McGuire Nuclear Station
Regulatory Conference

Foreign Material Found in the Unit 2 ECCS Sump

NRC Region II Office
Atlanta, Georgia
25 Oct 2007

Agenda

- Introductions
- Opening Remarks
- Debris Testing
- PRA Highlights and Results
- Actions Taken
- Closing Remarks

Introductions - Duke Participants

Gary Peterson	McGuire Site Vice President
Regis Repko	McGuire Station Manager
Jim Kammer	McGuire Safety Assurance Manager
Jeff Nolin	McGuire MCE Engineering Manager
Duncan Brewer	Duke Safety Assessment Manager
Ken Ashe	McGuire Regulatory Compliance Manager
Bryan Meyer	McGuire MCE Senior Engineer
Michael Barrett	Duke PRA Principal Engineer

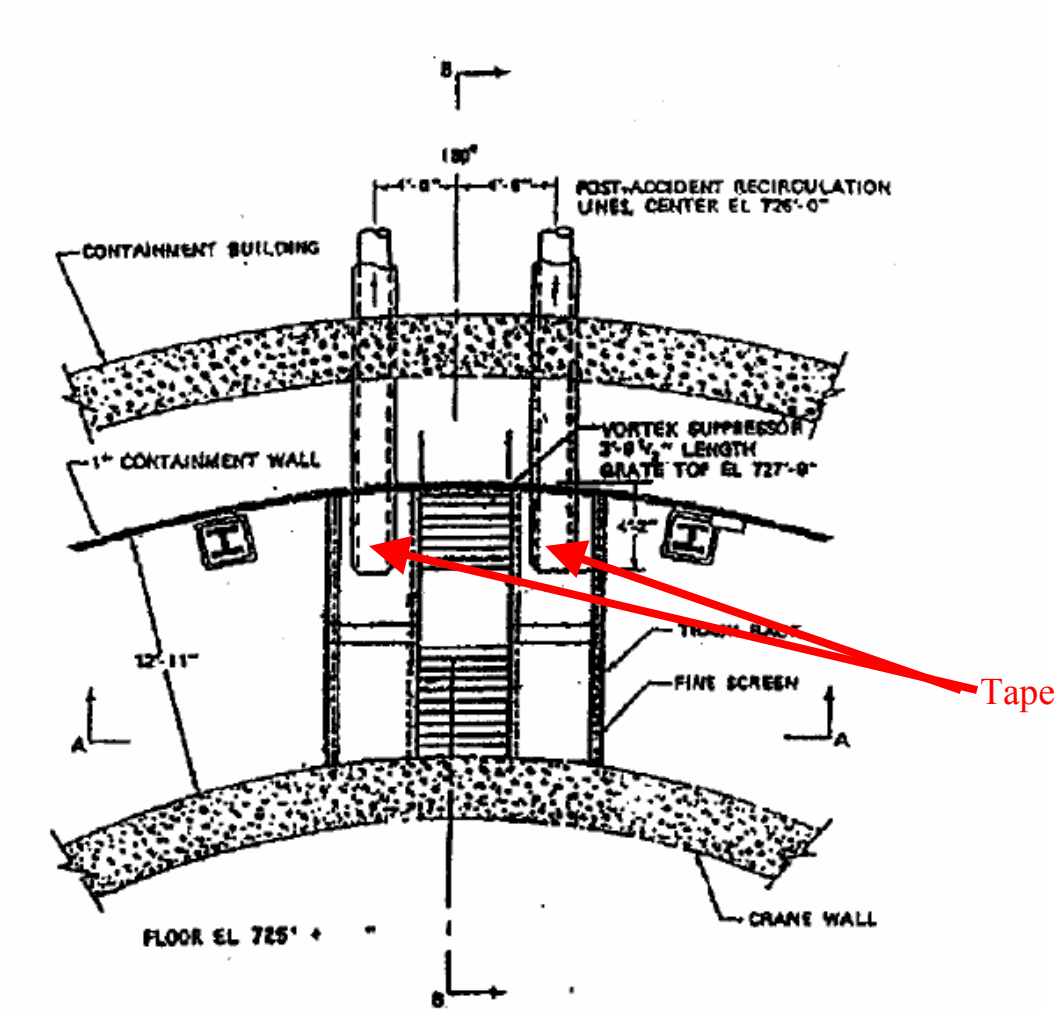
Opening Remarks

- The presence of foreign material in McGuire systems does not meet Duke expectations
- The duct tape could and should have been found in previous routine sump cleanliness and boric acid inspections.
- This issue is not indicative of current McGuire performance
  - Programs have been improved and strengthened
- Duke sponsored testing of the Unit 2 condition internally, and at Alden Labs.

