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Thomas A. Marlow
Director, Nuclear Safety Assurance
ANO

1CAN010603

January 6, 2006

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: Supplement to Amendment Request
Revision of the Allowable Value for Emergency Feedwater Initiation and Control Function (EFIC)
Arkansas Nuclear One - Unit 1
Docket No. 50-313
License No. DPR-51

REFERENCE: Entergy Letter dated January 3, 2006, *Request for Emergency Technical Specification Change to Revise the Actuation Allowable Value for Emergency Feedwater Initiation and Control Function (EFIC)* (1CAN010601)

Dear Sir or Madam:

By letter (Reference 1), Entergy Operations, Inc. (Entergy) proposed a change to the Arkansas Nuclear One, Unit-1 (ANO-1) Technical Specifications (TSs) to the Steam Generator (SG) Level – Low allowable value of Limiting Condition for Operation (LCO) 3.3.11, Emergency Feedwater Initiation and Control (EFIC) System Instrumentation.

On January 5 and 6, 2006, Entergy was notified by your staff that additional information with respect to the above subject was desired. As a result, 14 questions were determined to need formal response. Entergy's response is contained in Attachment 1.

There are no technical changes proposed. The original no significant hazards consideration included in Reference 1 is not affected by any information contained in the supplemental letter. There are no new commitments contained in this letter.

If you have any questions or require additional information, please contact David Bice at 479-858-5338.

A001

I declare under penalty of perjury that the foregoing is true and correct. Executed on January 6, 2006.

Sincerely,

Thomas A. Marlow

TAM/dbb

Attachment 1: Response to Request for Additional Information

Enclosure 1: EFIC System Loop Error and Setpoint Analysis

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Attachment 1

To

1CAN010603

Response to Request for Additional Information

Response to Request for Additional Information Related to Revision of the Allowable Value for Emergency Feedwater Initiation and Control Function (EFIC)

Question 1 (EICB-1):

Licensee has indicated that some aspects of the analysis of the phenomenon in question are not yet completed. Please confirm that all aspects of the setpoint-related analysis, including establishment of the level value assumed in the system dynamic analysis and including all aspects of the instrument uncertainty analysis, have, in fact, been completed and that the referenced letter (including all attachments) correctly represents the results of those analyses.

Response 1:

The Entergy setpoint calculation that was revised in support of the ANO-1 EFIC low level setpoint and time delay is complete (see Enclosure 1). During preparation for field implementation of the change for the new setpoints/time delay, a pre-existing condition was identified that field test surveillance procedures were not in full agreement with the original setpoint calculation (surveillance procedures did not explicitly verify calculation uncertainty allowances). Entergy has assessed the conditions potential impact on this proposed Technical Specification (TS) change request and subsequently determined that the proposed setpoints / TS change remain acceptable as originally submitted to the NRC. All necessary analyses to support the TS change request are complete and reflected in the January 3, 2006 submittal.

Question 2 (EICB-2):

With the control setpoint substantially above the actuation setpoint (31 inches vs something less than 10.4 inches), EFW will be initiated with a significant initial control error. This condition also exists with the present settings, but the initial control error is less. This larger error could lead to a larger damped oscillation in the level, or to a longer time required to approach the control setpoint if the control law and settings are such that there is no oscillation. Show whether and why the control loop is underdamped or overdamped, and that the resulting oscillation (both magnitude and period) or increased approach time is acceptable. If the control loop and settings are not directly included in the dynamic model used to evaluate the requested TS change, explain how it is ensured that the results are not adversely affected by them. If the control loop and settings are included in the dynamic analysis, explain how it is ensured that the assumed controller settings are, in fact, enveloped by the actual equipment settings. These considerations do not appear to be addressed in the timing discussion in the second paragraph of the "Technical Analysis."

Response 2:

The EFIC Control Modules are proportional plus integral controllers and, during normal power operation, maintain their associated flow control valves fully open by keeping the control integral at its maximum value with a preset bias error. The Control Modules remain in this state until released to control by an EFW actuation signal, at which time the bias is removed. Since the Control Modules are normally biased to their maximum integral value, keeping the control valves fully open, any difference in initial level upon receipt of an actuation signal will have no significant impact on the response of the control system.

In order to compensate for the integral bias, the Control Modules are tuned for under-damped operation with a quarter-wave decay ratio. The loop control constants are set to maintain stable EFW flow and result in a single level overshoot and undershoot over approximately six minutes, followed by stable level control. The magnitude of the level overshoot and undershoot is approximately twenty inches and five inches, respectively, with EFW flow remaining stable after pump starting transients. Since the EFW nozzles spray directly onto the SG tubes, stable EFW flow is more critical than SG level and the control system response closely matches the analysis assumptions of stable flow after initiation.

