ABB

ASEA BROWN BOVERI

17 December, 1999
LD-1999-0062

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

SUBJECT: RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION
SUPPORTING TOPICAL REPORT CENPD-397-P REVIEW ACTIVITIES
~~(ENCLOSURE 1 CONTAINS PROPRIETARY INFORMATION)~~

References: 1) Letter, I. C. Rickard (ABB CENP) to USNRC Document Control Desk,
"Submittal of CENPD-397-P, Rev. 00 – Improved Flow Measurement
Accuracy Using CROSSFLOW Ultrasonic Flow Measurement
Technology", LD-99-047, August 23, 1999
2) Letter, J. Cushing (NRC) to I. C. Rickard (ABB CENP), "Request for
Additional Information (RAI) Regarding CENPD-397-P, Improved Flow
Measurement Accuracy Using CROSSFLOW Ultrasonic Flow
Measurement Technology (TAC No. MA6452)", November 19, 1999

By letter dated August 23, 1999 (Reference 1), ABB Combustion Engineering Nuclear
Power, Inc. (ABB CENP) submitted and requested Nuclear Regulatory Commission
(NRC) review and approval of CENPD-397-P, Rev. 00 – Improved Flow Measurement
Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology". On
November 19, 1999 (Reference 2), the NRC issued a Request for Additional Information
(RAI) necessary for completion of the CENPD-397-P review effort. Enclosure 1
(PROPRIETARY) provides ABB CENP's response to the NRC RAIs. Enclosure 2 provides
the non-proprietary response to the NRC RAIs.

If the information provided herewith resolves the NRC reviewer RAIs, ABB CENP will
revise and reissue CENPD-397-P as Revision 01; as indicated in the responses
(Enclosure 1).

ABB CENP has determined that the material provided in Enclosure 1 is PROPRIETARY in
nature. Consequently, it is requested that Enclosure 1 be withheld from public
disclosure in accordance with the provisions of 10 CFR 2.790 and that these copies be
appropriately safeguarded. The reasons for the classification of this information as
PROPRIETARY are delineated in the affidavit provided in Enclosure 3.

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ABB Combustion Engineering Nuclear Power, Inc.

PDL TOPRP Combustion Eng.

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ML9935570063 change: NRC PDR

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If you have any questions concerning this matter, please do not hesitate to call me or Chuck Molnar of my staff at (860) 285-5205.

Very truly yours,
ABB COMBUSTION ENGINEERING NUCLEAR POWER, INC.

Ian C. Rickard, Director
Nuclear Licensing

Enclosures: As stated

xc: R. A. Browning (DAEC) *all*
      J. A. Calvo (NRC/NRR/DE/EEIB)
     √J. S. Cushing (NRC/NRR/DLPM/LPD4)
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Project Number:	2009155	Originator: C. M. Molnar	Initials: CMM

Project Name:
CROSSFLOW TOPICAL REPORT PREPARATION & REVIEW

Document Number:	LD-99-0062 Rev: 00	**Quality Record?**	

Document Title:
RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION IN SUPPORT OF TOPICAL REPORT CENPD-397-P, REV. 00 REVIEW ACTIVITIES

Quality Record?
☒ No   ☐ Yes (See note below)

Quality Record Retention Period (see QP 17.1):
☐ Lifetime   ☐ 3 years   ☐ 10 years

Transmittal Reason:
Transmit Subject Information to the NRC.

Reference:
See attached letter.

Name	Title	CEP Code	w/Encl. Y	w/Encl. N	Approval Requested Y	Approval Requested N	Signature	Date
I. C. Rickard			✓			✓		
C. B. Brinkman		Rockville, MD	✓			✓		
R. O. Doney			✓		✓		RO Doney	12-9-98
C. T. French	PROGRAM MANAGER		✓		✓		C.T.French	12/8/99
T. P. Jaeger			✓			✓		
G. J. Kanupka			✓			✓		
A. Lopez	AMAG	Ontario		✓		✓		
U. Gureisch	AMAG	Ontario		✓		✓		
				✓		✓		
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H. N. Carrington	Records Controller		✓			✓		
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Comments

All copies have been distributed with the Proprietary Enclosure. Heather Carrington will make all future distributions of Proprietary copies.

