EPRI HEAF with Aluminum - US Industry Survey

Analysis and Insights

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Background and Scope
EPRI Survey of US Industry related to HEAF with Aluminum

Why did EPRI conduct the survey?

- In 2019 EPRI conducted an industry wide survey to inform the discussion related to the Pre-Gi with as much information as currently available
  - Supplement the 2017 voluntary NEI survey to better understand where Aluminum exists in US NPPs
  - Assess if the complete data on Aluminum in HEAF susceptible equipment could inform what portion of the US fleet might/might not have concerns related to the pre-GI on this issue
  - If NRC moves forward with more testing, inform NRC-RES test plans based on validated information representing where/how Aluminum exists in HEAF susceptible equipment
  - Perform a bounding assessment using the current Fire PRA data and newly developed concepts in the HEAF PRA methodology

Large increase in CDF would require the following to exist together:

Aluminum + Long duration source to feed the HEAF +
Poor/Failed breaker protection + Risk-significant targets in ZOI

Purpose of the EPRI Survey and Analysis

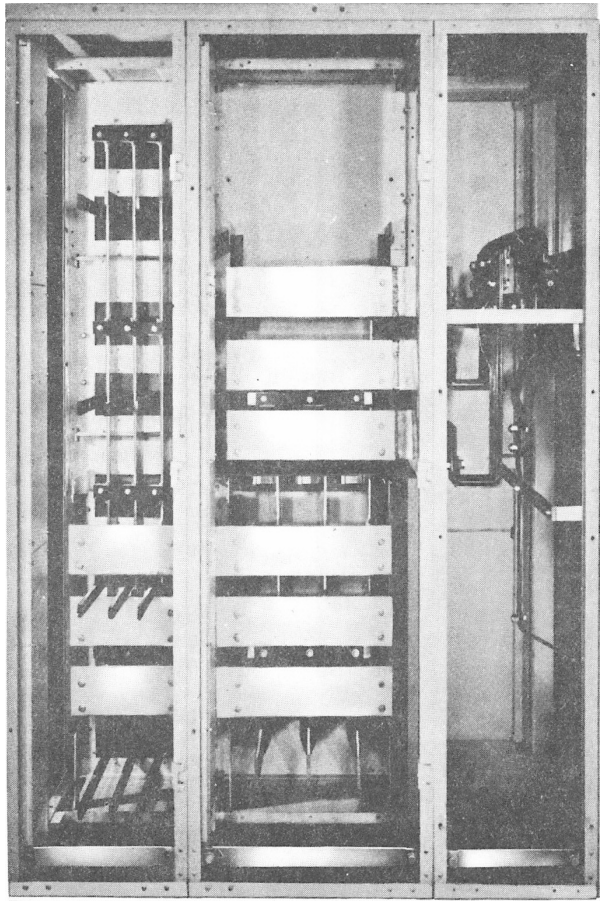
- Determine the scope of plants that may have a HEAF Al impact while the NRC continues to evaluate its pre-GI on the topic
  - Initial survey conducted in 2016-2017 suggested only few plants had Al
- Inform HEAF and Fragility test plans being led NRC-RES with Sandia National Lab
  - Ensure testing configuration, equipment and plant conditions are prototypical
- Inform the development of the more realistic HEAF PRA methodology being led by EPRI
  - Provide more realistic guidance to model HEAFs than the current one-size-fits-all approach
- Provide a conservative and bounding estimation that informs which units may require more site-specific analysis
  - EPRI analysis provides an intentionally conservative estimate of the potential to see an increase in risk based on a larger ZOI for HEAF involving Aluminum, based on bounding and conservative Fire PRA data inputs provided in response to the survey




