NRC Review of Combustion Engineering CENPD-397-P-A

"Improved Flow Measurement Accuracy Using CrossFlow Measurement Technology"

Revised Draft Safety Evaluation for Withdrawal of Acceptance

Comments by PJR, NRR/DE/EICB - October 12, 2006

The draft SE was provided to the reviewer in hard copy form, as a concurrence package, on October 12, 2006. My comments on the September 21 draft were issued within EICB via EMail on September 28, and provided (unchanged) to SPWB via EMail on October 2. Following discussions with SPWB on October 4 and 5, I provided revised comments via EMail to both SPWB and EICB on October 5. My September 28 comments remain unresolved, but were deemed more suitable as considerations for the review of a future resubmittal than for use in the present action. I believe that all of the points in those comments need to be addressed if XFlow is resubmitted for NRC acceptance. These points may also be useful in discussions with Westinghouse concerning the withdrawal of acceptance of the XFlow device. My October 5 comments are focused specifically upon the draft withdrawal SE.

Some of the concerns in my October 5 EMail have been addressed, others have not. This present listing incorporates and supersedes the October 5 comments entirely, although reference to the October 5 EMail may provide additional clarification.

The following comments address the draft SE as received on October 12:

<u>regarding the transmittal memorandum to DPR</u>:

1. The term "Calibration Factor" is used extensively in the SE and in the transmittal. There are various calibration factors applicable to this device, the most prominent of which are the velocity profile correction factor, which XFlow uses to compute the volumetric flowrate, and the venturi correction factor, which is used to adjust the output of the venturi-based flowmeter to match XFlow. The XFlow velocity profile correction factor itself may be composed of separate factors relating measured velocity to an ideal profile and relating the actual profile to the ideal. The specific meaning of "Calibration Factor" in this context is undefined. It would be sufficient in most places where this term is used to simply refer to "calibration."

2. The focus of the retraction continues to appear to be the unacceptability of laboratory testing. The problem is not laboratory testing *per se*, but rather the adequacy of the particular laboratory testing used to certify a particular device for a particular application. If laboratory testing could be shown to adequately simulate *in-situ* conditions, then it would be acceptable (assuming all other aspects of the testing were acceptable). This comment also applies to "Specific Weakness" #1 in the "Conclusions" section of the draft Safety Evaluation.

3. Reference to traceability to a national standard is questionable. The only thing that XFlow actually measures is the time-of-flight of an eddie pattern from one sensor channel to the other. That is surely traceable, or can easily be made so. But the major vulnerability of the system is related to the flow profile – that is, in relating the measured time-of-flight to the volumetric flowrate, in consideration of the fact that the fluid velocity is not uniform – and there is no national standard for flow profiles or volumetric flowrate. This comment also applies to "specific weakness" #2 in the "Conclusions" section of the draft Safety Evaluation.

4. Items 3 and 4 of the transmittal address discrepancies between requirements as expressed in the TR and requirements as subsequently established. That can be easily fixed by means of a supplement to the TR and the associated SE, without need for retraction of the SE altogether. But it is my understanding that even the upgraded requirements and instructions still fail to give adequate confidence that the instrument will function as required. It also seems that the need for such supplementary requirements and instructions suggests that the science underlying XFlow operation is not sufficiently understood or reflected in the design. For example, Westinghouse apparently neglected to consider the effects of acoustic noise in the piping system, even though XFlow is inherently an acoustic device. We should be careful of the inclusion of "easy-fix" items in the letter (and probably in the SE) when a solid case can be made without them and their presence could have the effect of misdirecting consideration and discussion of our more serious concerns.

5. The transmittal indicates that resolution of the four listed concerns would render a revised TR acceptable. There are many other issues that would need to be addressed in a revised TR. The listed items are only a small subset.

<u>regarding the transmittal letter to Westinghouse</u>:

6. ¶1: The accuracy and confidence specification must apply to the actual performance expected *in-situ*, not just to performance with fully-developed flow. Fully-developed flow may be specified as an application requirement, but the accuracy and confidence requirements themselves are related to the need for accurate core thermal power estimation, not to the details of the application.

7. ¶3: I believe the issue is larger than just inadequacies in the Topical Report, which can be easily repaired by a supplement or resubmittal. If I understand correctly, we are questioning the very nature of the instrument and its ability to render an adequate measurement as it is actually installed in a plant. The Topical Report may be deficient in failing to provide adequate support for the performance claim and for failing to provide adequate instructions concerning the application of the device, but if the device itself is inadequate to the task then the Topical Report is not the problem.

