COST ESTIMATE FOR THE CONCEPTUAL DESIGN OF FILTRATION STRATEGY HARDWARE ALTERNATIVES FOR BWR MK I AND MK II CONTAINMENTS

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INTRODUCTION AND PURPOSE

To support development of regulatory analyses for alternatives being considered under the filtering strategies rulemaking, cost estimates have been developed for the conceptual designs associated with the hardware enhancements credited for each rulemaking alternative. As part of the rulemaking process, industry and NRC are independently evaluating the potential costs and benefits of the following rulemaking alternatives:

1. Base Case
   (No hardware changes beyond implementation of EA 12-049, EA-13-109, and EPG/SAGs, Rev. 3)
2. Reliable makeup to the reactor pressure vessel (RPV)
   - 2A. Alternative 1 plus reliable water makeup to RPV
   - 2B. Alternative 2A plus wet well (WW)/drywell (DW) vent cycling
   - 2C. Alternative 2B plus water management to prevent the need for DW venting
   - 2D. Alternative 2A plus water management to prevent the need for DW venting
3. Reliable makeup to DW
   - 3A. Alternative 1 plus reliable water makeup to DW
   - 3B. Alternative 3A plus WW/DW vent cycling
   - 3C. Alternative 3B plus water management to prevent the need for DW venting
   - 3D. Alternative 3A plus water management to prevent the need for DW venting
4. Small Filter
   - 4A. Alternative 2A plus small filter
   - 4B. Alternative 3A with small Filter
5. Large Filter
   - 5A. Alternative 2A plus large filter
   - 5B. Alternative 3A plus large filter

The purpose of this document is to provide order-of-magnitude (OOM) cost estimates for the design, procurement, and installation of the necessary hardware changes for each conceptual design enhancement beyond Alternative 1.

Alternatives 2A and 3A require the provision of the capability of provide water makeup during severe accident conditions. In the case of Alternative 2, this makeup is to the RPV, in the case of Alternative 3, this makeup is directly to the drywell. The magnitude of the hardware changes required for these alternatives are considered equivalent for the purposes of this cost estimate. Alternatives 2B, 2C, 2D, 3B, 3C, and 3D are primarily procedural changes and are assumed to not require additional hardware changes beyond the water makeup capability.

Alternatives 4 and 5 involve water makeup with different sized filters. Alternatives 4A and 4B consider RPV/DW makeup with a small external filter. Alternatives 5A and 5B consider RPV/DW makeup with a large external filter. Note that the small and large filters differ in their capacity for decay heat and aerosol loading in addition to significant differences in both nominal physical dimension and weight. In addition to the actual cost of the filters, the size of filter has a significant impact on related scope due to restrictions related to locations that can accommodate the installation of the filter, size of building/structure housing the filter and associated shielding costs.

Thus, for the purposes of this order of magnitude cost estimate, these are considered captured as three different hardware modifications:

- Severe Accident Capable Water Makeup (Alternatives 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D)
  This enhancement would provide a means to provide a makeup path via a connection to an existing system. This pathway would be to either the RPV or to the drywell, not both. The primary physical changes involve providing a single connection for a portable, FLEX-type, pump external to the reactor building.

- Small Filter w/Water Makeup (Alternatives 4A and 4B)
  This enhancement would provide a smaller, more compact external containment filter in addition to the water makeup capability described above. The small filter requires a smaller engineering footprint than the large filter, but would have a limited capacity for decay heat and aerosol loading. However, the capacity would be sufficient to maintain high effectiveness for scenarios where the suppression pool has initially captured early fission releases while the wetwell vent is in use.

- Large Filter w/Water Makeup (Alternatives 5A and 5B)
  This enhancement would provide large external containment filter in addition to the water makeup capability described above. The large filter requires a substantial engineering footprint but has the capacity for the fission product inventory that would be released without credit for retention in the suppression pool (i.e., a filter that is used from only the drywell airspace).

OOM conceptual cost estimates are provided for the design, supply, and installation of these conceptual design enhancements.

