect on the top detectors.

These theories have been discussed extensively with APCo and EPRI personnel, including Dr. Pat Bailey, J. J. Thomas and the APCo reactor engineer, Randy Marlow and tentative conclusions based on Farley tests will be discussed later in this report.

HISTORY OF WATER LEVEL PROJECT - PREVIOUS TESTS

During the Summer of 1979, under EPRI contract TPS79-741, NNC conducted tests using a large ^{252}Cf source in a water tank which indicated the proposed method of level measurement had promise for levels up to 8'10" cold water depth.

Under contract TSA79-296, NNC made measurements at Rancho Seco (SMUD), Prairie Island (NSP), and Trojan (P.G.E.) reactors during their scheduled outages. Tests at Trojan in particular, which were made with a properly shielded and biased detector, indicated promise; so a much more extensive test, under EPRI sponsorship was planned for James M. Farley Unit No. 1 (APCo). The previous tests are summarized in "Water Level Tests at the Trojan Nuclear Generating Station and the Design of Prototype Water Level Indicator" May 4, 1980. This report is attached as Appendix D.

CONTRACTUAL RELATIONSHIPS AND PROJECT PERSONNEL

Experimental work on this project by NNC is being funded by EPRI. Dr. Pat Bailey is the Project Engineer. EPRI is also funding the manufacture and test of the complete set of detectors and electronics used in this experiment. Under separate contracts, EPRI is funding calculations by reactor physicists at SAI (San Diego) and by another group located near Oak Ridge. Finally, EPRI is arranging for a test of a single detector, at low water levels, by the E.G.&G. group at LOFT in INEL at Idaho. This test was performed in late 1980.

While NNC equipment and services during the test was funded by EPRI, this test would not have been possible without the extensive and continuous assistance of APCo and Southern Services personnel. Bill Hill of Southern Services served to coordinate the work in Alabama that led up to the conduct of this test. Ron George (APCo) participated in this preparatory work. During the test, NNC and APCo personnel worked essentially as a unit to install equipment and to collect and interpret the data. In general, APCo installed equipment, particularly in areas where respirators were required, or where work interfaced with other APCo operations. NNC could, therefore, concentrate on installing and maintaining electronics and on taking and interpreting data during the test. In the later stages, however, as APCo technicians became accustomed to using the equipment, APCo also operated the counting equipment. Only through this close relationship could this test have been completed without serious interference with the normal APCo shutdown schedule.

Personnel involved in this test and their principle functions were as listed below:

- J. J. Thomas, APCo, Controls and Instrument Supervisor at Farley. Thomas was in overall charge of this test, and made all arrangements for its conduct. He also suggested many improvements in the procedure and in the equipment. In particular, his suggestion for shielding the detectors materially improved the utility of the system. Under Thomas' direction, many technicians, generally supervised by Bill Lee, handled work on the test throughout the plant. All level readings and startup counter readings taken in the control room were obtained through personnel under Thomas' direction.
- S. Untermyer, Project Manager, NNC
- L. Kornblith, Principal Engineer, NNC
- M. Schmitt, Field Engineer, NNC. Installed and maintained electronic equipment

Test operations during the period November 10-14 were on a continuous basis round-the-clock. NNC personnel took reactor head counter data until November 13, when APCo technicians took over all data collection. Throughout the test, APCo provided data from the control room (level and startup counters, as well as boron content of reactor water).

OBJECTIVES AND TEST PROGRAM

The objective of the test was to obtain definitive measurements of the relationship between neutron count rate above the reactor vessel after shutdown and reactor vessel water level.

A second objective was to discover which variables such as core reactivity, shielding, and neutron background affected this relation.

A third but incidental objective was to learn approximately how rapidly this count rate decayed during the period of measurement.

A fourth objective was to determine as well as practical the true counter background of these counters due to cosmic rays, naturally produced neutrons, and alphas from the detector materials.

The test procedure prepared by J. J. Thomas is contained in Appendix C. This procedure follows the patterns laid out during a meeting at Farley on September 31. A few changes were made in this procedure during the test to accommodate information developed during the test.

The procedure for setting the gamma descrimination level is described in Appendix B. This test procedure resulted in selection of the following electronic equipment settings:

- Detector Voltage 3600
- Amplifier Gain 20
- Descriminator Setting 7 volts

Section 2

DESCRIPTION OF EQUIPMENT

REACTOR

The Farley reactor is a Westinghouse 800-Megawatt class pressurized water reactor located near Dothan, Alabama. The plant has been producing power since late 1977 and the tests were conducted during the early days of the second refueling outage.

An elevation of the reactor pressure vessel is shown in Figure A-1 of Appendix A. The vessel is installed in a containment building that includes a minimum thickness of three feet of concrete shielding. Although the concrete is provided for other purposes, it affords a substantial shielding against cosmic rays.

Figures A-2 and A-3 of Appendix A show, respectively, a more detailed vertical cross-section of the reactor vessel head area and a plan view. In Figure A-2 the vertical location of the detectors is shown. It is on top of the vessel head insulation at an elevation of approximately 134'9". The plan view shows the initial location of the four units. As noted in the table at the bottom of that drawing, the detectors were originally installed at radial distances outside of the insulation ranging from 14 to 26 inches, but on November 11 all were moved to positions such that the detector centerlines were 14 inches from the surface of the insulation. This was as close as they could practically be installed. The circumferential locations shown are approximate and, in some cases, were changed slightly when the detectors were moved closer to the centerline.

The proposed final location for the detectors in this plant would be on brackets down and in towards the vessel from the ventilation duct support structure shown above and to the left of the detector in Figure A-2. The location would be chosen, subject to the existing physical constraints, to be as close to the centerline as possible, to avoid shadow-shielding by the very thick reactor vessel flange, and to be as low as possible to maximize the counting rate. The many physical interferences will, of course, limit the possible location, and will require a compromise of the several parameters.

DETECTORS

The complete set of detectors supplied to Alabama Power Company to be used in the final installation consists of two sets of detectors, one above the reactor and one below, used as described in the section above on the theory of the measurement system. Each set consists of eight 2-inch diameter, 24-inch active length $^{10}BF_3$-filled thermal neutron counters. These detectors are made from stainless steel and are filled to 70 cm. Hg pressure. They are shielded by a 7/16-inch thick lead sleeve, and they are surrounded by a plastic moderator. An additional ½-inch lead shield is provided between the reactor vessel and the detectors.

The top set consists of four assemblies, each containing two counters. Each pair of counters, with its plastic moderator and lead shield, is contained in a steel box approximately 0.64 inches thick. Figure A-4 is an assembly drawing for the top detectors showing both the approximate overall dimensions and the arrangement of the parts. The bottom detectors are all contained in a single unit shown in Figure A-5. Alabama Power is investigating to determine if the single unit can physically be installed in the space available. If not, it will be rebuilt into two half-size units. This may eventually be necessary anyway, in order to comply with NRC redundancy requirements. For the top set, these requirements can be met with the present units but with slight modifications to the initial wiring external to the detectors and some additional electronics equipment in the control room.

Only the top set of detectors was used in the current test program.

A separate set of detectors will be provided in the final installation for use during reactor operation. This is necessary because the large detectors are too sensitive for use under such conditions. The set will consist of two small, less sensitive ^{10}B-lined counters, one above and one below the reactor. They will be provided with moderator and shielding similar to that provided for the large detectors. The geometry will be different and will probably make use of the lead and plastic presently contained in the large detectors. If redundancy requirements make it necessary, two detectors will be furnished for each location. Switching between the large and small detectors will be automatic. These small detectors were not included in the present test installation.

ELECTRONICS

The electronics used in the test program is a subset of the equipment provided for the complete installation. The basic arrangement planned for the test was modified

as the program was carried out in order to make operation more convenient, but no changes were made that would make the test less representative of the final arrangement.

A Tennelec Model TC 175 FET Charge Sensitive Preamplifier was mounted on the end of each of the four detector assemblies. The output signals from the four preamplifiers were combined and fed, through about 150 feet of RG-59 cable, to a Tennelec Model TC 216 Linear Amplifier and Single Channel Analyzer, located on the 155-foot level in the containment building. The output of the single channel analyzer was intially fed to an adjacent scaler, but soon after the test started this was changed so that the SCA fed, through a long cable terminated for impedance-matching purposes in a second amplifier, a separate scaler located in the hot instrument shop, also on the 155-foot level but outside of containment. This eliminated the need for protective clothing for the people operating the counting equipment.

Low voltage power was provided to the preamplifiers from a power supply located in the NIM bin housing the linear amplifier and single channel analyzer. The high voltage power supply for the counter tube was also housed in this bin and both power supplies were connected to the detectors by appropriate 150-foot long cables. A sketch of the system is shown in Figure A-6.

Section 3

CHRONOLOGY OF TESTS

November 8: Set up detectors outside containment

Desiccant packages had shorted some terminals

Repaired detectors

November 9: Ran plateau and threshold curves using background neutrons and gamma source.

November 10: Measured background inside containment

Set detectors on reactor head

Measured gamma level at detectors

Connected amplifier analogue output to descriminator in hot instrument lab

Counted during night November 10-11

Due to discrepancy in liquid manometers, level was reduced during night, but no change on counters

November 11: Moved detectors closer to center of head

Remeasured gamma levels

Took single 1000 second counts at two foot intervals

Data were erratic

November 11-12: Connected pulse output from amp-discriminator in containment to counter in hot instrument room to eliminate double count errors

Obtained first reliable data night of November 11-12

November 12: Found that highest level (with some water above detectors) gave anomolous high reading

Meeting at 0900 on results and program included Dr. Pat Bailey, EPRI; J. J. Thomas, APCo; W. H. Hill, Southern Company Services; Dr. Tom Albert, SAI; S. Untermyer, NNC; L. Kornblith, NNC. Recommendations: Bailey - provide complete data and run lower discriminator to get more counts. Albert - provide raw data and check for streaming, run one detector. Thomas - provide addition shielding around detectors.

Following the meeting, about six inches saturated boronated water in plastic bottles was placed on sides and top of the detectors.

Operation of detectors was checked with an 8 curie Pu Be neutron source in a shielded cask. This source in a cask gave many counts even at long distances.

Obtained data with shields on detectors

Anomolous effect with completely full vessel was eliminated and counts were generally lower, indicating lower background.

November 12-13: Continued counts

During the night, workmen damaged a cable from one preamp to junction box. This increased pulse height from remaining detectors, introducing gamma counts and raising count levels. In morning, a discriminator check showed the damage which was repaired, and counting was resumed.

Experiment showed neutron source in storage contributed slightly to background counts.

November 13-14: Counting was continued

In early morning, Operations increased boron level in reactor about 50%, decreasing startup detector counts about 50% without changing top detector counts

November 14: Removed detectors from reactor head to new position in containment at level 155

Placed detectors to provide maximum mutual radiation self shielding.

Counted detectors with and without water shield bags

As elevator had failed, could not remove Pu-Be neutron source, but measurements with additional shield in front of this source showed effect to be small

November 14: Conclusion of test

Section 4

TEST RESULTS

RELATIONSHIP OF COUNT RATE AND WATER LEVEL

A summary of test data, prepared by J. J. Thomas is shown on Figure 4-1. This figure clearly shows the increase in count rate as the water level is lowered, as well as the reduction in count rate with time after shutdown. The point at 136 elevation with unshielded detectors is believed to be high due to the effect of water above the detectors.

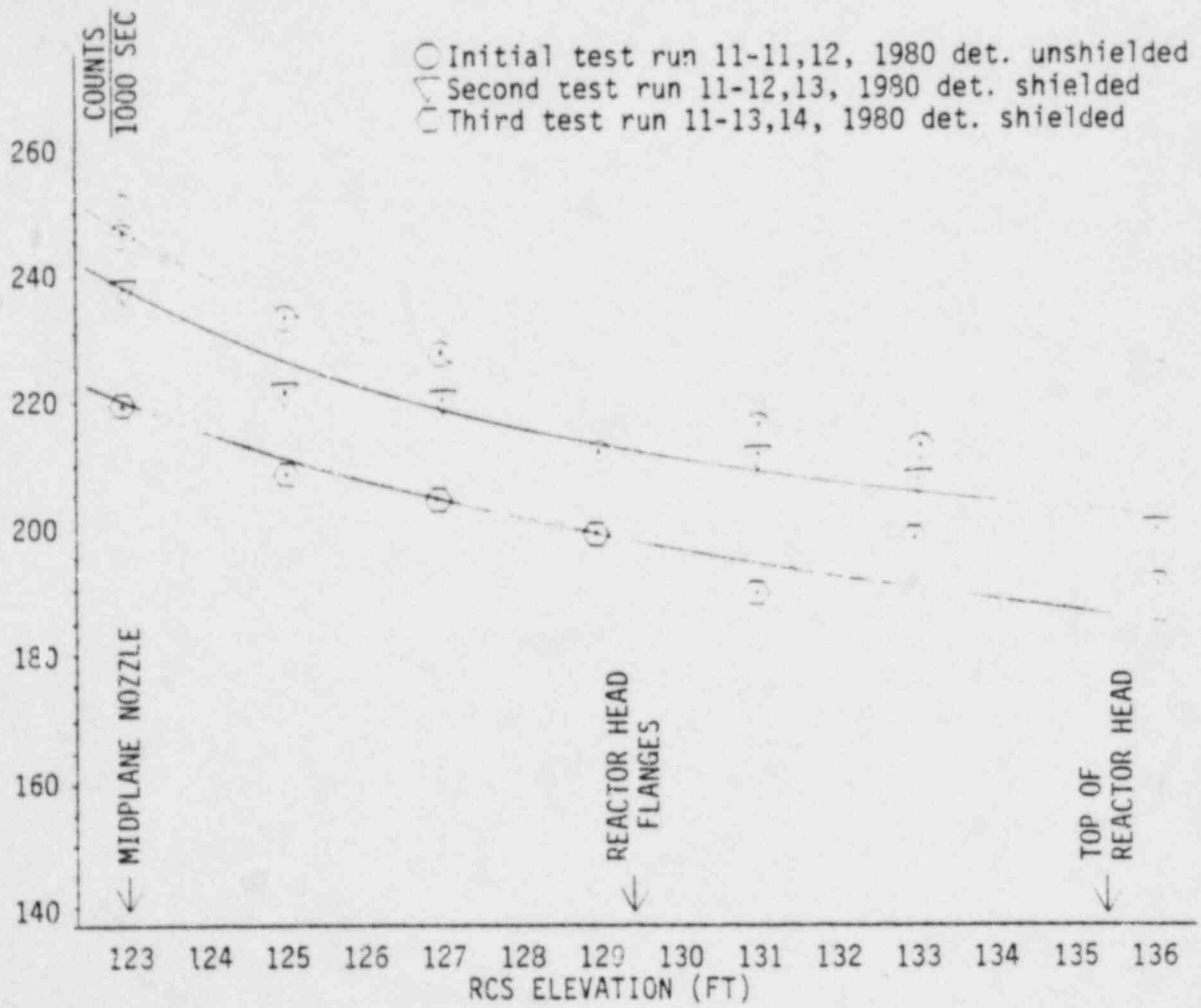


Figure 4-1. Farley Unit 1 NIRVLMS test data - count rate versus RCS level data obtained via FNP-1-ETP-192 on November 11-14, 1980

The single, averaged curve 4-2 was prepared as foll s:

1. The 136 elevation point with unshielded detectors was not used.

2. 12 additional points not included in the APCo data sheets, but recorded by NNC were added to the compilation.

