Entergy – Waterford 3 Meeting with NRC on Steam Generator Batwing Issue

September 6, 2007

Introduction

- Nuclear Safety Priority
  - Conservative Operational Assessment
  - Defense in depth mitigation strategy
  - Conservative monitoring and action limits
  - Heightened awareness (ODMI)
  - Conservatively performing a mid-cycle
- Meeting Objectives
  - Inspection scope
  - Expected findings
  - Contingency criteria and planning

Agenda

Discussion Topic	Presenter	Time
Overview of Batwing Mitigation Strategy	Keith Nichols	5
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Mid-Cycle Contingencies and Criteria	Rex Putnam	40
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Summary and Q&A	Joe Kowalewski	10

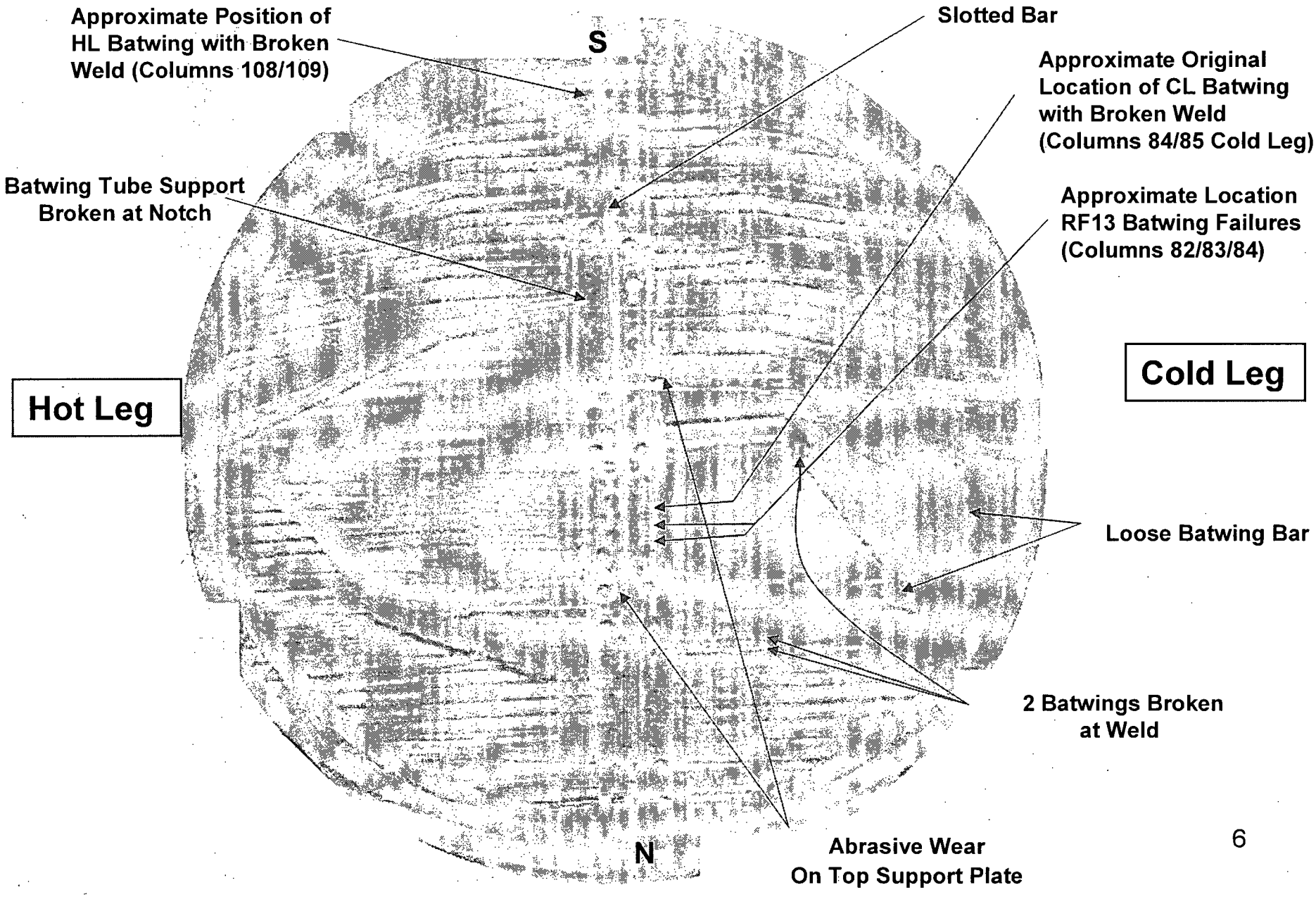
Overview of Batwing Mitigation Strategy

Keith Nichols

SG 32 - Status

- 22 broken batwings in stay cavity region
- Wrap Around Bar welds in the stay cavity region have been inspected and reinforced except BW at Column 84/85 (cold leg)
- Column 84/85 (cold leg) batwing slid into the tube bundle
  - held in place by tube friction
  - Adjacent tubes were plugged, sentinel plugged, or plugged and stabilized

Waterford 3 Steam Generator 32 Batwing Inspection from Lower Handhole



Refuel-14 Repairs

- Defense-in-depth mitigation strategy
  - Analysis of potential loose parts
  - Analysis and validation of tube wear rates
  - Analysis of forces on welds for batwing to wrap around bar
  - Batwing welds to wrap around bar in SG 2 enhanced for batwings that traverse through stay cavity
  - Inner row of tubes around stay cavity and loose batwing are plugged and stabilized
  - Sentinel plugs added in on wrap around bar perimeter, around stay cavity and around loose batwing

