E U R E K A:
SUCCESSFUL IMPLEMENTATION OF POWER SUPPRESSION TECHNIQUES IN LOCATING INCORE FUEL LEAKERS DURING LOW-POWER OPERATION

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ABSTRACT

This summary provides a synopsis of an unwitting attainment of the Kuosheng “station nuclear engineers” (SNEs) who tried their hands for the very first time at the so-called “power suppression techniques” (PST) to locate failed fuel during reactor operation. For one thing, the test was conducted under an unconventionally low-power condition imposed by the regulatory authorities. Nevertheless, the undeterred Kuosheng SNEs succeeded in predicting the location of the suspected leaker, drawing only on their in-house capabilities and support. This example also deomonstrates that a PST conducted in an unorthodox, yet systematic, manner can still provide a sound basis for informed decision over continued plant operation at issue.

Power suppression testing (or, alternatively, flux tilting) has been accepted by many nuclear utilities as a valuable aid for on-line management of failed fuel. Once located by the PST, the leaker’s impact on continued reactor operation can be minimized by inserting one or more adjacent control rods to suppress local power levels and impose ramp rates associated with the leaker. Essentially, this method is simple in concept but rather tedious to implement in practice. In fact, insightful engineering judgment (or, art of guesstimation) plays a significant role in a successful PST exercise.

Conventional wisdom held that core power levels between 50% and 65% of rated power should provide an appropriate condition for performing the PST. This popular criterion was determined based on two competing considerations: (1) to prevent local power from rising above a stipulated operating envelope, and (2) to perform the test at a level where the control rod-induced activity changes can be detected. However, operating experience also showed that PST exercises were not always successful due to (1) an incomplete testing program, and/or (2) uncertainties in off-gas radioactivity data. Thus, until this case in point was performed at Kuosheng, a PST performed at a power level below 50% rated had been rarely, if ever, heard of, and none under 25% reported.

By all odds, the Kuosheng SNEs might as well consider a well-nigh unthinkable idea pioneering the PST at a power level of only 23.5% rated. Indeed, it was literally forced upon them by several factors, technical and otherwise, that converged altogether unexpectedly. Briefly, the whole episode began with a sudden fuel failure event while the reactor was operating in full-power conditions. Reactor shutdown was necessitated by the offgas post-treatment Hi-alarm that had persisted during the course of the graded power reduction. The persistent radiation levels were, in turn, identified as a direct effect of the ill-performing charcoal beds upstream of the post-treatment filters.

The timing of this unscheduled shutdown was inopportune because it was right in the middle of a period of peaked demand for electricity. A contingency plan for exercising the PST procedure was drawn up, with the first strategic target set to raise the reactor power to a level as high as to what the offgas system could still cope. Unfortunately, faced with pressures from the mass media, the regulatory authorities mandated that the reactor power level not exceed 30% rated before the charcoal bed performance problem could be resolved. Accordingly, the station management further instructed to maintain the reactor power below 25% rated until the load-dispatcher would permit extended shutdown for tackling problems with the offgas charcoal beds.

In spite of these unfavorable circumstances, the Kuoshang SNEs determined to follow out the PST exercise as part of the amended contingency plan. Reactor startup and power ascension was conducted at a slow pace, with extra precaution given to avoid triggering the offgas Hi alarm. In particular, during power ascension, one control rod at a time was withdrawn from position 12 to full-out (i.e., position 48), with the next withdrawal scheduled at least one hour later. This seemingly overly-cautious tactic turned out to be a blessing in disguise, for the hour-long period between two control rod movements facilitated core conditions to stabilize more completely. In addition, relatively meaningful data were possible to come by thanks to two plan-specific features: (1) on-line offgas radioactivity indication and (2) on-line sampling of reactor coolant activities.

As one particular control rod was withdrawn that raised reactor power to 232.5% rated, a barely notable increase in offgas radioactivity caught the attention of one of the authors (J.F. Chen). That control rod was maneuvered again to confirm its effect. This “fluke” finding greatly inspired the minds’ eyes of the authors’ in refining the scheme for selecting candidate control rods to be tested. Each candidate control rod selected was systematically tested as per the standard PST procedure.

As a result, 40 control rods out of a total 145 were tested. Putting all the data together in perspective, followed by brainstorming on a technical basis, the authors were able to identify three most likely locales for further verification. These three locales finally came down one “supercell” which enclosed eight fuel bundles including the suspected leaker as well as two control rods. This prediction was strikingly borne out at the first sip of the incore sipping task that was brought to pass two weeks later in response to persistent public concern for offsite radioactivity leakage.