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Open Session

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THERMAL-HYDRAULICS ACCIDENT ANALYSIS SUBCOMMITTEE

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OPEN SESSION

+ + + + +

WEDNESDAY

JUNE 7, 2023

+ + + + +

The Subcommittee met via hybrid in-person and Video Teleconference, at 8:30 a.m. EDT, Jose March-Leuba, Chairman, presiding.

COMMITTEE MEMBERS:

JOSE MARCH-LEUBA, Chair

RONALD G. BALLINGER, Member

CHARLES H. BROWN, JR., Member

VICKI BIER, Member

VESNA DIMITRIJEVIC, Member

GREGORY HALNON, Member

WALT KIRCHNER, Member

DAVID PETTI, Member

JOY L. REMPE, Member

MATTHEW SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

KENT HOWARD

ALSO PRESENT:

KURTIS CRYTZER, EPRI

LOIS JAMES, NRR

JOSHUA KAIZER, NRR

SCOTT KREPEL, NRR

SILAS ROGERS, GSES

C-O-N-T-E-N-T-S

P-R-O-C-E-E-D-I-N-G-S

8:30 a.m.

CHAIR MARCH-LEUBA: The meeting will now come to order. This is a meeting of the Accident Analysis Thermal-Hydraulics Subcommittee.

I am Jose March-Leuba, the SC Chair. In addition to in-person attendance at NRC headquarters, the meeting is broadcasted via MS Teams. Members in attendance are Ron Ballinger, Vicki Bier, Charles Brown, Vesna Dimitrijevic, Greg Halnon, Walter Kirchner, Dave Petti, Joy Rempe, and Matthew Sunseri.

Today we are reviewing EPRI's Topical Report Number 3002018337, entitled Use of Data Validation and Reconciliation Methods for Measurement Uncertainty Recapture.

Portions of our meeting may be closed to the public to protect EPRI proprietary information. We have not received requests to provide comments, but we'll have an opportunity for public comments before the beginning of the closed section of the meeting.

The ACRS was established by a statute and is covered by the Federal Advisory Committee Act, FACA. As such, the Committee only speaks to its published letter reports.

The rules for participation in all ACRS

meetings were announced in the Federal Register on June 13, 2019. The ACRS section of the U.S. NRC public website provides our charter, bylaws, agendas, letter reports, and full transcripts for the open portions of all full and Subcommittee meetings -- including the slides presented there.

The Designated Federal Official today is Kent Howard.

A transcript of the meeting is being kept, therefore speak into the microphones clearly, and state your name for the benefit of the Court Reporter. And if you're in a conference room with multiple people on the line, please remember to identify yourself regularly for the accuracy of the transcript. Please keep all your electronics and microphone on mute when not in use.

As I said earlier, let me remind you that ACRS only speaks through its public letters, written by the Full Committee.

Today we're having a Subcommittee meeting with the purpose of obtaining information that will be considered by the Full Committee, likely in July. The comments you hear today are not from ACRS, but ideas from individual members.

So, I should have checked earlier, but is

Scott on the line? Scott Krepel?

MR. KREPEL: Good morning. Yes, this is Scott Krepel here -- speaking through a sign language interpreter, of course.

CHAIR MARCH-LEUBA: Thank you. So, at this point let's request that Scott and his interpreter from the NRC Staff to present his opening remarks, and then introduce the staff that will present the Open Session.

Scott?

MR. KREPEL: Great, thank you.

As I just mentioned, my name is Scott Krepel, speaking through a sign language interpreter. I currently am the Acting Director for the Division of Safety Systems.

Josh Kaizer is one of my staff who works under me, as my official role as a Branch Chief in the Nuclear Systems and Methods -- and Fuel Branch.

For opening comments on DVR for this topical report, I just want to mention that I understand this is a priority for a number of licenses and industry. This method will allow them to recapture the measurement of uncertainty, to be able to do power upright without necessarily having to use a more better flow meter, among other items.

With that being said, I will turn it over to Josh Kaizer who I believe is present in the room with you.

CHAIR MARCH-LEUBA: I believe it's James Lois who'll do the open portion?

MS. JAMES: Hello --

(Simultaneous speaking.)

MS. JAMES: My name is Lois James --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: Yeah. Lois.

MS. JAMES: I was going to do the NRC opening slides but, due to time constraints, we are volunteering -- can you hear me?