8. ¶4: The qualifier "for future licensing applications" does not seem appropriate. This suggests that XFlow remains acceptable in existing applications and for future applications not specifically related to licensing, such as for "megawatt recovery." If we have decided that the device is deficient, then we should not suggest that it is sometimes acceptable. The point is, we do not have adequate confidence in this device to support its use in any application wherein it influences a license-related measurement. Use of XFlow for "megawatt recovery" alters the calibration of the FW venturi-based flowmeter, and therefore influences the estimation of core thermal power, and is therefore not acceptable if the

instrument is not trustworthy. This comment also applies to the penultimate paragraph of the "conclusions" section of the draft Safety Evlauation.

regarding the Safety Evaluation:

9. 2.0¶1, final sentence: XFlow has also been used for "megawatt recovery," wherein it is used to modify the calibration of the venturi-based flowmeter. Since the calibration of the venturi is modified by means of a device whose accuracy has been questioned, the accuracy of the venturi is compromised. The adequacy of the 2% margin specified in Appendix k is therefore questionable under these circumstances. Therefore there are regulatory concerns in regard to "megawatt recovery" applications as well as in regard to power uprates. If the device does not perform as expected, then the bases for the 50.59 evaluations that found an application acceptable, are undermined.

10. 2.0¶3: Delete reference to "fully-developed flow" for reasons indicated earlier in these comments in regard to a similar usage in the letter to Westinghouse.

11. 2.0¶3, final sentence: This says that the instrument only works properly when used in accordance with the TR now deemed unacceptable. The point is that the TR is inadequate, not that licensees have failed to adhere to it.

12. 3.1¶1: see earlier comment regarding "calibration factor" and related terms

13. 3.1¶3, final sentence: It is not possible to know whether the eddies used in the averaging traveled the same path or not. Some may have been embedded in a high-velocity stream (such as near the pipe axis), and others in a low-velocity stream (such as near the pipe wall). All that is known is that they are all inside the pipe.

14. 3.1¶4: The assumption is not just that the profile is stable, but also that it is known or at least known to be sufficiently similar to the one that existed in the laboratory test set-up. A flow profile that is stable but not fully-developed or that is not sufficiently similar to the laboratory flow profile is merely unchanging but still unknown. This issue of stable vs fully-developed flow occurs in many places in the concurrence package.

15. 3.1¶5: The conclusion of this paragraph just says that the requirements of the TR cannot be met, not that the TR is wrong.

16. 3.1¶6: see earlier comments regarding stable vs fully-developed flow.

17. 3.1¶7: Swirl should cause XFlow to tend to read high, not low. Do we know for sure that the problems were due to swirl and not to flow profile uncertainty? Also, the discussion of stable vs fully-developed flow seems secondary to the (unstated) conclusion that the flowmeter was giving inaccurate readings even though it was applied in accordance with the manufacturer's recommendations.

18. 3.2¶2: If the flow is merely stable but not fully-developed, then the velocity-to-volumetric flowrate conversion factor(s) may be different at the two locations. The issue is not the unacceptability of laboratory testing, but rather the unrepeatability of flow profiles between the two locations and between those locations and the laboratory test. The problem with this approach is both that the calibration of the "reference" XFlow is questionable for the

reasons already discussed and that there is insufficient correlation between the flow profiles at the two locations. In any case, the best that could be gained from this sort of testing would be to establish a calibration adjustment for a device that is not installed properly on the basis of a device that is installed properly.

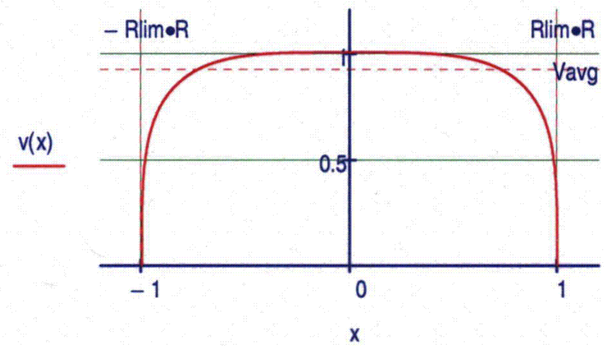
The pipe radius is normalized to unity. A central region is defined, having boundaries at a some fraction of the radius and centered on the axis. This central region is introduced here so that it can be shown on the graphs, and will be applied in the analysis of XFlow behavior.

$R := 1$ $\qquad$ $Rlim := 100\%$

The velocity profile is assumed to be represented as a 4th-order circle centered on the pipe axis (velocity at the pipe wall is zero).