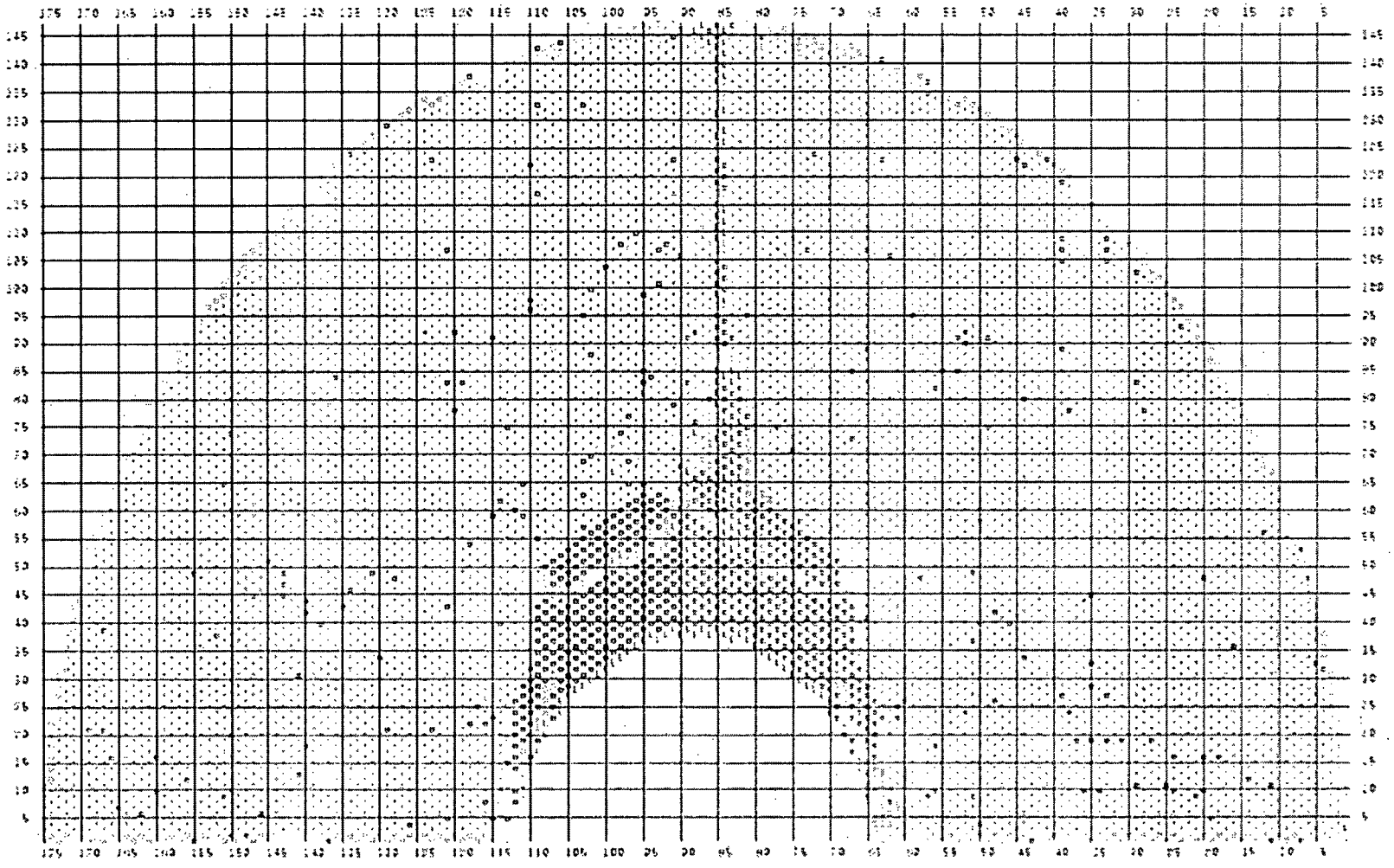
SG - 32 TUBE REPAIR HISTORY

RF13 AND RF14 - REV 4
Waterford RFO14 WTR3 3410

L 125 LONG STABILIZER • 7 STAY POSITION

H 1 LONG STABILIZER - HOT LEG 2011 ▫ 772 Plugged Tube

S 209 RFO13/RFO14 CL SENTINEL PLUG



Preventive Plugging also in SG#1

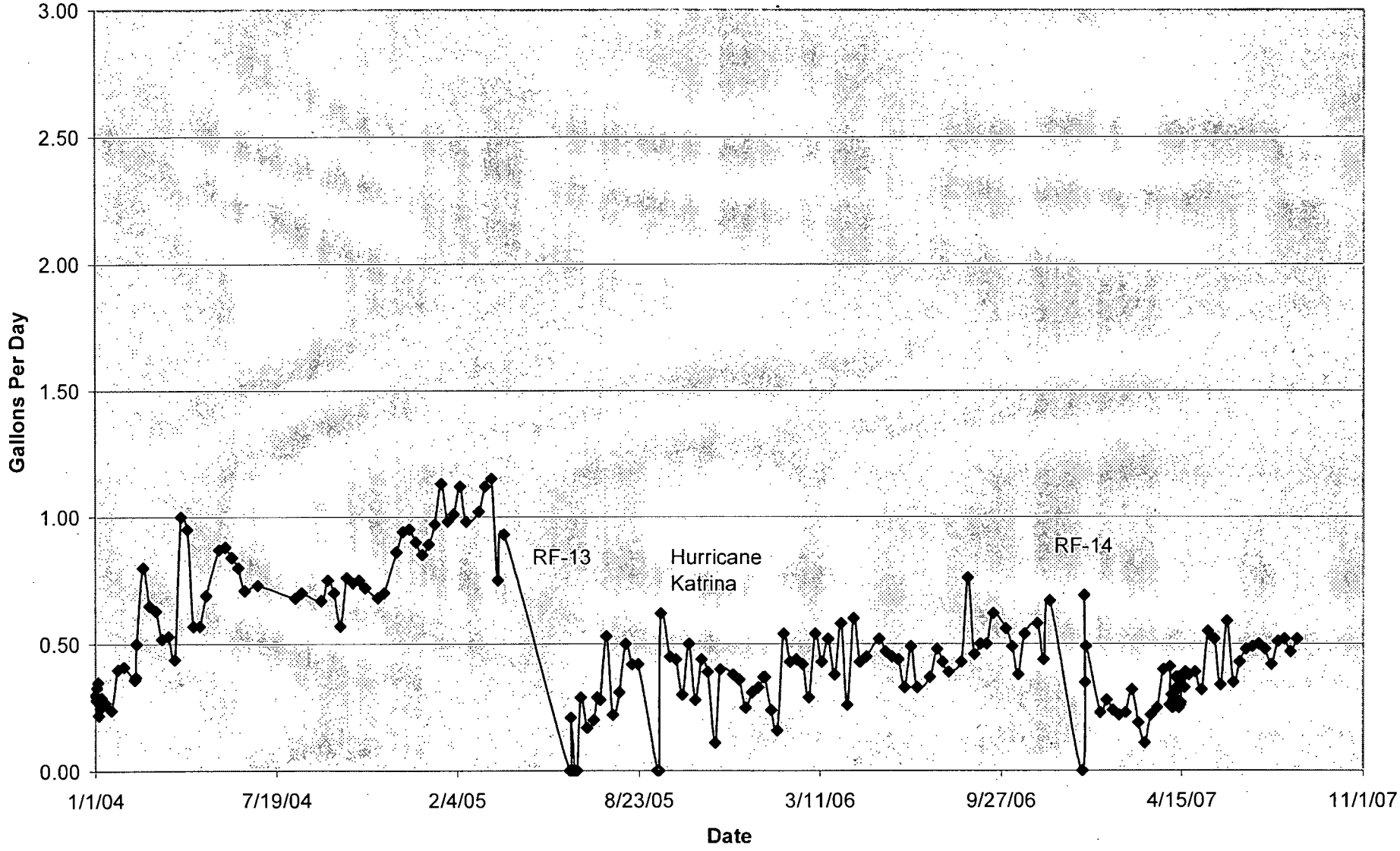
Steam Generator Monitoring Update

Keith Nichols

SG Monitoring Update Summary

- Dedicated loose parts monitor installed to monitor SG
  - No metallic impacts identified
- Operational Decision Making Issue for primary to secondary leak rate
  - 0.5 gpd steady and consistent with previous cycle
  - 2 gpd and 5 gpd triggers increased monitoring and evaluation
  - 5 gpd with a rate of 7.5 gpd/hr administrative shutdown
  - 15 gpd administrative shutdown
- High level of site awareness and sensitivity
  - Seven tube leak simulator training sessions this year with each operating crew
  - Operations, Engineering and Chemistry monitoring

Steam Generator Primary to Secondary Leak Rate



Mid-Cycle Planned Activities

Rex Putnam

Mid-Cycle Inspection Purpose

- Visually inspect the secondary side of the steam generators for the purpose of:
  - determining any unforeseen extent of condition
  - determining any unforeseen change in the critical variables that were the basis for the repair plan and operational assessment
- Secondary inspections will confirm no unforeseen changes
  - BW to Wrap Around Bar Interface [Weld, Clip, Deformation]
  - Examine Stay Cavity (Bottom Up) for Visible Deformation of the Tube Bundle
  - A BW segment extending beyond the Seventh Eggcrate Support
  - A BW segment outside of the stay cavity region
- Conservative Operational Assessment
  - RF14 Operational Assessment predicted margin for all mechanisms
  - Batwing related tube wear model was validated in RF14
  - Forces (and thus wear) attenuates as the batwing extends further into the tube bundle
  - Open tubes would not be impacted until after the Sentinel plugged tubes
  - Sentinel plugged tubes remain intact
  - Active tubes are not expected to have significant wear for 16 years

Mid-Cycle Inspections

- Secondary visual exam of upper batwings
  - verify no upper batwing weld/clip failures in stay cavity area
  - verify no gross deformation twisting of wrap around bar
- Foreign object search and retrieval
  - remove accessible foreign objects
  - no batwing segment outside of stay cavity
- Secondary visual inspection of stay cavity area
  - monitor batwing degradation
  - verify that batwing at column 84/85 cold leg has not dropped
- Secondary diagonal visual inspection of upper stay cavity area (SG2 only)
  - provide additional information in support of repair options in RF15

Upper Batwing Visual Inspection

- Critical Variable: No additional batwings have slipped into the tube bundle and no wrap around bar deformation
- Inspection: Visual exam to verify no upper weld failures for batwings in stay cavity area and no gross deformation twisting of wrap around bar
- *Analysis: Wear growth rates and wear distribution.*

FOSAR Inspection

- Critical Variable: No large mass foreign objects
- Inspection: Foreign object search and retrieval and visual inspection
- *Analysis: Ginna tube rupture event analysis involved the repeated impacts of a large mass foreign object over several years.*

FOSAR Inspection

- Critical Variable: Effectiveness of stabilizer fence for containing loose segments and maximum size of loose batwing segments in stay cavity
- Inspection: Visual exam of stay cavity region and FOSAR to verify no large batwing segments or segments outside stay cavity
- *Analysis: Broken batwing analyses assumed containment of BW segment in stay cavity region to evaluate acceptability of tube impacts and wear, including normal and accident condition*

Visual Inspection of Stay Cavity

- Critical Variable: No extruded batwings
- Inspection: Visual inspection of stay cavity area for extruded BW segments
- *Analysis: Loose parts analysis for impact and wear. Note that attenuation analysis is conservatively based on a maximum force determined by BW material plus sail area.*

45° Inspection

- Provide additional information for RF15 repair options
- Inspection contingencies are developed

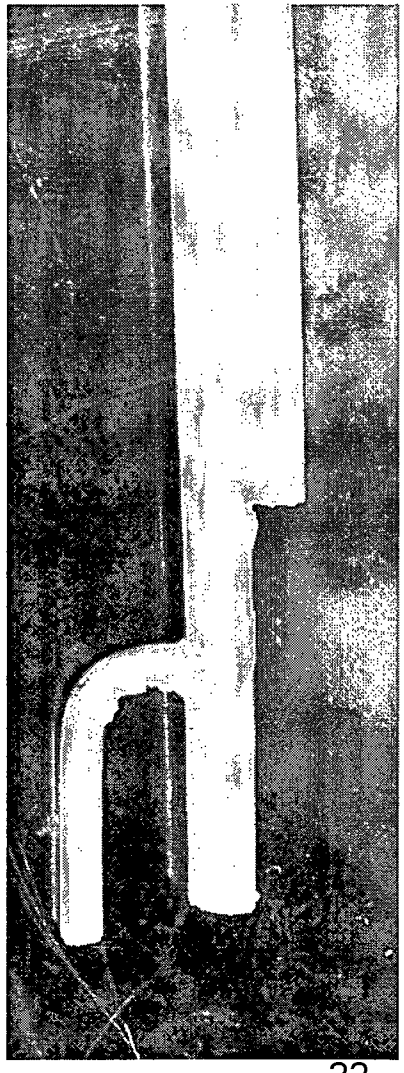
Expected Batwing Condition

- SG#1
  - Upper batwing welds should be intact.
  - Stay cavity damage has not been observed, but is possible. A mitigation strategy similar to that used in SG2 was applied in SG1 in RF-14.
- SG#2
  - Upper batwing welds/clips and wrap around bar should be intact
  - Propagation of batwing damage in the stay cavity is expected
  - No indications of gross tube deformation is expected
  - Column 84/85 batwing may move but is not expected to damage the stabilizer fence or active tubes
  - Stabilized tubes around the stay cavity may have visible through wear but tube and stabilizer are expected to remain structurally intact
  - No gross tube damage is expected

