Westinghouse

Westinghouse Electric Company
Nuclear Services
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington DC 20555

Direct tel: 412-374-4643
Direct fax: 412-374-4011
e-mail: greshaja@westinghouse.com

Your ref:
Our ref: LTR-NRC-05-44
July 20, 2005

Subject: NRC Request for Additional Detail on Charging/Safety Injection Pump Runout Part 21 Evaluation

Reference: 1. LTR-NRC-05-25, "Interim Report of an Evaluation of a Deviation or Failure to Comply Pursuant to 10CFR21.21(a)(2)," dated April 12, 2005.

The attached information is provided in response to the NRC's request for additional detail in support of the closeout of Westinghouse Interim Report No. 04-006 (Reference 1).

If you have any questions regarding this matter, please contact me at (412)374-4643.

Regards,

/for

James A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Attachment

7010

Background

As part of an evaluation of Emergency Core Cooling System (ECCS) realignment from normal charging to injection, it has been determined that the Charging/ Safety Injection (CH/SI) pump flow rate may exceed the defined runout limits in a transient mode lasting for less than 7 seconds.

The runout condition occurs within a 10-second valve stroke interval following a large break LOCA (LBLOCA) when, on S-signal actuation, the CH/SI pump discharge isolation valves stroke closed in parallel with the SI isolation valves stroking open, coincident with the CH/SI pump coming up to speed. The extent of the runout condition (assuming non-degraded pump performance) can be seen in Table 1. The maximum predicted duration of the runout condition is 7 seconds.

Table 1 - Systems Performance

Valve Stroke Time (sec)	CH/SI Pump Flow (gpm)	
	3-loop 675 gpm	4-loop 580 gpm*
1	630.3	
2	747.6 (73)	556.8
3	796.0 (121)	573.2
4	809.2 (134)	579.3
5	815.1 (140)	584.2 (4)
6	818.6 (143)	588.3 (8)
7	814.6 (140)	589.9 (10)
8	771.3 (96)	577.3
9	673.6	534.8
10	673.9	

* Approved maximum runout limit for a duration of up to 15 minutes.

The event is a short-term transient and exists only under the following specific low-probability combination of initiating events and conditions for 3-loop and 4-loop Westinghouse NSSS plant designs that use centrifugal charging pumps (CCP) for post-LOCA high-head injection:

- An ANSI-defined Condition IV Double Ended Guillotine Break (DEGB) LOCA with subsequent rapid RCS depressurization.
- Loss-of-Offsite Power (LOOP) coincident with the DEGB LOCA.
- Loss of a CH/SI pump (either by pump failure or by loss of a full train of SI – loss of full train of SI was evaluated as the more limiting case).
- Repositioning of the charging flow control valve to the full open position by the pressurizer level control system.

As part of the evaluation of this plant condition, an assessment was made of the likelihood of the CH/SI pump being able to perform its safety function for a limited time period (~ 250 hours) subsequent to exposure to the hydraulic transient associated with the ECCS realignment. The 2½-inch RL-IJ 11-stage CH/SI pumps (600 bhp and 900 bhp versions) are postulated to briefly runout beyond their maximum flow limits (560 gpm and 675 gpm, respectively). As noted in Table 1, the 560 gpm pump is approved for limited operation at a runout limit of 580 gpm for up to 15 minutes. Comparison with the 580 gpm limit is appropriate for the short term transient (< 10 seconds) being considered here. It is recognized that the expected hydraulic conditions resulting from this transient are outside the design bases considered for the 2½-inch Model RL-IJ pump. However, since this scenario is part of the LBLOCA design basis event, the objective of this evaluation is to demonstrate reasonable assurance that the pumps will recover and continue to perform their safety function after the hydraulic transient, when system valves have completed the post-SI re-alignment.

The estimated system performance (assuming adequate NPSH is provided) during this short transient period is based on conservatively extrapolated non-degraded pump performance and is defined in Table 1. The amount of flow beyond the runout limit is indicated in parentheses.

Evaluation

The scope of this evaluation covers the two Pacific Pumps (now Flowserve) described above.

The general scenario evaluated is pump operation at flows beyond the previously approved runout flows discussed above. The pumps are installed in the plants such that a flooded pump suction condition is always provided (i.e., there is no suction lift duty required for these pumps to maintain pump prime). Since the 675 gpm pumps (3-loop plants) runout much further than the 560 gpm pumps (4-loop plants), the 675 gpm pump has been evaluated to bound both applications (see Table 1).

Actual data from NPSH testing of the 675 gpm pump (shown in Attachment 2) has been provided by Flowserve, and is used in the evaluation of this condition. The pump test performance data includes NPSH-required (NPSH-r, based on 3% head degradation), along with the associated head-flow points for the higher pump flows considered.

