Presentation of Dr. Joram Hopenfeld to the ASLB in Response to Dr. Horowitz Regarding CHECWORKS

Indian Point License Renewal Proceeding

Adjudicatory Hearing

October 15, 2012

I FUNDUMENTALLY DISAGREE WITH DR. HOROWITZ REGARDING HOW THE CHECWORKS PROGRAM WAS DESIGNED AND HOW IT WORKS

MAIN POINTS OF DISAGREEMENT

Subject	CLAIMED BY ENTERGY	Disagree/Agree	NOTES
Background	Need for single phase inspection	Disagree	Not the main need
Model's technical basis	All known data	Disagree	Selective data was used
Mathematical Analogue	Inputs represent known quantities, (mass transfer rates Cr, geometry)	Disagree	Component Cr. Content is unknown. Incorrect relation between metal loss and mass transfer coefficient
Designed to handle changes in Plant Conditions	Can handle changes in flow	Disagree	No correlation before and after flow changes
Model predictions	Validated and Refined	Disagree	40-60% of the time predictions are not conservative

BACKGROUND

- CHECWORKS was introduced by EPRI 7 months after the Surry accident. To meet schedule, EPRI developed its own definition of FAC:
    i. EPRI's Definition: FAC = corrosion (controlled by diffusion mass transfer)
    ii. Common definition: Erosion/ Corrosion = Corrosion + Erosion + Synergy

  Note: Corrosion is relatively easy to predict; corrosion + synergy is very difficult to predict

- To support its FAC definition, EPRI did the following:
    i. Ignored scholarly papers offering different theories
    ii. Did not provide any technical basis
    iii. Used data selectively, regardless its applicability
    iv. Misrepresented the validity of model predictions

CHECWORKS underlying assumptions are wrong

- **<u>CHECWORKS Assumption #1</u>: Non-conservative predictions, 50% of the time, are acceptable**
  - Not acceptable: "model must be recalibrated" when non conservative (NUREG-1801, Rev. 2)

- **<u>CHECWORKS Assumption #2</u>: Component Chromium content is known**
  - a factor of six in Chromium uncertainty leads to a factor of 10 in FAC uncertainty

- **<u>CHECWORKS Assumption #3</u>: Wall thinning by FAC is controlled solely by chemical dissolution**
  - Existing theoretical and experimental data indicate that FAC is controlled by both dissolution and erosion (for example, see reference: Digby D. Macdonald, *The Point Defect Model for the Passive State*, J. OF THE ELECTROCHEMICAL SOCIETY, Vol. 139, Issue No. 12 (Dec. 1992)); NRC findings in LR-ISG-2012-01 (Draft License Renewal Interim Staff Guidance, Wall Thinning Due to Erosion Mechanisms, Exhibit ENT000573) and its own data at IPEC.

- **<u>CHECWORKS Assumption #4</u>: Average mass transfer coefficients are applicable**
  - ASME code requirements are based on maximum local rates (Tcrit – is the minimum local thickness)

- **<u>CHECWORKS Assumption #5</u>: Corrosion rate equations derived from tests of electrochemically driven copper dissolution in hydrofluoric acid are applicable** (reference: Bryan Poulson and Russel Robinson, *The Use of A Corrosion Process to Obtain Mass Transfer Data*, SCIENCE, Vol. 26, No.4, pp. 265-280 (1986))
  - Such tests are not applicable to carbon steel in the reactor environment (reference: G.J. Bignold, K. Garbett, R. Garnsey, & I.S. Woolsey, *Erosion/Corrosion in Nuclear Steam Generators*, *in* WATER CHEMISTRY OF NUCLEAR REACTOR SYSTEMS 5, Paper 1 (British Nuclear Engineering Society, 1980)).