3. The three curves were adjusted to allow for decay.

4. Data was averaged and error bars were added.

5. A scale was added to show net count rate, based on the background measured after the test on level 155.

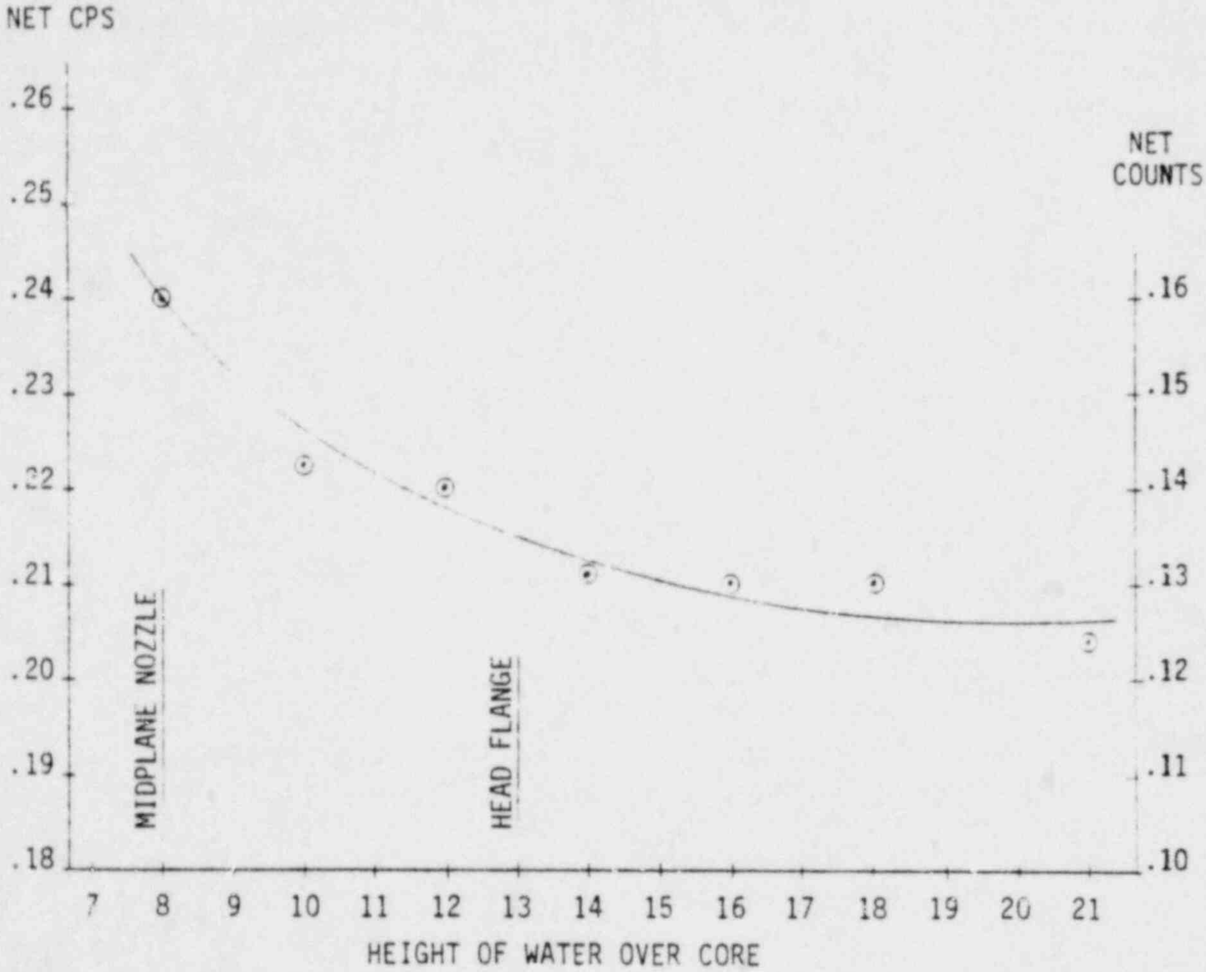


Figure 4-2. Average dat from Figure 4-1 measurements with cool reactor water

WIDE RANGE INDICATION AT TEMPERATURE

Figure 4-3 shows the net count data on Figure 4-2 replotted on semi-logue paper and extended to lower water levels based on the water level test data. As pointed out by Dr. Bailey, the water tank data has a much greater dependence on level than does the shutdown reactor data. Also shown on Figure 4-3 is a curve corrected for the water density at operating temperature, on the assumption that a 10 foot depth of hot water gives the same count rate as 6 feet of room temperature water.

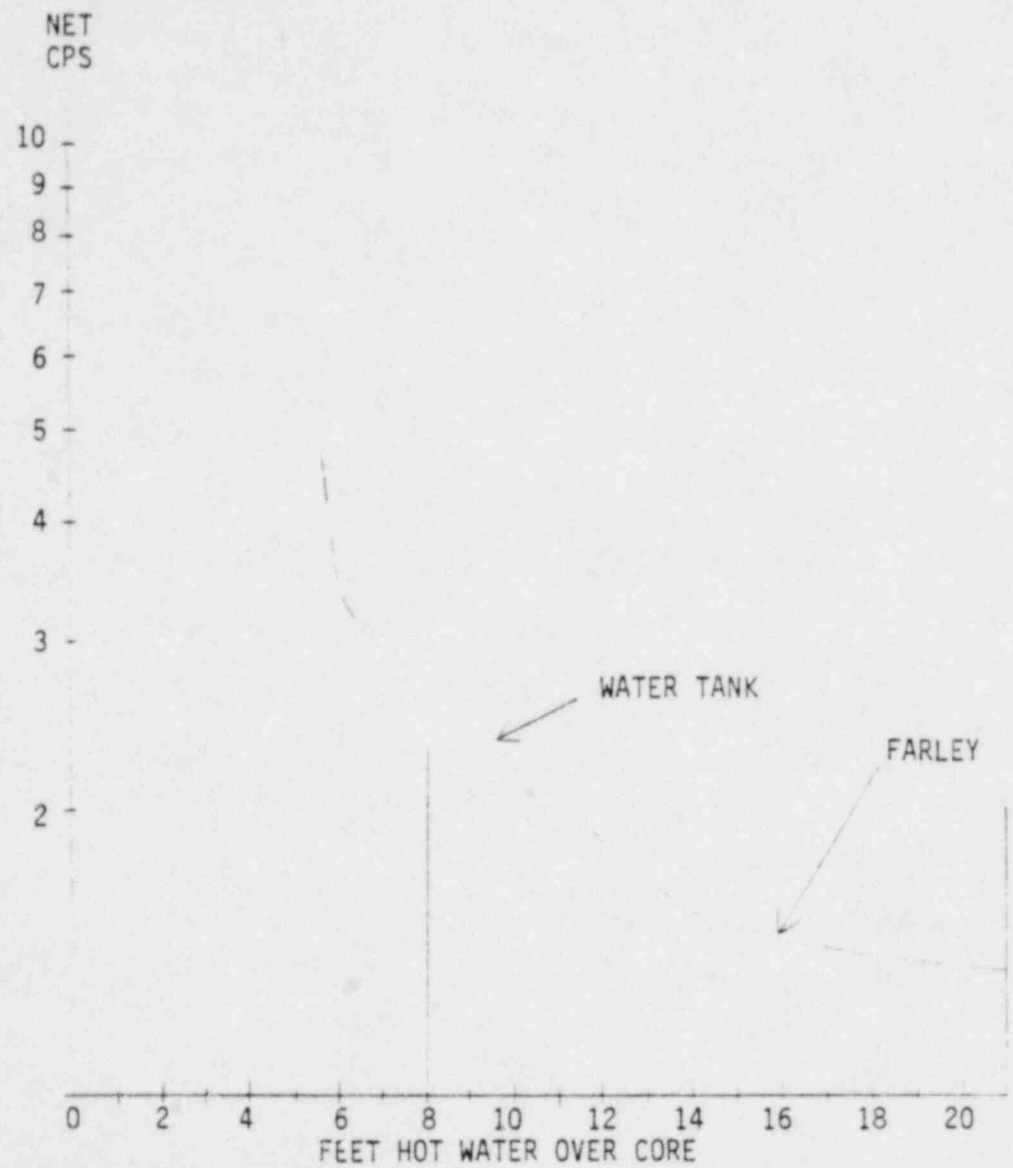


Figure 4-3. Composite curve Farley data corrected to operating density and normalized to Farley count rate

STREAMING OR PHOTONEUTRONS?

The temperature correction method used assumes most neutrons travel through the water to the detectors, but SAI has suggested that, in fact, most neutrons stream to the detectors from the core through small openings between the shielding and the reactor vessel. This section attempts to summarize evidence for each of these theories.

Evidence For Streaming

1. SAI calculations on similar reactors show streaming contributes most above the reactor.

2. There does not appear to be any way for the neutrons or gamma rays to penetrate such large water thicknesses.

3. For the same water thicknesses, the water tank tests show much higher count rates with roughly similar neutron source terms. Also, the effect of water thickness is much greater in the tank tests. This difference, however, may perhaps be explained by the difference in the gamma energies between primarily fission gammas in the tank test and primarily fission products at Farley.

Evidence For Photoneutrons

1. When measurements were made with unshielded detectors, the 136 foot elevation point with water both below and to the side of the detectors showed a higher than expected count rate. This effect disappeared when the detectors were shielded on top and sides. This can be explained if photoneutrons reached the detectors from both below and from water to the side of the detectors whenever the water level approached or exceeded the detector elevation (about 135 feet).

2. At 0340, November 14, Operations increased boron in the reactor from 1040 PPM to 1584 PPM. Randy Marlow (APCo Reactor Engineer) estimates this decreased core reactivity 6.75%. As shown in Table 4-1, abstracted from APCo data sheet No. 7 shows that startup detectors (which read fast neutron leakage through the vessel wall from the core) decreased about 50%. Nevertheless, vessel top counters did not change appreciably. On the balance, from available evidence, it is believed that neutrons detected above the reactor do not originate in the reactor core and are produced in the water near the detectors.

DECAY OF COUNTS AFTER REACTOR SHUTDOWN

Data are not accurate enough to provide an accurate estimate of the half-life of the radioactivity which leads to neutron counts in the detectors above the reactor vessel. Only the second and third runs had identical detector arrangements.

Table 4-1

COUNT RATE DATA AS A FUNCTION OF TIME AND BORON CONTENT

Time	Level	Boron (PPM)	Startup Counters (CPS) N-31	Startup Counters (CPS) N-32	Top Reactor Counters (CPS)
0005	125	1040	222	339	0.227
0130	123	1040	221	338	0.222
0147	123	1040	221	338	0.212
0204	123	1040	221	339	0.214
0221	123.5	1040	222	339	0.229
0340		Added Boron			
0354	129	1584	118	169	0.219
0411	130	1584	116	167	0.196
0650	134	1584	Not Taken		0.216
0707	135	Diluting Boron	Not Taken		0.204
0725	136		192	282	0.178
0734	136		194	286	0.185
0759	136		203	298	0.204
0816	136		211	308	0.184

On the average, these runs were made about 20 hours apart. The later run was about 15 counts lower, and the net count rate was about 130. Using these crude values, the mean life would be:

$$\frac{130}{15} \times \frac{20}{24} = 7 \text{ Days. } \quad \text{(5 days half-life)}$$

This is not inconsistent with 12.8 day ^{140}Ba- 40 hour ^{140}La mixed with other shorter lived isotopes.

BACKGROUND COUNT RATE

The best background counts were obtained after the test when the detectors were moved to level 155. Detectors were placed close together to provide mutual shielding, and counts were taken both with and without 6" of boronated water shielding.

In a previous test, with the detectors on top of the reactor head, (APCo Data Sheet 5) it appeared that the Farley calibration neutron source (8 curies Pu Be estimated 10^7 N/S) produced more than one sigma increase in count rate when stored outside the containment (3'9" concrete plus 18" plastic shielding). In the background test, due to a broken elevator, it was impossible to store the source below ground so counts were taken both with and without an extra 10 gallon plastic filled bucket between the source and the detectors.

