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: 412-374-4419
Direct fax: 412-374-4011
e-mail: maurerbf@westinghouse.com

Your ref:
Our ref: LTR-NRC-05-44, Rev. 1
February 9, 2006

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). This revision incorporates additional detail discussed during phone conferences with the NRC and removes information no longer pertinent.

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

Regards,

Bradley F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Attachment

IE19

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 (CC/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 an 'S-signal' actuation, the CC/SI pump discharge isolation valves stroke closed in parallel with the SI isolation valves stroking open, coincident with the CC/SI pump coming up to speed. 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 CC/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 CC/SI pump being able to perform its safety function) subsequent to exposure to the hydraulic transient associated with the ECCS realignment. The 2½ inch RL-IJ 11-stage CC/SI pumps (600 bhp – 4 loop plant and 900 bhp -3 loop plant versions) are postulated to briefly runout beyond their maximum flow limits (560 gpm and 675 gpm, respectively). 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.

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.

Hydraulic Evaluation

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 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 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-available (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.

Lateral Shaft Dynamic/Vibration Evaluation

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

The Reference 1 dynamic analysis (for the 560 gpm 2½-inch RL-IJ model pump) is not intended to directly apply to, or bound, the 675 gpm pumps. The report provides an indication of the amount of wear the 550 gpm pump wear rings could tolerate, and therefore provides general insight as to how the pump is expected to dynamically respond with lower levels of shaft support at the higher runout flows. This information was applied by using the study results showing that even if the wear ring clearance increased to approximately 2X (i.e., two times the initial wear ring clearance) along with the low inter-stage delta-P (which would be similar to the effect of lower shaft support due to slightly lower inter-stage delta-P) the pump would be expected to operate in the acceptable range for the operating speeds applicable to these pumps (e.g., as shown in Figures A3 and A4 of Reference 1; Note Figure A4, with the heavier coupling, would be closer to the 675 gpm pump application).

Although the pressure differential for the 675 gpm pump is slightly less than 59 psi across each stage as evaluated in Reference 1, 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.

To further confirm the above expectations, Flowserve was able to locate the actual pump vibration test data for the 675 gpm pump (pump No. NE91100-01 – the same pump shown in Attachment 2) at the flow conditions as shown below in Table 1. The filtered vibration velocity data (inches per second – IPS) was measured at the conditions defined on the test data sheet as: Min Flow, Rated Flow and Max Flow.

Table 1 – Vibration Test Data for Pump No. NE91100-01

Location	Min Flow 60 gpm (IPS)	Rated Flow 140.7 gpm (IPS)	Max Flow 677.2 gpm (IPS)	Comments on Results
Inboard bearing housing – vertical	0.061	0.061	0.066	Good
Inboard bearing housing – horizontal	0.041	0.023	0.039	Good
Outboard bearing housing – vertical	0.038	0.050	0.041	Good
Outboard bearing housing – horizontal	0.016	0.013	0.015	Smooth
Outboard bearing housing – axial (thrust)	0.080	0.042	0.029	N/A

The following general criteria were applied to judge the results:

≤ 0.0049 IPS	Extremely Smooth	0.0196 - 0.0392 IPS	Very Good
0.0049 - 0.0098 IPS	Very Smooth	0.0392 - 0.0785 IPS	Good
0.0098 - 0.0196 IPS	Smooth	0.0785 - 0.157 IPS	Fair

The above criteria compares to the ASME OM Code (2004) as follows:

≤ 0.325 IPS	Acceptable
0.325 - 0.70 IPS	Alert
≥ 0.70 IPS	Required Action

From Attachment 2, the best efficiency point (BEP) for the 675 gpm pump evaluated occurs at approximately 430 gpm. The maximum flow for which vibration data was measured is 677 gpm, or 57% above BEP. As shown in Attachment 1, the pump flow will run out to approximately 709 gpm, or 64% above BEP. Since the vibration levels at 677 gpm (57% above BEP) are well within the acceptable range, the vibration levels at 709 gpm would be expected to only increase slightly at 64% above BEP and remain well within the acceptable (or below the alert) range during the short transient time at high pump flow. Therefore, it is concluded that the pump vibration levels will be acceptable during the short runout flow transient evaluated.

Shaft Axial/Thrust Load Evaluation

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 horsepower (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 CC/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, along with the associated vibration levels are considered to be acceptable, as well as the pump shaft 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. Based on these evaluation results, there is no safety impact from this issue.

