SEA 97-3703-A:1

PROPOSED CRITERIA FOR ECCS STRAINER DESIGN
EDWIN I. HATCH NUCLEAR PLANT - UNIT 1

TECHNICAL EVALUATION REPORT

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Attachment

1.0 INTRODUCTION

In response to Bulletin 96-03, the Southern Nuclear Operating Company (SNC) has submitted 'Proposed Criteria for ECCS Strainer Design, Edwin I. Hatch Nuclear Operating Plant - Unit 1' for US Nuclear Regulatory Commission (NRC) review [Ref. 1]. Science and Engineering Associates, Inc. (SEA) is tasked to review the submittal by NRC.

The resolution option is based on installation of passive large capacity suction strainers, designed and manufactured by the General Electric Company (GE). The submittal estimated debris loading on the strainer following a postulated 'worst-case' break using methodology provided by the Boiling Water Reactors Owners Group (BWROG) in the Utility Resolution Guidance (URG) document [Ref. 2].. Estimates for quantities of fibrous debris, sludge, and paint-chips transported to the strainer were evaluated on a plant-specific basis, but using guidance provided in the URG. On the other hand, generic estimates provided in the URG were used for Dust and Dirt; and Rust from unpainted structures. In addition, Transportable Foreign Material with a surface area of 1.0 ft^2 was used to account for miscellaneous debris that may exist in the suppression pool.

The plant intends to design strainers subject to single failure analysis, which resulted in availability of one (1) Residual Heat Removal (RHR) and two (2) Core Spray (CS) pumps for injection into the core. The large capacity strainers to be installed on the RHR and CS pumps will be sufficiently large to accommodate the debris and result in head loss less than the available NPSH Margin of 9.3 ft-water for RHR and 12.2 ft-water for CS. The corresponding flow rates are 7700 GPM and 4725 GPM for RHR and CS, respectively. The flow rates are consistent with ECCS design criteria and accident analysis sections of the Utility Final Safety Analysis Reports (UFSAR) [Ref. 3]. Estimates of Available NPSH incorporated a credit of 5 psig for containment pressure. The utility has stated that design of strainers without reliance on containment pressure is not practical.

The utility did not provide actual sizes of the strainers to be installed on the RHR and CS pumps. Instead, it provided a methodology proposed by GE for sizing the strainers [Ref. 4]. It is the intent of the utility to finalize the strainer design upon receiving NRC approval of the 'Proposed Criteria for ECCS Strainer Design' and, if necessary, to forward the design configuration to NRC staff when the design is completed. SEA is reviewing Ref. 4 as part of this task.

SEA performed a preliminary review of the licensee submittal and forwarded a Request for Additional Information (RAI) to the utility. On May 13, 1997 in a conference call with the utility, SEA provided detailed explanation of the RAI. Utility response to the RAI is contained in their letter (dated: May 28, 1997), 'Response to Request for Additional Information on Proposed Criteria for ECCS Strainer Design' [Ref. 5]. The utility response provided required clarifications regarding debris generation estimates and reduced their estimate of the quantity of sludge to be used in sizing the strainers from initial value of 920 lb. listed in Ref. 1 to 675 lb.

The focus of the SEA review of the submittal [Ref. 1] and the supporting documentation [Ref. 4 and 5], is the following:

1. To assess adequacy/accuracy of the utility estimated debris loading to be used in sizing the strainer. In particular, SEA focused on determining if the breaks were selected in accordance with Regulatory Guide 1.82, and if the methodology used by the utility has been previously

approved by NRC to provide reasonable estimate for debris generation and transport. Finally, has the plant made efforts to ensure that head loss predicted for the 'worst-case' break is, in fact, higher than that corresponding to all other possible breaks.

2. To assess accuracy of the strainer sizing criterion provided by the vendor. In particular, SEA focused on a review of the experimental data provided in the GE topical report [Ref. 4] and its usage by GE to derive the head loss correlation.

SEA did not devote any efforts to examine validity of licensee's assumption related to containment pressure. The Licensee determined that NPSH calculation was performed under 10 CFR 50.59.

To achieve these goals SEA performed a series of calculations. Calculations related to debris generation are summarized in Appendix-A, whereas calculations related to the GE stacked disc strainer assessment are documented in Appendix-B. The following sections summarize SEAs findings.