We are volunteering not to actually speak our slides. They're just introductory, they've got the ML numbers, they've got the history. And so, at this point we would like to turn it over to EPRI so we can get started with the technical discussion.

CHAIR MARCH-LEUBA: As I said earlier, ACRS only speaks through letters, so this is a comment from a one member of ACRS. I applaud your decision, thank you --

(Simultaneous speaking.)

MS. JAMES: Okay.

(Laughter.)

MS. JAMES: Thank you.

CHAIR MARCH-LEUBA: And for the transcript, for the record, the slides will be part of the transcript. So, you can read them yourself, if you're reading the transcript.

MS. JAMES: Thank you, that would be great.

CHAIR MARCH-LEUBA: So, let me go back. We are ready now for Kurtis Crytzer from EPRI, to present his opening remarks on an introduction to the topic in open session.

We will have a full-scope discussion during -- including the proprietary aspects during the closed session.

Kurtis?

MR. CRYTZER: Thank you. As mentioned, my name is Kirk Crytzer, I am with EPRI. I'm a --

CHAIR MARCH-LEUBA: They need to show the slide. I don't know who is in charge of that.

MR. CRYTZER: I'm plugged in --

CHAIR MARCH-LEUBA: Do you have his slides?

MS. JAMES: I will get them up there as soon as I can.

CHAIR MARCH-LEUBA: Okay. So, keep going,

we have your slides.

MR. CRYTZER: Thank you.

Okay. Yeah, so I'm a Principal Project Manager in the Plant Engineering Group. Today I want to talk at a high level for the opening presentation about the use of data validation reconciliation methods, as evaluated for a measurement uncertainty application.

CHAIR MARCH-LEUBA: As I said earlier, feel free not to read every bullet.

MR. CRYTZER: Yeah, absolutely --

CHAIR MARCH-LEUBA: Because you have very dense slides.

MR. CRYTZER: Yeah. So, I apologize for all the content -- I'll touch briefly on the objective of each slide, so --

CHAIR MARCH-LEUBA: No, you don't need to apologize. This is good, I mean --

MR. CRYTZER: Okay.

CHAIR MARCH-LEUBA: The purpose of the Subcommittee is to inform the members present so we -- and obtain information so we can report to the Full Committee.

As it happens today, we have the Full Committee members -- everybody is here. But, the

process is still to inform, but the secondary purpose is to inform the public of what you're doing.

So, by placing all this information in the record, you're informing the public. So, that's good.

MR. CRYTZER: Okay, great. Thank you.

So, the objective of the topical report was to evaluate the methodology for data reconciliation for measuring uncertainty recapture, and specifically used as an input into the core thermal power calculation.

The topical report is built around a German code, VDI code. And the VDI standard, VDI-2048, captures that methodology. And the idea behind the topical report was to evaluate the methodology, capture it within the EPRI document, evaluate the technical basis, evaluate the uncertainty claims against those that are commonly used in other scenarios within nuclear power, perform a failure modes and effects analysis.

And we wanted to develop this around the use of the ultrasonic flow meter as a guide, since that was the currently accepted license practice for MUR.

CHAIR MARCH-LEUBA: And again, ACRS will always interrupt you -- and I will more. When you say

code, VDI code, you don't mean computer code, you mean the standard?

MR. CRYTZER: That's correct. Standard, yeah, thank you for that clarification.

So, without repeating myself, the VDI code that this is based on uses first principles of thermodynamics and statistical analysis. It takes measurements all across the secondary side of the plant, and in the steam side of the plant -- individually and in aggregate -- to provide more accurate data points for each value -- the true physical value. And we'll talk about that a little bit more as we go into the closed session.

Again, DVR -- we're looking at this for MUR, but has been used for power recovery. It has been used in Europe, so it's been around since -- at least, we're aware of, since 1999. EPRI didn't really get engaged until 2014, in which case we got engaged in looking at a power recovery application.

So, this is somewhat of a repeat. But, the point that I wanted to stress here is, what we are not trying to do is have one specific software approved. We're trying to look at the methods themselves in the VDI-2048 methodology and keep it agnostic to the software vendor, as long as the

software is compliant with VDI-2048.

CHAIR MARCH-LEUBA: And off the top of your head, how implemented is it in Europe -- 90 percent of the plants use it, five percent of the plants use it? Half of them?