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 for 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:

- The replacement of CVCS flow control valves with valves of higher flow coefficient (C_v) capability.
- Changes to motor-operated valve stroke times used to realign system configuration.
- Rethrottling the SI parts of the CCP 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
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 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, Revision 1 (Reference 2) to all affected plants with the 2½ inch RL-IJ 11-stage CCPs.

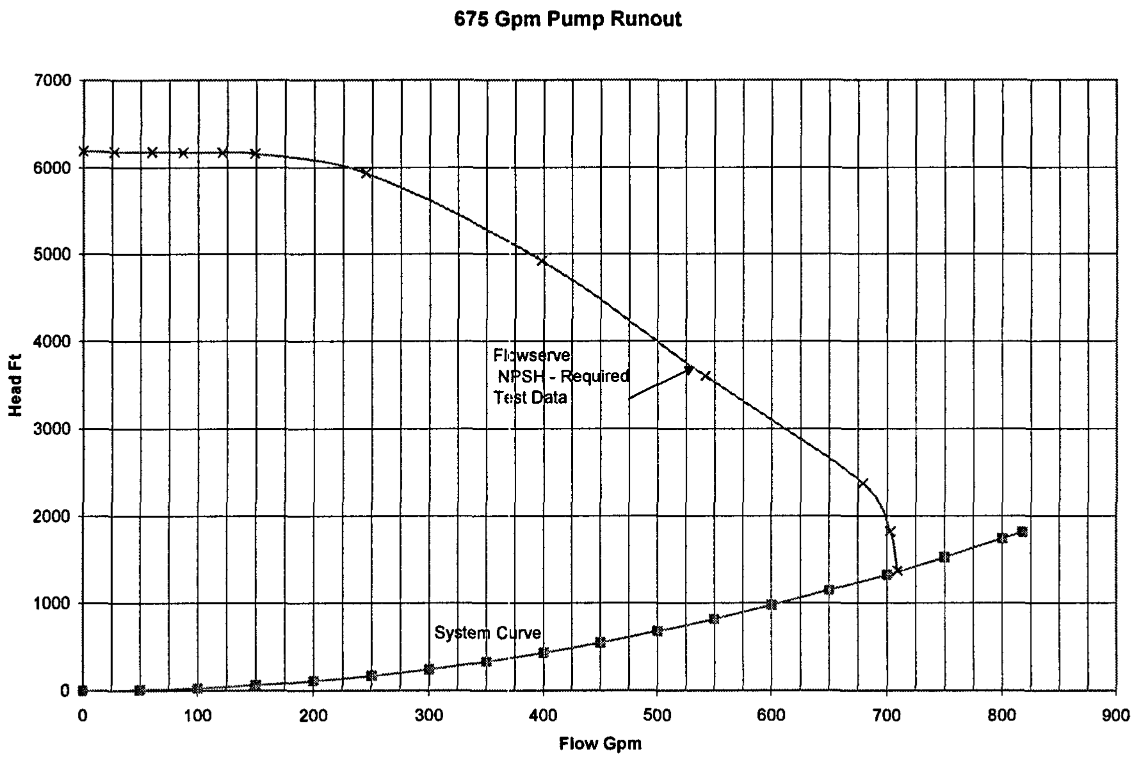
References

1. Flowserve Pump Division Report Number SR-1072, "Summary Report, Lateral Rotor Dynamic Analysis, Pump Size/Type 2.5" RL-IJ 11 Stages and 3.0" JHF 10 Stages," March 9, 2005.
2. Westinghouse Nuclear Safety Advisory Letter NSAL-05-3, Revision 1 "Centrifugal Charging Pump Runout During Safety Injection," February 9, 2006.

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

Attachment 1

675 GPM Pump CC/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

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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-60479
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_v	189.96	
Size (in.)	2.5" RL	
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)	4887	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	3655.8	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

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P.O. Box 355
Pittsburgh, PA 15230-0355

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	[illegible]
Item no.	B-50479
Date	12/[illegible]/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			

