Nebraska Public Power District

"Always there when you need us"

NLS2008059
July 21, 2008

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Subject: Revised Root Cause Investigation – Diesel Generator Amphenol Connector
Cooper Nuclear Station, Docket No. 50-298, DPR-46

Reference: Letter to Nuclear Regulatory Commission (NRC) dated June 19, 2008, "Cooper Nuclear Station (CNS) – Reply to Preliminary White Finding Regarding NRC Inspection Report 05000298/2008002"

Dear Sir or Madam:

The purpose of this correspondence is to submit Nebraska Public Power District's (NPPD) revised root cause evaluation regarding the diesel generator amphenol connector at Cooper Nuclear Station (CNS).

The referenced letter stated that CNS was performing further investigations that may challenge the basis of our root cause evaluation of the diesel generator amphenol connector. This was an internal initiative to understand the effects of vibration on the amphenol connector through detailed vibration testing performed by an outside vendor. This action was taken based on a review of our corrective actions during implementation of our root cause corrective actions.

Results of the laboratory testing on the connector identified that vibration is not a time-based failure mechanism for the loosening of the amphenol connector. The root cause has been revised to reflect a most probable cause of insufficient worker attention during connector reassembly. The revised root cause evaluation is enclosed.

IE01
NRR

COOPER NUCLEAR STATION
P.O. Box 98 / Brownville, NE 68321-0098
***Telephone:** (402) 825-3811 / **Fax:** (402) 825-5211*
www.nppd.com

If you have questions, you may contact me at (402) 825-2904.

Sincerely,

David W. Van Der Kamp
Licensing Manager

/jf

Enclosure

cc: Regional Administrator w/ enclosure
USNRC – Region IV

Cooper Project Manager w/ enclosure
USNRC – NRR Project Directorate IV-1

Senior Resident Inspector w/ enclosure
USNRC – CNS

NPG Distribution w/o enclosure

CNS Records w/ enclosure

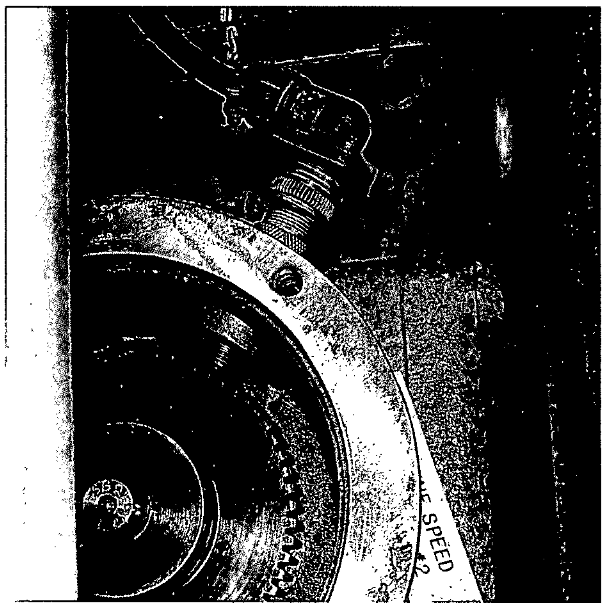
Enclosure

Root Cause Investigation (Rev. 1)
Unexpected DG-2 Shutdown
CR-CNS-2008-00304
Dated 7/11/2008

NLS2008059
Enclosure

ROOT CAUSE INVESTIGATION (REV. 1)

UNEXPECTED DG-2 SHUTDOWN
CR-CNS-2008-00304



Investigation Team

Dan Buman, SED Manager	Responsible Manager
Dave Barker, Root Cause Supervisor	Root Cause Team Leader
Mark Metzger, SED	Root Cause Team Member
Ray Rexroad, SED	Root Cause Team Member
Jeff Beatty, Security	Root Cause Team Member
Chuck Behr, Maintenance	Root Cause Team Member
Mike England, Work Control Manager	Root Cause Team Member

Responsible Manager Dan Buman Date: 7-11-08

CARB Chairperson Mike Colomb Date: 7-11-08

Table of Contents

EXECUTIVE SUMMARY

NOTE: This is a revision to the investigation approved on 2-12-08 due to receipt of additional information obtained through laboratory testing of the connector which refutes vibration as a failure mechanism, as well as additional analysis to further explore the human performance aspects associated with the event.

Event Description

On 1-15-08, DG-2 was started from the Control Room per Procedure 2.2.20.1 for post maintenance testing for WO 4610296. Normal voltage and frequency levels were achieved and the unit ran for ~60 seconds, and then shut down. No abnormal alarm conditions were received at the DG control panel or in the Control Room. The "run" and "cranking" lights on Panel C were noted to cycle several times during the shutdown.

Problem Statement

What should be	DG2 relay tachometer speed sensing circuit should maintain continuity when in service
What is	Intermittent connection in the DG2 relay tachometer speed sensing circuit
What is wrong	Intermittent connection in relay tachometer speed sensing circuit resulted in unexpected shutdown during post-maintenance testing on 1-15-08
Consequences	Shutdown represents a load failure of DG2

Immediate and Interim Actions Taken

- Troubleshooting performed 1-16-08 per WO 4610394
- DG1 run to confirm no common mode failure
- Amphenol-type connection reassembled on DG2 relay tachometer speed sensing circuit per WO 4610394.
- Performed inspections/tightness checks on other DG1 and DG2 amphenol-type connectors

Note: The electrical connector discussed in this report is manufactured by ESC Electrical (ESC type MS3057-4A). However, the type of connector utilized is commonly referred to by another brand name (Amphenol) that has become synonymous with this type of connector. For clarity, when not addressing the specific manufacturer of the CNS connector, they will be referred to as "amphenol-type" connectors in this report.

Summary of Conclusions

Table of Elements, Causal Factors, & Corrective Actions

Element	Description	Action
Most Probable Cause	Insufficient worker attention applied to correctly perform reassembly of the DG2 Relay Tachometer speed probe connector	A – (Action) Develop lessons learned from this event as it relates to application of sufficient attention to detail when removing & reassembling electrical connections in critical applications. Present the lessons learned to appropriate Maintenance personnel.
Extent of Condition	Governor and relay tachometer speed sensors for both DG1 and DG-2	Addressed in immediate actions taken
Extent of Cause	Applies to workers responsible for connector reassembly – I&C Maintenance	Addressed in Corrective Action A
CAER	Corrective action effectiveness review	D – (CAER) Verify completion of above corrective actions.
Other	OE review of CR-CNS-2007-00480 CA-8 indicate that scope of actions taken were too narrow	CR being initiated to address outside of this report
	Need to determine if CNS practices for control of electrical connections of this type reflect industry standards	B – (ENHN) Benchmark best practices to establish controls for ensuring removed connectors in critical applications are properly reassembled. Create subsequent corrective action(s) to implement benchmark results. C – (ENHN) Revise procedures 14.17.1 and 14.17.2 to provide the specific connector identifications

Analysis

Summary of Techniques Utilized and Investigation Approach

Data Gathering – Personnel statements/interviews, document reviews (CNS procedures, drawings, logs), OE documents, and communication with other plants.

Analysis Techniques – Failure Mode Analysis, Human Performance Analysis and Event & Causal Factor Charting.

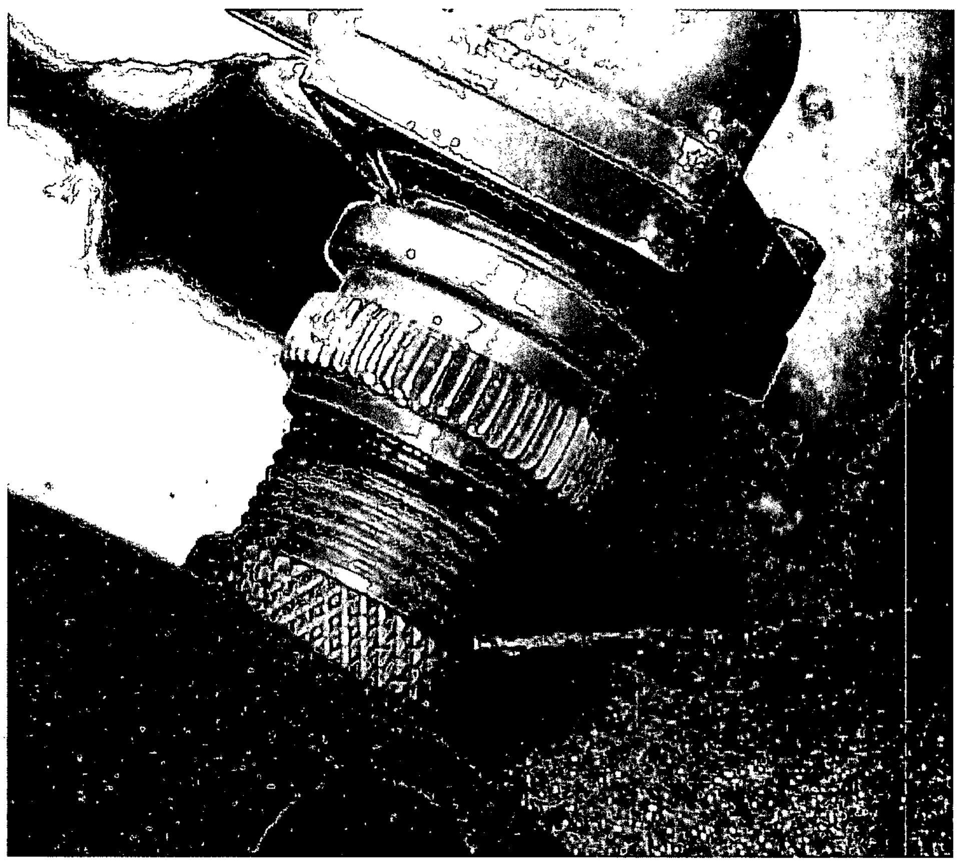
Two primary areas of interest were pursued in this investigation. The first was to identify the failure mode and mechanism that resulted in the DG2 shutdown. The second was to determine how/why the component was in the state in which it was found.