Location of Aluminum in the Plants:
Survey Results and Insights

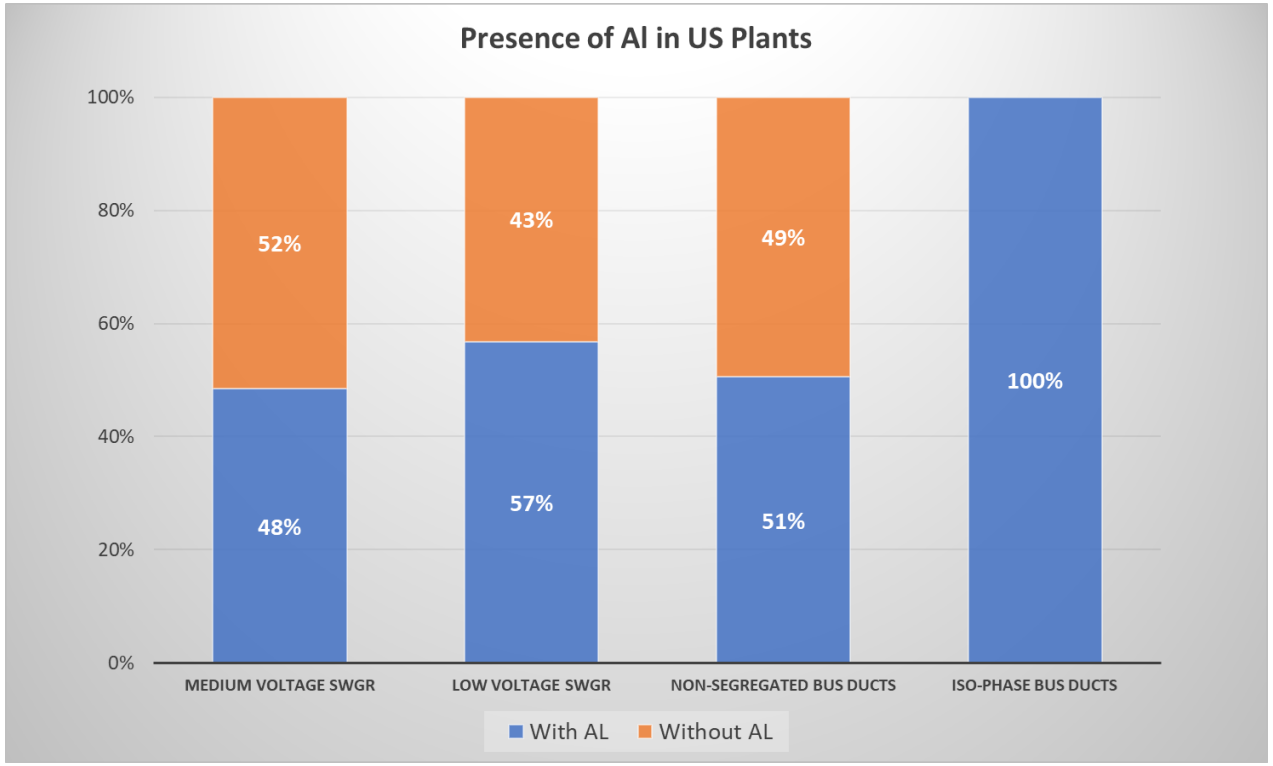
HEAF Survey Data Collected for each Plant

- Aluminum usage in the electrical equipment susceptible to HEAFs
  - Iso-phase bus ducts
  - Non-segregated bus ducts
  - Medium voltage (MV) switchgear (SWGR)
  - Low voltage (LV) switchgear (load centers)
- Electrical design
  - Backup protection fault clearing time
- Fire PRA data
  - Existing HEAF scenario information
    - HEAF Conditional Core Damage Probability (CCDP)
    - Full Room Burn CCDP (worst case scenario)