Using the Flowserve information, the plot in Attachment 1 was constructed for a conservative operating configuration based on the system resistance curve for a representative 3-loop plant. This configuration bounds the 560 gpm system (4-loop plant) since the 675 gpm system would experience a higher pump runout flow, and therefore generate more limiting conditions of pump performance. The pump performance beyond runout in Table 1 is obtained by estimating a non-degraded pump operating point. The minimum system resistance curve is based on a configuration having both the charging and safety injection system flow paths open in parallel. The resulting system flows are shown in Table 1 and the system resistance curve for the 3-loop plant is shown in Attachment 1. The pump test data provided by Flowserve (Attachment 2) was then plotted against the system resistance curve in Attachment 1. The non-cavitating (i.e. limited to 3% head degradation for NPSH-r testing purposes) flow break point, where the pump head would fall off due to high flow, was then determined using the Flowserve NPSH-r test data. This conservative flow point (about 709 gpm at 1372 ft of head with an NPSH-r = 53 ft) is assumed to occur even though adequate NPSH-actual (NPSH-a) is provided to the pump. The limiting NPSH-a is 102 ft from the refueling water storage tank (RWST) (and at a much higher flow), and may be higher still if NPSH-a is provided by the volume control tank (NPSH-a = 149 ft). Since the actual plant NPSH conditions will result in no, or insignificant, cavitation during the transient, it is concluded that the pump hydraulic performance during the transient will be stable.

For the Pacific 2½-inch RL-IJ 11-stage pump, the pump manufacturer considers the developed pressure across each stage in order to assess adequate support of the rotating assembly (via the impeller wear rings) for stable long term operation. From the above operating point for the 11 impeller stages, the following pressure differential is estimated across each stage:

1372 ft / 11 stages = 125 ft per stage / 2.3 ft/psi = 54 psi per stage

Using the rotor dynamic analysis presented in Reference 1 for the 560 gpm pump, the following pressure differential information is obtained.

1500 ft / 11 stages = 136 ft per stage / 2.3 ft/psi = 59 psi per stage

Although the pressure differential for the 675 gpm pump is slightly less than 59 psi across each stage, 54 psi is judged to provide adequate radial shaft support and damping during the short transient period evaluated such that damaging vibration and wear ring rubbing will be precluded. The resulting pressure differential is considered acceptable since: 1) excessive pump vibration, due to significant cavitation, will be prevented with adequate NPSH-a provided during the transient; 2) pump flow will be stable during the

transient and then return to the approved 675 gpm runout flow after the short transient time period; and 3) based on pump repair inspections, the wear ring clearances will be well within the stable operating range analyzed in Reference 1.

The rotating element thrust loading for the Pacific pumps is self balancing, with the use of a thrust balancing bushing arrangement. Therefore, the rotating element thrust loading is expected to remain balanced and well within the capability of the thrust bearing design loading during the flow transient. The pump performance curves show that the 675 gpm and 560 gpm pumps have a maximum Brake Horse Power (BHP) at the runout flow condition (675 gpm or 560 gpm, respectively). BHP at flow rates above this value will either decrease or result in no change. Therefore, it is concluded that maximum pump BHP is not affected by this transient event.

Evaluation Conclusions

The Pacific model 2½-inch RL-IJ 11-stage CH/SI pump is expected to briefly operate with insignificant cavitation at a higher flow capacity beyond the current approved runout flow limit during the transient period without damage or loss of safety function. The resulting pressure differential across each stage is considered to be acceptable, as well as the pump thrust loading. Maximum brake horse power is not impacted. The pump is therefore expected to recover to normal operating conditions when the runout conditions end, and to perform its design function for the required time needed for post-LOCA recovery.

Safety Impact

Westinghouse has concluded that there is no safety impact from this issue based on the judgment that the pump will be able to perform its design function for the required period needed for post-LOCA recovery. However, as part of this evaluation, the scenario where the remaining CH/SI pump is postulated to be unavailable was also examined.

For the DEGB specific to this issue, the need for high-head injection quickly becomes less critical as primary system fluid is discharged to containment through the break. With all CH/SI pumps unavailable, a decrease in the overall SI flow delivery would be experienced during the short-term portion of the LBLOCA transient. The resulting decrease in delivered SI flow is relatively small compared to the total flow provided by the remaining SI subsystems. However, the loss of the CH/SI pump flow may affect two aspects of LBLOCA long-term cooling: decay heat removal and the potential for boric acid precipitation within the core region.

For the Westinghouse 3-loop NSSS plants, the CH/SI pumps typically provide hot leg flow after alignment to hot leg recirculation. At hot leg switchover (HLSO), plants may or may not align the low-head residual heat removal (RHR) pump flow to the hot legs, depending on the plant-specific Emergency Operating Procedures. While hot leg flow from the CH/SI pumps would normally contribute to the available core boil-off make-up flow, the RHR pump flow (to either the hot legs or cold legs) would provide sufficient flow to replace core boil-off. As for the potential for boric acid precipitation, the limiting condition would be a cold leg break where boron concentration buildup occurs prior to the switchover to hot leg recirculation. With no CH/SI pumps available at HLSO, operators could take action to align some or all of the RHR pump flow to the hot legs. If no cold leg injection is maintained after realignment to hot leg recirculation, the operators have time to evaluate the need to return to cold leg injection after an extended period of time in hot leg recirculation.