MR. CRYTZER: Yeah, that's a good -- as far as data reconciliation process in itself, that I'm aware of -- and this is a guess -- I would say 50 percent. With respect to measurement uncertainty recapture, I'm just aware of one country that has that.

So, in fact --

CHAIR MARCH-LEUBA: If it's a whole country ever since 1999, it's a lot of experience.

MR. CRYTZER: Yeah. I know Germany and Switzerland for sure, and we've just recently received some questions from Sweden that have come in, that use this methodology. But, for specific for MUR, it's --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: As the Staff will talk about in their presentation, what we need to review is what can possibly go wrong.

MR. CRYTZER: Yes.

CHAIR MARCH-LEUBA: And when you go into smart technologies -- which this is one of the smart

technologies -- the question is, will it work nicely on the table top but then, once every 10 years, it will fail catastrophically. But, by having experience, you know, when it applies, we know it doesn't. So, that provides a lot of confidence.

MR. CRYTZER: Yes. So, with that, using in the core thermal power calculation, currently is largely dominated by feedwater flow. So, if there's an inaccuracy in the feedwater flow measurement due to either, filing of a differential pressure flow meter -- such as Venturi -- or an inoperability of an ultrasonic flow meter, that directly has a substantial impact on the core thermal power calculation.

Within the industry itself, reliability issues with the ultrasonic flow meters -- EPRI has heard multiple discussions about that. And, you know, there is costs to maintain the MUR condition through the ultrasonic flow meter. So, there is a desire to find a potential alternate technique to --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: This goal to eliminate loose parts, because the ultrasonic flow meters are in contact -- are inside the pipe. If they fail to work, because they break and they go into the --

(Simultaneous speaking.)

MR. CRYTZER: Yeah, they're --

(Simultaneous speaking.)

MEMBER HALNON: The ultrasonic --

MR. CRYTZER: Yeah. They're --

(Simultaneous speaking.)

MR. ROGERS: It depends --

MR. CRYTZER: Yeah, go ahead.

MR. ROGERS: On the flow meter --

MEMBER HALNON: state your name.

MR. ROGERS: This is Silas with GSES. It depends on the flow meter, whether it's drilled into the pipe or if it's on the surface of the pipe.

MR. CRYTZER: There have been at least one more recently, that I'm aware of, where the actual inside condition of the pipe does affect the quality of the ultrasonic. In this case, there was, I guess a eccentricity was smoothed out on one side causing an error in that calculation.

So, what we have done within EPRI, at least with the VDI-2048 methods -- as I mentioned, it'd been around since '99, we started in 2014 -- we did an evaluation on a Boiling Water Reactor that was underpowered. That evaluation actually showed about 15 megawatt electric under power, due to a fouled Venturi.

The second research that we did was, we understood that there are certain times where the differential pressure flow meter is changing during time. And this is times during polyacrylic acid injection, you'll defoul a Venturi as a result of injecting that into a pressurized water reactor to control deposit inventory. And also during on-line noble metal chemistry for the boiling water reactors, where you're shifting the redox potential during periods of time.

So, we wanted to evaluate the two scenarios with that to see the data reconciliation was robust enough to be able to accurately and effectively monitor the feedwater flow, while the Venturi itself was changing. And so, we published that report.

And then we decided there needed to be a guidance document for implementation, not only for power recovery, but for use in condition-based maintenance or condition-based monitoring.

So, you'll see through the process, because you are reconciling various data points within the plant, that this can be used for condition monitoring, for condition-based maintenance or even calibration of equipment. And it can quickly and effectively identify off normal conditions.

So, with that, the usefulness that we're looking at here -- again, the pie chart we'll go into in a little bit more detail, but the top one is heavily dominated by the feedwater flow for the power calculation. And the VDI code allows you to take in more measurements to exploit those redundancies available, and correct the errors -- or, the uncertainties, with the instruments.

There are commercial software products that are available that are compliant with VDI-2048, you'll see them under data validation and reconciliation, or process data reconciliation. And there's currently, under the performance test code, there's discussions of bringing the VDI-2048 methods into our domestic codes.

So, just to finalize where we are. We started this initial development -- we had a pre-meeting right before the pandemic in 2020, in February. And then, we had had that pre-meeting following our topical report publications.

