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November 5, 2009

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

Subject: White Paper for MUR Uprates

Gentlemen:

Please find enclosed the following white paper that proposes a template and process for the Technical Acceptance Criteria for MUR Uprate Licenses Amendment Requests. This paper is being submitted for information only.

- Cameron, Caldon® Ultrasonics Engineering Report: ER-769 Rev. 1 "Acceptance Criteria for Review of Licensee Submittals for MUR Uprates" – Non-Proprietary

If you have any questions or require additional information, please contact me at 724-273-9300.

Regards,

Ernie Hauser
Director of Sales

cc: Kate Lenning, NRC Project Manager
George Bacuta, NRC Project Manager

Enclosure (1)

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Measurement Systems

Caldon® Ultrasonics

Engineering Report: ER-769 Rev. 1

Acceptance Criteria for Review of Licensee Submittals for MUR Uprates

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Reviewed by: Herb Estrada

October 2009

Engineering Report: ER-769 Revision 1

Acceptance Criteria for Review of Licensee Submittals for MUR Uprates

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1.0 PURPOSE

This white paper proposes a template and process for the Technical Acceptance Criteria for MUR Uprate License Amendment Requests, in accordance with Office Instruction LIC-109 Revision 1. LIC 109 establishes guidelines for acceptance reviews by NRC Staff. It is general in nature and so its interpretation for specific processes, such as MUR uprates, must be established. LIC-109 also provides an additional requirement: Section 5 states that all NRR Staff *".are ... responsible for identifying possible improvements to the guidance and submitting suggestions for such improvements to their management, to the assigned office contact for this Office Instruction, or by submitting a Process Improvement Form as described in ADM-101, "NRR Process Improvement Program.""*

The template and process proposed herein are narrowly focused on a particular, but significant issue that has arisen, after the publication of the guidance, with respect to MUR Uprates. The question is whether an MUR Uprate License Amendment Submittal may be considered "Acceptable for Technical Review" if it is submitted prior to the collection and analysis of calibration data for the meters that will be installed in the plant.

The question is significant because project time schedules could be detrimentally impacted by as much as eighteen months to two years (one refueling cycle) if the application cannot be submitted without incorporating actual meter calibration data in the LAR submittal to NRC. Additionally if calibration test results are made a precondition to the LAR submittal, time schedules requested by Licensees for review are compressed, because of the desire to obtain the uprate as soon as possible after the flow measurement system is installed,

On the other hand, a more flexible approach to the content of the LAR submittal could allow a longer review time. Specifically this outcome would be achieved if LARs without calibration test results could be submitted. Such submittals could be made earlier in the overall project schedule. Figure 1 shows an example schedule based upon submittal of a Rev 0 Uncertainty Analysis (that is, an analysis based on bounding calibration uncertainties, in advance of the actual calibration tests). Figure 2 shows the same example based upon a Revision 1 submittal (that is, an analysis in which actual calibration test results are incorporated in the uncertainty analysis) with an extended project schedule, and Figure 3 shows a schedule based upon a Revision 1 submittal with a shorter requested review time for NRC. Thus, a procedure whereby submittals could be made and considered complete could benefit all stakeholders.

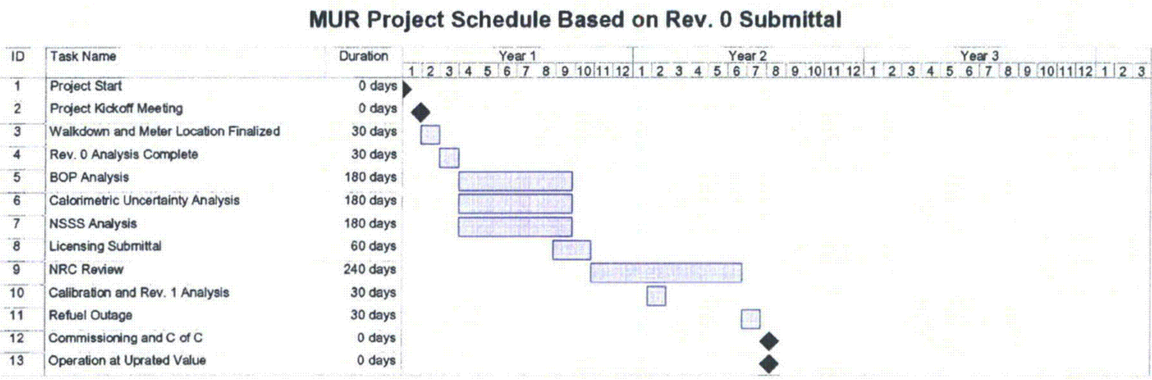

Figure 1: MUR Project Schedule Base on Rev. 0 Submittal

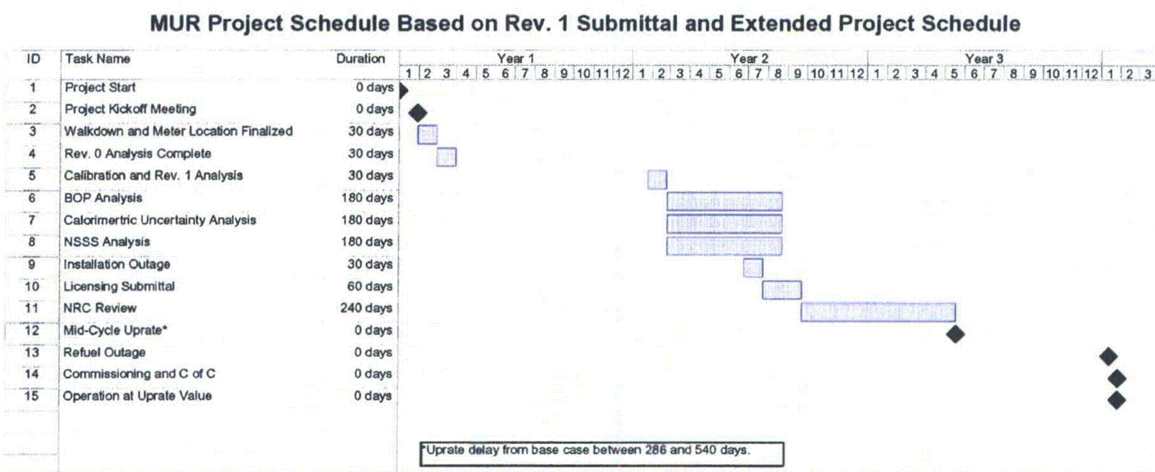

Figure 2: MUR Project Schedule Based on Rev. 1 Submittal and Extended Project Schedule

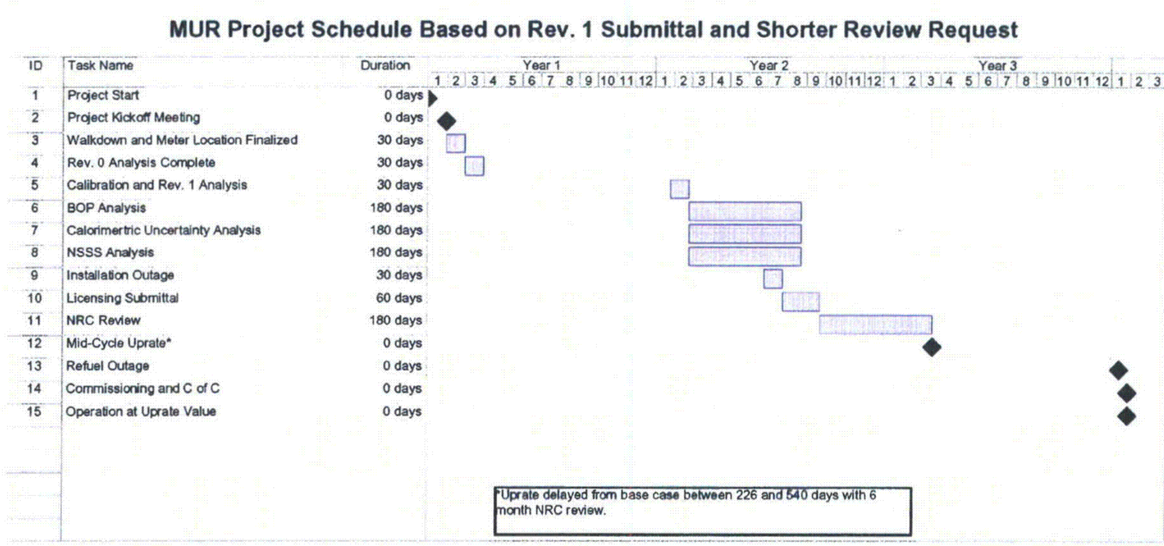

Figure 3: MUR Project Schedule Based on Rev. 1 Submittal and Shortened Review Request

2.0 BACKGROUND

In the initial review of the MUR Uprate Concept, and in the majority of MUR uprates submitted thus far, the process was well defined and involved the a submittal based upon a bounding analysis containing site specific information, including projected dimensional and time measurement uncertainties for the LEFM CheckPlus meter that would be installed in the plant, as well as budgeted numbers anticipated by experience for hydraulic and calibration uncertainties. The analysis was considered bounding and was referred to as a "Rev 0 Analysis". It took advantage of the fact that the LEFM CheckPlus Systems are relatively insensitive to hydraulic disturbances that cause variation in velocity profiles. In particular, Meter Factor uncertainties are typically bounded by +/-0.25%, and this uncertainty value is usually carried in the Rev 0 Analysis.[1]

The LEFM CheckPlus meters were then calibrated at a traceable laboratory in a model of the intended installation location in the plant feedwater piping system. A number of parametric tests designed to test and verify the bounding sensitivity of the meter to changes in velocity profile were also conducted. The results would then be included in a "Rev 1" uncertainty analysis where the hydraulic uncertainty budget would be replaced with actual values. Historically, the rev 1 analysis was not included in the NRC Review scope, but it was the licensee's obligation to confirm, using this data as well as the final commissioning data, that the uncertainty basis of the license was valid.

The Rev 1 uncertainty analyses for all plants have been bounded by the Rev 0 uncertainty analyses because of the predictability of the calibration uncertainty results.[2] Typical calorimetric margin differences between bounding Rev 0 analyses and Rev 1 analyses are between 0.002 and 0.003%. This difference and the difference in the schedules suggests that, if both submittals could be considered acceptable for review by NRC, the licensees could make a trade-off between using a bounding analysis and achieving the uprated power authorization sooner, or using the actual analysis with a delayed implementation schedule.

Additional Considerations

The NRC has inspected Cameron on several occasions and concluded each time that Cameron's program and processes are active and fulfilling the commitments made in the topical report. Review of a bounding (Rev 0) analysis would transfer the responsibility of the implementation and formal review of the calibration analysis from the NRC staff to the Licensee and Cameron. The historical record has demonstrated that this has worked very well, but the NRC may choose to retain some technical oversight of the process prior to approval. To address this concern without any schedule impact, the bounding Rev 0 submittal could contain the technical details of the proposed calibration plan, for NRC review. In this way, the licensee and Cameron would make a firm commitment to conduct certain testing during the calibration process, and could incorporate NRC comments or suggestions into the calibration process. It would also allow for NRC to witness the calibration process during its review of the LAR submittal, which could (1) increase the efficiency of the technical review, (2) provide for ongoing training of new reviewers

[1] In some cases, particularly where the LEFM CheckPlus System within 10 diameters downstream from tube-type flow straighteners, the bounding uncertainty for MF uncertainty may be somewhat higher, on the order of +/-0.32% for a single meter.

