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October 14, 1992

US Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Re: Report on Inadvertent Reactivity Addition
Penn State Breazeale Reactor
License Number R-2, Docket Number 50-05

On October 5, 1992, an incident occurred at the above facility which is described in the attached report. In summary, an operator error when changing a control system parameter with all rods fully inserted caused an inadvertent partial withdrawal of one rod. This incident does not constitute a reportable occurrence under the Technical Specifications, but is never-the-less considered a serious matter which is appropriate for regulatory review.

On the morning of October 6, 1992, members of our staff discussed the incident with Mr. Alexander Adams of the NRC Non-Power Reactor Directorate, outlining the cause, response, immediate corrective action, and long-term corrective actions under consideration. In a call later that day, Mr. Adams reported that the incident had been discussed with his management and with Region I; there was concurrence with our interpretation of the reporting requirements stated above.

The control system vendor was informed on October 6, 1992, as was the Penn State Reactor Safeguards Committee which was convening that day for its regularly scheduled quarterly meeting. Both the vendor representative and the safeguards committee concurred with the preliminary analysis and corrective actions and asked to be kept informed of additional long-term corrective actions.

In addition to this preliminary report, we intend to submit a follow-up report within 30 days, describing final resolution of this matter.

Sincerely,

David A. Shirley

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Senior Vice President for Research and
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DAS/MHV/ldl441

Attachment

pc: Region 1 Administrator
Mr. Gilbert Raiskums, AECL Technologies

IE22 1/1

The following is a description and initial analysis of the event that occurred October 5, 1992 at 1606.

Reactor Initial Status:

Reactor was shutdown with all rods at the lower limit (≈$5.85 subcritical). The key switch was on with air applied to the transient rod (total worth of the transient rod ≈$3.00).

Background:

With our console, the control and monitoring software was developed using a high level block language. The available blocks can be linked, much like analog electronic components are connected, to perform the desired function. The blocks are software subroutines that are linked with calls and transfers of data. Once the blocks are linked with source code and compiled, that particular compilation of the system is fixed until a software change is needed that requires a different arrangement of the blocks. Each block has within its subroutine the capability of being changed a limited amount by making tuning parameter changes. These can be made after the the software has been compiled. As an example, there is a block called a limit block (LIM) that passes the input to the output without change as long as the input is within the upper and lower limit parameters. If the input is greater than the upper limit parameter the output will be equal to the upper limit parameter. If the input is less than the lower limit parameter the output will be equal to the lower limit parameter. To change the limits of the LIM block the limit parameters of the block can be changed by entering the software maintenance mode. Tuning parameter changes can be made without compiling the software again.

The Electronic Designer was performing checks of the tuning parameters in the rod drive portions of the control and monitoring software of DCC-X. He had verified that a parameter (ratio/bias block gain) that converted the rod velocity from inches per second to revolutions per second was wrong. This parameter was erroneous because the gear ratio of the drive mechanism was changed, during the installation, after the Factory Acceptance Test (FAT) and the initial Site Acceptance Tests (SAT) had verified the initial design specification. The effect of this parameter on operation was moot because the actual physical parameter, inches/second, was measured by operating the drive mechanism and timing the drive displacement. After installation the measured value was acceptable in terms of control and Technical Specification requirements and was therefore not compared to the program data value (rod velocity in inches/second). It is possible to display the program data value as a time trend but it is not normally displayed to the operator or used in day to day operation.

When the ratio/bias block gain was found to be wrong a determination of the correct value was made. This was done by withdrawing the full 15 inches of the transient rod while counting the revolutions. The facility change procedure (AP-13) was initiated to make the parameter change to correct the ratio/bias

gain and rod velocity program data value while maintaining the measured physical rod velocity at its previous value. The new ratio/bias gain and the change was verbally verified and approved by the Manager of Engineering Services (there is at present no formal independent verification process called for by AP-13). AP-13 required post change verification and validation (V&V) by appropriate Check and Calibration Procedures (CCP's) but there was no requirement for intermediate or process V&V for such a perceived simple change. Those staff involved were the most knowledgeable of the system but they did not anticipate any need for additional intermediate V&V requirements. They were not cognizant of the fact that the process of change could create an unanticipated result.

To enter the software maintenance mode to make parameter changes, there are two security checks. First the key switch must be on operate and, second, the proper password must be entered. There is no requirement that all scrams be reset or in this case no need for air to be applied to the transient rod. Having just completed the measurement of the physical velocity of the transient rod the air was applied and it was not removed (scrammed) prior to the initiation of the software tuning change. It was not anticipated that the rod would move, even with intermediate errors, during the change, therefore it was not determined that unlatched rods (de-energized scram bus) was a required precondition.

Error #1:

After the successful change of the ratio/bias gain, an input error was made during the change of the limit block upper and lower limit values. The LIM block output is the input to the ratio/bias block. A change of this block was necessary to compensate for the now altered input from the ratio/bias block. Since the same limits on the physical rod velocity were desired, the limits had to be changed by the inverse of the ratio/bias gain change.