For the Westinghouse 4-loop NSSS plants, the CH/SI pumps typically continue to provide cold leg flow after re-alignment of the other SI subsystems (i.e. RHR and/or SI pumps) to hot leg recirculation. This

cold leg flow addresses the potential for boric acid precipitation for hot leg breaks, after an extended period of time in hot leg recirculation. At HLSO, plants may or may not align the RHR pumps to the hot legs, depending on the plant-specific Emergency Operating Procedures. While cold leg flow from the CH/SI pumps would contribute to the available core boil-off make-up flow, the RHR and intermediate-head SI pump flow would provide sufficient flow to replace core boil-off. As for the potential for boric acid precipitation, the limiting condition would be a hot leg break when boron concentration increases starting after HLSO. In this case, the operators have time to evaluate the need to return to the cold leg alignment after an extended period of time in hot leg recirculation.

Corrective Action

The Westinghouse evaluation of this issue considered the CVCS and SI systems of two plants representative of 3-loop and 4-loop Westinghouse NSSS designs to determine the level of pump runout and/or pump performance degradation and the duration of the condition. Westinghouse is confident that this evaluation adequately addresses the as-supplied CVCS/SI configurations provided by Westinghouse. However, there is the potential that plants have made modifications to their system configurations that could impact the applicability of the generic evaluation. Therefore, the only generic recommendation that can be made is that affected plants that have made modifications to their CVCS or SI systems should evaluate the impact of the modifications for this issue as a precautionary action. Examples of plant changes that could impact this evaluation are:

- Replacement of CVCS flow control valves with higher C_v capability valves.
- Changes to motor-operated valve stroke times used to realign system configuration.
- Changes to setpoints and/or basis for overcurrent protection.
- Re-throttling the SI parts of the CH/SI pump system to flow rates higher than pump vendor approved flows.

Plant Applicability

The following table identifies the specific Westinghouse NSSS plants for which this issue is applicable.

3- Loop Plants		4-Loop Plants	
Beaver Valley Units 1 & 2	Ringhals Unit 2	Braidwood Units 1 & 2	Millstone Unit 3
Farley Units 1 & 2	Vandellos Unit 2	Byron Units 1 & 2	Salem Units 1 & 2
Shearon Harris	Kori Units 3 & 4	Callaway	Seabrook Unit 1
North Anna Units 1 & 2	Maanshan Units 1 & 2	Catawba Units 1 & 2	Sequoyah Units 1 & 2
V. C. Summer	Takahama Unit 1	Comanche Peak Units 1 & 2	Vogtle Units 1 & 2
Surry Units 1 & 2	Yonggwang Units 1 & 2	D. C. Cook Units 1 & 2	Watts Bar Unit 1
Almaraz Units 1 & 2		Diablo Canyon Units 1 & 2	Wolf Creek
Ascó Units 1 & 2		McGuire Units 1 & 2	OHI Units 1 & 2

Westinghouse 2-loop NSSS plants, as well as some of the 3-loop and 4-loop NSSS designs and the Combustion Engineering NSSS designs are not affected by this issue because these plants do not use CCPs for safety injection.

Communications

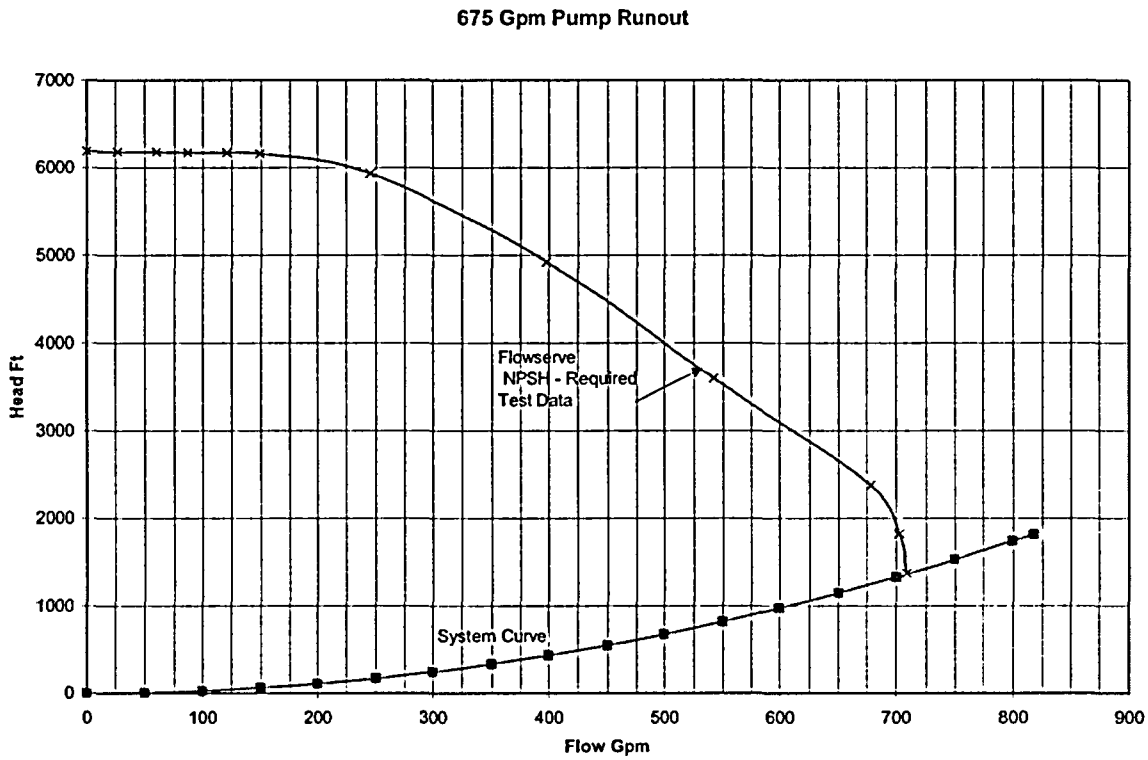
Westinghouse has issued the attached Nuclear Safety Advisory Letter NSAL-05-3 (Reference 2) to all affected plants with the 2½-inch RL-IJ 11-stage CCPs.