As counts were taken the last day, after APCo logues were prepared, the data are listed here:

Time (Nov. 14)	Condition	Counts Per 1000 Sec.	Average CPS
1310	No Water Shields	118, 158, 141, 148	0.141 ± 0.006
1426	6" Boronated Water Shields	91, 76, 87	0.085 ± 0.005
1500	Boronated Water With 10 Gal. Case in Front of Source	77, 91, 96	0.088 ± 0.006

From these data, and considering the extra shield inherent in the location within the reactor cavity, the value of 0.08 CPS was used for background on top of the reactor.

This background is due to alpha emitters in the counter tubes, cosmic rays, and other miscellaneous neutron background contributions. By comparison, these detectors had a background in the NNC unshielded laboratory in California of approximately 2 CPS.

The following page gives Reuter Stokes estimates for alpha background levels in proportional counters. In the Farley test there were eight stainless steel tubes, 2" diameter, 24" long. Using an average value of 5.3 Counts per hour per 100 cm^2:

$$\frac{5.3 \times 8 \times 2\pi \times 24 \times 6.45 \times 1000}{100 \times 3600} = 114 \text{ Counts Per 1000 Seconds}$$

As this value is higher than the total measured background, Reuter Stokes may have bettered the background levels of their counters.

REUTER STOKES DATA
NATURAL BACKGROUND OF PROPORTIONAL COUNTERS

Practical materials for the construction of the bodies of these counters are aluminum, stainless steel, copper or brass. Natural background consists of alpha and beta particles generated from the inner surface of the counter. Two comparisons of materials for the alpha effect are:

Alpha Background of Materials

		Brass	Copper	Stainless Steel	Aluminum
Counts/100cm^2/hr	(1)	6	1	6	31
Counts/100cm^2/hr	(2)	-	1.1	4.8	27

The energy and ionizing efficiency of alpha particles is sufficient to produce pulses induced by the (na) reaction of thermal neutrons; i.e. alpha emission by the counter body will be indistinguishable from neutron pulses.

The common requirements of 1 cpm background can be routinely met in one inch diameter counters with up to 1000cm^2 internal area. The figures indicate that this requirement can be met in aluminum counters of approximately 200cm^2 area. In practice, our counters using 1100 Aluminum have an even lower background than that theoretically derived above. For example, we are supplying BF_3 counters with aluminum bodies with a maximum background of 1.0cpm where in the counter has an internal surface area of 263.4cm^2. The natural beta activity of materials is:

Beta Background of Materials

	Brass	Copper	Stainless Steel	Aluminum
Counts/100cm^2/hr	16-30	3-6	300	240

The beta particles have low energy and poor ionizing efficiency, and pulses produced from this source are not sufficient to significantly effect the neutron pulses since they are buried in the system noise and/or are below the discriminator level of the counting system.

Section 5

DISCUSSION AND CONCLUSIONS

APPLICATION TO POWER REACTORS

1. Tests at Farley conclusively demonstrate that neutron detectors mounted above the reactor vessel respond to changes in water level within the vessel.

2. Improvements may be made through better threshold adjustments on the detectors (as suggested by Dr. Bailey) and marked improvement is possible with detector shielding (suggested by J. J. Thomas). Note: B_4C plastic shields for the detectors are now being fabricated.

3. Since neutrons above the vessel do not follow the pattern of core shutdown power, a normalizing detector array below the vessel is required to provide good accuracy in water level measurement. Such a detector does not appear needed to provide a warning, only as planned for the Farley 1 initial installation.

4. While count rates measured after four days shutdown were very low, the count rates during the critical period shortly after shutdown are estimated to be about 100 times higher, which should be ample.

FURTHER AREAS FOR INVESTIGATION

1. A clear understanding is needed of the mechanism whereby neutrons reach the detectors when the core is covered by 10-20 feet of water.

2. Tests, similar to those at LOFT, should yield a better understanding of behavior at lower water levels, at shorter times after shutdown, and under transient conditions.

Appendix A

EQUIPMENT AND LOCATION DRAWINGS AND DIAGRAMS

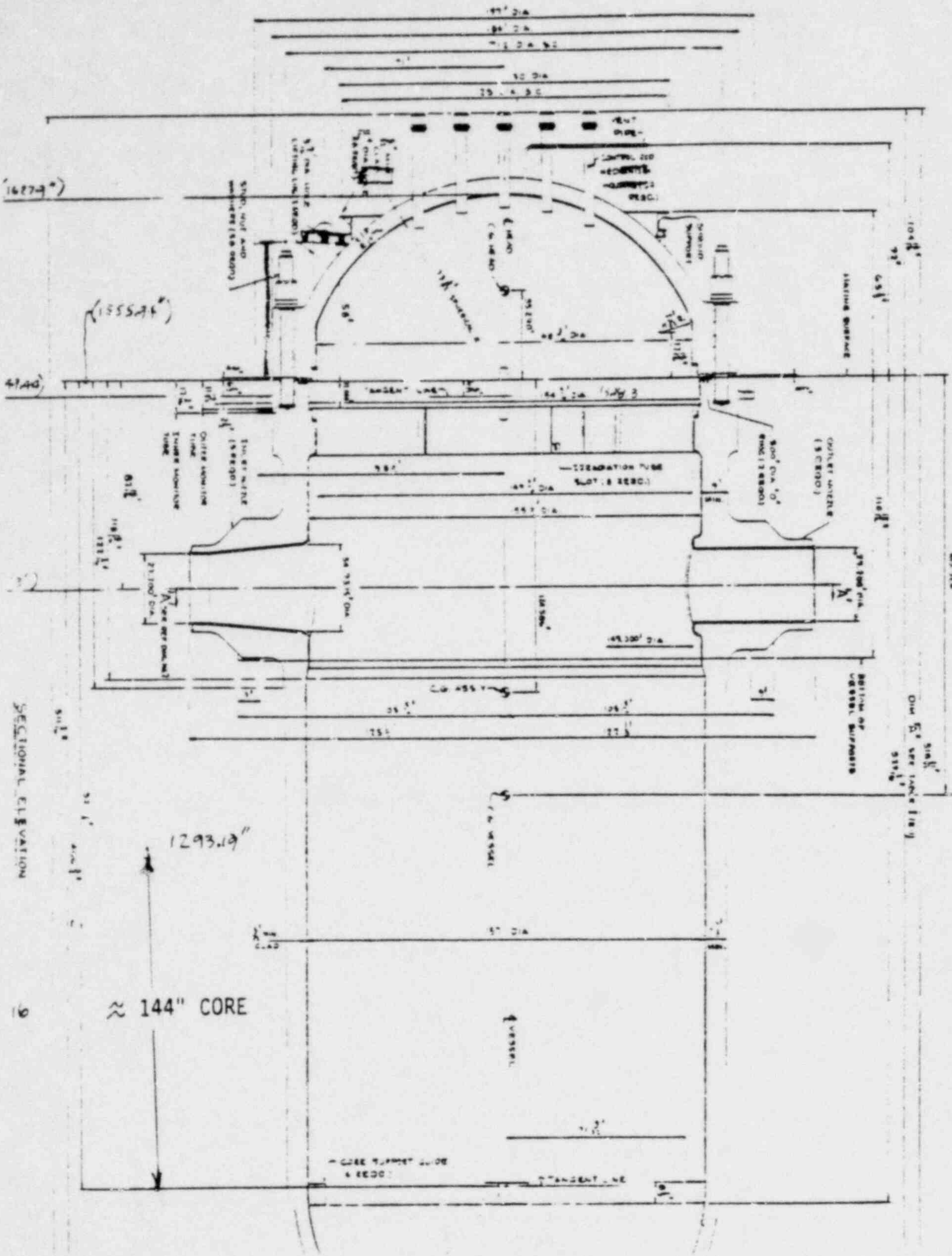


Figure A-1

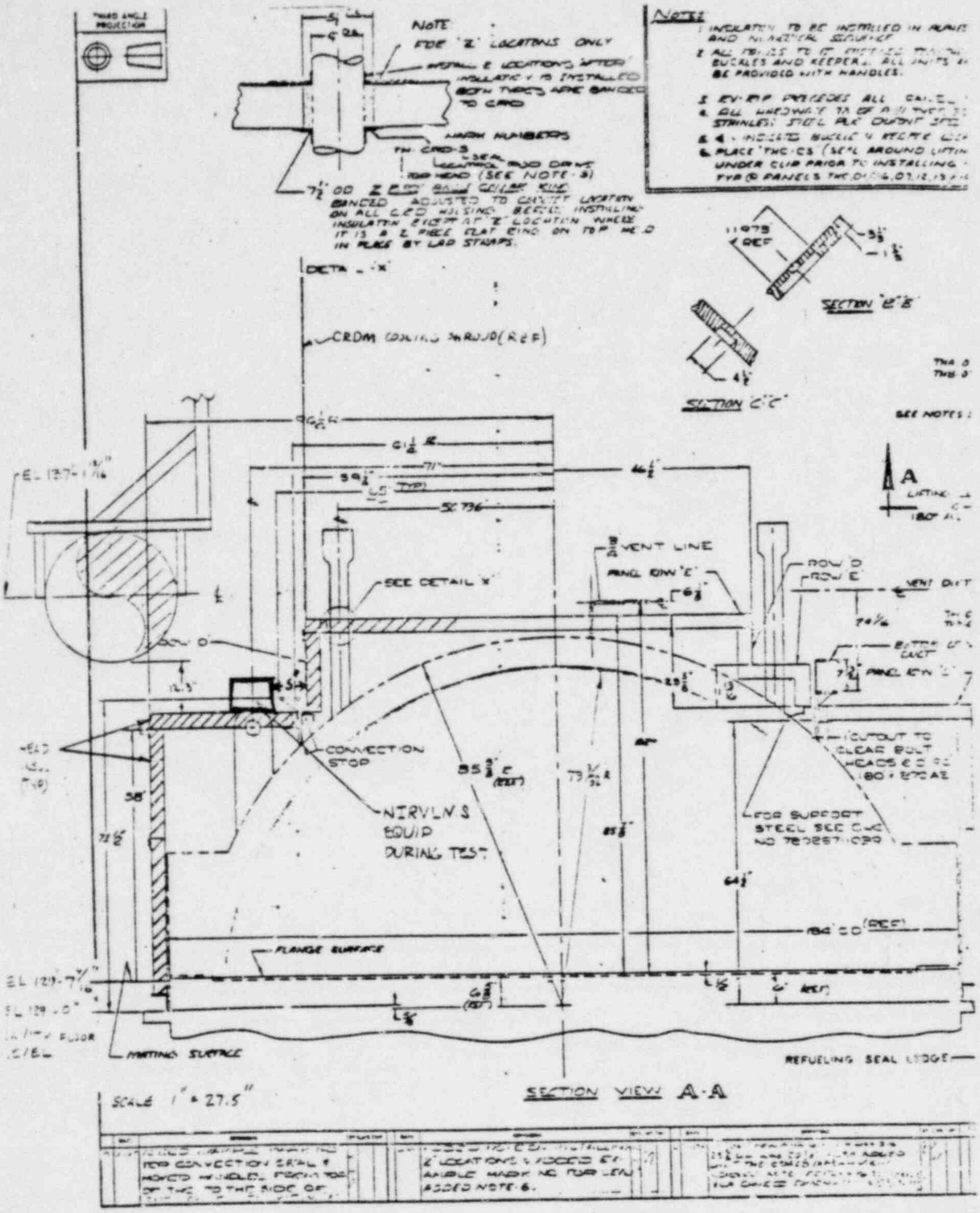
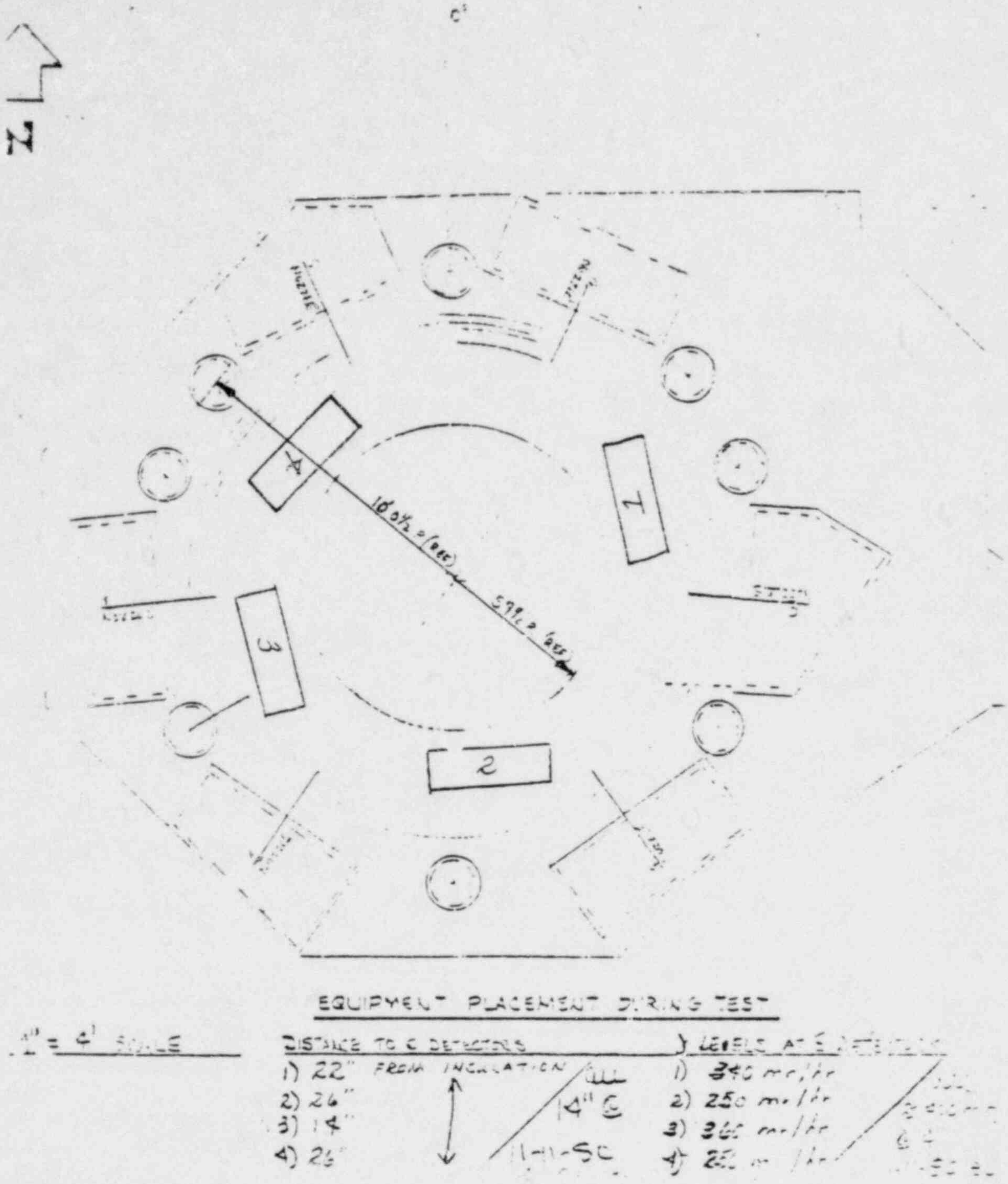