$v(x) := \left(R^4 - x^4\right)^{\frac{1}{4}}$ $\qquad$ The average velocity is thus: $\quad Vavg := \dfrac{\int_{-R}^{R} v(x)\,dx}{2R}$ $\qquad Vavg = 0.9270$

Factors influencing inferred volumetric flowrate:
- eddie travel time
- flow profile deviation
- radial distrubution of usable eddies
- probability of incorrect eddie identification



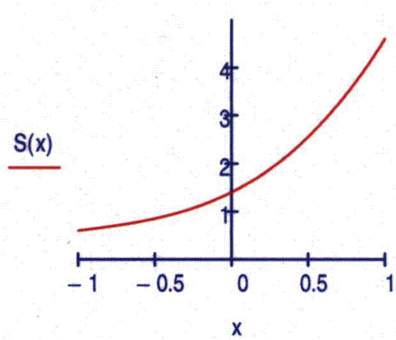
Nonuniform flow is represented by a skew factor applied to the ideal profile. The skewed flow profile is normalized to result in unchanged average flowrate.

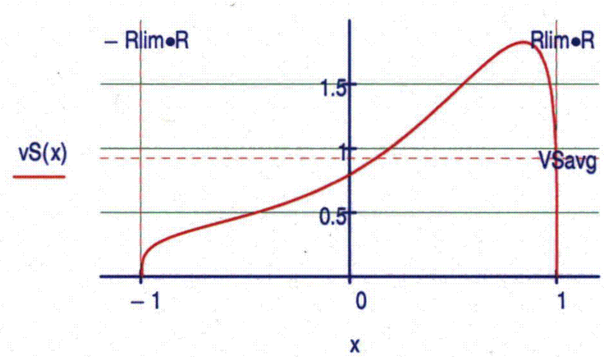
$S(x) := 0.4x + 0.4(x+1)^3 + 1$

$vS1(x) := v(x) \bullet S(x)$ $\qquad VS1avg := \dfrac{\int_{-R}^{R} vS1(x)\,dx}{2R}$ $\qquad vS(x) := \dfrac{Vavg}{VS1avg} \bullet vS1(x)$ $\qquad VSavg := \dfrac{\int_{-R}^{R} vS(x)\,dx}{2R}$

$VS1avg = 1.6311$ $\qquad VSavg = 0.9270$

$Vavg - VS1avg = -0.7041$ $\qquad Vavg - VSavg = -2.2204 \cdot 10^{-16}$





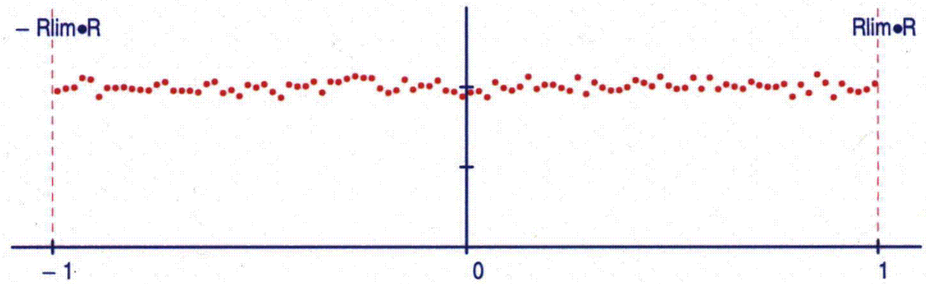
$$\frac{vS(0) - VSavg}{VSavg} = -14.1689\,\%$$

The CrossFlow flowmeter measures the axial velocity of eddies in the fluid flow, and computes the volumetric flowrate on the basis of the average axial velocity. The distribution of usable eddies across the pipe diameter will influence the measurement. We assume the distribution to be uniform. The measurement process is examined via Monte-Carlo simulation:

Number of trials: $N := 10^5$

eddie location vector: $xE := \mathrm{runif}(N, -Rlim \cdot R, Rlim \cdot R)$

Histogram of Eddie Locations



eddie velocity vectors: $n := 0..N-1$ $\quad vEref_n := v(xE_n)$ $\quad vES_n := vS(xE_n)$

$vRmax := \max(vEref)$ $\quad vRmax = 1.0000$ $\quad vSmax := \max(vES)$ $\quad vSmax = 1.8314$

$vRavg := \mathrm{mean}(vEref)$ $\quad vRavg = 0.9272$ $\quad vSavg := \mathrm{mean}(vES)$ $\quad vSavg = 0.9278$

change in average flow induced by flow profile error: $\dfrac{vSavg - vRavg}{vRavg} = 0.0621\,\%$

eddie velocity histograms: $Nbins := 100$ $\quad Ev := \mathrm{histogram}(Nbins, vEref)$ $\quad EvS := \mathrm{histogram}(Nbins, vES)$

graph markers: $a := vRavg$ $\quad b := vRmax$ $\quad c := vSavg$ $\quad d := vSmax$