NMP1 Torus Corrosion

As of 1R26 – April 2021

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Safety Issues and Best Inspector Practices

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- Safety Issues
  - Licensee Evaluation was not Technically Justified
  - Time between examinations (20 years) was excessive

- Lessons Learned
  - In depth independent safety review and analysis can be time consuming – Take the time
  - Ask for help

71111.08 Inservice Inspection Activities

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- If applicable, review at least one volumetric or surface examination from the previous outage with relevant indications that the licensee analytically evaluated and accepted for continued service. The licensee's acceptance needs to be in accordance with the ASME Code or an NRC-approved alternative. Confirm that any indications were examined for acceptability for continued service.

10CFR55a.(g)(4)- ASME Section XI

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- Requirements for examination (component, methods, boundaries), components), acceptance criteria, frequency of examination, qualifications, repair
- 10-year inspection interval. Each interval divided into 3 periods.
- Section IWE – Requirements for Class MC and Metallic Liners of Concrete Containments
- If ASME Section XI Indication that doesn't meet acceptance criteria. 3 options (IWE-3122):
  - Repair or Replace it.
  - Reexamine it and it meets acceptance criteria.
  - Evaluate and accept it for further service

Section XI IWE Examination Requirements

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- Item E.12 – Wetted Surfaces of Submerged Areas
  - General Visual Examination
  - Once per 10-year interval

- IWE-3510 Acceptance Criteria
  - Owner Specified

2019 1R25 Owner's Activity Report (OAR)

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Exelon Generation.	Nine Mile Point Nuclear Station Unit 1 FOURTH INSERVICE INSPECTION INTERVAL 2019 OWNER'S ACTIVITY REPORT FOR INSERVICE EXAMINATIONS	NMP1-OAR-004-25 Rev. 00 Date: April 29, 2019 Page 7 of 9

TABLE 1

ITEMS WITH FLAWS OR RELEVANT CONDITIONS THAT REQUIRED EVALUATION FOR CONTINUED SERVICE
As required by the provisions of the ASME Code Case N-532-4

EXAMINATION CATEGORY	ITEM NUMBER	ITEM DESCRIPTION	EVALUATION DESCRIPTION
B-N-2	B13.30	Reactor Vessel Interior Attachment Weld – Beyond Beltline Region (Steam Dryer Support Bracket)	Visual inspection during the spring of 2019 (N1R25) has confirmed that no change in visual indications has occurred during the past cycle. Previously submitted flaw evaluations remain applicable through the next scheduled UT and visual examination schedule for 2021 (N1R26). Reinspection during 2021 will be the third successive period reinspection as required by IWB-2420(b). Repeat inspections have been performed on the steam dryer support brackets since initial flaw detection in 2011. Subsequent UT and visual inspections in 2013, 2015 and 2017 have confirmed that indications remain relatively shallow, are located entirely within the bracket base metal and run parallel or away from the vessel attachment weld. As such, observed flaws are not considered a threat to propagate into and/or through the vessel attachment weld toward the vessel. Prior to the N1R23 re-inspections, NMP revised the Engineering Evaluation using the N1R22 UT/EVT-1 data to allow two-cycles of operation. The revised supporting Engineering Evaluation concluded that the indications are acceptable for continued service for at least two additional operating cycles. In accordance with IWB-3144(b) the Engineering Evaluation of the examination results was submitted as an attachment to the 2015 Owner's Activity Report for RFO-23 Inservice Examinations (ML15191A385). The repeat UT/EVT-1 examinations in successive outages confirms that the crack growth depth and length changes are well below the conservative growth rates used in the 2-cycle flaw evaluation. All flaws remain acceptable under the previously submitted flaw evaluation.
E-A	E1.12	Torus Inside Under Water and Downcomers Under Water	Corrosion identified on the torus and downcomers under water. ECP-19-000143 provided a qualitative evaluation on the acceptability of the identified above referenced ECP evalu torus and associated vent sy design function.

- Sometimes referred to as the 90 Day report
- 10CFR50.55a Section XI Condition
  - 10CFR50.55a(b)(2)(xxxii)
  - Code Case N-532-X
- Summary of Repair Activities
- Listing of items with flaws or relevant conditions that exceeded acceptance criteria and required evaluation to determine acceptability for continued service.