The RELAP5 calculation models the actual thermal-hydraulic conditions in the system. The steam generators (SGs) dry out near the time Emergency Feedwater (EFW) initially reaches the tubes. EFW flow will continue until the level in the SG tube region reaches 31 inches. For this analysis, a SG level does not develop until after the analysis is terminated at 1000 seconds. The EFW spray starts to remove more heat from the reactor coolant system (RCS) than is generated through the combination of decay heat and the reactor coolant pumps (RCPs) at about 500 seconds as the RCS starts to cool down. Modeling of the control system with an overshoot/undershoot of as much as 31 inches would have no effect on the results of the analysis, since level restoration does not begin until after the event calculation is terminated and well after the point where EFW is starting to cool the RCS.

Question 3 (EICB-3):

The submittal appears to assume a complete loss of normal feedwater together with complete isolation of the FW inlet port. It seems that a partial loss of feedwater could also result in a need for EFW, and that FW leakage could result in reverse flow through the adjustable orifice and therefore a high bias in the level measurement.

a. *With a partial loss of FW, the level could conceivably attain a value below the assumed control minimum but above the actuation setpoint. Thus core cooling could be insufficient but EFW not invoked.*

b. *With FW leakage, flow-induced bias in the level measurement could delay initiation of EFW, resulting in an extended period of time with inadequate core cooling.*

Please show that these possibilities either are not credible or are irrelevant.

Response 3:

As the secondary fluid is boiled in the tube region, a two phase mixture is formed. The mixture swells to near the aspirator port. The aspirator port connects the tube region to the downcomer and effectively establishes a manometric pressure balance between the two regions. A liquid level is established in the downcomer region which compensates for the pressure loss through the tube support plates. Therefore, any liquid added via normal feedwater will tend to raise the level in the downcomer resulting in a downward flow direction. The orifice plate resistance is to provide stability and does not affect the flow direction. Therefore, reverse flow through the orifice plate will not occur while MFW flow is being provided.

Any postulated feedwater leakage event that could possibly result in reverse flow would also result in depressurization of the SG. In such an event, EFIC is actuated on low SG pressure and will isolate the affected SG and feed only the intact SG. There is no reliance on the EFIC Low Range level transmitter for this condition.

The RELAP5 analysis that was performed assumes that normal feedwater is completely lost after 7 seconds, simulating a fast coastdown of the main feedwater pumps. The complete loss of feedwater yields the worst-case response of the system for the Safety Analysis Report (SAR) acceptance criteria of peak RCS pressure and minimum DNBR. A partial loss of feedwater would result in less severe conditions. The RCS would heat up at a slower rate. The reactor would still trip on high pressure, but with a slower pressure ramp resulting in a lower peak RCS pressure.

Question 4 (EICB-4):

The dynamic analysis appears to be based upon an assumption that EFW will be initiated with at least 6 inches of water in the OTSG. This would suggest that that 6-inch value refers to actual water level, not to the measured value. The 4th paragraph of the "Technical Analysis" refers to this as an "indicated" value. We take this reference to be in error, with the intent being to reference the "actual" value rather than the "indicated" value. This is significant, because an "indicated" value would include measurement error, whereas an "actual" value would not. We take this 6 inches to be the Analytical Limit (assumed actual value without allowance for uncertainty) to be invoked in the instrument channel uncertainty analysis used to establish the Setpoint-Related TS requirements. Please confirm.

Response 4:

As correctly characterized in other sections of Attachment 1 to 1CAN010601 (Reference 1), the statement contained in the fourth paragraph under Section 4.0, Technical Analysis, is representative of the analytical value which was assumed in the analysis. This statement should therefore have been "...assumed to actuate at 6 inches ..." (the term 'indicated" is deleted from this phrase) and does refer to "actual" level. As a matter of further clarification, the proposed allowable value and trip setpoints for the SG Level – Low function in the setpoint uncertainty calculation are based on having an actual trip at 6.5 inches for added conservatism.

Question 5 (EICB-5):

Please explain how the 6-inch water level value assumed in the dynamic analysis relates to the actual 2-phase conditions surrounding the OTSG tube bundle. Is this the top of the water froth? The top of the region of solid (single-phase) water? The top of an equivalent column of condensed water? It seems unlikely that there would be any condensed water present at such very low water levels. How is the measured value of the water level related to actual conditions in the interior of the OTSG?