References

1. Westinghouse Topical Report WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," June 2005.
2. Westinghouse Nuclear Safety Advisory Letter NSAL-05-3, "Centrifugal Charging Pump Runout During Safety Injection," May 4, 2005.

Attachment 1

675 GPM Pump CH/SI Runout Performance



Flowserve Test Data for Above Plot
(From Attachment 2)

Flowserve Data (gpm)	Flowserve Data (ft)	NPSH-r
0	6191	
27	6180	
60	6180	
87	6173	
121	6172	
149	6159	
245	5934	
398	4926	
542	* 3601	18.1
679	* 2373	25.5
703	* 1822	37.9
709	* 1372	53.4

* Head degraded 3% for NPSH-r test data

Attachment 2

675 GPM Pump Performance Curves from Flowserve

Ingersoll-Dresser Pump Company
Huntington Park, California

PUMP TEST DATA
Doc. No. 264-NE-91100-01922

JOB ORDER INFORMATION

COMMERCIAL

Shop order no.	NE-91100-01
Serial no.	52920-922
Customer	Westinghouse Electric
Contractor	
Purchase order	MA-57571-D
Item no.	B-50479
Witnessed by	
Tested by	Bonner, R. E.
Checked by	Bonner, R. E.
Approved by	Alpan, K.
Date	12/22/94

TECHNICAL

	Suction	Radial
Imp. diameter (in.)	8.2500	8.200
Imp. pattern	M-8063	M-7475
Imp. material	11-13% Cr-St.	
Case material	11-13% Cr-St.	
Wrg. ring clr. (in.)	.012	
Spacer slv. clr. (in.)	.013	
Bal. drum clr. (in.)	.013	
Suct/Disch Dia (in.)	6.0650	4.0260
Flow meter C,	189.96	
Size (in.)	2.5" BL	
Type/Stages	IJ	11

GUARANTEED PUMPING CONDITIONS

RPM	Flow (GPM)	T.D.Head (ft)	NPSHR (ft)	Sp. Gr.	Temp. (°F)
4850	150.0	5780.0	16.00	1.0200	30

TEST DATA POINTS

	1	2	3	4	5	6	7	8	9	10
Speed (RPM)	4867	4866	4864	4867	4876	4896	4895	4891	4890	4887
Torque (in-lb)	6795.0	9650.0	9725.0	9330.0	8030.0	4895.0	5180.0	5510.0	5830.0	6280.0
Power (BHP)	526.89	745.05	750.53	720.49	621.25	380.26	402.32	427.60	452.34	486.95
Suction pressure (psi)	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Diff. pressure (psi)	2711.0	1042.0	1578.0	2144.0	2603.0	2714.0	2708.0	2706.0	2704.0	2703.0
Diff. head (feet)	6252.1	2413.5	3655.0	4961.8	6023.4	6284.6	6273.5	6275.0	6266.2	6265.2
Velocity head (feet)	.178	3.649	2.383	1.281	.485	.000	.006	.029	.061	.118
Total diff. head (feet)	6253.3	2418.2	3659.1	4964.0	6024.9	6285.6	6274.5	6276.1	6267.2	6266.3
Suction temp. (°F)	73	86	91	92	93	94	94	94	96	96
Suction S. G.	.998	.996	.995	.995	.995	.995	.995	.995	.994	.994
Discharge temp. (°F)	81	91	96	94	98	105	109	118	110	112
Discharge S. G.	1.005	.998	.999	1.001	1.002	1.000	1.000	.998	.999	.999
Average S. G.	1.002	.997	.997	.998	.998	.998	.997	.996	.997	.997
Venturi pressure (psid)	0.62	12.66	8.26	4.44	1.68	0.00	0.02	0.10	0.21	0.41
Temp. correction factor	1.001	1.002	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003
Flow (GPM)	149.68	677.22	547.32	401.32	246.89	.000	26.94	60.24	87.32	122.01
* Efficiency	44.94	55.36	67.19	69.70	60.36	.000	10.58	22.24	30.45	39.51

* The efficiency curve represents the true performance characteristics of test head and power measurements.