- Selected the Torus evaluation as it is primary containment, the last of the fission product barriers. (Risk Informed)

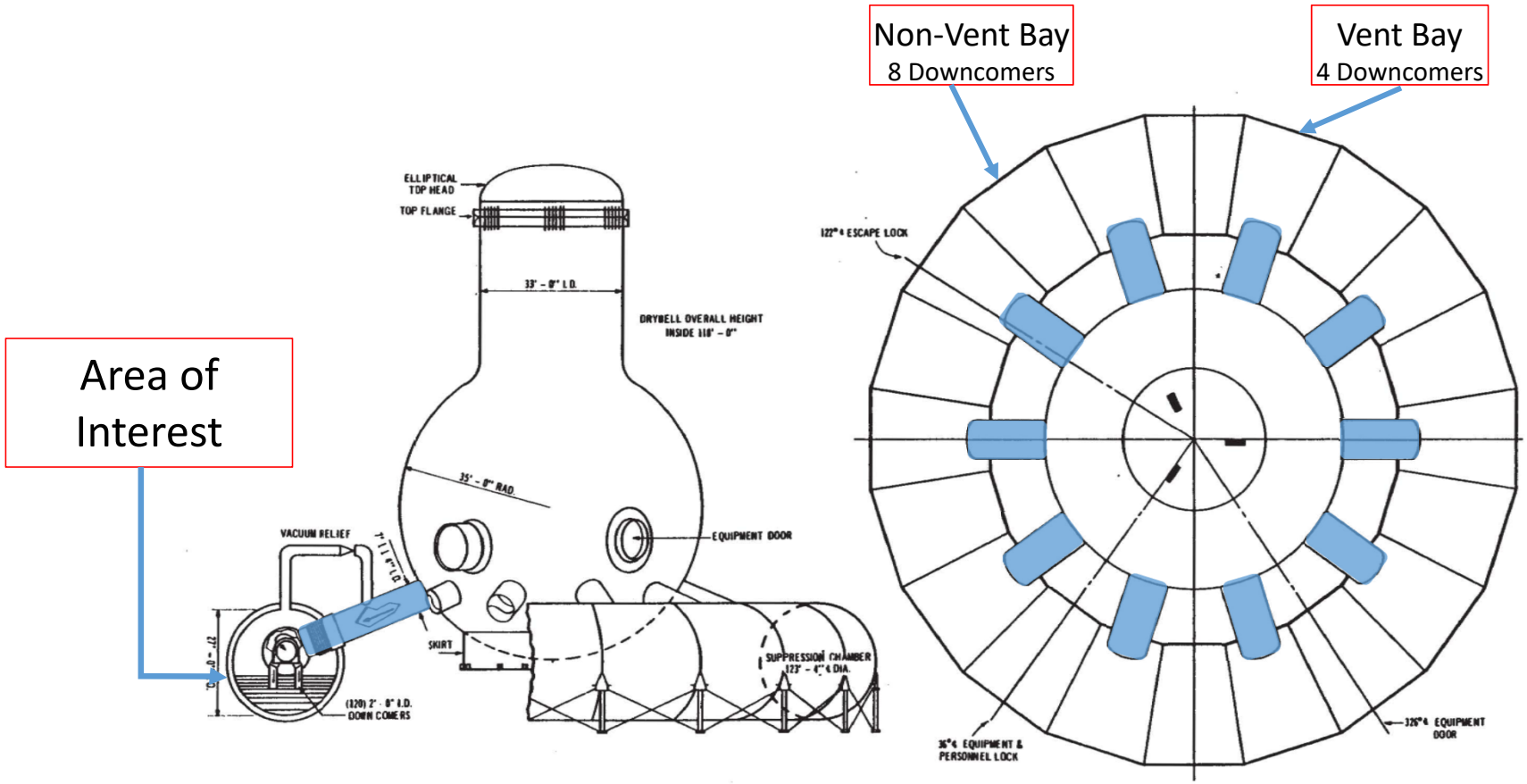
E-A	E1.12	Torus Inside Under Water and Downcomers Under Water	Corrosion identified on the torus and downcomers under water. ECP-19-000143 provided a qualitative evaluation on the acceptability of the identified torus/downcomer corrosion. The above referenced ECP evaluation has determined that the torus and associated vent system is capable of performing its design function.