Analysis Details

Failure Mode

After the unexpected DG2 shutdown, an FMEA was generated (see Appendix A) which was used to develop a troubleshooting plan. The resulting troubleshooting performed on 1-16-08 identified a loose amphenol-type connector to the relay tachometer speed sensor (DG-SE-3143). The as-found condition was as follows:

- The coupling nut was observed to be engaged ~¼ turn (compared to an additional ~5 turns to full engagement/tight). Note that there were differing recollections of the as-found connector ring engagement from the technicians that were present. No measurement was taken.
- The connection was felt to be loose when manually manipulated
- Resistance measurements showed instability when the connector was moved



The loose relay tachometer speed sensor connection is deemed to be the failure mode that resulted in the unexpected DG2 shutdown based on the following:

- A loose connector will result in the same symptoms and equipment responses as was noted during the DG2 runs.
- The recorded information gathered during the 1-16-08 0327 DG2 run confirmed that the shutdown "command" came from the relay tachometer.
- Observation of the local RPM meter during the 1-16-08 0327 DG2 run indicated that the relay tachometer output did not increase beyond ~400 RPM.
- After tightening the loose connector, a subsequent DG2 run was performed 1-16-08 at 1645 with a recorder connected to relay tachometer pick-up inputs. Resulting data showed a clean waveform with no noted abnormalities. Also noted during the run that the local RPM display indicated the proper value of 600 RPM.

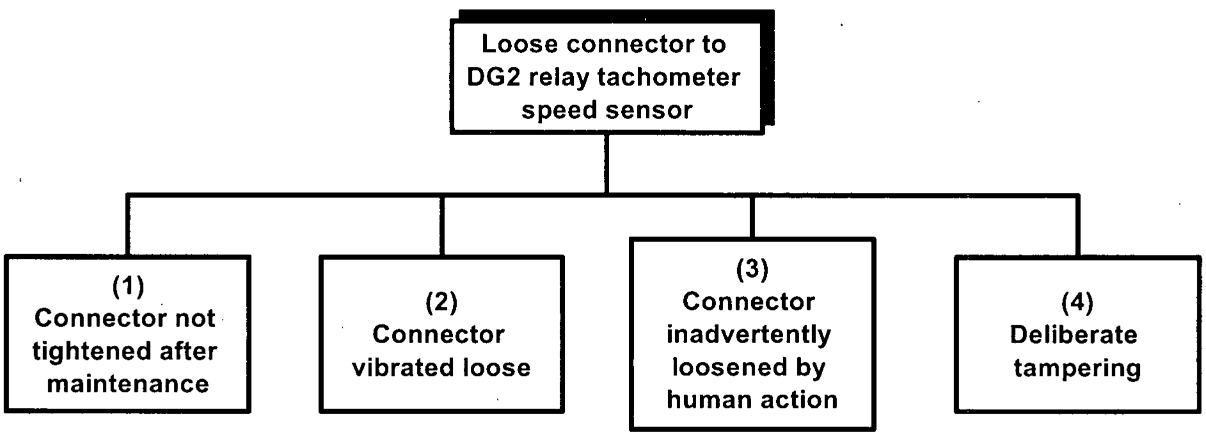
To rule out other potential problems in the connector, the connector was disassembled and checked for.

- Broken or bent pins,
- Bad solder connections,
- Broken wires,
- Strain points in the cable, and
- Cleanliness of the connector and pick-up assembly.

No abnormal conditions were noted.

Failure Mechanism

The next analytical question becomes, how did the connector become loose to the point of intermittent continuity? Four possibilities were considered:



1) Connector not tightened after maintenance

Supporting data:

- Review of maintenance work history on the relay tachometer magnetic pick-up indicated the following:
  - 12/2000 – Replaced DG2 magnetic pick-up and relay tachometer (no work on connector, but would have to be removed to replace magnetic pick-up). Re. **WO 00-3915**

- 12/1995 – Repaired connector for relay tachometer magnetic pick-up. Loctite 242 was applied to the connectors for both the governor magnetic pick-up and the relay tachometer magnetic pick-up due to Condition Report 1-19594 in which the author noted the DG2 governor magnetic pick-up had "vibrated" loose during a run. Re. **WO 95-04362** and **WO 95-03959**

- Connector reassembly is considered a skill-of-the-craft evolution and is not a separate operation in work order instructions.
- No check is performed following connector reassembly
- DG2 operated successfully the day prior during the normal monthly surveillance, and the failure was observed the following day (after performing maintenance) during post work testing. There were no signs of electrical instability or intermittent connection during or prior to the 1/14/08 surveillance run. After maintenance was performed on 1/15/08 (for governor oil sight glass repair), a post-maintenance run was performed on 1/15/08 which was when the problem resulted in the DG2 shutdown. The discontinuity was repeatable on subsequent runs until the probe was restored. See Safety Significance section for additional details.

Refuting data:

- None

Conclusion: Likely failure mode

2) Connector vibrated loose

Supporting data:

- Previous Condition Report (CR 1-19594 written 12-11-95) which stated "*Amphenol connection to MPU for governor is vibrating loose during DG run*". Condition noted to have been discovered 12-10-95 @ 1500 while "*looking for reason for DG load spiking*". Associated Minor Maintenance History Index Sheet states the following under "work completed" :

  Loosen both MPU amphenol connectors and applied Loctite 242 sparingly ensuring Loctite did not come in contact with wire insulation. Tighten connectors firmly.

  Document indicates that this was performed on both the magnetic pick-up connectors for both DG1 and DG2.

Refuting data:

- Different connector than that found loose in this (the 2008) event
- Testing performed by MPR of the actual connector with only minimal engagement at 10 times the level of vibration did not show any signs of backing off (see App. D)
- No supporting data for the conclusion in the 1995 CR that vibration led to the loose connector.
- Lack of internal or external operating experience that indicates vibration has led to Amphenol-type connectors loosening. There are a large number of these connectors used at Cooper and in the industry. The one anecdotal Cooper CR from 1995 and the 2003 Browns Ferry failure that was partially attributed to vibration (but was unsubstantiated by supporting facts), indicate that vibration has not been a failure mode that challenges the electrical integrity of the connection.

Conclusion: Not a likely failure mode

3) Inadvertent loosening by human action

Supporting data:

- The governor magnetic pick-up sensor/connector is located in close proximity to the relay tachometer pickup sensor/connector that was found loose. That connector is periodically disconnected as part of procedure 14.17.1, DG2 Annual Calibration (and the sister procedure for DG1, 14.17.2) Step 9.8, which states, "At DG-EHO-EHOV2, disable electrical governor by disconnecting electrical connector (south side of the actuator)". Both connectors have labels attached at the connectors which read as follows:
  - "DG-SE-3143" for the relay tachometer speed sensor, and
  - "DG-SE-DG2" for the governor speed sensor.

  It is noteworthy that the procedural guidance does not provide the component identification for the specific connector. DG-EHO-EHOV2 is a designator for "DG2 Hydraulic Actuator" per SAP, and is not specific to the connector. The procedure does contain a specific step for restoring the connector, including independent verification.

  The most recent performance of this procedure as a PM was on 3-14-07 according to SAP data.

Refuting data:

- The magnetic pickup connector is located on the side of the engine near the top at the southwest corner. Based on the location of the connector and the number of turns it was found from full-tight makes it unlikely that inadvertent contact with the connector coupling nut (e.g., bumping or stepping on) caused the connector to be in the as-found condition.

Conclusion: Possible failure mode

4) Deliberate tampering

Supporting data:

- Deliberate human action could result in the as-found condition

Refuting data:

- Investigation by Security under CR-CNS-2008-00329 found no physical evidence of tampering (tool marks, damaged paint, missing parts)
- The knowledge needed to pinpoint this instrument to disable DG2 is not common knowledge
- Security Patrol Officers that toured the diesel generator rooms reported no suspicious activity

Conclusion: Not a likely failure mode

Failure Mode Conclusions:

Review of industry operating experience has shown no industry experience with loosening of amphenol-type connectors due to vibration. Prior OE with this as a failure mode for loose connectors has not been substantiated either by internal or external testing. MPR Associates has performed vibration testing on the MPU/connector assembly at a test facility (see Appendix D) using parameters supplied by NPPD that were taken directly from DG2. The report identifies that after 250 hours of exposure to vibration levels well in excess of that seen on DG2, the connector has shown no discernable loosening throughout the test. This includes vibration testing with thread engagement similar to that in the as-found condition following the failure. In addition, this testing demonstrated that it takes positive force to connect or disconnect the electrical connector from the MPU.

Based on this testing, it is concluded that the failure mechanism for the MPU connector becoming loose is not time-based vibration induced.

Deliberate tampering and vibration-induced connection loosening are refuted. This leaves the most likely premise that the relay tachometer speed sensor connector was loose due to,

1. Improper reassembly following previous maintenance or troubleshooting activities, or
2. Inadvertent disconnection of the relay tachometer speed sensor connector instead of the governor speed sensor connector, and failure to properly reassemble.

Although when the failure to properly re-assemble the connector occurred is not known it is more likely to have occurred in the recent past due to:

1. The testing has demonstrated the loosening is not a result of time based vibration.
2. The testing has demonstrated that pin connection alone is sufficient to maintain solid contact.
3. The testing has demonstrated that to disengage the pins requires positive action.
4. Monthly surveillances include intrusive checks (such as looking for oil leaks, etc.) that have the potential to disturb this connection.
5. Major maintenance includes activities that could have disturbed this connection.
6. Any electrical discontinuity of between the MPU and the relay tach (from disturbance of the connection) would have been self revealing during normal monthly surveillances.

Causal Analysis

The ensuing question is why the connector was not reassembled.

A review of the work orders associated with the 1995 and 2000 work done on this connector and interviews with Work Control personnel indicate that separate operations for reassembly of the connector is not provided in Work Order instructions. Reassembling of the connector is considered a skill-of-the-craft evolution.

There are maintenance plans associated with the governor magnetic pickup and the relay tachometer. Applicable maintenance plans:

Maintenance Plan 800000014879 (PM 10445) checks and cleans the DG Governor magnetic pickup every 5 years, but is not performed on the Relay Tachometer magnetic pickup.

Maintenance Plan 800000005976 (PM 01446) calibrates the Relay Tachometer and Speed Indicator per Procedure 14.17.10, but the procedure does not direct disconnecting the magnetic pickup Amphenol connector.

In addition, other maintenance tasks can be performed which are done skill-of-the-craft and may result in disconnecting a connector without explicit documented guidance and/or checks for proper reassembly.

