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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002581

July 31, 2009

Subject: AP1000 Response to Request for Additional Information (SRP 6)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 15. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP6.2.2-SRSB-10 R2
RAI-SRP6.4-SPCV-06 R1

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager
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/Enclosure

1. Response to Request for Additional Information on SRP Section 6

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NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 6

RAI Response Number: RAI-SRP6.2.2-SRSB-10
Revision: 2

Question:

In TR 26, Revision 3, in the "Break Selection Criteria" subsection on page 13, Westinghouse states:

> "Note that the debris reaching the core is based on a DVI LOCA in the loop compartment. For this event the containment water level rises above the break so that some water can enter the reactor coolant system (RCS) directly and thereby bypass the Containment Recirculation Screens. It is calculated for such an event that no more than 60% of the total recirculation flow will bypass the screens. As a result, the core debris is set at 60% of the Containment Recirculation Screen amount."

The staff notes that in Table 3 the best estimate total mass bypass to the core is 14.35 lbm, and requests the following information.

a. Clarify, since the amount of bypass debris is significant for determining the effect on the core, the basis for the 60% number.
b. Describe how this relates to the total residue mass in the containment of 227 kg (500 lb) that you assumed, as documented in NUREG-1793, Section 6.2.1.8.2.
c. Clarify whether the total mass number to the core includes bypass debris from the recirculation and IRWST screens.

Additional Question:

In its review of part a. to the response to RAI-SRP-6.2.2-SRSB-10, the staff asked Westinghouse to identify if the 60% bypass flow assumption was based on low water level in the containment, which would limit the recirculation flow, or was based on a high water level, which could drive a bigger percentage of unfiltered debris through the DVI break location? On review of the calculation APP-PXS-M3C-049 Rev. 0, the staff found that the 60% number was based on integrated flow through the break divided by the total integrated flow into the core region, but time periods during the transient changes this percentage significantly. Describe the variations you expect in this percentage split with respect to time. Also, using the flow percentage splits between the break and the recirculation screens is not an adequate representation of the debris split because sump recirculation screens are protected from debris by barriers such as the large protective shelves above the screens. On the other hand, there are no protective barriers for the break location and it is completely open to all suspended debris in the containment sump area. Clarify how this bias accounted for in the calculation?

Westinghouse Response: < The original response has been revised as shown below to address the additional questions. Changes from Revision 1 to Revision 2 are not shown for ease of reading the response. Changes can be determined by comparing the revisions.>

The long-term cooling analysis for a DEDVI break in the loop compartment shows that less than 75% of the integrated RCS flow will enter through the break. The other 25% will pass through the recirculation screens. As a result, the recirculation screens will collect 25% of the latent debris and the remaining 75% will enter the core through the break for this scenario.

a. The AP1000 did not assume 500 lb of debris were inside the containment. Refer to the response to RAI 6.2.2-SRSB-07 for an explanation of how the AP1000 latent debris was calculated. The 75% value is the percentage of the recirculation screen debris that could be transported into the core.
b. The AP1000 did not assume 500 lb of debris were inside the containment. Refer to the response to RAI SRP 6.2.2-SRSB-07 for an explanation of how the AP1000 latent debris was calculated.
c. The amount of bypass debris that might pass through the AP1000 screens will be very small considering the low debris loading of these screens and is bounded by the 75% value.

Additional Response:

Limiting Break Selection Criteria with Respect to Debris Loading

For LOCA scenarios the DEDVI break in the loop compartment is the most limiting with regards to debris loading on the fuel assemblies (debris loading on the screens have already been tested and analyzed and found them to be acceptable). There are several reasons for this:

i.) The DEDVI loop compartment case results in faster IRWST draindown due to the injection line break, and thus containment recirculation is achieved faster than for any other coolant pipe break. Achieving recirculation faster causes decay heat to be higher which causes recirculation flow to be higher than for other scenarios. This maximizes the available transport velocities for latent debris.