SECTION VIEW A-A
SCALE 1" = 27.5"
CRDM COOLING SHROUD (REF)
SEE DETAIL "X"
CONVECTION STOP
FLANGE SURFACE
MATING SURFACE
REFUELING SEAL LEDGE
SECTION "B-B"
SECTION "C-C"

Figure A-2



EQUIPMENT PLACEMENT DURING TEST
1" = 4' SCALE
DISTANCE TO C DETECTORS
1) 22" FROM INSULATION
2) 26"
3) 14"
4) 26"
14" C
LEVELS AT
1) 340 mr/hr
2) 250 mr/hr
3) 360 mr/hr

Figure A-3

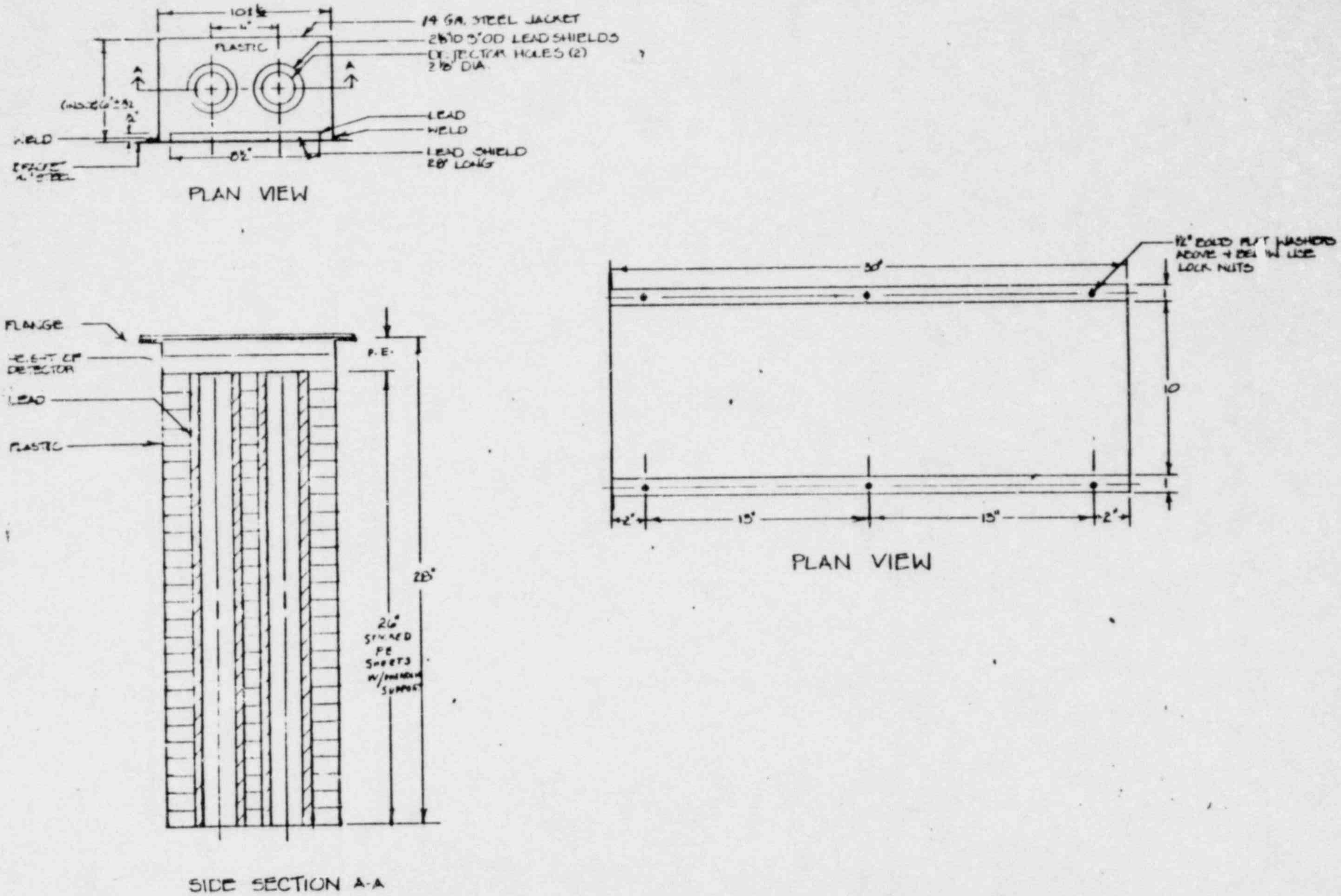


Figure A-4. Top Detector Attachment Arrangement

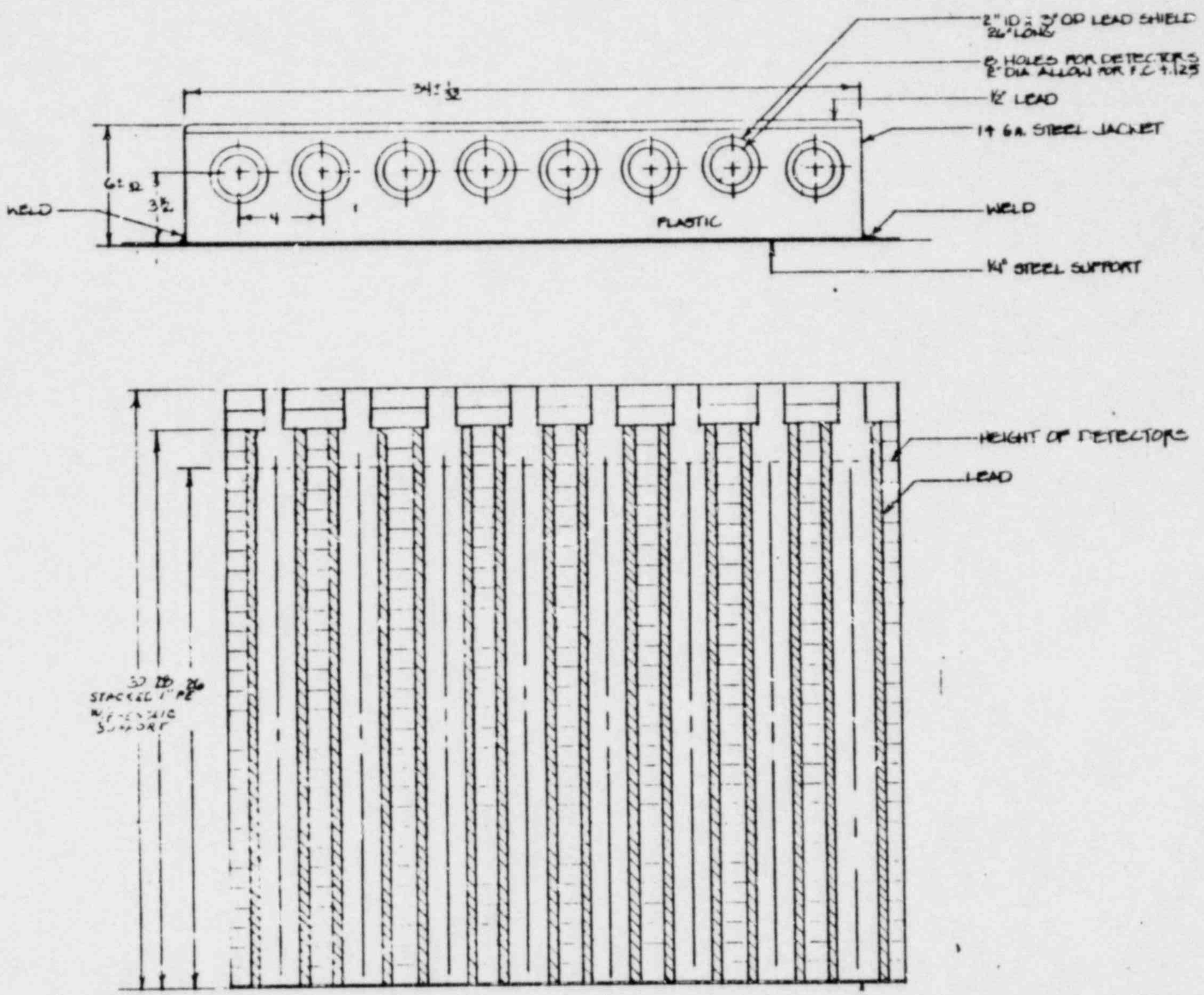


Figure A-5. Botom Detector

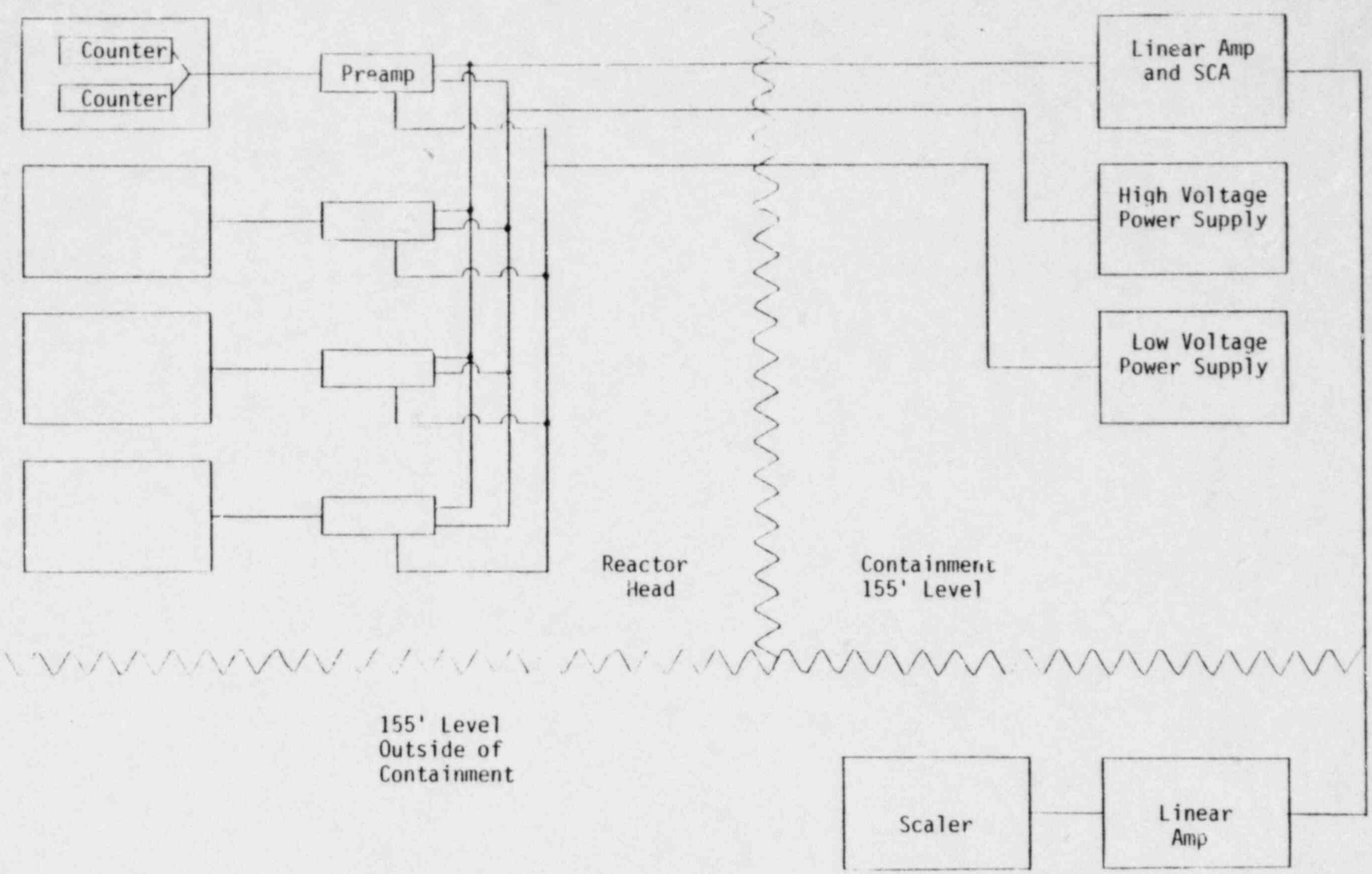


Figure A-6. Test Instrumentation

Appendix B

EQUIPMENT ADJUSTMENT PROCEDURES

DETECTOR THRESHOLD SELECTION

Previous experience with these detectors indicated that the operating voltage should be between 3200 and 3800 volts.