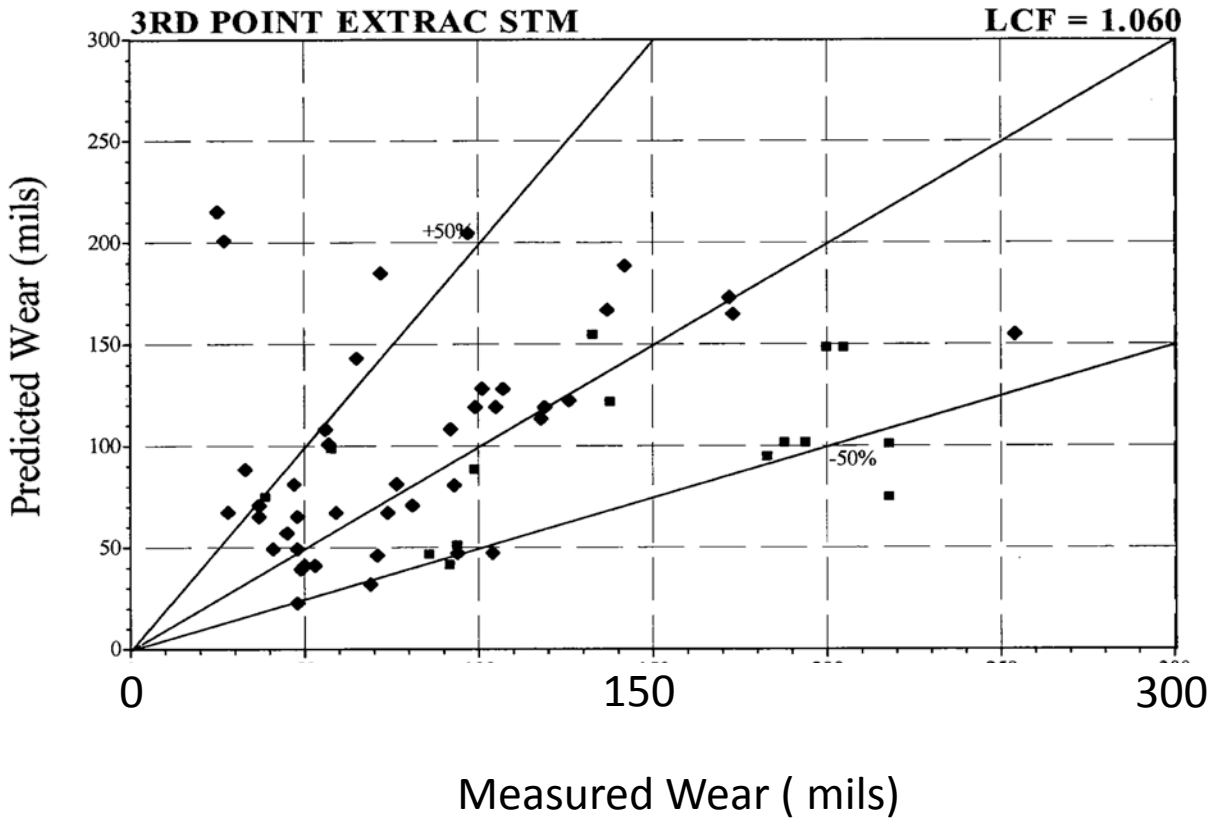
CHECWORKS Predictions:
Non-conservative by as much as a factor of 10

CHECWORKS predictions are presented in a manner that hides the degree of non-conservatism, resulting in misleading plots.

- As shown in Figures 1A and 1B, interchanging the y and the x axes , increases the number of non-conservative points, exceeding the 50% line, by a factor of 6.

