SNUPPS
Standardized Nuclear Unit
Power Plant System

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June 29, 1984

SLNRC 84- 0100 FILE: 0278
SUBJ: Inadequate Core Cooling
Instrumentation Testing

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Docket Nos: STN 50-482 and STN 50-483

Dear Mr. Denton:

License Condition 9(c) of Facility Operating License NPF-25 for Callaway Plant Unit No. 1 requires the submittal of additional qualification testing information for the Class 1E/non-Class 1E devices used in the Core Cooling Monitor System. The enclosure provides the required additional information. This information is also applicable to the Wolf Creek Generating Station.

The enclosure demonstrates that sufficient testing has been done to qualify the devices used to isolate the safety-grade portions of the CCMS from non-safety-grade appurtenances and to assure the safe operation of the SNUPPS plants at rated full power.

Very truly yours,

N A Petrick

Nicholas A. Petrick

MHF/nldllal4
Enclosure

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Enclosure

Thermocouple/Core Cooling Monitor (TC/CCM) Electrical Isolation Testing

References

1. Westinghouse letter (P. Rahe) to NRC (G. Edison), NS-EPR-2812, September 1, 1983
2. Westinghouse Topical Report, WCAP-8892-A, 1977

Background

At an NRC review meeting in August 1983 on the SNUPPS design for protection against inadequate core cooling, Westinghouse committed to perform tests to verify the isolation capability of the as-built TC/CCM portion of the design. In response to this action item, Westinghouse submitted a draft test procedure to the NRC in Reference 1. Because of similarities in the physical and electrical separation design of the TC/CCM and Westinghouse protection systems, Reference 2 formed the basis for the TC/CCM isolation test requirements. Reference 2 contains the basis for all Westinghouse tests performed on protection systems to show that adequate isolation exists and to confirm system functional capability should it be faulted at the time its action is required.

Testing Summary

As stated above, the Westinghouse test philosophy and acceptance criteria were as restrictive as those set forth for the Westinghouse protection systems tests and covered in Reference 2. The destructive high potential fault testing outlined in Reference 1 was deemed unnecessary based on manufacturer's performance specification testing which had been performed on the isolation devices and which exceeded the tests agreed upon by the NRC and Westinghouse (Reference 2) for protection systems. Details of these performance specification tests can be found in Attachment 1 which consists of selected pages from the manufacturer's test report. Part 3 of the Cumulative Test Results table documents results for AC and DC voltage testing, and section 3.2.2 on pages 3.9 and 3.10 discusses a high voltage production test performed on all isolation devices.

Noise tests on the subject system are not required since the circuit board architecture precludes the close proximity of Class 1E circuits with non-1E circuits. The proximity of 1E circuitry with non-1E circuitry was what created NRC concerns in the mid-1970's and which culminated in the noise tests discussed in Reference 2. Nevertheless, prudent engineering has lead to the performance, by Westinghouse, of the noise tests on the subject system as covered in Attachment 2. The system successfully met all acceptance criteria as described in Section IV of Attachment 2.

Conclusion

The high voltage fault and noise tests on the subject system confirm the functional operation and reliability of the system even if faulted concurrent with the operator's need for the information that it provides.

