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OSCAR R. LEE
VICE PRESIDENT

August 21, 1984
Fort St. Vrain
Unit #1
P-84290

RECEIVED
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Mr. E. H. Johnson, Chief
Reactor Project Branch 1
Region IV
Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 1000
Arlington, TX 76011

SUBJECT: Fort St. Vrain Control Rod Drive Refurbishment

REFERENCE: P-84221 (Lee to Johnson, Dated July 18, 1984)

Dear Mr. Johnson:

This letter is to provide you with our findings and positions regarding the Fort St. Vrain control rod failure investigation which began as a result of the June 23, 1984 event where six control rods failed to automatically insert upon scram. To date, four of the six control rod drives (CRDs) have been examined. Attachment 1 summarizes the work performed and the observations made on each of these four CRDs.

A number of tests have been developed throughout the CRD work in order to better ascertain the mechanism for the apparent binding of the drive system. A brief description of these tests and their status is provided in Attachment 2. By far, the most conclusive of these tests is T-227, Back-EMF Testing. This test provides the most sensitive indication of control rod drive train performance available and has the additional benefit that it can be conducted even while the reactor is at power to confirm CRD operability. A "back-EMF" (voltage) is generated by the CRD shim motor as its control rod is scramming. The peak-to-peak value of the back-EMF is a function of driving force on the motor and hence provides an indication of the amount of frictional resistance within the shim motor <u>and</u> the gear train (200 Assembly). Ideally, a back-EMF trace (which shows the voltage amplitude modulation throughout scram) should exhibit the following characteristics:

1) The average peak-to-peak voltage should increase from a voltage of zero to a 'first maximum' at which the motor speed exceeds the constant speed for the remainder of the scram. This first maximum should occur at 2 - 5 seconds after scram initiation.

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2) The first maximum peak voltage should taper off to a relatively constant peak-to-peak voltage until the scram is completed (i.e., 'flat' on the edges of the trace).

3) There should be minimal oscillating behavior in the trace after the first maximum.

Samples of back-EMF data taken from CRD No. 44 (installed in Region 28 on June 23, 1984) are provided in Attachment 3. Figure 1 of Attachment 3 shows the back-EMF signature at the beginning of scram prior to any refurbishment work having been performed. Note the amount of time that it took the control rod to reach maximum scram velocity. Scram was initiated at T = 0 seconds, and the point at which the maximum scram velocity was reached (i.e., the first voltage maximum or regenerative peak) was at T = 5.25 seconds. Also note the magnitude and the erratic variations in the voltage wave amplitude subsequent to the first peak voltage. Figure 2 shows the signature after refurbishing only the CRD shim motor and brake assembly. A marked improvement was observed. (The data was digitized for computer analysis and plotting. The slight variations on the edges of the trace are normal.) This signature is very similar to that of an ideal trace on a new CRD. The data shown in Figure 3 was taken following refurbishment of the 200 Assembly. Based on this signature, it was concluded that a gear train assembly problem had been created during rework, and the 200 Assembly was disassembled again. It was found that a shim had been placed incorrectly during the first reassembly. The shim placement was corrected, and the 200 Assembly was reassembled a second time. Figure 4 shows the signature after all work was completed. By comparing Figure 2 and Figure 4, it can be concluded that refurbishment of the 200 Assembly did not significantly improve the CRD operation.

All of the CRDs that failed to scram on June 23, 1984, for which pre-refurbishment back-EMF signatures have been obtained (from Regions 6, 10, 25, and 28), had pre-refurbishment back-EMF signatures exhibiting similarities to Figure 1 of Attachment 3. The magnitude of the average peak-to-peak voltages was generally low, and erratic wave amplitude variations were characteristic. Back EMF signatures taken on a majority of the CRDs that scrammed properly on June 23, 1984, have exhibited larger average peak-to-peak voltage values and more constant wave amplitudes similar to Figure 4 of Attachment 3.