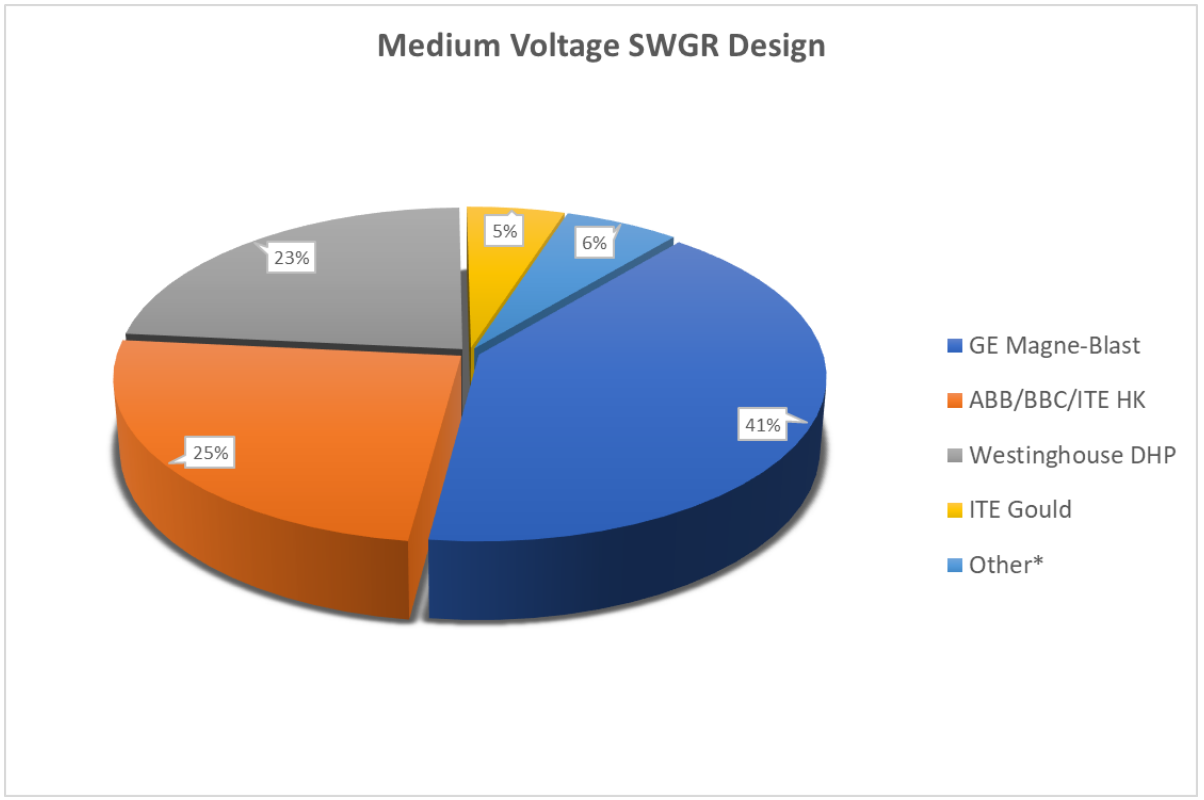
Summary of the HEAF Survey Responses

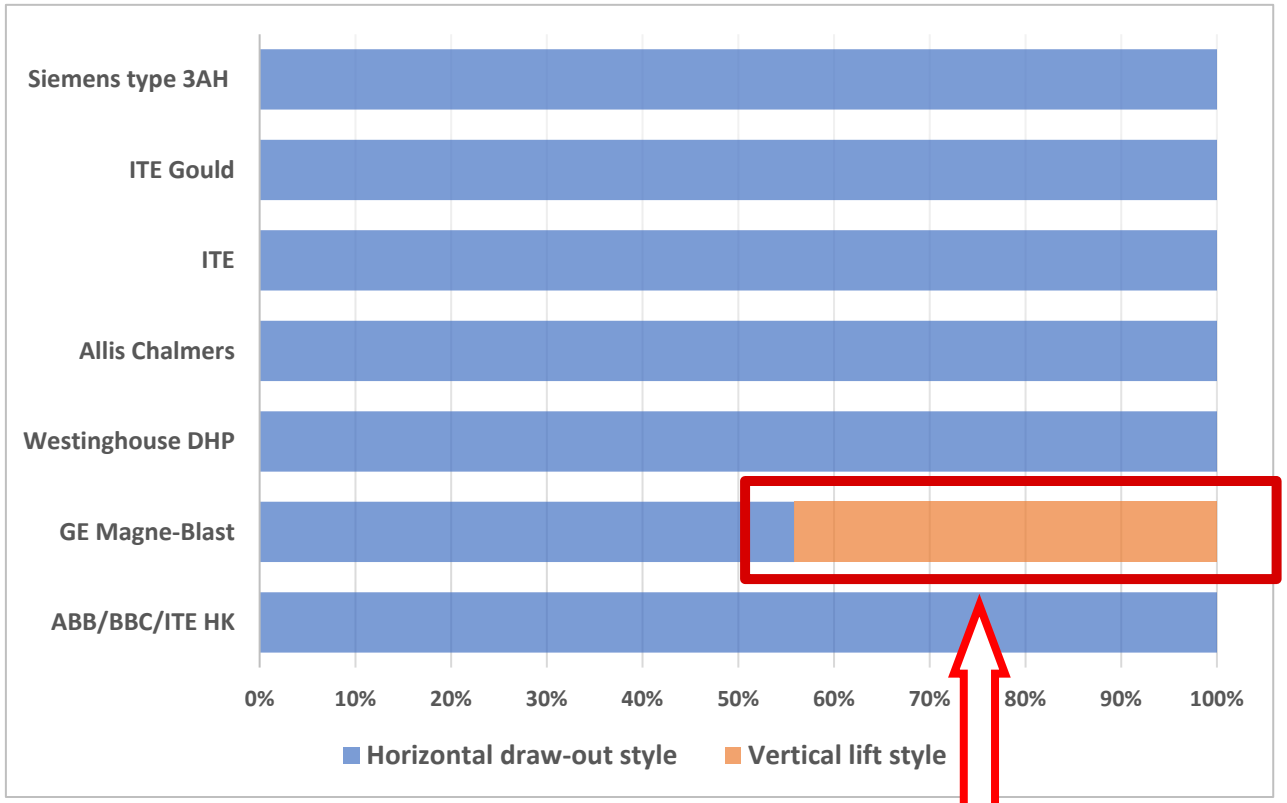
- Current progress and initial insights
  - Responses received from 100% of plants.
  - 80% of plants provided Fire PRA data
  - 20% do not have Fire PRAs sufficient to provide data



