PWROG

PWR Owners Group

Global Expertise • One Voice

PWROG-15060-P, “Pump Suction Gas Accumulation Operability Criteria Guidance ” Draft Safety Evaluation Review Meeting

Ken Schrader – PWROG Chairman

Steve Benesole – PWROG SEESC Chairman

Jim Andrachek- Westinghouse

Steve Swantner - Westinghouse

August 30, 2018

Westinghouse Electric Company LLC
1000 Westinghouse Drive
Cranberry Township, PA 16066, USA

Agenda

- Introductions and Introductory Remarks
- Objective of the meeting
- Background
- High Level Review of Draft Safety Evaluation
- Summary and conclusions
- Open Discussion

Objective

- Obtain agreement on the path forward for the issuance of a revised draft safety evaluation (DSE) for PWROG-15060-P that approves the methodology without any additional limitations

Background

- NRC issued FSE for NEI-09-10 in April, 2013
- The FSE for NEI 09-10 contained several limitations on the usage of WCAP-17271-P
- In June 2014, Farley Nuclear Plant received a URI regarding pump suction acceptance criteria that was based on the Purdue test data
- The PWROG met with the NRC in January, 2015 to discuss the Farley URI
- The NRC feedback was that adequate guidance was not available to address the limitations in the NEI 09-10 FSE
- The PWROG-15060-P contained this guidance and was submitted to the NRC in May, 2016
- The objective was to obtain NRC approval for the guidance contained in PWROG-15060-P

Background (continued)

- NRC RAIs were received in July, 2016
- PWROG met NRC to review RAI responses on July 14, 2016
- The NRC audited the technical basis of PWROG-15060-P in August, 2016
- The closeout report of the FNP URI (September, 2017) determined that PWROG-15060-P provided an adequate basis to address the NRC concerns regarding pump suction acceptance criteria
- The DSE for PWROG-15060-P was issued in June, 2018
- The DSE for PWROG-15060-P contains numerous limitations on the methodology and requires that additional judgment be used by the licensee
- The NRC did not give the PWROG an opportunity to address these limitations via the RAI process
- Satisfying those limitations and conditions would be subject to interpretations which obviate the objective of PWROG-15060-P

Technical concerns with DSE

- The DSE concludes:
  - TR Eq. 6-6 is valid only for $1.25 \leq N_{FR} \leq 1.75$
  - TR Figure 12-8 is an over-simplification and is unacceptable
  - TR Eq. 6-9 is unsubstantiated and unacceptable
  - The TR can only be used for past operability
- In several locations, the DSE indicates that justified judgments must be used in addition to the TR; The intent of the TR was to preclude or minimize licensee justification of the TR methodologies
- The DSE discussion on formation and growth of kinematic shock downstream of elbow is incorrect

Operability

- The DSE statements regarding operability are inconsistent
- DSE 1.0 Introduction
  - The NRC staff has determined that the topical report (TR) methodologies are acceptable when voids have been discovered that exceed the DB value during the time when the voids cannot be removed and the cause of the void formation is addressed. The TR methodologies have not been approved for determination of DB values. (DSE Page 8; Lines 19-22)
  - The methods are acceptable for operability determinations following discovery of a void subject to the limitations that (1) applicability is limited to evaluation of gas movement in pump suction pipes, (2) to determine if a system, although degraded, would have continued to perform its specified function, and (3) other limitations apply as addressed in this SE. (DSE Page 9; Lines 1-4)
- DSE 4.0 Conclusions
  - provides acceptable methods for past operability determinations to predict the volumetric flux (β) of a non-condensable gas at a pump inlet based on the gas volume at an upstream location. This enables licensees to develop acceptance criteria to be used in operability determinations and evaluations for allowable gas volumes in pump suction piping. (DSE Page 73; Lines 7-11)
  - is weak when addressing the location of a kinematic shock in a lower horizontal pipe that can affect a downstream pump; a condition that the NRC staff will accept as allowed for past operability determinations in NRC SE Section 2 but a condition that should be improved. The TR treatment of this condition was summarized as acceptable in SE Section 3.12. (DSE Page 73; Lines 13-17)