A test using background neutrons outside the containment was run on November 8 (Figure B-1) and plateaus were obtained which indicated 3600 volts to be suitable.

A test was then run (Figure B-2) which indicated the detectors would count neutrons with a gain of 20 and thresholds as high as 8 volts. A threshold of 7 was used in all tests.

METHOD OF ESTIMATING THE REQUIRED GAMMA RAY REJECTION THRESHOLD

If a randomly spaced chain of P uniform length square pulses is received per second, then if each pulse has a length of T, the rate of counting single pulses will be P, the rate of counting two superimposed pulses will be P (PT) or $\frac{(PT)^2}{P}$ and the rate of counting X superimposed pulses will $\frac{(PT)^X}{P}$. These expressions neglect higher order effects, but are accurate in the range required.

The rate of observing pulses of height greater than X pulses high is then $\frac{(PT)^X}{P}$ plus negligible higher order terms. Putting this rate equal to Y;

$$Y = \frac{(PT)^X}{P}$$

$$\log_{PT} PY = X$$

Thus when the logue of the count rate from such a pulse chain is plotted against threshold setting, it results in a straight line.

Similar arguments indicate that other combinations of pulse pileups result in a straight line when pulse rate is plotted against threshold on similar paper. This

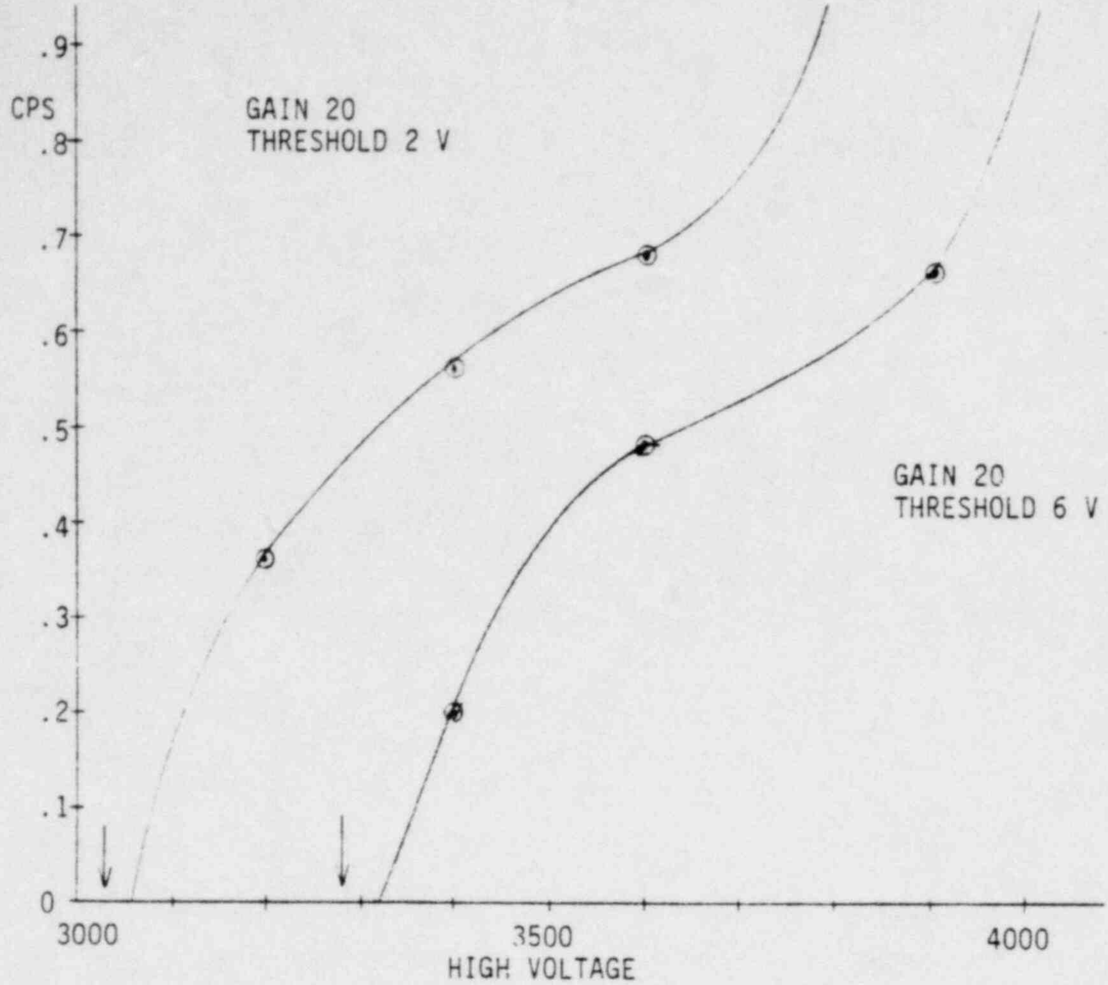


Figure B-1. Detector threshold November 8, 1980 outside containment counting background neutrons

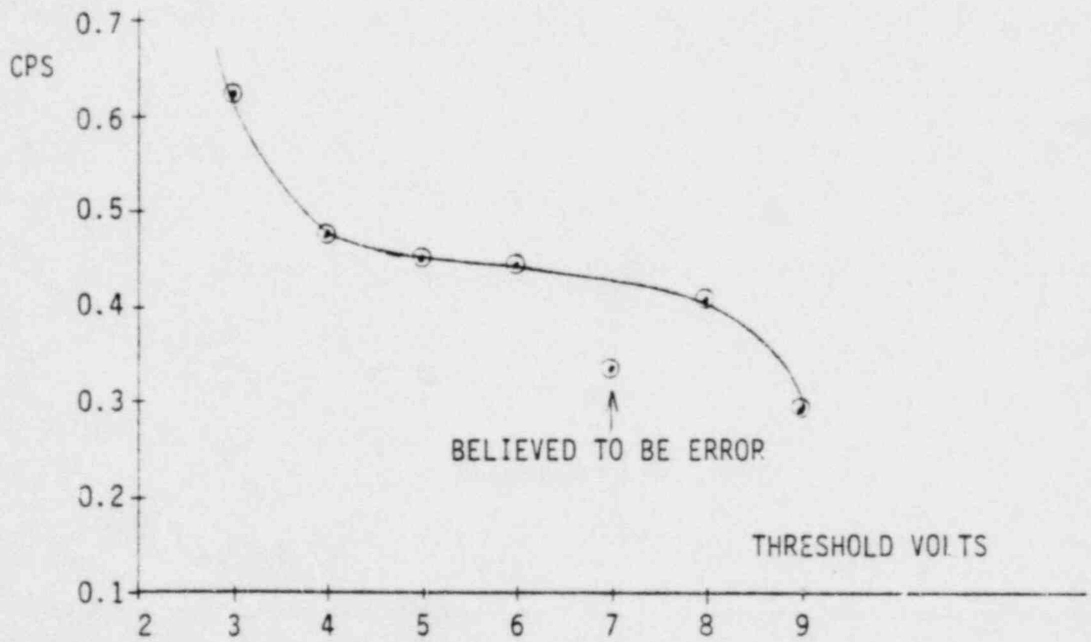


Figure B-2. Threshold check in shop with background neutrons 3600 HV 6 = 20 100 sec. counts

fact serves as the basis for setting the threshold bias at the lowest value that will discriminate against gamma rays.

The method used is shown on Figure B-3 and B-4. Figure B-3 shows that a threshold more than 5 is needed to eliminate 200 MR/H of ^{60}Co gammas in the shop. Figure B-4 curve a shows the count rate from background gamma rays and desired neutrons when the detectors were placed above the reactor where the gamma radiation level was about 300 MR/H. The straight portion of the curve is due to gammas, the deviation is due to neutrons. Subtracting an estimated neutron count rate of 0.23 per second yields a curve which is due to gammas only, and hence is a straight line on semi-log paper.

This shows that the chosen threshold of 7.0, the gamma background is less than 1% of the neutron count rate.

On November 13, during the course of the experiment, a workman inadvertantly dislodged one of the 4 cables leading from the preamplifiers to the junction box. This reduced the preamplifier output loading from 75 ohms ÷ 4 to 75 ohms ÷ 3; in effect lowering the bias to 7 x 3/4 while reducing the counters from 4 to 3. The immediate effect was an <u>increase</u> in the count rate at threshold 7, from about 0.2 up to 0.3 CPS. This increase was due to gamma interference at the lower threshold. The cause was understood as soon as the bias curve b on Figure B-4 was obtained. It can be seen that each point on the gamma line is at a bias level 4/3 higher but at this higher bias there are 3/4 as many counts. The net effect is to increase the gamma interference greatly.

Such semi-log plots provide a powerful diagnostic tool to set the correct threshold for neutron counting in high gamma fields.

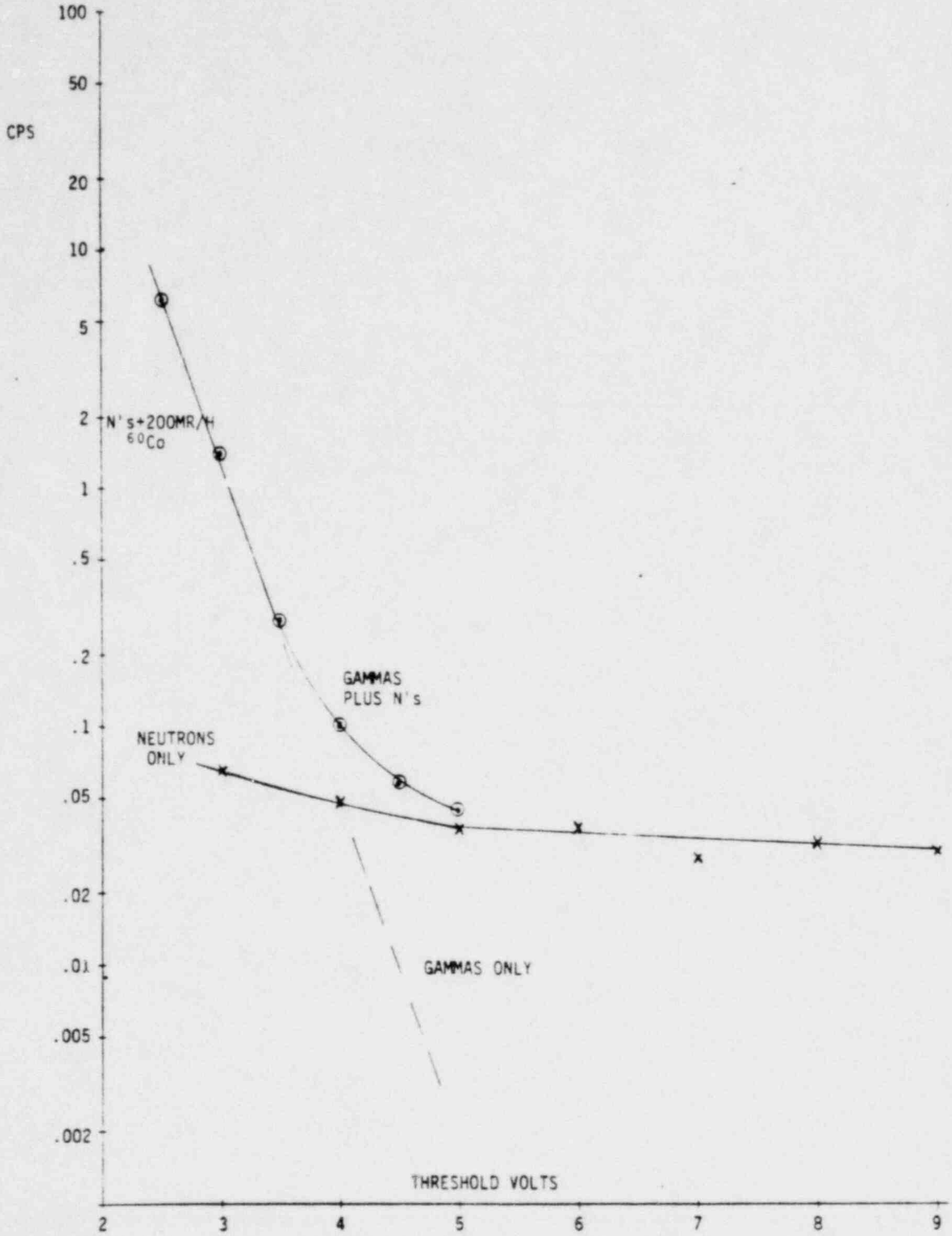
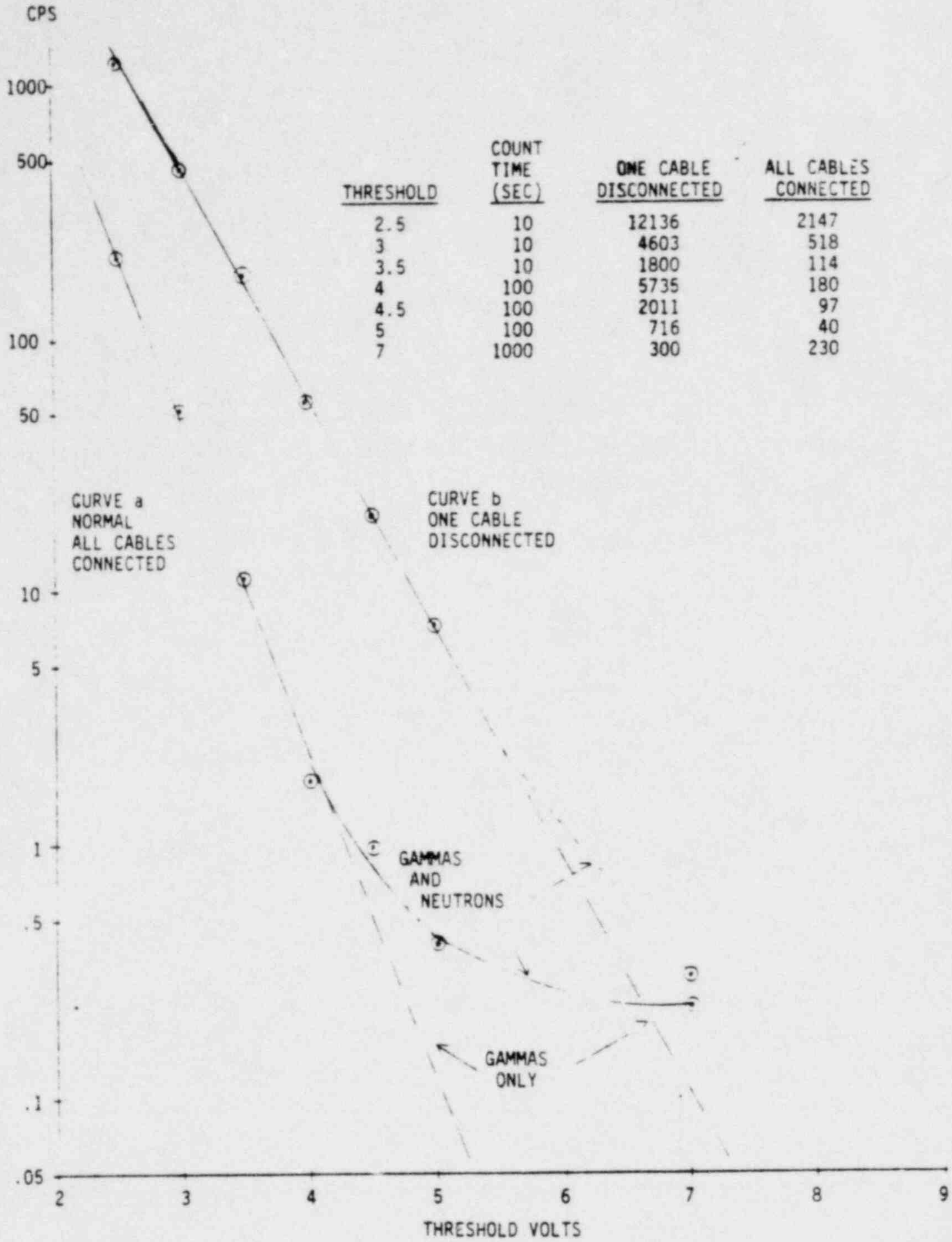