MHF/nldllal6

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COMPONENTS

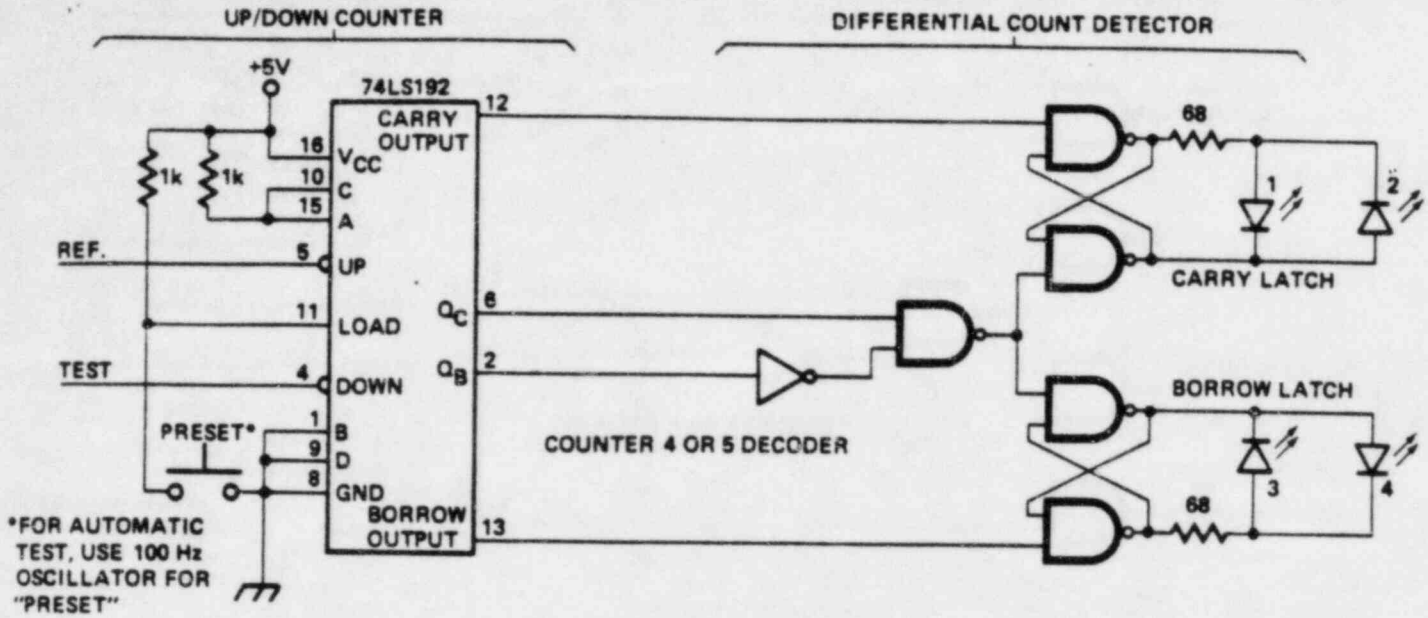
RELIABILITY TEST DATA

The following cumulative test results have been obtained from testing performed at HP-Optoelectronics Division in accordance with the latest revisions of Military Specification MIL-STD-883.

I. Epoxy Encapsulated Optocouplers (4N45/6, 6N135/6/7/8/9, HCPL-2502/2530/2531/2601/2602/2630/2730/2731)

A. Cumulative Test Results (All Part Types)

Test	MIL-STD-883 Reference	Test Conditions	Units Tested	Failed
1. Environmental tests				
Temperature Cycling	1010 Condition B	100 cycles from -55°C to +125°C 10 min. at extremes (min.), 5 min. transfer (max.)	820	10
Thermal Shock	1011 Condition A	15 cycles from 0°C to +100°C 5 sec. at extremes (min.), 10 sec. transfer (max.)	378	2
Temperature Humidity		T_A = 85°C, RH = 50%, t = 1000 hrs. Reverse biased	317	0
2. Mechanical tests				
Constant Acceleration	2001 Condition D	1 min. each X, Y average at 20,000 G	279	0
Mechanical Shock	2002 Condition B	5 blows each X_1, X_2, Y_1, Y_2, Z_1, Z_2 1500 G, 0.5 msec. pulse	231	0
Solderability	2003	Sn 60, Pb 40, Solder at 230°C, 5 sec.	397	0
Terminal Strength	2004	2 lb. tension 8 oz. lead fatigue, 30 sec. min.	150	0
Vibration Fatigue	2005 Condition A	32 ± 8 hrs. each X, Y, Z 96 hr. total, 60 Hz, 20G min.	299	0
Vibration Variable Frequency	2007 Condition A	4 cycles, 4 min. each X, Y, Z at 20 G min., 20 to 2000 Hz	279	0
External Visual	2009	Device profile at 20 x 60	220	0
3. Insulation voltage tests				
Short Term DC Insulation Voltage		V_{I-O} = 3000 V_{DC}, t = 168 hrs. I_{I-O} < 1 µA	1,738	18
Long Term DC Insulation Voltage		V_{I-O} = 2000 V_{DC}, t = 1000 hrs. I_{I-O} < 1 µA	80	0
Short Term AC Insulation Voltage		V_{I-O} = 3000 V_{peak}, t = 168 hrs.	80	0
Long Term AC Insulation Voltage		V_{I-O} = 3000 V_{peak}, t = 1000 hrs.	80	1



CONDITION		INDICATOR NUMBER (LED) 1	2	3	4	DESCRIPTION OF CONDITION
PASS	A	OFF	ON	OFF	ON	PERFECT OPERATION
FAIL	B	ON	ON	OFF	ON	TEST INPUT MISSING SOME COUNTS
	C	OFF	ON	ON	ON	EXTRANEOUS COUNTS AT TEST INPUT
	D	ON	ON	ON	ON	HIGH-RATE MIXTURE, CONDITIONS B&C
	E	ON	OFF	ON	OFF	PROBABLY OK – CHECK PRESET
	F	FLICKER	FLICKER	OFF	ON	OCCASIONAL CONDITION B
	G	OFF	ON	FLICKER	FLICKER	OCCASIONAL CONDITION C
	H	FLICKER	FLICKER	FLICKER	FLICKER	LOW-RATE MIXTURE, CONDITIONS B&C

Figure 3.2.1-3 Up/Down Counter, Differential Count Detector Sense Transmission Error.