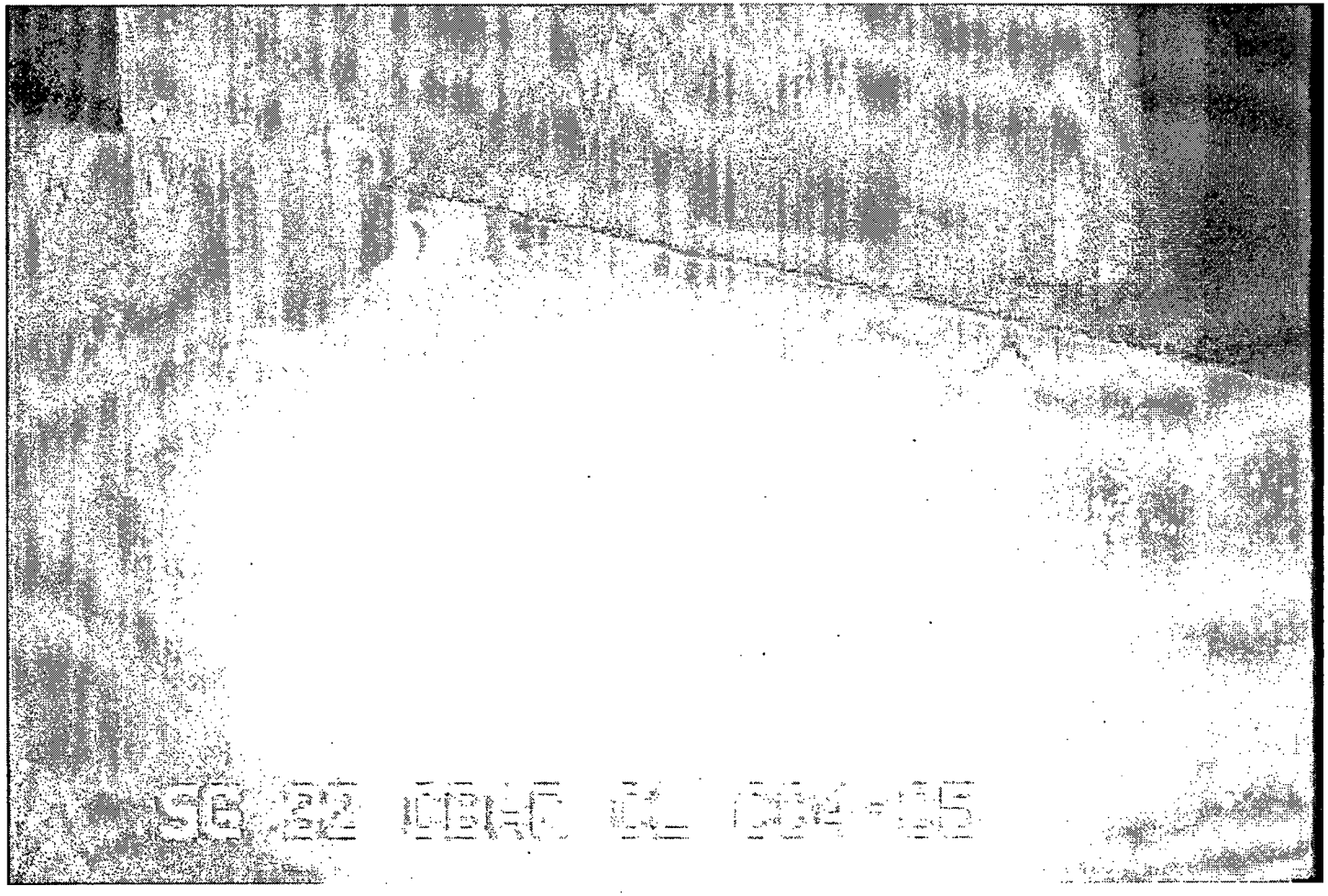
Secondary Inspection Techniques

Wrap Around Bar Inspection Tooling

- Access wrap around bar from steam drum
- Guide hooks on the wrap around bar
- Video probe inserts into guide tube for inspection