Pump Inlet Condition

- The DSE statements concerning the use of Table 3-2 are inconsistent.
- DSE Section 1.2
  - The TR Table 3-1 criteria are conservative. TR Table 3-2 from the Electric Power Research Institute (EPRI) Roadmap program (EPRI, August 2012) provides more realistic criteria. The difference between the TR Table 3-1 and TR Table 3-2 criteria may be credited as a conservatism when performing an operability determination if the TR Table 3-1 criteria are satisfied. (DSE Page 12; Lines 11-15)
- DSE Section 1.9.1
  - When a pump is located close to the elbow exit and is removing gas at the rate that gas is leaving the elbow, the NRC staff will accept an assumption that a kinematic jump will not occur in the lower horizontal pipe provided the rate at which gas enters the pump meets the TR Tables 3-1 or 3-2 criteria; the latter with a factor to account for potential non-conservatism. An acceptable factor is the difference between the TR Tables 3-1 and 3-2 criteria. (DSE Page 17; Line 41-48).
- DSE Section 3.9.4.1
  - The TR states that the pump operating flow rate and pump best efficiency flow rate should be applied to determine the allowable gas volumetric flux ratio from TR Tables 3-1 or 3-2 based on the applicable pump type. This is acceptable. The TR Table 3-1 criteria may be applied with no allowance for uncertainty. An appropriate safety factor typically equal to the difference between TR Tables 3-1 and 3-2 should be applied if the TR Table 3-2 criteria are used.

Chemical Effects

- The DSE states in four different sections that chemical effects need to be addressed. However, this subject was not raised via an RAI or during the technical audit.
- DSE Section 1.4
  - The TR did not address that reactor coolant system (RCS) water contains chemicals that may change the water flow characteristics yet the analysis methods are based on tests that used clean water. The NRC staff concluded the potential flow differences could be neglected on the basis of published regulatory guidance (NRC, January 31, 2014). However, the TR should be updated to address this topic. (DSE Page 14; lines 9-14)
- DSE Section 3.1
  - Existing tests have used clean water. Yet a typical PWR RCS uses water that contains chemical additives that may affect the flow characteristics. PWROG-15060 does not address this topic, a weakness that should be corrected. From this point in this SE, the assumption is generally made that the test data are applicable to the RCS, an assumption that is consistent with the SE Section 2 guidance. (DSE Page 21; Lines 18-32)
- DSE Section 3.5.3
  - The exception is the need to address the effect of chemical additives that are added to RCS water that is not addressed in the test results that were associated with the WCAP-17271 and WCAP-17276 gas movement methodologies and the development of DC size determination methods such as the factor of four criterion and TR Eq. 5-6. (DSE Page 42; Lines 16- 19)
- DSE Section 4.3
  - The TR did not address that RCS water contains chemicals that may change the water flow characteristics yet the analysis methods are based on tests that used clean water. The NRC staff concluded the potential flow differences could be neglected on the basis of published regulatory guidance (NRC, January 31, 2014). However, the TR should be updated to address this topic. ((DSE Page 74; Lines 8-12)

Kinematic Shock in Horizontal Pipe

- The DSE description of the formation and growth of a kinematic shock in the horizontal pipe is incorrect. Some examples are:
- DSE Section 1.9
  - Gas accumulates along the inside of the elbow and a shock is shown toward the left where the void fraction decreases and the void fraction flowing toward a pump located to the left of the sketch is effectively zero, less than occurring near the elbow. (DSE Page 17; Lines 4-8)
    - The gas flow rate to the left of the sketch is greater than the gas flow near the elbow, which is zero.
- Section 3.5.3.5.1
  - In the W test, as the gas injection rate was increased, conditions in the upper DC reached a point where no additional gas could accumulate in the DC or the lower elbow and an increased gas flow rate would occur downstream. (DSE Page 45; Lines 20-22)
    - This is not correct; the gas flow rate out of the elbow did not increase – the gas accumulation at the elbow increased.

Allowable Gas Flow to Avoid a Hydraulic Jump

- The DSE limitations on Froude number for TR Eq 6-6 is not justified
- Section 1.9.2
  - The TR correlated the β required to form a kinematic shock from the W data for $1 \le N_{FR} \le 1.9$ with an R-squared value of 0.99 in TR Eq. 6-6. TR Eq. 6-6 was incorrectly assumed to hold for $1 \le N_{FR} \le 2.25$ with $\beta_{min\ reqd} = 0.188$ for $N_{FR} > 2.25$. (DSE Page 18; Lines 12-15)
    - TR Eq 6-6 is valid for $1 \le N_{FR} \le 2.25$ as shown in slide 17
  - The TR provided a comparison of β_{avg} and β_{max} by TR Eq. 6-9. Comparisons showed that β_{max} is more representative of the behavior than is β_{avg}. However, comparisons also showed that TR Eq. 6-9 is not substantiated and is therefore not acceptable. (DSE Page 18; Lines 17-19)
    - TR Eq 6-9 is substantiated as shown in slide 18
- Section 1.9.3
  - Further NRC staff conclusions include (1) Eq. 6-6 is not acceptable for use significantly outside of $1.25 \le N_{FR} \le 1.75$, (2) no shock will form in the lower horizontal pipe if β_{max} < **[ ]**, (3) if a shock forms, there is limited information to establish the shock formation location, (4) Eq. 6-7 is an acceptable description of void behavior when conservative assumptions are used, and (5) if a pump is located near the end of the lower elbow, a methodology based on average fluid properties should be further justified. (Page 18; Lines 41-46)
    - This is not correct; see slides 16-18
-