Nine Mile Point Unit 1

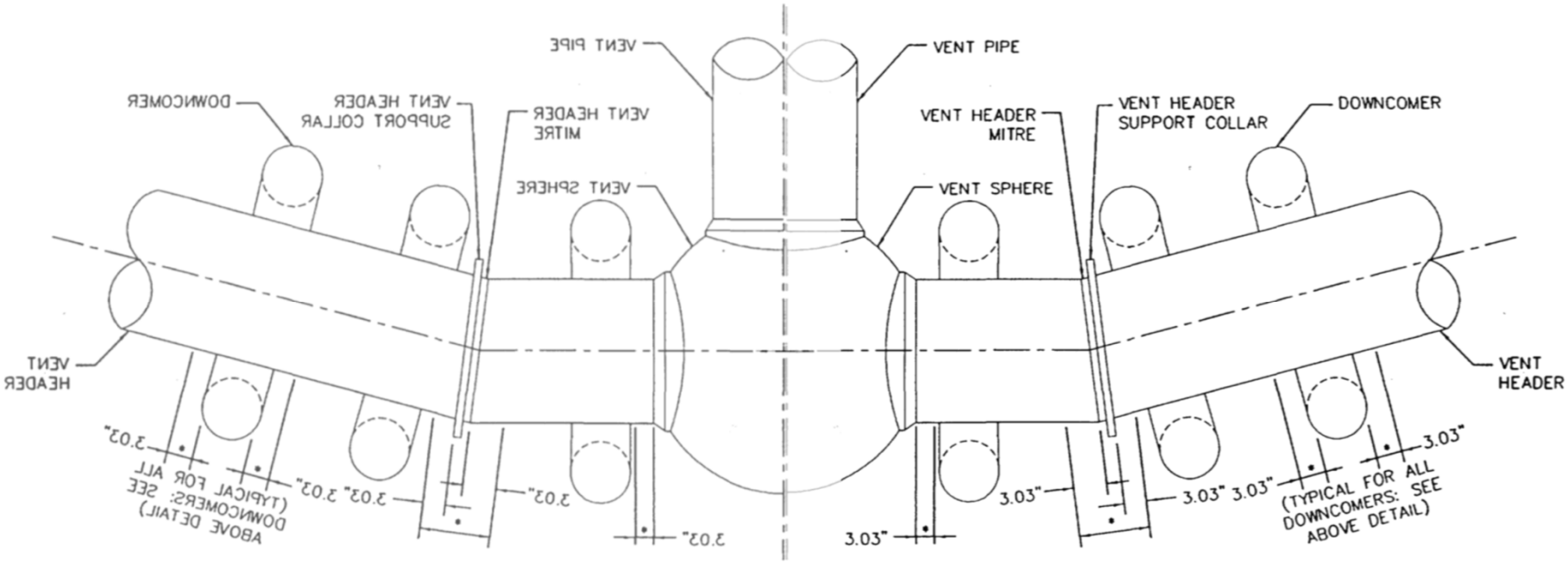
- Constellation Energy
- Oswego NY on Lake Ontario
- BWR-2
  - Online in 1969.
  - License extended to 2029.
  - ~650 MWe,
  - Mk-1 Containment, Isolation Condenser, no HPCI or RCIC.
  - Uncoated Torus

MK-1 Containment

Terminology and Area of Interest



Vent Header


VENT PIPE
VENT HEADER MITRE
VENT HEADER SUPPORT COLLAR
DOWNCOMER
VENT SPHERE
VENT HEADER
3.03"
3.03" 3.03"
3.03"
(TYPICAL FOR ALL DOWNCOMERS: SEE ABOVE DETAIL)

1R24 (2019) Torus Examination Results

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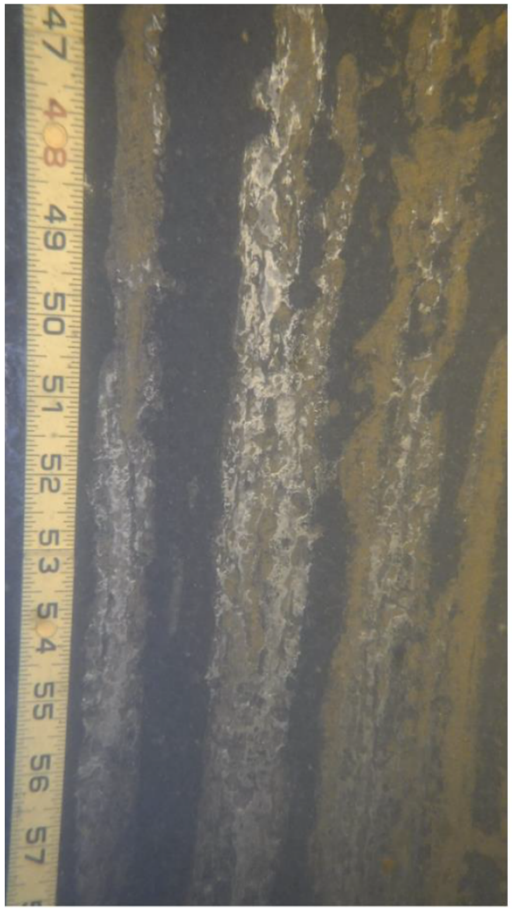