PERFORMANCE AT RATED CONDITIONS OF FIELD RPM & 1.0200 SP. GR.

	1	2	3	4	5	6	7	8	9	10
Flow (GPM)	149.07	672.09	542.63	398.26	245.0	.000	26.74	59.78	86.66	121.08
Total diff. head (feet)	6159.0	2381.7	3603.9	4926.3	5934	6190.8	6179.85	6179.9	6172.66	6171.8
Power (BHP)	526.28	744.8	749.7	725.0	620.4	379.9	402.3	427.67	452.49	488.27
@ RPM =	4850	4829	4827	4830	4839	4859	4858	4854	4853	4850

Ingersoll-Dresser Pump Company
Huntington Park, California

NPSH TEST DATA

Doc. No. 258-NE-91100-01922

Shop order no.	NE-91100-01
Serial no.	52920-922
Size	2.5" RL
Type	IJ
Number of stages	11
C_v	189.96

Customer	Westinghouse Electric
Contractor	
Purchase order	74A 5353/ D
Item no.	B-50479
Date	12/21/94

TEST DATA POINTS

	1	2	3	4	5	6	7	8	9	10
Speed (RPM)	4829	4833	4835	4864	4847	4887	4891			
Diff. pressure (psid)	582.0	776.0	1010.0	1510.0	2081.0	2629.0	2630.0			
Diff. head (feet)	1355.5	1804.7	2353.5	3519.5	4851.6	6129.2	6131.5			
Velocity head (feet)	3.968	3.904	3.651	2.406	1.247	.180	.029			
Total diff. head (feet)	1360.5	1809.6	2358.2	3522.9	4853.9	6130.4	6132.6			
Barometric Press. (Hg")	29.98	29.98	29.98	29.98	29.98	29.98	29.98			
Suction Pressure (psi)	8.4	1.6	-3.4	-6.3	-8.2	-11.2	-11.6			
Suction temp. (°F)	107	101	109	110	111	111	111			
Suction S. G.	.992	.993	.991	.991	.991	.991	.991			
Venturi pressure (psid)	13.70	13.50	12.60	8.30	4.30	0.62	0.10			
Temp. correction factor	1.004	1.004	1.005	1.005	1.005	1.005	1.005			
Flow (GPM)	706.18	700.49	677.41	549.87	395.83	150.30	60.36			
NPSH (feet)	51.12	35.68	23.49	16.67	12.14	5.148	4.215			
Vel. head suction (feet)	.959	.944	.883	.582	.301	.043	.007			
Elevation Head (feet)	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
NPSHR (feet)	53.08	37.63	25.38	18.25	13.44	6.192	5.223			

PERFORMANCE AT RATED CONDITIONS OF 4850 RPM & 1.0200 SP. GR.

	1	2	3	4	5	6	7	8	9	10
Flow (GPM)	709.26	702.95	679.51	548.29	396.07	149.17	59.86			
Total diff. head (feet)	1372.3	1822.3	2372.8	3502.7	4859.9	6037.9	6030.2			
NPSHR (feet)	53.54	37.89	25.54	18.14	13.46	6.098	5.135			

Doc./Curve No. 262-NE-91100-01!