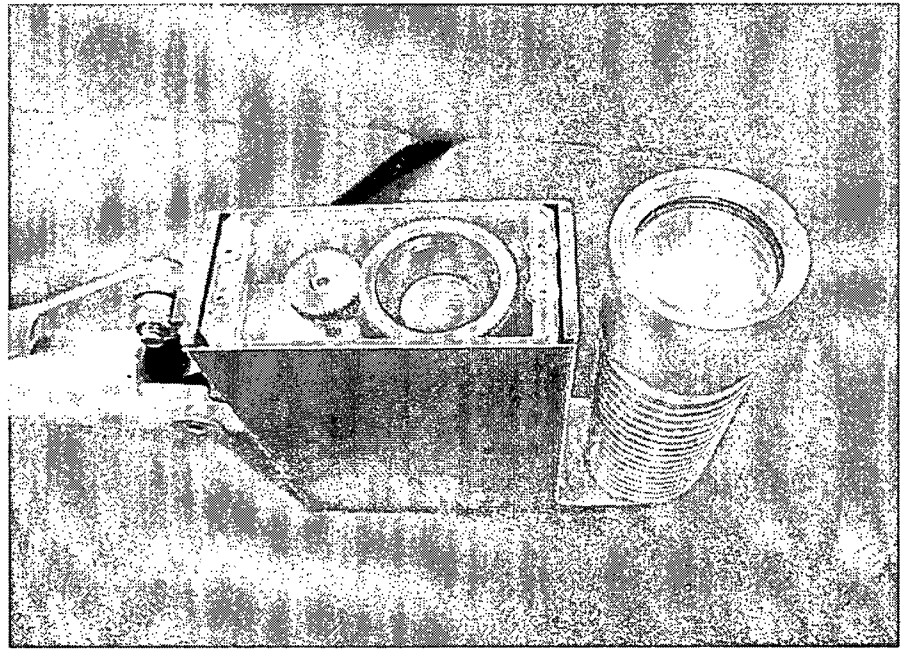


Wrap Around Bar Inspection - Results

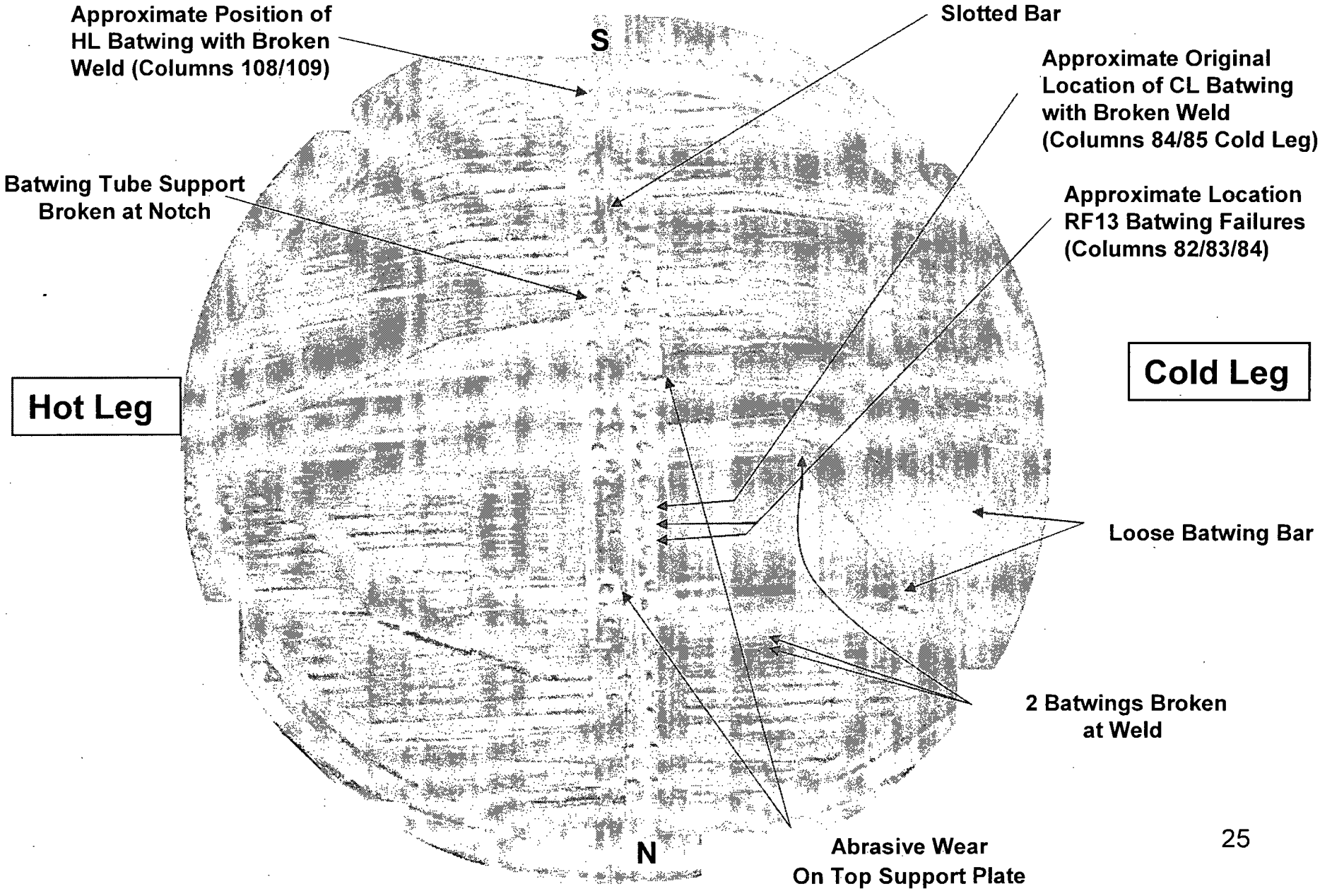


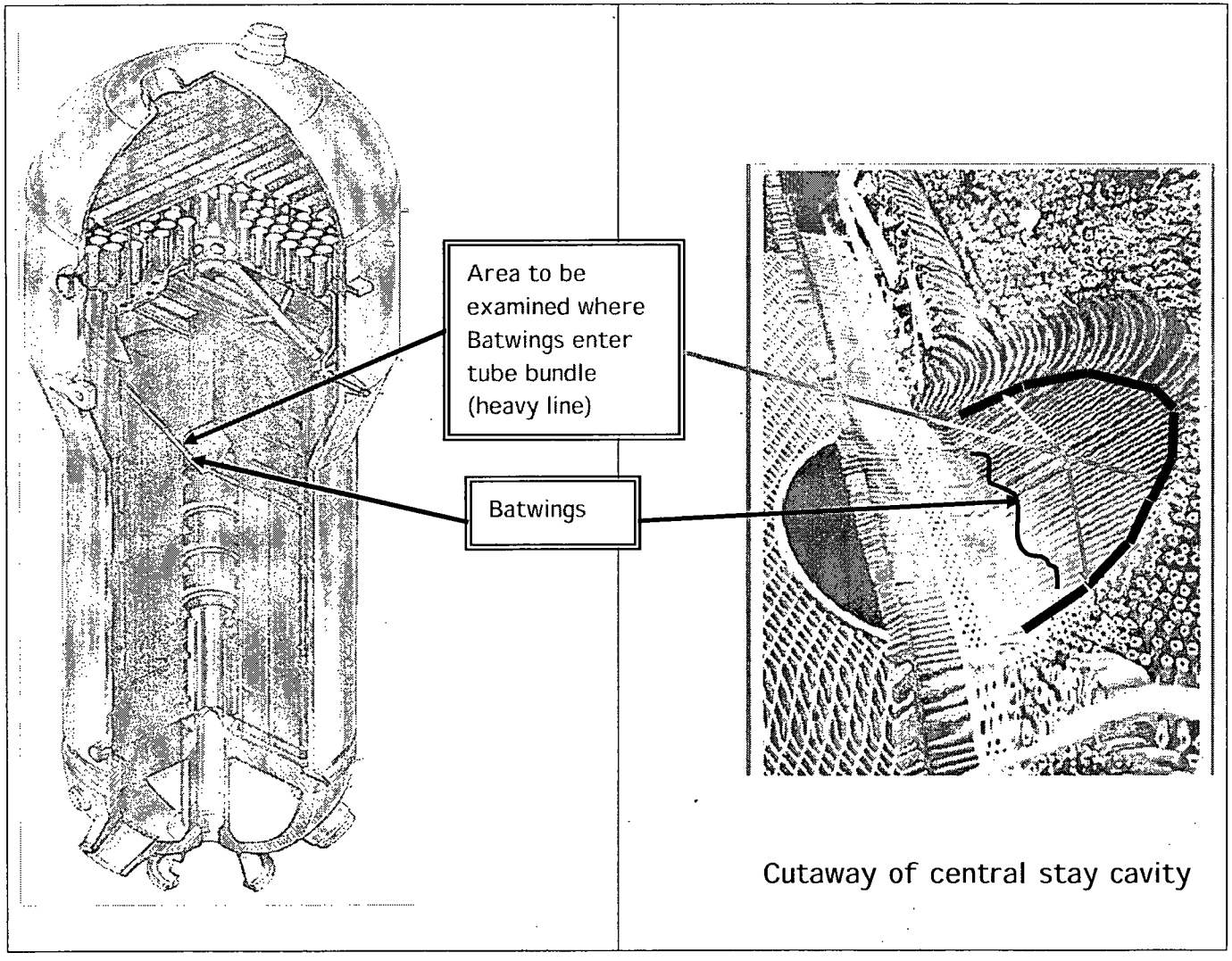
Lower Batwing Visual Inspection Tooling

- Installs through secondary handhole at tubesheet
- 18x fixed magnification

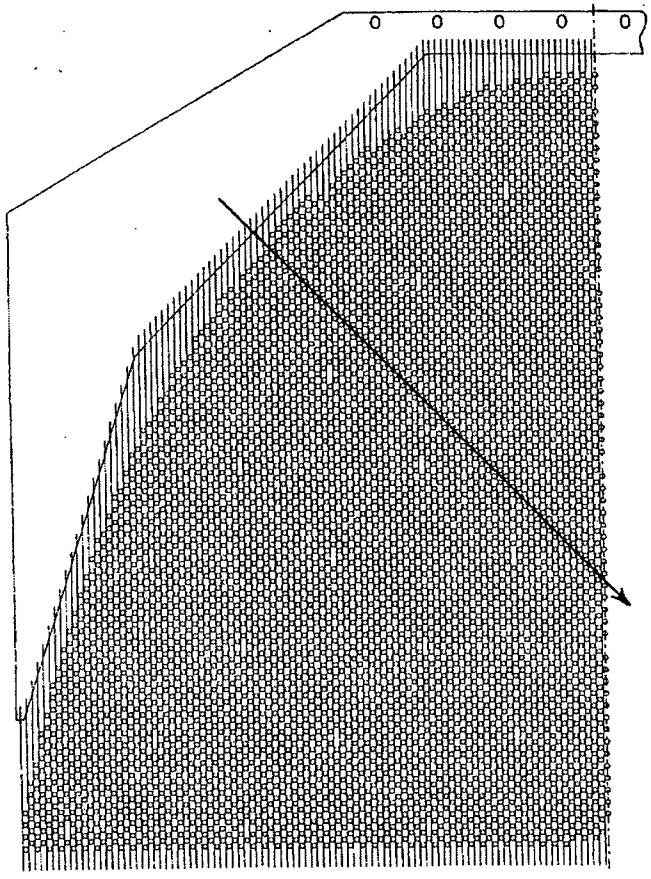


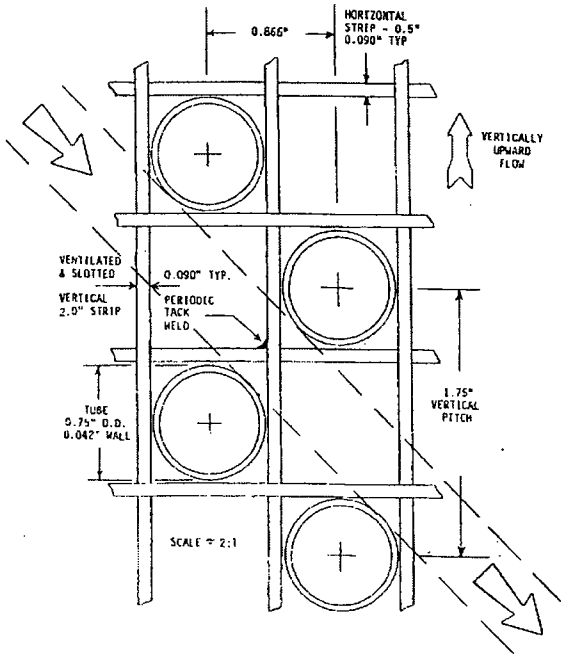
Waterford 3 Steam Generator 32 Batwing Inspection from Lower Handhole




Area to be examined where Batwings enter tube bundle (heavy line)
Batwings
Cutaway of central stay cavity

First of a Kind Diagonal Inspection





UPPER TUBE BUNDLE SLUDGE LANCING
(Flowstream Width = 0.48 in.)

Waterford Project Overview

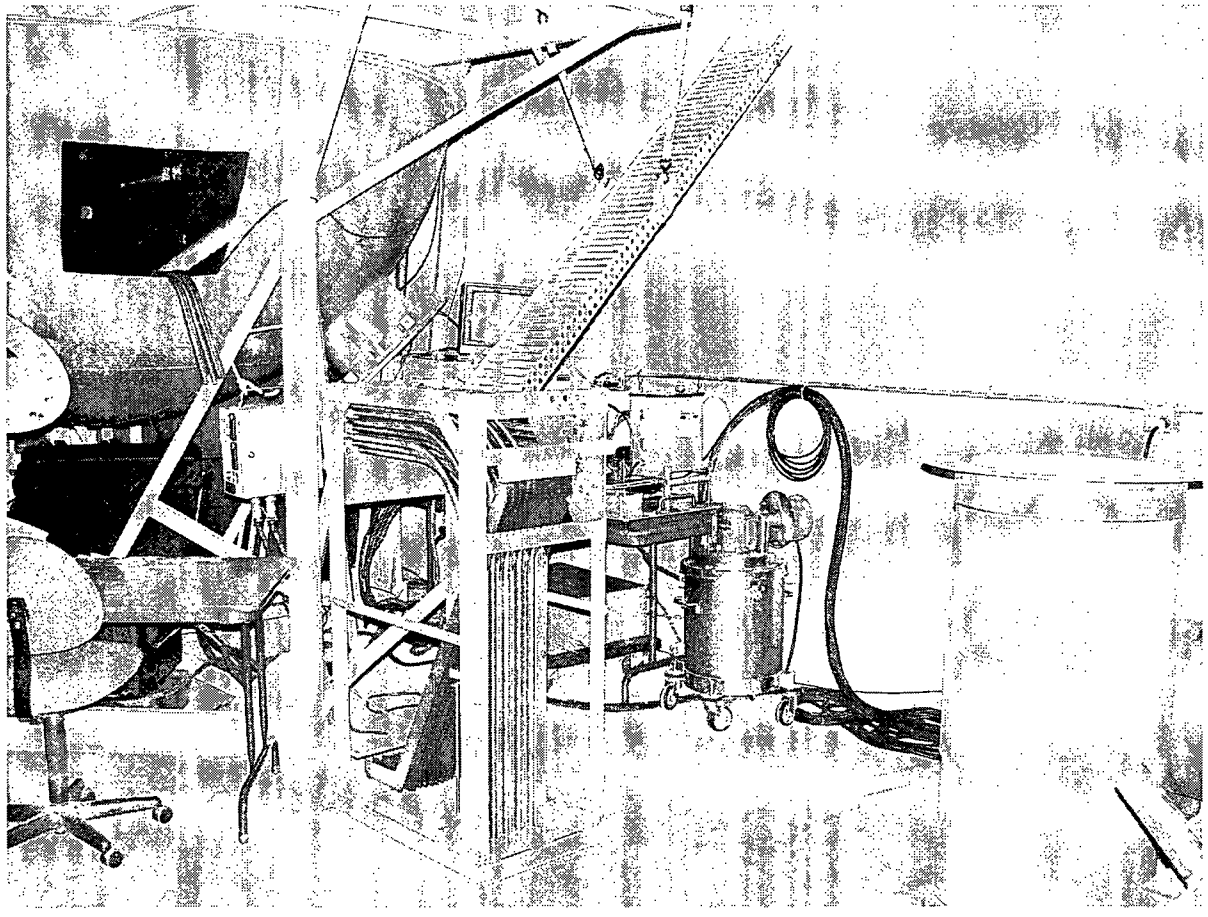
- Diagonal Inspection Development Milestones

Westinghouse Letter LTR-NFSM-07-118 "Diagonal Inspection and Mockup Requirements"	April 07
Brooks Specification FS 55-05 "Diagonal Inspection Specification Requirements"	May 07
Mockup and Tooling Design	June 07
Mockup and Tooling Material Procurement	June 07
Lower and Upper Mockup and Tooling Fabrication	July 07
Video Probe and Tooling Prototype, Dry Mockup Testing	August 07
Video Probe and Tooling Prototype, Wet Mockup Testing	August 07
Video Probe and Tooling Final Design Development	August 07
Video Probe and Tooling Final Manufacturing and Testing	September 07
Video Probe and Tooling Qualification Testing	September 07

- Mockup Tests were witnessed by Westinghouse and Waterford 3 personnel at Brooks