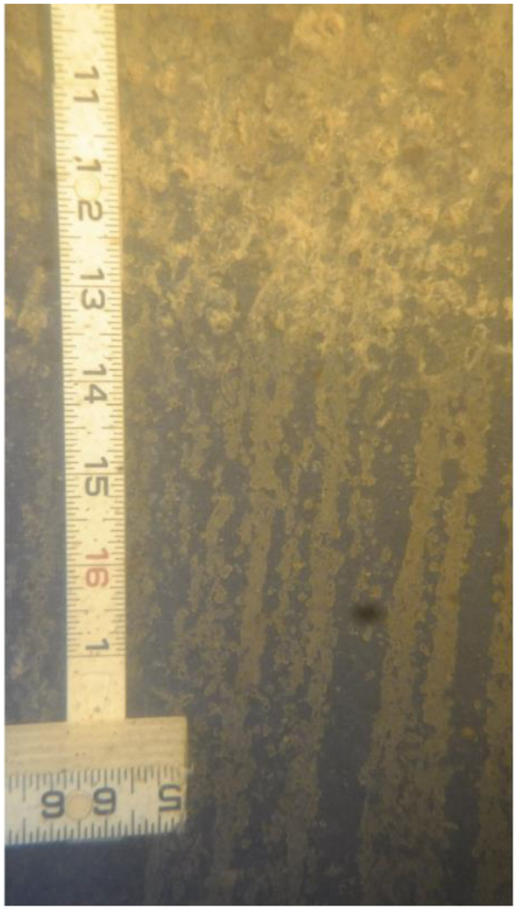
- Indications reported by divers.
  - "Tiger Striping" – vertical stripes of black oxide covered steel and bare steel
  - 10-70 mils in depth.
  - Black oxide stripes approximately 1 inch wide
  - Bare metal stripes approximately ½ inch wide
  - Vertical stripes extend to at most 9 feet below waterline.
  - 1 large area of bare metal, could not be measured (Bay 8)
  - 2 large pits (.08 inches deep by 0.5 inch dia. and 0.1 inches deep by 3 inch dia.) (Bay 4)
  - Bays 1-20 examined and recorded separately