Figure B-3. November 8, 1980 threshold check with ^{60}Co source 3600 HV 20 G



THRESHOLD	COUNT TIME (SEC)	ONE CABLE DISCONNECTED	ALL CABLES CONNECTED
2.5	10	12136	2147
3	10	4603	518
3.5	10	1800	114
4	100	5735	180
4.5	100	2011	97
5	100	716	40
7	1000	300	230

Figure B-4. November 13, 1980 threshold check after cable failure
3600 HV G = 20

Appendix C

TEST PROCEDURES AND DETAILED DATA SHEETS

FNP-1-ETP-192
October 22, 1980
Revision I

FARLEY NUCLEAR PLANT

ENGINEERING TEST PROCEDURE

FNP-1-ETP-192

SAFETY RELATED

NON INVASIVE REACTOR VESSEL WATER LEVEL
MEASUREMENT SYSTEM DEVELOPMENTAL TEST

801104-1

OFFICIAL
TEST COPY

Approved:

Wm. B. Shipman
Maintenance Superintendent

Date Issued: 10-23-80

Diskette #ETP-17

PROCEDURE REQUEST FORM

1. Procedure Number FNPH-ETP-192 Revision Number 1
Procedure Title NON INVASIVE REACTOR VESSEL WATER LEVEL TEST

- ☑ Safety Related ☐ Non-Safety Related
- ☐ New Procedure Request
- ☐ Procedure Revision, New Revision Number ______
- ☐ Change of Intent
- ☑ Temporary Procedure Change, Effective until next permanent change, TCN 1A
- ☐ One time Temporary Procedure Change, Effective from ______ to ______, TCN ______

2. Change Summary

2.1 Procedure Page Numbers Affected by Change
3

2.2 Description of Changes
ADD: AFTER FIRST TEST, SHIELD DETECTORS WITH 350 gm BORON [illegible]
REPLACE PAGE 3 WITH ATTACHED

OFFICIAL TEST COPY

2.3 Reason for Change
TO SHIELD NEUTRON DETECTORS FROM STRAY NEUTRONS IN VICINITY OF REACTOR HEAD

3. Prepared By [signature], [illegible], 11-12-80
Signature, Title, Date

4. Reviewed By Wm. [signature], M. Swift, 11-12-80
Signature, Title, Date

5. Cr[oss] Disc[i]plinary/PORC Review

Group	Signature	Title	Date

6. Temporary Change Approval (Signature/Date)

- ☑ Member Group Staff [signature] 11/12/80
- ☐ Shift Foreman
- ☑ Senior Reactor Operator James [signature] 11-12-80

7. Final Approval (Signature/Date, required within 30 days of temporary approval)

- ☐ Group Supervisor ______/______
- ☐ Plant Superintendent Wm. B. [signature] / 11-12-80
- ☐ Manager of Operations QA ______/______
- ☐ Manager of Nuclear Generation ______/______
- ☐ Plant Manager ______/______

Figure 1 Rev. 7

LIST OF EFFECTIVE PAGES

	REVISION NO. 1											
PAGE NO.	0	1	2	3	4	5	6	7	8	9	10	11
1	X											
2	X	x										
3	X	X										
FIGURE 1												
DATA PACKAGE COVER SHEET		X										
2		X										
3		X										
4		X										
5												
6												

FARLEY NUCLEAR PLANT
UNIT 1
ENGINEERING TEST PROCEDURE ETP-192

NON-INVASIVE REACTOR LEVEL MEASURING SYSTEM TEST

1.0 Purpose

1.1 The purpose of this procedure is to establish and verify the accuracy of the Non-invasive Reactor Level Measurement System including detectors and associated signal processing equipment.

2.0 Acceptance Criteria

2.1 Alabama Power Company will evaluate the results of this test to determine feasibility of a similar system for permanant installation at the plant. At the present time no formal Acceptance Criteria Exist.

3.0 References

3.1 FNP-1-ETP-192 Data Package

3.2 EG & G Ortec Model 778 Dual Counters Operating and Service Manual

3.3 Tennelec Model TC 175 Fet Charge-Sensitive Preamplifier Instruction Manual

3.4 Tennelec Model TC 216 Linear Amplifier & SCA Instruction Manual

3.5 Bertan Model NIM 342, 346, 353, 355 Single Width High Voltage Power Supplies Instruction Manual

3.6 National Nuclear Corp. Preliminary Test Procedure

4.0 Test Equipment

4.1 Fluke Digital Multimeter, Model 8120A or Equivalent

4.2 Tektronix Oscilloscope Model 5403 or Equivalent

4.3 Stopwatch

4.4 4 sets of sound powered headphones and extension cables

5.0 Precautions and Limitations

5.1 All reference to data sheets by this procedure is to data sheets contained in reference 3.1.

5.2 Critical procedure sections and steps are listed on page 1 of the data package used with this procedure and are marked with an asterisk (*) within the body of this procedure. As each critical step or section is completed, initial on the space provided on Table 1 of the data package.

5.3 Observe all precautions and limitations listed in FNP-0-IMP-0, General Instrumentation and Controls Precautions and Limitations.

*6.0 Initial Conditions

6.1 The Shift Foreman has granted administrative authority to perform this test and is aware of indications, printouts, and alarms that will result.

6.2 Verify FNP-1-IMP-201.42 Refueling RCS Level Procedure has been Implemented.

7.0 Detailed Test Procedure

7.1 Prior to Shutdown, set up equipment, (Per Vendor Instructions), outside of Containment. Check neutron plateau of detectors. Adjust sensitivity to reduce gamma background. Record setpoints on data sheet 1.

7.2 As soon as possible after Reactor Shutdown, set up equipment on Elevation 155' in containment. Measure neutron countrate. Record neutron countrate on data sheet 1.

7.3 Place each of the four top NNC detector assemblies above the reactor vessel on existing reactor vessel insulation. Locate the assembles as close as possible to the Control Drive Cooling Shroud. Document Detector locations on Figure 3.

7.4 Connect all equipment per FIGURE 1.

*7.5 Apply system power. Calibrate and verify system readouts per vendor instructions. Record inital equipment settings on Data Sheet 1.

Rev. 1

*7.6 Observe counts with reactor vessel full of cool water (≤ 200° F). Take (4) 1000 second counts to observe trends and stability of counting system. Record all pertinent data on sheet 2.

*7.7 Measure Gamma Radiation Level at the detectors. Record levels on Data Sheet 1.

7.8 Arrange communication with the control room (ie: Sound Powered Headphones).

7.9 Have plant operations personnel lower the Reactor Vessel water level two (2) feet per normal plant UOP's. Take a 1000 second count. Record all pertinent data on data sheet 2.

7.10 Have plant operations personnel lower the Reactor Vessel water level another two (2) feet. Take a 1000 second count. Record all pertinent data on data sheet 2.

7.11 Repeat step 7.10 until reactor vessel water level is at centerline of nozzles. Record all pertinent data on data sheet 2.

7.12 Have plant operating personnel raise reactor vessel water level two (2) feet take a 1000 second count. Record all pertinent data on data sheet 2.

7.13 Repeat step 7.12 until reactor vessel is full of water.

JWH ADD → 7.13.1 AFTER FIRST TEST, SHIELD DETECTORS WITH POLY BOTTLES FULL OF 3500 PPM BORON SOLUTION. SHIELD TOP AND SIDES OF DETECTORS.

*7.14 Repeat steps 7.9 through 7.13.1 as required by vendor to obtain necessary data (Maximum of 4 cycles).

~~*7.15 From data collected in steps 7.9 through 7.14, calculate the Ratio:~~

~~Top Detector Counts / Source Range Detector Counts~~

~~Record calculations on data sheet 2~~

~~*7.15.1 Plot calculated ratio (above) vs. Water Level on Figure 2~~

DELETE

*7.16 Notify Shift Foreman of Test Completed.

*7.17 Disconnect & Remove all equipment from containment.

Rev. 1

TCN 1A

CONTAINMENT

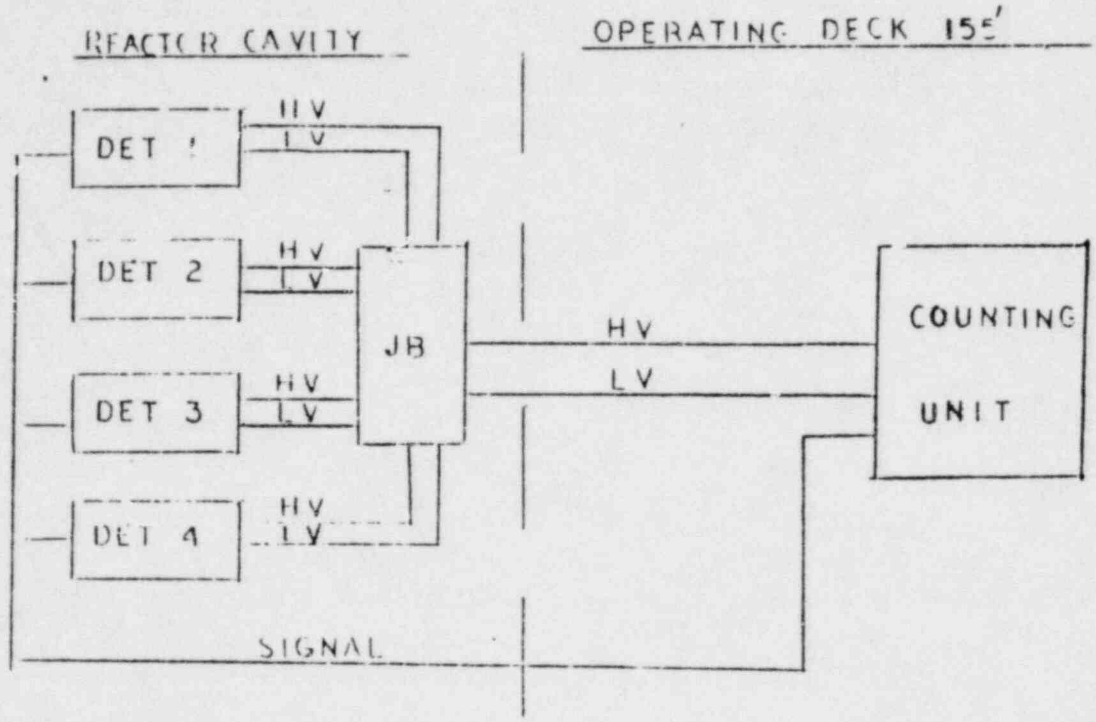


FIGURE 1

FARLEY NUCLEAR PLANT
UNIT 1
ENGINEERING TEST PROCEDURE DATA PACKAGE ETP-192

NON INVASIVE REACTOR LEVEL MEASURING
SYSTEM

1.0 Purpose

This data package is to used in conjunction with procedure FNP-1-ETP-192 to record data.

2.0 References

2.1 National Nuclear Corp. Preliminary Test Procedure

3.0 Procedure Sign-Off Sheet and Alteration Log

3.1 Initial the appropriate space in Table 1 as each step or section is completed in ETP-192

3.2 Record any temporary alterations on Table 2

4.0 Test Results

4.1 Test completed satisfactory

4.2 Deficiencies occurred (see data sheets for explanation)

4.3 Time required for test 96 HRS Procedure Rev. used 1

4.4 Test Performed by B. Lee Date 11/18/82

4.5 Test Reviewed by [illegible] Date 11/18/82

This data package consists of 13 pages.