In summary, this is our evidence:

1) Back-EMF data provides an effective means for identifying degraded CRD performance. CRD operability, both prior to startup and during power operation, can be confirmed using this method.

2) Based on preliminary assessment of back-EMF data taken on all CRDs, there are indications that some CRDs which scrammed properly on June 23, 1984, may also exhibit degraded performance.

3) No significant benefit is gained by refurbishing the 200 Assembly of the CRDs. To date, all performance improvements observed in the CRDs refurbished have been achieved following shim motor refurbishment alone.

4) We have performed an historical search of past operation with the intent of identifying periods in which the reactor was operated under high moisture conditions for a relatively long period of time, and in which all rods inserted following an automatic PPS action. From this search, a reactor dew point of at least 60°F has had no adverse effect on control rod scram capability.

We believe strongly that the cause of the event was the migration of moisture from the PCRV into the CRD motor area. Our evaluation of purge flow requirements, under the existing CRD design, has lead to the conclusion that this migration could not have been prevented even if full design purge flow requirements were met. Therefore, it is our position that the decrease in purge flow which occurred on June 22, 1984, could not have significantly reduced the effects of the high primary coolant moisture levels on the motors.

To elaborate, there are four passages through the CRD orifice motor plate which could result in a free-flow area being available for moisture migration. These four passages are: (1) one hole which provides access through the orifice motor plate for the RSD hopper pressurization line; (2) one hole for the RSD hopper vent line (3) and, two holes for access to eyebolts connected to the CRD lower assembly. In addition, there are four windows through the CRD housing which permit access to the CRD internals, and which could allow a flow path for primary coolant to reach the motor area (the windows are covered, but not sealed). The combination of areas presented by the four orifice plate passages and by possible gaps around the four window cover plates results in a flow path being available for primary coolant to reach the CRD motor area. The purge flow capability, which is only intended to reduce plate-out in the motor area, is insufficient to overcome by-pass flow via the aforementioned flow paths.

Therefore, Public Service Company of Colorado commits to the following to be completed prior to restart:

1) Continue the refurbishment effort for the two remaining CRDs that failed to scram on June 23, 1984 (Regions 6 and 25). This refurbishment effort will include both the motor and gear train assemblies.

2) Repair the two control rods (Regions 19 and 30) which we have removed from the core for unrelated problems.

3) Continue to clean disassembled components of the CRDOAs inspected, as appropriate, using wet or dry wiping, nitrogen blowdown, or alcohol solution methods.

4) Disassemble and inspect the motor-brake assemblies of two CRDOAs which properly scrammed on June 23, 1984. In addition, one of the selected CRDOAs will undergo disassembly and inspection of its 200 Assembly gear train.

5) Functionally test one 30 weight percent and one 40 weight percent reserve shutdown hopper, and perform a physical examination of the Reserve Shutdown material subsequent to testing.

6) Perform a test to determine the back EMF generated during scram for all 37 CRDOAs. To date, all but the Region 30 CRDOA have been tested.

7) Perform a test to determine the sensitivity of the motor bearing assembly to moisture relative to free rotational torque.

8) Perform a test to determine the effects of exercising a CRDOA to ascertain the self clearing characteristics of the assembly.

9) Develop an acceptance criteria for establishing CRD operability based on reviews of back-EMF data, compare the back-EMF data taken from all CRDs against this acceptance criteria, and refurbish the CRDs that do not meet the acceptance criteria as necessary to return them to an acceptable status.

10) Complete i vestigations into the effects of purge flow loss coincident with high primary coolant moisture levels.

11) Complete and report the results of our analyses of the identification/composition of debris found in the assemblies.

12) Evaluate and develop as necessary a CRDOA preventive maintenance program for future refuelings.