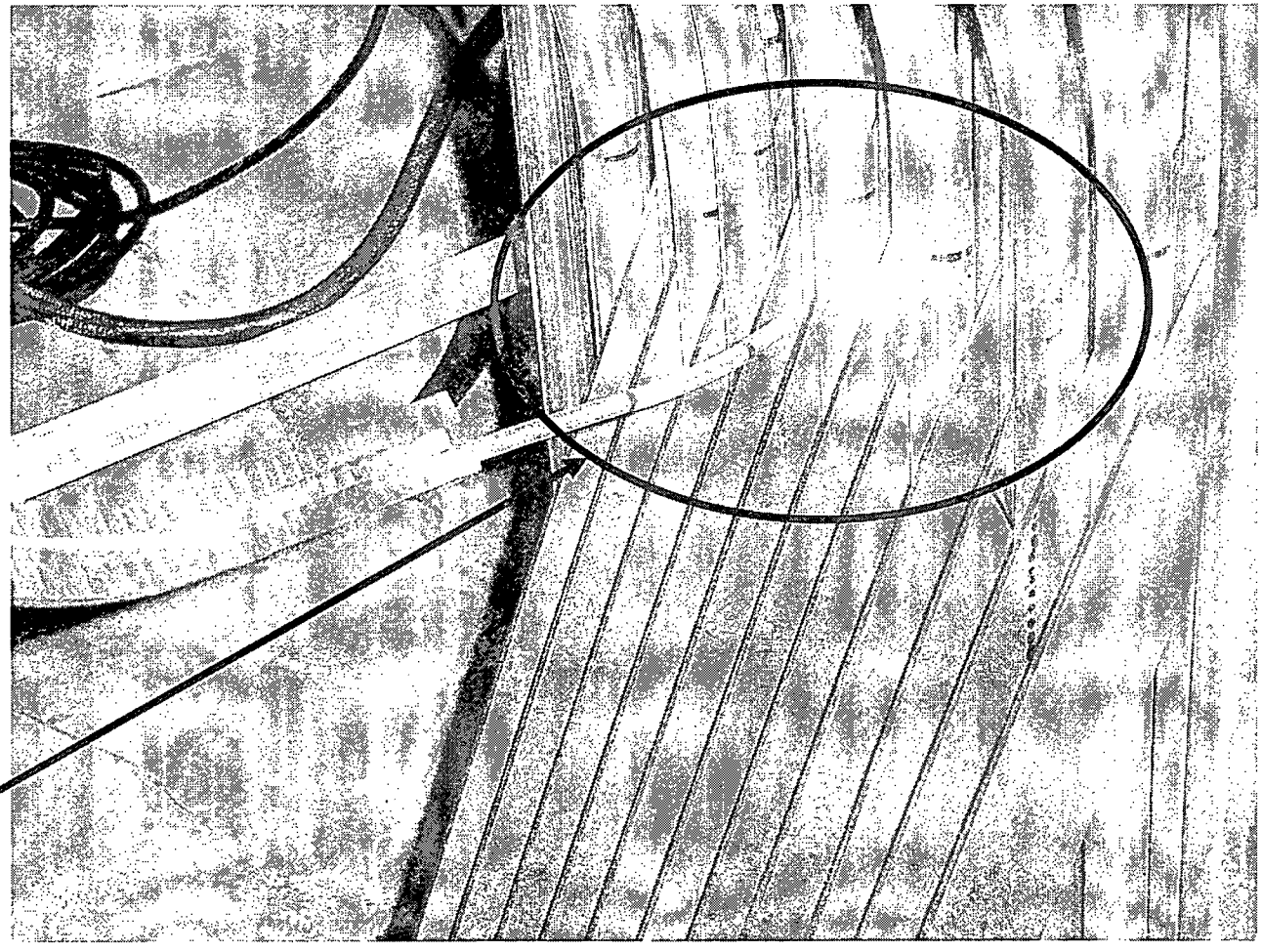
Mock-up of Upper Stay Cavity

- Simulates the upper stay cavity region
- Limited draw back space (21”)



Mock-up of Upper Stay Cavity 45° Inspection

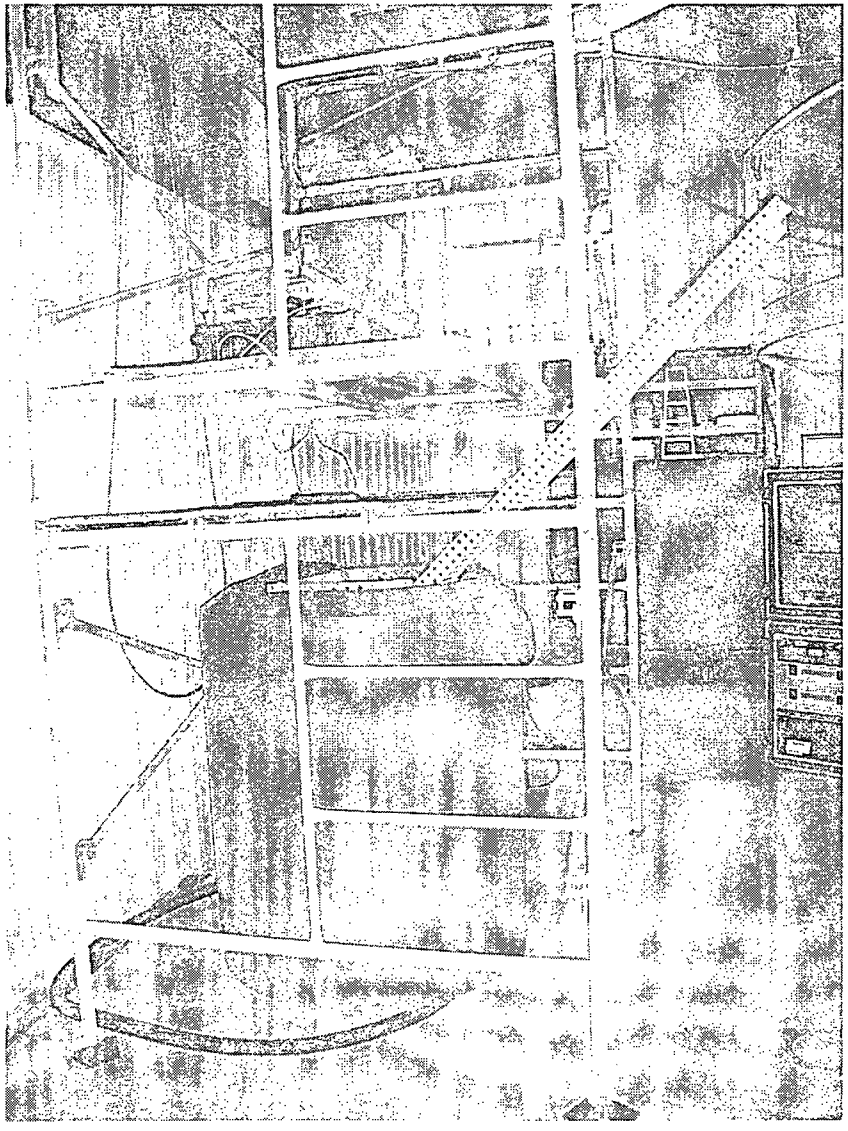
- This is a view of the mockup showing the tube to batwing interface
- Mockup test is underwater in dark environment
- Guide tube is .40" thick in a .48" gap



Area of interest for diagonal inspection

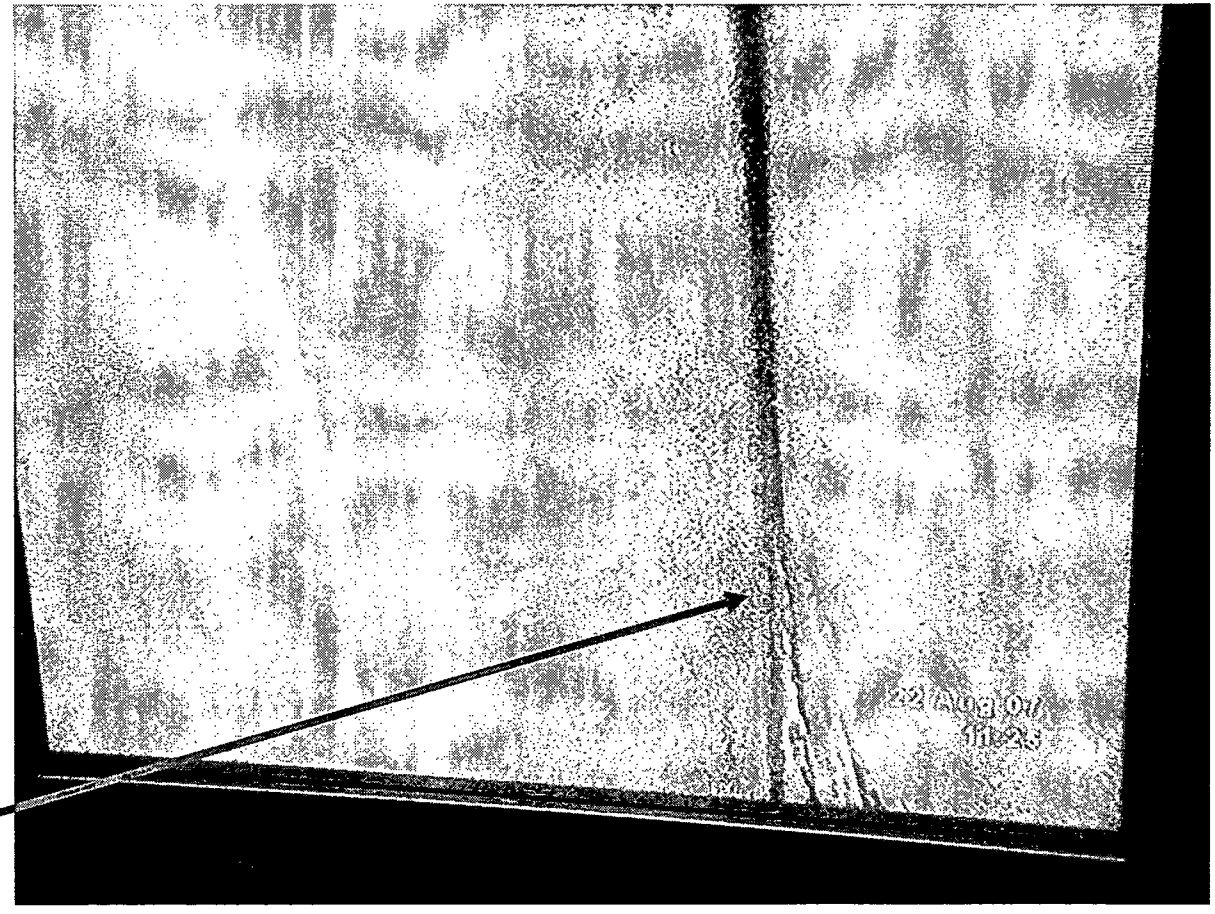
Mock-up of Upper Stay Cavity

- Mock-up is in the tank and includes platform to closely represent correct distance to entry point



Mock-up of Upper Stay Cavity 45° Inspection

- Mockup photo from video probe in wet and dark environment
- 45° inspection mock-up testing was successful
  - Able to see tube to batwing interface
  - Able to see tube and batwing degradation
  - Able to see 1-3 tubes in bundle



Batwing to tube interface

Mid-Cycle Planned Activities Summary

- Secondary inspections (Upper, Lower and FOSAR) will verify that the critical variables used for the repair plan and operational assessment are met
- 45° inspection mock-up testing has been successful and will help establish RF15 repair plan

Mid-Cycle Contingencies and Criteria

Rex Putnam

Contingency Planning

- The potential outcomes of each secondary inspection activity were evaluated
- Appropriate contingencies planning has been taken
- A comprehensive decision flow chart has been prepared
- As found conditions will be evaluated and contingencies implemented as necessary