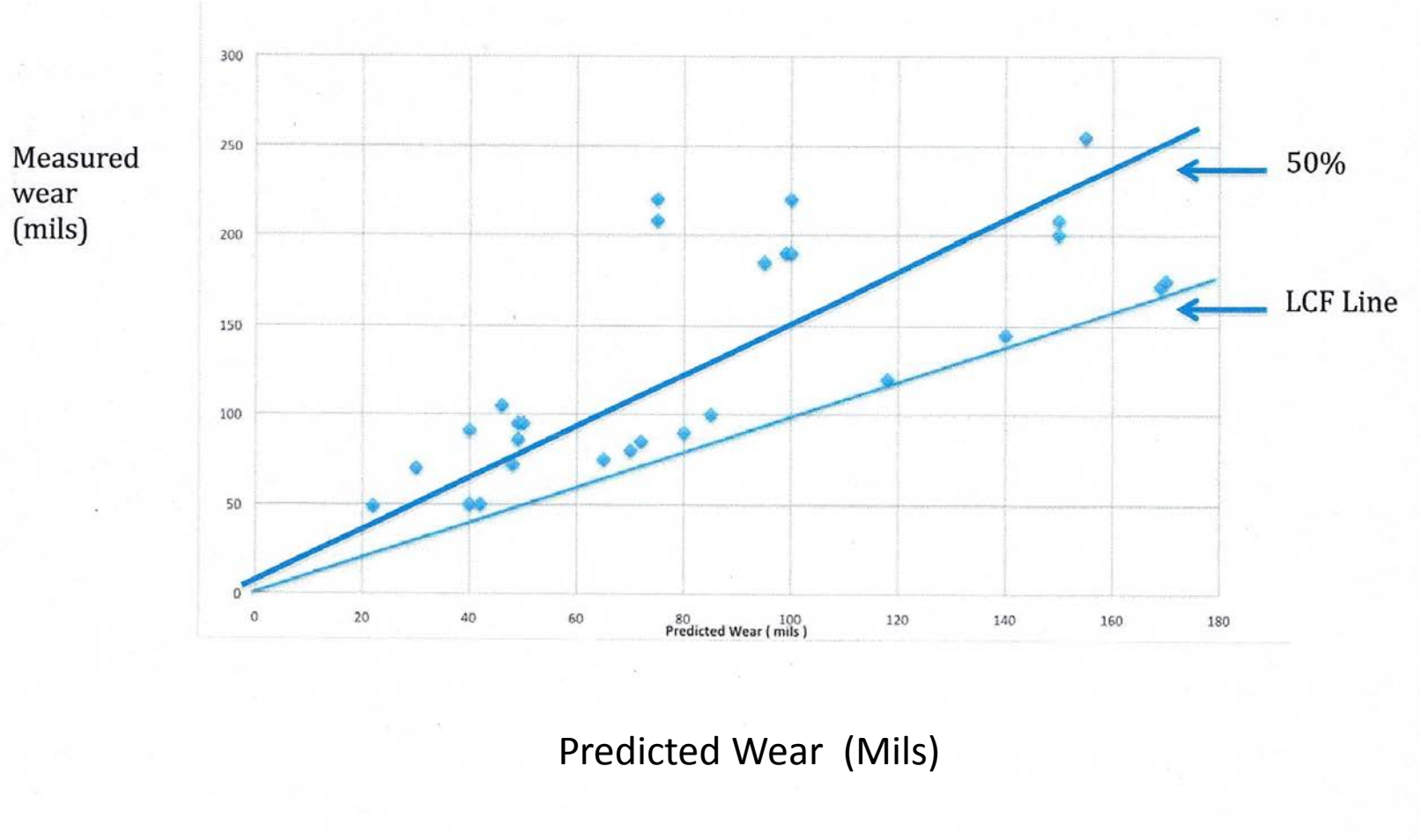
- The upper line is labeled +50% instead a +100%, misrepresenting CHECWORKS' accuracy

Figure 1A -Shows how almost all the non-conservative data points <u>appear</u> to be bound by the -50% line



(Reference: RIV000111 - Hopenfeld Re-plotted CHECWORKS data)

Figure 1B – By interchanging the x and the y axes, the number of non–conservative points in Figure 1A, exceeding the 50% line, was increased from 2 to 12 i.e., by a factor of 6



(Reference: RIV000111 - Hopenfeld Re-plotted CHECWORKS data)

Local variation wall thinning shows that FAC is controlled by both corrosion and erosion: wrong Input to model

Definitions: MTCRE: Maximum elbow to pipe mass transfer coefficient ratio = Maximum elbow to pipe metal loss

MTCRE criteria can determine whether FAC is controlled by chemical dissolution or erosion