[2] Appendix A is a summary of results for over 409 hydraulic model calibration tests conducted with over 94 LEFM CheckPlus meters. Two standard deviations for the entire population is 0.22%, and the amount carried for in a Rev 0 analysis is 0.25% for the system (from 1 to four loops).

as they were assigned to the MUR uprates, and (3) provide a forum for answering questions that could significantly reduce RAI's.

It should be noted that in *every* MUR uprate to date, NRC approval has been granted in advance of the final confirmation of the uncertainties associated with the flow measurement systems. This final confirmation occurs at commissioning and ensures that uncertainties in the actual in-plant time measurements and in the actual in-plant non fluid time delays conform with the budgets of the Rev 0 and Rev 1 analyses. The final confirmation is documented in Rev 2 of the uncertainty analysis which is part of each licensee's record for the uprate.

3.0 RECOMMENDED PROCESSES

The discussion demonstrates the technical and resource efficiency benefits for two equivalent processes, both of which could result in MUR uprate submittals which would be acceptable according to the Office Guidance LIC-109.

1) Licensees could base their submittal on a bounding analysis (Rev 0), which would contain some additional (typically 0.02 to 0.03%) margin over the expected calibration results. The test plan details would be contained in this submittal for staff technical review and the staff would have the option to witness the calibration testing if they deemed it necessary or helpful. The submittal could be "Accepted for Review" by the NRC, based on the increased margin, and the on historical track record, which is considered as the proper Use of Precedent contained in LIC-109 Appendix B Section 3.1.2 Technical Staff Criteria.

2) Licensees could base their submittal on an uncertainty analysis that contained the calibration results for the meters that were to be installed in the plant (Rev 1). This course of action could result in a power uprate slightly larger than Option 1 above, but would also result in a longer project implementation schedule. This analysis could be "Accepted for Review" because all information needed to properly bound the calorimetric power uncertainty, except that gathered during commissioning, would be included with the submittal package.

A determination that one or both of these processes would be acceptable will provide clarity to the Licensees evaluating project schedules and future submittals for MUR Uprates.

Appendix A

Validating the Accuracy of Multi-Path Transit Time Ultrasonic Flowmeters (TP-139)

VALIDATING THE ACCURACY OF MULTI-PATH TRANSIT TIME ULTRASONIC FLOWMETERS

By

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INTRODUCTION

Transit time ultrasonic flow meters (UFMs) employing multiple chordal paths are now applied in many industries. One recent development is the nuclear industry using Cameron Caldon Ultrasonics (CCU) UFMs to improve their calorimetric determination instrumentation. This improvement is part of a program called "Measurement Uncertainty Reduction Uprate" or MUR. The MUR allows nuclear power plants to increase their licensed power levels by as much as 1.7%, using multi-path meters.

A nuclear power plant's calorimetric determination requires accurate knowledge of the feedwater flow rate and temperature. Cameron Caldon Ultrasonics UFMs for the nuclear industry, known as the LEFMCheckPlus (8 path), can be used to determine both parameters with accuracies of ±0.3% and ±0.3°C respectively.

Due to the feedwater flow measurement accuracy requirement, Cameron Caldon Ultrasonics calibrates their nuclear flowmeters in a full scale plant model. These models provide opportunities to perform parametric tests that quantify the sensitivity of multi-path UFMs to upstream hydraulics.

Over the past 10 years, Caldon Ultrasonics has performed their laboratory calibration tests at the Alden Research Laboratory (Holden, Massachusetts, USA). These calibration tests included a range of meter sizes and upstream piping configurations. The multi-path transit time technology has demonstrated insensitivity to upstream and downstream configurations that include elbows, manifolds, and Y branches.

Metrics such as flatness ratio (FR) and swirl rate are used to characterize the velocity profile. These metrics also validate the meter factor determined at Alden Laboratory by relating the field installation to the laboratory calibration.

THE METER

The meter relating to these tests is the LEFMCheckPlus UFM. It has 8 paths, but more specifically it has two chordal planes at right angles to each other. The calibration of 4 path chordal meters can be sensitive to transverse fluid velocity, since such velocity components may project onto the chordal paths. Transverse velocity components sometimes change over time if, for example, they are brought about by the distortion produced by a flow regulating valve. Changes in relative roughness can also produce changes in the magnitude of transverse velocity components.

To eliminate this sensitivity to transverse velocity, nuclear applications requiring the highest accuracy employ an 8-path arrangement, shown in Figure 1, below. The paths are arranged so as to form, effectively, two separate meters each having 4 paths in a plane with the two planes lying at plus and minus 45° with respect to the nominal flow axis. Each of the two meters numerically integrates the velocities projected onto its chords. The arrangement is such that transverse velocity components that project onto the chords of one of the two meters are effectively cancelled by the measurements of the second meter, while the axial velocity components reinforce each other. This becomes an important issue when trying to use the path data to assess uncertainty. The 8 path arrangement also provides the robustness required of the nuclear measurement; the meter can tolerate any single failure and still deliver accuracies close to what it delivers with all components operational.

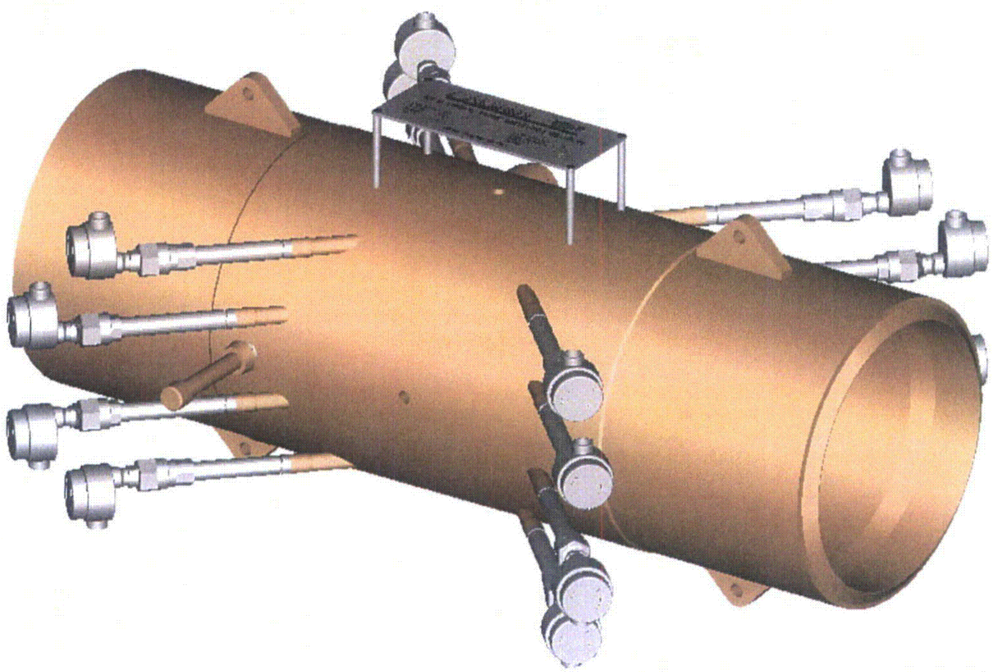

Figure 1 - LEFMCheckPlus UFM

A further piece of data available from this meter is the actual value of the swirl, useful in assessing the potential performance of the meter under the operational conditions.

BACKGROUND OF THE DATA

The data presented in this paper include ISO17025 traceable calibration data for 94 LEFMCheckPlus flow elements. The calibration data in this report were obtained in full scale models of the applicable feed water installations at Alden Research Laboratory. A meter factor is obtained by comparing the flow calculated by Alden Labs to measured flow by the LEFMCheckPlus.

For each installation, the meter factors are analyzed using two metrics: swirl rate and flatness ratio. The latter metric is the ratio of the fluid velocity measured along the outer chords to that measured along the inner chords. Flatness is a quantitative measure of the axial velocity profile and can be used to characterize differences in the profile seen by the flow element in the field versus the profile(s) prevailing during calibration in the lab. In nuclear feed water systems, flatness can range from 0.80 to 1.050--values over 1.000 are indicative of cupped or dish shaped profiles, such as that produced by some high swirl flow conditions or downstream of elbows.

ALDEN LAB DATA

Figure 2 summarizes the nuclear feedwater UFM calibrations. The figure's vertical axis is the ratio of ARL laboratory flow/volume to the LEFMCheckPlus flow/volume, commonly known as the meter factor. Note that the lab tested data is in the range of 0.99 to 1.01 or +/- 1%. This data includes the effects of installation but also the effect of manufacturing and mechanical measurement of for example the path length. It is therefore the measurement of the variation of calibration on fluid and a "dry" calibration. Meters are typically installed downstream of elbows or other piping disturbances that distort the velocity profile. The average meter factor of the population of data from lab testing is 1.002[1] with a standard deviation of ±0.0040. This represents a population of 94 meters tested in 409 different hydraulic configurations.

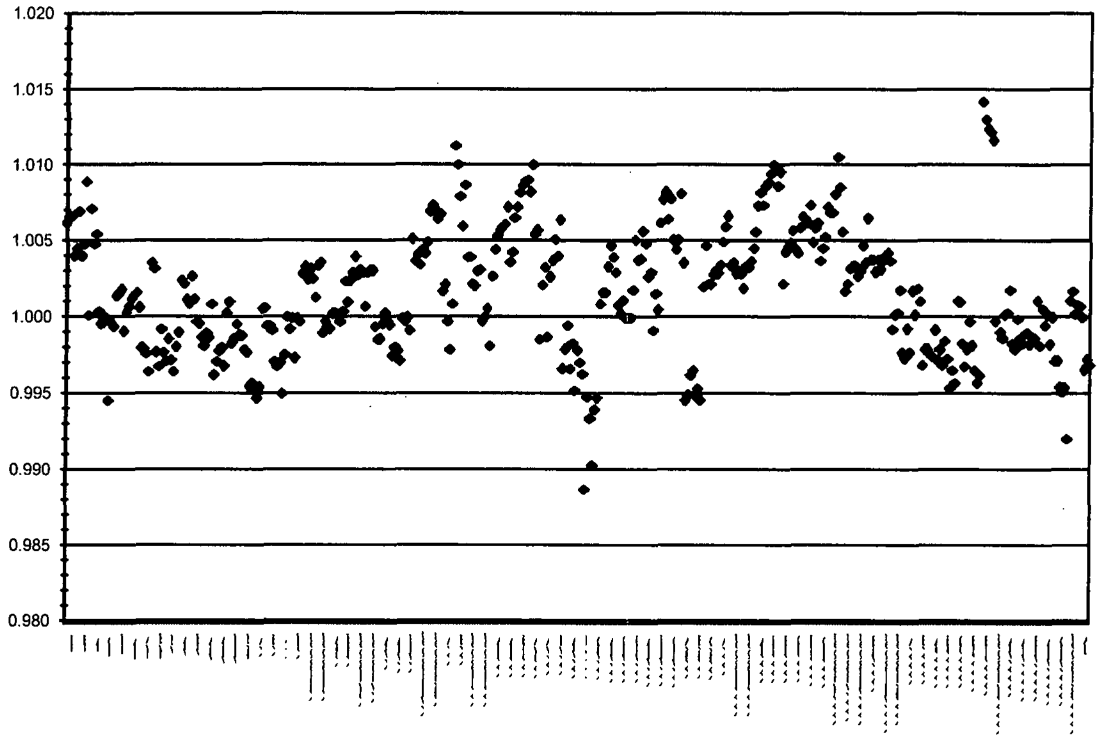

Figure 2- Summary of Nuclear Meter Calibrations[2]

[1] 1.002 is also the meter factor that is computed when integrating a turbulent velocity profile in a round pipe with 4 paths spaced according to Gauss-Legendre numerical integration.