Response 5:

RELAP5/MOD2-B&W was used in the system analysis. The calculation determines the fluid conditions in the SG tube and downcomer regions during the transient. The actuation of EFW was based on the calculated collapsed liquid level in the tube region. This level is calculated by multiplying the local liquid void fraction times the height for each of the control volumes that represent the tube region and adding the products at each time step. This value is then compared to the trip setpoint to determine when EFW would be actuated.

Once feedwater flow is stopped, the SGs evolve to essentially a boiling pot and a manometric balance is established between the downcomer region and the tube bundle. The reactor is tripped on high RCS pressure because of the loss of heat transfer. However, the RCPs continue to circulate water through the SGs and the combination of residual core decay heat and the energy input by the RCPs continue to boil off SG inventory. The liquid in the downcomer continues to replenish the inventory in the tube region until the level drops below the orifice plate. Up to this point the collapsed level in the downcomer was greater than in the tube region. After this time, the levels and fluid condition in the tube region and the downcomer are nearly the same. Therefore, the calculated value in the safety analysis should match the actual SG level.

Question 6 (EICB-6):

Please provide the uncertainty analysis for the subject instrument channels, showing the derivation or source of the Analytical Limit, limiting setpoint, As-Left setting tolerance, As-Found acceptance criteria, and Analytical Limit. If the analysis relies upon supporting information from other analyses, it may be necessary for us to see those supporting analyses as well and therefore it may be advisable for the licensee to include them in the submittal.

Response 6:

The loop error and setpoint calculation [80-D-1083C-01 DRN-05-3577] supporting the proposed changes is included in Enclosure 1 of this submittal.

Question 7 (EICB-7):

The proposed TS Bases for SR 3.3.11.2 presents the acceptance criteria band as ±1.08 inches, but does not specify the center of that band. Please confirm that this band is centered upon the previous As-Left setting, or specify and justify an alternative reference point.

Response 7:

The acceptance criteria band of 1.08 inches is centered on either side of the limiting trip setpoint of 10.42 inches. Therefore, the lower limit of the acceptance band is at 9.34 inches (allowable value) and upper acceptance band will be 11.5 inches. The determination of the acceptance band is further discussed on pages 221, 257 and 258 of the attached setpoint calculation.

Question 8 (EICB-8):

Please provide more detail on comparative analysis that was done to address this concern during the pre-operational phase of design/engr./installation. Documented descriptions of analyses and results would be appreciated.

Response 8:

EOTSG Orifice Design Philosophy

The original Once-Through Steam Generator (OTSG) orifice plates were only practically adjustable between fully closed (0% open) and 25% open. Operating at greater than 25% open resulted in excessive OTSG instability. In an effort to provide more adjustability of the Enhanced OTSG (EOTSG) orifice plates while maintaining stability, the design value of the radial gap between the plate outer diameter (OD) and shell inner diameter (ID) was reduced from 3/4" to 5/8". Thus, for the same total orifice flow area, the EOTSG adjustable plate would be open to a larger area than the original OTSG plate.

As discussed in Reference 1, the orifice plate was set such that the operate range would be similar to that of the OTSG. When unfouled, the OTSG operate ranges were on the order of 55% to 60%. The operate range level indication gradually increases as the tube support plates foul and their unrecoverable pressure losses increase. The minimum required operate range level was 50% (to meet the LOFW limit) and the maximum desired operate range level was 80% (to provide operating margin to flooding of the aspirating port when level increases as fouling occurs). It is also known that density wave instability will occur in OTSGs if the orifice plate differential pressure (ΔP) is too low compared to the two-phase ΔP occurring inside the tube bundle. Based on minimizing the potential of being less than the 50% loss of feedwater (LOFW) limit, being unstable at lower levels, or losing operating margins if greater than 80%, an operate range of 65% was selected as midway in the target range. In addition, the 65% target value provides calculated stability ratios that are greater than those of the OTSG. With the orifice plate setting established to control the operate range level, the effects on EFIC indicated level were then evaluated.

EOTSG Level Predictions

The RELAP5 thermal hydraulic computer code was used to model the OTSG and EOTSG. OTSG plant startup and operate range level data was used to benchmark the OTSG model and the EOTSG changes were incorporated into the OTSG to form the EOTSG predictions, as shown in Figures 1 and 2. Data from the EOTSG at 98% power agree well with these predictions for startup and operate range.