Percentage of Al is higher than initial voluntary response.
Presence of Al is not directly related to increased risk.

Insights for Medium Voltage (MV) Switchgear (SWGR) with Aluminum





- Phase II testing has only tested GE Magne-Blast vertical lift configuration
- However, >80% of the MV SWGR with Aluminum in the plants are horizontal draw-out style
- Note: Phase I testing performed one test with horizontal draw-out style Westinghouse DHP breaker, however the enclosure was an ES style (not identified in the in the US industry survey)

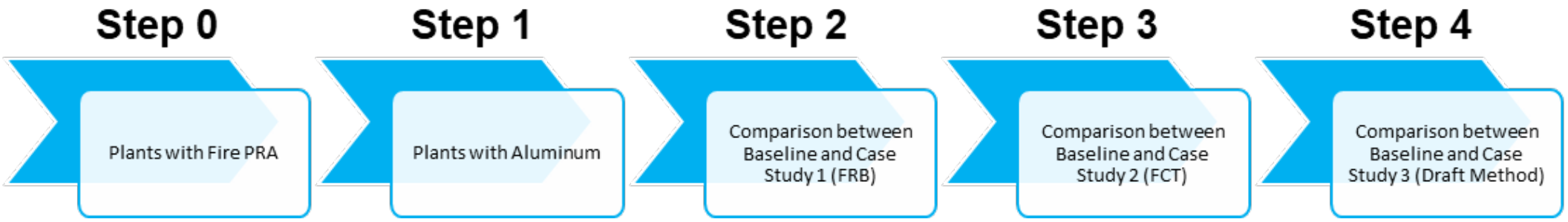
MV SWGR testing on vertical lift style switchgear is not representative of the majority of plant configurations

Summary of the Insights based on Survey Results

- US Fleet
  - Aluminum exists and has existed across the US fleet in MV SWGR, LV SWGR, iso-phase and non-segregated bus ducts.
  - Majority of plants have Al in multiple types of SSCs
  - Issue not based on any observation in US OE suggesting substantially larger ZOIs for HEAFs involving Aluminum
- MV SWGR
  - Horizontal draw-out style representing more than 80% of MV SWGR with Aluminum in the plants
  - Most faults initiate at the breaker stabs which are made of copper
  - >85% of bus work (where Al exists) is insulated
  - For many MV SWGR buses fed from SATs, transformer backup protection would clear a fault very quickly, thus current ZOI is expected to be bounding
- LV SWGR
  - OE and testing both demonstrate that it is very difficult to achieve and maintain an arc in the main bus bars of LV SWGR
  - OE suggests that arcs in LV SWGR have all initiated at the breaker stabs which are copper. Plants do not have Aluminum at the LV SWGR breaker stabs
  - Sustaining an arc in LV SWGR long enough to propagate to Al location (beyond melting) may be even more challenging. The current ZOI is expected to be bounding.
- Iso-phase bus ducts
  - 100% of iso-phase bus ducts are Al
  - Current ZOI for iso-phase bus ducts (5ft radial sphere) in NUREG/CR-6850, Supplement 1, FAQ 07-0035 already includes Aluminum