[2] On the horizontal axis of the graph, the names of the plants have been replaced by Roman numerals. Additionally, each item has a suffix, such as an "A", "B", "C", "D" or "Header". The suffix describes the plant configuration – the letters ("A", "B", "C", and "D") refer to installations that individual feedwater lines either coming from separate heater chains or going to separate steam generator inlets, while the "Header" refers to applications where the total feedwater goes through one flow meter.

Figure 2 therefore reflects the data scatter due to both the differences between individual meters[3] and the differences in upstream hydraulics.

A typical meter has between 4 to 5 "parametric" calibration tests[4] performed. Parametric tests performed to validate/verify the calibration sensitivity can be described in one of three ways, as follows:

Model Component Parametric Tests

The hydraulic model entails the upstream piping including any major hydraulic features that could influence the flow meter's hydraulics/calibration. This modeling approach has resulted in models that include multiple elbows, venturi(s), valves, Tees, Wyes, reducers etc. In order to validate that the calibration is not sensitive to the model itself, parametric tests are then performed where flow conditioners are installed within the model, to demonstrate the sensitivity, if any, to the construction of the hydraulic model.

Inlet Conditions Parametric Tests

In order to eliminate the possibility that the inlet condition provide by the laboratory influences the calibration itself, the inlet is modified. Modifications include installing and removing plate flow conditioners at the plant model inlet. Occasionally, an eccentric orifice at the inlet has even been installed to demonstrate that even extremely distorted inlet conditions have little effect.

Model Velocity Profile Parametric Tests

To demonstrate that multi-path UFMs with path spacing based on numerical integration of the velocity field are not sensitive to changes in velocity profile, the flatness and/or swirl is intentionally changed. These tests typically use knowledge of the model to increase or decrease the swirl within the system. Sometimes, these changes are accomplished by adding components (for example an eccentric orifice plate) or by changing flow inlet ratios when two or more inlets are entering.

Figures 3 shows a diagram of the typical parametric tests, and Figures 4, 5 and 6 shows photographs of some complex models of nuclear installations that have been built.

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[3] Difference include inside diameters ranging from 12 inches to 32 inches. Further, each meter has uncertainties due to dimensional and angle measurement errors and machining differences.

[4] A hydraulic test itself includes 5 tests at 5 flowrates that are distributed evenly over a nominal 10:1 flowrate turn down. The flowrates range from a minimum of ~454 m^3/hr to the ARL maximum flow rate achievable, nominally 4543 m^3/hr. The maximum flowrate depends on the model components that may choke max flow to a slightly lower value.

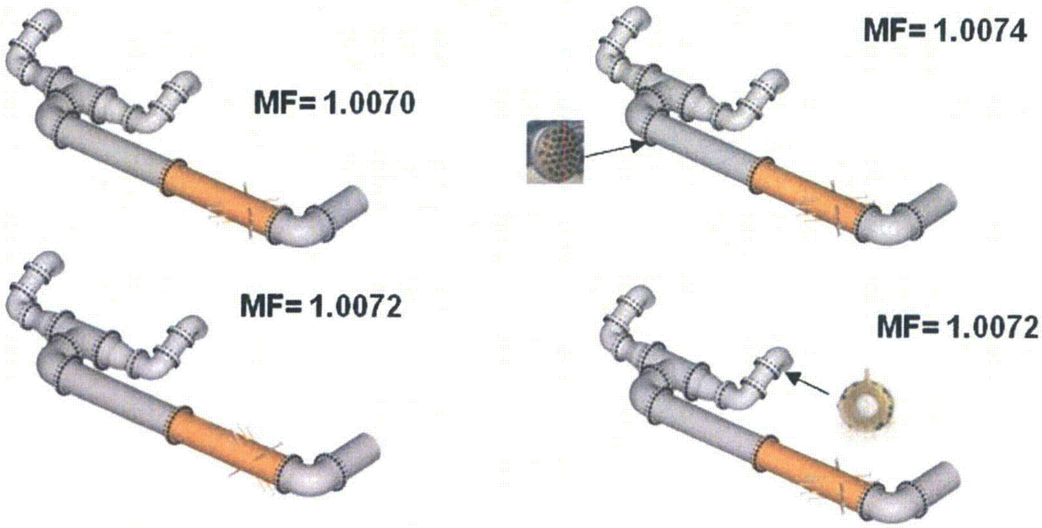

Figure 3 - Example of Different parametrics for a Given Installation

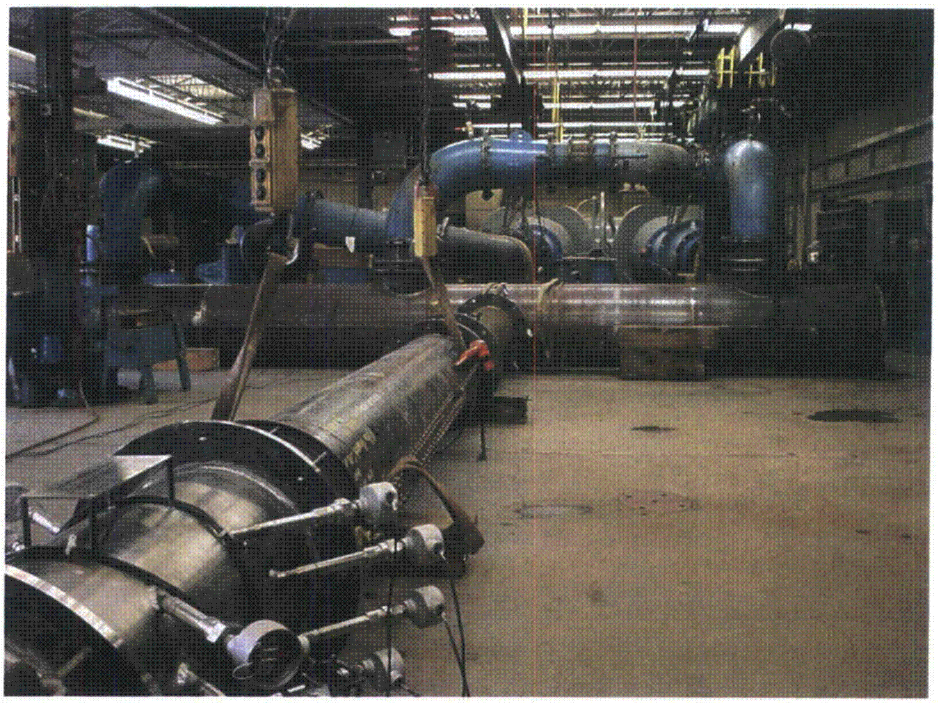

Figure 4 - Example of Calibration with Multiple (Non-Planar) Flow Inlets

Figure 5 - Example of Calibration with Non-Planar Model Components with Meter in Close Proximity to Upstream Elbow (Two meters shown)

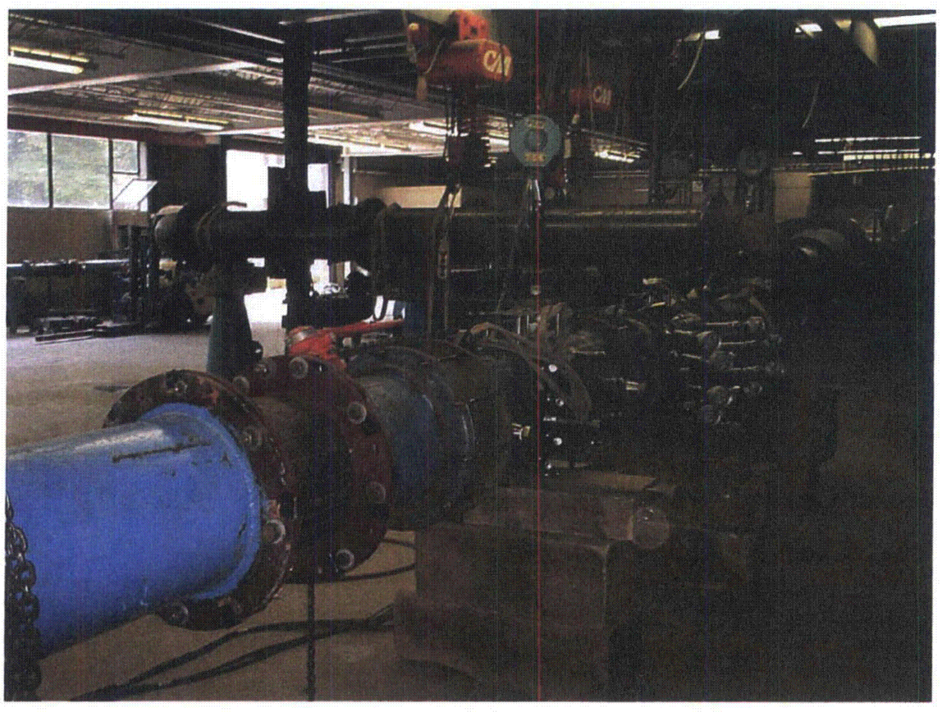

Figure 6 - Example of Calibration with Meter in Close Proximity to Non-Planar Coupled Upstream Elbows

The data shown in Figure 2 is re-analyzed by subtracting each flowmeter's average meter factor from its parametric tests to eliminate the geometric uncertainty from the hydraulic uncertainty. The net meter factors are analyzed and graphed below. The standard deviation of the net meter factor due to hydraulic configuration alone is ±0.11%. Throughout this the remainder of this report, the net meter factor data will be considered, unless otherwise stated.

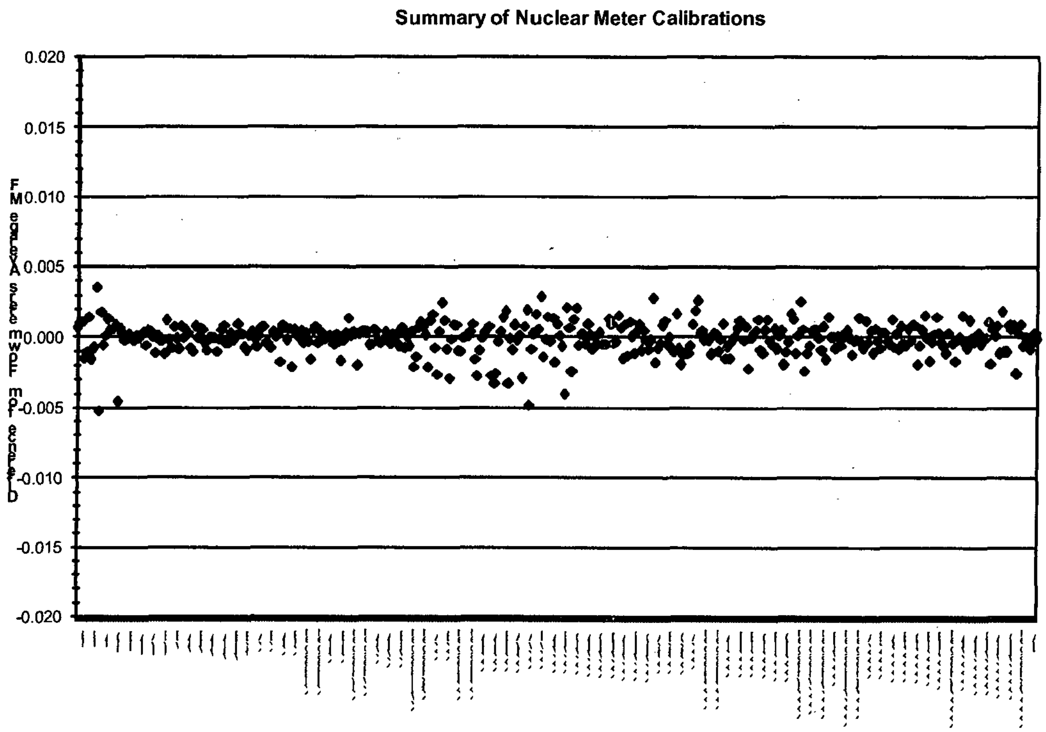

Figure 7 - Net Meter Factor for all Calibrations
(Net MF = Difference from the flowmeter's Average MF)

METRICS FOR DESCRIBING VELOCITY PROFILE

In each test, the velocity profile of the calibration can be measured. Depending on the hydraulic model, these velocity profiles can range from symmetric to quite distorted (see Figures 8 and 9 as examples of symmetric and distorted).