RELAP5 predictions of the OTSG EFIC level did not match OTSG plant data effectively. This is attributed to difficulties in computing localized void distributions in unheated (non-boiling) regions such as the EFIC span rather than large heated regions that occur over the startup and operate ranges.

EFIC Level Calculations

As a result, EFIC level predictions for the EOTSG were performed on a comparative basis. The EFIC level basically senses the elevation head less the unrecoverable losses across the orifice plate. At low flow rates or when normal feedwater is lost, this indication becomes the elevation head since EFW is not fed through the downcomer. To predict the EOTSG EFIC levels, the OTSG EFIC level plant data were adjusted by the difference in EOTSG and orifice plate resistance (i.e., the increase in orifice plate resistance was subtracted from the OTSG data). As-built dimensions of the OTSG orifice plates were not available, and due to accessibility limitations to the orifice plates it was not practical to obtain them. Therefore, the OTSG/EOTSG adjustment employed the nominal design dimensions for the OTSG orifice plates and shell IDs and also assumed that the OTSG orifice plate was fully closed. Based on a relatively small difference in orifice plate pressure losses (based on design dimensions), only about a 10" difference in level was predicted at 100% power, as shown in Figure 3. With the margin between this predicted value and the EFIC setpoint to account for uncertainty, the results were deemed acceptable, considering the concern was margin to inadvertent actuation.

Question 9 (RSB-1):

Provide a comparison of pressure differential across the adjustable orifice between the original once-through steam generator (OTSG) and the replacement enhanced OTSG (EOTSG) based on the actual orifice settings, including the following information.

a. *Current actual setting of the adjustable orifice flow area and SG downcomer flow area.*

b. *Main feedwater (MFW) flow rate, aspirator flow rate, and the quality of the saturated MFW/aspirator flow mixture in the downcomer for the power level between 98% and 100%.*

c. *Estimated orifice pressure drop coefficient (based on the current orifice setting) and two-phase multiplier corresponding to the flow quality.*

Response 9:

EOTSG

The current orifice plate settings are 2.012 ft^2 and 2.019 ft^2 ft for EOTSG A and B (an area of 2.01 ft^2 was used in the following equations). The downcomer flow area is 25.22 ft^2 (downstream of the orifice plate). The form loss factor was calculated using the equation from Idel Chik's *Handbook of Hydraulic Resistance for an orifice.*

k = 1.58 relative to 2.01 ft^2

The main feedwater flow rate is 1500 lbm/s and the aspirator flow is 225 lbm/s. Thus, the flow through the orifice plate is 1725 lbm/s. The flow is assumed saturated with a density of 46.9 lbm/ft^3. Test data and TH models suggest that there is only 1 to 2% (quality) steam carryunder.

The unrecoverable pressure loss through the orifice plate at a flow rate of 1725 lbm/s and a density of 46.9 lbm/ft^3 is:

$$\Delta P = (W^2/\rho)(k/A^2)/2gc = (1725^2/46.9)(1.58/2.01^2)/(64.4*144) = 2.68 \text{ psid}$$
$$= 2.68*(144*12/46.9) = 98.7 \text{ inches of saturated } H_20 \text{ at } 46.9 \text{ lbm/ft}^3$$

<u>OTSG</u>

The orifice plates were assumed to be closed with a nominal peripheral gap of 0.75". Thus, the flow area is 2.24 ft^2 and the downcomer area is 22.00 ft^2 (downstream of the orifice plate). Using the same methodology and operating conditions (i.e., main feedwater flowrate, aspirator flow, and flow through the orifice), the form loss factor and unrecoverable pressure loss were calculated to be 1.81 relative to 2.24 ft^2 and 2.47 psid, or 90.9 inches of saturated H_20 at 46.9 lbm/ft^3.

Question 10 (RSB-2):

In Technical Analysis section, it is stated (4th paragraph on page 5) that "... Therefore, the minimum departure from nucleate boiling ratio will not change. Once the reactor trips, the DNBR will decrease and thus, no fuel failure will occur."

a. *Clarify this statement since fuel failure would occur as the DNBR continues to decrease below the DNBR limit, and also since the DNBR will increase sometime after the reactor trips because of emergency feedwater (EFW) mitigation functions.*

b. *Provide a figure of DNBR as a function of time for the analyzed loss of main feedwater (LOFW) event, Including an indication of the DNBR limit and the critical heat flux (CHF) correlation.*

Response 10:

The Technical Analysis section of Reference 1 was correct in noting no fuel failure will occur, however, the statement that "Once the reactor trips, the DNBR will decrease…" is in error. This sentence should have stated "Once the reactor trips, the DNBR will increase..." The DNBR increase is mainly due to reactor trip. The influence of EFW flow on DNBR is small as it doesn't occur until almost three minutes after reactor trip.