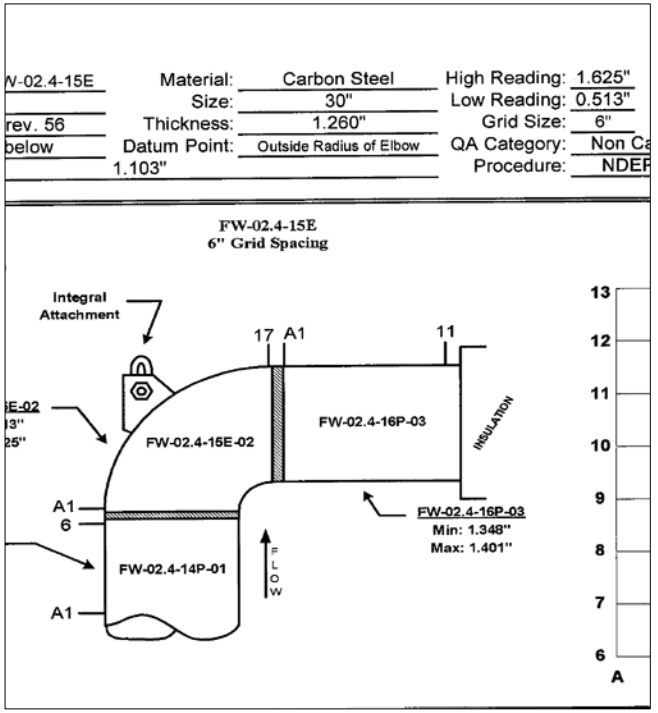
- Chemical dissolution controlled: MTCRE < 1.6
- Erosion controlled: MTCRE > 1.6

Calculations:

Elbow. Max. metal loss: (pt1) 1.446-1.325=0.121" (Pt2) 1.547-0.513=1.034"

Straight pipe, Max. metal loss : 1.399-1.379=0.020"

Metal loss Ratio, (Elbow /straight pipe):(0.121/.02) & (1.034/.02) i.e. **6 to 52**



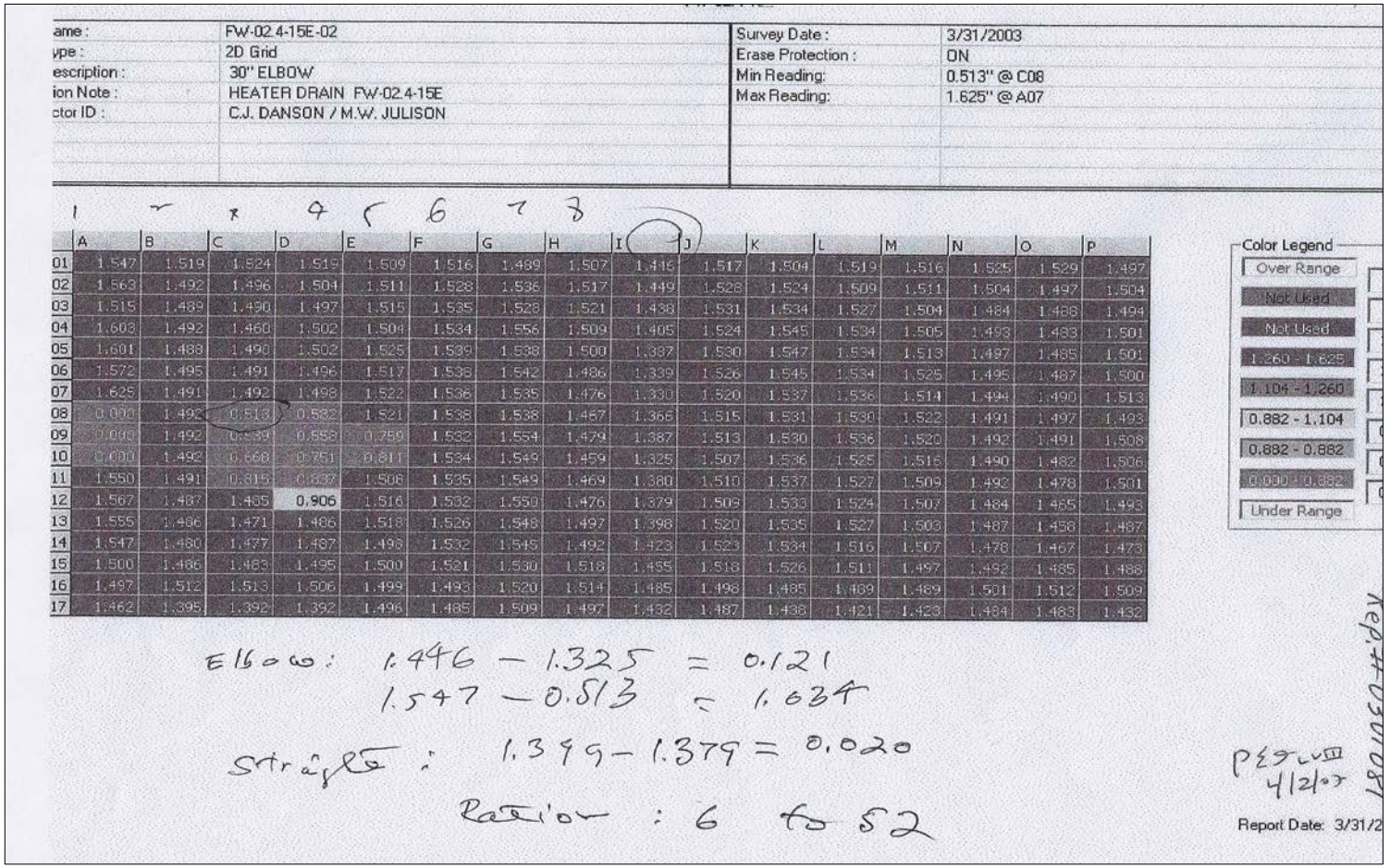
Reference: Entergy Ultrasonic Examination Report, IPEC00020853, at batestamp IPEC00020856