So, we published in November of 2020, we provided both, proprietary and non-proprietary versions. We had a pre-meeting, as well, before publishing this. We'd have an industry technical advisory group that has utility personnel, we've also

brought in academia from -- Texas A&M has looked at it. And we've had two separate vendors of the software, VDI-2048 software compliant.

We've gone through two audits, one of which was an on-site audit. Currently, we have responded to 17 requests for additional information.

And, with that, I'll take questions.

CHAIR MARCH-LEUBA: Let me ask a general question. For what purpose do you submit this topical report to the Staff? And let me give you a multiple choice. You're essentially asking for a safety evaluation report for a topical report, but this is not an application that is ready to go into the field, the way I see it. I mean, this just kind of creates an umbrella, guidelines. And then, we have a specific license amendment request, we will look at the details -- by we, I mean the Staff.

So, what are you asking the Staff to do for you in the SER?

MR. CRYTZER: Yeah. So, the staff is -- I guess what we're trying to do is, really have the evaluation of the acceptability of the methods of VDI-2048, so they --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: More like, the

concept?

MR. CRYTZER: Yeah, the concept. And --

CHAIR MARCH-LEUBA: And then, the method, the particular application will be up to the first licensee?

MR. CRYTZER: Yeah. So, within the license amendment request, the specific type of software, the auxiliary conditions that are defined, all that would be included.

CHAIR MARCH-LEUBA: But, we are reviewing the concept, does this makes sense.

MR. CRYTZER: Yes.

CHAIR MARCH-LEUBA: Or, don't bother sending because we don't like it. That's what basically we're talking about?

MR. CRYTZER: That's right.

CHAIR MARCH-LEUBA: Members, anymore questions in the open session for EPRI, or the Staff?

MEMBER HALNON: Yeah, I just had a -- I guess it's more of a curiosity. Since we got time frames back to 1999, you know, 20-plus years. It struck me when you said there was, what, 17 RAIs. Can you generally group those, were they technical in nature, admin in nature, or was it trying to train the reviewers on heat balance?

MR. CRYTZER: I would say -- if you want to answer some, and then I'll give my opinion.

MR. ROGERS: I think they were mostly technical in nature. There were a few related to, you know, how things would be handled. But, mostly they were technical and trying to clarify certain concepts with the reviewers.

MEMBER HALNON: Because it didn't seem that these were very exotic concepts that we're presenting here, they're relatively straightforward thermodynamics and heat-balance type --

(Simultaneous speaking.)

MR. ROGERS: That part is very simple, actually. And then, the complicated part is the application of corrections and --

(Simultaneous speaking.)

MEMBER HALNON: Is that generally -- I mean, when I say generally, is that more of the technical issues were generally -- the statistical portions?

MR. ROGERS: There were quite a few questions related to those, yes.

MEMBER HALNON: All right, thanks. I just wanted to get a sense of why it seemed to be so many questions for such an established methodology.

Especially if it's been used in Europe for quite a while.

MR. CRYTZER: Yeah, I think the other part of it that goes to the earlier point was, what were we actually trying to get approved. And --

(Simultaneous speaking.)

MEMBER HALNON: Goes to the regulatory admin portion of it.

CHAIR MARCH-LEUBA: Any questions, Vesna? Giving you an opportunity while we ask a --

Okay. Vesna says no.

Members of the public, if this will be the last opportunity for you to present some comments on this topic on the record. So, if a member of the public wants to make a comment, please do so.

Hearing none, we are going to close this open session Teams meeting. And everybody that can be in the closed session will have a secondary link where you're supposed to go and call in right now.

We are going to finish the open transcript right now, and we'll start the new closed transcript in five minutes.

(Whereupon, the above-entitled matter went off the record at 8:50 a.m.)

Use of Data Validation and Reconciliation Methods for Measurement Uncertainty Recapture

EPRI Topical Report 3002018337

Kurt Crytzer
Principal Project Manager

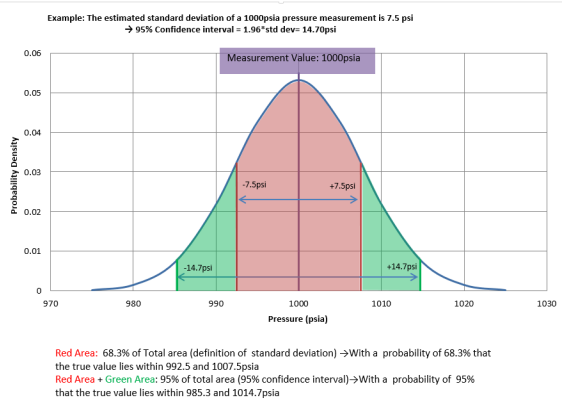
ACRS Subcommittee - Open Session
June 7, 2023