Opening Remarks – cont.

- The following presentations will describe
  - Our testing program and results
  - Our PRA results
  - Our Corrective Actions to ensure that the lessons learned are institutionalized into our programs, procedures and directives

ECCS Sump Original Configuration



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Duct Tape as-found Location

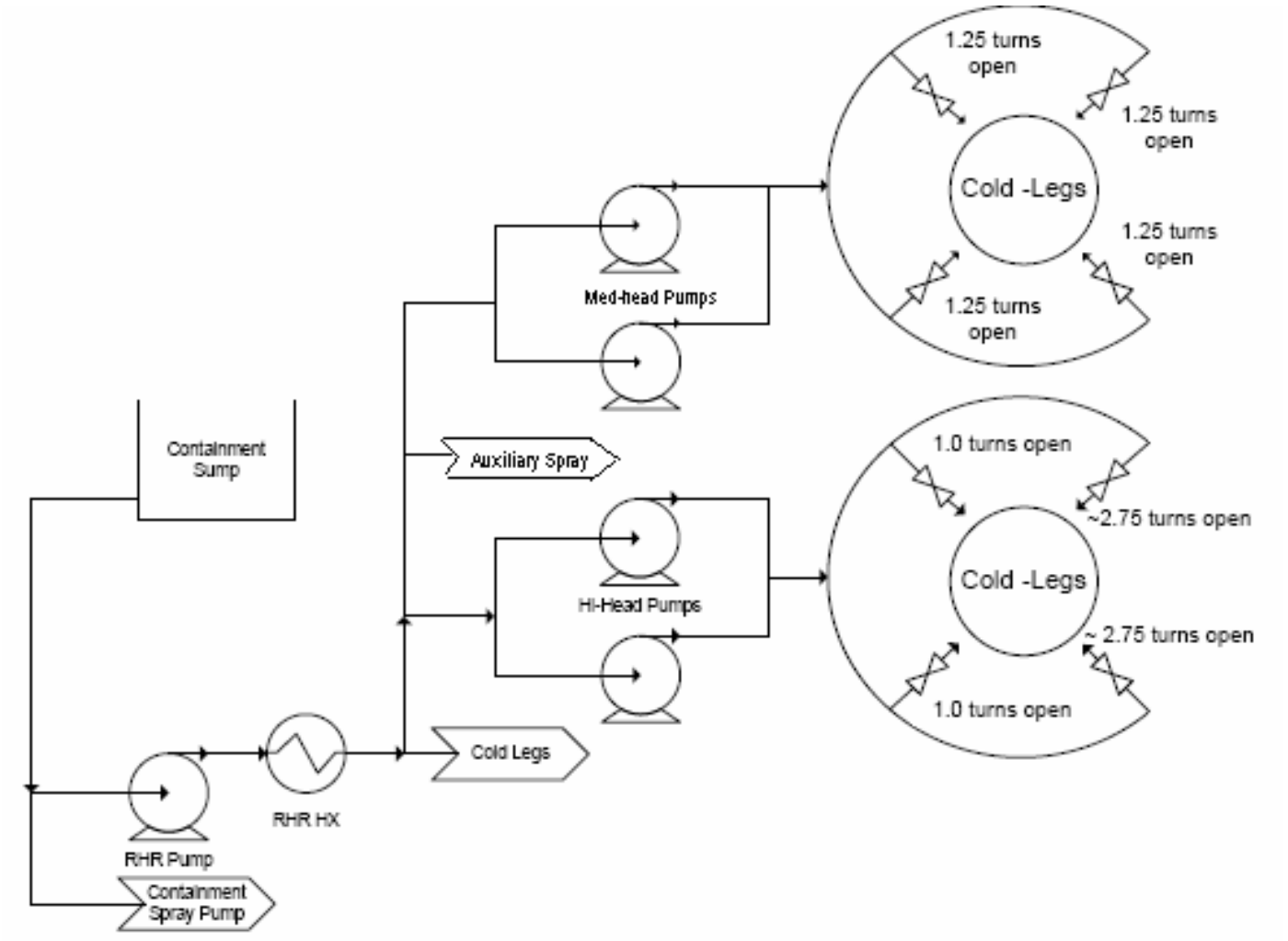
- Tape presence was obscured by a piping support, poor lighting, and was located in relatively inaccessible area. Inspection "tunnel vision," focus was on loose floor debris, boron and corrosion.
- Inspection procedure lacked formal requirement to inspect inaccessible area behind the pipe support.
- A performance deficiency did exist due to the failure to previously identify and remove the duct tape in prior inspections