13) Develop appropriate Technical Specification changes to include at least the following:

    a) The requirements to perform an immediate orderly shutdown when a moisture ingress event occurs resulting in primary coolant moisture levels exceeding a not yet specified dewpoint.

    b) The requirement to perform periodic back-EMF tests to verify control rod operability, probably in conjunction with SR 5.1.1

    c) Revise SR 5.1.1 frequency from monthly to weekly. Note that our reevaluation of the ~ 6" rod drop distance is more than adequate to verify scram times and to obtain back-EMF data.

d) The requirement to obtain CRD motor temperature data in conjunction with SR 5.1.1 whenever power levels are above 30%.

e) The development of a definition of 'operable control rod' (to include minimum requirements for position indication).

In the event that a Technical Specification revision can not be issued prior to the desired restart date, but a proposed revision which is satisfactory to both Public Service Company of Colorado and the Nuclear Regulatory Commission has been developed, then we will implement the necessary controls to incorporate the propcsed revision into our operation.

We are also evaluating design modifications to the control rods to decrease the free-flow area available for the moisture to enter the motor area, with the goal of <u>not</u> requiring an immediate orderly shutdown following a moisture ingress event. Preliminary analyses/tests indicate that such a design modification is possible. Therefore, we commit to design and manufacture devices which reduce the flow area available for primary coolant to reach the motor area via the orifice motor plate passages and CRD windows. This flow area will be reduced to the point where the existing purge system can overcome these by-pass flow paths. We will schedule installation of this modification as a part of the future CRD preventive maintenance program.

We have a difficult task before us, both in the completion of the CRD refurbishment effort and in the development of appropriate Technical Specifications. I am confident of the correctness and completeness of the analyses that have been performed to date on the control rods, and I am basing the aforementioned commitments on these analyses. Your prompt concurrence with this position will be appreciated.

I would like to propose a meeting of my staff and the Nuclear Regulatory Commission in Arlington, Texas on September 11, 1984 to discuss the technical aspects of our findings and positions. Due to previous commitments, however, I will be unable to attend this meeting, but I plan to come to Arlington later in September to introduce myself to Mr. Robert Martin.

Very truly yours,

O. R. Lee
Vice President, Electric Production

Attachments

ORL/djm

OBSERVATIONS ON REWORKED CONTROL

ROD MECHANISMS

Serial Number 25

This was the first mechanism to be reworked. At this time of the incident, it was installed in Region 14 and was a shim group rod mechanism. This mechanism was removed to the hot cell, had its shim motor only disassembled and reworked, and was subsequently returned to the Reactor in Region 7. After return to the Reactor, during the performance of T-227, which observed generated voltage during scram (back-EMF), slack cable indication was observed during run-out and the rod pair was inserted observing motor wattage. Although a slight increase in wattage was observed, it is not believed that this indicated a stuck or separated rod. It is thought that spurious activation of the slack cable indication occurred as a result of incorrect preload on the slack cable spring. This mechanism awaits a second removal from the reactor to correct the slack cable assembly problem.

Serial Number 18

This mechanism, the second to be examined, was installed in Region 7 at the time of the incident and was withdrawn to 190". It was removed to the hot cell where both the shim motor and the gear train were disassembled and reworked, and was subsequently returned to Region 10. This mechanism also failed to scram in the February 22, 1982 incident (Reference LER 82-007).

Serial Number 14

This mechanism, the third to be reworked, was installed in Region 10 at the time of the incident, and was a shim group mechanism. The mechanism was removed to the hot cell, and both the shim motor and gear train were reworked. This is the first mechanism for which pre-disassembly back-EMF's were taken (although this mechanisms trace was first taken in the hot cell, not the reactor). After rework, the mechanism was returned to Region 6.