Note: This form must include the attached document when designated a Quality Record.

ABB Combustion Engineering Nuclear Power, Inc.

NON-PROPRIETARY RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION SUPPORTING TOPICAL REPORT CENPD-397-P REVIEW ACTIVITIES

ABB Combustion Engineering Nuclear Power

NON-PROPRIETARY RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION SUPPORTING TOPICAL REPORT CENPD-397-P REVIEW ACTIVITIES

RAI – 1

Figure 2-2 compares the plot of the velocity profile correction factor (VPCF) vs. Reynolds Number to experimental results. The topical report claim of high confidence in the extension of the VPCF to high Reynolds Number is supported by limited data. Provide additional data for high Reynolds Numbers plotted in Figure 2-2, or provide additional basis for the topical report claim.

ABB-CENP RESPONSE

Extrapolation of the calibration results to high Reynolds Number (Re) is also the subject of RAI 18. Hence, responses to RAI's 1 and 18 are provided here.

Justification for the extrapolation of the Velocity Profile Correction Factor (VPCF) can best be explained by considering the origin of the equations that are used to calculate the velocity profile correction factor at higher Re. Equation 2-16 and the supporting Equations 2-13 and 2-14 from the topical report are all fundamental equations taken from Schliching's book, "Boundary Layer Theory". Furthermore, Equation 2-13 for the frictional velocity has its bases in the Moody diagram of friction factor versus Re, ASME Transaction, Volume 68, 1944, Page 672. This equation is the mathematical expression that describes how the fiction factor, λ, in the Moody diagram varies with Re for fully developed turbulent flow in a smooth pipe.

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In order to plot the experimental data points on Figure 2-2, the VPCF, C_o, was calculated for each data point using the following equation:

$$C_o = \frac{Q_{measured}}{Q_{CROSSFLOW}}$$

where: $Q_{measured}$ is the volumetric flow measured by the weigh tank or plant venturi

$Q_{CROSSFLOW}$ is the corresponding volumetric flow measured by the meter without the velocity profile correction factor. $Q_{CROSSFLOW}$ is defined as:

$$Q_{CROSSFLOW} = A\ L/\tau$$

where: A is the flow area
L is the spacing between the ultrasonic beam
τ is the time that it takes for the eddies to pass between the ultrasonic beams

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A comparison of the VPCF curve with plant operating data must be done at a plant. Because of the high fluid temperatures required to achieve these Reynolds Numbers (Re), it is not possible to use a weigh tank test to independently measure the flow. Hence, the comparisons are limited to in-plant tests, where it is known that the venturi and plant instrumentation have recently been calibrated and will provide an accurate measurement of the flow.

It is a rare opportunity, when these conditions can all be met. For the plant data point shown on Figure 2-2, the plant had just sent their ASME flow element back to the Alden Research Laboratory (ARL) for calibration. It was then returned to the plant and reinstalled in the feedwater line, where the measurements were taken shortly after reaching full power before any potential venturi fouling could significantly affect the results.

FIGURE 2-2

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RAI – 2

The topical report associates Equations 2-15 and 2-19 with Reference 2-1 (Schlichting), yet the equations do not appear in the same form in the Schlichting reference. Provide the basis for the equations using a derivation traceable to something in Schlichting or some other source.

ABB-CENP RESPONSE

C. Equation 2-15

[

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D. Equation 2-19

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To demonstrate that the two equations are essentially the same, the following table compares
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[

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RAI – 3

Summarize the detailed analysis mentioned in Section 2.3 supporting Equation 2-22 for r^*_t and provide the reference(s) containing the supporting analysis.