Ingersoll-Dresser Pump Company
Huntington Park, California

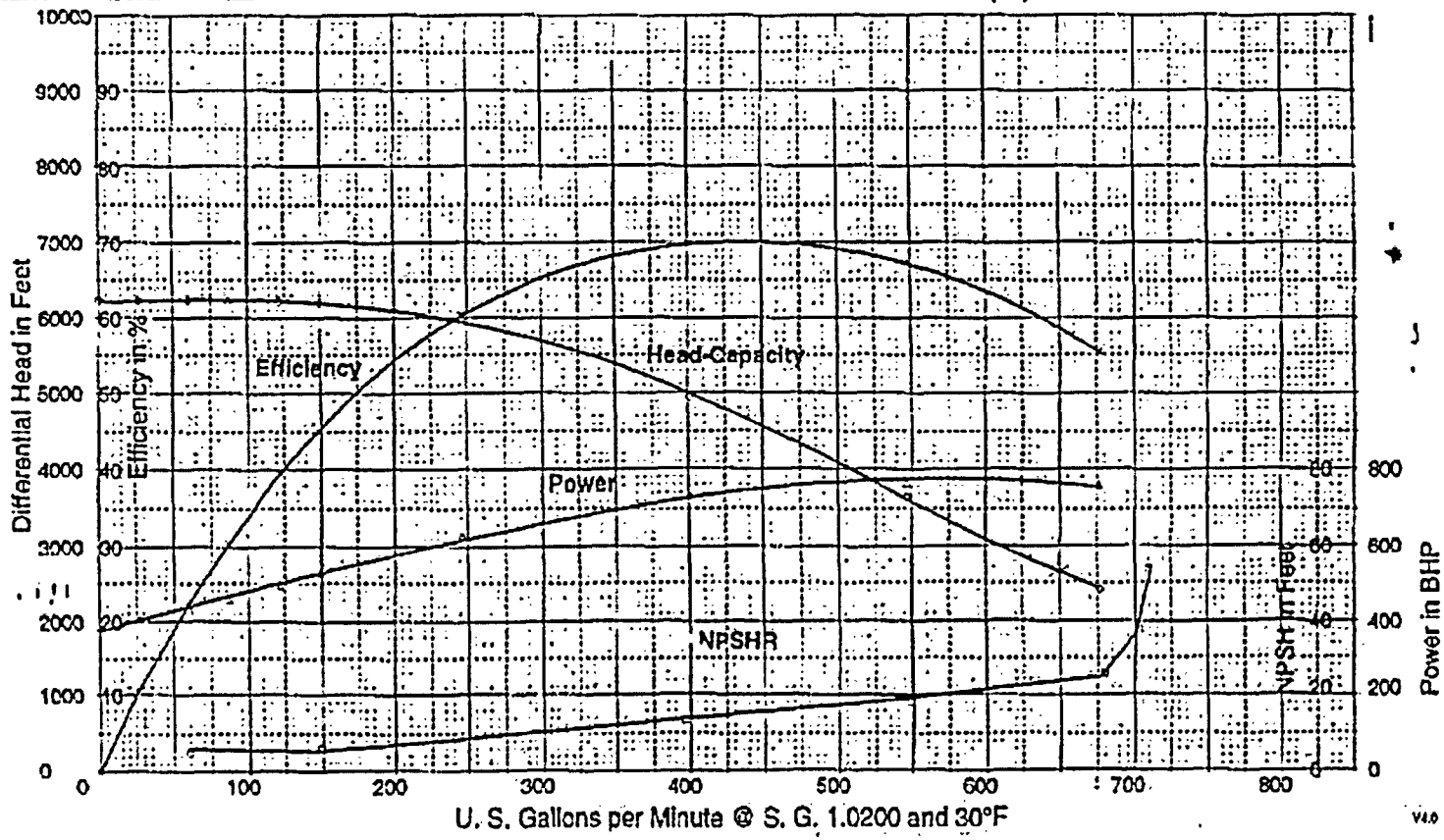
Test Engr.	
Witness	

Contractor _____
Customer Westinghouse Electric
Item No. B-50479
P. O. No. MA-57571-D

Pump Serial Number 52920-922
Ref. Job _____

Size 2.5" BL Type JJ Stages 11 R.P.M. FIELD
Date 12/22/94 Impeller Eye Area (sq. in.) 11.90

	Suction	Radial
Impeller Pattern	M-8063	M-7475
Maximum Diameter (in.)	8.250	8.250
Rated Diameter (in.)	8.2500	8.2000
Minimum Diameter (in.)	7.250	7.250



Nuclear Safety Advisory Letter

Westinghouse Electric Company

This is a notification of a recently identified potential safety issue pertaining to basic components supplied by Westinghouse. This information is being provided so that you can conduct a review of this issue to determine if any action is required.
P.O. Box 355, Pittsburgh, PA 15230

Subject: **Centrifugal Charging Pump Runout During Safety Injection**	Number: **NSAL-05-3**
Basic Component: Centrifugal Charging Pump	Date: 05/04/05

Affected Plants: All 3-loop and 4-loop Westinghouse NSSS designs that use centrifugal charging pumps for safety injection (See list on page 4)

Substantial Safety Hazard or Failure to Comply Pursuant to 10 CFR 21.21(a)	Yes ☐	No ☒
Transfer of Information Pursuant to 10 CFR 21.21(b)	Yes ☐	
Advisory Information Pursuant to 10 CFR 21.21(d)(2)	Yes ☐	

References:
1. LTR-NRC-05-5, "Interim Report of an Evaluation of a Deviation or Failure to Comply Pursuant to 10CFR2121(a)(2)", January 27, 2005.
2. LTR-NRC-05-25, "Closure of Westinghouse Interim Report No. 04-006", April 12, 2005.

SUMMARY

A recent effort to extend a 10-second stroke time of the centrifugal charging pump (CCP) discharge isolation valves and the safety injection (SI) isolation valves has identified an issue that could cause a single operating CCP to exceed its runout flow for a portion of the current valve stroking period. The issue arises when receipt of an SI (S) signal, initiated by a large break loss-of-coolant accident (LBLOCA) event, actuates these motor-operated valves in parallel, coincident with start of a single CCP. This action realigns the system (isolates charging) from a normal charging configuration to the SI configuration. The actual flow rate during the valve stroking period is not important to system performance, but LBLOCA analysis assumptions credit the CCP operating at a performance level consistent with design parameters following the realignment. A postulated total loss of pump operability would have no significant plant safety consequences due to the alternate capabilities in system design to provide adequate post-LBLOCA short-term and long-term core cooling and hot leg recirculation to preclude boron precipitation.