2.0 CONTRACTOR FINDINGS

2.1 Selection of the Break:

The utility explicitly stated that break location was selected not based on criterion of High Energy Line Breaks (HELB), which refers to locating the break close to the high stress points. Instead, break was selected so as to maximize the quantity of debris generated. [Ref. 5, Response to Question #2]. Our calculations suggest that selected break is located in the most congested part of the containment and it will most likely bound the fibrous debris generation estimates. Because the remaining debris are particulate debris and are break-independent (except for Calcium Silicate), break selected by the licensee will provide largest debris loading for sizing the strainers. Also, stacked disc strainer is not expected to have the 'thin-bed effect' and hence Regulatory Position 2.3.1.5 of Regulatory Guide 1.82, Rev. 2 does not apply. Note that Regulatory Position 2.3.1.5 requires the licensee to identify 'the medium and large breaks with largest potential particulate to insulation ratio by weight.'

SEA concludes that selection of the break is appropriate, and is consistent with the guidance provided in RG 1.82, Rev. 2.

2.2 Debris Generation:

The utility used Method 3 of the URG to estimate the zone of influence (ZOI) and the quantity of debris generated by the jets. The ZOI used by the licensee for estimating fibrous debris generation is a sphere whose radius is approximately 12 x Diameter of the Recirculation Line (12D). This ZOI is about 4 times larger than the ZOI used in NUREG/CR-6224 [Ref. 6] in volume. The licensee estimated value of 580 ft^3 of NUKON is slightly more than approximate value of 500 ft^3 derived independently by SEA (see Appendix-A). Licensee used a smaller ZOI with a radius of 5D to estimate damage to calcium silicate. SEA previously expressed reservation about accepting zone of influence for calcium silicate because both the ZOI and the size distribution were obtained using insufficient data base. However, SEA does not believe this poses a serious challenge to strainer design because a) calcium silicate is located in the neck region of the drywell and is not likely to be a target for most of the breaks, and b) the total quantity of calcium silicate expected to be transported is significantly smaller than the volumes of other particulate debris already assumed to

reach the strainer. Licensee screened out Urethane insulation as it has specific gravity substantially less than 1.

SEA concludes that usage of Method 3 of URG is acceptable and that licensee has appropriately estimated the quantity of debris generated. The estimated quantities of fibrous debris appear to provide a reasonable upper bound. Argument to screen out Urethane appears reasonable. The estimates of Calcium Silicate reaching the strainer (0 ft^3) will likely have little impact on the overall head loss (see Appendix-B), since significantly larger quantities of other particulate debris are included in the strainer design.

2.3 Debris Transport:

Licensee has determined that 100% of the generated debris for the 'worst-case' break was contained above the lowest grating. SEA independently confirmed their finding. URG transport factor of 0.28 was used by the licensee to estimate the total quantity of debris reaching the strainer. This value was recommended by URG and includes 100% transport of small debris which amount to 22% of the total and 6.25% transport of the remaining large debris due to erosion. A transport factor of 1.0 was used for all other debris. A transport factor of 1.0 was used for suppression pool transport.

SEA believes that these transport fractions are reasonable and that estimated quantities appear to provide a reasonable upper bound for the quantity of debris loading on the strainer.

2.4 Debris Loading on the Strainer:

The following table summarizes the debris loading assumed and its basis for each type of debris.

Type of Debris	Quantity	Comment
Fibrous Debris (Nukon)	162 ft^3	Checked independently by SEA. Reasonable.
Calcium-Silicate	0	There may be some trace quantities of Ca-Si.
Sludge	675 lb.	Estimate revised from 920 lb. in the original.
Dust and Dirt	150 lb.	URG Number. Also NUREG/CR-6224
Rust from Unpainted	50 lb.	URG Number.
Paint		Licensee estimates. Not checked by SEA.
Inorganic Zinc	47 lb.	
IOZ with Epoxy topcoat	85 lb.	No documentation provided for review.
Epoxy	71 lb.	
Unqualified Paint Coating	117 lb.	Licensee estimates. Not checked by SEA.
Other (Trans. For. Mat.)	1.0 ft^2	Licensee estimate. Actual survey information.