There is no explicit calculation of the DNBR during this transient because the core thermal conditions during the transient do not approach the limiting conditions for DNB. The transient begins with a loss of feedwater with no loss of offsite power. The RCS temperature and pressure begin to increase. The reactor trips on high RCS pressure at approximately 17 seconds. By this time, the core inlet temperature has increased by less than 3 °F while the RCS pressure has increased more than 200 psi. The RCS mass flow does decrease somewhat, but the RCPs continue to maintain forced circulation through the core. Since the change in core inlet temperature is so small, there is no appreciable increase in core power, even with a slightly positive MTC of $+0.13 \times 10^{-4}$ Δk/k/°F. The core remains more than adequately subcooled. As a result, there could be an initial small, but nonetheless insignificant, decrease from the initial DNBR. However, once the control rods begin to insert, the affect of the post-trip decrease in core power on the DNBR more than offsets any impact of the increasing RCS temperature during this event.

A set of steady-state DNBR calculations are performed for each new fuel cycle that establish a pressure/temperature limit for plant operation. These pressure/temperature points are established based on calculating a minimum DNBR at the statistical design limit for the fuel with a core power level at 112% of rated and using the minimum thermal design flow rate. These points define the variable low pressure trip setpoint described in the Core Operating Limits Report (COLR). As long as the coolant remains subcooled, the influence of pressure and temperature on DNBR will be small. The largest contributor is core power. As long as core power does not approach 112% of rated power and the RCPs remain operating, no specific calculation of DNBR is necessary to verify that the acceptance criterion is met. Based on the plot of core power for the LOFW event (Figure 10 of Reference 1), it is obvious that the core power level did not reach 112% of 2568 MWt. Therefore, no DNBR concerns exist for this event.

Question 11 (EICB-9):

Cite the specific pages in the calculation where the following are presented:

a. *Limiting Setpoint*

b. *Setting Tolerance (technician allowance for As-Left setpoint, without consideration of other errors)*

c. *Deviation Limit (amount by which the As-Found setpoint may differ from the previous As-Left setpoint)*

Response 11:

a. A & B Channels: Pg 221, presented as Calc. Setpoint = 10.42 inches (above LTS)
C & D Channels: Pg 257, presented as Calc. Setpoint = 9.53 inches (above LTS)
See Response #12 below for selection of most conservative setpoint for Tech Spec.

b. Presented as Device Tolerance (Dtol) for device SU1 = ±0.65% Span (±0.975 inches)
A & B Channels: Pg 200 for SU1 initial presentation, Pg 221 for presentation in Conclusion.
C & D Channels: Pg 250 for SU1 initial presentation, Pg 257 for presentation in Conclusion.

c. Presented in Conclusion as Test Error = [(RADtol^2 + CAL^2 + DR^2)^1/2] = ±0.721% Span (±1.08 inches)
A & B Channels: Pg 221
C & D Channels: Pg 257

Question 12 (EICB-10):

It appears to us that Section 5 of the calc applies to one set of EFIC level channels, and that Section 6 applies to another. Section 5 concludes (on page 221) that the limiting setpoint is 10.42 inches and Section 6 concludes (on page 257) that it is 9.53 inches. Since a higher setpoint is more conservative, licensee has selected 10.42 inches for all EFIC EFW initiation level channels. Please confirm.

Response 12:

The above observation is confirmed. Section 5 is associated with A & B channels, while Section 6 is associated with C & D channels. A & B channels have more signal conditioners than C & D channels, resulting in the larger uncertainty, setpoint, and allowable value. Entergy has conservatively selected the single higher setpoint and allowable value for the TSs.

Question 13 (EICB-11):

It appears that the setting tolerance as used by the licensee in this calculation does include reference accuracy, rather than being limited to the tolerance granted to the instrument technician. If that is the case, then permitting the As-Left setpoint to exceed the calculated value by this amount would be inappropriate because such a practice would, in effect, take the RA etc. back out of the Total Loop Uncertainty allowance. The TS reset requirement should therefore require reset to a value "no less conservative than the limiting setpoint" rather than permitting the As-Left value to exceed the limiting value by as much as the ST.