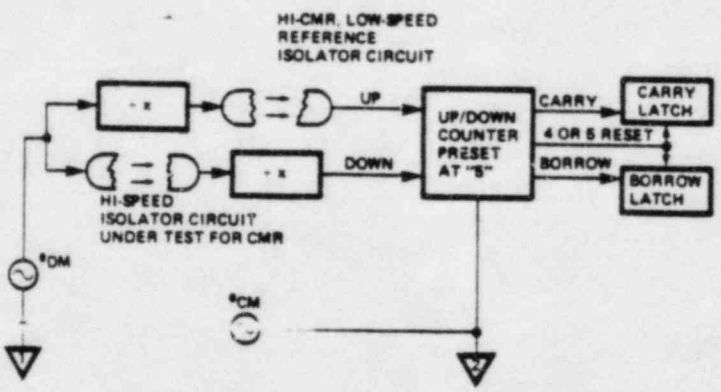


Figure 3.2.1-4 "Heroic Measures" to Assure Clean Reference Count in Dynamic CMR Test.

isolator to operate at a lower data rate so speed can be traded for better CMR. The isolator circuit under test must operate at the full data rate in the presence of the same interference. If the test is to be done with e_{DM} being a randomly coded data stream, the two ÷ x counters should be pre-set at the same count (e.g. 0000) with e_{DM} at a fixed logic state. For most consistent results, inverters should be used, as needed, so that at "preset" all counter inputs are "zero" if they are negative-edge triggered or "one" if they are positive-edge triggered.

3.2.2 Insulation

A common, but usually erroneous, assumption is that insulation can be operated at any voltage up to that at which it breaks down. Many designers are unaware of corona and its effect on insulation. Of those who are aware of corona, some believe it occurs only at exposed terminals.

Corona (also known as "partial discharge") can occur within insulation materials, particularly those having an abundance of "microvoids". Due to inhomogenous electric fields within the material, the local field across a "microvoid" can rise to a level at which there is a local breakdown resulting in a partial discharge. This partial discharge at one microvoid shifts the field so it builds up across some other microvoid. Each partial discharge causes ions that locally degrade the insulation. The cumulative effect over long periods of time (weeks or months) is to lower the terminal-to-terminal breakdown voltage.

There is a voltage, called Corona Inception Voltage, CIV, above which corona can be observed using specialized equipment capable of responding to each partial discharge. As the test voltage is raised above CIV, there is an increase

in the rate of occurrence of these partial discharges. Correspondingly, there is an increase in the rate at which the insulation is degraded.

To maintain a high quality of insulation, HP optoisolators are given a special treatment called "backfilling". After molding, they are placed in a silicone oil bath in a chamber which is evacuated until the gases from the microvoids have escaped. Then the chamber is pressurized, forcing silicone oil to fill the microvoids. With this treatment, CIV is believed to be well above the rated V_{I-O}, but 100% production testing for corona is not practical; with the methods and equipment now available, it is too time consuming.

However, to insure rejection of devices with initially defective insulation, there is 100% production testing with 3000 Vdc applied for 5 seconds at 45% relative humidity, rejecting for leakage greater than 1.0 μA.

The production test assures that each part meets the Underwriters Laboratories requirements for 220 Vac, 50/60 Hz operation. The UL formula for prescribing the test voltage:

line voltage = 220 Vrms
times 2 = 440 Vrms
plus 1000 Vrms = 1440 Vrms 50/60 Hz for 1 minute
or plus 20% = 1728 Vrms 50/60 Hz for 1 second
or times $\sqrt{2}$ = 2444 Vdc for 1 second

Except for those in hermetic packaging, all HP optoisolators easily meet UL requirements for status as a "Recognized Component" under File No. E55361.

Another important property of insulation is its leakage resistance. In HP optoisolators R_{I-O} is typically 10^{12} ohms. This appears to be an unreasonable claim when compared with the 1.0 μA leakage allowed in the 3000 Vdc test. Here again, it is a matter of practicality. With 3000 Vdc applied to 10^{12} ohms, the resulting current is only 3 nA. Precise observation of so small a current in a 5 second test is impractical, so the $R_{I-O} = 10^{12}$ ohms in given as typical, with periodic verification done on randomly selected samples. Both kinds of testing (R_{I-O} and V_{I-O}) are performed with all input leads connected to one side of the test voltage and all output leads to the other side -- a two-terminal test.