ii.) The broken DVI line resistance for the DEDVI loop compartment case is less than that for the DEDVI PXS Room B case because the loop compartment case assumes that the DEDVI break occurs right next to the RV. The reduced line resistance into the vessel as compared with the PXS room break causes the maximum flow split to occur and this configuration yields a flow ratio of 75/25. This ratio implies 75% of core flow will enter from the broken DVI line as opposed to the 50/50 split observed from the PXS Room B DVI break.

iii.) For hot let breaks up to and including a DEHLB, the location of the break makes these breaks less limiting. There are several reasons for this including:

- Such a break location will not result in spill of IRWST injection so that the start of recirculation will be later, with lower decay heat.
- The flow that enters the core through the downcomer from the DVI injection lines will tend to exit through the HLs as well as the ADS lines. There could also be inflow through the HL break especially for the break of a HL itself. This would result in a counter-current flow path within the HL due to the competing effects of inflow from the break and outflow from the core. Any debris brought into the RCS through the HL would tend to be deposited in the top portion of the fuel assemblies which would not create the concentrated debris bed formation seen in the tests conducted with debris entering the bottom of the fuel. In any case, the PXS injection flow path would still be available to support core cooling.

iv.) For a DECLB, the flow split between the PXS recirculation flow path and through a double-ended rupture of a cold leg pipe is calculated to result in less than 85% of the flow through the CL and 15% through the PXS. This split is calculated with the containment at its final flooded level. As is observed for DVI LOCAs, recirculation starts through the break before the PXS recirculation begins, so that the integrated split over the time required to pass one containment volume through the RCS is a few percentage points higher. So the integrated flow split for a DECLB will be 90% through the break and 10% through the PXS. However, this split is considered excessively conservative for the following reasons:

- The cold legs are leak-before-break lines, which have a much lower probability of rupture than other cold leg or DVI branch lines. There are several reasons for this difference:
    - There are only 4 cold leg pipes, each with only 2 welds– there are many more cold leg branch and DVI lines (at least 10 times more).
    - The RCS leakage detection instruments are designed to detect leakage at a rate that is significantly less than that exhibited at the critical flaw size for a 4" pipe. Since the CLs are 22", leakage for a CL pipe will be detected with flaw sizes that are much smaller than its critical flaw size.
- The total amount of debris assumed to be in the containment is conservatively large (150 pounds total and 8 pounds fiber). This amount is conservative because the operating plant walkdowns show that the average amounts are about 90 pounds.
- The AP1000 assumes that all latent fibrous and particulate debris transports. This is conservative because the AP1000 does not have a containment spray system, and as a result, much of the latent debris located on the containment operating deck or above will not be washed into the recirculation flows. In addition, there are several rooms in the containment that will not be flooded in

this event; these rooms include both PXS valve rooms and the CVS room. As a result, the latent debris located in these rooms will not be transported.

- None of the debris that is transported is assumed to settle out before reaching a screen or a flooded break. As observed in the screen tests, the fiber debris tends to settle out even in the higher velocities approaching the IRWST screens. The velocities approaching the CR screens are significantly lower and there is at least two hours of settling time between the time of the break and the start of recirculation.
- In considering the maximum amount of debris that may be transported into the core through a flooded break, it is assumed that all of the debris in the containment would be transported to the loop compartments and therefore be available to the CR screens and/or a flooded break. None of the debris is assumed to be transported into the IRWST screen in this case. Assuming that no debris is transported into the IRWST is conservative because some of the latent debris located above the operating deck will be washed into the IRWST. For the design and testing of the IRWST screens it has been assumed that 50% of the total debris in the containment is washed into the IRWST.
- A single failure is assumed in the PXS recirculation and IRWST injection lines. This assumption is conservative because it is most likely that if there is a failure, it will be from one of the many other valves in the AP1000.
- The amount of chemical precipitates is conservative because:
  - The amount of aluminum inside containment is less than the design limit.
  - The assumed corrosion rate of aluminum is conservatively high because the presence of trisodium phosphate (TSP) will reduce corrosion.
  - The testing of the core head loss is performed using AlOOH mixed at a very high concentration which forces a large amount of precipitates.
- The magnitude of recirculation flow is biased high because the LTCC analysis uses the Appendix K decay heat (P/P_0) which has an associated 20% uncertainty biased high. Since decay heat is what drives the passive system operation, this assumption results in a higher flow rate. The larger flow rate results in a larger pressure drop across the fuel due to debris loading associated resistances and supplies a larger fluid velocity for debris transport.
- The viscosity of the recirculation water will be significantly lower than in the tests that were conducted on the head losses through the screens and fuel assemblies. As a result the head loss across the fuel assemblies and the screens will be significantly less. The lower viscosity will also improve settling of debris.