Based on the Westinghouse-supplied chemical and volume control system (CVCS) configuration, the current CCP/system pump runout flow limits and information available in the open literature, a generic Westinghouse evaluation has concluded that with the abundant net positive suction head (NPSH) initially available after SI actuation providing a continuously flooded pump suction, the CCP will not completely

Additional information, if required, may be obtained from the originators. Telephone (412) 374-4314 or -5629

Originator:(s)

W. D. Klein
Regulatory Compliance and Plant Licensing

G. G. Konopka
Systems and Equipment Engineering

Approved:

J. S. Gresham, Manager
Regulatory Compliance and Plant Licensing

Official record electronically approved in EDMS

lose prime and will re-establish normal flow following some degraded performance due to high pump flow cavitation. It is expected that during this short period of cavitation, pump vibration amplitude may increase and intermittent metal-to-metal contact and rubbing may occur at the wear ring locations within the low-pressure stages of the CCP. Given the nature of the material of the wear rings, the short duration and the once-in-a-plant-lifetime frequency, Westinghouse concludes that this transient will not result in more wear to the wear ring than is considered by the original design, which occurs from normal contact during CCP startup and shutdown. It is Westinghouse's judgment, therefore, that the runout condition for 3-loop and 4-loop Westinghouse NSSS plants will not significantly impact the post-LBLOCA availability or capability of the CCP.

ISSUE DESCRIPTION

The issue involves CCP availability and capability following operation for a very short period of time at beyond vendor-approved runout flow rates. The runout condition occurs following a LBLOCA during the period of time when, on S-signal actuation, the CCP discharge isolation valves stroke closed in parallel with the SI isolation valves stroking open, coincident with the CCP coming up to speed.

The event is a short-term transient (less than10 seconds) and exists only under the following specific low-probability set of conditions. For the 3-loop and 4-loop Westinghouse NSSS plant designs that use CCPs for post-LOCA high-head injection, the following specific combination of initiating events and conditions may lead to CCP flow rates beyond the pump vendor approved values:

- An ANSI-defined Condition IV double ended guillotine break (DEGB) LOCA with subsequent rapid RCS depressurization.
- Loss-of-offsite power (LOOP) coincident with the DEGB LOCA.
- Loss of a CCP (either by pump failure or by loss of a full train of SI – loss of full train of SI was evaluated as the more limiting case).
- Repositioning of the charging flow control valve to the full open position by the pressurizer level control system.

Westinghouse has conservatively estimated the probability of these conditions existing simultaneously to be between 5.0E-10 and 2.0E-12 per year.

Although the interval of beyond-runout conditions is short, and only a single occurrence of a LBLOCA in plant operating life is permitted by design, pump operation beyond-runout flow has not been approved by the pump vendor and no prediction of the post-transient capability of the pump has been provided by the pump vendor.

TECHNICAL EVALUATION

For affected plants using an 11-stage Pacific Pump model 2.5" RLIJ (600 bhp or 900 bhp) in an SI application, Westinghouse has characterized the runout conditions (assuming no pump performance degradation) for a representative 4-loop NSSS plant as a 3-second period of the 10-second stroke time when flow exceeds runout. During this interval, the amount of flow over runout reaches a maximum of approximately 10 gpm. A representative 3-loop NSSS plant would experience a 7-second period of the 10-second stroke time with flow beyond runout, reaching a maximum of approximately 145 gpm.

An in-depth review of information available in the open literature has enabled Westinghouse to make the judgment that although some additional wear cannot be precluded, impact is expected to be limited to minor incremental wear on the pump wear rings. The increased wear is judged to remain within the

normal range of the wear rings, as considered in the original CCP design. The CCPs normally experience wear ring contact during each startup and shutdown. Some temporary hydraulic performance degradation, due to cavitation in the low pressure stages of the pump, is expected during the short time period of the runout flow condition (i.e., limited to the valve stroke time period). However, the pump is expected to recover to normal operating conditions when the system transient (i.e., valve alignment) is completed, and to be able to perform its design function for the required period needed for post-LOCA recovery. Since the normal delay in SI flow delivery bounds the valve stroke times as well as the pump start up time, there is no shortfall in delivered SI flow during the short period of diminished CCP performance when the valves are stroking. Therefore there is no impact on the conservative assumptions used to calculate licensing-basis SI flows and the associated delay time in SI flow delivery.

The 3-loop and 4-loop CCP performance curves show that the CCP has a maximum brake horsepower (BHP) at the runout flow condition. BHP at flow rates above this value will either decrease or result in no BHP change. Also, the head loss due to cavitation will reduce the BHP below the maximum BHP. For plants that set the CCP motor overcurrent protection setpoint based on the maximum motor BHP at the pump design runout condition, this scenario should not result in additional challenges or failures to the CCP motor.

There is one 3-loop plant identified in the evaluation of this issue that uses a nine-stage Byron-Jackson model D.V.M.X., 550 gpm CCP for SI. Westinghouse has no current information on the system performance or the pump runout flow limits for the Byron-Jackson CCP to evaluate this issue; therefore, Westinghouse has contacted the utility and identified the issue to them.