ABB-CENP RESPONSE

It should be noted that Section 2.3 of the topical report, CENPD-397-P, has been revised. Equation 2-22 is now Equation 2-16 and r_t^* is now r^*.

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RAI – 4

Section 3.4.1 discusses the intended application of the Crossflow system. The Crossflow output is not to be directly used as input to the calorimetric calculation of thermal power, but to provide data to adjust the venturi flowmeter flow coefficient. What uncertainty components are introduced in the calibration of the venturi measurement from the Crossflow data? How are venturi-related uncertainties accounted for in power measurement in order to support a reduced (i.e. less than 2 percent) margin? Provide supporting details.

ABB-CENP RESPONSE

As described in Section 3.4.1 of CENPD-397-P, Rev. 00, the CROSSFLOW meter is used to calibrate the existing feedwater venturis. This adjustment would only be applied to the feedwater flow that is used in the thermal power calculation. The adjustment is not applied to the feedwater flow used by the feedwater level controllers or by the feedwater flow trips.

This calibration process [

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Portions of this response have been added to Section 5.9.2 of the topical report.

RAI – 5

How were values of measured C_0 given in table 4-1 determined (appears to be inverse of Equation 4-9)? What measurement or supporting experimental information is represented by V^* in the table?

ABB-CENP RESPONSE

It should be noted that Section 4.1 of topical report, CENPD-397-P, Rev. 00 has been revised. Equation 4-9 was incorrect and is now presented correctly as Equation 4-6. The corrected equation now reads:

$$C_0 = Q_{weigh\ tank}/Q_{cross-correlation} \qquad \text{Eq. 4-6}$$

The V^* header in Table 4-1 has also been modified to make it consistent with Equation 4-2. The new header is V^*/V_a and if one knows the Re for the flow, V^*/V_a can be calculated using Equations 4-2 and 4-3:

$$\left(\right) \qquad \text{Eq. 4-2}$$

$$ \qquad \text{Eq. 4-3}$$

The following statement will be added to Table 4-1 of CENPD-397-P, Rev. 01' to clarify the bases for V^*:

"Given the Reynolds Number for the fluid, V^*/V_a can be calculated using Equations 4-2 and 4-3."

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RAI – 6

Equation 4-6 should be the inverse of Equation 4-3, but Equation 4-6 appears to be missing the V_a term. If the omission is confirmed, provide corrections to equations and other material in the topical report that follow from Equation 4-6.

ABB-CENP RESPONSE

It should be noted that Section 4.1 of topical report, CENPD-397-P has been revised. Equation 4-6 is now shown in Section 4.1 as Equation 4-1 and Equation 4.3 is no longer needed.

Equation 4-1 will be changed in the topical report to read:

$$\Big[\qquad\qquad\qquad \Big]$$

RAI – 7

Explain the apparent disparity among the curves and plant data depicted in Figures 2-2, 4-1, and 4-2.

ABB-CENP RESPONSE

There was an error in plotting the plant data shown on Figure 2-2 of CENPD-397-P, Rev. 00. The topical report will be revised to correct this error. Additionally, the same symbols will be used in each figure for a particular data set. The revised figures are provided on the following pages.

FIGURE 2-2

FIGURE 4-1

FIGURE 4-2

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RAI – 8

Provide Reference 4-2.

ABB-CENP RESPONSE

Please find attached a copy of CENPD-397-P, Rev. 00, Reference 4-2, [

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This reference has also been added to Section 4.4 as Reference 4-1 of the topical report.

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RAI – 9

What is the effect of corrosion products on the ultrasonic measurement of inside pipe diameter discussed in Section 5.4.1 of the topical report? Discuss how operating procedures or plant specific data should be used to demonstrate that the measured value of pipe inner diameter remains valid for operation of the Crossflow system.