Response 13:

Entergy-ANO process guidelines typically apply reference accuracy (RA) within uncertainty calculations with calibration procedures required to have setting tolerances or calibration As-Left limits set accordingly (i.e. equal to or less than RA). As seen within the calculation for this application, a tolerance (Dtol = ±0.65% Span) has been allowed for slightly greater than the stated RA = ±0.539% Span. Calibration procedure setting tolerances or As-Left limits may be established less than or equal to the Dtol. Setting Tolerance (ST), as presented in this calculation, is simply the difference between the larger allowed calibration procedure setting tolerance / As-Left limit and the stated RA. With calculation tolerances and procedure tolerances established in agreement, the statistical confidence in protecting the process limit is preserved so long as the setpoint is established conservative with respect to the process limit by an amount greater than or equal to the calculation uncertainty.

Question 14 (EICB-12):

We find no analysis of the anticipated deviation in the setpoint over the interval between calibrations. Please explain how the value in the proposed TS was derived. We also find no analysis showing that the As-Found setpoint may be referenced to any value other than the previous As-Left value. Please provide these analyses, or confirm that the applicable procedures require assessment relative to the previous setting, and adjust the TS accordingly.

Response 14:

Anticipated deviation over time for instruments is presented as Drift (DR) within the calculation. As presented in the Introduction section(s) of the calculation, the statistical method of the Square Root of the Sum of Squares (SRSS) is used to determine the random error on a component level and for the loop. As-Left tolerances are as described in #13 above. As-Found tolerances are slightly larger than As-Left tolerances as they include allowance for DR (i.e. refer to #11.c above). Due to the statistical SRSS error combination method, As-Found tolerances are typically only slightly larger than As-Left tolerances (i.e. refer to slight difference between #11.b and #11.c above). As-Found values are not referenced back to the previous As-Left value as this would be a varying value dependent upon where actually calibrated to within the fixed As-Left band during the previous surveillance. Both As-Left and As-Found values must be within the fixed procedure bands which are centered about the required ideal target value. Measured values are to be dealt with in accordance with the proposed TS notes and TS Bases statements. For example, see the presentation below (relative to the subject procedure setpoint value) for a partial listing of typical requirements when found within the indicated regions:

Initiate CR for evaluation, Adjust back within As-Left
------12.080" As-Found
Adjust back within As-Left
------11.975" As-Left

------11.000" Ideal Target Value

------10.025" As-Left
Adjust back within As-Left
------9.92" As-Found
Initiate CR for evaluation, Adjust back within As-Left

------9.340" ALLOWABLE VALUE
Immediately declare Inoperable, Initiate CR for evaluation, etc.