Decision Matrix Purpose

- Assures a consistent pre-thought decision for credible secondary inspection outcomes for conditions that cannot be accepted
  - Reviews assure consistency with technical analyses
  - Used to establish level of contingency planning and resource allocation
- Assures a thorough communication of specific decisions and criteria
- Facilitates rigorous and timely decision-making during the outage
- Labeled decision blocks and actions have written guidance explaining criteria and intended actions
- Color coded for previously described contingency action

Mid-Cycle Outage Contingencies

- Decision chart contingencies are color coded for ease of use
  - Eddy Current Test
  - Install new 6” Access Port
  - Batwing Weld Repair
  - Batwing Stabilization

Wrap Around Bar Inspection Contingencies (Chart I)

- Weld/clip failures in stay cavity area
  - Indicated by irregular spacing and detached batwings with separation to a weld remnant on the wrap around bar and comparison with as-left video from RF14.
  - If batwing has migrated into the tube bundle, contingency is to bobbin test the open tubes on both sides of the displaced batwing to locate it, then perform Plus Point testing of tubes with identified wear
  - If batwing is retrievable, contingency is to re-weld the batwing to the diagonal bar using same repair plan used in RF14

Wrap Around Bar Inspection Contingencies (Chart I)

- Gross deformation twisting of wrap around bar
  - Indicated by visible twisting deformation of the wrap around bar and multiple nearby adjacent batwing cross-sections with a scuff, gouge or indentation indicating possible shroud impact. Damage would be confirmed by comparison with as-left video from RF14.
  - Contingency is to bobbin test 5 open tubes per column for 5 columns on each side of the damage and Plus point identified wear. Develop and implement repair plan, such as a support attached to the wrap around bar.

Diagonal Tube Bundle Inspection Contingencies (Chart III)

- Gross tube damage is identified
  - Indicated by irregular tube spacing, tube dislocation, through-wall wear greater than one-third of the tube.
  - Contingency is to bobbin test 5 open tubes per column closest to the damage and plus point identified wear. If stabilized tube, evaluate and determine whether needed to deplug and stabilize next tube in column to reinforce fence.

Gross Tube Damage

Gross tube damage that could compromise fence integrity

- Tube spacing
- Force attenuation

Criteria For Gross Tube Damage (Assumes Failed Batwing)			
Location	**Unacceptable**	**Acceptable**	**Comments**
Cavity Peripheral Tube	Tube Severed	BW Penetration Less Than ~1/3 of the way through the tube	Severed Tube is Weakness in Defense Line
Cavity Peripheral Tube	Penetrated By Batwing ~1/3 of the way through the tube	BW Penetration Less Than ~1/3 of the way through the tube	~1/3 of the way through the tube does not result in loss of cable function.
Cavity Peripheral Tube-Double Sided Wear	Total Through Tube section Wear greater than ~1/3 of way through tube diameter	Less Than ~1/3 Through total Tube Wear	This value is the summation of wear on both sides of the tube
Interior Tube From Cavity	Collapsed Or Visibly Distorted Tube	No visible distortion	Collapsed Tube w/o Cable is potentially unacceptable
Interior Tube From Cavity	Visible Thru Wall Tube Wear greater than that found in adjacent peripheral tube	Visible Thru Wall Tube Wear less than that found in adjacent peripheral tube	Unexpected wear condition

Criteria For Gross Batwing Induced Tube Prying Action (Assumes Failed Batwing)			
Location	**Unacceptable**	**Acceptable**	**Comments**
Cavity Peripheral Tubes	Tube Spacing greater than ~1/3 tube diameter between adjacent tube columns viewed along batwing	Tube Spacing less than ~1/3 tube diameter between adjacent tube columns viewed along batwing	1/3 tube diameter criteria is developed from 140 mil fluid force load displacement plus 116 mil original gap. Adjacent batwings must be examined to determine if tube experienced significant prying forces or if the source of the abnormal spacing is due to plastic deformation of a worn adjacent batwing.
Cavity Peripheral Tube	Tube/ Unworn batwing gap greater than ~1.5 times thickness of nominal batwing	Tube/ Unworn batwing gap less than ~1.5 times thickness of nominal batwing	This equates to about 140 mil gap plus 116 mil original gap. Nominal Tube to Batwing Clearance is 0.026 inch (0.013 inch on each side).
Any Location (Except Col 84/85 in SG 32)	Tube To Tube Contact At Vertical Tube Section	See Above	This indicates that large tube displacements are occurring in the SG.
Any In Bundle Location	Distorted batwing observed in innermost portion of tube bundle	Undistorted batwings	This indicates that large tube displacements are occurring in the SG.

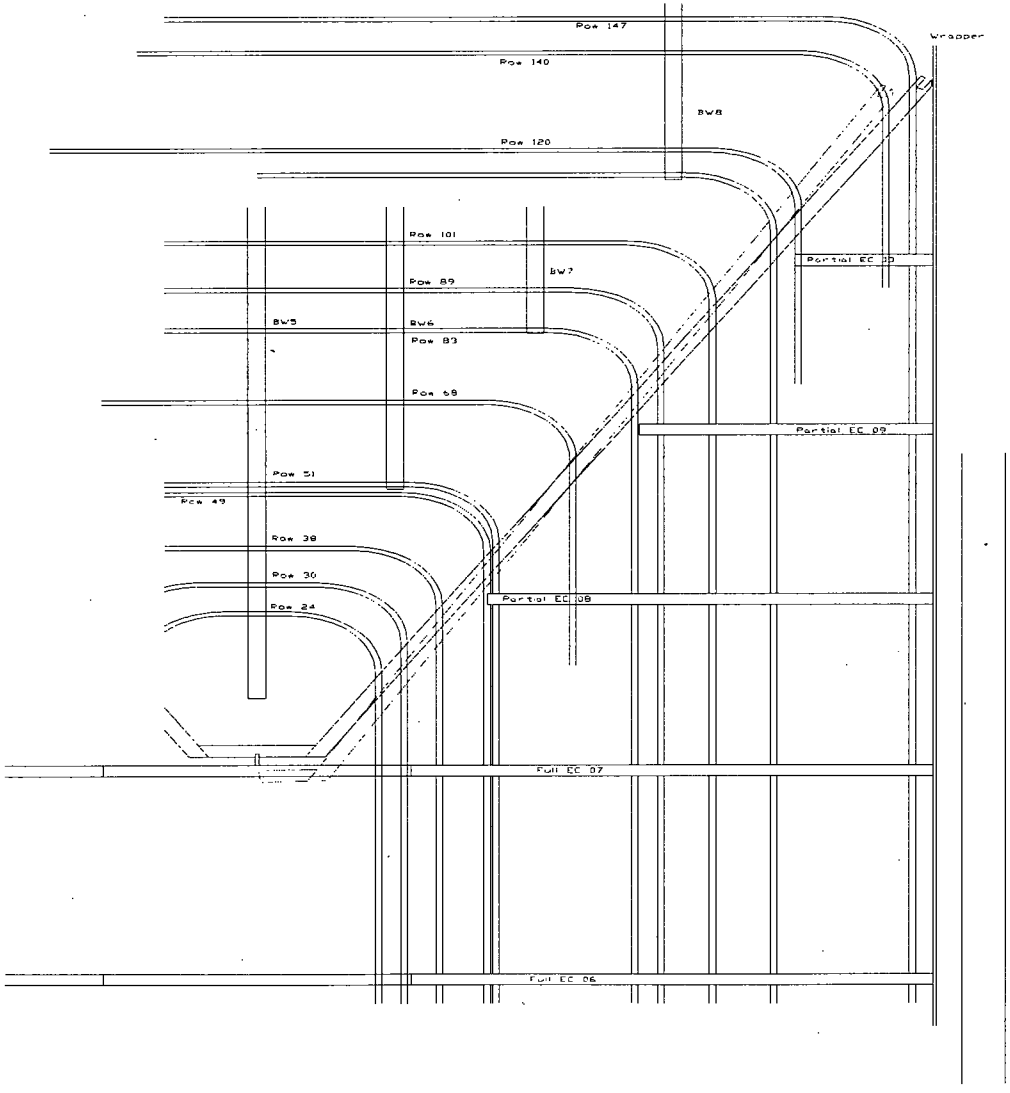
Foreign Object Search and Retrieval Contingencies (Chart IV)

- Large mass foreign objects are present
  - Indicated by visible large loose batwing segment
  - Contingency is to evaluate and if needed remove the part and install a new 6" access port to retrieve using special tooling
- Loose part with new visible wear scar on an active tube
  - Indicated by visual scar on an active tube and comparison with as-left video and eddy current inspection from RF14.
  - Contingency is to remove accessible parts and perform Plus Point test of affected tube and surrounding open tubes to determine depth of wear scar.

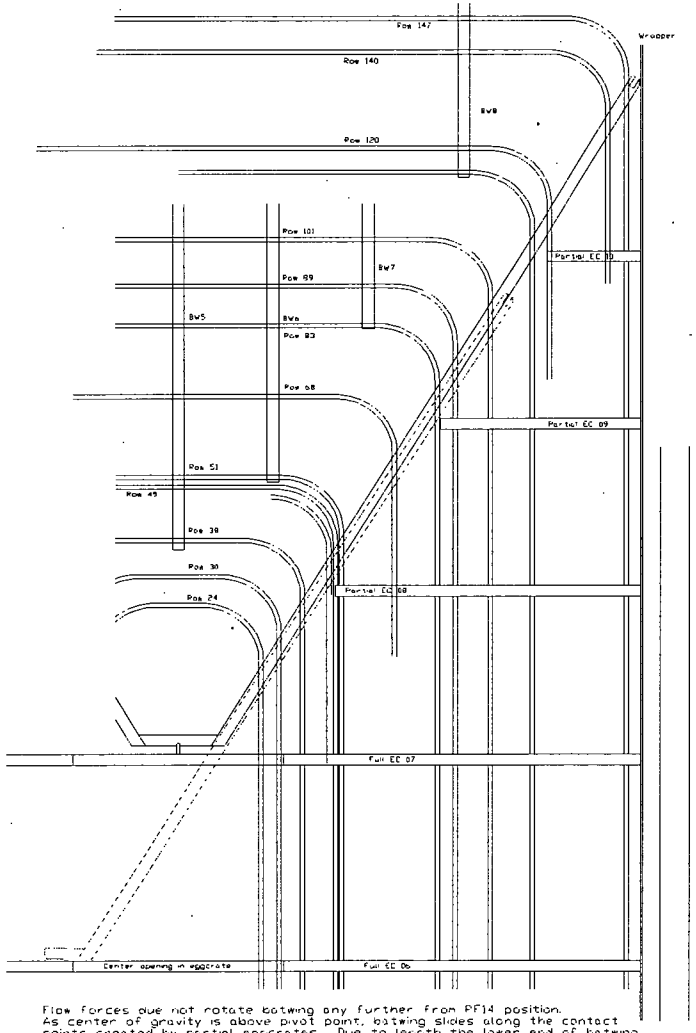
Stay Cavity Inspection Contingencies (Chart II)

- Gross tube deformation is identified
  - Indicated by irregular tube spacing, tube dislocation, through-wall wear greater than one-third of the tube.
  - Contingency is to bobbin test 5 open tubes per column closest to the damage and plus point identified wear. If stabilized tube, evaluate and determine whether needed to deplug and stabilize next tube in column to reinforce fence.
- Batwing at column 84/85 cold leg has dropped
  - Indicated by visual extrusion beyond the 7th eggcrate and comparison with as-left video from RF14.
  - If above the ~6th eggcrate, contingency is to ECT open adjacent tubes to locate the displaced batwing and hydraulically expand selected tubes to capture and restrain the batwing.
  - If below the ~6th eggcrate, contingency is to install a new 6" access port to retrieve using special tooling.