These numbers and their rationale for usage appears reasonable. Note: The estimate for sludge was revised from 920 lb. used in the original submittal, ' Proposed Criteria for ECCS Strainer Design,' (dated March 25, 1997) to 675 lb. per Fax Memo, 'Response to Request for Additional Information (dated: May 28, 1997).' According to the later memo 675 lb. was estimated based on actual plant measurements for Hatch Unit 2. BWROG survey provides an estimate of 150 lb./yr., which translates to 675 lb. for 3 cycle cleanings (each cycle of 18 months) planned by the utility.
The licensee should not use Transportable Foreign Material of 1.0 ft^2 as a substitute for FME Program.

2.5 STRAINER DESIGN

ECCS Operating Parameters

The utility provided the following parameters for ECCS pumps:

System # pumps	Flow Rate (GPM)	$NPSH_{Available}$ (ft-water)	$NPSH_{Required}$ (ft-water)	T_{pool} ^oF	Comments
RHR	9600	45	20.7	165	Short-term (no throttle)
(4)	7700	26	16.7	209	Long-term (throttle)
CS	5900	45	18.5	165	Short-term (no throttle)
(2)	4725	26	13.8	209	Long-term (throttle)

The utility proposes to take credit for decreased ECCS flow after core reflood (≈10 minutes post-LOCA) and thus reduced the flow from 9600 GPM to 7700 GPM. During long-term operation the suppression pool temperature is assumed to be 209 ^oF, which is higher than 202 ^oF used in the FSAR. As a result of increased suppression pool temperature, NPSH available decreased to 26 ft-water, while at the same time NPSH required also reduced slightly (≈ 4 ft-water) due to reduction in ECCS flow.

The $NPSH_{available}$ was estimated by crediting containment over-pressure of 5 psig. As noted above SEA has not performed any calculations to examine accuracy of that assumption or its consistency with licensing basis. Note that licensee determined to carry out NPSH calculation under 10 CFR 50.59.

The values used for flow rate and suppression pool temperature appear reasonable and are consistent with UFSAR numbers. The licensee assumed scenario (i.e., higher flow at start-up, decrease after 10 m; lower suppression pool temperature initially and increase during long-term operation) are consistent with accident analyses result in UFSAR.

The single failure analysis by the plant assumes availability of two RHR pumps and one CS pumps in the present plant configuration. On the other hand, future modifications may change the single failure criterion to one RHR pump and two core spray pumps. Usage of the later case to design the strainer poses more severe constraints than the former, because the later one allows for accumulation of more debris on the RHR strainer and hence higher head loss (Note that volume of debris collected on each strainer is proportional to the ratio of the flow through that strainer to the total ECCS flow from suppression pool). Since the design criteria is not to loose any of the pumps, the later case maximizes potential for loss of strainer if surface area is not

sufficiently large.

Head Loss Correlation and GE Strainer Sizing Criteria:
The plant intends to use vendor provided head loss correlation and sizing methodology described in Ref. 4. The actual size of the strainers were not provided. The approximate strainer sizes were provided in Ref. 5 to be 40"-diameter and 49"-long GE stacked disc strainers for RHR and 34"-diameter and 35"-long GE stacked disc strainers for CS. However, the licensee stated that fabrication issues may influence in the selection of the strainer design.

SEA is independently reviewing Ref. 4 and has several concerns. These concerns relate to GE's usage of the strainer performance data and derivation of the head-loss correlation. SEA is not in a position to make a judgment regarding the generic acceptability of the GE methods at the present time as the work is in progress. In particular it is not clear if GE methodology will result in either realistic or conservative estimate of head loss for a generic plant. SEA recommends that such an evaluation instead be made on a plant-specific basis. To facilitate such a plant-specific evaluation it is recommended that the licensee finalize the strainer design and forward it to NRC for review.

3.0 DEFICIENCIES

No serious deficiencies were noted regarding the criteria to be used for strainer design. Licensee is asked to finalize the design and forward their finalized strainer descriptions to NRC. This judgment does not reflect on licensee's usage of 5 psig for containment over-pressure. SEA believes this value to be larger than that most likely available during long-term operation. However, licensee intends to perform NPSH calculations under 10 CFR 50.59 and independent of strainer design criteria.