Serial Number 44

This mechanism was the fourth to be reworked. It was installed in Region 28 and was withdrawn to 190" at the time of the incident. After removal from the reactor, it was placed in an Equipment Storage Well (prior to installation in the hot cell for refurbishment). In-Reactor and hot cell back-EMF traces indicated that this rod exhibited poor back-EMF behavior. Performance of T-236, to establish that the rod would scram from any withdrawn position, showed that initially the rod pair would not insert freely from a variety of positions below the approximately half-withdrawn position. A second performance of this test approximately twelve hours later showed dramatic improvment. This improvement is attributed to natural 'drying' of the CRD motor while it was in the hot cell. The shim motor only was disassembled and reworked, and re-installed on the mechanism. A back-EMF trace showed a very smooth voltage signature indicative of very little restriction of motion. After the refurbishment of the motor, the rod pair would scram freely from any position. After refurbishment of the gear train mechanism, another back-EMF trace indicated a substantial increase in mechanism resistence during scram. The gear train was again reworked, this time yielding a good back-EMF trace. (The gear train problem was traced to an improperly installed shim.) This mechanism was also involved in the February 22, 1982 failure-to-scram incident (Reference LER 82-005). This mechanism is currently in an Equipment Storage Well awaiting return to the reactor.

T-TEST SUMMARY AND STATUS

T-214 CRDOA Motor Wattage Test

PURPOSE: This test is to establish a data base of Control Rod Drive Motor characteristics and to monitor the performance of the rod drive mechanism.

STATUS: This test was performed in March and April of 1984 on all CRDOA's in the core. It was conducted again on all CRDOA's in the core within three days following the failure to scram incident.

T-226 Visual Examination of the Six CRDOA's That Failed to Scram

PURPOSE: This test is to make observations that possibly will enable the determination of the cause for the failure of CRDOA's in Regions 6, 7, 10, 14, 25, 28 to "SCRAM" on June 23, 1984.

STATUS: CRDOA's from Regions 14, 7, 10, 28 have been examined prior to, during and after refurbishment.

T-227 Shim Motor Back EMF Generated During Scram

PURPOSE: This test is to establish a data base of CRDOA back-EMF. It consists of obtaining coarse and detailed signatures of the EMF generated by the shim motor/generator when the rods are scrammed.

STATUS: This test has been performed on all CRDOA's in the core except Region #30 CRDOA. This CRDOA shim motor is believed to be bad. The signatures for the six CRDOA's that failed to scram on June 23, 1984 are all of an irregular pattern indicating frictional resistance during scram.

T-228 Susceptability of Brake Assembly to Seize When Exposed to Moisture

PURPOSE: To investigate the possibility of the brake assembly to seize when exposed to moisture.

STATUS: This test has been completed. This test indicated no tendency for the brake assembly to be affected by moisture.

T-232 Shim Motor Exercise Debris Removal

PURPOSE: This test consists of recording the torque required to rotate the shim motor before and after exercising the shim motor.

STATUS: This test has been performed on CRDOA #44 from Region #28. No conclusions have been reached pending results.