SCOPE OF ESTIMATE

The cost estimates herein are based on incremental costs of filter installation relative to current conceptual designs planned for compliance with NRC Order EA-13-109 and do not include previously incurred or planned expenditures related to NRC order compliance. The wide variance in design of the base vent systems also creates the potential for wide variation in design. The base case assumptions used in this estimate assume vent designs that included installation of some new piping (“dedicated” or “mixed” systems). For plants maximizing the use of existing piping for their severe accident capable vents, the impact will generally be greater. The costs are unescalated and are a combination of cost data obtained from equipment vendors, in-house data bases for common items such as pipe, concrete, structural and reinforcing steel. Costs for construction labor, supervision, construction equipment, tools and consumables were developed by comparison of estimates prepared for multiple sites. Cost estimates include all hardware that might be included in a generic conceptual design including valves, valve actuators, pipe, hangers, instruments, power supplies, cable, conduit, tornado and missile enclosures, engineering and design services for detailed design, fabrication and procurement, construction forces mobilization and demobilization, on-site HP training and badging, construction craft labor, supervision, QC and QA services, shop and field inspection, project management, and related services.

The costs contained herein are related to installation and commissioning. Ongoing operation and maintenance costs are not included. Decommissioning costs similarly are not included.

CRITICAL INPUTS AND ASSUMPTIONS

Applicability	Assumption	Basis	Range/variation
Makeup[1]	Severe accident makeup capability requires modification of FLEX piping to provide connection/control outside of Reactor Building (mechanical)	Survey of FLEX OIPs identifies that majority of plants have connections inside the Reactor Building. Severe accident conditions postulated ***could*** prevent operation from those locations.	Wide variation in access point locations (from 50' + penetration to 200'+ and two penetrations). Also, penetration sizes dependent on credited flow rates
Makeup	Modifications for enhanced makeup capability are mechanical only	Assumes that FLEX repowers all required valves, that additional hardening of flowpath valves is not required, and that additional operating stations not required	Some plants have MOVs in the DW makeup flowpath that would require modifications to repower/control.
Filters[2]	Filters located at grade level	Informal survey of 10 units height and weight of filter units versus available space shielding requirements	Some units have limited site availability and could require: Demolition of existing structures, additional piping length, erection of elevated superstructure to house filters and allow traffic flow; missile protection and/or elevated pipe runs.

[1] Some plants may have severe accident accessible locations within the Reactor Building. This assumption and the next (mechanical only) generally offset each other, although additional electrical supplies/controls would be a greater expense.

[2] Very few plants could accommodate filter inside of existing buildings. The potential increase in scope relative to the assumption is much greater than any potential reduction in scope.

Applicability	Assumption	Basis	Range/variation
Filters	Base filter dimensions/weight (without aux equipment) Small filter: 7ft diameter x 20ft height; 20 tons Large filter: 15ft diameter x 30 ft height; 60 tons	Vendor information	Small filter: Potential to slightly reduce height and use multiple tanks (15' minimum height). Single tank weights as low as 16 tons. Large filter – Could be >70 tons (with water, no additional equipment)
Filters	Shielding required (3' high density concrete)	Unshielded radiation levels exceeding 1 x 10^7 at 3' from filter possible.	Proximity to operator actions and critical equipment varies
Filters, makeup	Qualification requirements (including temp, seismic, radiation) per EA-13-109	Consistency of regulations	Location of filter and housing structure relative to Reactor Building has significant impact on foundation design and analysis
Filters	Inerting system required for Hydrogen	Benchmark of international designs plus review of impact to systems planned for EA-13-109 vents	
Filters	Filter bypass line/valves required	Prevent impact to anticipatory venting (primary means to PREVENT severe accident). Minimum filter D/P ~7 psid.	
Filters	Makeup system to filters required	Vendor information regarding water capacity	Makeup systems range from transfer pump system with controls to makeup system with additional water tank. Base assumption does not include additional tank.