4.0 CONCLUSIONS

It is concluded that licensee estimated the quantity of debris reaching the strainers appropriately. These methodologies are consistent with RG 1.82, Rev. 2 and other methods previously reviewed by the NRC. Licensee's choice of 1 ft^2 of transportable material adds a reasonable conservatism, but should not be treated as an alternative to an effective Foreign Material Exclusion program. Licensee should provide finalized strainer design for NRC review (In the mean time SEA will be reviewing the approximate strainer information provided by the plant to facilitate quick-turn around).

5.0 REFERENCES

1. Southern Nuclear Operating Company, 'Proposed Criteria for ECCS Strainer Design, Edwin I. Hatch Nuclear Plant - Unit 1,' Docket No. 50-321, March 25, 1997.
2. BWROG, 'Utility Resolution Guidance for ECCS Suction Strainer Blockage,' NEDO-32686, November 20, 1996.
3. Updated Final Safety Analysis Reports.
4. General Electric Company, 'Licensing Topical Report: Application Methodology for GE Stacked Disk ECCS Suction Strainer (Proprietary Information),' NEDC-32721P, March 1997.
5. Southern Nuclear Generating Company, ' Response to Request for Additional Information on Proposed Criteria for ECCS Strainer Design,' Docket No. 50-366, May 28, 1997.

Appendix-A

Confirmatory Calculations Conducted by SEA to Assess Accuracy of Utility Estimates of Debris Loading on the Strainer

A.1 Selection of the Break

The utility explicitly stated that break location was selected not based on criterion of High Energy Line Breaks (HELB), which refers to locating the break close to the high stress points. Instead, break was selected so as to maximize the quantity of debris generated. [Ref.: See Response to Question #2 of Request for Additional Information].

Elevation of the break is 153' 1". It is about a foot above the upper grating. It is located in the most congested part of the containment, with respect to location of other target pipes. It is very similar to RCA-J006 of the Reference plant of NUREG/CR-6224 [Ref.: NUREG/CR-6224, Page 3-3; UFSAR].

Likely targets: a) Recirculation Line in which break occurred, b) Recirculation Manifold, c) Recirculation Risers, d) Feed Water Lines, e) Main Steam Lines and f) ECCS Injection Line. [Ref. NUREG/CR-6224, UFSAR].

During discussions with the utility they have stated that several breaks were analyzed, and that selected 'worst-case break' bounds debris generation estimates.

It is SEAs opinion that the utility selection of the break provides reasonable assurance that estimated debris would be bounding in terms of the quantity of fibrous. Further calculations are performed to ensure that the break bounds head loss estimates.

A.2 Debris Generation Estimates:

Utility used ***Method 3 of the URG*** to estimate zone of influence. The following calculations were performed as sanity check of utility estimates:

Insulation Quantities in the Containment:

Type	Volume (ft3)	Largest Pipe OD[1] (in)	Location
NUKON (un-jacketed)	2, 300	26 + 6	All primary and ECCS piping, RCIC also.
Calcium Silicate	361	26 + 6	MSL above the top weld. Neck region.
Urethane	274	Unknown	On chilled water supply pipes.

[1] Actual pipe size is unknown (SEA did not have this part of the FSAR). However, NUREG/CR-5640 (Overview and Comparison of US Commercial Nuclear Power Plants) suggests a value between 24" and 28" for the recirculation pipe OD. We selected a value of 26". This selection is not expected to influence our calculations significantly.

Urethane was screened out from the remaining calculations because it floats above water and, therefore, will not reach the strainer. Appears reasonable, although no supporting documentation is provided to confirm this finding.

Zone of Influence (ZOI) Estimates:

Type	P_{dest}[2] (psi)	Pipe Size[3] Correction	P_{dest} (psi)	A[4]	Recirc.[5] Correction	Final A
NUKON (un-jacketed)	10	1.0	10	4708	1.0	4708
Calcium Silicate	160	0.5	80	1750	0.4	700
~~Urethane~~						

The URG experimental data for calcium silicate is from three tests for aluminum jacketed. Page #157 provides damage information. Minimal damage is noted. These tests have limitations:

1. No tests were conducted between 19 L/D and 7 L/D.
2. Data obtained at 7 L/D may not be representative of the LOCA because of narrow nozzle used in the experiments.
3. Finally, Swedish experiments suggest that calcium silicate destruction is by erosion, which is proportional to the duration of exposure and temperature of the jet. BWROG tests did not address these issues.