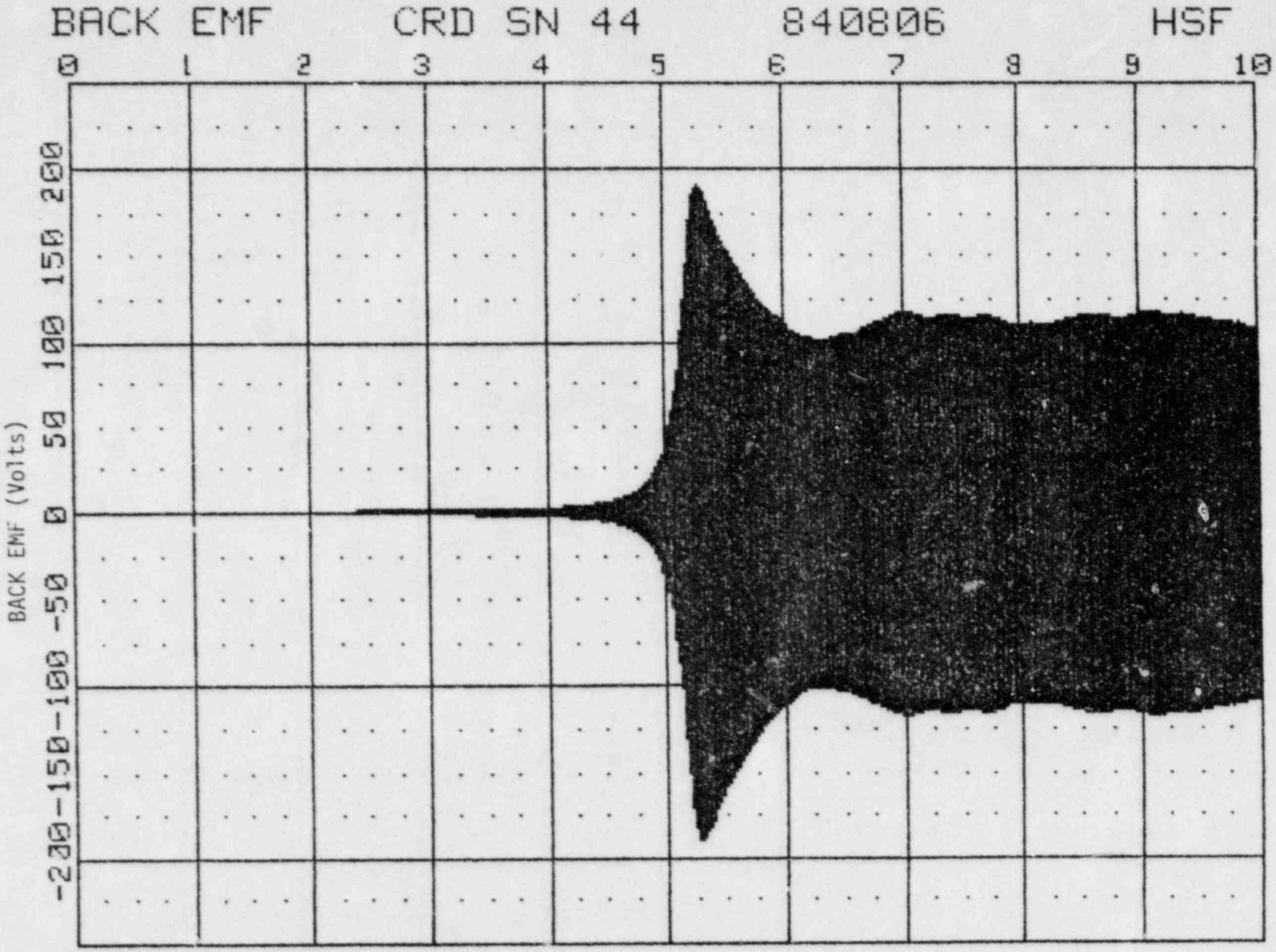
T-236 Scram Test

PURPOSE: This test will record the rod drop velocities through timed scram tests. It will indicate if the rod is capable of scramming from various positions.

STATUS: CRDOA's from Regions 14, 7, 10, 28 have been examined thus far.