Rev. 1

STEP OR SECTION		INITIALS	STEP OR SECTION	INITIALS
6.9	Initial Cond.	BL		
7.5	Initial Settings	BL		
7.6	Trend Data	BL		
7.7	Gamma Radiation Levels	BL		
7.14	Test Data	BL		
7.15	~~Ratio Data~~ DELETE			
7.15.1	Plot Calculations			
7.16	Notify Shift Foreman			
7.17	Remove Equipment			

TABLE 1 PROCEDURE SIGNOFF

DESCRIPTION OF ALTERATION	ALTERED	RESTORED

TABLE 2 TEMPORARY ALTERATION LOG
REV. 1

DATA SHEET 1

INITAL SETTINGS

EQUIPMENT	SETTINGS
NEUTRON COUNTRATE (Step 7.2)	7.2 .345 CPS 7.5 .267 CPS

GAMMA RADIATION AT DETECTORS

DET #		RAD LEVEL	
1		340 mr/hr	REFERENCE FIGURE 3
2		250 mr/hr	
3	400mr @ Location CHANGE REF FIGURE 3	360 mr/hr	
4		250 mr/hr	

Data Recorded By:
RMF/DL 11-24-78

Rev. 1

Sheet 1 of

DATA SHEET 2

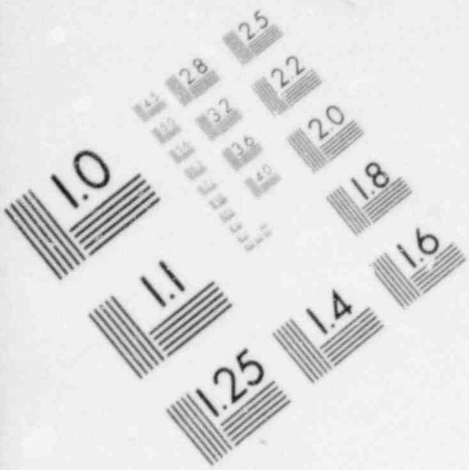
NON INSTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El.	Source Range N11 Counts	Source Range N32 Counts	NIRVLMS Countrate	Ratio Top DET Counts / Source DET Counts	Data Recorded By
1-10-80	1307	60.1	135.7°	FULL	193064	307075	278		
1-10-80	1325	60.4	136.4°	FULL	193558	307031	281		
-10-80	1341	60.7	136.4°	FULL	193153	308687	278		
-10-80	1358	61.0	137.6°	FULL	193984	307681	252		
	END COUNTS AT 1414 (61.2 HRS AFTER SHUTDOWN) RCS TEMP @ 138.5°F LEVEL · FULL								
1-11-80	1000	81 hrs.	100°F	136'	NOT TAKEN		246		
1-11-80	1000	81.0	100°F	136'			258		
1-11-80	1000	81.0	100°F	136'			246		
1-11-80	1030	81.5	100°F	136'			258		
1-11-80	1200	83.0	100°F	134'	~~174761~~ 176041	273088	245		
-11-80	1255	83.9	103°	132'	176041	273835	263		
-11-80	1335	84.5	103°	130.2'	176178	275776	242		
-11-80	1450	85.8	103°	126.1'	176821	274456	276		
-11-80	1714	88.2	103°	123.1'	177057	274977	260		
-11-80	1840	89.7	103°	123.2'	177152	276265	253		
-11-80	1856	89.9	103°	123.1'	177266	275891	263		
1-11-80	1927	90.5	102°	123.3'	176572	275194	265		
1-11-8	2200	93.0	103°	137.5'	211616	329734	235		

DATA SHEET 2

NON INTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El	Source Range N31 Counts	Source Range N32 Counts	NIRVLMS Count Rate	Ratio Top DET Counts / Source DET Counts	Data Recorded By
11-80	2250	93.9	103.0°	137.0'	212357	327790	220		
11-80	2306	94.1	103°	136.8	210812	328166	225		
11-80	2342	94.7	103°	136.5'	211057	329009	219		
12-80	0144	96.7	103°	133.1'	210440	326710	START CTS	AFTER LOWERING	LEVEL
12-80	0200	97.0	103°	133.1'	211320	328857	217		
12-80	0218	97.3	103°	132.8'	211875	327128	204		
12-80	0403	99.0	103°	131.0'	210961	326279	207		
12-80	0421	99.3	103°	131.0'	211553	327479	199		
12-80	0436	99.5	105°	131.0'	211556	326580	235		
12-80	0453	99.9	105°	131.0'	210787	327665	210		
12-80	0610	101.0	108°	128.9'	209134	323850	218		
12-80	0727	102.5	107°	127.0'	211254	325254	217		
12-80	0744	102.7	108°	126.9'	209704	325938	234		
12-80	0800	103.0	109°	126.9'	210543	325274	223		
12-80	0816	103.2	109°	126.9'	BL ~~Raising~~ Lowering	Level To	123'		
12-80	0916	104.2	105°	122.9'	209038	322423	235		
12-80	0934	104.5	105°	122.8'	209216	322614	244		
12-80	0949	104.8	105°	122.8'	209649	322326	260		
12-80	1006	105.0	105°	122.9'	209863	322650	244		



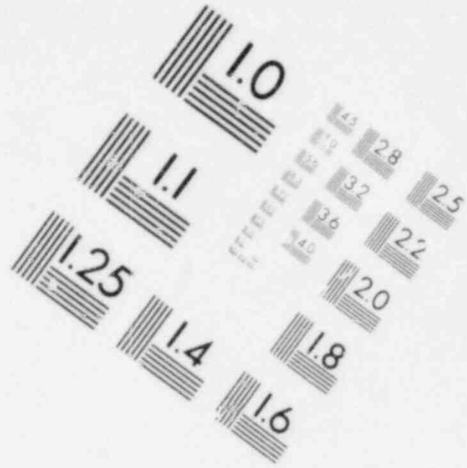
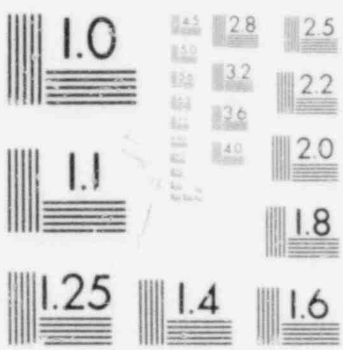


IMAGE EVALUATION TEST TARGET (MT-3)



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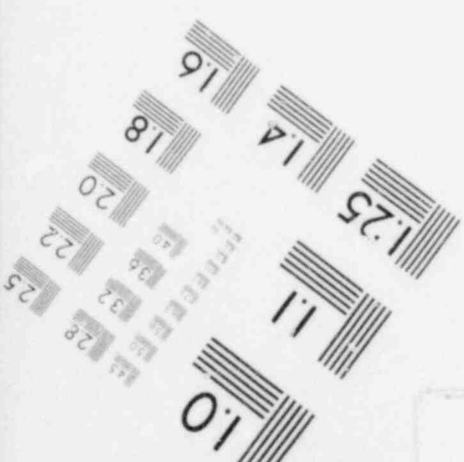
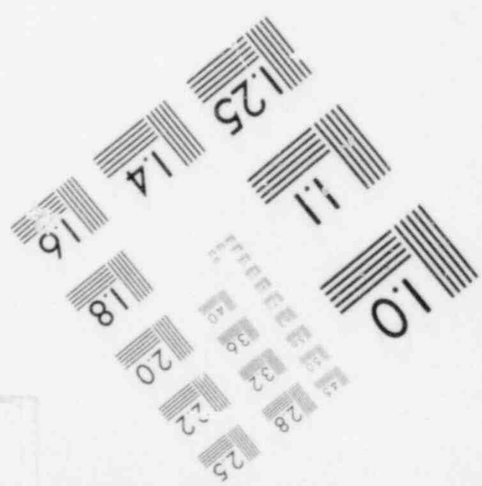
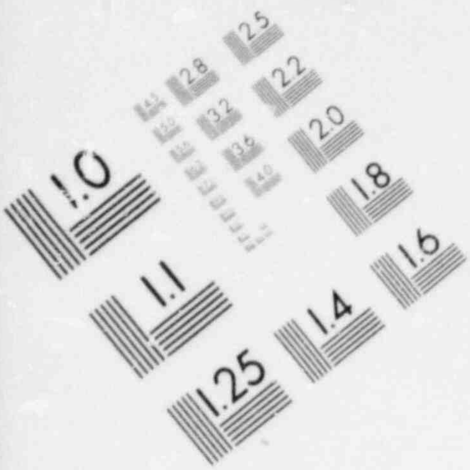






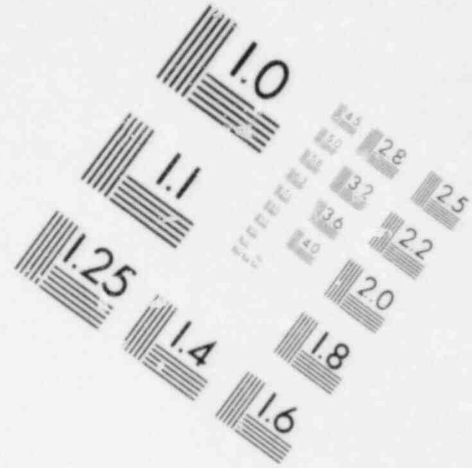
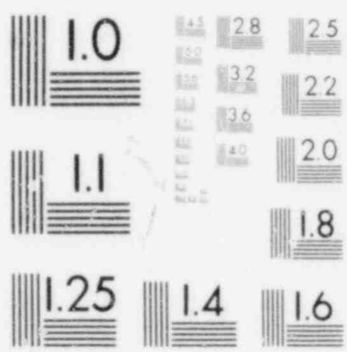


IMAGE EVALUATION TEST TARGET (MT-3)



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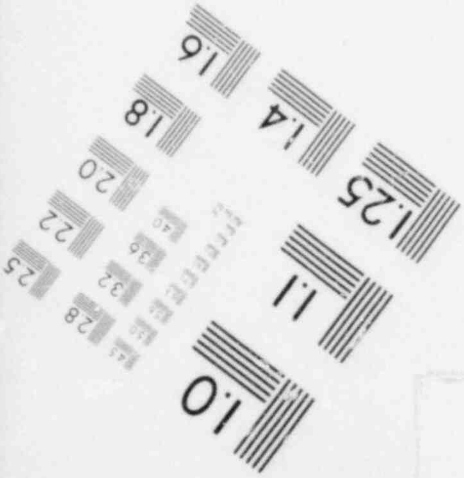

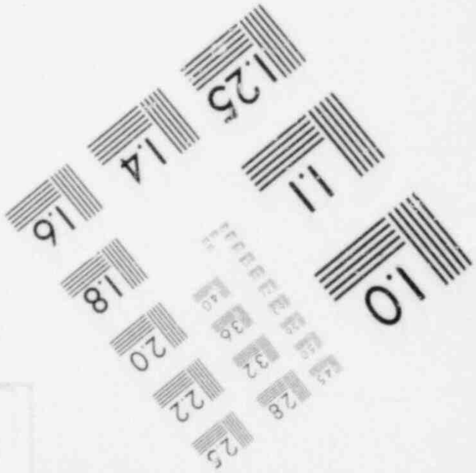

DATA SHEET 2

NON INSTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El.	Source Range N11 Counts	Source Range N12 Counts	NIRVLMS Countrate	Ratio Top DET Counts / Source DET Counts	Data Recorded By
12-80	1023	105.4	105°	122.9'	209678	309425	247		
12-80	1039	105.6	105°	122.9'	210330	320776	254		
12-80	1039	Raising Level to 125'							
12-80	1152	106.9	108°	124.9'	210732	323046	235		
12-80	1209	107.1	108°	124.9'	209915	323616	241		
12-80	1226	107.6	108°	124.9'	210014	323360	225		
12-80	1243	107.7	108°	124.9'	210311	322957	220		
12-80	1243	Lowering Level to 123' (added Borated Water Shielding around detectors)							
12-80	1417	109.3	108°	122.9'	210727	323378	255		
12-80	1434	109.5	108°	122.9'	210691	324080	249		
12-80	1451	109.8	108°	122.9'	210745	322622	235		
12-80	1502	110.0	108°	122.9'	210925	323148	230		
12-80	1524	110.4	108°	123.2'	210306	322577	223		
12-80	1524	~~Lowering~~ Raising Level to 125'							
12-80	1617	111.3	108°	125.1'	210297	323685	207		
12-80	1634	111.5	108	125.3'	209570	322557	238		
12-80	1651	111.8	108°	125.2'	209633	323612	219		
12-80	1651	Raising Level to 127' ↓							

DATA SHEET 7

NON INSTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El	Source Range N41 Counts	Source Range N42 Counts	NIRVLMS Countrate	Ratio Top DET Counts Source DET Counts	Data Recorded B
12-80	1827	113.5	108°	127.0'	210492	302224	210		
12-80	1844	113.7	108	127.0'	209817	↑ [illegible]	243		
12-80	1901	114.0	108	126.9'	210807		217		
12-80	1901	Raising Level to 129'							
12-80	2012	Problems with Countrate / Suspect Detector Wiring							
13-80	0900	128.0	→ Commence Counting @ 131' Level						
13-80	0934	128.5	107°	131.1'	215756	289115	197		
13-80	0951	128.9	107°	131.0'	215692	243712	203		
13-80	1008	129.1	107°	131.0'	214792	243712	211		
13-80	1008	Raising Level to 133'							
13-80	1044	~~132.8~~ 129.7	107°	132.8'	217166	328350	238		
13-80	1101	130.0	107°	132.7'	217642	311695	191		
13-80	1118	130.3	107°	132.9'	217251	291506	224		
13-80	1135	130.5	107°	132.8'	217490	328024	180		
13-80	1135	Raising Level to 135'							
13-80	1225	131.5	107°	134.6'	221081	315495	189		
13-80	1243	131.7	107°	134.6'	220880	Malfunction	184		
13-80	1300	132.0	107°	134.6'	221482	"	213		

NNID Neutron Source Removed to 83' level.