Further explanation is provided in the SEA report

Equivalent Sphere Parameters:

Type of Insulation	Volume of the ZOI		Equivalent Radius	
	(D^3)	% of Containment	(D)	(ft.)
NUKON (un-jacketed)	4708	≈33%	≈11D	≈26
Calcium-Silicate	700	≈5%	≈5.5D	≈12

Comment:

1. These zones of influence are reasonable. Note that for NUKON, NUREG/CR-6224 assigned a zone of influence of about 7D compared to 12 D used by the utility.
2. In the case of calcium silicate their zone of influence is 5.5 D, which is slightly lower than the 7D used in the NUREG/CR-6224.

[2] Table 2 of Utility Resolution Guidance (Page #46)
[3] Note #3 to Table 2 in Utility Resolution Guidance (Page #47)
[4] Table #1, Radial Off-set > 3D/2 of the Utility Resolution Guidance (Page #45)
[5] Note #5 to Table 1 in Utility Resolution Guidance (Page #46)

Sanity check on the utility estimates of insulation targeted:

Sys ID	OD	Type	Thick	Length	Volume Targeted
Recirc. Line	26	Nukon	3	43.92	83.32
Recirc. Manifold	16	Nukon	3	30	37.29
Recirc. Risers	10	Nukon	2.5	60	40.89
Feed Water	16	Nukon	2.5	55.2	55.67
Main Steam Line	26	Nukon	3	114.86	217.9
ECCS Lines	16	Nukon	2.5	25	25.21
Valves etc.					40
				Total =	500.27

Assumptions:

1. NUREG/CR-6224 plant layout is similar to the Hatch plant layout. This assumption is expected to be reasonable.
2. Insulation Thickness as described by the Vendor during NUREG study.

SEA estimated volume of insulation targeted by the jet (or volume contained in a 12D sphere) is 500 ft^3, which is slightly lower than the utility estimated value of 580 ft^3. This confirms that utility estimates are reasonable.

A.3 Location of the Debris Generated

Utility stated that no debris is generated below the lowest grating. This appears reasonable for this postulated break location. The location of the break is 153', where as the location of the lowest grating is 127'. The elevation difference of 26' is approximately equal to 12D of the recirculation pipe. Thus, it is reasonable to assume that no debris are generated below the lowest grating.

A.4 Debris Loading on the Strainer

Fibrous debris reaching strainer: 580 ft^3 x 0.28 (transport factor) = 162 ft^3

Type of Debris	Quantity	Comment
Fibrous Debris (Nukon)	162 ft^3	Checked independently by SEA. Reasonable.
Calcium-Silicate	0	There may be some trace quantities of Ca-Si.
Sludge	675 lb.	Estimate revised from 920 lb. in the original.
Dust and Dirt	150 lb	URG Number. Also NUREG/CR-6224
Rust from Unpainted	50 lb.	URG Number.
Paint		Licensee estimates. Not checked by SEA.
Inorganic Zinc	47 lb.	
IOZ with Epoxy topcoat	85 lb.	
Epoxy	71 lb.	
Unqualified Paint Coating	117 lb.	Licensee estimates. Not checked by SEA.
Other (Trans. For. Mat.)	1.0 ft^2	Licensee estimate. Actual survey information.

The debris loading on the strainer appears reasonable.

Appendix-B
Confirmatory Calculations Conducted by SEA to Assess Licensee Assumptions Related to Head Loss

B.1 Break Details

The licensee has provided information for two breaks. The following table provides strainer loading for these two breaks:

Debris	Break #1		Break #2	
	Total	RHR Strainer	Total	RHR Strainer
Nukon	162 ft^3 (388 lb)	174 lb.	84 ft^3 (200 lb)	90 lb.
Calcium-Silicate	0	0	40 lb.	17.9 lb.
Sludge	675 lb.	303 lb.	675 lb.	303 lb.
Dust and Dirt	150 lb.	67.3 lb.	150 lb.	67.3 lb.
Rust from Unpainted	50 lb.	22.4 lb.	50 lb.	22.4 lb.
Paint - IOZ	47 lb.	21.1 lb.	47 lb.	21.1 lb.
Paint - IOZ with Epoxy	85 lb.	38.2 lb.	85 lb.	38.2 lb.
Paint - Epoxy	71 lb.	32 lb.	71 lb.	32 lb.
Unqualified Paint	117 lb.	52.5 lb.	117 lb.	52.5 lb.
Other	1.0 ft^2	1.0 ft^2	1.0 ft^2	1.0 ft^2