FIGURE 1

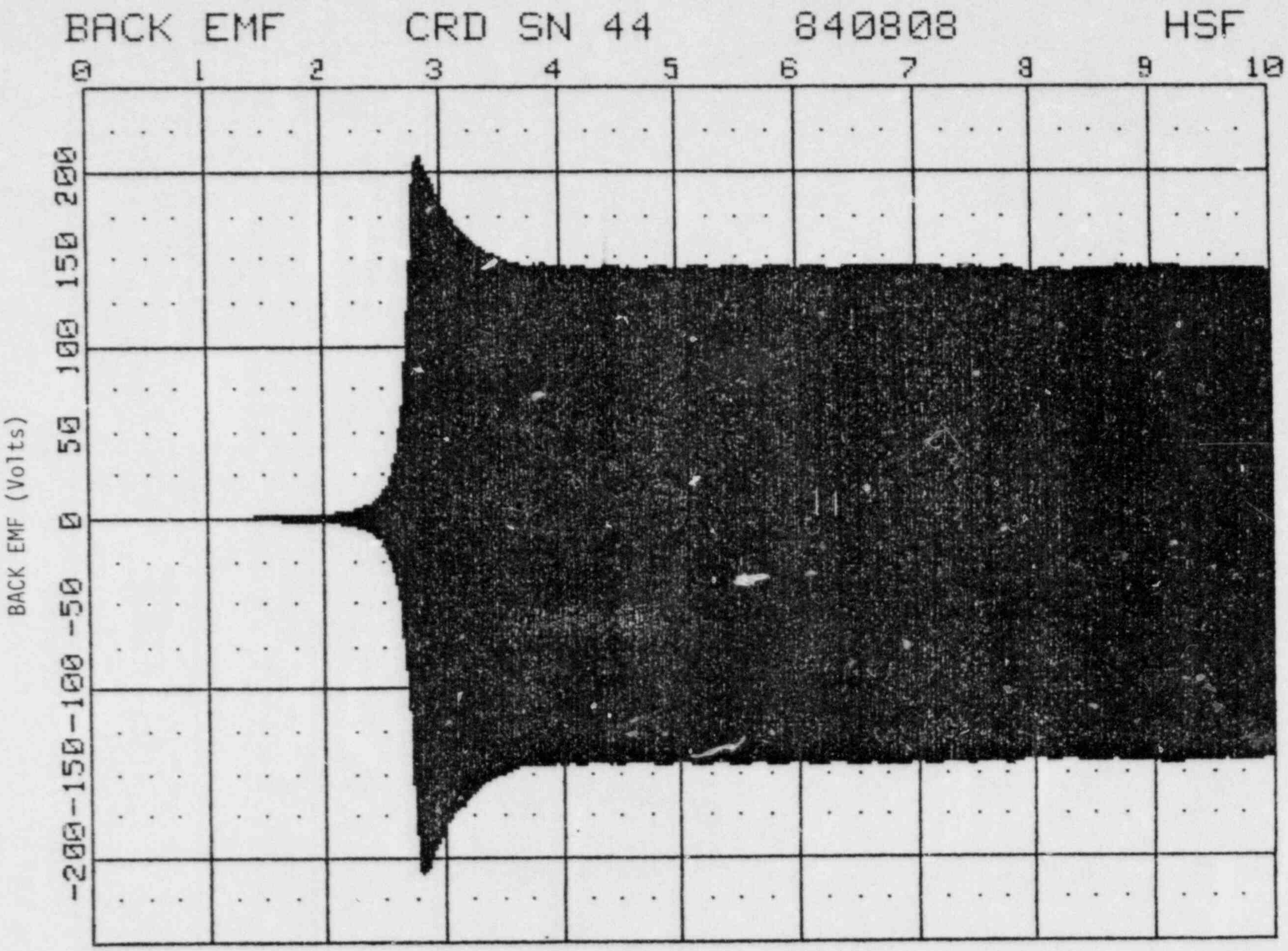
Back-EMF Trace for
CRD No. 44 (Installed in Region 28 on 6/23/84)
Taken Prior to Refurbishment



TIME AFTER SCRAM (Seconds)