Figure 1

EOTSG Startup Level Predictions

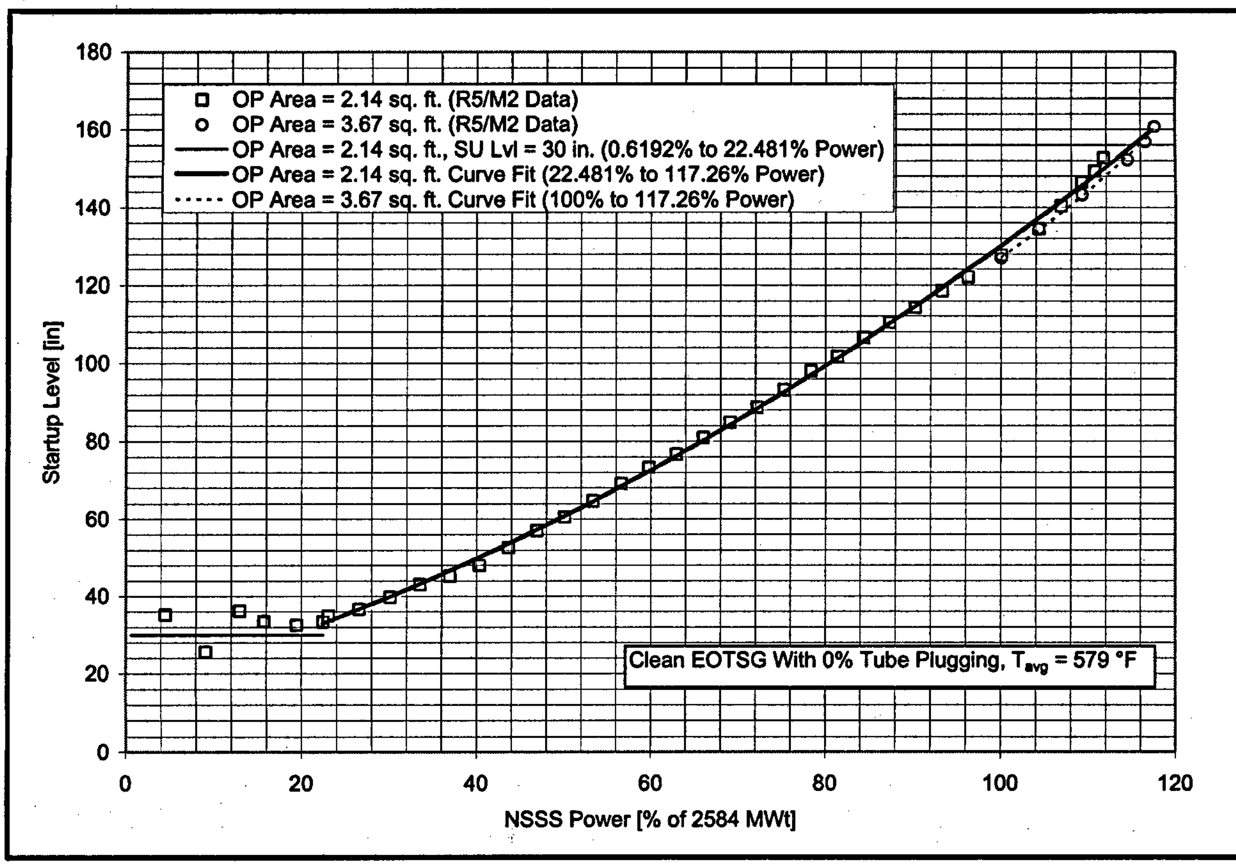


Figure 2

EOTSG Operate Range Level Predictions

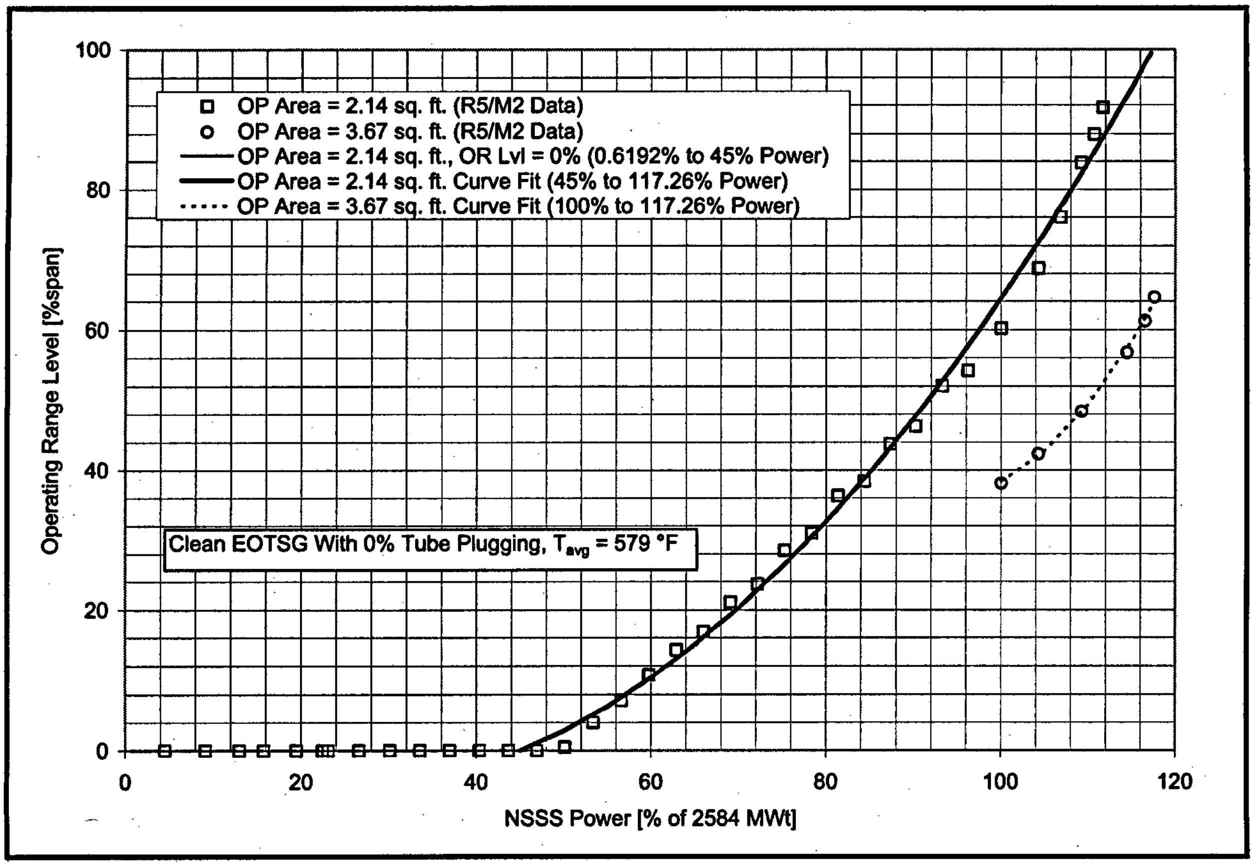