__Note:__

__Total:__ Total quantity of debris introduced into the pool. Reproduced from Table in Section A.4.

RHR Strainer: Quantity approaching the RHR strainer calculated as: ***Total *(RHR Flow of 7700 GPM/Net ECCS Flow of 17150 GPM)***

B.2 Interpretation of GE Data for Application to RHR Design

GE Licensing Topical Report 'Application Methodology for GE Stacked Disk ECCS Suction Strainer (NEDC-32721P)' provides data for type of strainers proposed for use by the licensee. SEA has not endorsed the methodology proposed in this document. Instead, SEA is conducting the following back-of-the envelope calculations to get order-of-magnitude estimates of head loss.

Assume that the strainer is 40" in diameter and 49" in hydraulic length as described in Licensee's response to the RAI. For such a strainer, SEA estimates a trough (or cavity) volume of 23 ft^3 or it can accommodate approximately 55 lb. of the fibrous insulation within the cavities, without much increase in the head loss; typically about 2-3 foot-of-water or less (see Test #GE-3 and GE-7). However, the expected loading in the present case is much larger than 50 lb. implying that a thick bed of insulation will form on the strainer surface. Its effectiveness in filtering the particulate debris should be adequately modeled.

Two sets of data for fibrous and sludge mixtures at 7500 GPM; the results of the tests are given below:

Test	Conditions	ΔH	
GE-7	100 lb. Fiber + 500 lb. Sludge	130 in-H_2O	Less fiber loading than plant
GE-3	50 lb. Fiber + 100 lb. Sludge	34 in-H_2O	Less both fiber and part. load

Clearly in both cases the strainer data cannot be used directly. One has to rely on the correlation developed by GE for design and strainer performance assessment.

B.3 SEA Assessment of GE Correlation

SEA is in the process of reviewing data and head loss correlation reported by GE. In general, SEA identified following draw-backs related to GE Methodology:

1. The experimental data for sludge were obtained for lower strainer loadings than anticipated in the plant application. For example, majority of the data were obtained for fibrous debris loading of 17 lb., 25 lb., and 50 lb., at which the cavities are not filled (i.e., 17 and 25 lb.) or only barely filled (50 lb.). Only few tests were reported for 75 lb. and 100 lb. where debris bed is expected to form on the strainer surface.
2. The correlation lacks theoretical basis for extrapolating head loss measurements obtained at lower strainer loading to the plant application (174 lb. of fibrous debris).
3. SEA is presently evaluating if the GE correlation nevertheless provides conservative head loss estimates. (Further discussions in a detailed report later).

B.4 Which Break should be used as the Design Basis Break? Break#1 or Break #2.

Two types of calculations were performed to determine which form the worst case.

NUREG/CR-6224 Correlation:

For the conditions of interest NUREG correlation predicts that:

$$\Delta P = K\,(1+0.54\eta)^{1.5}\,\Delta L$$

This gives that:

$$\Delta P_1/\_\Delta P_2 = (1+0.54\eta_1)^{1.5}\,\Delta L_1/(1+0.54\eta_2)^{1.5}\,\Delta L_2$$

where

ΔP is pressure in ft-water
η is sludge-to-fiber ratio filtered on the bed (not added to bed)
M_c/M_f is the particulate to fiber ratio added to pool
ΔL is the theoretical-thickness of the bed

The following table provides these variables for the plant application:

Quantity	Break #1	Break #2
DL_0	5.88	1.68
M_c/M_f	2.10	4.31
Filtration-Efficiency	0.85	0.80
η	1.80	3.45
$\Delta P_1/\_\Delta P_2$	2.0	--

This clearly establishes that increase in particulate ratio does not compensate for increase in circumscribed thickness on the strainer. The Break #1 is the worst case.

GE Correlation:

$$\Delta P = K\,(1+0.15\,M_c/M_f)\ \Delta L$$

$$\Delta P_1/\_\Delta P_2 = (1+0.15\eta_1)\ \Delta L_1/(1+0.15\eta_2)\ \Delta L_2$$

For this case it can be easily shown that Break #1 once again results as the worst-case break.