Human Performance

The following are possibilities for the connector to have been left in the as-found condition:

- A human performance error associated with

- Inadvertently disconnecting the wrong probe (and not subsequently reconnecting it), or
- Not applying sufficient attention following a skill-of-the-craft task to ensure the connector was properly reassembled.

The NUREG 6751 Human Performance Evaluation Process (HPEP) cause tree was utilized to assist in identifying the causes associated with human error.

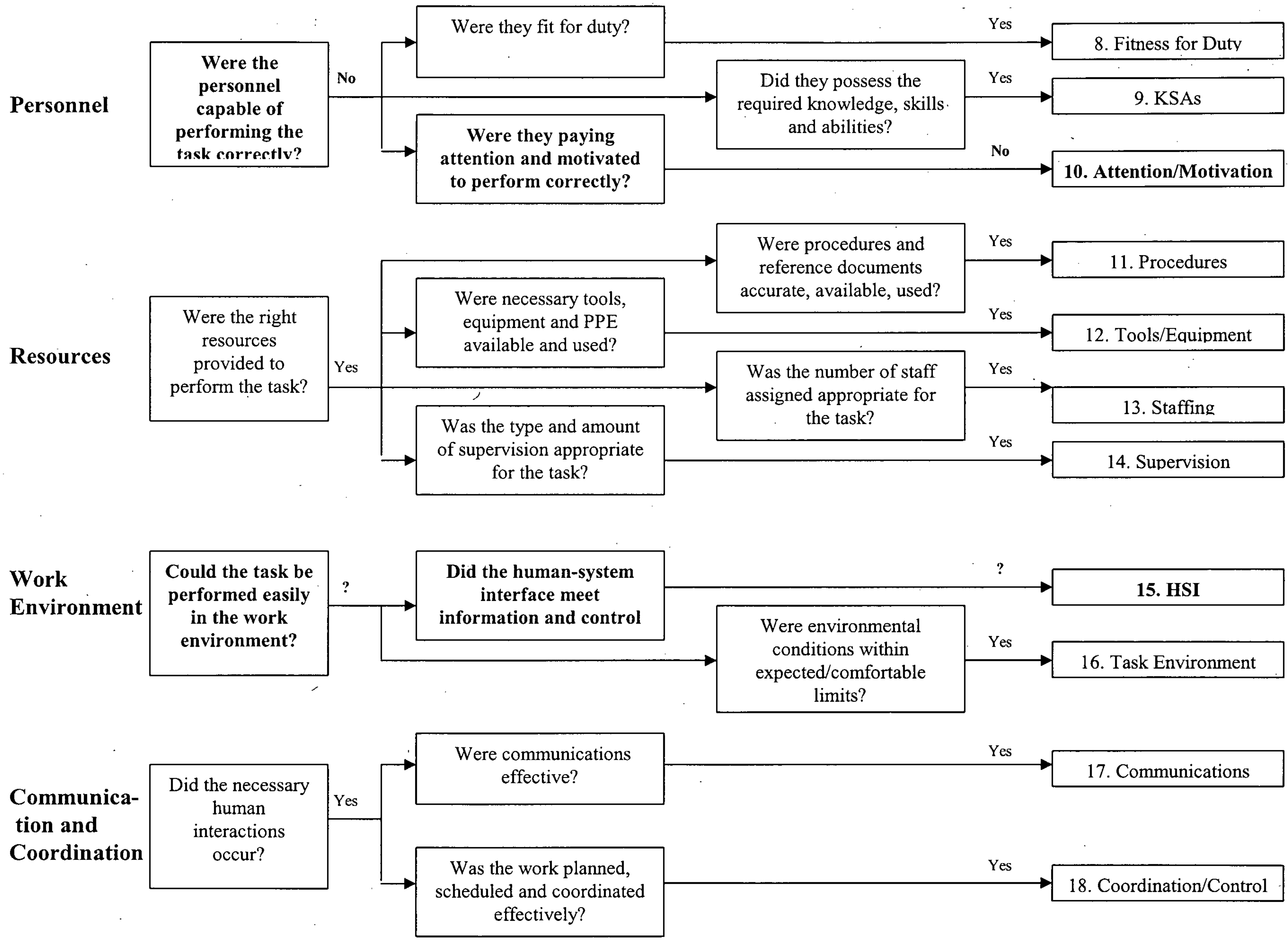


Figure 7-1 The HPEP Cause Tree

Resources - The task did not involve special tools or oversight, therefore this path is not considered applicable.

Communication/Coordination – The task did not involve interaction with other personnel, therefore this path is not considered applicable.

Personnel -

- There is no evidence or (due to the unknown time in which the error occurred) a way to establish whether the individual was unfit for duty. Therefore the presumptive conclusion, based on the CNS fitness-for-duty program, is that the individual was not unfit for duty.
- Based on the lack of complexity, the error would involve insufficient application of attention to the task at hand.

Work Environment –

- Although the work area is somewhat tight quarters, it is not deemed to pose an excessive risk to satisfactory performance of this task.
- The human/system interface may pose a challenge to successful task completion for the following reasons:
  - The MPU and Relay Tachometer probes are in close proximity to each other
  - Current CNS practices allow performance of connector removal and reinstallation as a skill-of-the-craft task

<u>Conclusions</u>

Due to the inability to pin-point when or under what conditions the error occurred, determination of a definitive root cause is not possible. Therefore, the most probable cause is determined to be the following:

> Insufficient worker attention applied to correctly perform reassembly of the DG2 Relay Tachometer speed probe connector

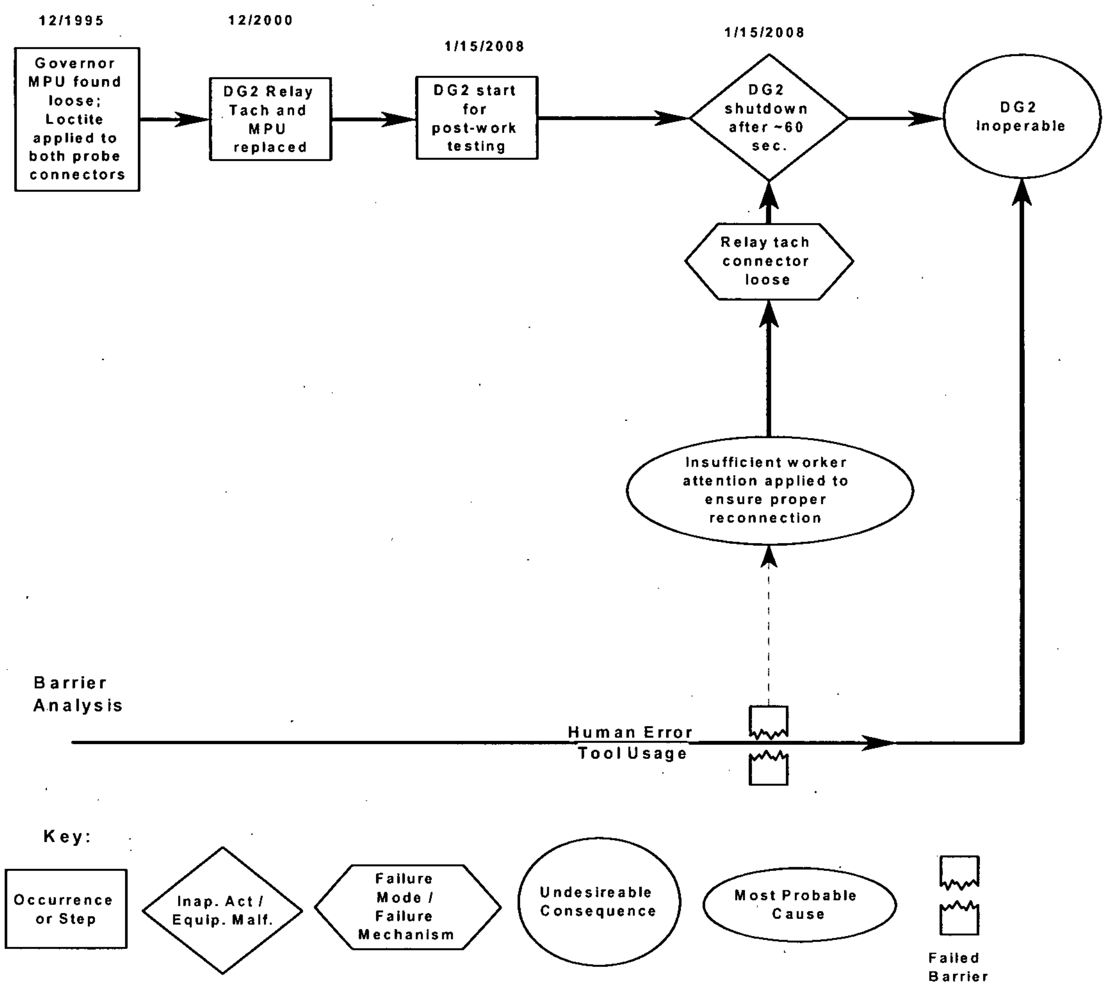
Whether the CNS practice that allows performance of connector removal and reinstallation as a skill-of-the-craft task reflects a deviation from industry standards is unknown at this time. Actions will be provided to compare CNS practices to industry practices and to reconcile deviations in standards.

Although we are unable to pin-point when or under what conditions the MPU connector was not properly assembled, the safety significance section provides further discussion that demonstrates the actual electrical discontinuity did not occur prior to or during the successful monthly surveillance that was performed the previous day prior to the maintenance window. Also, the failure to improperly assemble the connector was more likely to have occurred in the recent past due to:

1. The testing has demonstrated the loosening is not a result of time based vibration.
2. The testing has demonstrated that pin connection alone is sufficient to maintain solid contact.
3. The testing has demonstrated that to disengage the pins requires positive force.
4. Monthly surveillances include intrusive checks (such as looking for oil leaks, etc.)

that have the potential to disturb this connection.

5. Major maintenance includes activities that could have disturb this connection.
6. Any electrical discontinuity of between the MPU and the relay tach (from disturbance of the connection) would have been self revealing during normal monthly surveillances



Extent of condition/cause

Extent of Condition

Based on similarity of location and equipment type, the extent of the condition of loose amphenol-type connectors includes the governor and relay tachometer speed sensors for both DG1 and DG-2. These were verified to be tight as an immediate action.