In the consideration of a DECLB with 90% of the total latent debris being transported to core, minor reductions in one or more significant margins listed above would result the same amount of fiber being transported into the RCS as in the DEDVI case. One example would be if 17% of the debris either does not transport into the recirculation water or settles out after entering the water, then the DECLB would be less limiting than the DEDVIB. Another example would be if 10% of the debris either does not transport into the recirculation water or settles out and 8% is transported into the IRWST.

For the reasons discussed above the DEDVIB is considered to be the most limiting with regards to debris transport to the core. Table 1 shows the latent debris amounts for the AP1000. This table lists the total latent debris, how much is fiber, and how much is transported where.

Table 1 – AP1000 Latent Debris Amounts for the DEDVI Debris Loading

	DEDVIB (in Loop Compartment)		
	Total	Fiber	Particles
Total in Containment (lb)	150.0	8.0	142.0
% transported	100%		
	150.0	8.0	142.0
% settles	0%		
	150.0	8.0	142.0
% to Loop Compartment*	100%		
	150.0	8.0	142.0
% to core (1)	75%		
	148.0	6.0	142.0

Note (1) 25% of the debris that transports to the PXS screens results in the fibers being deposited on the CR screens but the particles are assumed to pass through and end up in the core.

Table 2 Integrated Flows for Complete Volume Turnover Determination

1	2	3	4	5	6	7	8	9	10	11	12
		Recirc via		Break (DVI A)		PXS Rec (DVI B)				Integrated	% Total
Time		Break	PXS	time step	total	time step	total	Percentage		total	
(sec)	(hr)	(lb/sec)	(lb/sec)	(lb)	(lb)	(lb)	(lb)	Break	PXS	(lb)	
2700	0.8	0.0	0.0								
3000	0.8	39.0	0.0	5,850	5,850	0	0	100.0%	0.0%	5,850	0%
4000	1.1	117.0	0.0	78,000	83,850	0	0	100.0%	0.0%	83,850	2%
5000	1.4	147.0	0.0	132,000	215,850	0	0	100.0%	0.0%	215,850	4%
6000	1.7	166.0	0.0	156,500	372,350	0	0	100.0%	0.0%	372,350	7%
6999	1.9	185.0	0.0	175,325	547,675	0	0	100.0%	0.0%	547,675	10%
7000	1.9	185.0	85.0	185	547,860	43	43	100.0%	0.0%	547,903	10%
7500	2.1	185.0	85.0	92,500	640,360	42,500	42,543	93.8%	6.2%	682,903	13%
8000	2.2	185.0	85.0	92,500	732,860	42,500	85,043	89.6%	10.4%	817,903	16%
9000	2.5	185.0	85.0	185,000	917,860	85,000	170,043	84.4%	15.6%	1,087,903	21%
11000	3.1	185.0	85.0	370,000	1,287,860	170,000	340,043	79.1%	20.9%	1,627,903	31%
13000	3.6	185.0	85.0	370,000	1,657,860	170,000	510,043	76.5%	23.5%	2,167,903	41%
15000	4.2	185.0	85.0	370,000	2,027,860	170,000	680,043	74.9%	25.1%	2,707,903	52%
17000	4.7	185.0	85.0	370,000	2,397,860	170,000	850,043	73.8%	26.2%	3,247,903	62%
19000	5.3	185.0	85.0	370,000	2,767,860	170,000	1,020,043	73.1%	26.9%	3,787,903	72%
21000	5.8	185.0	85.0	370,000	3,137,860	170,000	1,190,043	72.5%	27.5%	4,327,903	83%
23000	6.4	185.0	85.0	370,000	3,507,860	170,000	1,360,043	72.1%	27.9%	4,867,903	93%
24000	6.7	185.0	85.0	185,000	3,692,860	85,000	1,445,043	71.9%	28.1%	5,137,903	98%
25000	6.9	185.0	85.0	185,000	3,877,860	85,000	1,530,043	71.7%	28.3%	5,407,903	103%
27000	7.5	185.0	85.0	370,000	4,247,860	170,000	1,700,043	71.4%	28.6%	5,947,903	114%