ABB-CENP RESPONSE

When the pipe wall thickness is measured using an ultrasonic thickness meter, the actual measurement includes both the thickness of the pipe wall and the thickness of any magnetite corrosion products since the composition of the corrosion products is essentially the same as that of the pipe wall. Thus, when the measured thickness is subtracted from the pipe outside diameter, a true measurement of the pipe's flow area is obtained.

ABB CENP understands that several plants have seen deposition of oxides on feedwater pipe internal surfaces that may change the surface roughness and increase the indicated flow. However, the deposition does not usually change flow area to a measurable degree. Pipe wall thickness measurements are not routinely monitored or trended.

Throughout the industry, there is little evidence of pipe wall loss in straight runs of feedwater piping systems. Since the CROSSFLOW UFM is recommended for application on straight runs of feedwater piping, it is unlikely that the inside diameter of the feedwater pipe would be subject to long-term wall loss of a type that would impact meter performance. However, it is recommended that a Utility evaluate this potential on a plant-by-plant basis. This evaluation could utilize the site Flow Accelerated Corrosion Program, or a separate program of pipe wall monitoring. It is also recommended that this evaluation/monitoring be performed near the location of the CROSSFLOW UFM, or at a point in the feedwater line where a potential wall loss rate would be equal to (or greater than) the rate where the meter is installed. If wall losses are identified, then it is expected that the Utility would take appropriate actions to reflect any pertinent changes in the feedwater flow calculations.

Portions of this response have been added to Section 8.1.1.2 of the topical report.

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RAI – 10

Explain why sensor angular orientation relative to the flow disturbance is not a factor in determining the pipe configuration correction factor (Equation 5-24)?

ABB-CENP RESPONSE

The angular orientation of the sensors is important when using Equation 5-24 to obtain a VPCF downstream of a 90° elbow. This equation is only applicable when the sensors are orientated in the plane of the elbow. The topical report will be revised to reflect this constraint on the use of Equation 5-24.

Portions of this response have been added to Sections 5.6.1 and 8.1.1 of the topical report.

RAI – 11

Error analysis and uncertainty calculation based on square root sum-of-the-squares methods discussed in Section 5 must use contributors that are random, normally distributed, and independent. Explain how, for a specific installation, that each of the terms in Equation 5-34 can be assured to meet the randomness, distribution, and independence requirements. For example, explain how independence of the profile correction factor and feedwater density error terms is assured if each error involves measurement of feedwater temperature using the same instrumentation.

ABB-CENP RESPONSE

Traditionally, a majority of the utilities have utilized methodologies presented in ANSI/ASME PTC 19.1 to determine feedwater flow/flow uncertainty for input to the core thermal power evaluations where the SRSS method is an accepted practice for combining "biases" at the 95% confidence level. However, [

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Portions of this response have been added to Section 5.9.2 of the topical report.

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RAI – 12

Explain the basis for the flow disturbance factor (ΔC) in Equation 5-24.

ABB-CENP RESPONSE

Equation 5-24 is based on [

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RAI – 13

How does the internal time delay check mentioned in Sections 3.3.5 and 5.8 confirm the values input to Equation 5-29 (the time delay confidence interval)? Explain how the terms on the right side of Equation 5-29 are independent.