No Batwing Movement
No Action

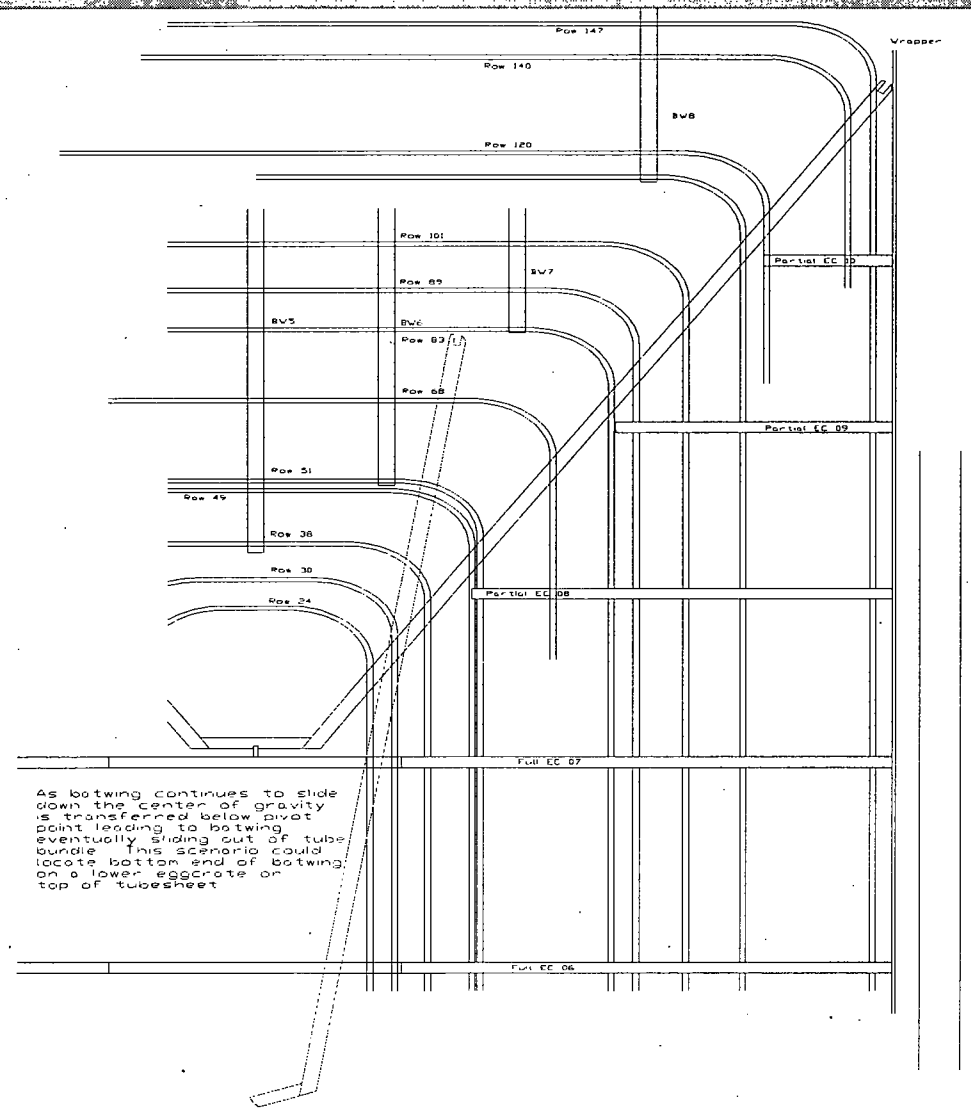


Moderate Batwing Movement
Batwing Stabilization



Flow forces due not rotate batwing any further from PF14 position.
As center of gravity is above pivot point, batwing slides along the contact points created by partial eggcrates. Due to length the lower end of batwing rests atop the 06 eggcrate

Large Batwing Movement
Access Port to Remove Batwing

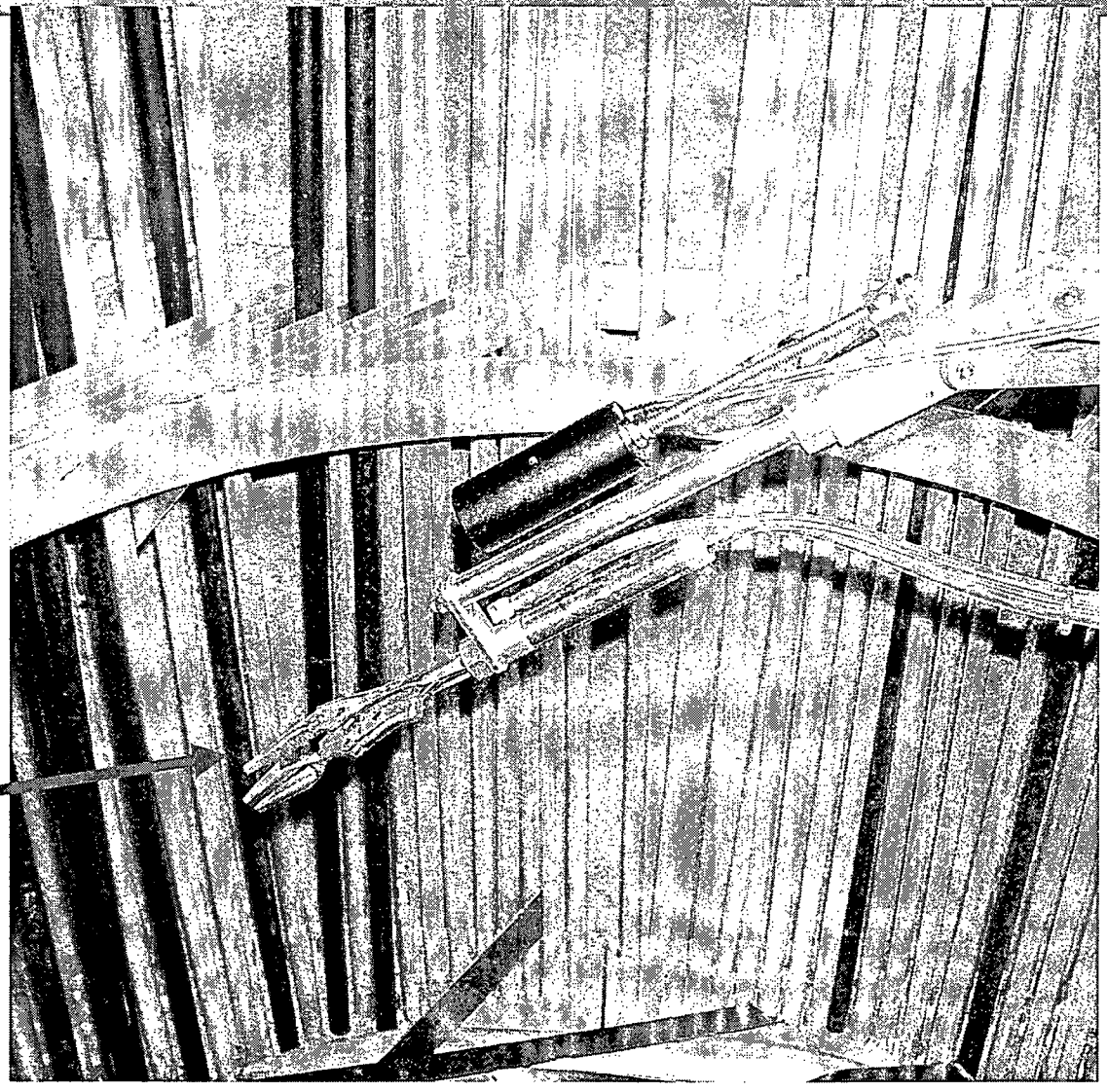


Contingency Tooling Development

- Substantially improved tooling has been developed to facilitate contingency plans
- Batwing cutting tool is different from previously discussed
  - Diamond wire mockup tests were unsuccessful
  - Versatile hydraulic tool developed