As shown above in Table 2, it takes about 6.67 hours to recirculate the full volume of the containment water once. This is considered the absolute minimum amount of water to be recirculated in order to capture all of the latent debris in the whole containment. Consider that this debris is initially dispersed throughout the containment on all of the different surfaces (floors, walls, equipment, pipes, ducts, cable trays). Table 2 shows that the integrated flow split is about 71.9% through the break and 28.1% through the PXS by the time the containment water mass has passed through the RCS one time. For fuel assembly debris testing the flow split was conservatively rounded to 75%/25% Note that the break flow ramps to 39 lbm/s from 2700 to 3000 before the PXS recirculation flow begins at 7000 seconds. Also, from 2700 seconds until 7000 seconds Table 2 shows the flow to be 100% from the broken DVI line. This is equal to 100% of the total flow at that time, 75% of the total maximum recirculation flow. At 7000 seconds flow recirculation begins in the intact DVI line injection 85 lbm/sec into the core while the recirculation from the break remains at 185 lbm/sec. This flow split is maintained from 7000 seconds through the first complete containment volume turnover. A complete explanation of calculations for Table 2 can be found in Revision 4 of TR26.

In order to ensure a conservative calculation of the flow split during containment recirculation for the DEDVI break in a loop compartment, this break location is analyzed assuming a different single failure from that assumed in the DCD case. Specifically, the failure of one PMS division / battery is assumed, resulting in the failure to open of one containment recirculation valve and one IRWST delivery line valve. This failure maximizes the flow resistance through the intact DVI line, when taken together with the upper bound line resistance factors for the delivery flow path(s) therein that remain available. By also assuming best-estimate resistance for flow through the broken DVI nozzle into the downcomer, the flow resistance split is conservatively skewed in this case to favor recirculation flow through the break location. With the higher intact line resistance, the start of recirculation through the intact line is delayed slightly.

The 75% bypass flow is based on the low water level in the containment because this limits the recirculation flow, which is conservative for long-term cooling of the core. However, if the water level in the containment were increased, the flow fraction for bypass would remain constant, since the flow rate is proportional to the elevation head, and the elevation of the DVI lines injecting the flow is the same.

No settling of the resident debris is assumed in the calculations. Settling would reduce the amount of debris available to be deposited on the screens or to enter the break. The resident debris is assumed to be divided at the same ratio as the flow fraction between the recirculation and broken loop flows.

The figures on the following pages show the calculation of the flow ratio for recirculation through the break. The WCOBRA/TRAC time scale is such that zero seconds on the x-axis corresponds to 2500 seconds after the initiation of the DEDVI break. Containment recirculation begins at 7000 seconds (9500 seconds after the initiation of the DEDVI break), so the time interval of most interest on the WCOBRA/TRAC plots begins at 7000 seconds. Figure 1 provides the intact DVI line flow following recirculation. Figure 2 provides the flow into the reactor vessel from the break location. Figure 3 provides the instantaneous ratio of flow into the core from the break location to total core flow (flow through break into the reactor vessel / total flow into reactor vessel) following recirculation. At all times after recirculation, the instantaneous flow through the break ratio is less than 75% of the total core flow.