Conclusion: If metal loss were controlled by dissolution alone it would have not exceeded 1.6X; in fact it exceeded it by 6X to 52X, meaning that FAC is controlled by both chemical dissolution and erosion.

Reference: Jianrong Wang, Siamack A. Shirazi, A CFD based correlation for mass transfer coefficient in elbows, INT'L J. OF HEAT AND MASS TRANSFER, 44 (2001) 1817-1822.

CHECWORKS Methodology Results in Overly Large Grid Size

Abrupt local thickness despite Entergy claim that FAC is uniform:



ame :	FW-02.4-15E-02
ype :	2D Grid
escription :	30" ELBOW
ion Note :	HEATER DRAIN FW-02.4-15E
ctor ID :	C.J. DANSON / M.W. JULISON

Survey Date :	3/31/2003
Erase Protection :	ON
Min Reading:	0.513" @ C08
Max Reading:	1.625" @ A07

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
01	1.547	1.519	1.524	1.519	1.509	1.516	1.489	1.507	1.446	1.517	1.504	1.519	1.516	1.525	1.529	1.497
02	1.563	1.492	1.496	1.504	1.511	1.528	1.536	1.517	1.449	1.528	1.524	1.509	1.511	1.504	1.497	1.504
03	1.515	1.489	1.490	1.497	1.515	1.535	1.528	1.521	1.438	1.531	1.534	1.527	1.504	1.484	1.488	1.494
04	1.603	1.492	1.460	1.502	1.504	1.534	1.556	1.509	1.405	1.524	1.545	1.534	1.505	1.493	1.493	1.501
05	1.601	1.488	1.490	1.502	1.525	1.539	1.538	1.500	1.387	1.530	1.547	1.534	1.513	1.497	1.485	1.501
06	1.572	1.495	1.491	1.496	1.517	1.538	1.542	1.486	1.339	1.526	1.545	1.534	1.525	1.495	1.487	1.500
07	1.625	1.491	1.492	1.498	1.522	1.536	1.535	1.476	1.330	1.520	1.537	1.536	1.514	1.494	1.490	1.513