Applicability	Assumption	Basis	Range/variation
Filters	No additional local control building is required		
Filters, makeup	Existing containment parameter instrumentation will not be upgraded	Most containment instrumentation LOCA qualified	
Filters	Valve position, effluent pressure downstream of filter, filter water level, additional radiation instruments required	Conceptual design	
Filters, makeup	Flex diesel generators will be able to be qualified for severe accident use[3]		
Filters	Heat trace required for filters in northern climates[4]		

[3] Power for filter-related instrumentation and associated control valves required. Significant additional costs would be associated with provided an additional dedicated power source.

[4] Costs for heat trace not included in base estimates. This represents a cost risk item.

ESTIMATE ACCURACY

The estimates developed are based on a conceptual design with limited details and vendor quotes for only the most expensive items (filters, valve/actuator combinations). Estimates of this type traditionally have an uncertainty range from -25% to +75%. In addition, plant-to-plant design details can significantly influence the plant-specific costs. These estimates should be considered representative, and the use of these estimates should consider these uncertainties in the quantitative estimates. For example, standard industry practice at the conceptual phase of projects would normally be to add a 50% contingency to any base cost estimate.

SUMMARY OF EQUIPMENT, MATERIAL, ENGINEERING & CONSTRUCTION COSTS

Description	Severe Accident Capable Makeup (stand-alone)	Small Filter w/make-up	Large Filter w/make-up
Project Management (including planning and construction oversight)	$295,000	$1,500,000	$1,800,000
Project/Installation Support	$95,000	$468,000	$468,000
Filters (vendor)	N/A	$7,000,000	$13,000,000
Materials (excluding filter)	$140,000	$3,400,000	$5,675,000
Engineering	$315,000	$2,700,000	$3,150,000
Equipment	$20,000	$104,000	$160,000
Install piping/valves/filter	$1,423,000	$3,600,000	$6,150,000.00
Install filter building/shielding	N/A	$2,100,000	$3,450,000
Severe Accident Capable Makeup	N/A	$2,000,000	$2,000,000
Scaffold/labor support	$50,000	$275,000	$275,000
Tools and consumables	$22,000	$203,000	$203,000
Scanning	$35,000	$82,000	$82,000
Procedures & training	$85,000	$175,000	$175,000
	$2,480,000	**$23,607,000**	**$36,588,000**
Total with 50% Contingency added	**$3,720,000**	**$35,410,500**	**$54,882,000**

Material Quantities:

1) **Valves and Actuators:** 16” ASME III Class 2 150 lb. flanged carbon steel body with stainless steel ball valves, with pneumatic piston/spring actuators and handwheel for manual operation, complete with extended drive shafts with seals and universal joints. Action shall be spring to close, pressure to open. Required: 5/unit.

2) Vent Pipe and Fittings	**Small (nominal)**	**range**	**Large (nominal)**	**Range**
16" SA-106 Grade B schedule 40 carbon steel pipe, ASME III, N2, LF	0	0-220	0	0-220
16" A-106 Grade B schedule 40 carbon steel pipe, commercial grade, LF	210	160-440	360	200-640
16" elbows, long radius, N2, ea	0	0-12	0	0-12
16" elbows, long radius, commercial grade	12	6-18	16	8-32
Misc fittings and hangers, separator, nitrogen piping	1 lot		1 lot	
Miscellaneous small bore pipe and fittings(filter makeup)	1 lot		1 lot	
6” pipe and fittings (water makeup)	1 lot		1 lot	

3) Instrument & Control Devices:

Solenoid valve – 1/valve

Limit switches on valves – 1/valve

Valve position transmitter - 1/valve

Pressure transmitter - 2/unit

Pressure gage - 2/unit

Power supplies - 1 lot/unit

Pneumatic accessories - 1 lot/unit

System operation and status displays - 2/unit

4) Electrical Equipment & Cabling

Control cable & conduit, valve stations to control room for solenoid valve actuation – 1 lot

Power cabling, from 1E DC breaker panel to valve actuator stations and radiation and flow transmitters for powering transmitters and limit switches plus cabling to FLEX connection point for backup power supply – 1 lot

Lighting (normal and emergency) for valve station enclosures – 1 lot

Miscellaneous electrical accessories – 1 lot

5) Structures & Foundations

Support structure and foundations for filters and pipe bridges: 430 (725) CY reinforced concrete for filter buidlings and 30 (60) tons of steel pipe bridges.