ABB-CENP RESPONSE

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Portions of this response have been added to Section 5.8 of the topical report.
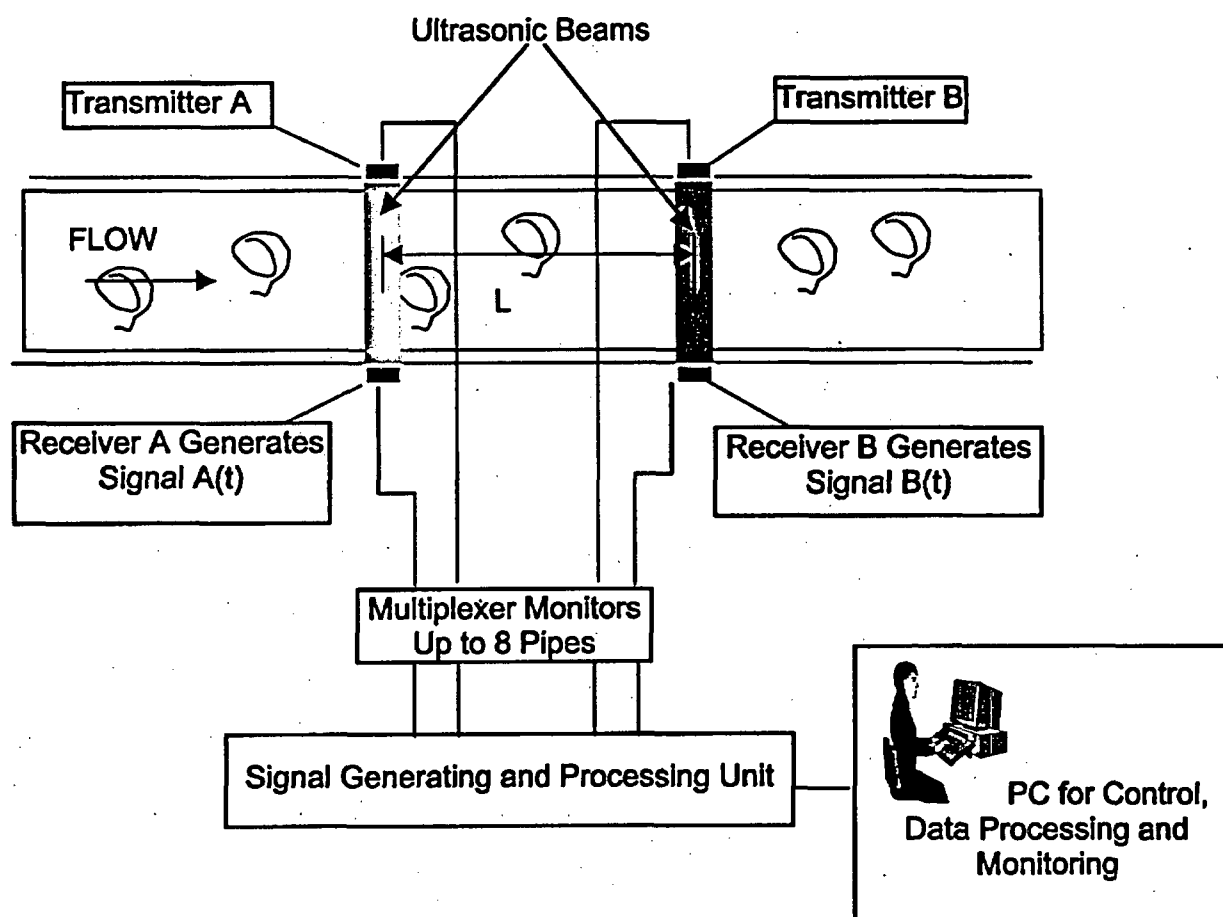
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RAI - 14

Section 2.2.2 defined cross-correlation as a "mathematical process for determining the displacement in time between similar curves." Please explain equations 2-9 and 2-10 and graphically identify the similar curves. Are the two signals A(t) and B(t + τ) through two different eddies or through the same eddy traveling between station A and station B?

ABB CENP Response

It should be noted that the equations in Section 2.2.2 have been renumbered due to revisions in Section 2.1 of the topical report, CENPD-397-P, Rev. 00. Equation 2-9 is now Equation 2-5 and Equation 2-10 is now Equation 2-6.

The underlying principle of the cross-correlation technique is illustrated in the following figure:

Ultrasonic Beams

Transmitter A

Transmitter B

FLOW

L

Receiver A Generates
Signal A(t)

Receiver B Generates
Signal B(t)

Multiplexer Monitors
Up to 8 Pipes

Signal Generating and Processing Unit

PC for Control,
Data Processing and
Monitoring

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Portions of this response have been added to Section 2.2.2 of the topical report.