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Pittsburgh, PA 15230-0355

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

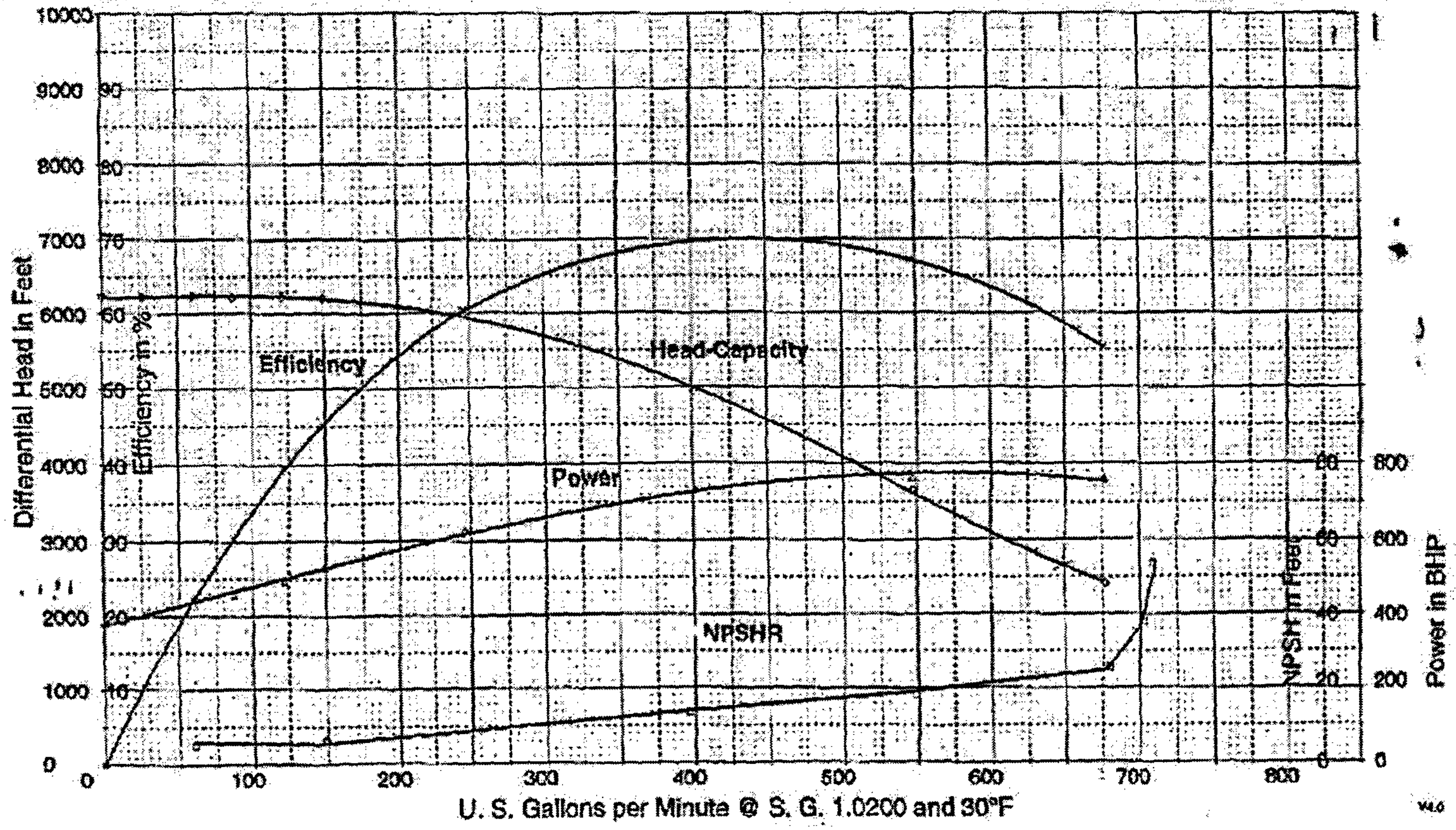
Ingersoll-Dresser Pump Company
Huntington Park, California

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 __LL__ 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

Westinghouse Electric Company

Advisory Letter

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, Rev. 1**
Basic Component: Centrifugal Charging Pump	Date: 02/09/2006

Affected Plants: All 3-loop and 4-loop Westinghouse NSSS designs that use centrifugal charging pumps for safety injection. (See 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.
3. LTR-NRC-05-44, Rev. 1, "NRC Request for Additional Detail on Charging / Safety Injection Pump Runout Part 21 Evaluation," February 9, 2006.

SUMMARY

An evaluation of emergency core cooling system (ECCS) realignment from normal charging to injection has identified a condition that could cause a single operating Pacific model 2½ inch RL-IJ 11-stage centrifugal charging/safety injection (CC/SI) pump to exceed its runout flow for a portion of the current valve stroking period. The condition 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 CC/SI pump. 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 CC/SI pump operating at a performance level consistent with design parameters following the realignment.