Tiger Stripe Corrosion

- Measured by divers using gauges in 2019 during Section XI, IWE Exams
- 10-70 mils in depth
- 4-6 feet from surface of water along inside and outside diameter walls of torus.
- Dark oxide high points, bare metal low points
- Appears in photographs taken in 1999 when torus was drained (next slide)
- Review of IWE Reports –
  - Area of tightly adherent rust scale
  - Tiger stripes
  - Pits
  - Bay 8 had conditions similar to bare metal low points without dark oxide high points.





1999 Inspection of Torus (Drained)

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Licensee "Use As-Is" Evaluation

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- ASME Requires Evaluation but doesn't specify how to do it
  - Lowest average wall thickness reading – Bay 8 - 0.448 inches (TCMP – discussed later)
  - Deepest measured valley - 0.070 inches
  - Acceptance Criteria - Required minimum wall in area of degradation – 0.397 inches
    - Position Dependent

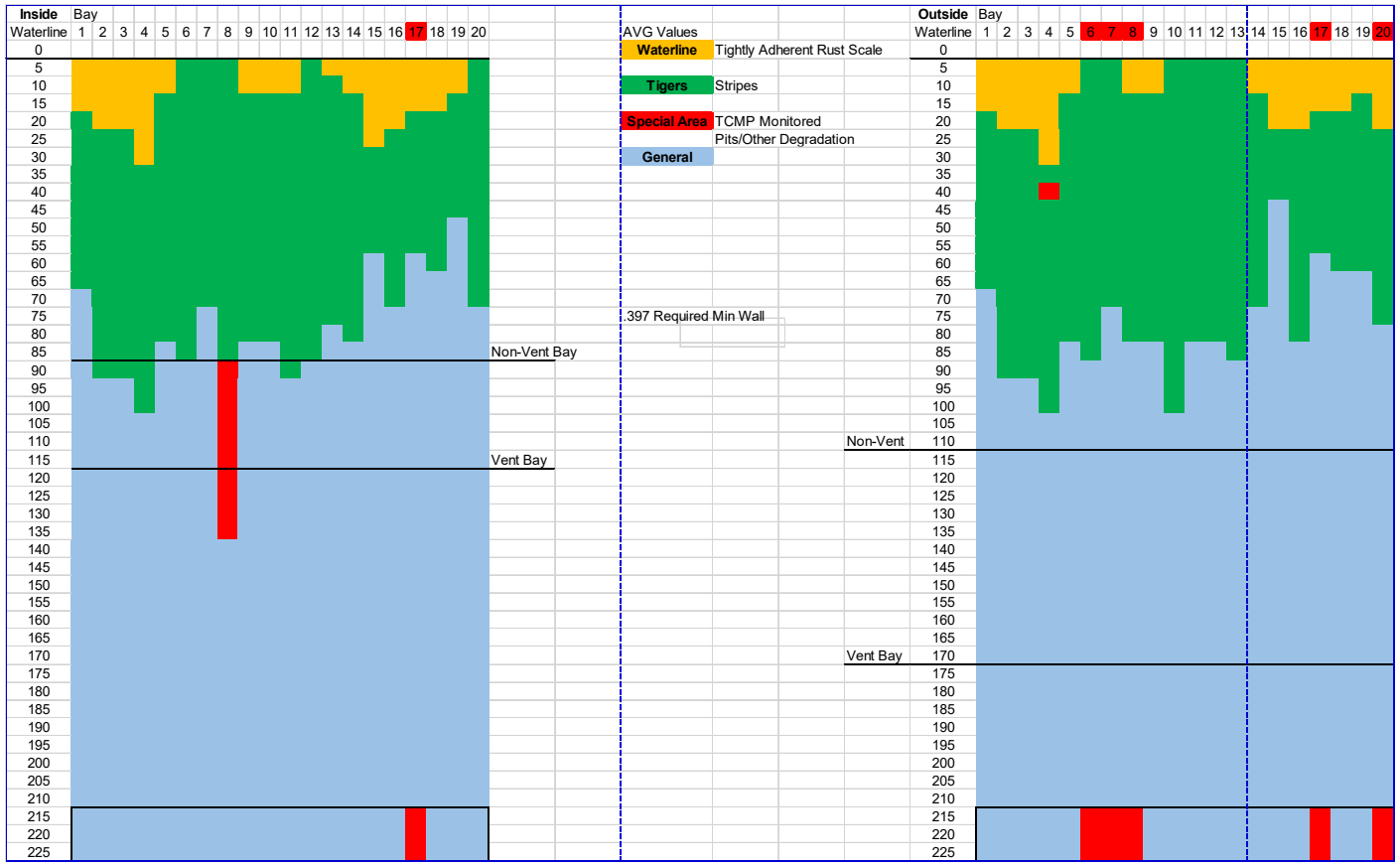
- Calculation of remaining wall thickness
  - Remaining wall: 0.448 – 0.070 = 0.378 inches – Below minimum required wall.

- Evaluation
  - $Average\ Remaining\ Wall = \frac{[Lowest\ Average\ Wall + 2*(Remaining\ Wall\ at\ deepest\ tiger\ stripe)]}{3}$
  - Average remaining wall = [0.448 + 2*(0.378)]/3 = 0.401 with a required 0.397 at that location.

Inspector Questions

- Evaluation seemed simplistic.
  - Does the evaluation justify structural integrity to the next examination?
  - Is the calculation technically justifiable?
- Where did the remaining wall thickness values come from?
- What is the required minimum wall thickness?
  - What is the standard?
- What is the corrosion mechanism?
  - What is the corrosion rate of the tiger strip areas?
- How long will the evaluation be good for?
- Are there any reinspection requirements?
- How did we get here?

Inspector Mapping of Licensee's Data



Evaluation

- The calculation method seemed very simplistic, and the basis wasn't discussed in the evaluation.
  - $Average\ Remaining\ Wall = \frac{[Lowest\ Average\ Wall + 2*(Remaining\ Wall\ at\ deepest\ tiger\ stripe)]}{3}$

- Deriving design equations is not my specialty.

- **Best practice: Ask for help when you need it.**
  - NRC has lots of specialists. They can save you lots of time.
  - Contacted NRR Staff from DNRL/DEX for expertise.
  - Determined that the basis was in design hoop stress calculations and use of average remaining wall thickness was adequate for showing structural integrity of the torus.

Inspector Concerns with Evaluation

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- Engineering evaluation did not demonstrate integrity to next exam.
  - Licensee showed 4 mils margin.
  - No corrosion rate determined
  - Evaluation used old data. (2017 vice 2019 data)
    - Result was 1 mil margin vice 4 mils in original evaluation in 2019.
    - Did not update as new data received – Using 2020 data, zero mils margin.
- Licensee reevaluated in response to inspector concerns
  - Used weighted average of typical (average) tiger stripe depth and thinnest remaining wall average wall thickness in each bay.
  - Generated a corrosion rate to show structural integrity to next required examination with little margin.
- Pitting in Bay 4 – Used approved method.
- Bay 8 Intermediate Area – Licensee took UT thickness measurements to determine adequate thickness.