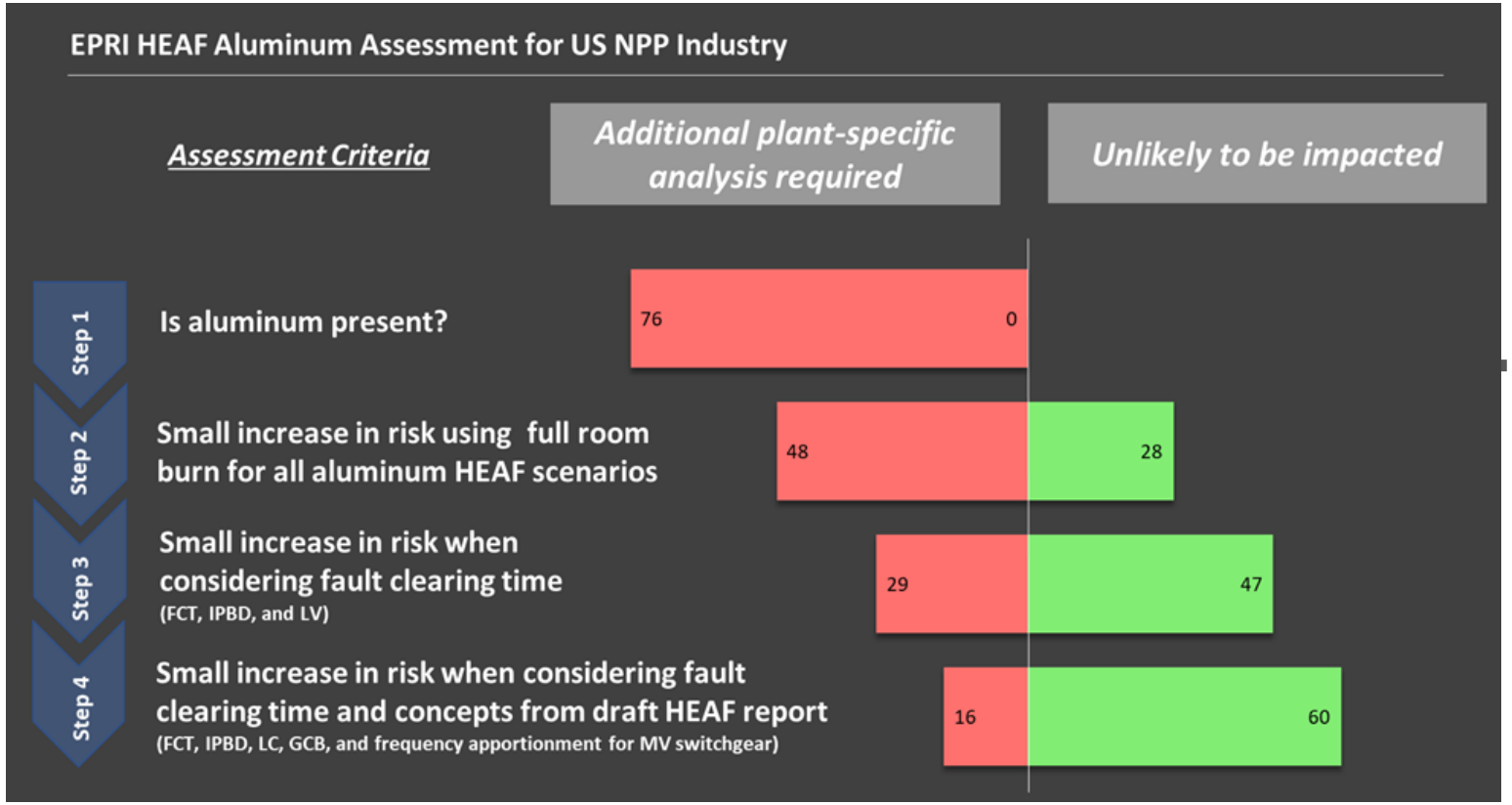
Description of EPRI Analysis
Utilizing Plant-Provided Fire PRA Data with an Intentionally Conservative Analysis Approach