- Note the photo above is a typical piping configuration, but not typical of the lighting or visibility in the area (pipe diameter 18")

Duct Tape as-found Condition

- Tape was visibly aged in appearance.
- The as-found duct tape was removed from the ECCS pipe.
  - The outer polyethylene coating was brittle and friable. Portions of outer edges exhibited some de-lamination of the outer polyethylene coating.
  - The inner layer and adhesive was tightly adhered to the piping.
  - Solvent and mechanical force was used to remove the adhesive from the piping

ECCS Containment Sump Recirculation Alignment - Simplified Flow Diagram



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Duct Tape Transport in ECCS Piping

Tape release during the expected mission time of Medium/High-head injection is unlikely.

- Low flow rate at screens.
- Tape did not come off easily, particularly the rubber adhesive and webbing under-layer.
- Pipe support blocks path of full tape segments.
- Metallurgical Laboratory testing of new duct-tape (unadulterated and perforated) exhibited no release from piping after a 9 hour soak in high-temperature borated water solution.

Duct Tape Testing

- Even though the tape was not expected to release nor transport into the system, a hydraulic test plan was created to understand the behavior of duct tape transport through the RHR heat-exchanger and Medium/High-Head throttle valves.
- The Duct Tape Testing was conducted by Alden Research Laboratory.
  - Hydraulic test loop built to model physical arrangement of the RHR heat exchanger channel head and tube sheet. The purpose of test was to determine the extent of tube-sheet tape capture.
  - Hydraulic test loop built to determine if tape could significantly block flow through an ECCS throttle valve.

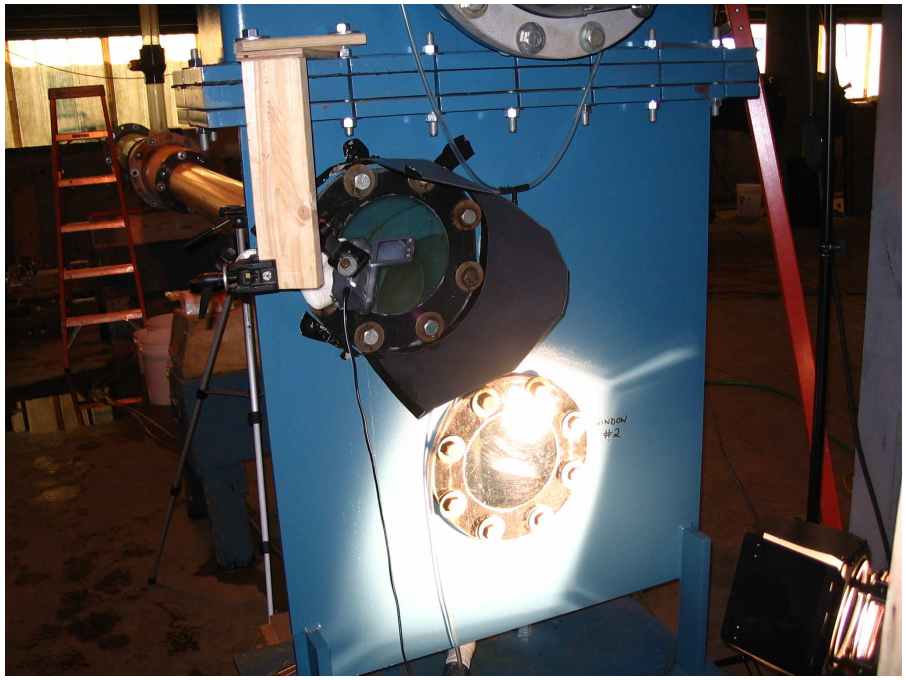
Testing / Analysis Overview

- Impact of debris on nuclear safety is contingent on transport of duct tape to high head injection throttle valves during ECCS sump recirculation mode, and subsequent clogging of the throttle valves.
- The required core cooling flow demand for the sump recirculation phase of an accident is considerably lower than during the initial injection phase (50% of single pump).
- Critical results of the hydraulic testing:
  1) RHR heat-exchanger is very effective for duct-tape capture.
  2) Tape would not have caused a significant flow reduction for 1 turn open valves (<17% flow reduction vs. 50% allowed by analysis).
  3) Tape had no effect for 2.75 turns open valves.