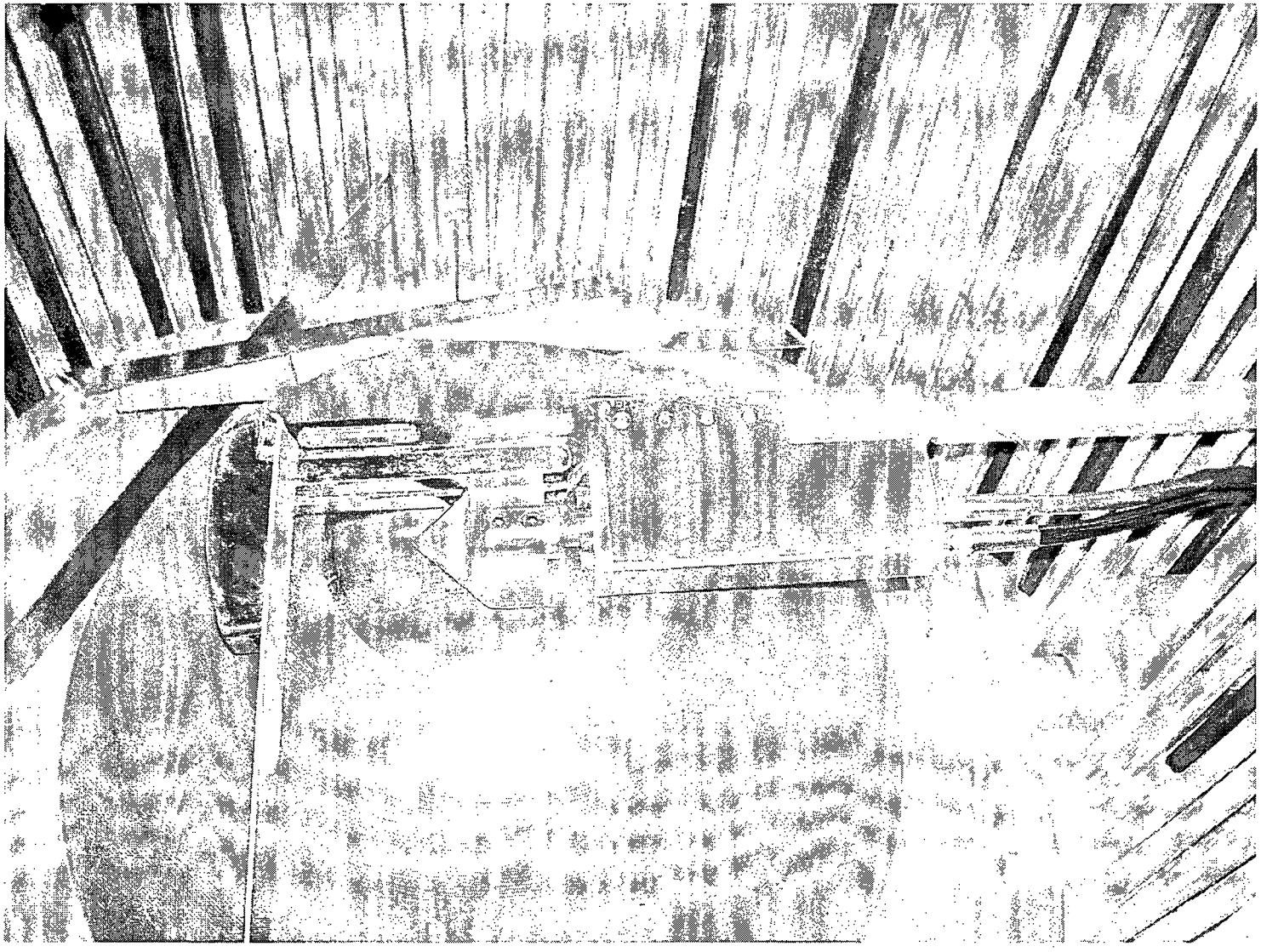
Retrieval/Delivery Tool

- Delivery tool will have ~150° range of motion
- Multiple end effectors can be used with this delivery tool



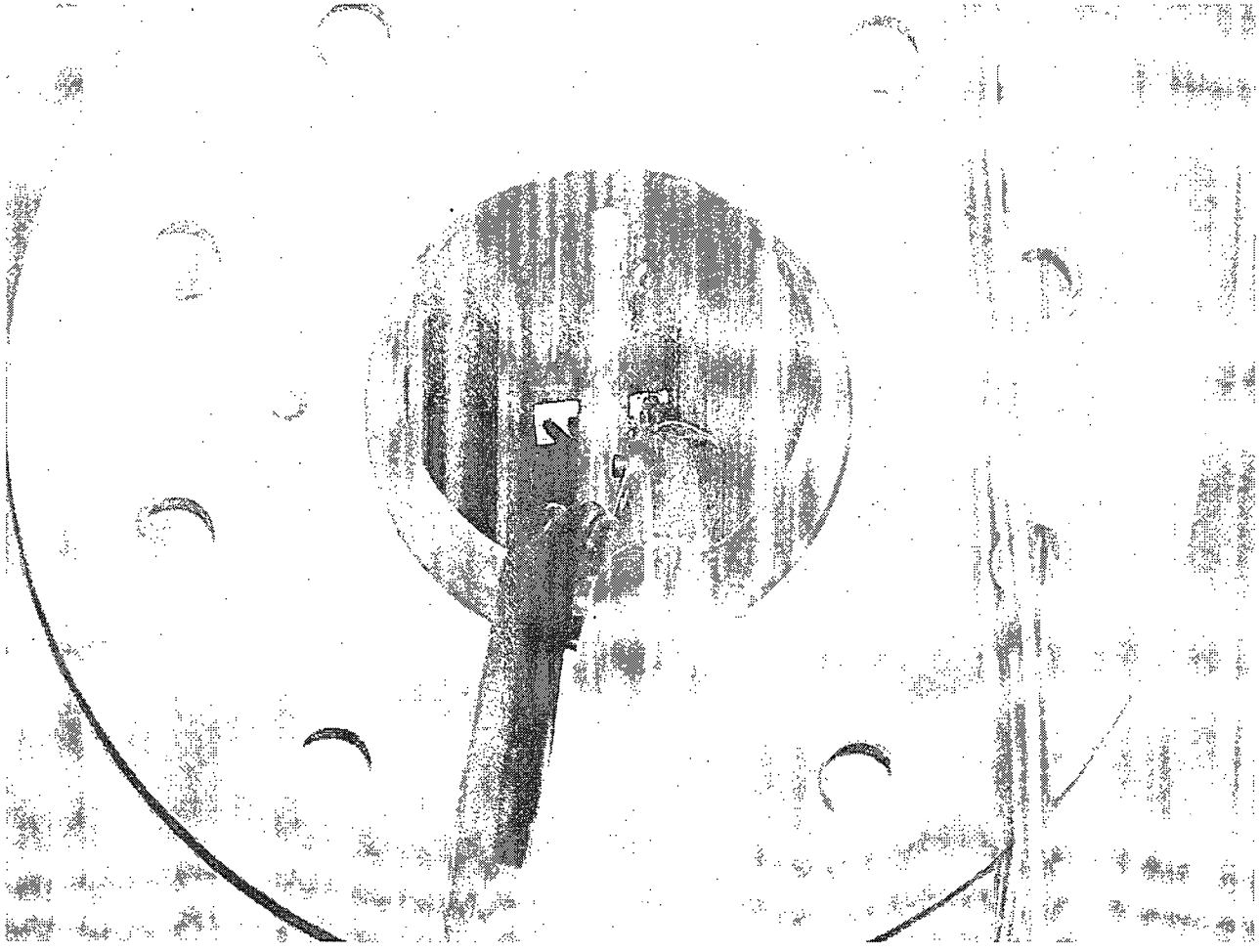
Air Gripper

Batwing Cutting Tool in Stay Cavity Mockup



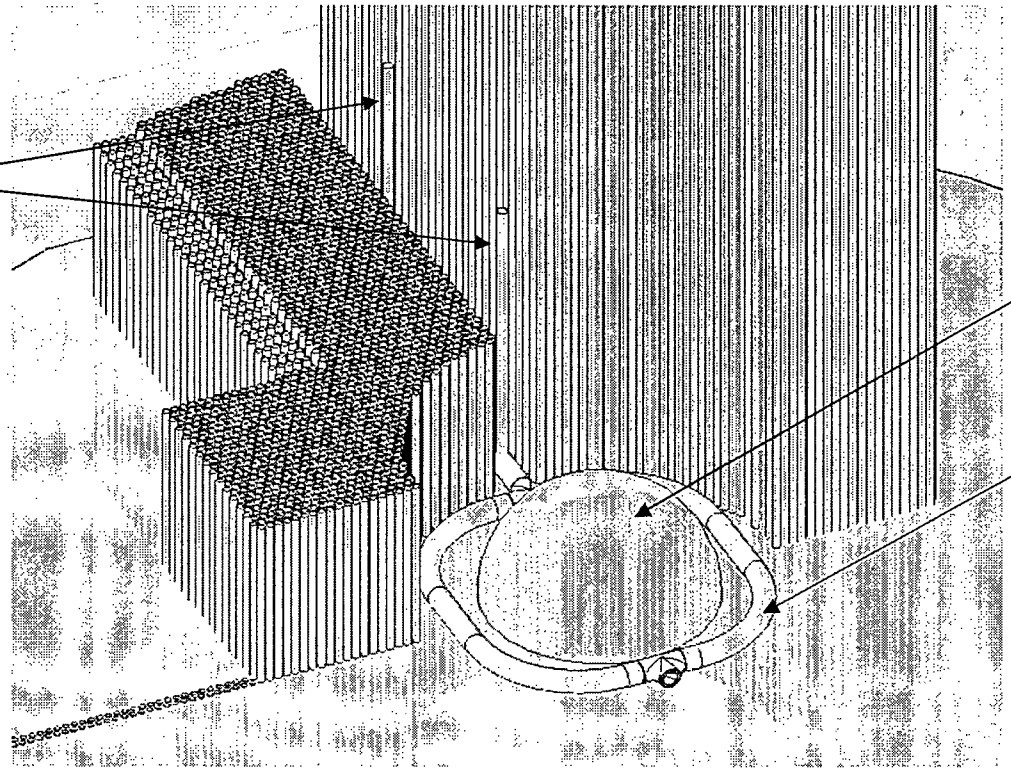
Access Hole Constraints

- This image is of the handhole showing the tubelane with the center tie rods in place
- The center tie rods sleeves are 1.125” and the tubelane is 4.25”, leaving 1.56” on either side



Mock-up Lower Stay Cavity Region

- Model showing the center stay area with stay cap and blow down



Mid-Cycle Contingencies and Criteria Summary

- Secondary inspections (Upper, Lower and FOSAR) will verify that the critical variables used for the repair plan and operational assessment are met
- The potential outcomes of each secondary inspection activity have been evaluated and appropriate contingencies planning has been taken
- A comprehensive decision flow chart has been prepared

Mid-Cycle Communication Plan

Bob Murillo

SG Mid-Cycle Communication Plan

- Licensing Manager will be focal point for communications with NRC
- Pre-established communication plan
  - NRR and Region IV management points of contact
- NRC Resident Inspector will be briefed daily
- Teleconference with NRR/Region IV, as needed
  - Review of inspection results
  - Review of contingency decision making
  - Expansion of inspection scope
  - Finding of unexpected results
- NRC requested photographs or video media will be made available via Licensing Manager

Summary and Q&A

Joe Kowalewski

Conclusions

- Continued focus on safe operation
- Continued conservative approach to evaluation and mitigation of batwing condition utilizing defense in depth strategy
- Continue the operational monitoring, heightened awareness and conservative action limits
- Visual inspections planned for the mid-cycle outage will identify any unforeseen extent of condition or unforeseen change in the critical variables that were the basis for the repair plan and operational assessment
- Appropriate contingency actions are planned with pre-determined decision criteria to facilitate decision making for any unexpected findings.
- Communication strategy is in place for prompt information exchange