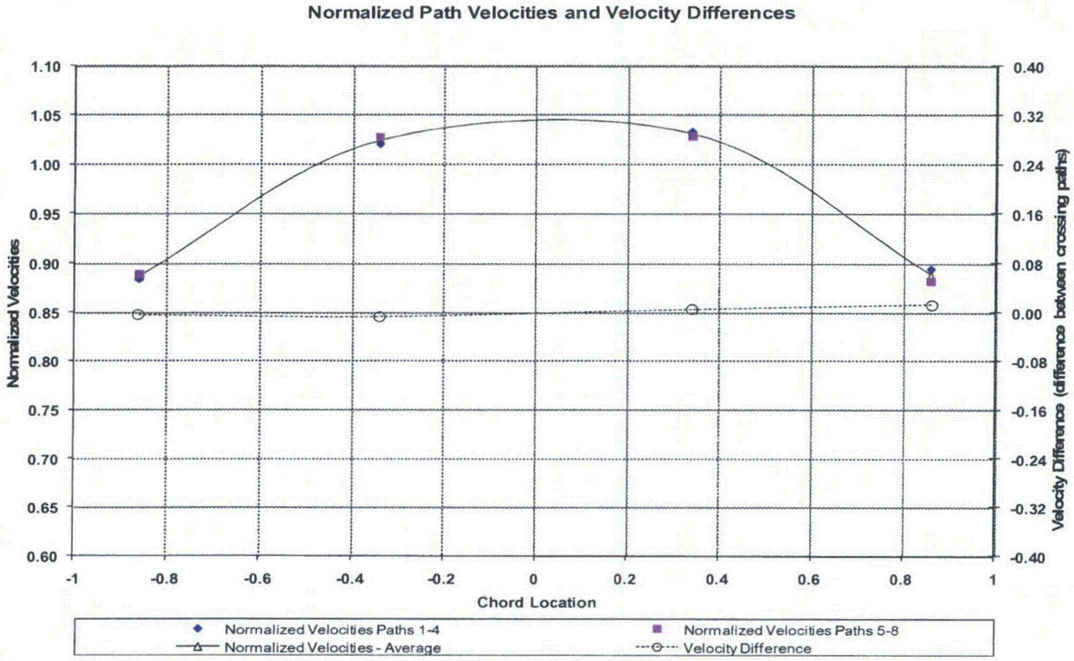

Figure 8 - Example of Measured Symmetric Velocity Profile

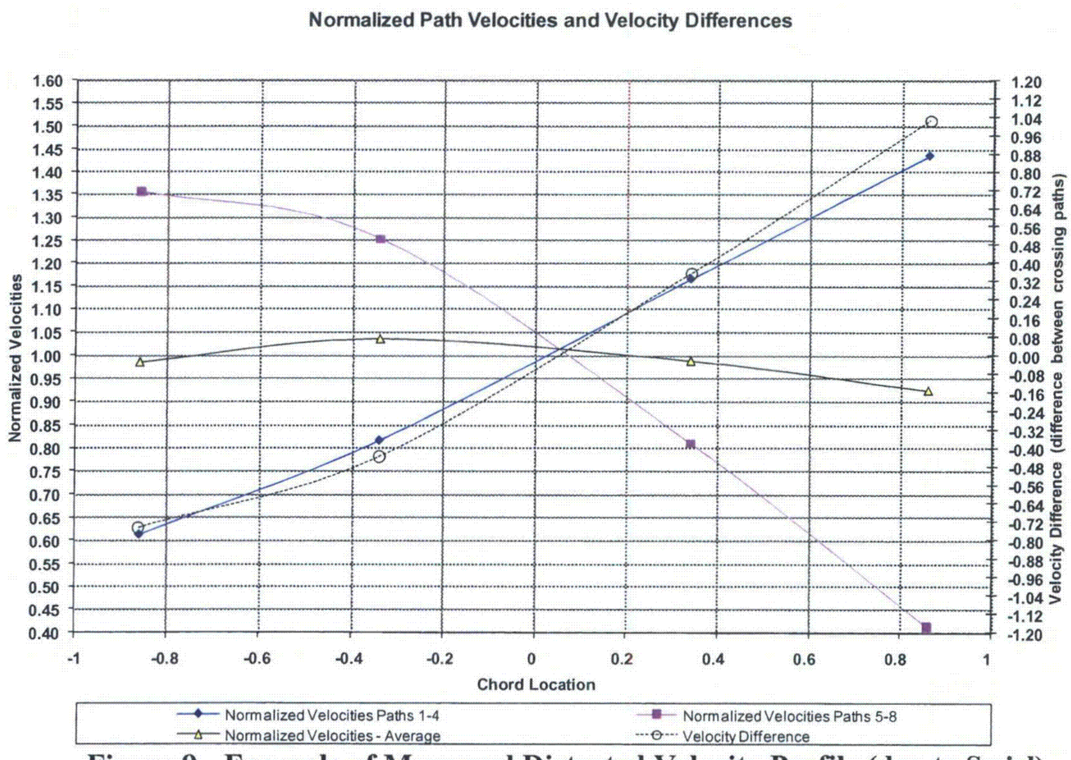

Figure 9 - Example of Measured Distorted Velocity Profile (due to Swirl) – same meter as in Figure 6

When faced with so many models and their individual velocity profiles, a metric(s) is required to help organize these velocity profiles[5]. CCU defines two metrics, swirl rate and flatness ratio.

Swirl Rate

$$\text{Swirl Rate} = \text{Average}\left[\frac{V_1 - V_5}{2 \cdot y_S}, \frac{V_8 - V_4}{2 \cdot y_S}, \frac{V_2 - V_6}{2 \cdot y_L}, \frac{V_7 - V_3}{2 \cdot y_L}\right]$$

Where:

V_1, V_4, V_5, V_8	=	Normalized velocities measured along outside/short chords
V_2, V_3, V_6, V_7	=	Normalized velocities measured along inside/long chords
y_S, y_L	=	Normalized chord location for outside/short and inside/long paths

This gives the swirl, or cross-flow as a proportion of the total flow. Swirl rates computed to be less than 3% are considered to be low and are typically observed in models with only planar connections. Swirl rates greater than 3% are considered "swirling". Swirl rates greater than 10% are considered to have strong swirl. Figure 10 summarizes the swirl rates observed in model testing.

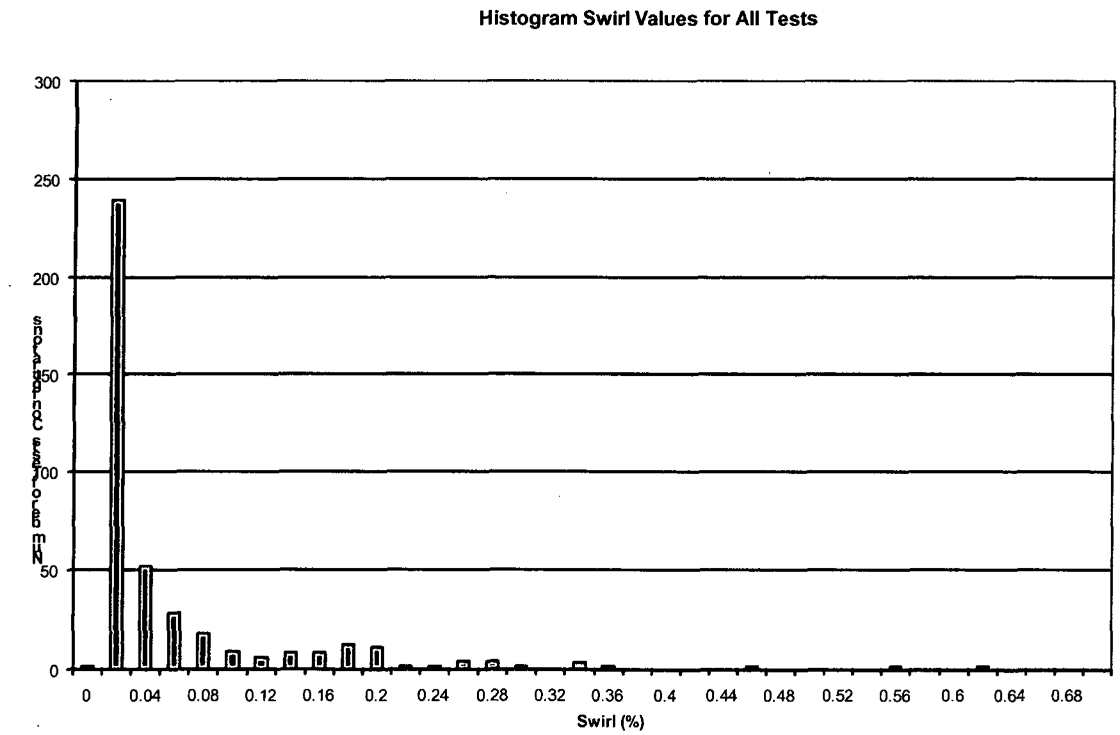

Figure 10 - Swirl Rates Observed in Model Testing

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[5] It is understood that metrics reduce the fine details of any observed velocity profile into a single number, but this is necessary when comparing so many calibrations.

Flatness Ratio

$$\mathrm{FR} = \left[\frac{V_1 + V_4 + V_5 + V_8}{V_2 + V_3 + V_6 + V_7}\right]$$

When a velocity profile is perfectly flat, then FR equals 1.0. When a velocity profile is laminar, then the FR equals approximately 0.38. The limits of 0.38 and 1.0 represent extremes. The FR is a function of Reynolds number but also is strongly influenced by the hydraulics upstream of the flow meter.

Typical feedwater applications have FR in the range of 0.8 to 0.9. Downstream of flow conditioners, the velocity profile tends to be pointier and the FR value is lower, 0.78 to 0.80. Downstream of elbows and tees the velocity profile tends to be flatter and the FR value is higher, 0.85 to 0.95. The actual range at a given plant is dependent upon site upstream conditions (for example the hydraulic fittings such as tees, elbows, etc.). Figure 11 summarizes the FR values observed in model testing.