Extent of Cause

For the most probable cause associated with the worker attention to detail, the extent of cause is bound by the workers that perform probe reassembly – I&C Maintenance. A corrective action is provided to provide lessons learned to I&C Maintenance personnel.

Operating experience summary

Internal OE

The internal OE search included both work order history and CR searches.

12/2000 (WO 00-3915) – Most recent work on the DG2 relay tachometer where the DG2 magnetic pick-up and relay tachometer were replaced (no work on connector, but would have to be removed to replace magnetic pick-up).

12/1995 (CR 1-19594, WO 95-04362 and WO 95-03959) – CR noted that while looking for reason for DG2 load spiking, the governor magnetic pick-up connector was noted to be loose. CR states that connection is "vibrating loose during DG run". The CR was designated as a work item to apply Loctite sparingly to the connector coupling nuts for the DG1 and DG2 magnetic pick-up probes. Note that there is some ambiguity in the documentation on the scope of the work (i.e., was the work done on both MPUs for both DGs?). The work authorization was approved on 12-11-95 (Minor Maintenance # 95-03959) with the annotation that the work was authorized by the WCC Supervisor/WCC SRO for "#2 DG only". However, in the completion notes there are two sets of statements that indicate the Loctite was applied to both MPUs on both DGs.

> *"Loosen both MPU amphenol connectors and applied Locktite 242 sparingly ensuring Loctite did not come in contact with wire insulation. Tighten amphenol connectors firmly."*

This was signed and dated on 12-11-95, and was followed by another entry:

> *"Loosened both MPU connectors on DG1, applied Locktite 242 and reassembled per instructions, sat. Returned to service."*

This was signed and dated on 12-15-95.

Discussion with the CR author indicated that the conclusion that the connection was loose due to vibration was based on a personal observation and was not derived from testing or physical evidence.

CR-CNS-2007-00480 documented an unexpected trip of DG2 during a monthly run in January 2007. Although the root cause was determined to be a manufacturing defect in a diode on the voltage regulator card, initial troubleshooting after the event did identify several loose connections (where individual wires were landed) which were subsequently determined to not have contributed to the event. However, due to the potential for one of those connections causing a VAR or voltage excursion under different conditions, a corrective action was assigned to establish PMs to periodically perform physical checks of electrical connections in the DG1 and DG2 control systems and to use thermography to detect "hot spots" in DG2 and DG2 electrical control system connections.

The response to this corrective action (CR-CNS-2007-00480 CA-8) included an evaluation to establish the extent of the PMs (since the action was for DG control circuits and checking all terminations on the DG was deemed excessive). Three assumptions formed the basis for the ultimate scope of this effort:

1. Some terminations, if loose, would not adversely affect DG operation. An example is a switch that controls a function that is bypassed during emergency operations. Also included is an assumption - the assumption that a wire with a loose fastener will not move from its location. This is due to the fact that the wire is "trained" or formed into a position, and the wire will not move on its own away from its termination.
2. It is assumed that all on-engine/skid components have other maintenance actions for calibration or periodic replacement, etc. Therefore, based on this assumption, none of these components will be separately inspected.
3. Vibration can cause terminations to loosen. The farther away from the engine, the less the vibration. For those components that are not on or adjacent to the engine vibration levels should not be sufficiently strong to warrant inspections (the OMAS (the switch found with loose terminations) is located remote from the engine (in the metering and relay panel), which is adjacent to the engine).

Based on the occurrence of this event, the above assumptions will need to be reanalyzed to identify additional scope.

Note that the comment for Assumption #3 that vibration can cause terminations to loosen was not applicable to this type of connector. Also note that with the completion of the laboratory analysis that refutes time-based vibration as a failure mode for this event, the above observations to not relate to this event. An additional CR is being initiated to address this.

External OE

12/2007 (San Onofre) – Event in which an emergency diesel generator failed during surveillance testing. San Onofre plant personnel were contacted and discussions yielded the following:

- There was an intermittent speed probe signal
- Trouble was initially thought to be grid induced equipment response, partly due to the fact that there plant information system only sampled at once per second, so that the resultant spikes were very small and of short duration. In addition, at "about the same time", the grid behavior was "abnormal".

- Later in the month, the input signal "went away", and the DG went to maximum load.
- After the December failure, an instrumented run was performed. The channel for the magnetic pickup displayed signal dropouts.
- Upon disassembly of the probe connector, found one of the pin terminations had an obviously inadequate solder connection. "It looked like one of the wires was tinned, and then inserted into the plug pin, and soldered without adding any additional solder". The adjacent conductor was appropriately soldered.

The solder connections for the Cooper connector were examined during troubleshooting per WO 4610394 with no deficiencies noted (see Page 6 for details of inspection results). This OE is therefore considered to not be relevant to the event currently being investigated.

04/2004 (J.A. Fitzpatrick CR 2004-01590) – CR describing that during troubleshooting of a Containment Air Monitor problem, found and amphenol detector cable loose. When an I&C technician went to remove the connector the day before to remove high voltage from the detector, it was noticed the connection was tight, but the connector did not seem to be seated properly as it only took a few turns to remove the connector (this style connector has extensive thread engagement). The connector was disconnected and reconnected properly and another Work Order initiated to inspect the connector in the future.

05/2003 (Browns Ferry 2, LER 2003-002) - HPCI turbine issue where the speed sensor amphenol failed and the turbine kept sensing 0 speed, and the control system kept calling for more steam (opening the valve fully), resulting in high HPCI flow which in turn resulted in the system isolating the HPCI system and tripping the turbine. The amphenol was an Amphenol 97-3106 (similar to the Cooper DG2 relay tachometer connection, the primary difference being the Browns Ferry connector is an angled connection vs. straight connection). Browns Ferry attributed the failure to "age, excessive wear, and vibration". Their corrective actions were to replace the connector, look at the similar connectors on the other HPCI and RCIC systems, revise procedures to visually inspect the connectors (doesn't specify when or how often), revise post-maintenance instructions to ensure connector continuity is demonstrated, and added PMs to periodically replace the HPCI/RCIC speed sensing amphenols.

04/2003 (J.A. Fitzpatrick CR 2003-01942) – CR describing that a Work Request documented a loose amphenol as the cause for corrective maintenance on a component. CR states that the connector was tightened and the CR was closed via "admin closure".

Repetitive Event Analysis

A repetitive event is defined in Procedure 0.5 as "Any significant condition adverse to quality that resulted from the same identified root cause as a previous event or non-conformance for which CAPRs were established within the past 5 years."

Because the root cause is not the same as a previously identified root cause and no previous CAPRs were established to deal with this issue, this is not a repetitive event.

safety significance

Actual Safety Consequences

DG2 unexpectedly shut down during the monthly run and resulted in declaring DG2 inoperable pending troubleshooting and repair. The shutdown represents a load failure in performance indicators. DG1 was available and operable for the duration of the event.

Potential Safety Consequences

The primary question to answer is how the existing condition would or could have been worse under different plant operating conditions. Had DG1 been inoperable and/or unavailable, the condition rendering DG2 inoperable is clearly more severe as reflected in the plant Technical Specifications, until such time as the problem was diagnosed and repaired.

What if the event occurred during an emergency start/run demand? Would the DG start and perform its function, and would the DG continue to run?

Would the DG start and perform its function?

Discussion

The DG logic includes various local and remote annunciations. The control logic interfaces with the annunciation logic so that "run alarms" are not received when the DG is not running. An example is the CONTROL AIR PRESSURE LOW alarm. The pressure switch which is annunciated is pressurized when the DG is running. When the DG is not running, the pressure switch is not pressurized, and the annunciator system would "see" that the contacts of the pressure switch are open. An open contact would cause an alarm to be received.

However, when the DG is not running, an unpressurized pressure switch is a normal condition. In order to only receive an alarm when the pressure switch contact is open AND the DG is running, a contact from the DG start/run/shutdown logic is placed in parallel with the pressure switch contact. Given this design, the start/run/shutdown logic provides a closed contact when the DG is not running, so that the annunciator will not be continuously received. When the DG is running, the start/run/shutdown logic contact opens so that a closed pressure switch contact would then be sensed, and alarmed, if a loss of air pressure in the control air system would occur.

For DG2, this annunciator point is 3622. This annunciation is normally received for every DG shutdown. When the DG is shutdown, the pressure switch contact closes first (and thus alarms), followed by the start/run/shutdown logic contact closing at 550 RPM, which cancels the sensed alarm condition. Once the start/run/shutdown logic contact closes (as the DG speed remains less than 550 RPM), the annunciator cannot again be "sensed" until the DG is again running (and speed rises above 550 RPM).

A review of annunciator point 3622 data history clearly indicated that point 3622 is normally received one time for each DG shutdown (point 3612 for DG1 was also reviewed, and the equipment response is identical - one alarm for each DG shutdown). This same history also clearly demonstrates that the expected CONTROL AIR PRESSURE LOW alarm was not received on 1/15/2008, when the DG unexpectedly shutdown, and was not received on 1/16/2008, when the DG was operated for troubleshooting purposes. This alarm was received at the end of the operability run performed on 1/14/2008. This alarm has also been received at the end of the DG runs that had been performed for the prior six months.

What does this mean?

The data for the duration of each annunciation was collected and plotted. The plots indicate that the average duration for DG1 is approximately 4.8 seconds (and is steady), and the duration for DG2 is approximately 5.3 seconds (and is marginally "noisier"). The duration for DG2 on 1/14/08 dropped to about 3.4 seconds.

This information indicates that the Relay Tachometer had been, for prior DG runs, providing a change-of-state output for each DG shutdown per its design. Since this change-of-state did occur for each shutdown, the Relay Tachometer (and it sensed input) had been operational in prior DG runs, including the 1/14/08 run. This information may or may not have been an indication of the connector became loose during engine coastdown.

This information indicates that for the runs prior to and including 1/14/08, the duration was "normal" and DG2 was capable of starting and performing its function. The earliest documented instance of anomalous magnetic pickup operation is during the engine coastdown on 1/14/08.

Would the DG continue to run?