SAFETY SIGNIFICANCE

Westinghouse has concluded that there is no safety impact from this issue based on the judgment that the pump will be able to perform its design function for the required period needed for post-LOCA recovery. However, as part of this evaluation, the scenario where the remaining CCP is unavailable was also examined.

For the DEGB specific to this issue, the need for high-head injection quickly becomes less critical as primary system pressure is discharged to containment through the break. With all CCPs unavailable, a decrease in the overall SI flow delivery would be experienced during the short-term portion of the large break LOCA transient. The resulting decrease in delivered SI flow is relatively small compared to the total flow provided by the remaining SI subsystems. With respect to large break LOCA long-term cooling, the loss of the CCP flow may affect two aspects of long-term cooling: decay heat removal and the potential for boric acid precipitation within the core region.

For the Westinghouse 3-loop NSSS plants, the CCPs typically provide hot leg flow after alignment to hot leg recirculation. At the hot leg switchover (HLSO) time, plants may or may not align the low-head residual heat removal (RHR) pump flow to the hot legs, depending on the plant-specific Emergency Operating Procedures. While hot leg flow from the CCP(s) would normally contribute to the available core boil-off make-up flow, the RHR pump flow (to either the hot legs or cold legs) would provide sufficient flow to replace core boil-off. As for the potential for boric acid precipitation, the limiting condition would be a cold leg break where boron concentration buildup occurs prior to the switchover to hot leg recirculation. With no CCPs available at HLSO time, operators could take action to align some or all of the RHR pump flow to the hot legs. If no cold leg injection is maintained after realignment to hot leg recirculation, the operators have time to evaluate the need to return to the cold leg injection after an extended period of time in hot leg recirculation.

For the Westinghouse 4-loop NSSS plants, the CCPs typically continue to provide cold leg flow after re-alignment of the other SI subsystems (i.e., RHR and/or SI pumps) to hot leg recirculation. This cold leg flow addresses the potential for boric acid precipitation for hot legs breaks, after an extended period of time in hot leg recirculation. At the HLSO time, plants may or may not align the RHR pumps to the hot legs, depending on the plant-specific Emergency Operating Procedures. While cold leg flow from the CCPs would contribute to the available core boil-off make-up flow, the RHR and intermediate-head SI pump flow would provide sufficient flow to replace core boil-off. As for the potential for boric acid precipitation, the limiting condition would be a hot leg break when boron concentration increases starting after the HLSO time. In this case, the operators have time to evaluate the need to return to the cold leg alignment after an extended period of time in hot leg recirculation.

NRC AWARENESS

An interim report was filed with the NRC (Reference 1) and a final report was filed with the NRC (Reference 2).

AFFECTED PLANTS

The following table identifies the specific Westinghouse NSSS plants for which this issue is applicable.

3- Loop Plants		4-Loop Plants	
Beaver Valley Units 1 & 2	Ringhals Unit 2	Braidwood Units 1 & 2	Millstone Unit 3
J. M. Farley Units 1 & 2	Vandellós Unit 2	Byron Units 1 & 2	Salem Units 1 & 2
Shearon Harris	Kori Units 3 & 4	Callaway	Seabrook Unit 1
North Anna Units 1 & 2	Maanshan Units 1 & 2	Catawba Units 1 & 2	Sequoyah Units 1 & 2
V. C. Summer	Takahama Unit 1	Comanche Peak Units 1 & 2	Vogtle Units 1 & 2
Surry Units 1 & 2	Yonggwang Units 1 & 2	D. C. Cook Units 1 & 2	Watts Bar Unit 1
Almaraz Units 1 & 2		Diablo Canyon Units 1 & 2	Wolf Creek
Ascó Units 1 & 2		McGuire Units 1 & 2	Ohi Units 1 & 2

Westinghouse 2-loop NSSS as well as some of the 3-loop and 4-loop NSSS designs and the Combustion Engineering NSSS designs are not affected by this issue because these plants do not use CCPs for SI.

RECOMMENDED ACTIONS

The Westinghouse evaluation of this issue considered the CVCS and SI systems of two plants representative of 3- and 4-loop Westinghouse NSSS designs to determine the level of pump runout and/or pump performance degradation and the duration of the condition. Westinghouse is confident that this evaluation adequately addresses the as-supplied CVCS/SI configurations provided by Westinghouse. However, there is the potential that plants have made modifications to system configuration that could impact the applicability of the generic evaluation. Affected plants that have made modifications to their CVCS or CCP/SI system should evaluate the impact of the modification(s) for this issue as a precautionary action. Examples of plant changes that could impact this evaluation are:

- The replacement of CVCS flow control valves with higher C_v capability valves
- Changes to motor-operated valve stroke times used to realign system configuration.
- Changes to setpoints and/or basis for overcurrent protection.
- Rethrottling the SI parts of the CCP system to flow rates higher than pump vendor-approved flows.

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