Allowable Initial Void to Avoid a Hydraulic Jump (cont.)

- Section 3.5.3.5.1
  - TR Figures 6-10 and 6-11 illustrate that β_{max} provides better agreement between the W and Purdue results than β_{ave}. However, the Purdue tests appear to provide a β_{max} that is independent of N_{FR} in contrast to the W values that show an increase in β_{max} with increasing N_{FR}. (DSE Page 46; Lines 1-4)
    - This is not correct; see slides 18-19.
  - TR Eq. 6-6 predicts a negative $\beta_{min\ reqd}$ for $N_{FR} < 0.734$, an obviously incorrect prediction. A significant linear extrapolation of N_{FR} to significantly smaller values is not justified and the smaller N_{FR}, the greater will be the $\beta_{min\ reqd}$ under-prediction (DSE Page 46; Lines 24-26)
    - TR Eq. 6-6 is only intended four use when $N_{FR} > 1.0$.
  - The TR assumed linear behavior could be assumed out to $N_{FR} = 2.25$ and that $\beta = 0.188$ for $N_{FR} > 2.25$. The effect of not choosing a linear fit is shown in Figure 17, where the dot line provides a third order fit to all of the points and the solid line is the straight line provided by TR Eq. 6-6 that excludes the points for N_{FR} = 1 and 1.9 (DSE Page 46; Lines 28-31)
    - The 3rd order fit is not consistent with the flow regime map (slide 16) or test results (slide 17)