RAI – 15

The asterisk (*) In equation 2-12 indicates the complex conjugate of a function. What does *
mean in equations 2-15, 2-18, 2-22, and $\tau=\tau^*$ In section 2.2.2.

ABB-CENP RESPONSE

It should first be noted that the equations In Sections 2.1 through 2.3 have been renumbered
due to revisions in these sections of the topical report, CENPD-397-P, Rev. 00. Equation 2-12 Is
now Equation 2-8 and Equations 2-15 and 2-22 are now respectively Equations 2-12 and 2-16.
Equation 2-18 has been eliminated.

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RAI – 16

Section 3.2.4.5 states that the CROSSFLOW software includes data filtration criteria, yet, not all of the criteria are explained.

ABB-CENP RESPONSE

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Portions of this response have been added to Section 3.2.4.5 of the topical report.

RAI – 17

Section 3.2.4.6 states that the "cumulative cross-correlation function is the result of the summation of all instantaneous cross-correlation functions that are processed in each data acquisition cycle over a user specified average size." What is a data acquisition cycle and what is the basis for specifying an average size?

ABB-CENP RESPONSE

The data acquisition cycle is the time interval, T, in Equation 2-6. For feedwater flow measurements, it is typically [   ]

The cumulative cross-correlation function is simply an average of the cross-correlation function. The user can specify through input the number of time delays he would like to be averaged.
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Portions of this response are included in Section 3.2.4.6 of the topical report.

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RAI – 18

Section 4-2 states that a limited amount of data has been collected from several plants where the accuracy of the in-plant flow instrumentation was independently confirmed at Alden Research Laboratory (ARL). It is understood that the plant data are all for 25 million or higher Reynolds numbers whereas the ARL tests were limited to a lower Reynolds number shown on Figure 2-2. Explain how the plant data with high Reynolds numbers were confirmed at ARL and how Figures 2-2 and 4-1 curves were developed without sufficient data needed to perform a regression analysis.

ABB-CENP RESPONSE

See response to RAI No. 1.

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RAI – 19

In section 5.6.1, definition of C_p indicates that VPCF is affected by the upstream piping configuration/disturbance other than an elbow. Has ABB report provided methodology for calculating PCCF?

ABB-CENP RESPONSE

CENPD-397-P, Rev. 00 does [

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Portions of this response are included in Sections 5.6.1 and 8.1.1 of the topical report.

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RAI – 20

Section 5.8 indicates that a random normally distributed uncertainty is procedurally controlled and periodically verified by an internal time delay check. On what basis did the Advanced Measurement and Analysis Group (AMAG) assign this uncertainty value to the CROSSFLOW UFM instrumentation? Explain the control procedure and verification method and the guideline if the assigned uncertainty is exceeded.

ABB-CENP RESPONSE

As noted in RAI 13, there are [

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Portions of this response are included in Section 5.8 of the topical report.

RAI – 21

Table 5-1 shows uncertainty of measured and calculated parameters at various power plants. What is the reason for such a wide range of difference in the minimum and maximum values? Did the plants follow other methodologies than those outlined in sections 5.5, 5.7, and 5.8 for the measurement uncertainties of the respective parameters?

ABB-CENP RESPONSE

The methodologies are the same for all measurements. The reason for the variations [

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RAI – 22

What is the confidence level of repeatability and reproducibility of ARL test results? Explain how extrapolation for higher Reynolds numbers is performed and how its uncertainty is bounded by the AMAG assigned uncertainty value.

ABB-CENP RESPONSE

The 95% confidence level for Alden Research Laboratory (ARL) test results is [

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FIGURE RAI-22-1

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RAI – 23

What is the indication of the CROSSFLOW UFM instrumentation failure and what actions are recommended?

ABB-CENP RESPONSE

In case of a CROSSFLOW UFM System failure, [

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Portions of this response are included in Section 3.3.6 of the topical report.