Scenario One: The DG has started in response to an emergency LOCA start signal, the *initiating signal for the DG start has not cleared*, and the magnetic pickup/relay tachometer responds exactly as they did on 1/15/2008 and 1/16/2008. The following text is based on circuit analysis as follows (Re. drawing G5-262-743 SH 10):

1. DG has started and is running.
2. The relay tachometer momentarily senses less than 280 RPM.
3. Relay R102 momentarily de-energizes.
   a. When Relay R102 momentarily de-energizes, Relay 14RX3 momentarily de-energizes.
      i. When contact 1-3 of Relay 14RX3 opens, Relays 14RY1 and 14RY2 de-energize.
         1. When contact C1-C2 of Relay 14RY1 closes, a second power path is provided to the "normal run relays" (Relays 4MX, 4MX1, 4MX2, 4MX3, and 4MX4) as well as from the "emergency start relay" (Relay 4EMX3).
         2. When contact C3-C4 of Relay 14RY1 closes, nothing occurs (the annunciator circuit alarms on an open circuit).
         3. When contact C7-C8 of Relay 14RY1 closes, the Control Room CRANKING light comes on.

4. When contact 1-3 of Relay 14RY2 opens, nothing occurs. When the contact closes, however, the fuel oil booster pump will start and run for three seconds).
5. When contact 5-6 of Relay 14RY2 closes, the fuel oil booster pump will start/run.
6. When contacts 8-11/9-11 of Relay 14RY2 change state, room HVAC will cycle.

ii. When contact 6-7 of Relay 14RX3 opens, power is NOT removed from the "normal run relays" (Relays 4MX, 4MX1, 4MX2, 4MX3, and 4MX4) as well as from the "emergency start relay" (Relay 4EMX3).

iii. When contact 8-11 of Relay 14RX3 closes, energizing Relay 62CLX.

b. When Relay R102 momentarily de-energizes, Relays 14RX4 and 14RX5 momentarily de-energize.

i. When contact 1-4 of Relay 14RX4 closes AND contact 1-4 of Relay 14RX5 closes, the right bank starting air admission valves open.

ii. When contact 5-6 of Relay 14RX4 closes AND contact 5-6 of Relay 14RX5 closes, the left bank start air admission valves open.

iii. When contact 8-11 of Relay 14RX4 closes, the engine start counter advances by one.

iv. When contact 9-11 of Relay 14RX5 closes. the RED light in the Control Room comes on.

4. Relay R103 momentarily de-energizes.

a. When Relay R103 momentarily de-energizes, Relay 14S1 momentarily de-energizes.

i. When contact 1-7 of Relay 14S1 opens, the breaker closure permissive for the DG output breaker is removed. This has no effect on the breaker.

ii. When contact 4-8 of Relay 14S1 closes, the CONTROL AIR PRESSURE LOW annunciator would alarm.

b. When Relay R103 de-energizes, Relay 14S2 de-energizes.

i. When contact 3-7 of Relay 14S2 closes, Relay 14S3 energizes, and the Auxiliary Lube Oil Pump would start.

ii. When contact 4-8 of Relay 14S2 closes, the TURBO BEARING WEAR annunciator would alarm.

5. RESULT - DG2 CONTINUES TO RUN.

<u>Scenario Two</u>: The DG has started in response to a *non-LOCA emergency start (i.e., an under voltage signal)*, and the magnetic pickup/relay tachometer responds exactly as they did on 1/15/2008 and 1/16/2008. The following text is based on circuit analysis as follows (Re. drawing G5-262-743 SH 10):

1. DG has started and is running.
2. The output breaker closes and reenergizes the bus and clears the emergency start signal.
3. The relay tachometer momentarily senses less than 280 RPM.
4. Relay R102 de-energizes. (NOTE: Other relays change state, but since this logic chain causes the DG to shut down, the other information is not included in this discussion).

5. When Relay R102 de-energizes, Relay 14RX3 de-energizes.
6. When contact 6-7 of Relay 14RX3 opens, power is removed from the "normal run relays" (Relays 4MX, 4MX1, 4MX2, 4MX3, and 4MX4) as well as from the "emergency start relay" (Relay 4EMX3).
7. DG2 SHUTS DOWN.
8. DG2 would automatically restart in response to the resultant under voltage start signal. Given the repeatable behavior of the magnetic pickup/relay tachometer, the DG would subsequently shutdown, and the process would repeat until the high drywell signal comes in from the loss of drywell FCUs.
9. After one or two cycles, operators would actuate the emergency stop to prevent the DG from cycling.
10. Based on simulator, the high drywell pressure signal is actuated in 5 minutes.
11. One of the first steps of troubleshooting, operators reset the emergency stop.
12. DG2 automatically starts and now has same response as scenario 1.
13. RESULT DG2 CONTINUES TO RUN

<u>Safety Significance Conclusion</u>

This condition is judged to have resulted in only minor safety significance. This is based on:

1. This would not have resulted in a complete loss of DG2.
   a. The as found condition of the probe demonstrates that the electrical discontinuity was only momentary and of short duration as the DG was restarted as part of troubleshooting and the condition did not repeat until 52 seconds later.
   b. The logic would have automatically restarted DG2 as soon as troubleshooting began with only minimal interruption.
2. Based on PMIS data, the electrical discontinuity did not occur PRIOR to, or DURING the successful surveillance test conducted the day before.
   a. Most likely the electrical discontinuity was a result of the maintenance window that occurred just prior to the post work testing where the DG unexpectedly shutdown.
3. The failure to properly assemble the connector is more probable to have been recent event as.
   a. Testing demonstrates vibration is not a time based failure mode.
      i. As found most likely same as left condition of connector
   b. ANY electrical discontinuity would have been self revealing during monthly surveillances.
      i. Monthly surveillances have high likelihood of disturbing the connector due to activities such as checking for oil leaks, etc.
      ii. Maintenance activities performed on the engine have high likelihood for disturbing this connection.

Appendix A: causal analysis background information
Failure Modes and Effects Analysis performed during event response:

#	Possible Cause	Refuting Evidence	Supporting Evidence	Follow-Up Actions	Comments	Possible Cause
	Facts: Voltage and frequency came up to normal levels as expected and the unit ran for approximately 40 seconds, then shutdown. No abnormal alarm conditions were received at the DG control panel nor in the Control Room. The "run" and "cranking" lights on panel C were noted to cycle several times during the shutdown.					
1	Overspeed Governor	Overspeed gov did not actuate. Overspeed butterfly valves did not actuate. Overspeed fuel shutdown valve was not tripped. Freq trace 599 RPM. Need 655 electrical trip. Mechanical trip 665.	Last component worked on. Oil drained during repair of sight glass.		No mechanical shutdown signal was present	NO
2	Plugged fuel filter	Voltage response would not have dropped out. Engine speed was steady until trip. Would expect decrease in engine speed or oscillations if fuel problem. Subsequent DG loaded runs were acceptable without intervening fuel filter maintenance.				NO
3	Fuel oil strainer clogged.	Voltage response would not have dropped out. Engine speed was steady until trip. Would expect decrease in engine speed or oscillations if fuel problem. Subsequent DG loaded runs were acceptable without intervening fuel filter maintenance.				NO

4	Voltage regulator	Voltage regulator given signal to shut down. OSIPI traces support no voltage regulator problem. Startup trace same as previous start. S/D trace same as previous S/D. Voltage output at 0 will not cause DG shutdown. Voltage regulator output and engine speed reduced at same time, and comparable to a normal shutdown.				NO
5	Components in run logic	Took voltage measurements post run. As found was SAT.	Intermittent operation of "logic chain" components remains possible.			NO
5a	Relay 4MX	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible. As found voltage, after initial DG shutdown, demonstrated contact was closed.	Intermittent contact opening is electrically equal to a "shutdown command".			NO
5b	Relay 14RX3	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible. As found voltage, after initial DG shutdown, demonstrated contact was closed.	Intermittent contact opening is electrically equal to a "shutdown command".			NO
5c	Remote/Local switch	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible.	Intermittent contact opening is electrically equal to a "shutdown command".			NO

		As found voltage, after initial DG shutdown, demonstrated contact was closed.				
5d	Isolation switch	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible. As found voltage, after initial DG shutdown, demonstrated contact was closed.	Intermittent contact opening is electrically equal to a "shutdown command".			NO
5e	Board C stop control switch	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible. As found voltage, after initial DG shutdown, demonstrated contact was closed.	Intermittent contact opening is electrically equal to a "shutdown command".			NO
5f	Emergency shutdown switch	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible. As found voltage, after initial DG shutdown, demonstrated contact was closed.	Intermittent contact opening is electrically equal to a "shutdown command".			NO
5g	Relay 630SDX	As found after engine shutdown. Relay found de-energized not sealed in. As found voltage, after initial DG shutdown, demonstrated contact was closed.	Intermittent contact opening is electrically equal to a "shutdown command".			NO

5h	Maintenance lockout switch	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Concurrent failure not credible. As found voltage, after initial DG shutdown, demonstrated contact was closed. No "loss of lights/indication" was reported by Operations.	Intermittent contact opening is electrically equal to a "shutdown command".			NO
6	Butterfly limit switches	No work done on LSs. Operators do visual prior to DG start, no problems noted. Post inspection limit switches appear OK. Should see annunciator 3-4 if LS activated.	LS will give trip signal.			NO
7	Control air regulator	Voltage response would not have dropped out. Would look the same as blocked fuel.	Failure could shut down engine.			NO
8	Relay tachometer (not the connector, see #10)	No visible damage or anomalies on probe.	Instrumented troubleshooting run indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Local meter indicated 400 RPM when engine speed was actually 600 RPM.			NO
9	Relay tachometer power supply ES-3143	After initial failure, power supply available light remained lit. Engine speed sensor connector found loose on engine. Connector	 Instrumented troubleshooting run			NO

		electrical integrity affected when connector was "wiggled". With connector restored, and no other actions taken on relay tachometer power supply, operation was stable at 600 RPM during subsequent run.	indicated that relay tachometer contact opened, causing the equivalent of a "shutdown command". Local meter indicated 400 RPM when engine speed was actually 600 RPM.			
10	Magnetic Pickup Connector		Intermittent connection would cause relay tachometer to mal-operate, and cause electrical "shutdown command". Engine speed sensor connector found loose on engine. Connector electrical integrity affected when connector was "wiggled".			YES
11	Magnetic Pickup	Magnetic pickup gap was inspected and SAT. Magnetic pickup output was instrumented and evaluated after connector was re-tightened, and output waveform was SAT.	Intermittent operation would cause relay tachometer to mal-operate, and cause electrical "shutdown command".			NO

Appendix b: capr Due-date risk assessment

Risk Analysis for Establishing CAPR Due-Dates

CR #2008-00304

Condition: Unexpected shutdown of DG2

Causal Factor: N/A

As there is no root cause identified, there is no associated CAPR. Therefore no CAPR due-date risk assessment is performed.