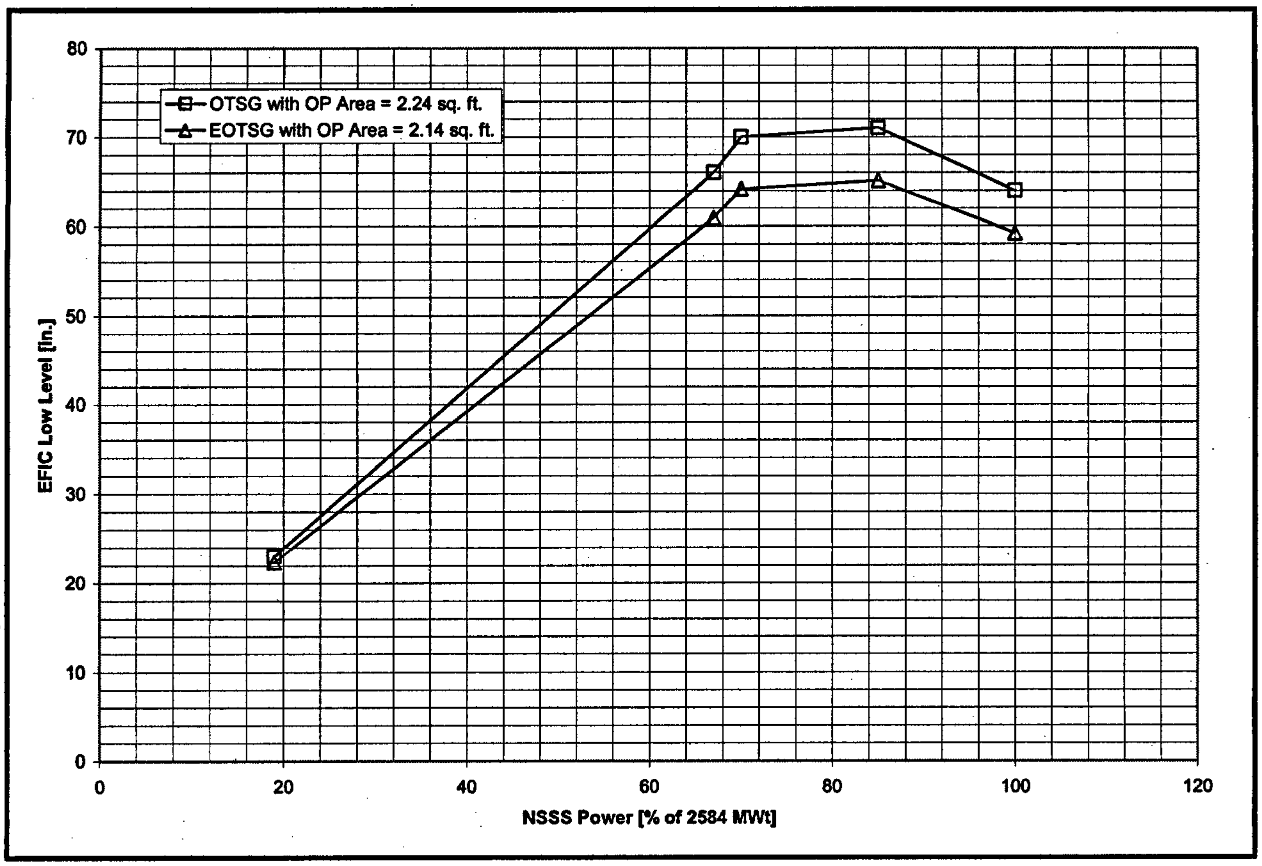


Figure 3

EOTSG/OTSG EFIC Level Predictions



Enclosure 1

To

1CAN010603

EFIC System Loop Error and Setpoint Analysis