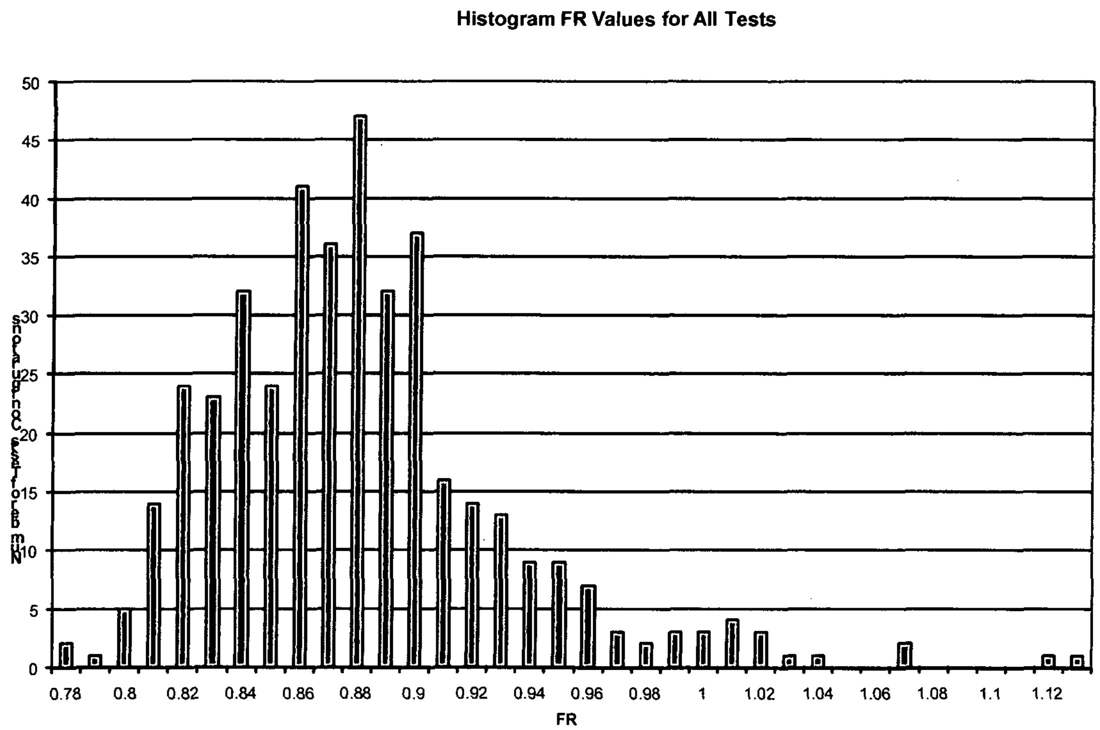

Figure 11 - FR Values Observed in Model Testing

METER FACTOR RELATIONSHIP TO VELOCITY PROFILE METRICS

Figure 12 plots meter factor variation as a function of swirl. There is no correlation between the MF and percentage of swirl for an 8 path meter. This is indicative of the effective removal of the effect by the use of cross-paths. At very low values of swirl there is a wider scatter of data. Some of this may just be the relative paucity of data at the higher swirls. It also strongly suggests that higher swirl has the effect of ordering the profile and controlling the boundary layer, thus reducing the range of differing boundary layers among the tests.

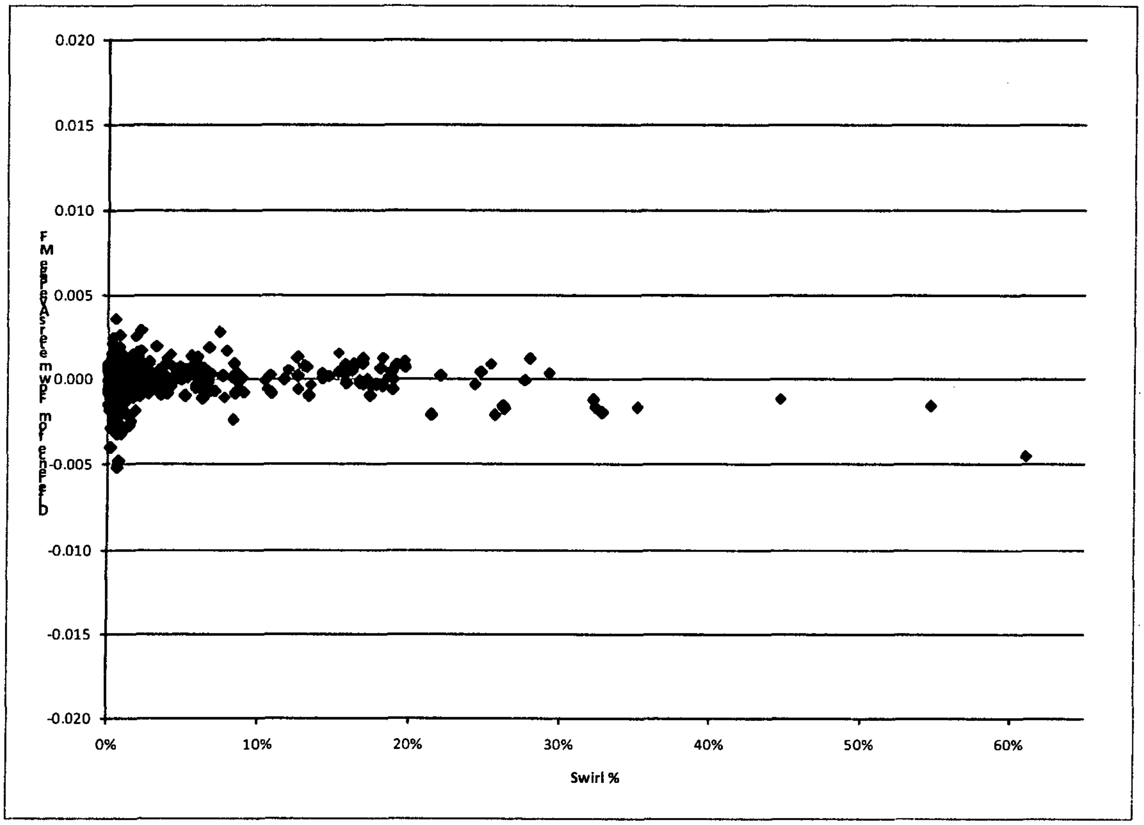

Figure 12 - Net Meter Factor[6] vs. Swirl

Figure 13 plots meter factor variation as a function of FR. Again, much of the data is uncorrellated. Nevertheless, a slight relationship exists between meter factor and flatness ratio.

Notwisthanding, the concept of meter factor to characterize profile variations can be sucessfully used on a specific meter, particularly if that meter has a more axi-symmtric velocity profile.project by project basis. Further, the FR observed during calibration can be compared to that observed in the field.

[6] Meter factor normalized against the average meter factor for each meter.

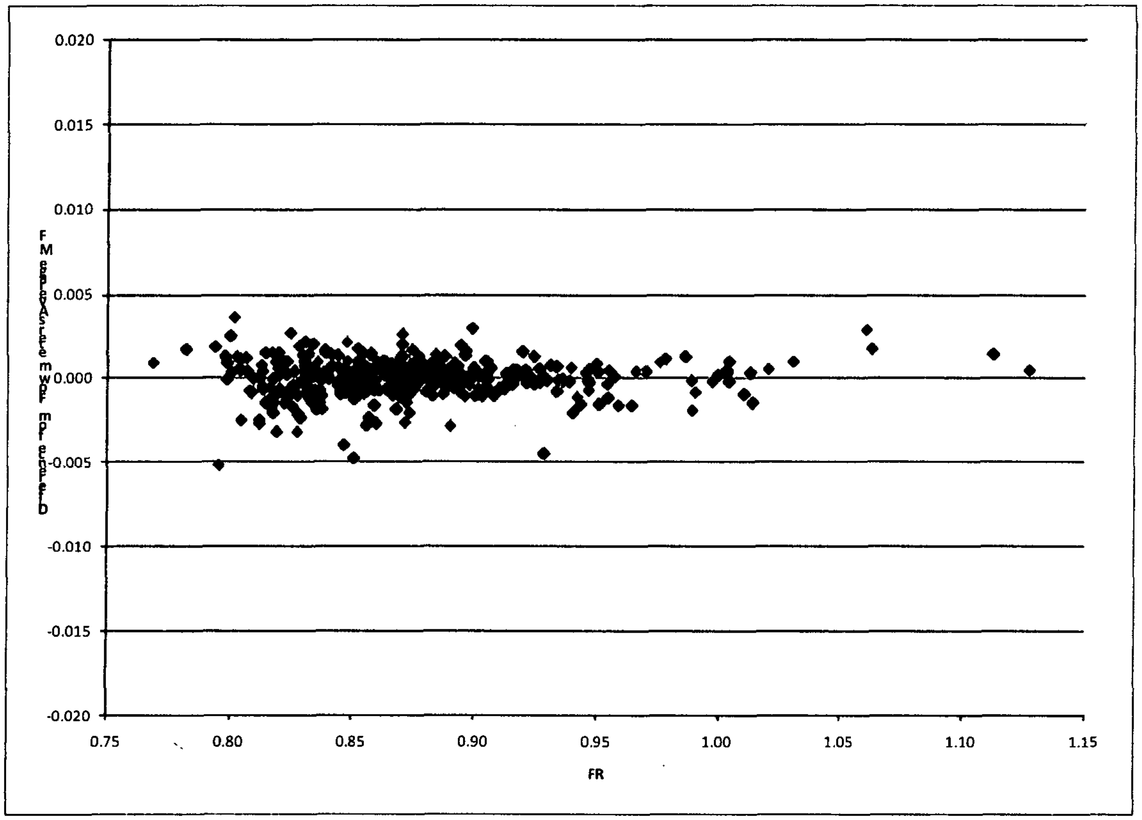

Figure 13 - Net Meter Factor vs. FR

Meter Factor Relationship to Reynolds Number/Flatness Ratio

In determining the meter factor for the flow meter, differences between the laboratory and the field must be considered, particularly the difference in Reynolds number.

At first, the practice was to extrapolate integration uncertainties only based on Reynolds Number (Re) from laboratory conditions to the field. This involved extrapolations of Re from laboratory conditions of 1 to 3 million to field conditions Re of 10 to 30 million[7]. It was suggested that the measured flatness ratio would be a better indication of actual meter performance in the field.

Flatness Ratio Basis

In order to perform this extrapolation a model was developed based on wall law-exponent functions. Symmetrical axial profiles can be described using the inverse power law, which represents the spatial axial velocity distribution in a pipe of circular cross section as follows:

$$u / U = (y / R)^{1/n}$$

Where u is local fluid velocity,

[7] Since the viscosity of the high temperature water (230°C) is significantly less than that of laboratory water (40 to 45°C).

U	=	fluid velocity at the centerline,
y	=	distance from the pipe wall,
R	=	internal radius of the pipe, and
n	=	empirically determined exponent.

The inverse power law was used extensively by Nikuradse and others to fit flow profiles over a wide range of Reynolds Numbers in rough and smooth pipe, in the development of the methodology for calculating friction losses in turbulent flow[8].

Flatness ratios and meter factors calculated using the power law function is shown in Figure 14.