08	0.000	1.492	0.513	0.582	1.521	1.538	1.538	1.467	1.366	1.515	1.531	1.530	1.522	1.491	1.497	1.493
09	0.000	1.492	0.589	0.668	0.759	1.532	1.554	1.479	1.387	1.513	1.530	1.536	1.520	1.492	1.491	1.508
10	0.000	1.492	0.668	0.751	0.811	1.534	1.549	1.459	1.325	1.507	1.536	1.525	1.516	1.490	1.482	1.506
11	1.550	1.491	0.815	0.837	1.508	1.535	1.549	1.469	1.380	1.510	1.537	1.527	1.509	1.492	1.478	1.501
12	1.567	1.487	1.465	0.906	1.516	1.532	1.550	1.476	1.379	1.509	1.533	1.524	1.507	1.484	1.465	1.493
13	1.555	1.486	1.471	1.486	1.518	1.526	1.548	1.497	1.398	1.520	1.535	1.527	1.503	1.487	1.458	1.487
14	1.547	1.480	1.477	1.487	1.498	1.532	1.545	1.492	1.423	1.523	1.534	1.516	1.507	1.478	1.467	1.473
15	1.500	1.486	1.483	1.495	1.500	1.521	1.530	1.518	1.455	1.518	1.526	1.511	1.497	1.492	1.485	1.488
16	1.497	1.512	1.513	1.506	1.499	1.493	1.520	1.514	1.485	1.498	1.485	1.489	1.489	1.501	1.512	1.509
17	1.462	1.395	1.392	1.392	1.496	1.485	1.509	1.497	1.432	1.487	1.438	1.421	1.423	1.484	1.483	1.432

Color Legend
- Over Range
- Not Used
- Not Used
- 1.260 - 1.625
- 1.104 - 1.260
- 0.882 - 1.104
- 0.882 - 0.882
- 0.000 - 0.882
- Under Range

Elbow: 1.446 − 1.325 = 0.121
1.547 − 0.513 = 1.034

Straight: 1.399 − 1.379 = 0.020

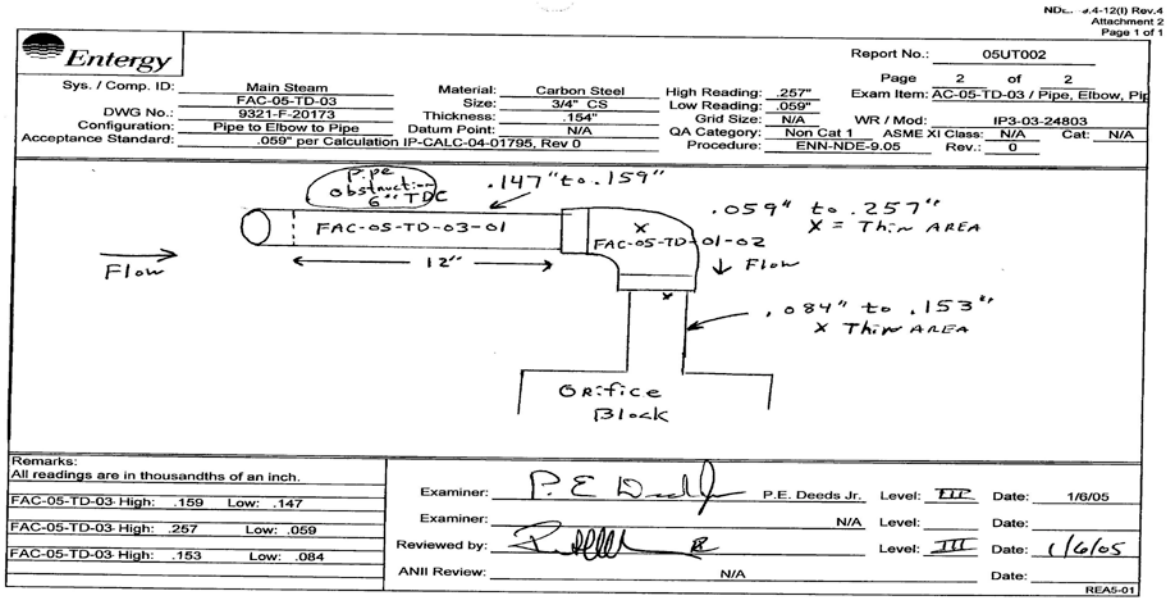
Ratio: 6 to 52

Report Date: 3/31/2

Reference: Entergy Ultrasonic Examination Report, IPEC00020853, at batestamp IPEC00020858