EPRI Topical Report on use of Data Validation and Reconciliation Methods (DVR) for Measurement Uncertainty Recapture (MUR)

- Objective:
  - Evaluate if the DVR methodology is an effective technology for use as an input to the calculation of plant CTP and the detection of plant measurement errors with CTP related or other plant instrumentation
  - Developed for implementation of the German Standard VDI-2048 Data Reconciliation methodology to reduce the uncertainty of determinations of nuclear plant core thermal power (CTP)
  - Evaluate the use of DVR Acceptability for use in MUR in conjunction with and/or in lieu of an ultrasonic flow meter (UFM)
- Topical Report Considerations
  - Developed for implementation of VDI-2048 Data Reconciliation methodology to reduce the uncertainty of determinations of nuclear plant core thermal power (CTP)
  - Establish the technical basis for Data Validation and Reconciliation/Process Data Reconciliation (DVR/PDR) methodology
  - Conducts evaluations to substantiate the uncertainty claims of the DVR process
  - Captures failure modes and effects analyses (FMEA) to identify errors in the results and objective justification for self-identification of process failure
  - Developed using the topical report for MUR with an Ultrasonic Flow Meter (UFM) as a guide

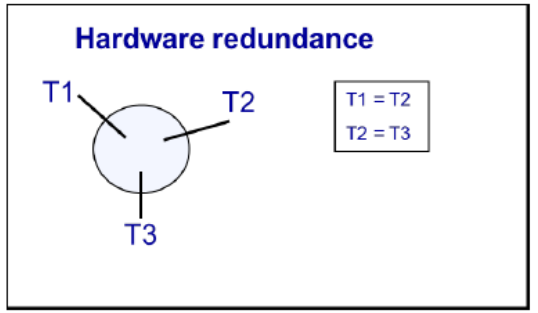
Data Validation and Reconciliation Process Background

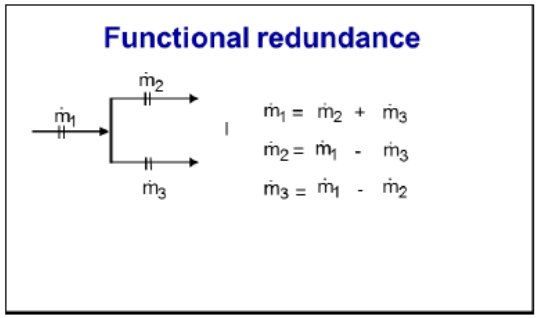
- Data Validation and Reconciliation (DVR)
  - Captured in the German standard VDI-2048 Uses first principals and statistical analysis of multiple plant measurements, in aggregate, to provide accurate core thermal power
    - Uses the data points collected by plant equipment
    - Defined physical relationships between measurements are used to evaluate the most probable value for each measurement in the power calculation
- DVR used for power recovery
  - The DVR process provides an opportunity to accurately determine CTP using significantly more instrumentation, reducing the vulnerable of single element failure
- DVR may be used for condition monitoring and condition-based maintenance
- DVR software has been used by the nuclear power industry in the U.S. and Europe since 1999 to assess turbine cycle thermal performance, balance of plant feedwater flow metering and accuracy of the plant calorimetric
- MUR has been achieved in Europe using DVR Methods



DVR Methodology/Technology

- VDI-2048 (DVR Methodology)
  - Developed as an industry code for balance of plant turbine acceptance testing
    - Statistical analysis is performed to calculate the overall uncertainty for the system and the individual measurement uncertainties
    - Determine the uncertainty errors associated with a measurement based on the instrument uncertainty and other measurements functionally related to each other
- Software / DVR methodology uses the functional relationships between the measurements to create a system of redundant measurements
  - Errors are determined by solving for mass and energy balances around the components and the entire system of measurements.
  - Objective statistical standards are used to verify that the calculation is providing the best possible solution
- DVR Combines:
  - Closed mass, energy and material balances
    - First Principle of Thermodynamics
  - Gaussian compensation theorem
    - Redundant instrument measurement / parameter use and statistical modeling to reduce uncertainty
- This Result in:
  - Elimination of systematic error
  - Minimization of random error
  - Determination of process values to get closer to the true process value

