Criscione, Lawrence

From: Criscione, Lawrence
Sent: Wednesday, October 20, 2010 8:08 PM
To: Beaulieu, David
Subject: Input based on today's discussion
Attachments: IN Reactivity - discussion suggestions.pdf

Dave,

Here's the input you requested today. My opinion is that it is a little on the long side, but I am having trouble determining what to trim.

I am free most of the day tomorrow if you want me to come by and help you whittle it down. If you'd prefer to take a stab at it yourself, that's fine with me too. Just let me know if you need anything.

Thanks,

Larry

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3/21

The causes of the event included failure to follow the NI calibration procedure, miscommunication between the I&C technician and the reactor operator, failure to conduct a pre-job brief, and lack of supervisory oversight. Additional information is available in "Arkansas Nuclear One—NRC Integrated Inspection Report 05000313/2010003 and 05000368/2010003," dated August 5, 2010 (ADAMS Accession No. ML102180209).

BACKGROUND

The following are related NRC generic communications:

- NRC IN 92-39, "Unplanned Return to Criticality during Reactor Shutdown," dated May 13, 1992, discussed events involving unplanned returns to criticality caused by the cooldown of the reactor coolant system during reactor shutdowns (ADAMS Accession No. ML031200314).

- NRC IN 96-69, "Operator Actions Affecting Reactivity," dated December 20, 1996, highlighted several events in which poor command and control during reactivity evolutions have led to unanticipated and unintended plant conditions (ADAMS Accession No. ML031050475).

DISCUSSION

One of the most important responsibilities of an on-duty licensed reactor operator and senior reactor operator is reactivity management in order to maintain the reactor in the desired condition, consistent with plant technical specifications, by properly anticipating, controlling, and responding to changing plant parameters. Reactivity management involves establishing and implementing procedures for operators to use in determining the effects on reactivity of plant changes, and to operate the controls associated with plant equipment that could affect reactivity. Although there is no specific NRC requirement, before conducting planned evolutions involving reactivity changes (e.g., power decreases and increases), many licensee reactor engineering staffs prepare a reactivity management plan that helps control room operators maintain the reactor in the desired condition by providing expected plant responses and expected alarms. Required training is expected to give licensed operators an understanding of facility operating characteristics during steady-state and transient conditions, including causes and effects of temperature, pressure, coolant chemistry, and load changes, as well as, operating limitations and their bases. Licensee post-transient reviews are important for determining the cause of transients or unexpected plant responses and for taking corrective actions, such as procedure changes and training, to prevent recurrence.

During the October 21, 2003 down power at Callaway Plant, the operators did not recognize that the negative reactivity inserted by the buildup of xenon was being compensated for by the positive reactivity inserted from the lowering reactor power (i.e. negative power coefficient of reactivity) and the programmed lowering of average coolant temperature. Because of this compensation, in the hours before the temperature transient the operators were not having to dilute in order to compensate for xenon buildup but instead were having to occasionally insert control banks. When the operators attempted to stabilize reactor power at approximately 10%, the continued build up of xenon was no longer being compensated for by the 10%/hour load decrease and as a result the reactivity balance was met by an unanticipated steady drop in reactor coolant temperature. A well written Reactivity Management plan could have focused the operators on the possibility they would need to substantially increase their frequencies of dilutions and rod withdrawals once the constant load decrease was ceased.

During ~~one of the events discussed above~~the October 21, 2003 shutdown, after the reactor became subcritical through xenon buildup and a reactor coolant temperature increase, operators delayed inserting control rods to establish adequate shutdown margin for nearly 2 hours. NRC IN 92-39 discusses an event in which, after the operators brought the reactor subcritical by inserting control rods, an inadvertent unplanned return to criticality occurred because operators delayed actions to continue inserting control rods while changing shifts. Although not specifically required, licensees may revise procedures and train operators so that, after the reactor becomes subcritical, the operators will proceed without delay to establish adequate shutdown margin by inserting control rods or adding boron.

Normally during power operations reactor operators are not required to directly respond to reactivity changes. Changes in core reactivity are passively responded to (i.e. without operator action) by average coolant temperature changes. The operator conducts active reactivity manipulations (e.g. rod withdrawals and dilutions) to maintain temperature and relies on passive temperature changes to maintain the reactivity balance. That is, the operator is normally able to rely on the inherent stability afforded by temperature-reactivity feedback to maintain the reactor critical. When this inherent stability is not present, reactor operation is substantially more difficult for now the operator can no longer rely on temperature changes to passively maintain the reactor critical and instead must use active reactivity manipulations to directly respond to both anticipated and unanticipated changes in core reactivity. Operation of the reactor with a positive moderator temperature coefficient is an example of when the operator might be challenged due to the absence of temperature-reactivity feedback. Another example is operation of the reactor in MODE 2 descending. Low in MODE 1 (typically between 5-10% rated power but varies with reactor type, core age, power history, etc.), the non-fission heat rate is a substantial enough fraction of total power that it begins to degrade temperature-reactivity feedback. That is, as fission power lowers, the non-fission heat rate dampens the response of reactor coolant temperature and hence retards the inherent reactivity feedback that comes from having a negative moderator temperature coefficient of reactivity. This degraded temperature-reactivity feedback worsens in MODE 2 descending as fission power lowers towards the point of adding heat and total power approaches the non-fission heat rate. Note that these effects are not typically as pronounced during MODE 2 ascending due to less decay heat. Also, during MODE 2 ascending, transient xenon is typically either negligible or lowering.

On most commercial reactor plants the controls are not human factored for operating at low reactor power levels. Intermediate Range Nuclear Instruments are the only accurate indication of fission power near and below the point of adding heat and these instruments are human factored for MODE 2 ascending (i.e. reactor startup) when the operator deliberately transitions the reactor through several decades of reactor power. While trying to maintain the reactor critical in MODE 2 descending, the logarithmic scaling of the IRNIs and the read out in ion chamber amps (ica) is a hindrance to the operator who must maintain reactor power in a narrow range typically defined in percent rated reactor power and not ica. Primary calorimetric instruments (e.g. ΔT meters) are usually the most accurate indication of reactor power throughout MODE 1, however as fission power approaches the point of adding heat these instruments asymptotically approach the non fission heat rate. Secondary calorimetric computer points and instrumentation are similarly skewed as reactor power lowers. Due to moderator shielding effects, the Power Range Nuclear Instruments are biased low during low power operations. As the point of adding heat is approached, these instruments asymptotically approach a level dictated by the amount of decay gammas striking the instruments. Although the PRNIs, primary calorimetric and secondary calorimetric meters are all human factored for maintaining rated reactor power bands (i.e. they are scaled in percent rated power), none of these instruments are accurate indicators of fission power in MODE 2 descending.

Because of the factors discussed above (degradation of temperature-reactivity feedback at low power levels, human factoring of the control board instrumentations, variability of inherent passive responses to transient xenon) it is recommended that operation of commercial reactor plants at low reactor power levels be avoided. Providing operators with procedural guidance for maintaining reactor power at a high enough power level to avoid degradation of temperature-reactivity feedback is a recommended measure for lowering the likelihood of operator errors which result in unplanned passive reactor shutdowns. Although an unplanned passive reactor shutdown in and of itself is inherently safe, it jeopardizes reactor safety in that if it is unrecognized by the operators it is possible for it to lead to an unplanned reactor restart and a challenge to reactor protection systems.

CONTACT

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below or to the appropriate Office of Nuclear Reactor Regulation project manager.

Timothy J. McGinty, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Technical Contact: Geoffrey Miller
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Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under Electronic Reading Room/Document Collections.