CHECWORKS was designed to predict average thinning rates by corrosion, not local rates by either corrosion or erosion

- Elbow's thickness varied from 0.257" to 0.059", (77%), more than 30 component grids exhibit large local variations, yet Entergy does not consider FAC as a local phenomenon (reference: Testimony of Entergy Witnesses Regarding Contention RK-TC-2, ENT000029, at p.54)
- Unpredictable component to component local thinning variation (geometry changes with time)
- CHECWORKS comparison of local thinning predictions with measurements was never provided



(Reference: RIV000049 - Entergy Indian Point U3, FAC, 3RF13 Outage, 2005)

CHECWORKS non-conservative predictions and the definition of FAC caused confusion; NRC issued new guidance

- NUREG-1801, Rev. 2, at XI M17-2, now requires that,

  "when measurements show the predictions to be non-conservative, the model must be re-calibrated using the latest field data."

- Draft License Renewal Interim Staff Guidance, LR-ISG-2012-01, Wall Thinning Due to Erosion Mechanisms (Exhibit ENT000573), revised the definition of wall thinning to include erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement.

CHECWORKS is Not Used for Steam Generator Components

- 10 CFR § 50.49(b)(1) Requires AMP for steam generators
- Steam generators components such as inlet piping, nozzles, blow down piping, and distribution ring, are highly susceptible to FAC
- Entergy approach to Steam Generator AMP, **“**When FAC Program inspections reveal wall thinning, that data is evaluated against the appropriate design loading conditions, including seismic loads” is in direct violation of Part 50

Summary

Issue	CLAIMED BY ENTERGY	FACTUAL	NOTES
ACCURACY	+/- 50% with respect to LCF	+ /- a factor of 2 (observed /predicted)	As much as a factor of 10
FAC Mechanism	Dissolution only	Consequences: wrong input parameters	More Probable: Combined Chemical and Mechanical
Conservatism	Conservative results	40-60% results are not conservative	Code was not designed to be conservative
Meet NUREG-1801, Rev. 2	YES	NO	Cannot be recalibrated
10 CFR § 50.49	Compliance by evaluating conseq. on discovering Tw<Tdes	NO	

CONCLUSION:

CHECWORKS does not meet Part 54 and NUREG-1801 requirements

- CHECWORKS can neither predict wall thinning for establishing inspection frequencies nor can it be used to identify new components for inspections.

- Because of its inherent design CHECWORKS can not be recalibrated:
  - CHECWORKS predictions for the years 2000-2011 show that 40-60% of the time the code produced non-conservative results by as much as a factor of 10.
  - CHECWORKS was designed to over-predict and under-predict data by 50%.
  - Uncertainties in Chromium content input, would prevent any meaningful recalibration of the code.
  - After 20 years of operations CHECWORKS remains uncalibrated.
  - The inputs on the effects of geometry and velocity on FAC rates are incorrect because they were based on tests of copper in an acid. In aggressive acids, the dominant damage is by chemical dissolution; these tests are not applicable to steel in water.

- Entergy cannot meet Part 50, Part 54 and NUREG-1801 requirements because it does not have a predictive methodology as required by NUREG-1801, Rev. 2:
  - **Monitoring and Trending**: CHECWORKS or a similar predictive code is used to predict component degradation in the systems conducive to FAC;
  - ***Acceptance Criteria:*** Inspection results are input for a predictive computer code, such as CHECWORKS, to calculate the number of refueling or operating cycles remaining before the component reaches the minimum allowable wall thickness;
  - **NSAC 202L-R3** "The purpose of quantitative analysis of using predictive methodology such as CHECWORKS is to predict the FAC wear rate and to determine the remaining service life for each piping component, including uninspected components."