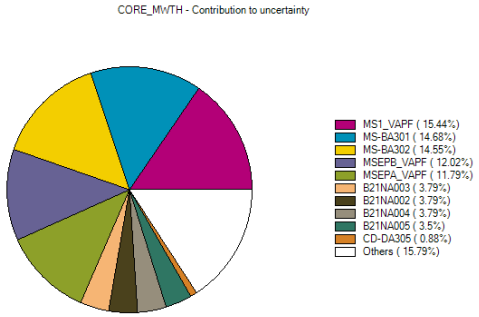




Data Validation and Reconciliation for CTP – MUR Relevance

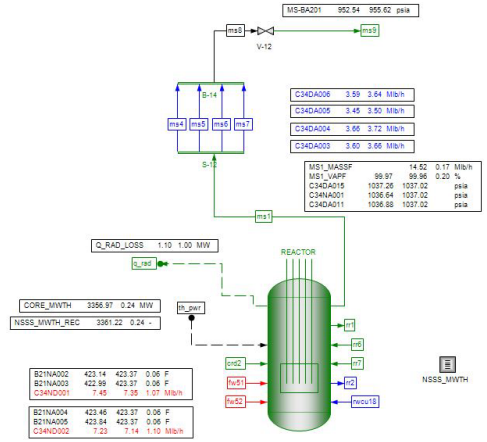
Current Practice of Determining Core Thermal Power (CTP)

- Current determination of Core Thermal Power (CTP) has significant reliance on feedwater flow measurements
  - Inaccuracies in the direct measurement of feedwater flow have resulted in lost generation and documented cases of overpower conditions
- Ultrasonic flow measurement devices (UFM) have been used to gain measurement accuracy, but are often single element and a failure of the instrumentation will result in an error of the power calculation
  - UFM measurement reliability issues or failures result in the need to use less accurate venturi measurements, backing down from MUR to lower power conditions
  - A utility may incur costs to maintain, correct, or upgrade equipment



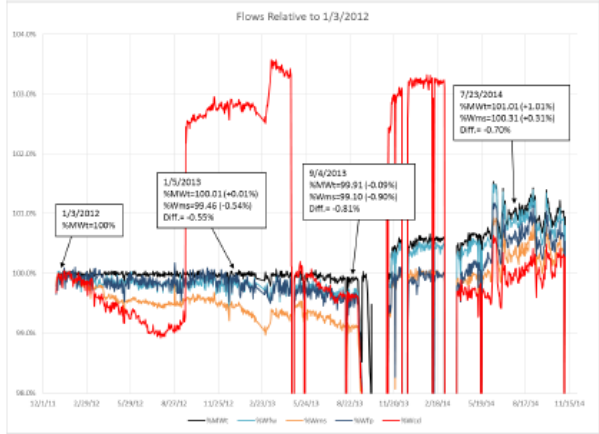
Data Validation and Reconciliation (DVR)

- Data Validation and Reconciliation techniques (DVR), as captured in the German standard VDI-2048, uses first principles and statistical analysis of multiple plant measurements, to provide accurate CTP
- The DVR process provides an opportunity to accurately determine CTP using significantly more instrumentation, reducing the vulnerable of single element failure
- DVR uses the data collected by plant equipment and using defined physical relationships between the measurements, to evaluates the most probable value for each measurement to be used in the power calculation
- DVR can provide input for condition-based maintenance



EPRI Research in Data Validation and Reconciliation

- Prior EPRI Research:
  - Initial EPRI Research on Data Reconciliation started in 2014 (BWR with a fouled venturi)
    - Program on Technology Innovation: Evaluation of Data Reconciliation Methods for Power Recovery. EPRI, Palo Alto, CA: 2015. 3002005345.
  - Research report Evaluated DVR Methods when Feedwater Flow was changing (PAA & OLNC)
    - Using Data Validation Techniques to Evaluate the Impact of Chemical Addition at Nuclear Power Plants: Effects of Polyacrylic Acid and Online Noble Metal Injections on Steam Side Parameters. EPRI, Palo Alto, CA: 2018. 3002013194.
  - Technical Report: Guidance for Implementation of DVR
    - Guidance for Implementing a Data Validation and Reconciliation Program at Nuclear Power Plants. EPRI, Palo Alto, CA: 2018. 3002013197
- Additional Benefits
  - Increased reliability of the power cycle measurement system
  - Improve overall plant operations in the event of a failure of specific important instruments
  - Reduced upgrade, obsolescence, and maintenance costs
  - Higher confidence in plant instrumentation improving operational evaluation of events