Based on test data from the pump vendor, the Pacific model 2½ inch RL-IJ 11-stage CC/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, along with the associated vibration levels are considered to be acceptable, as well as the pump shaft thrust loading. Maximum brake horsepower is not impacted.

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:

B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Official record electronically approved in EDMS

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. Based on these evaluation results, there is no safety impact from this issue.

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.

ISSUE DESCRIPTION

The issue involves CC/SI pump 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 CC/SI pump discharge isolation valves stroke closed in parallel with the SI isolation valves stroking open, coincident with the CC/SI pump 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 CC/SI pumps for post-LOCA high-head injection, the following specific combination of initiating events and conditions may lead to CC/SI pump 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 CC/SI pump (either by pump failure or by loss of a full train of SI – loss of a 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.

TECHNICAL EVALUATION

For affected plants using an 11-stage Pacific Pump model 2½ inch RL-IJ [600 brake horsepower (bhp) or 900 bhp] in an SI application, Westinghouse has characterized the runout conditions. Using vendor-supplied data from net positive suction head (NPSH) testing of the 675-gpm pump, which included flow beyond runout, and rotor dynamic analysis for the 560 gpm pump, the Westinghouse evaluation examined hydraulic performance of the pump, lateral shaft dynamic/vibration, and shaft axial /thrust load.

The evaluation of pump hydraulic performance plotted vendor test data against a representative 3-loop-plant minimum system resistance curve based on a conservative operating configuration having both the charging and safety injection system flow paths open in parallel. 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 non-cavitating [i.e. limited to 3% head degradation for NPSH-required (NPSH-r) testing purposes] flow break point, where the pump head would fall off due to high flow, was then determined using the vendor 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-available (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 developed pressure across each stage is used to assess adequate shaft support of the rotating assembly (via the impeller wear rings) for stable long-term operation. From a rotor dynamic analysis performed by the pump vendor for the 560 gpm pump (600 bhp – 4-loop plant configuration), the pressure differential across each of the 11 stages with 1500 feet of operating head at run out conditions is estimated to be 59 psi. Dynamic characteristics of the pump degrade as wear occurs and wear ring clearance increases. The dynamic analysis concluded that the 560 gpm pump can satisfactorily be operated at twice its design wear ring clearance at run out conditions. The conclusion of the dynamic analysis may not bound the 675 gpm pump, but provides an indication of the amount of wear the wear rings of the 2½ inch RL-IJ model pump could tolerate, and therefore provides insight as to how the pump is expected to dynamically respond with lower levels of shaft support experienced at runout flows.

For the 1372 feet of operating head at runout flow, the pressure differential across each of the 11 impeller stages, is estimated to be 54 psi (900 bhp, 675 gpm pump – 3-loop plant configuration). 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. The 54 psi 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 acceptable twice design clearance. Vendor-supplied vibration test data on the 675 gpm pump supports this conclusion in that the vibration test data includes a maximum flow of 677 gpm with resultant vibration levels well within the acceptable range. At 677 gpm, the pump is 57% above its best efficiency point (BEP). At a flow of 709 gpm, the pump would be approximately 64% above BEP with only an expected slight increase in vibration, yet remain within the acceptable level. Therefore, it is concluded that the pump would be expected to operate at vibration levels in the acceptable range for the operating speeds applicable to these pumps during the short runout flow transient evaluated.

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 horsepower at the runout flow condition (675 gpm or 560 gpm, respectively). Brake horsepower at flow rates above this value will either decrease or result in no change. Therefore, it is concluded that maximum pump brake horsepower is not affected by this transient event.

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 conclusion that the pump will be able to perform its design function for the required period needed for post-LOCA recovery.

NRC AWARENESS

An interim report was filed with the NRC (Reference 1) and a final report was filed with the NRC (Reference 2). Reference 3 is the final resolution of an NRC request for addition detail on the evaluation following submittal of 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 chemical and volume control system (CVCS) and SI systems of two plants representative of 3- and 4-loop Westinghouse NSSS designs to determine the level of pump ruout 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 valves of higher flow coefficient (C_v) capability
- Changes to motor-operated valve stroke times used to realign system configuration.
- Rethrottling the SI parts of the CCP system to flow rates higher than pump vendor approved flows.