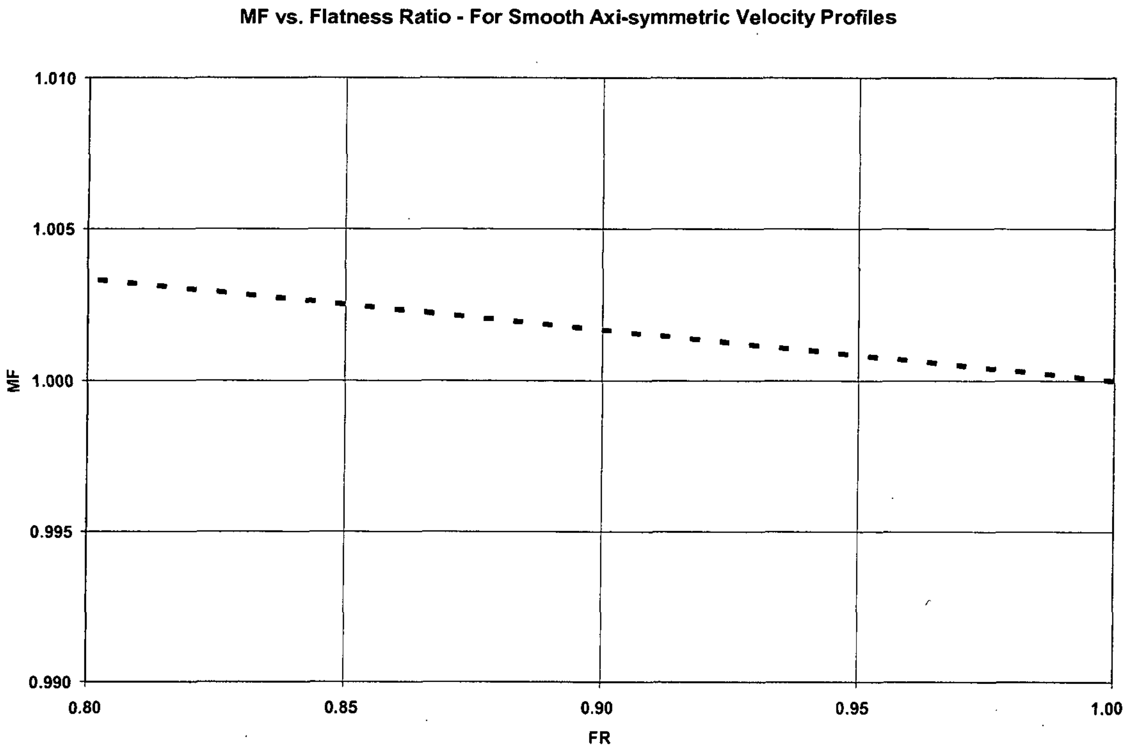

Figure 14 - Theoretical MF vs. Flatness Ratio

The relationship between meter factor is expressed in the equation MF= -0.0167 FR+ 1.0167. This analysis assumes that the flow has an axis-symmetric, non-inverted profile, asymmetric and inverted profiles will cause deviations from this law.

EXAMPLES OF MF VS FR RELATIONSHIP

Plant "XII" (see Figure 1) is used to demonstrate the effectiveness of flatness ratio. In Figure 15, the actual data when compared to the theoretical data is very close to the expected value. Figure 15 illustrates the actual meter data along with the theoretical curve (offset to the

[8] Schlichting, Dr. H. Boundary Layer Theory 6th Ed. McGraw-Hill 1968 N.Y. pp563

average of that flowmeter's meter factor). It should be noted that the piping had sufficient lengths of straight pipe to allow swirl to become axis-symmetric (approximately 10 diameters upstream).

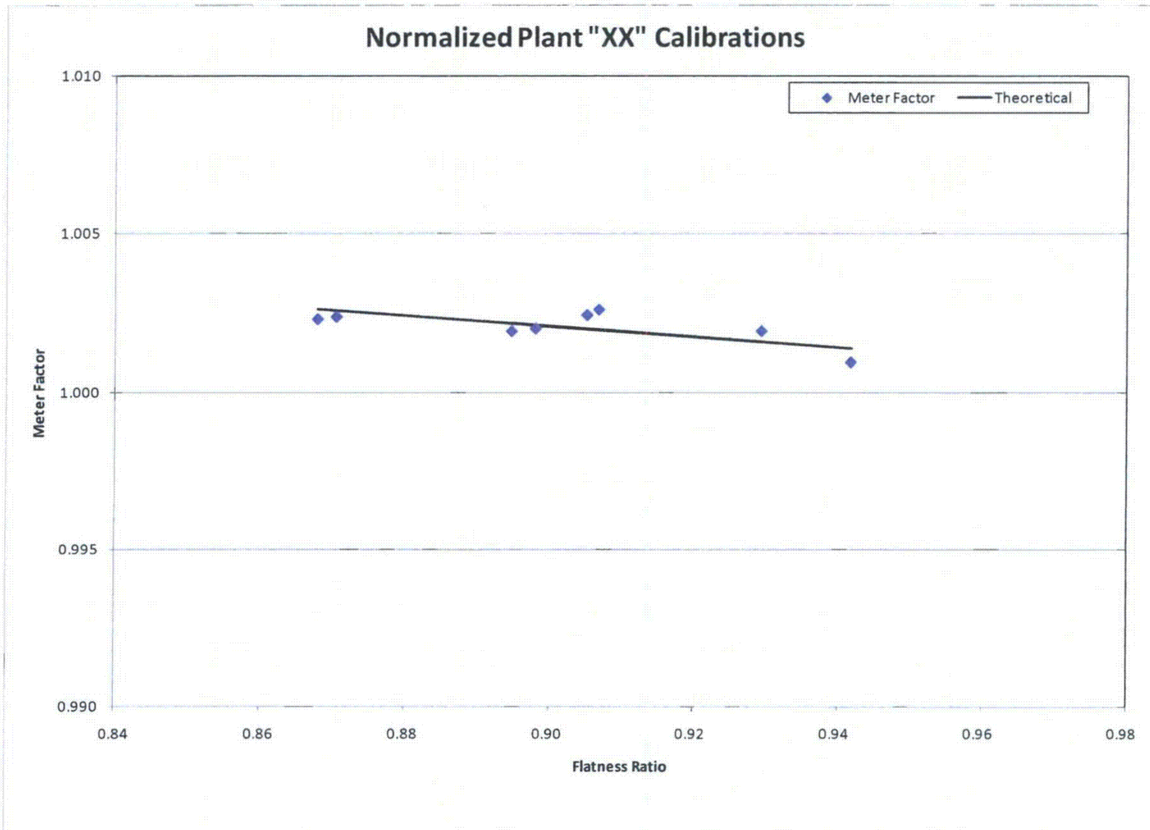

Figure 15 - Plant "XX" Calibrations

The lab data obtained in Figure 15 can be used to extrapolate to other flatness ratios. More importantly, this data can be used to put a bounding uncertainty on the extrapolation. Rather than a direct correction this is used to give the additional uncertainty due to the installation. The validity of the extrapolation and hence the added uncertainty can be confirmed by the flow meter's measurement of FR at the plant.

The effectiveness of the FR is based on an axi-symmetric assumption. Clearly where the velocity profile does not conform to that assumption, the validity of the approach is weakened. Further, in tests where the velocity profile is not smooth, particularly downstream of tube bundles and plate flow conditioners (like a Mitsubishi flow conditioner), the FR relationship to MF is not maintained. These flow conditioners produce small scale velocity profiles (due to the jets produced by the flow conditioner) that produce meter factors that clearly differ from the FR relationship.

The meter installation shown in Figure 16 is a case that validates the conditions for the use of FR as an extrapolation tool and shows its limitations.

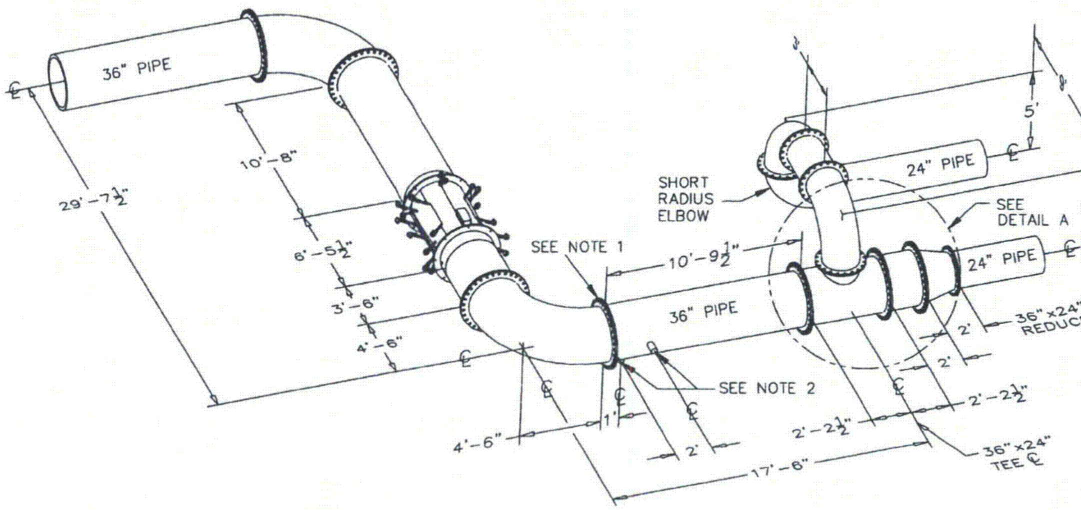

Figure 16 - Meter Installation Model

Not only is it a complex installation, but it has the opportunity for both a planar flow and swirl, depending on the flow paths and fittings. Figure 17 shows an analysis of different swirls

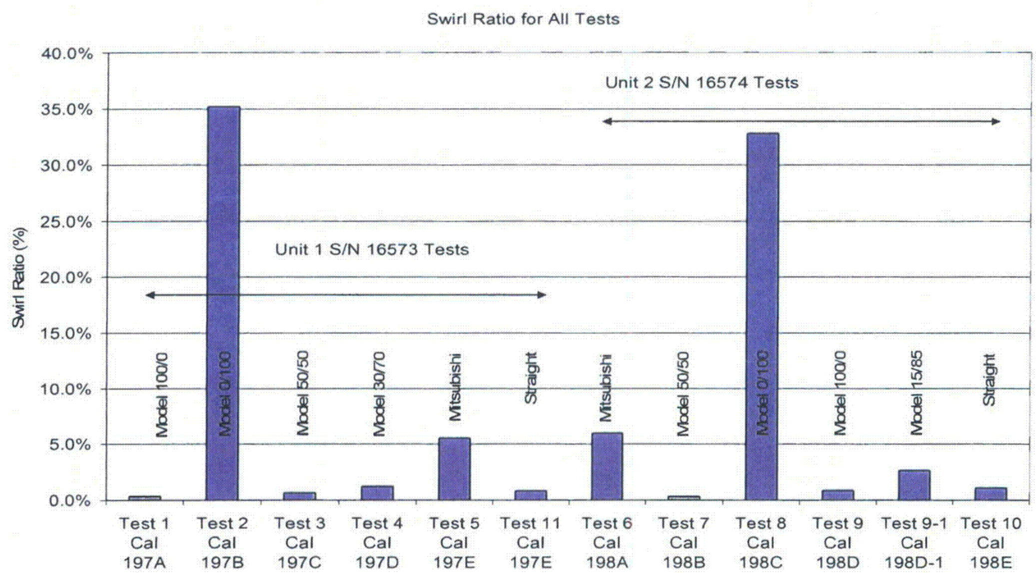

Figure 17 - Analysis of the Swirl Conditions for Different Tests

The profile with a long straight pipe is shown in Figure 18. It is marginally asymmetric, but would generally be acceptable for flatness ratio determination.