3.2.3 Speed of Response

For both analog and digital operation, the speed of response is highly dependent on the circuit as well as on characteristics of the optoisolator. In both analog and digital modes, the speed of response can be enhanced by use of feedback and peaking. These techniques are discussed in Section 3.5.6 for analog operation, and in Section 3.6.3 for digital operation. In this section, discussion centers on isolator properties affecting speed of response, and how the speed is characterized.

Analog operation requires the isolator to operate in its "active region", i.e., with the output collector neither cut off nor saturated over the required excursion range. In the circuit of Figure 3.2-1, e_{DM}, R_s, R_{PI}, and R_L should be selected for $I_F = (I_{F_{dc}} \pm \Delta I_F)$ such that $0 \ll V_C \ll V_{CC}$ between the excursion limits of I_F. Speed of response is then characterized either in terms of 10%-90% rise time if ΔI_F is a step function, or in terms of 3 dB bandwidth if ΔI_F is a sinusoid.

In the isolator itself, the principal bandwidth-limiting elements are the photoemitter, the amplifying transistor, and the capacitance of the photodiode. In the photodiode, the photoelectrons are created within a few picoseconds after photons enter. The resulting photocurrent flows to the base with a rise time constant as seen at the base. The base time constant depends not only on the transistor in the isolator but also on the circuit used with the transistor. If the transistor is operated common-emitter as in Figure 3.2-1, then the base time constant:

$$\tau_B = R_B (C_{PD} + C_{BC}) + \beta R_L C_{BC} \qquad (3.2.3\text{-}1)$$

where:

$C_{PD} \approx$ 10 pF is the photodiode capacitance

C_{BC} = Base-to-collector capacitance = 0.5 pF plus stray external capacitance between collector and base connections

R_L = Load resistance

R_B = Dynamic resistance to ground at the base

If no external resistance is added to bypass the base, then R_B is just the dynamic resistance at the base:

(3.2.3-2)

$$R_B = \frac{\partial V_B}{\partial I_b} = \frac{25\text{ mV}}{I_b} = \beta \left(\frac{25\text{ mV}}{I_C}\right) = \beta \left(\frac{25\text{ mV}}{\frac{CTR}{100\%} \times I_{F_{dc}}}\right)$$

where CTR = Current Transfer Ratio (see Section 3.2.5). Then in equation 3.2.3-1

(3.2.3-3)

$$\tau_B = \beta \left(\frac{25\text{ mV}}{\frac{CTR}{100\%} \times I_{F_{dc}}}\right) (C_{PD} + C_{BC}) + R_L C_{BC}$$

Substituting typical values, CTR = 20% and $I_{F_{dc}}$ = 15 mA yields

(3.2.3-4)

$$\tau_B = \beta C_{BC} \left[R_L + 8.33\Omega \left(1 + \frac{C_{PD}}{C_{BC}}\right)\right] = \beta C_{BC} [R_L + 175\Omega]$$

Attachment 1

Thermocouple/Core Cooling Monitor Test Outline

I. Introduction

1. Reference values will be acquired prior to the noise tests. These values will be compared later with the noise test output values.

2. Noise Testing

Non-destruct testing will be completed with the optical isolators connected in the test circuit board. This involves injecting various forms of noise individually into an antenna(16 AWG wiring) strapped for approximately forty feet to the Non-1E wiring and observing the output indications and monitoring the 1E input circuitry.

II. Pre-test

1. Apply analog inputs to simulate actual operating signalling.

2. Observe the microprocessor run status lamp on the control panel.

3. Observe the input status and the output indications on the remote display.

III. Noise Testing

All inputs should simulate a normal condition before and during the application of the noise.

1. Transient noise

A surge transient generator with an output of approximately 4800V peak-to-peak was employed.

2. Crosstalk noise

a. Random noise generator

A random noise generator with an output of approximately 20V peak-to-peak over a frequency range of 2-50K Hz was employed.

b. 118V ac and 125V dc chattering relays

c. Military spec noise (per Mil Std N-199008)

Noise: Switching of 0.01 henry, 2 ohms.

IV. Test Acceptance Criteria

1. The microprocessor function should not be affected during and after the application of each noise source such that the information provided to the operator could be misleading.

2. The control panel and remote control panel and display information should not change during or after the application of each noise source.

3. The control panel and remote control panel and display must respond to simulated transients while subjected to noise.

4. Noise will not feed through the optical isolators to degrade the Class 1E input circuits.