Inspector Concerns with Exam Frequency

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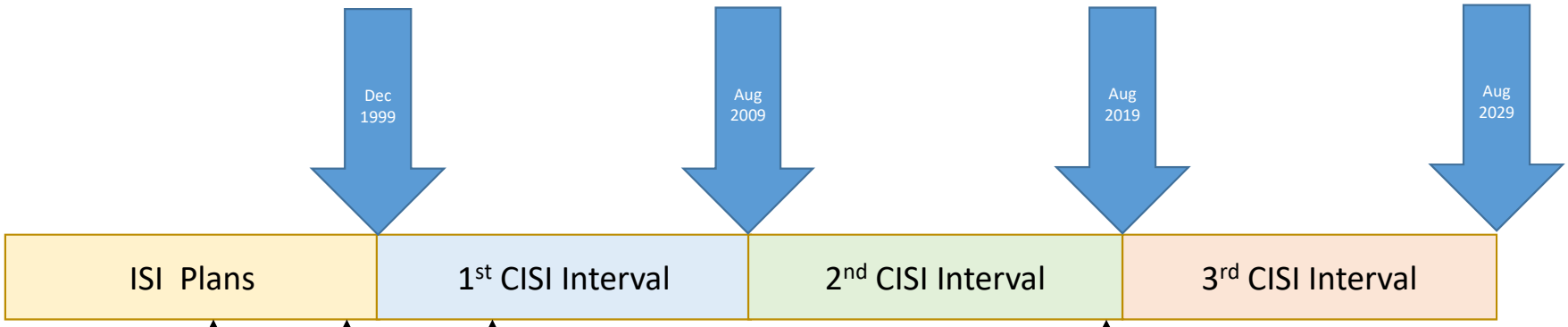
- Examinations completed in 1989, 1999 and 2019
- 10-year frequency required by IWE
- Where is the 2009 examination?

Inspector Retrieved Examination History



July 2003 – Letter forwarding RFO 15/16/17 OARs states taking credit for April 99 inspection for 1st Interval

April 2019 - Torus Examination - Divers

April 1999 – RFO-15 Torus Drained for Expedited Examination

September 1996 – 50.55a requires inspection of Class MC and CC Components by September 2001

Issues

- 10 CFR 50.55a (g)(6)(ii)(B)(3) addresses the use of an expedited examination to satisfy a required interval examination (1997 version of 10CFR)
- Sec XI - Should be scheduled in same period
- No inspection occurred between April 1999 and April 2019

Inspection Results *NMP Resident Report 2021002 (ML21222A021)*

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- **NCV of ASME Section XI, Subsection IWE concerning adequacy of the evaluation**
  - Green finding and associated NCV of ASME Section XI, paragraph IWE-3122.3, “Acceptance by Engineering Evaluation,” when Exelon performed an engineering evaluation that did not meet the applicable requirements in ASME Section XI, subsection IWE as required by 10 CFR Part 50.55a(g)(4)(v). Specifically, the engineering evaluation did not demonstrate that the torus wall thickness satisfied the minimum wall thickness requirements in their design specification through the period the evaluation applied which ends in 2023.

- **NCV ASME Section XI, Subsection IWE concerning missed examination.**
  - Green finding and associated non-cited violation (NCV) of ASME Section XI Subparagraph IWE-2412(a), “Inspection Program B” when Nine Mile Point did not perform an inspection for wetted surfaces of submerged areas (ASME Item E1.12) at Unit 1 in the first containment inservice inspection interval which spanned between December 26, 1999, and August 22, 2009.

Next Steps

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- Licensee is performing a new finite element analysis with hopes to recover some margin and refining minimum wall requirements.
- Examination is due during 2023 outage.
- Licensee to sample the tiger stripe area to determine corrosion mechanism and corrosion rate.

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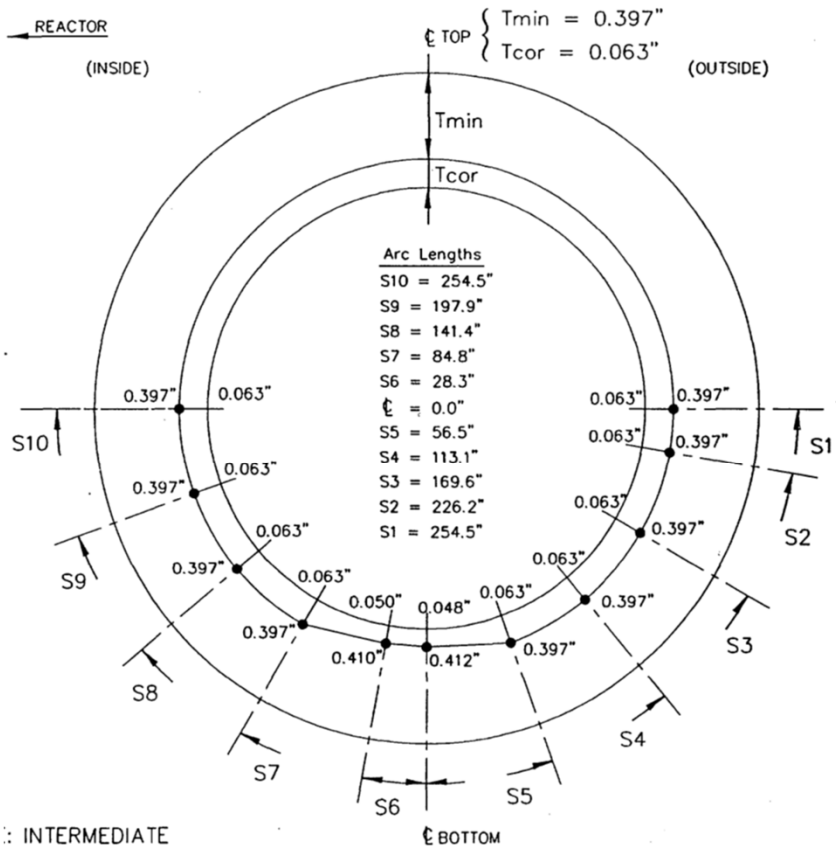
Questions?