Duct Tape Testing

- Both new and old "aged" tape were tested to characterize their physical properties. New duct tape was conservatively specified for hydraulic testing based on:
  - "Aged" tape adhesive would not readily release from pipe in as-found condition.
  - Only the brittle outer vinyl layer would release from "aged" tape.
  - Strength of new duct tape is greater than aged tape (i.e., more resistant to break/puncture, more apt to cause restriction).
- New duct tape adhesive was treated with talcum powder to simulate condition of released tape.
- New duct tape would not release from pipe after extended submergence test.

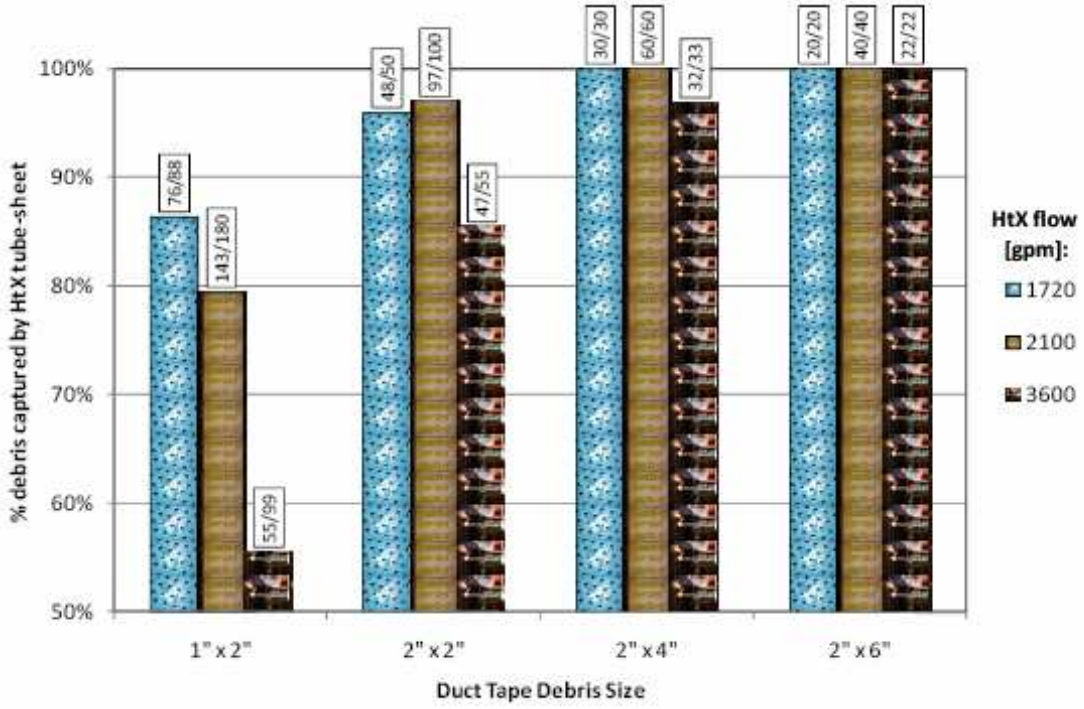
RHR Heat-Exchanger Test Loop Model



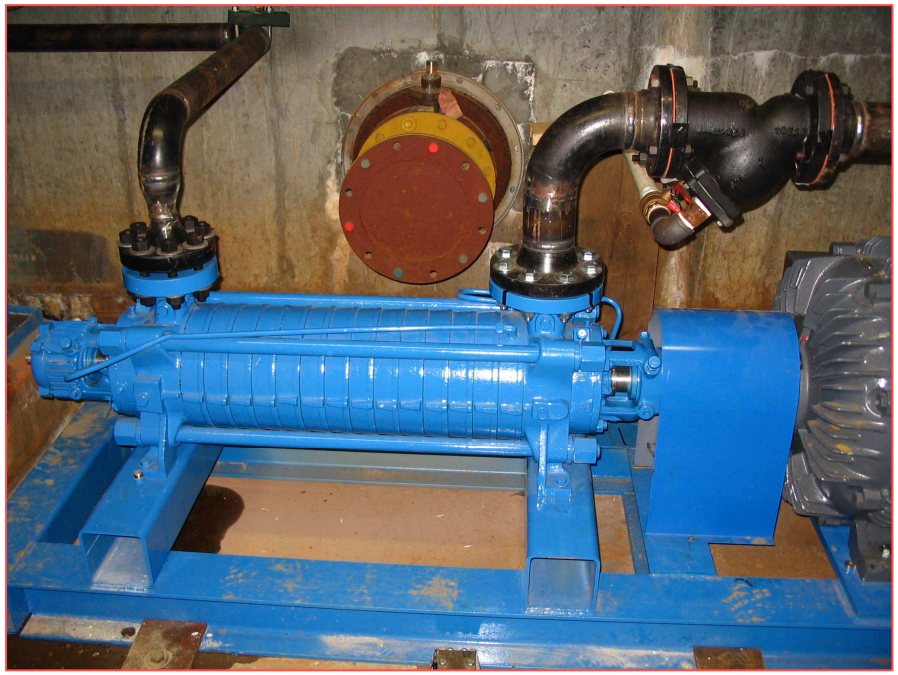
Purpose of test was to demonstrate duct tape transport behavior thru the heat-exchanger, and maximum size which could transport to downstream throttles.