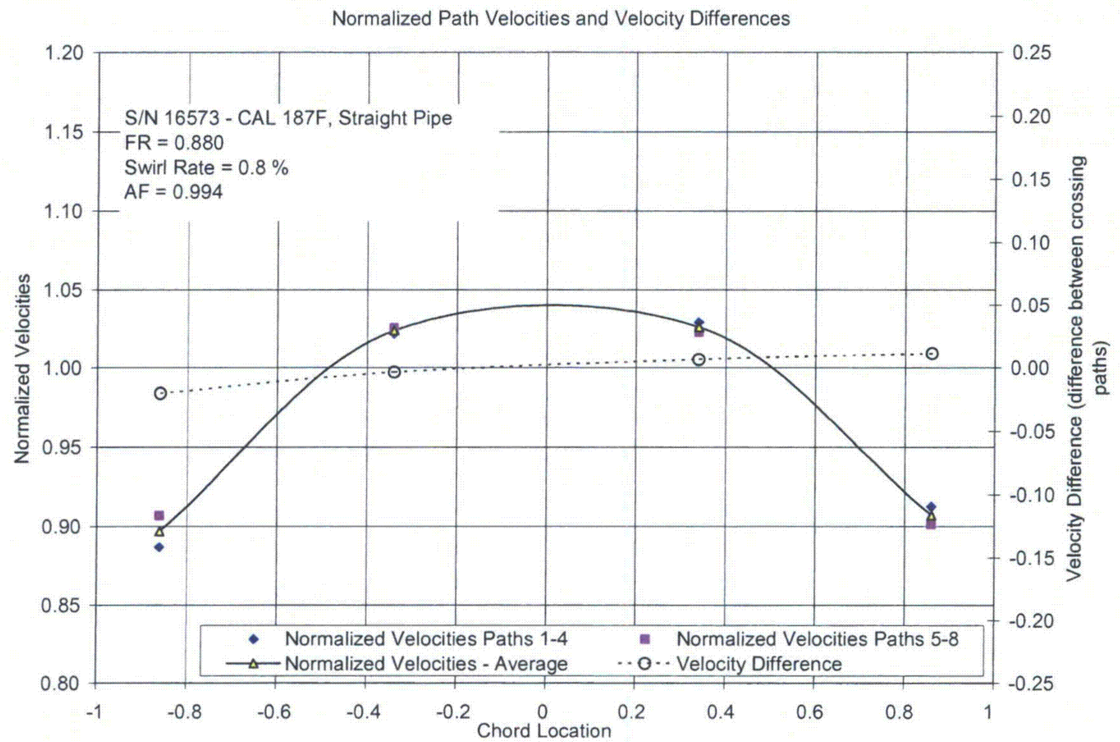

Figure 18 - Velocity Profile with a Straight Pipe Upstream

The profile, however, with a Mitsubishi conditioner immediately upstream of the final bend, Figure 9 shows an extreme profile, one plane of which shows clearly a inverse effect.

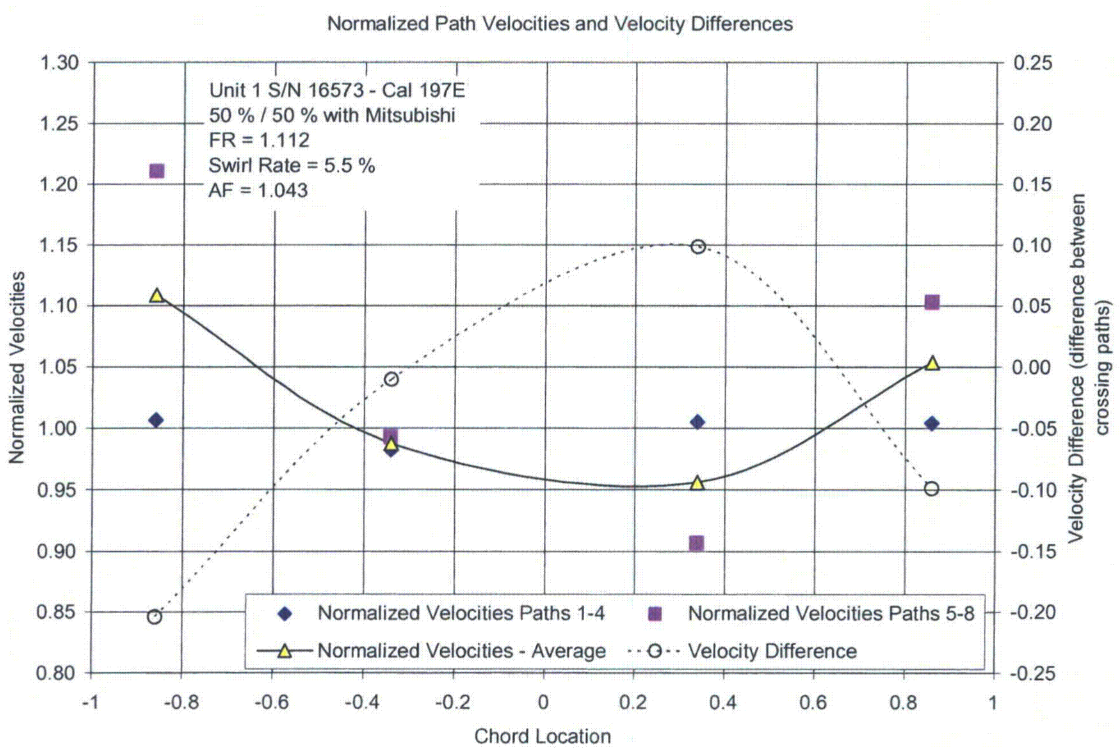

Figure 19 Flow Profile with Mitsubishi Plate Upstream of Last bend

The effects of the different conditions on the relationship of MF to FR are shown in Figure 19. There is a general trend of the data along the axi-symmetric relationship line, but factors such as the heavily distorted profile, and the excessive swirl, over 30% drive the data away from the prediction. It should be noted, however, that the spread of data even under excessive conditions is no more than 0.35%

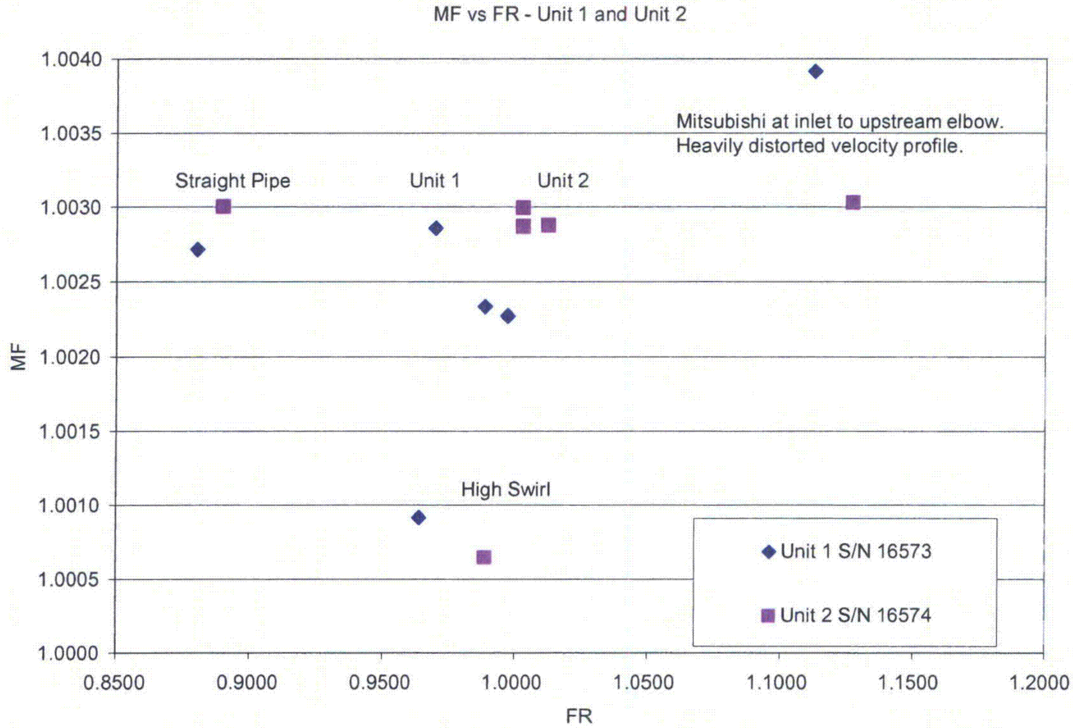

Figure 19 MF Against FR

CONCLUSIONS

A population of 94 flow meters, ranging in inside diameter from 12 inches to 32 inches, was calibrated at an ISO17025 traceable laboratory. 409 different hydraulic configurations were tested. The meter factor population average is 1.002. This average value equals that analytically calculated based on turbulent flow. The meter factor's sensitivity to upstream hydraulics is ±0.11%. The meter factor variability between meters (excluding the hydraulic effects) is computed to be ±0.39%.

Two metrics, Swirl rate and Flatness ratio are used to describe the different velocity profiles of the calibration population. The meter factor population is slightly correlated to flatness ratio. The correlation to FR is stronger on an individual meter basis, particularly if the meter's installation has a few diameters upstream to become more axi-symmetric. Use of the FR to determine a meter factor without a calibration is possible, particularly on cases where the hydraulic profile is axi-symmetric, even including swirl. The approach needs more field data to verify its effectiveness.

Appendix B

ER-769 Summary Discussion

Background

ER-769 was written to provide a suggested template for the MUR Uprate Process, consistent with NRC Office Guidance LIC-109. In subsequent discussions with the staff about the proposed procedure on September 15, 2009, members of the staff suggested that the report could be augmented with a cost/benefit analysis of the recommended procedure compared to its alternative. This analysis and discussion responds to that suggestion.

Purpose

The purpose of this Appendix to ER-769 Rev 0 is to analyze the economic effects of the proposed procedure for Acceptance Criteria and Review of Submittals for MUR Uprates.

Discussion

The body of the report recommends that the Licensee have the option to submit an MUR LAR based upon a "Rev 0" bounding uncertainty analysis that is subject to verification during the review process. The bounding analysis approach would result in slightly smaller uprates, to allow for somewhat higher margins, but would result in accelerated implementation schedules.

There are several key aspects which result in positive benefits when compared to an approach which would demand that the calibration for the LEFM CheckPlus be available prior to submittal, and one negative aspect of the proposed accelerated schedule option. These are reviewed and discussed below.

Positive benefits of accelerated schedule

1) An MUR power uprate schedule, typical of previous submittals and equivalent to the one proposed in ER-769 is shown in Figure 1 in the body of the report. The time from initial commitments of orders to implementation of the approved MUR uprate is approximately 18 months (This figure includes the time for the engineering analyses to support the uprate). This schedule can be achieved when there is reasonable certainty of the target uprate value such that engineering analyses can be begun early in the project. Figures 2 and 3 present alternative schedules based upon the requirement for complete calibration data prior to submittal of an MUR LAR. The schedule of Figure 2 shows that implementation would be delayed between 286 and 540 days, assuming an NRC review cycle of 8 months. The schedule of Figure 3 shows an implementation delay of 226 to 540 days, assuming an NRC review schedule of six months. A cash flow analysis of each schedule is provided in the spreadsheet in Appendix B-1. The difference in net present value after 20 years from project start is $8,095,948, in favor of the Rev 0 submittal. It should be noted that the difference in net present value between the two schedules is fixed at $8,095,948 after three years once implementation occurs.
2) Efficiency gains in the review by NRC are also accomplished by the Rev 0 submittal. If. On the other hand, the submittal is made after calibration testing is complete, RAI's pertaining to that testing could reasonably be expected. NRC has indeed become more interested in the hydraulic testing results in recent submittals, as experience with certain systems revealed questions about the bounding nature of uncertainties calculated from generic type tests as applied to specific plant installations. The NRC has determined that more particular attention to the tests for a specific Licensee request is appropriate. The schedule proposed for a Rev 0 application would require submittal of the calibration test

plan with the LAR request, so that the staff would have opportunity to provide feedback on the plan outside the formal RAI process, thereby addressing potential questions that would otherwise result in RAI's, In and of itself this early interaction has value in the staff's time and review effort. Additionally, the opportunity for the staff to witness calibration testing has proven to be a beneficial process, whereby RAI's can be avoided and the review time required by the staff can be condensed significantly. The analysis of these avoided costs and efficiency savings is provided in Appendix B-2. The savings represented by the proposed schedule would be as high as $64,960.