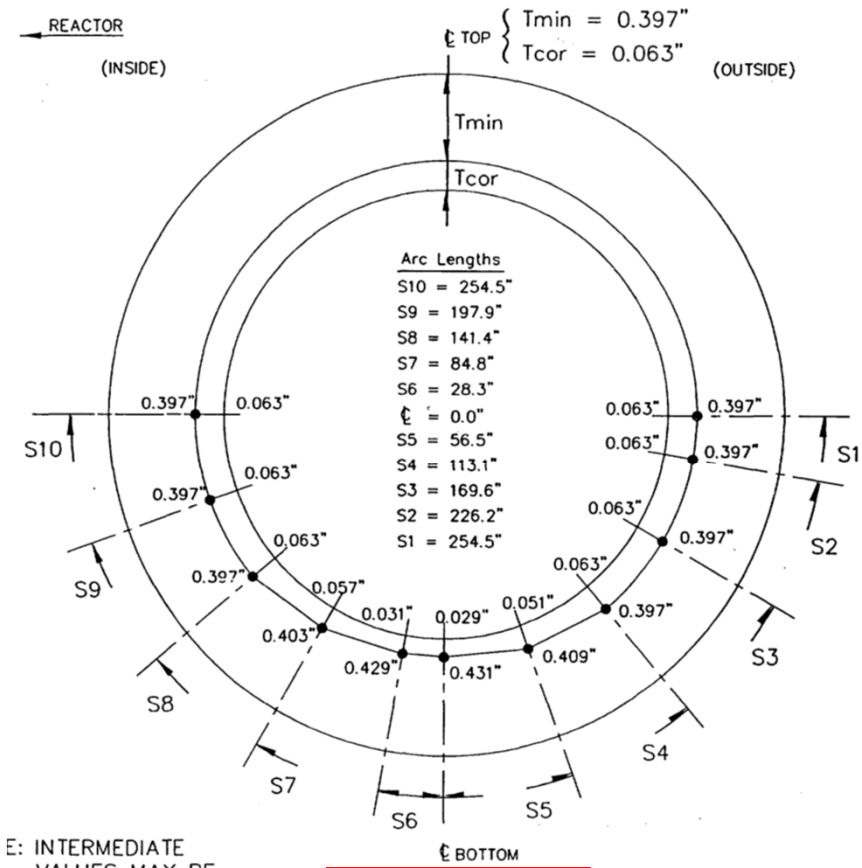
Backup Slides

Minimum Wall Requirements

Location Dependent



Vent Bay



Non-Vent Bay

Minimum Wall Thickness Requirements

- Dependent on Bay type and location on torus shell
- Accounts for hydrodynamic effects on shell due to LOCA and SRV lifts
- Important Numbers:
  - 0.460 – As Built Thickness
  - 0.431 – Minimum required wall due to hydrodynamic effects
    - Min required wall at most stressed location.
    - UFSAR
    - License Renewal
    - SERs
    - Torus Corrosion Monitoring Program
  - 0.397 – Accident Pressure only
    - Min required wall for pressure of 35 psi