Valve station enclosures, steel plate, 1/unit

Access ladders, platforms, doors – 1 lot

Miscellaneous pipe thrust anchors and dynamic forces restraints – 1 lot

Tornado missile shields – 1 lot

Engineering, Design, QA and Construction Support Services Scope

1) Project Management, Administration and Misc. Services

1.1 PM, Lead Engineers & staff admin tasks (general supervision, meetings, travel, indoctrination, clerical)
1.2 Project Controls - Planning, scheduling, budgeting, status tracking, performance measurement
1.3 On-site activities - Badging, HP training, site indoctrination, documenting existing facility configuration, planning and checking proposed designs
1.4 Procurement of materials and equipment, expediting, receiving inspection
1.5 Document Control
1.6 Design Reviews with Owner, ALARA and 50.59 reviews, Progress review meetings and reports

2) Mechanical Engineering & Design

2.1 Engineering & Design of vent system piping and components, preparation of construction drawings, procurement, fab & installation specs and instructions, tests and inspections. Vendor document review and approval.
2.2 Engineering and design of pipe and equipment supports and restraints, tornado shields, thermal and seismic analysis, preparation of procurement and installation specs for pipe and equipment supports
2.3 Thermal-hydraulic calculations and analyses of vent paths, shielding calculations, transient analyses, dynamic effects analyses
2.4 Preparation and approval of ASME Section III Design Specs for N-2 class components

3) I&C Engineering & Design

3.1 Engineering & Design of instrumentation and control components and systems, operating logic, alarms, preparation of procurement specifications, vendor data review and approval
3.2 Preparation of installation and test documentation for I&C loops

4) Civil/Structural Engineering & Design

4.1 Engineering and Design of foundations, structures, tornado-proof enclosures, access ladders/stairways/platforms
4.2 Preparation of procurement, fabrication and erection specifications for structural components; vendor data review and approval
4.3 Soils engineering, foundation design, geotech engineering

5) Electrical Engineering & Design

5.1 Engineering & Design of power supply systems for powered components, preparation of procurement, fab & installation specs and instructions, tests and inspections.
5.2 Engineering and design of conduit, raceway, cable schedules, termination sheets and schematics, preparation of procurement and installation specs for electrical components. Vendor document review and approval

6) Quality Assurance

6.1 Develop and apply Engineering & Design QA Program, surveillance for compliance, audits, and corrective actions
6.2 Manufacturing QA - Vendor inspections, pre-ship inspections and tests
6.3 Construction QC/QA Oversight

7) Construction Engineering

7.1 Constructability reviews, construction packaging, planning installation sequence, liaison with constructor
7.2 Construction oversight & support

8) Licensing Support

8.1 Engineering and analysis support for NRC submittals, response to RAI's

9) Final Documentation Preparation

9.1 Prepare as-built physical configuration documents
9.2 Prepare Design Basis Document for Systems and Equipment

This engineering estimate considers the required activities to produce, review and approve modification packages consistent with site requirements.

Installation Scope

The following lists the typical major construction activities for the installation only:

1) Site Mobilization, indoctrination, badging, and HP training of construction staff

2) Pre-outage construction activities such as:

Partial Reactor Buidling penetration installation
Work outside the reactor building
Installation of pipe and pipe hangers inside building
Installation of pipe and pipe hangers outside building
Seismic Category I Supports (pre-fabrication by supplier) preparation
Coatings
Weld Maps
Weld Procedures
Restraints for Scaffolding

3) Staging of pipe and pipe supports / anchors for outage related work

4) Ground scanning and preparation

5) Foundation construction

6) Fabrication of shield building

7) Installation of electrical connections/cable routing

8) Filter installation

9) Installation of pipe, inspection, and test of pipe welds (not in outage)

10) Final tie-ins during plant outage including the following:

Connection to existing pipe
Preparation of weld ends
Welding and inspection of pipe welds
Adjustments to pipe supports
Final electrical/instrumentation tie-ins

11) Installation of tornado-proof enclosure and encased ladders (furnished by others)

12) 'System acceptance testing

13) Cleanup and site demobilization