3) If it is required that calibration results be submitted with the LAR, it is very likely that RAI's would be generated on those tests. It is possible, perhaps probable, that, to fully address and answer these RAI's, additional testing would be required. The schedule delays while further tests were planned, conducted and analyzed would have significant economic costs to the licensee. In addition, if the RAI's required the construction of additional meters (because the initially tested meters had already been installed), the costs and schedule delays would be even more significant. Appendix B-3 provides an analysis of these potential costs, and concludes that the costs could be as high as $395,000.

Licensee 20 year costs associated with use of a conservative bounding value for the MUR LAR.

Experience has proven that a margin of between 0.02 to 0.03% power, over and above a best estimate of the expected value of an uprate is sufficient to assure that the bounding uncertainties used in a Rev 0 submittal would not be exceeded as a result of calibration testing and instrument commissioning. The 20 year cost of this conservatism is $935,481, which subtracts from, but does not offset the benefits of the Rev 0 submittal. An analysis of this cost in provided in Appendix B-4.

Conclusion

The proposed schedule, based upon MUR LAR submittals using a bounding Rev 0 analysis, has a net present value of approximately $7,000,000 greater than the LAR submittals based upon a Rev 1 analysis, and the risks are reduced.

Appendix B-1

Cash Flow Analysis

ER-769 Appendix B-1
20 Yr Cash Flow Comparison between Rev 0 and Rev 1 Schedules
1-Oct-09
Prepared by EMH

Assumptions

1. The overall budget cost for MUR Uprate Project is $5,000,000	5,000,000
2. Flowmeter Hardware Cost is $1,600,000	1,600,000
3. Flowmeter Installation Costs are $ 500,000	500,000
4. NSSS Engineering Analysis Cost is $1,800,000	1,800,000
5. BOP Analysis Cost is $ 800,000	800,000
6. LAR Submittal Preparation Costs are $50,000	50,000
7. NRC Review Fee Costs are $ 150,000	150,000
8. Tech Spec and Procedure Modifications are $100,000	100,000
9. Incremental Revenue from MUR is achieved from date of implementation	
10. Average Plant size	1,100
10. Average uprate is 1.65%	18.150
11.Capacity factor assumed is 90%	90%
12. Incremental value per Mwe-hr is $50.00	50
	7,154,730

Rev 0 Submittal Schedule

month	Line item Total	1	2	3	4	5	6	7	8	9	10
Hardware	1,600,000	400,000									800,000
Installation	500,000						125,000				
NSSS Analyses	1,800,000			300,000	300,000	300,000	300,000	300,000	300,000		
BOP Analyses	800,000			133,333	133,333	133,333	133,333	133,333	133,333		
LAR Submittal	50,000									25,000	25,000
NRC Review	150,000										
Tech Spec/Procedure Mods	100,000							25,000	25,000	25,000	25,000
Incremental Revenue	7,154,730										
Total Cash in Period		(400,000)	-	(433,333)	(433,333)	(433,333)	(558,333)	(458,333)	(458,333)	(50,000)	(850,000)
Cumulative Cash		(400,000)	(400,000)	(833,333)	(1,266,667)	(1,700,000)	(2,258,333)	(2,716,667)	(3,175,000)	(3,225,000)	(4,075,000)

Net Present Value @
10% $ 46,959,507.60

Rev 1 Submittal Schedule

month	Line item Total	1	2	3	4	5	6	7	8	9	10
Hardware	1,600,000	400,000									800,000
Installation	500,000						125,000				
NSSS Analyses	1,800,000										
BOP Analyses	800,000										
LAR Submittal	50,000										
NRC Review	150,000										
Tech Spec/Procedure Mods	100,000										
Incremental Revenue	7,154,730										
Total Cash in Period		(400,000)	-	-	-	-	(125,000)	-	-	-	(800,000)
Cumulative Cash		(400,000)	(400,000)	(400,000)	(400,000)	(400,000)	(525,000)	(525,000)	(525,000)	(525,000)	(1,325,000)

Net Present Value @
10% $ 38,863,559.82

DIFFERENCE $ 8,095,947.78

Reviewed by: HE

11	12	13	14	15	16	17	18	19	20	21	22	23	24
	240,000						160,000						
							375,000						
18,750	18,750	18,750	18,750	18,750	18,750	18,750	18,750						
								596,228	596,228	596,228	596,228	596,228	596,228
(18,750)	(258,750)	(18,750)	(18,750)	(18,750)	(18,750)	(18,750)	(553,750)	596,228	596,228	596,228	596,228	596,228	596,228
(4,093,750)	(4,352,500)	(4,371,250)	(4,390,000)	(4,408,750)	(4,427,500)	(4,446,250)	(5,000,000)	(4,403,773)	(3,807,545)	(3,211,318)	(2,615,090)	(2,018,863)	(1,422,635)

11	12	13	14	15	16	17	18	19	20	21	22	23	24
	240,000						160,000						
							375,000						
		300,000	300,000	300,000	300,000	300,000	300,000						
		133,333	133,333	133,333	133,333	133,333	133,333						
								25,000	25,000				
										18,750	18,750	18,750	18,750
						25,000	25,000	25,000	25,000				
-	(240,000)	(433,333)	(433,333)	(433,333)	(433,333)	(458,333)	(993,333)	(50,000)	(50,000)	(18,750)	(18,750)	(18,750)	(18,750)
(1,325,000)	(1,565,000)	(1,998,333)	(2,431,667)	(2,865,000)	(3,298,333)	(3,756,667)	(4,750,000)	(4,800,000)	(4,850,000)	(4,868,750)	(4,887,500)	(4,906,250)	(4,925,000)

Reviewed by: HE

25	26	27	28	29	30	31	32	33	34	35	36
596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228
596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228	596,228
(826,408)	(230,180)	366,048	962,275	1,558,503	2,154,730	2,750,958	3,347,185	3,943,413	4,539,640	5,135,868	5,732,095

25	26	27	28	29	30	31	32	33	34	35	36	37
18,750	18,750	18,750	18,750									
												596,228
(18,750)	(18,750)	(18,750)	(18,750)	-	-	-	-	-	-	-	-	
(4,943,750)	(4,962,500)	(4,981,250)	(5,000,000)	(5,000,000)	(5,000,000)	(5,000,000)	(5,000,000)	(5,000,000)	(5,000,000)	(5,000,000)	(5,000,000)	

Reviewed by: HE

Appendix B-2

NRC Review Efficiency Savings

ER-769 Appendix B-2
NRC Review Efficiency Savings
1-Oct-09
Prepared by EMH

Assumptions

1. NRC Staff hourly rate	$	240.00
2. RAI preparation hours per question		4
3. Average Hydraulic Calibration RAI questions from Staff		8
4. Project Management Hours for RAI Publication and processing		40
5. Wait time for answers from Licensee (days)		30
6. NRC Staff Review of RAI answers per question(Hours)		4
7. Licensee Cost for RAI Answers per question	$	5,000.00
8. Total Estimated NRC Review Fees (From Appendix B-1)	$	150,000.00
9. NRC Review Schedule (Months)		8

Calculations

NRC Incremental Hours due to RAIs	$	24,960.00	17%
Incremental Calendar Schedule required for RAI's (Weeks)		6.9	
Licensee Costs for RAI Preparation	$	40,000.00	
Total Cost Savings for RAI Avoidance	$	64,960.00	
NRC Review Schedule Reduction (Months)		1.53	19%

Reviewed by: HE

Appendix B-3

Estimation of Potential Risk of RAI's Requiring Additional Testing

ER-769 Appendix B-3
Estimation of potential Risk of RAI's requiring additional Testing
1-Oct-09
Prepared by EMH

Assumptions

1. Additional testing at a hydraulic laboratory is required to address NRC RAI's
2. Additional testing would require the fabrication of additional 1 meter and parametric testing thereof
3. Scheduled installation delays are obviated by the fabrication of a new meterin number 2 (if RAI request occurs in Month 24, then results would be in within Month 33 and approval could take place on or near start-up in schedule shown in Appendix B-1
4. Fabrication and testing competed within 9 months

Description	Cost
New Meter (1)	$ 300,000.00
New Parametric Tests	$ 70,000.00
Project Cost Increases	$ 25,000.00
Total	$ 395,000.00

Appendix B-4

ER-769 Appendix B-4
20 Yr Cash Present Value Rev 0 Uncertainty with 0.03% conservatism
1-Oct-09
Prepared by EMH

Assumptions

1. The overall budget cost for MUR Uprate Project is $5,000,000	5,000,000
2. Flowmeter Hardware Cost is $1,600,000	1,600,000
3. Flowmeter Installation Costs are $ 500,000	500,000
4. NSSS Engineering Analysis Cost is $1,800,000	1,800,000
5. BOP Analysis Cost is $ 800,000	800,000
6. LAR Submittal Preparation Costs are $50,000	50,000
7. NRC Review Fee Costs are $ 150,000	150,000
8. Tech Spec and Procedure Modifications are $100,000	100,000
9. Incremental Revenue from MUR is achieved from date of implementation	
10. Average Plant size	1,100
10. Average uprate is 1.62%	17.820
11.Capacity factor assumed is 90%	90%
12. Incremental value per Mwe-hr is $50.00	50
	7,024,644

Rev 0 Submittal Schedule

month	Line item Total	1	2	3	4	5	6	7	8	9	10
Hardware	1,600,000	400,000									800,000
Installation	500,000						125,000				
NSSS Analyses	1,800,000			300,000	300,000	300,000	300,000	300,000	300,000		
BOP Analyses	800,000			133,333	133,333	133,333	133,333	133,333	133,333		
LAR Submittal	50,000									25,000	25,000
NRC Review	150,000										
Tech Spec/Procedure Mods	100,000							25,000	25,000	25,000	25,000
Incremental Revenue	7,024,644										
Total Cash in Period		(400,000)	-	(433,333)	(433,333)	(433,333)	(558,333)	(458,333)	(458,333)	(50,000)	(850,000)
Cumulative Cash		(400,000)	(400,000)	(833,333)	(1,266,667)	(1,700,000)	(2,258,333)	(2,716,667)	(3,175,000)	(3,225,000)	(4,075,000)

Net Present Value @ 10% $ 46,024,026.70

Reviewed by: HE

11	12	13	14	15	16	17	18	19	20	21	22	23	24
	240,000						160,000						
							375,000						
18,750	18,750	18,750	18,750	18,750	18,750	18,750	18,750						
								585,387	585,387	585,387	585,387	585,387	585,387
(18,750)	(258,750)	(18,750)	(18,750)	(18,750)	(18,750)	(18,750)	(553,750)	585,387	585,387	585,387	585,387	585,387	585,387
(4,093,750)	(4,352,500)	(4,371,250)	(4,390,000)	(4,408,750)	(4,427,500)	(4,446,250)	(5,000,000)	(4,414,613)	(3,829,226)	(3,243,839)	(2,658,452)	(2,073,065)	(1,487,678)

Reviewed by: HE

	25	26	27	28	29	30	31	32	33	34	35	36
	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387
	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387	585,387
	(902,291)	(316,904)	268,483	853,870	1,439,257	2,024,644	2,610,031	3,195,418	3,780,805	4,366,192	4,951,579	5,536,966