FIGURE 2

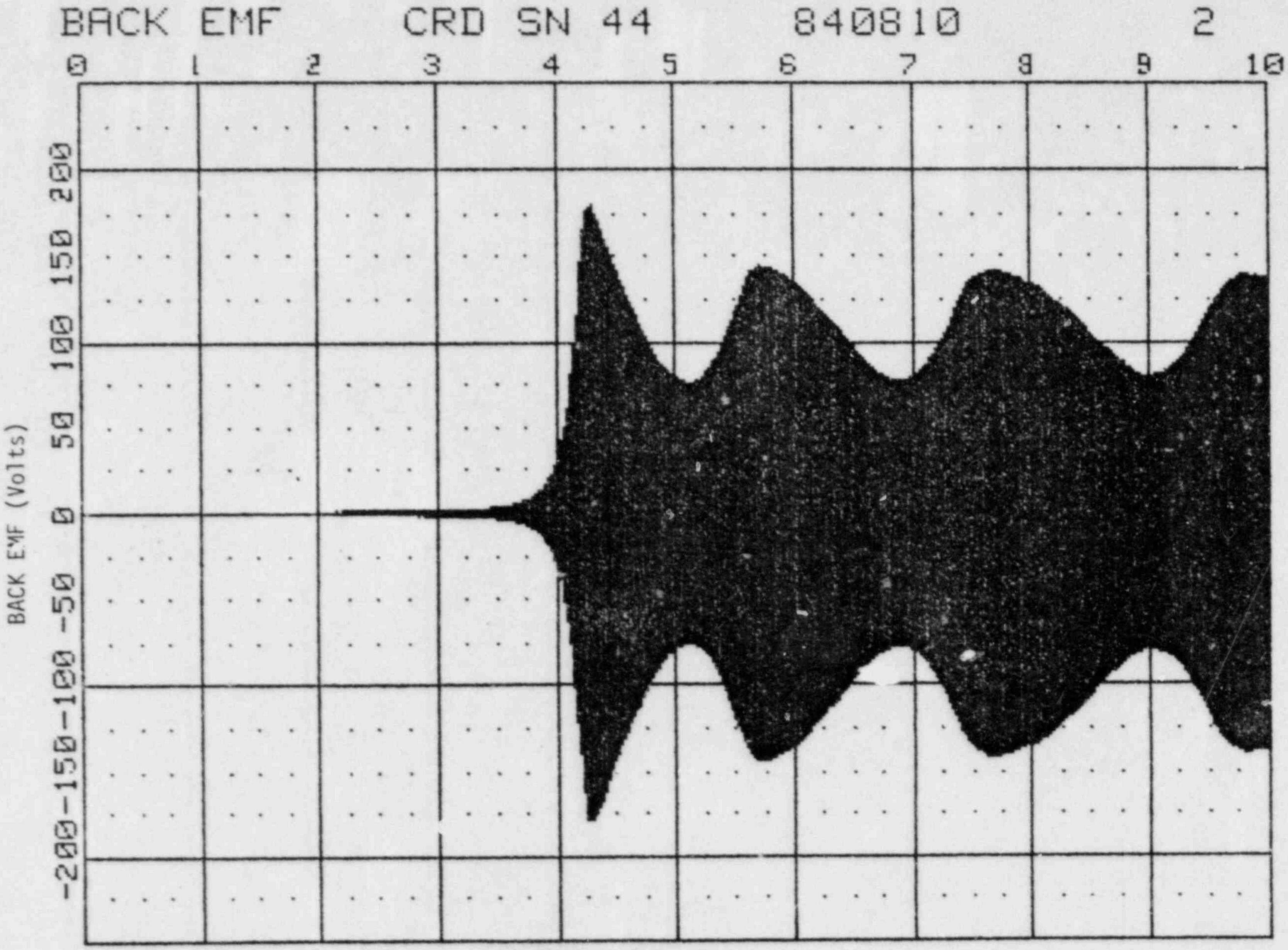
Back-EMF Trace for
CRD No. 44 (Installed in Region 28 on 6/23/84)
Taken After Refurbishment of Shim Motor/Brake Assembly Only



TIME AFTER SCRAM (Seconds)

FIGURE 3

Back-EMF Trace for
CRD No. 44 (Installed in Region 28 on 6/23/84)
Taken After Refurbishment (With Misplaced 200 Assembly Shim)



TIME AFTER SCRAM (Seconds)

FIGURE 4

Back-EMF Trace for
CRD No. 44 (Installed in Region 28 on 6/23/84)
Taken After Refurbishment (Correct 200 Assembly Shim Placement)