The integral ratio shown in Table 2 for recirculation flow represents the fraction of integrated recirculation flow entering the reactor vessel through the broken DVI line. The broken DVI line exhibits (negative) flow outward into containment for around 2700 seconds in WCOBRA/TRAC, as indicated, until the water level in the loop compartment has risen to the point that flow into the reactor vessel can begin. Therefore, the integral ratio is 1.0 for the time interval from 2700 seconds up to the start of containment recirculation flow passing through the intact DVI line and its sump screen.

As shown in Figure 3, once recirculation is established, the instantaneous flow split through the break is always less than the 75% value. From Figure 4, after 17000 seconds (approximately

2.75 hours after recirculation is initiated) the integrated flow ratios are less than the 75% value assumed. This 2.75 hour time is much less than the time required to “turn over” the entire containment water volume (6 to 8 hours). The calculation is continued out to 25000 seconds.

Figure 1: Intact Loop DVI Recirculation Flow

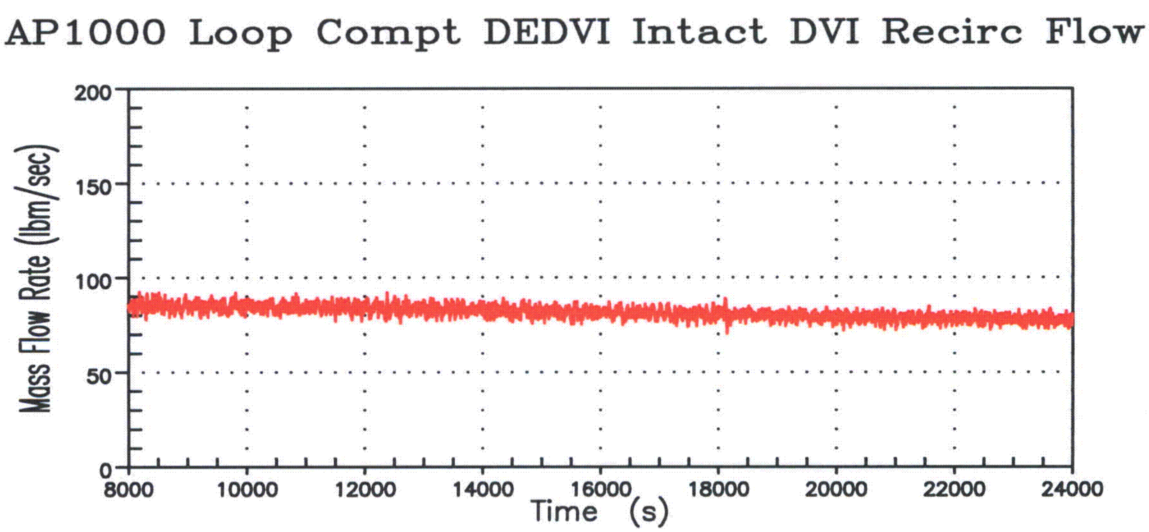


Figure 2: Broken Loop DVI Recirculation Flow

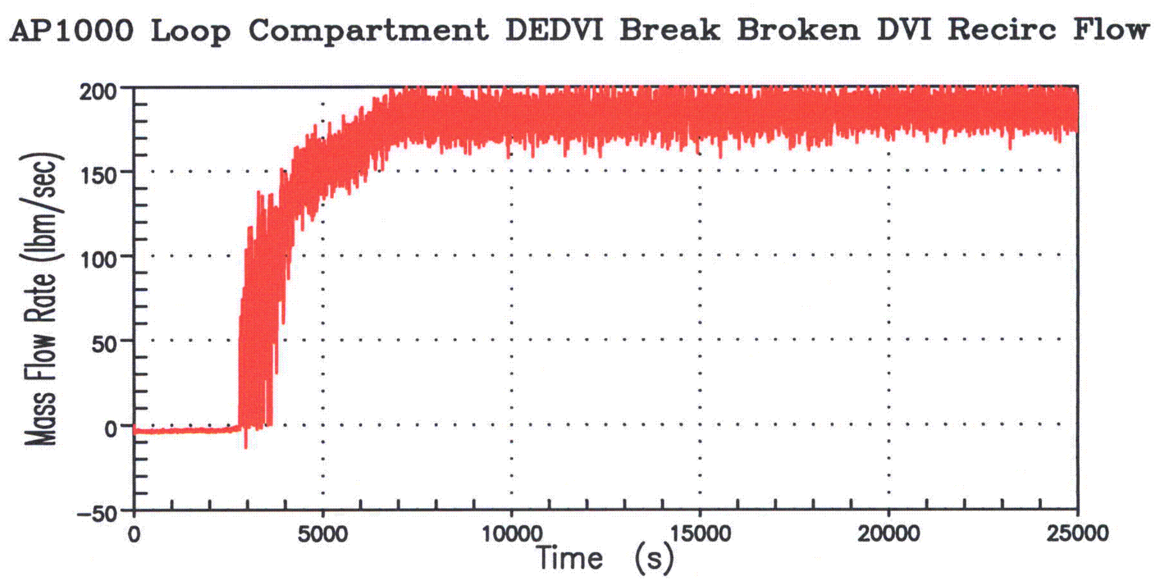


Figure 3: Instantaneous Flow through Break Ratioed to Total Core Flow

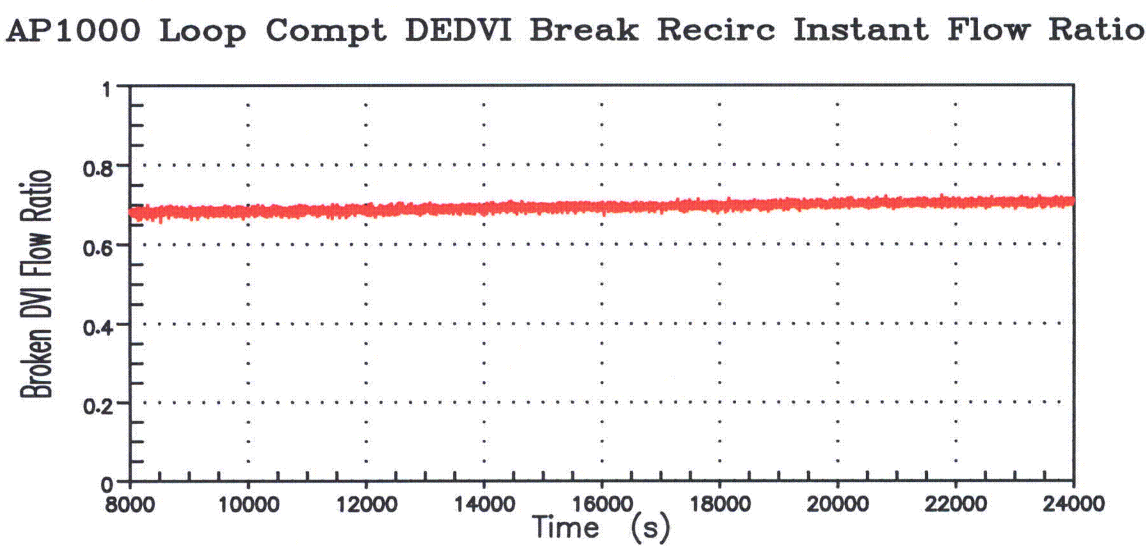
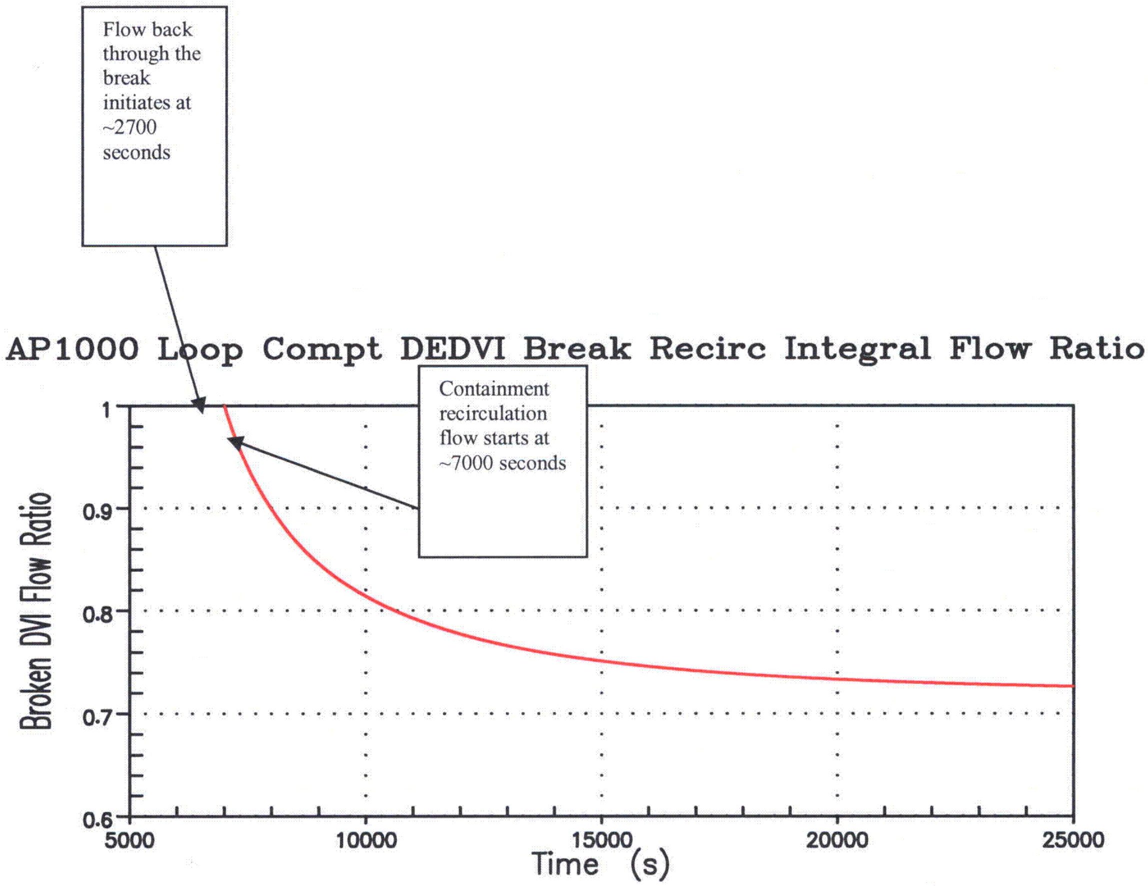


Figure 4: Integrated Flow Ratio (Int. Flow Through Break / Integrated Recirc Flow)



Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None

RAI Response Number: RAI-SRP 6.4-SPCV-06
Revision: 1

Follow Up Question:

On 6/23/09 a phone call was held with the NRC to discuss RAI-SRP 6.4-SCV-06. On the phone call three issues arose relative to the Westinghouse response to RAI-SRP 6.4-SPCV-06 Revision 0. Westinghouse committed to revising their response to the RAI to address these three issues.

- Provide the final revised markup to the DCD relative to the verified dose analysis calculations for the Main Control Room.
- Provide a justification to address passive failures in the VES passive air filtration line.
- Provide the basis for post 7 day control room habitability. The reviewed calculation indicated perfect VES air quality after 7 days which indicates that on-site air was not used to refill the VES emergency air storage tanks.

Westinghouse Response:

The final markup to DCD 6.4.4 and Table 15.6.5-2 is provided in the DCD markup section below. The markup is consistent with the dose calculations provide to the staff for review.

Treatment of passive failures is described in subsection 15.0.12 of the DCD.