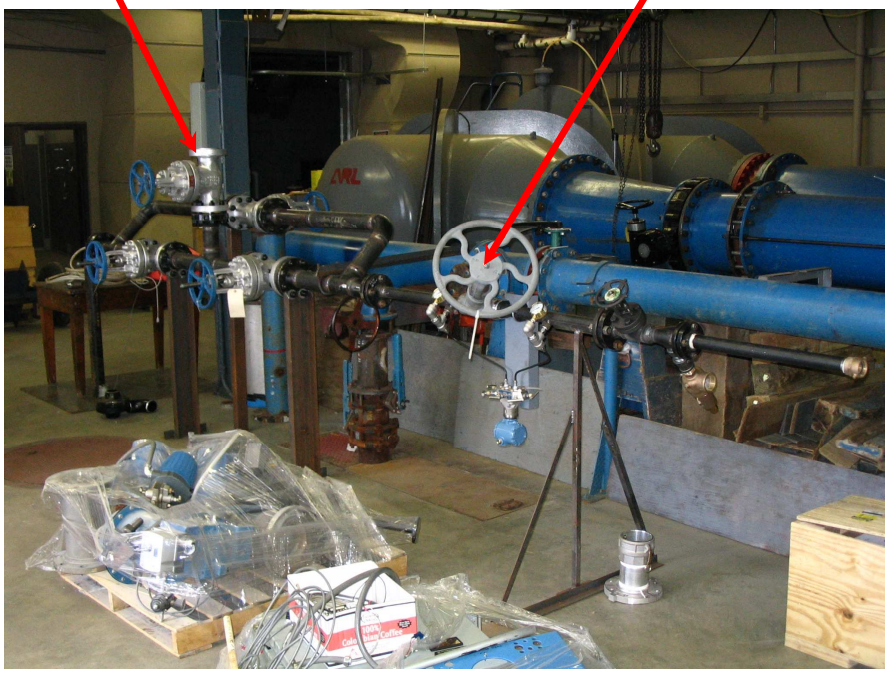
Heat-Exchanger Test Conclusions

- Test demonstrated that the RHR HX tube-sheet captured a significant amount of the duct tape.
- No duct tape greater than 2”x2” passed through heat-exchanger for 1700/2100 gpm flow rates.
- No duct tape greater than 2”x4” passed through.
- Margin exists for HX performance



Throttle Valve Testing





Purpose of test was to demonstrate the effects of duct tape on ECCS throttle valve performance.