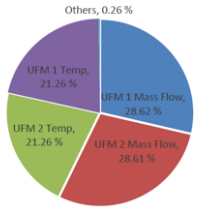


Usefulness of Data Validation and Reconciliation

- VDI-2048 Code introduces the concept of using Gaussian corrections and mass-energy balance calculations of the plant components and cycle to
  - Exploits measurement redundancies to make use of all available measurements
  - Correct errors with the test instruments
  - Assess the quality of the test measurements and results
- Data reconciliation methods have been used in Europe since 1999 to provide corrections to core thermal power measurement
- Provides an opportunity to accurately determine CTP using significantly more instrumentation
  - Reducing the vulnerable of single element failure
  - More robust approach to more accurately measure CTP as it is based on statistical reconciliation of instrumentation with the plant's actual operating condition
- DVR has been previously evaluated for power recovery and has been used in Europe for MUR
- DVR has been evaluated by EPRI for power recovery at a BWR
- Commercial software products are available that implement the VDI-2048 methods
  - Terms "process data validation" and "data validation and reconciliation" used by the commercial products to describe use of the VDI- 2048 methods

PWR Plant Thermal Power - Uncertainty Contributions
Standard FW Flow Power Calculation

Contributors to the calculation of the Core Thermal Power uncertainty in a traditional calculation

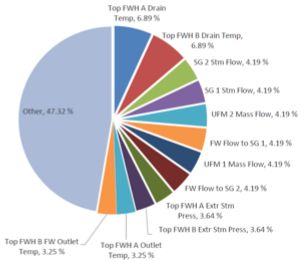


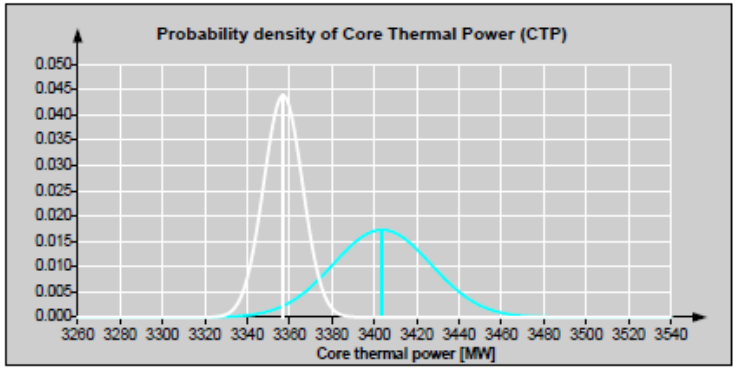
PWR Plant Thermal Power - Uncertainty Contributions
Full DVR Model Power Calculation

DVR model:

Failure of one instrument may not result in a failure of the core power calculation

The additional instrumentation increases the resilience of the power calculation





		Based on measured values		Based on reconciled values	
Core thermal power	NB-ND012	3.403,7		3.357,0	MW
Uncertainty (1.96σ)		± 45,3	±	17,8	MW
		± 1,33	±	0,53	%

EPRI Topical Report on use of Data Validation and Reconciliation Methods (DVR) for Measurement Uncertainty Recapture (MUR)

- EPRI Development of Topical Report
  - Initial Data Reconciliation Evaluations from EPRI Demonstrated DVR Reliability
  - VDI-2048 International Experience/Evaluations lend robust credibility
  - US Nuclear Industry experiences feedwater flow measurement challenges
    - Fouling/defouling and general precision
    - Reliability and associated costs associated with Ultrasonic Flow Meters
- Topical Report Status
  - Topical Report Published in November 2020
    - Submitted to NRC January 2021 (Both –P and –NP versions)
- Reviews Occurred during initial Topical Report publication
  - Technical Advisory Group - thermal performance subject matter experts
    - Initial Report
    - Responses to Request for Additional Information
  - NRC Review
    - Two Audits (one onsite)
    - Responses to 17 Requests for Additional Information

Questions?