Appendix C: corrective Actions

Corrective Action - A (Corrective Action)

Corrective Action Description: Develop lessons learned from this event as it relates to application of sufficient attention to detail when removing & reassembling electrical connections in critical applications. Present the lessons learned to appropriate Maintenance personnel.

CA Plant Constraint: Non-outage ; Priority 3 ; Initial Due Date 8-15-2008 ; LTCA (Y/N) N
Licensing Concurrence (Y/N) N ; Assigned Work Group: I&C Maintenance

Assigned Work Group Acceptance: T. Carson
Relationship to Causes: Addresses most probable cause #1 and extent of cause
Relationship to Extent of Condition and Cause: Addresses extent of most probable cause #1
Expected Benefit and Suitable Effectiveness: Will provide assurance that connectors are tightened

Corrective Action - B (Enhancement)

Corrective Action Description: Benchmark best practices to establish controls for ensuring removed connectors in critical applications are properly reassembled. Create subsequent corrective action(s) to implement benchmark results.

CA Plant Constraint: Non-outage ; Priority 3 ; Initial Due Date 9-19-2008; LTCA (Y/N) N
Licensing Concurrence (Y/N) N ; Assigned Work Group: I&C Maintenance

Assigned Work Group Acceptance: T. Carson
Relationship to Causes: Addresses most probable cause #2
Relationship to Extent of Condition and Cause: Addresses extent of most probable cause #2
Expected Benefit and Suitable Effectiveness: Will reduce likelihood of this and other amphenol-type connectors not being properly reassembled

Corrective Action - C (Enhancement)

Corrective Action Description: Revise procedures 14.17.1 & 14.17.2 to provide the specific connector identification (that matches the tag on the machine) when removed in Section 9.8 and when restored in Section 9.14

CA Plant Constraint: _Non-outage_; Priority _3_ ; Initial Due Date _9-19-2008;_ LTCA (Y/N) _N_
Licensing Concurrence (Y/N) _N_; Assigned Work Group: _I&C Maintenance_

Assigned Work Group Acceptance: T. Carson
Relationship to Causes: Partially addresses most probable cause #2
Relationship to Extent of Condition and Cause: Partially addresses most probable cause #2
Expected Benefit and Suitable Effectiveness: Will reduce likelihood of inadvertent removal of the wrong probe connector

Corrective Action -. C (CAER)

Corrective Action Description: Perform corrective action effectiveness review IAW applicable portions of procedure 0.5.CAER. Review completed corrective actions to establish appropriateness of responses, and to attest to non-repetition of issues with DG electrical connection tightness issues.

CA Plant Constraint: _Non-outage_; Priority _3_ ; Initial Due Date _9-25-08_; LTCA (Y/N) _N_
Licensing Concurrence (Y/N) _N_; Assigned Work Group: _SED_

Assigned Work Group Acceptance: D. Buman
Relationship to Causes: None
Relationship to Extent of Condition and Cause: None
Expected Benefit and Suitable Effectiveness: Effectiveness review

MPR ASSOCIATES, INC. ENGINEERS

July 8, 2008
LTR-0315-0802-004
Revision 1

Mr. Mark F. Metzger
Cooper Nuclear Station
72676 648A Avenue
Brownville, NE 68321

Subject: NPPD Purchase Order 4500089294; Report on the Vibration Testing Performed on the Relay Tachometer MPU Connector Removed from DG #2

Dear Mr. Metzger:

The attached report was prepared by MPR as required by NPPD purchase order 4500089294 amendment dated 6/5/2008. This report details the results of the vibration testing performed to evaluate the security of the Relay Tachometer Magnetic Pickup (MPU) and connector removed from Diesel Generator 2 (DG #2) at the Cooper Nuclear Station (CNS). This report is a follow up to the preliminary report issued on July 1, 2008 and includes the results of the long-term vibration tests performed under this contract. The purpose of this testing was to confirm or refute a root cause conclusion that the connector of this MPU came off as a result of engine vibration.

If you have any questions about this letter or the enclosed report, please contact me.

Sincerely,

Shawn M. Downey

Shawn M. Downey

Enclosure

MPR ASSOCIATES INC. ENGINEERS

Enclosure to MPR Letter Dated July 8, 2008 LTR-0315-0802-004

Cooper Nuclear Relay Tachometer MPU Connector Evaluation – Revision 1 (Final Report)

1. Purpose

This report documents the vibration testing performed to evaluate the security of the Relay Tachometer Magnetic Pickup (MPU) and connector removed from Diesel Generator 2 (DG #2) at the Cooper Nuclear Station (CNS). This testing attempted to determine if typical engine vibration was capable of loosening the threaded collar on the relay tachometer MPU. The intention of this report is to confirm or refute a root cause conclusion that the connector of this MPU came off as a result of engine vibration.

2. Background

During a recent surveillance test of DG #2, it was observed that the relay tachometer MPU connector had become disconnected. A root cause analysis concluded that this connector loosened and subsequently fell off as a result of engine vibration. As a result of this conclusion, this and other MPU connector threads were treated with Loctite ™ to prevent reoccurrence.

To gather additional evidence on this problem, CNS contracted MPR Associates to test the relay tachometer MPU and connector under various vibration conditions to see if the root cause conclusion is credible. The relay tachometer MPU and connector from DG #2 were removed and sent to MPR Associated for testing under an amendment to Purchase Order number 4500089294 for this purpose.

The vibration testing followed the test plan in Reference 10-3. The MPU is a Dynalco model M101 and the connector is an Amphenol style MS 3108A-10SL-4S. The cable to the relay tachometer MPU is secured about 12 inches away from the MPU in the plant.

CNS provided the following vibration data measured on DG #2:

0.0032 inches displacement
610 to 620 cycles per minute (10.166 to 10.333 Hz)

This vibration data was measured on DG #2 from a point on the gear housing opposite and in-line with the Governor MPU.

3. Conclusions and Recommendations

Based on the short-term and long-term (10-day) vibration testing performed for this report, no evidence could be found to support the conclusion that the relay tachometer MPU connector collar loosened as a result of engine vibration on DG #2.

Since this analysis does not support the root cause that the Relay Tach MPU cable disconnected as a result of engine vibration, MPR recommends that the investigation continue and that other possible causes be explored.

4. Materials Received from CNS

One (1) Model M101 Dynalco MPU removed from DG #2 after the connector and cable were found to be disconnected and

One (1) Amphenol style connector MS 3108A-10SL-4S also removed from DG #2 after the connector and cable were found to be disconnected.

5. Results of Inspection of Materials Received from CNS

A visual inspection of the connector threads of the relay tachometer MPU removed from DG #2 was performed. The threads showed no noticeable signs of damage or significant wear. The threads were coated with a black material presumed to be Loctite which was wiped off prior to inspection. Figures 1 and 2 below show the M101 MPU and a close up of the connector threads.