Throttle Valve Testing

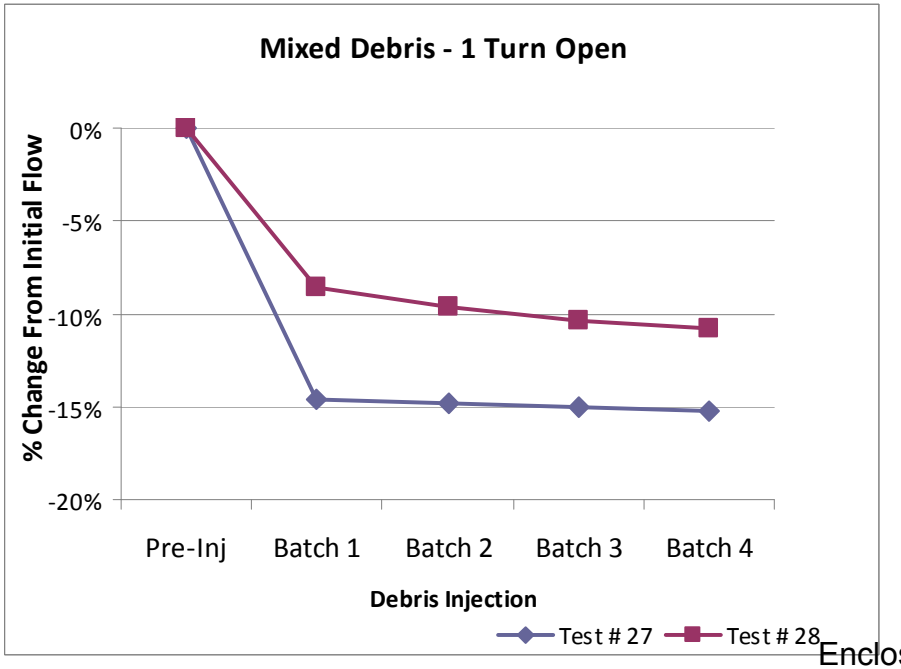
- Overview of Testing Performed:
  - Tests largely performed at minimum expected loop flow and throttle valve differential pressure representative for small break LOCAs.
  - 27 tests were run, with varying sequence of duct tape addition.
    - Tape sizes (1/2” x 1/2” up to 2” x 6”).
    - Tests performed with varying number of duct-tape specimens, up to 230 pieces in a single test.
  - 10 tests included a very large quantity of duct tape ~110” linear inches thru a single throttle valve (conservatively simulates transport of all tape, distributed equally to each of the 8 throttle valves).
  - Over 3000 pieces of various sized duct-tape readily passed through the test valve.

Test Conditions – fiber/ particulate

- Representative sump water conditions (fiber/ particulate) were simulated for two tests to assess the cumulative effect with tape.
- No significant differences in test results with mixed debris.
- Results are consistent with prior NRC sponsored testing with Nukon debris with similar (0.1”) valve clearances – no significant effects.
- Note that the two dominant PRA events are “Stuck Open Relief Valve” and “Feed & Bleed” events, which do not generate fiber/ particulate (90% of CDF contribution).
- For “other LOCAs”, the break size is small, Zone of Influence (ZOI) is very small, transport is low, and debris at sump would be negligible.

Throttle Valve Test Observations

- ECCS Throttle valve performance not significantly affected by small tape fragments in the size range and quantity that could pass through the RHR heat exchanger.
- NO flow reduction for 2.75 turn open position (2 high head valves)
- <17% flow reduction for 1 turn open position (vs. the 50% allowed by analysis)
- The flow reduction that was observed for 1 turn open position, did not continue to appreciably increase as more tape was added.



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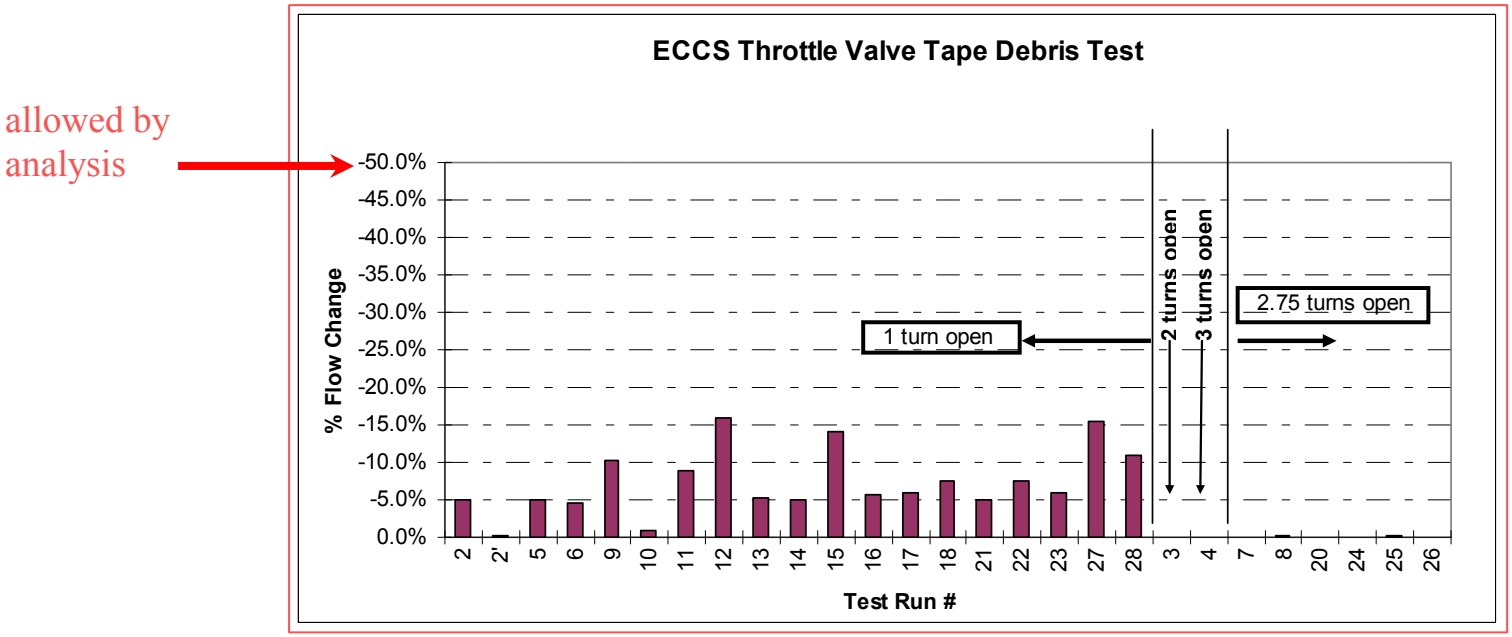
Throttle Valve Testing- Results