EPRI Approach for Detailed Analysis of HEAF Survey Data



- Steps in the EPRI detailed analysis were performed iteratively using sensitivity case studies based on
  - Current Fire PRA data
  - Location of the Aluminum in the plants
  - Worst case "full-room burn" scenario as conservative surrogate for potentially larger ZOI due to Aluminum
  - Plant electrical distribution system design and protection detail including fault clearing times (FCT)
  - More detailed PRA HEAF modeling concepts being developed by the joint EPRI – NRC-RES working group
- Information used in Steps 0-4 above:
  - Uses the data from the HEAF-Aluminum survey to estimate the change in the total Fire CDF
  - Where data is unknown (i.e., proposed realistic ZOIs for HEAF with Aluminum) an intentionally conservative and bounding surrogate was used to address the potentially larger ZOI (i.e., a full room burn (FRB) was hypothesized to represent a bounding worst-case scenario)
- A 10% increase in the total Fire CDF was used as a threshold for deciding if a unit is classified as "*Additional plant-specific analysis required*" or "*unlikely to be impacted*" due to aluminum
  - The 10% threshold corresponds to an average Fire PRA ΔCDF of 5E-06, remaining below the 1E-05 threshold (RG 1.1.74 Region II)
  - The criteria of 10% increase was applied solely to the Fire PRA ΔCDF, other contributors are not considered

Summary of the EPRI Detailed Analysis Results



- "*Additional plant-specific analysis required*" means that risk impacts are not yet known
  - With the conservative approach below, it is not possible to say there will not likely be a risk increase
  - However, no specific risk values or changes in risk can be calculated without the necessary ZOI values
- "*Unlikely to be impacted*" means the plant is unlikely to show significant risk increase even with bounding ZOI for Aluminum - based on:
  - Known data and plant design information
  - Currently Draft PRA modeling approaches for HEAF being developed by working group
  - Bounding/conservative approaches to address the unknown ZOI involving Aluminum (i.e., assuming a full room burn)

EPRI bounding assessment using the current Fire PRA data and early draft methodology highlights that for large portion of the US plants the AL presence would likely have a limited impact

Summary of the EPRI Detailed Analysis Results

Categorization	Number of Units	% of units that provided PRA Data	Total % of units surveyed (95 units)
Additional plant-specific analysis required; risk not known	16	21%	17%
Unlikely to be impacted	60	79%	63%
No Fire PRA, and no insights available	12		13%
No Fire PRA, but not likely to have increased risk	7		7%

Limitations of the EPRI Analysis

- HEAF modeling framework is evolving:
  - Assessment of the of Al and Cu ZOIs is ongoing
  - Concepts from the draft HEAF PRA modeling guidance are subject to change ⇨ Therefore the results of these analyses would have to be revisited

- The EPRI assessment is not intended to calculate refined, realistic Fire PRA risk results for each plant
  - Limited Fire PRA data along with intentionally bounding and conservative assumptions were used for the sensitivities

- Based on the above, the current analyses reflect estimates of the potential for risk increase and are not reflective of actual increases or decreases in risk for any specific plant

HEAF Survey Takeaways

- Aluminum exists in all plants to varying degree
- Detailed survey results on the location and types of SSCs containing Aluminum provide valuable information for the purpose of informing representative testing on HEAFs
- The presence of Al is NOT directly related to increased risk
- EPRI bounding assessment using the current Fire PRA data and draft methodology highlights that for large portion of the US plants a larger aluminum ZOI would likely have limited impact
- Actual changes in plant risk from Aluminum involved in HEAFs cannot be determined until realistic ZOIs are derived and applied with the newly developed Fire PRA modeling guidance




EPRI White Paper on HEAF Survey and Insights

- EPRI will publish a White Paper by May on the HEAF Surveys with detailed discussion on:
  - Use of the Aluminum in the HEAF susceptible components in the US NPPs
  - Location of the Aluminum
  - Insights from the survey results combined with the US HEAF operating experience and comparison with the HEAF testing
  - EPRI bounding assessment using the current Fire PRA data along with the refined framework for HEAFs
- EPRI White Paper will be publicly available on the EPRI website, once released, by searching 3002020692”