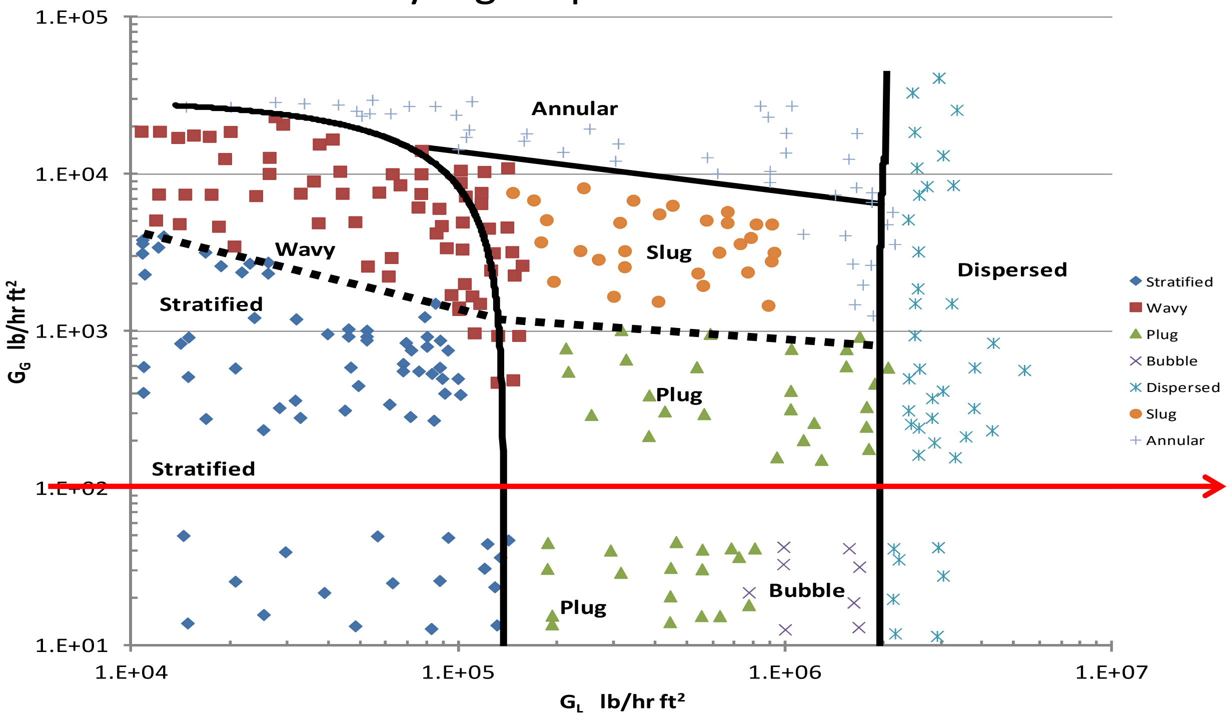
DSE Figure 17

Allowable Initial Void to Avoid a Hydraulic Jump (cont.)

- Section 3.5.3.5.1
  - This provides a good fit to the β points for **[**$0.93 \leq N_{FR} \leq 1.95$**]**. The Eq. 6-6 straight line is a good representation of β_{ave} for **[**$1.25 \leq N_{FR} \leq 1.75$**]** but the points are not linear with N_{FR} outside that range. The R-squared value of 0.99 for Eq. 6-6 is misleading. (DSE Page 47; Lines 10-12)
    - This is incorrect; see slides 16 and 17
  - The TR assumption predicts a larger β than supported by the β points for $N_{FR} \geq 1.75$, a non-conservative prediction since over-predicting β would over-predict when a kinematic shock would occur and a shock will reduce downstream β. (DSE Page 47; Lines 14-16)
    - This is not correct; as the liquid flow rate increases a higher gas flow must be required to form a shock; see slides 16-17.
  - The dash line provides a better fit to the Purdue information than provided by the original W data, but the trend is still incorrect. TR Figure 6-11 and the curve fit to the W data[ ] illustrate that βmax is more representative of the behavior than is βavg. TR Eq. 6-9 is not substantiated. This contradicts the TR that states "… TR Equation 6-9 can be used …." (DSE Page 48; Lines 5-9)
    - The trend is correct and Eq 6-9 is substantiated; see slides 16 and 17.

Flow Regime Map

As liquid flow rate increases flow regime transitions from stratified, to plug to bubble to dispersed; therefore, is not expected that a stratified layer of gas could be sustained at a very high liquid flow rate.



TR Figure 6-23: Horizontal Flow Regime Map

W 2018 Test Data

Data collected by Westinghouse in August, 2018 demonstrates required gas flow rate to form shock greatly increases at N_{FR}=2.25; A shock could not be formed at N_{FR}>2.25

The line is the limit proposed in the TR; it is very conservative at N_{FR}>2

DSE Figure 18; TR Figure 6-10

Limit based on dynamic venting data

Limit added by NRC in DSE

These two lines show same trend

Limit based on data in this figure; the limiting line has to be at or below all green data points

TR Figure 6-11

This is the limiting line based on β_{MAX} data; it is much closer to dynamic venting data than line based on β_{AVG} data; therefore, this figure suggests that the limit based on the dynamic venting data is appropriate

DSE Section 4.7 Errors and Approximations

- The TR examples and usage guidance contain errors that must be considered if the processes are followed. For example:
  - The TR Section 11 simplified equation example contains a calculation error that results in prediction of a time, Δt, = 0.3 sec and an allowable high point volume of 0.024 ft^3. The correct values are 1.466 sec and 0.116 ft^3.
    - This was entered into the Westinghouse Corrective Action program and will be corrected.
  - TR Figure 12-8 provides a method for determining if a horizontal off-take limits the allowable gas volume. This is an oversimplification and is not acceptable.
    - DSE Page 52; Lines 44-50 and DSE Page 53; Lines 1-5 said this method was acceptable. Figure 12-8 is merely a flow chart that implements the methodology.

Summary and Conclusions

- The objective of PWROG-15060-P was to provide NRC approved guidance for addressing the FSE limitations on NEI 09-10
- The DSE for PWROG-15060-P contains numerous limitations on the methodology and requires that additional judgment be used by the licensee
- Satisfying those limitations and conditions would be subject to interpretations which obviate the objective of PWROG-15060-P
- Obtain agreement on the path forward for the issuance of a revised draft safety evaluation (DSE) for PWROG-15060-P that approves the methodology without any additional limitations and conditions
- If the DSE cannot be revised to address these issues without significant PWROG effort, the PWROG will withdraw PWROG-15060-P

Open Discussion

- Schedule
- Questions
- Closing remarks

PWROG

PWR Owners Group

Global Expertise • One Voice

www.pwrog.com