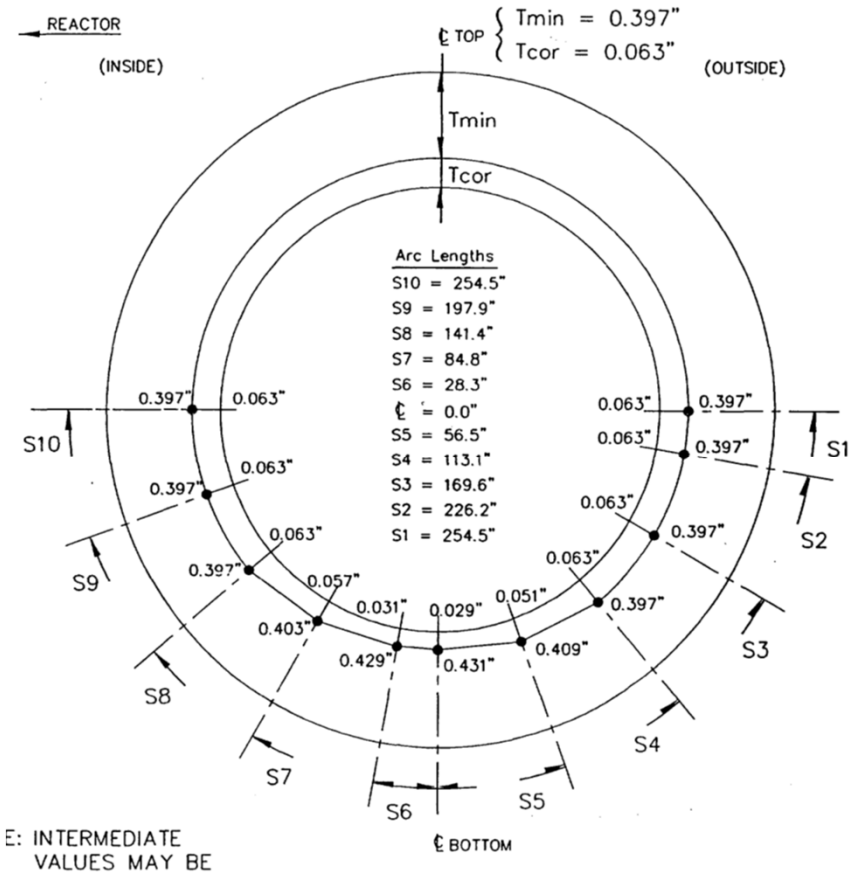


FIGURE 7

What is the corrosion mechanism?

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- TCMP – determines and trends the degradation in the wall thickness due to general corrosion.
  - Requires presence of oxygen and since torus is inerted, corrosion rate is low.
  - Uncoated surface.
- Tiger stripes
  - Cause and mechanism is not known at this time.
  - Potential causes – based upon internet research
    - Local galvanic cells
    - Sulphur reducing bacteria (internet research)
      - Anaerobic – flourishes in oxygen deficient environments (Inerted)
      - Dormant when oxygen is present
- Licensee will be sampling the tiger stripe area in the upcoming outage to identify the mechanism.

What is the corrosion rate of the tiger stripe area?

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- Depends on when you start the clock.
  - Measurements in 2019.
  - Can see the stripes in 1999
  - Licensee started the clock in 1989 based upon examination reports done in an outage
    - Done by examiners in an IBRB.
    - Could only see 2-3 feet below water surface due to murkiness of water and lighting.
    - My read was that the description fit the “tightly adhered rust scale” region identified in 2019.
    - Licensee claimed it identified the tiger stripes.
    - Licensee’s responsibility. Adamant to start in 1989.
- Why is this important? Tiger strip corrosion rate determines how long the evaluation is good for.
- Tiger stripes
  - Cause and mechanism is not known at this time.
  - Potential causes – based upon internet research
    - Local galvanic cells
    - Sulphur reducing bacteria (internet research)
      - Anaerobic – flourishes in oxygen deficient environments (Inerted)
      - Dormant when oxygen is present
- Licensee will be sampling the tiger stripe area in the upcoming outage to identify the mechanism.

How long is the evaluation good for?

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- What data is being used?
  - Worst case thinnest plate from TCMP in whole torus.
  - Worst case deepest tiger stripe in whole torus.
- Use of old data.
  - The 2019 evaluation used TCMP results from 2017 when results from 2018 and 2019 were available.
  - Substitute 2019 data in – less than 1 mil margin
  - Substitute 2020 data – at minimum wall
  - 2021 data – below minimum wall
- Corrosion Rate
  - General Corrosion – TCMP – 5 mils/year
  - Tiger stripe corrosion rate
    - 20 year - 3.5 mils/year
    - 30 year - 2.3 mils/year
- Updated evaluation method
  - Evaluated bay by bay using TCMP data and actual tiger stripe data for the bay being evaluated.
  - Using 30 year tiger strip corrosion rate – evaluation is good until 2024.

How did we get here?

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How did we make it to 2021 and the first indications there was a problem was when minimum wall and containment operability was being questioned?

Where did the data come from?

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- Torus Corrosion Monitoring Program – General Corrosion
  - Annual Ultrasonic Thickness Tests taken at 6 worst case locations in Torus since 1995.
  - Determines an Average minimum remaining wall thickness at those 6 locations
- Diver's measurement of depth of tiger stripes.
  - How accurate were the measurements?
  - 10-70 mils in depth

Next Week:
Vogtle AP1000 an Overview