DATA SHEET 2

NON INTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS. After Shutdown	RCS Temp °F	RCS Level Ft. El.	Source Range N11 Counts	Source Range N12 Counts	NIRVLMS Countrate	Ratio Top DET Counts / Source DET Counts	Data Recorded
-13-80	1340	132.7	107°	135.7'	223278	333064	176		
-13-80	1357	132.9	107°	135.7'	222654	335741	202		
-13-80	1415	133.3	107°	135.7'	222388	334515	202		
-13-80	1431	133.5	107°	135.7'	222543	335622	193		
-13-80	1431	Lowering (Raising) Level to			133' &	Neutron Source Brought Up to H/P Cal Lab.			
-13-80	1539	134.6	107°	133.0'	222120	332931	220		
-13-80	1556	134.9	107°	133.0'	221797	333299	203		
-13-80	1612	135.2	107°	133.0'	221664	333069	184		
-13-80	1628	135.5	107°	133.0'	222?98	332047	190		
-13-80	1653	135.9	107°	133.0'	222332	328683	No C/S Taken		
-13-80	1653	Lowering Level to			131'				
1-13-80	1710	136.1	107°	131.0'	222484	311081	183		
-13-80	1725	136.4	107°	131.0'	222154	312308	184		
-13-80	1745	136.8	107°	131.0'	223093	314135	194		
-13-80	1800	137.0	107°	131.0'	222622	321055	195		
-13-80	1800	Lowering Level to			129'				
-13-80	1837	137.6	105°	129.0'	222672	323906	184		
-13-80	1854	137.9	105°	129.0' ↓	223136	322582	177		

DATA SHEET 2

NON INSTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El.	Source Range N41 Counts	Source Range N42 Counts	NIRVLMS Countrate	Ratio Top DET Counts / Source DET Counts	Data Recorded B
-13-80	1910	138.1	104°	129.0'	223420	324670	230		
-13-80	1927	138.5	104°	129.0'	222863	324795	205		
-13-80	1927	Lowering level to 127'							
-13-80	2011	139.1	105°	127.0'	223376	323663	204		
-13-80	2027	139.5	105°	127.0'	222460	323253	200		
-13-80	2044	139.7	105°	127.0'	223439	321723	194		
-13-80	2101	140.0	105°	127.0'	223058	321429	214		
-13-80	2101	Holding for OPNS. level CHANGE				+6 inches	Taking (1)	Extra ct @ 127.0'	
-13-80	2212	141.2	105°	127.0'	222090	292758	212		
1-13-80	2212	Lowering level to 125'							
1-13-80	2258	141.9	105°	125.0'	222189		201		
-13-80	2315	142.2	105°	125.0'	222546		214		
-13-80	2332	142.5	105°	125.4'	222497		209		
-13-80	2332	Holding OPNS. level unstable							
1-14-80	0005	143.0	105°	125.0'	221787	329544	227		
1-14-80	0025	143.4	105°	125.0'	221982	328694	190		
1-14-80	0025	Lowering level to 123'							
1-14-80	0130	144.5	105°	123.1'	221501	328061	222		
1-14-80	0147	144.8	105°	123.1'	221442	328317	212		

DATA SHEET 2

NON INTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El.	Source Range N31 Counts	Source Range N32 Counts	NIRVLMS Countrate	Ratio Top DET Counts Source DET Counts	Data Recorded B
14-80	0204	145.0	105°	123.1'	221265	328856	219		
14-80	0221	145.3	105°	123.5'	221874	328870	229	RCS BORON 1040 ppm ↑	
14-80	0340	146.7	OPNS	BORATED	TO 3200	GALLONS.	≈ 60 CPS Decrease	ON N31/N32	
14-80	0354	146.9	105°	Due to	Boration =	Raising Level to		136.0' RCS BORON 1584 ↑	
	DATA ↓	TAKEN ↓	WHILE ↓	RAISING ↓	LEVEL ↓				
14-80	0354	146.9	105°	127.5 / 130.5	118192	169303	219		
14-80	0411	147.2	105°	127.6 / 131	115587	166902	196 ↓		
14-80	0650	149.8	105°	134.3 / 134.7	NOT TAKEN	UNSTABLE	~~207~~ 216		
14-80	0707	150.1	105°	134.7 / 136.2	LEVEL		204	OPNS DILUTING ELEVATION	
14-80	0708	150.1	105°	BEGIN	TAKING CTS	@ 136'	STABLE		
14-80	0725	150.4	105°	136.0'	~~282920~~ 192290	282920	178		
14-80	0742	150.7	105°	136.2'	194986	286377	185		
14-80	0759	160.0	105°	136.2'	203468	98226	204		
14-80	0816	160.2	105°	136.0'	210587	307688	184		
14-80	0883	160.5	105°	136.0'	209238	306149	193		
14-80	0850	160.	105°	136.0'	211977	307399	198	↑ faster.	
14-80	0503	148.0	105°	124.5 / 126.0	118475	170777	207		

DATA SHEET 2

NON INTRUSIVE REACTOR LEVEL MEASURING SYSTEM TEST AT FNP UNIT 1

Date	Time	HRS After Shutdown	RCS Temp °F	RCS Level Ft. El.	Source Range N41 Counts	Source Range N42 Counts	NIRVLMS Countrate	Ratio Top DET Counts Source DET Counts	Data Recorded B

K-E 46 1240

FNP-1-ETP-192
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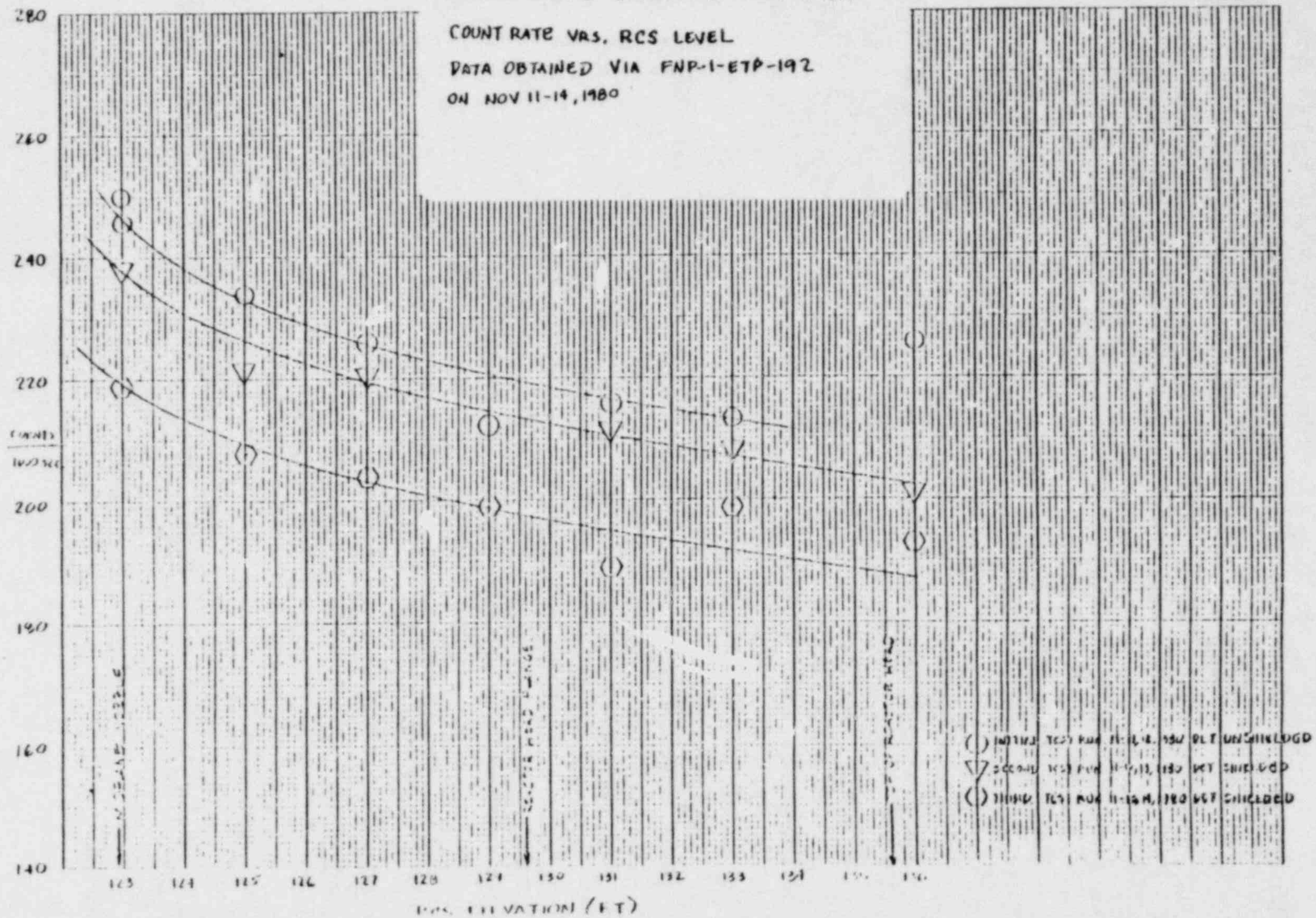
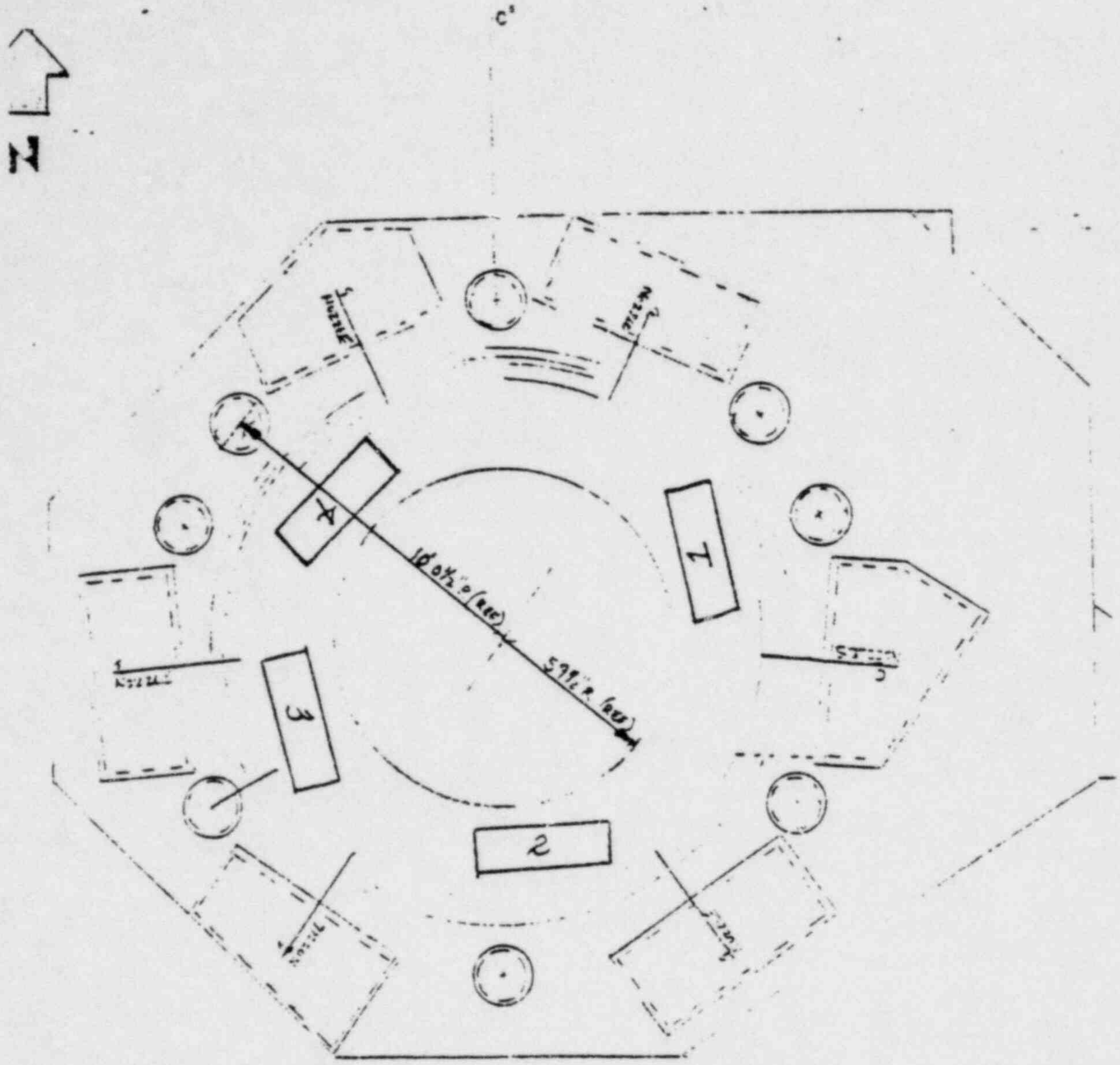
FARLEY UNIT 1 NIRVLMS TEST DATA

COUNT RATE VRS. RCS LEVEL
DATA OBTAINED VIA FNP-1-ETP-192
ON NOV 11-14, 1980





EQUIPMENT PLACEMENT DURING TEST

1" = 4' SCALE

DISTANCE TO C DETECTORS	LEVELS AT C DETECTORS
1) 22" FROM INSULATION	1) 340 mr/hr
2) 26"	2) 250 mr/hr
3) 14"	3) 360 mr/hr
4) 26"	4) 250 m[illegible]

14" C 11-11-80

@14" 11-11-80