A passives failure is the structural failure of a static component that limits the effectiveness of the component in carrying out its design function. Examples include cracking of pipes, sprung flanges, or valve packing leaks. In the VES passive filtration line, a passive failure is not credible. The passive filtration line contains no valves or flanges. A passive failure of the passive filtration line would only affect VES performance if it occurred between the inlet of the eductor and the discharge of the VES filters along lines VES –L052, -L053, or –L057. A failure in this region could potentially decrease the total filtration flow in the main control room envelope during VES operation. A failure in the duct upstream of the eductor would not decrease filtration flow through the eductor, and a passive failure downstream of the VES filters would only potentially affect distribution of air flow into the different areas inside the main control room envelope.

The section of ductwork that could potentially affect VES filtration flow resulting from a passive failure is a short section of approximately 20 feet of straight duct. There are no bends in the duct between the inlet to the eductor and the discharge of the filters. This ductwork will be subjected to very low pressures during VES operation. Pressure in the line is below 6" WG during VES operation. The ductwork and filters are periodically inspected and tested per the ventilation filter testing program as part of Technical Specifications. The technical specification requires that the passive filtration line be periodically tested to ensure adequate filtration flow is achieved.

Furthermore, VES is only required to actuate during an abnormal event when a high-high radiation setpoint is reached in the VBS duct work supplying the main control room or on an extend station blackout. Per SECY-77-439 Section 2D (Reference 1), the probability of a passive failure in a safety related system such as VES compounded with either an extended station blackout or a high-high radiation signal is sufficiently small that it can be reasonably discounted without substantially affecting overall system reliability.

The design basis for post seven day control room habitability has not changed as a result of the passive filtration design enhancement. Seven days after an accident that requires actuation of VES, the VES emergency air storage bottles will be refilled with clean offsite air assuming ac power has not been restored from either an offsite connection or the emergency diesel generators. This is consistent with the assumptions in the dose calculations reviewed by the staff.

References:

1. SECY-77-439, "Single Failure Criterion," August 1977

Design Control Document (DCD) Revision:

Note: The DCD changes below are in addition to the DCD changes provided in Revision 0 of the RAI response.

DCD Section 6.4.4

Doses were determined for the following design basis:

	VES Operating	VBS Operating
Large Break LOCA	4.41 rem TEDE	4.73 rem TEDE
Fuel Handling Accident	2.5 rem TEDE	1.6 rem TEDE
Steam Generator Tube Rupture		
(Pre-existing iodine spike)	4.3 rem TEDE	3.1 rem TEDE
(Accident-initiated iodine spike)	1.2 rem TEDE	1.7 rem TEDE
Steam Line Break		
(Pre-existing iodine spike)	3.9 rem TEDE	2.1 rem TEDE
(Accident-initiated iodine spike)	4.0 rem TEDE	4.9 rem TEDE
Rod Ejection Accident	1.8 rem TEDE	2.2 rem TEDE
Locked Rotor Accident		
(Accident without feedwater available)	0.7 rem TEDE	0.5 rem TEDE
(Accident with feedwater available)	0.5 rem TEDE	1.5 rem TEDE
Small Line Break Outside Containment	0.8 rem TEDE	0.3 rem TEDE

Table 15.6.5-3 **RADIOLOGICAL CONSEQUENCES OF A LOSS-OF-COOLANT ACCIDENT WITH CORE MELT**	
	TEDE Dose (rem)
Exclusion zone boundary dose (1.4 - 3.4 hr)[1]	24.6
Low population zone boundary dose (0 - 30 days)	23.4
Main control room dose (emergency habitability system in operation)	
– Airborne activity entering the main control room	4.25
– Direct radiation from adjacent structures	0.15
– Sky-shine	0.01
– Spent fuel pooling boiling	0.01
– Total	4.41
Main control room dose (normal HVAC operating in the supplemental filtration mode)	
– Airborne activity entering the main control room	4.56
– Direct radiation from adjacent structures	0.15
– Sky-shine	0.01
– Spent fuel pooling boiling	0.01
– Total	4.73

PRA Revision: None

Technical Report (TR) Revision: None