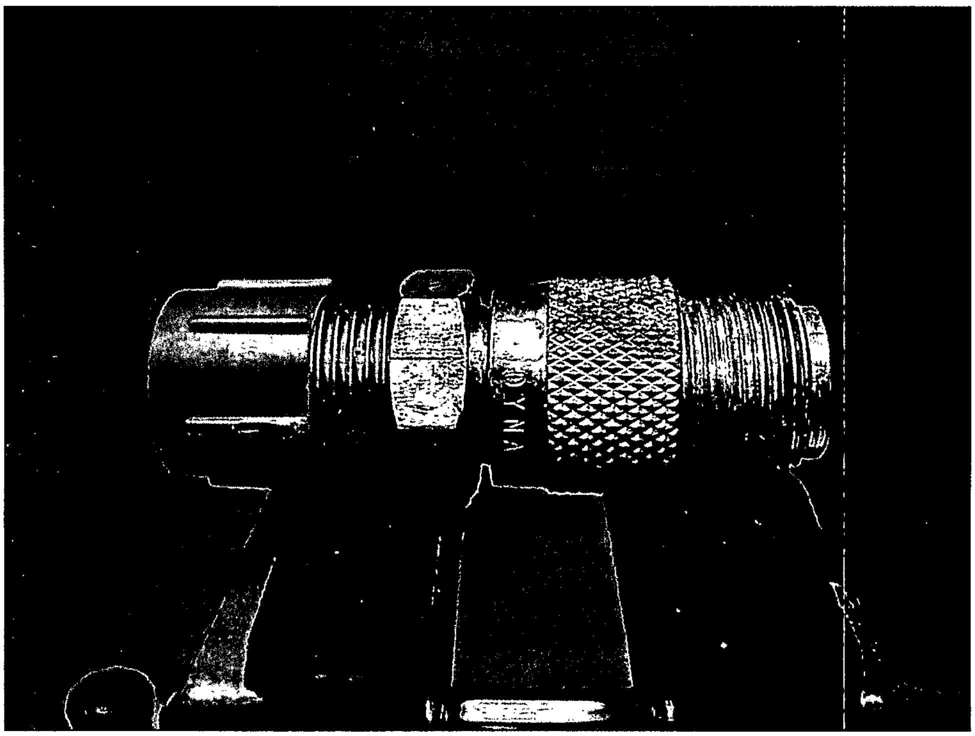


Figure 1. M101 MPU Removed from DG #2

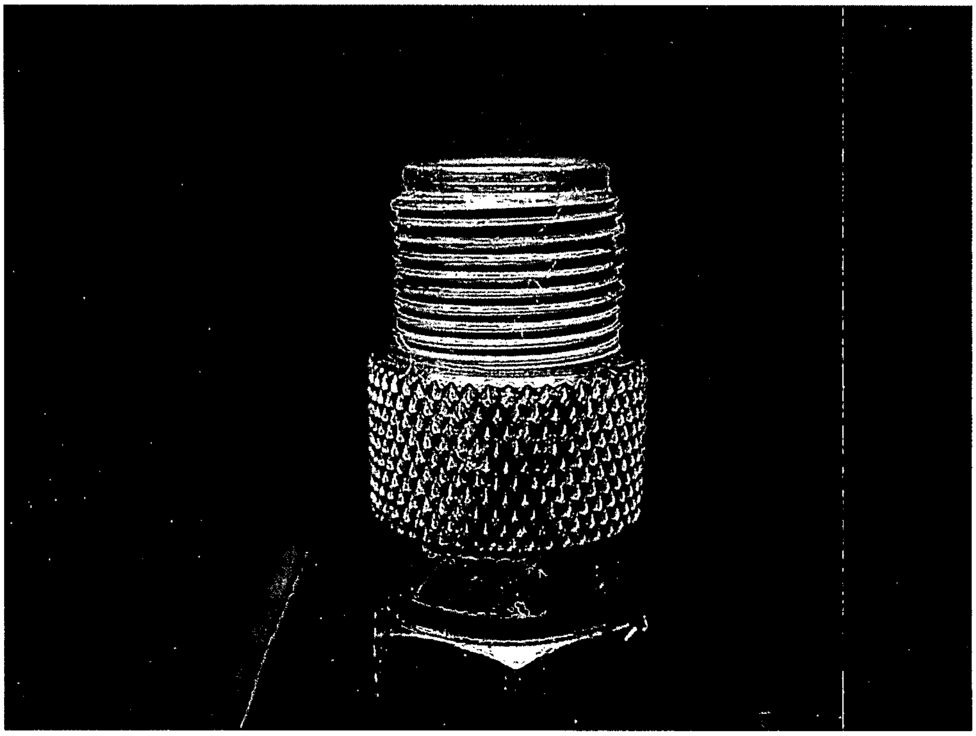


Figure 2. M101 MPU Removed from DG #2 (Close Up of Threads)

A visual inspection of the MS 3108A-10SL-4S connector removed from DG #2 was performed. The exterior of the connector shows obvious tool marks on the connector collar as well as other scratches. Some signs of wear are also evident on the socket sleeve which attaches to the MPU. None of the damage appeared significant enough to affect the electrical function of the connector. However, the signs of wear on the socket could contribute to making the connector attach less tightly to the MPU. The connector was plugged in and removed from the M101 MPU several times to gauge the tightness of this connection and it was found to be rather tight. That is to say, it seems very unlikely that the connector would fall off the MPU under its own weight. Inspection of the threads in the interior of the connector collar showed no signs of damage of significant wear. Figures 3 and 4 below show close up views of the MS 3108A-10SL-4S connector.

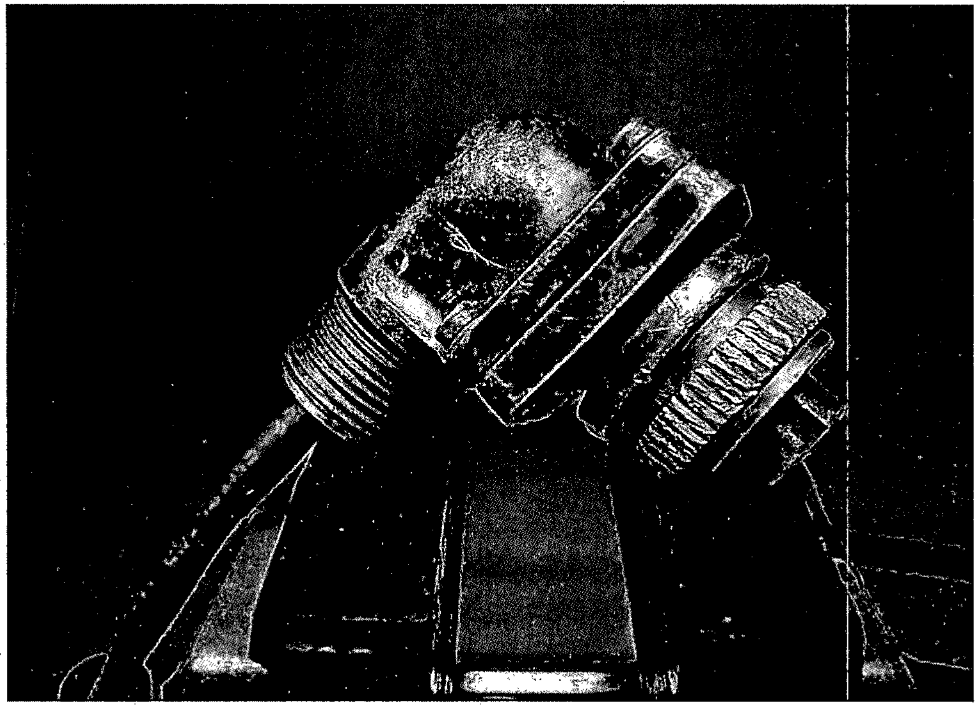
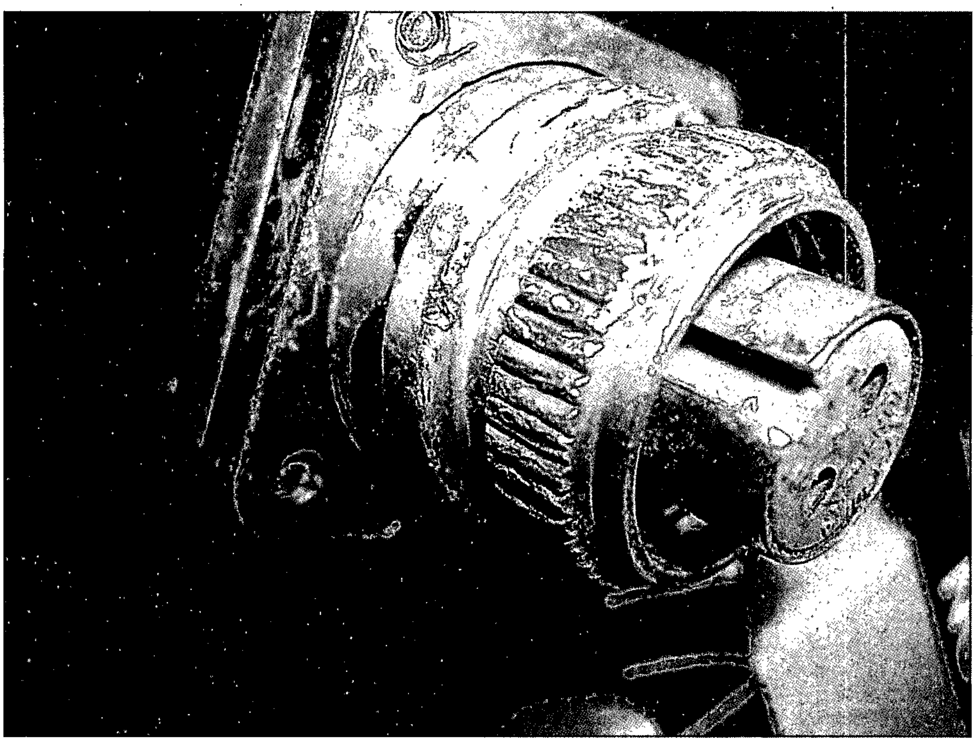


Figure 3. MS 3108A-10SL-4S Connector Removed from DG #2 (A cable was attached prior to taking this picture)

Figure 4. MS 3108A-10SL-4S Connector Removed from DG #2 (Close up of collar and socket showing tool marks and wear)



6. Test Rig Fabrication

A test rig was fabricated to hold the MPU and to secure it to the vibration table at various angles. The base of the test rig was constructed from a 0.8 inch thick carbon-steel mounting bracket, 6 inches tall by 6 inches wide. The MPU is held by a smaller L-bracket constructed from ¼ inch steel stock which can be bolted to the larger L-bracket at angles of 0, 30, 60, and 90 degrees. The smaller L-bracket's vertical face is threaded to accommodate the MPU and is locked in position with the MPU's nut. The base is secured to the shaker plate using a "dog down" or setup clamp. Three of these set-up clamps are used to secure the mounting bracket. Figure 5 (below) shows a photograph of the test rig mounted on the shaker plate.

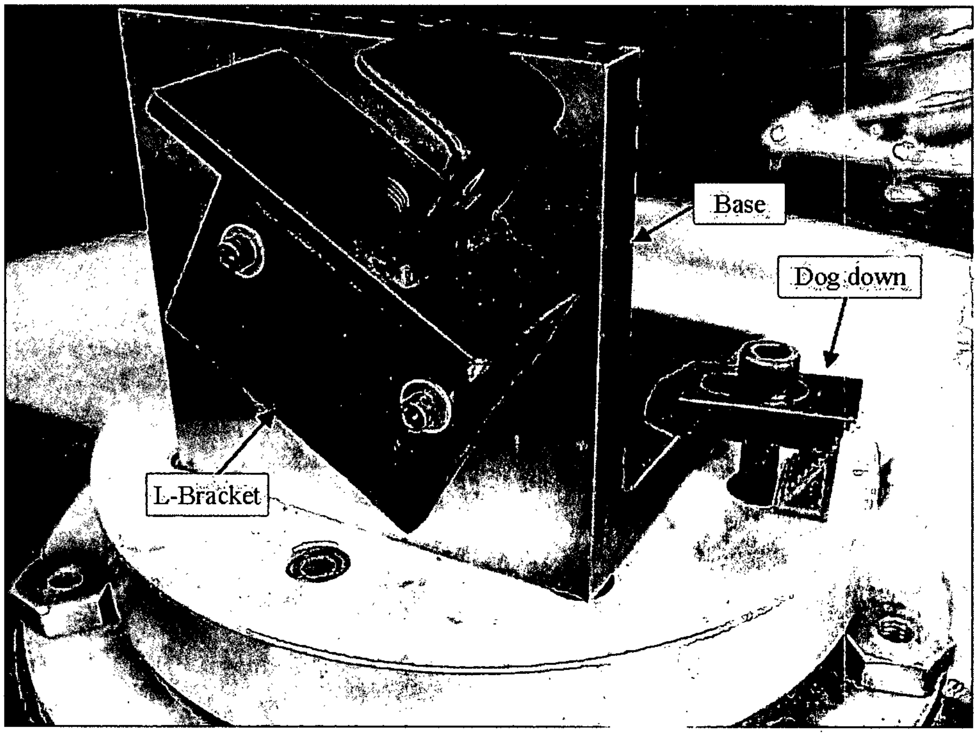


Figure 5. MPU Test Rig for Vibration Testing Set to 30° and Secured to the Shaker Plate

7. Vibration Test Facility

MPR Associates contracted with Innovative Test Solutions, Inc. (http://www.its-inc.com/) in Scotia, NY to perform controlled vibration testing of the relay tachometer MPU and connector removed from DG #2. This test facility also assisted in the fabrication of the test rig used for the testing.