- Maximum throttle valve flow reduction < 17% for 1 turn open position. No reduction for 2 further open high head valves.
- Analysis indicates that with only 50% of a single pump available there is sufficient flow to prevent core damage during the ECCS recirculation phase.



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Debris Test Program Conservatisms

- A number of factors provide defense-in-depth beyond what was considered in the hydraulic testing:
  - Testing performed with new duct tape, higher mechanical properties. Only the brittle outer layer of the aged duct tape is likely to have come loose. The adhesive and webbing was difficult to remove on the aged tape.
  - Low flow rates at the ECCS sump screens- little motive force to remove tape from pipe.
  - Tape transport from the sump would have been impeded by the pipe support.
  - Containment spray flow is considerably higher than ECCS injection flow (80-90% of sump flow will go to containment spray), and the branching favors transport of the duct tape to the containment spray system.

Duct Tape Test Program Conclusions

- RHR Heat-exchanger Test Results:
  - Only smaller tape fragments passed the RHR heat exchanger. The heat exchanger prevented transport of a significantly high percentage of the larger pieces of tape without challenging heat-exchanger function.
- ECCS Throttle Valve Test Results:
  - ECCS throttle valves performance is not significantly affected by small tape fragments in the size range and quantity that could pass through the RHR heat exchanger. Flow reductions observed for the 1 turn position were substantially below the analysis limits.
  - The limited flow reduction that was observed for 1 turn open position, did not continue to increase appreciably as more tape was added.
  - Two high head safety injection throttle valves are open 2.75 turns and no flow degradation was observed for this condition. Flow through only 2 valves is required by analysis.
  - The small flow reductions observed during the tape testing would not result in core damage.

PRA Overview

- Duke and NRC results are consistent with respect to the events of concern:
  - Stuck open pressurizer relief valve event is most important
  - Transients requiring feed and bleed also contribute
  - LOCAs are least important (1” – 3” dia)
- 2 Primary differences
  - MSLB initiator: SPAR model does not reflect MNS design and operation; correction would reduce importance and leave stuck open pressurizer safety as dominant sequence – same as Duke
  - Duke evaluated probability of loss of flow based on
    - Test results
    - Potential for release and transport

Loss of HPR Flow

- Deterministic considerations support that a significant flow reduction is not credible
  - Tape is unlikely to release from the pipe
  - Most tape would flow to containment spray pumps if transported
  - Larger tape pieces would be captured in the RHR heat exchanger.
  - Testing shows that tape has little impact on flow