Error #2:

The new parameter values are entered by typing in the new values and hitting the enter key. The new parameter values are not saved to disk or placed into the running software until the entered values are defined (by pressing the F3 function key). Comfortable in the knowledge that the post change V&V would ensure the proper result and due to the operator automatic response to define the change (much as a typist automatically adds a space after each word), the erroneous input was defined without verifying the entered values.

Event:

The operator entered the lower limit of the LIM block as 1.13 inches per second. It should have been - (negative) 1.13 in/sec. The upper limit was entered as 0.354 in/sec which was the correct value. The operator automatically defined the entered values. The software was written to not allow the lower limit to be greater than the upper limit and automatically changed the upper limit to 1.13 in/sec after the values were defined. The defined values became: upper

limit =1.13 in/sec and lower limit =1.13 in/sec. This effectively defined the LIM block such that no matter the input the output would be 1.13 in/sec. At that time and during the entire event the input was zero because no velocity was demanded by the manual rod up/down switches and because a software interlock prevents rod motion by demanding a zero velocity when the core/rod mimic is not showing on the DCC-X CRT. Since the output of the LIM block goes directly to the motor block the 1.13 in/sec velocity demand was sent to the motor controller and the motor started withdrawing the transient rod at that speed. The system does have an over speed trip set at 4.5 rev/sec (1.13 in/sec corresponds to 4.52 rev/sec) and the transient rod scrammed. By looking at the historical data after the scram, it was determined that the transient rod drive withdrew to end of travel but that the rod bottom switch was reversed (indicating that the transient rod was fully inserted) when the transient rod drive was at 2.92 inches. 2.92 inches corresponds to 43¢ transient rod worth. The actual position of the transient rod was (2.92 in-scram time (sec) X 1.13 in/sec), somewhat less than 43¢, probably ≈25¢. The rate of reactivity insertion was no greater than 17¢/sec.

An event evaluation procedure (AP-4) was completed. The AP-4 requires the evaluator to notify the appropriate personnel, investigate the event, determine the cause and obtain the required approvals before starting the reactor. After the cause of the event was determined, the AP-13 was completed and V&V'ed. It was considered more appropriate to close out the AP-13 than to leave it in some intermediate condition or return to the previous condition. The tuning parameter changes were made with the scram bus de-energized to ensure that the reactivity insertion would not be repeated.

Analysis:

The reactor safety and automatic shutdown was completely operational during the entire event.

Even though the reactor was shutdown (≥ $5.40 subcritical) during the entire event (shutdown by the Technical Specification definition) it was an unanticipated reactivity change of 43¢.

With a variation in the keyboard error, such as entering ≤1.1 in/sec as the lower limit (4.4 rev/sec), the over speed scram would not have occurred. Since the reactor was ≥ $5.85 subcritical and the total worth of the transient rod is $3.08 no other scrams would have occurred. It would have been an inadvertent reactivity change of ≥ $1.00. However, the reactor would have remained shutdown (> $2.70 subcritical).

The use of the AP-13 procedure in its present form for software tuning changes was based on the assumption that post change V&V was sufficient for simple changes. More extensive software changes were performed with an additional approved written procedure. All software tuning changes are recorded in the AP-13 and in a software change log. A procedure that asks guiding questions may be helpful in determining the appropriate process and V&V. Unfortunately, prior to this event no one on the staff may have anticipated the appropriate guiding questions to ask for this particular case.

There was a failure to realize that the process or sequence of the software tuning changes may be important to consider in the approval and V&V of a change.

There also was a failure to realize that if the consequences of each intermediate step in a given change are not fully understood the system must be rendered incapable of changing the state of the reactor (such as de-energizing the scram bus). If a scram had been active prior to the change, the movement of the transient rod drive without the attached rod would have been of no consequence.

The characteristics of the LIM block that allows it to alter the typed input to "acceptable" values without rejection of the defining process or a warning was not fully understood by the staff. Other software blocks in Protrol ™ reject irrational parameter changes and issue a warning message. If that had been true for the LIM block or its peculiarities more fully understood, the event may not have occurred.

The event was not cause by software or hardware error or failure. The system performed as designed.

This event occurred because of a combination of (1)operator errors and (2) procedural controls that did not adequately aid the staff in the analysis and approval of a software tuning change.

Immediate Corrective Action:

The Director of the facility was notified and he gave approval for the startup of the reactor on October 6, 1992. The Director called Alexander Adams of the Nuclear Regulatory Commission and described the event to him. Until further notice the Director has placed a moratorium on tuning parameter changes. The event was described and explained to the licensed operators in a staff meeting on October 8, 1992. On October 6, 1992 the event was described to the Penn State Reactor Safeguards Committee at a previously scheduled meeting. They determined that the staff had acted correctly and they wished to be informed of further developments and the final resolution. The staff is in the process of determining the long term corrective action.

Gilbert Raiskums of AECL, Mississauga, Ontario was informed of the event by telephone and FAX on October 6, 1992.