For the attended vibration testing performed for this report, an Unholtz-Dickie model 500, 1200 lb shaker (serial number 111) and amplifier were used. The frequency was set using an Hewlett Packard model 33120A wave form generator (serial number US34013719). The displacement was set using a Gaertner optical scope with 1 mil granularity.

For the unattended testing (the long-term testing) performed for this report, an MTS 55kip capacity frame, model 312.31 (serial number 1208) was used. A Linear Variable Displacement Transducer (LVDT) model 204.71 (serial number 663) was used to measure displacement. The MTS frame includes an MTS PC which controls the frequency and test duration. The MTS PC runs the TestStar2 software platform.

8. Attended (Short-Term) Vibration Testing

The following short period vibration tests were performed at the ITS vibration lab. Each of these tests were setup and observed by an MPR employee in their entirety.

8.1. Test #1: Vibration Magnitude Parametric Test

Using the M101 MPU and the MS 3108A-10SL-4S connector removed from DG #2 a series of 30 minute tests were performed to attempt to determine if the vibration displacement is a factor which could lead to the loosening of the MPU connector collar. This test was performed with the connector collar screwed on approximately 5 turns but not tightened. Because the vibration measured by CNS on DG #2 was small (0.0032 inches displacement), this testing significantly exceeded the displacement to increase the chance of loosening the MPU connector collar. Displacements of 4, 8, 16 and 32 mils (peak) were tried at a common frequency of 610 cycles per minute (10.167 Hz).

A summary of the vibration magnitude test is provided in Table 1 below.

Table 1. Vibration Magnitude Parametric Test Summary

Connector Tightness (turns)	Vibration Displacement (mils)	Vibration Frequency (cpm)	Vibration Axis (degrees)	Total Duration (minutes)	Observations
~5 turns (not tight)	0.004 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
~5 turns (not tight)	0.008 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
~5 turns (not tight)	0.016 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
~5 turns (not tight)	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.

There was no discernible evidence that vibration displacement is a factor in loosening of the connector collar. The highest displacement (0.032 inches) will be used for subsequent tests.

8.2. Test #2: Frequency Sweep Test

Using the M101 MPU and the MS 3108A-10SL-4S connector removed from DG #2 a test was performed in which the vibration frequency was swept over a range of 480 cpm (8 Hz) to 960 cpm (16 Hz) every 8 minutes for 120 minutes. This frequency range far exceeds the frequency range measured on DG #2 which was 610 to 620 cpm. This test attempts to determine if the vibration frequency is a factor which could lead to the loosening of the MPU connector collar.

Since displacement is generally expected to decrease as the frequency increases and increase as the frequency decreases, the vibration magnitude was adjusted to 0.032 inches (peak) at the center frequency of 12 Hz (720 cpm). This resulted in a displacement of 0.045 inches at the low frequency of 8 Hz (480 cpm) and 0.025 inches at the high frequency of 16 Hz (960 cpm). The connector collar was screwed on approximately 5 turns but not tightened for this testing.

There was no discernible evidence that vibration frequency is a factor in loosening of the connector collar. A frequency of 610 cpm (10.167 Hz) will be used for subsequent tests.

8.3. Test #3: Orientation Parametric Test

The M101 MPU and MS 3108A-10SL-4S connector were subjected to a series of 30 minute tests where the MPU was positioned at 0°, 30°, 60°, and 90° (where 0° is vertical and 90° is horizontal). The frequency for this test was set to 610 cpm (10.167 Hz) and the displacement was set to 0.032 inches peak. This test attempts to determine if the MPU angle is a factor which could lead to the loosening of the MPU connector collar. The connector collar was screwed on approximately 5 turns but not tightened for this testing.

A summary of the orientation test is provided in Table 2 below.

Table 2. Orientation Parametric Test Summary

Connector Tightness (turns)	Vibration Displacement (mils)	Vibration Frequency (cpm)	Vibration Axis (degrees)	Total Duration (minutes)	Observations
~5 turns (not tight)	0.032 inches peak	610 cpm (10.167 Hz)	0 degrees	30 minutes	No movement of the connector collar was observed.
~5 turns (not tight)	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
~5 turns (not tight)	0.032 inches peak	610 cpm (10.167 Hz)	60 degrees	30 minutes	No movement of the connector collar was observed.
~5 turns (not tight)	0.032 inches peak	610 cpm (10.167 Hz)	90 degrees	30 minutes	No movement of the connector collar was observed.

As can be seen from the above table, there was no discernible evidence that orientation is a factor in loosening of the connector collar. The 30° orientation will be used for subsequent testing as this was judged to be closest to the installed configuration.

8.4. Test #4: Connector Tightness Parametric Test

The M101 MPU and MS 3108A-10SL-4S connector were subjected to a series of tests in which connector collar was screwed on 5, 4, 3, 2, 1, and 0 turns. At 5 turns, the connector was not fully tight. This test attempts to determine if the tightness of the connector collar is a factor which could lead to its loosening. The frequency for this test was set to 610 cpm (10.167 Hz) and the displacement was set to 0.032 inches peak. The MPU orientation was 30°.
A summary of the orientation test is provided in Table 3 below.

Table 3. Connector Tightness Parametric Test Summary

Connector Tightness (turns)	Vibration Displacement (mils)	Vibration Frequency (cpm)	Vibration Axis (degrees)	Total Duration (minutes)	Observations
~5 turns (not tight)	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
4 turns	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
3 turns	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
2 turns	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
1 turns	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.
0 turns (pressed on)	0.032 inches peak	610 cpm (10.167 Hz)	30 degrees	30 minutes	No movement of the connector collar was observed.

As can be seen from the above table, there was no discernible evidence that the tightness of the connector is a factor in loosening of the connector collar or causing the connector to fall off (in the case where the collar was completely loose).

9. Unattended (Long-Term) Vibration Testing

For the long-term testing the test rig was moved from the shaker table to a servo-hydraulic frame. This was done only for the convenience of the test lab and vibration environment is substantially similar to the shaker plate used in the previous (short-term) testing.

Figure 6 (below) shows a photograph of the test rig mounted in the servo-hydraulic frame.

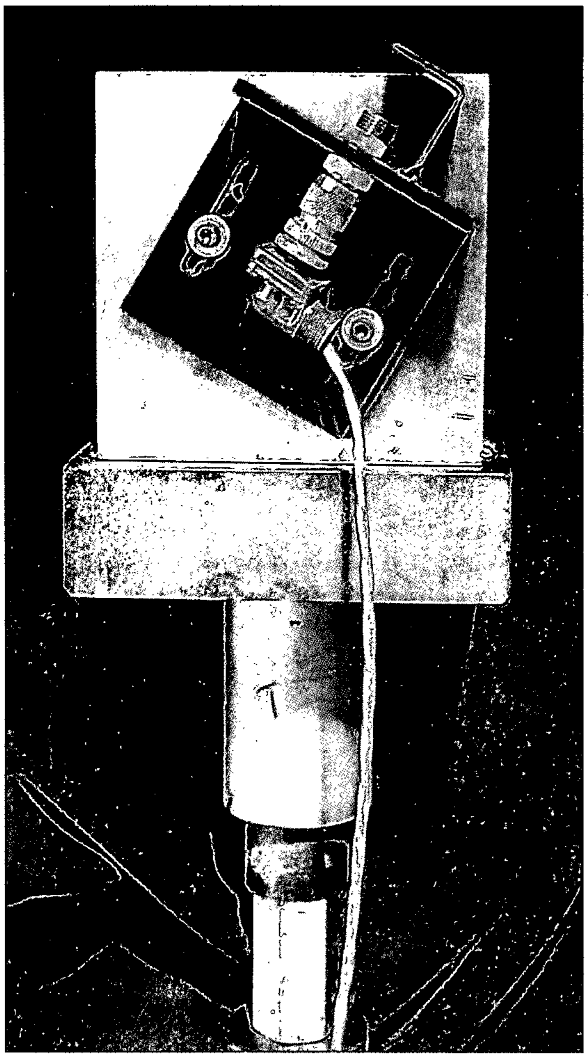


Figure 6. MPU Test Rig in Servo-Hydraulic Frame for Long-Term Vibration

The long-term testing was initiated on June 27, 2008 at 3:42:27 PM and continued for a total of 10 days (240 hours). The following conditions were used for this testing:

Connector Tightness (turns): ~5 turns (not tight)
Vibration Displacement (mils): 0.032 inches peak
Vibration Frequency (cpm): 610 cpm (10.167 Hz)
Vibration Axis (degrees): 30 degrees

After 240 hours of vibration under these conditions, the MPU connector collar was examined and found to have not moved by any measurable amount.

10. References

1 Dynalco Controls Brochure for M101 Magnetic Pickup.

2 Cooper Nuclear Station Drawing, "Governor and Engine Magnetic Pickups", 453243029, KSV-76-9, Revision NO2.

3 "Cooper Nuclear Relay Tachometer MPU Connector Evaluation Plan", MPR Associates, Document Number PLAN-0315-0802-003, Rev. 1, June 13, 2008.

ATTACHMENT 3 LIST OF REGULATORY COMMITMENTS©

Correspondence Number: NLS2008059

The following table identifies those actions committed to by Nebraska Public Power District (NPPD) in this document. Any other actions discussed in the submittal represent intended or planned actions by NPPD. They are described for information only and are not regulatory commitments. Please notify the Licensing Manager at Cooper Nuclear Station of any questions regarding this document or any associated regulatory commitments.

COMMITMENT	COMMITMENT NUMBER	COMMITTED DATE OR OUTAGE
None		