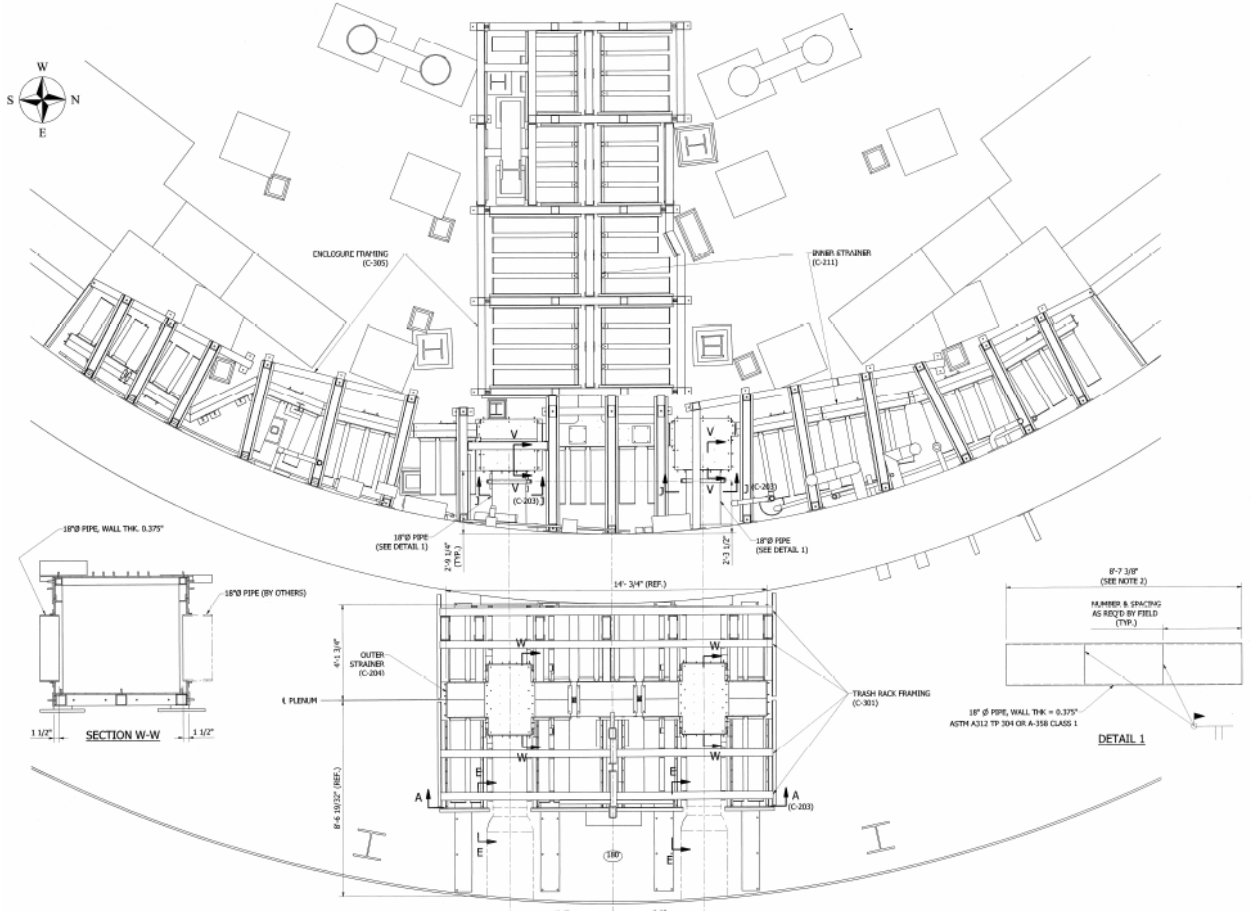
Loss of HPR Flow

- Evaluating the % reduction in flow as a continuous random variable supports the conclusion that the probability that the flow loss exceeds 50% is essentially zero
- Probability of loss of flow based on testing
  - Probability distribution based on 0 failures in 27 tests produces a mean of 0.018 for failure of a single valve exposed to tape
  - Multiple valves must experience significant flow reduction to challenge core cooling, assumed 0.0018
  - This straightforward technique does not recognize the significant margin to failure observed in the test data

PRA Conclusions

- Factors important to CDF Estimate
  - Release of tape from the pipe
  - Transport of the tape from the sump to the ECCS pumps
  - clogging of multiple throttle valves
- The increase in CDF is estimated to be approximately 2E-08/year
- Result is essentially 0 when margin to loss of flow is considered

Actions Taken



Modified ECCS Sump Arrangement

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Modified ECCS Sump Arrangement

- McGuire implemented a rigorous foreign material exclusion (FME) process for installation of the new ECCS Sump.
- The strainer received thorough inspections to ensure no debris was internally introduced during fabrication and assembly.
- Video inspections performed inside the previously existing sump piping to ensure no foreign material was present.
- The replacement ECCS sump strainer is a self-contained “closed system,” which provides protection against exterior foreign material intrusion.

Standards

- Inspection Procedures
- FME Program
- Boric Acid Corrosion Program
- Design Control/ 10CFR50.59

Closing Remarks

- The testing program has shown that adequate core cooling would have been available, and this issue is of very low safety significance.
- The increase in CDF is estimated to be approximately 2E-08/year
- Duke clearly recognizes the vital safety function performed by the ECCS.
- The conditions resulting in this finding do not meet Duke expectations
  - Improvements have been made and will continue to be made with FME processes and procedures.
  - Sump strainer design changes have addressed the throttle valve clearance non-conformance.