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Alabama Power
the southern electric system

October 3, 1988

Docket Nos. 50-348
50-364

Enforcement Action 88-113

Director, Office of Enforcement
U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Gentlemen:

Joseph M. Farley Nuclear Plant NRC Inspections of
February 22 - March 11, 1988

RE: Notice of Violation and Proposed Imposition
of Civil Penalty

This letter transmits Alabama Power Company's response to the Staff's transmittal letter and Notice of Violation and Proposed Imposition of Civil Penalty dated August 3, 1988. Attachments 1 and 2 to this letter, together with their enclosures, are Alabama Power Company's "Reply to the Notice of Violation" (see 10 CFR 2.201) and "Answer to the Notice of Violation" (see 10 CFR 2.205), respectively.

Alabama Power Company denies that it has violated the requirements of Technical Specifications or the Final Safety Analysis Report (FSAR) for Farley Nuclear Plant as it relates to this issue. This denial is based upon an independent evaluation of the as-found condition by Westinghouse and Dr. Elemer Makay, a nationally recognized nuclear industry pump consultant. Alabama Power Company would like to reconstruct the facts surrounding this issue in belief that these concerns are only reasonable in view of what is now known; that it is only with the benefit of hindsight that criticism can be levied. Alabama Power Company contends that a review of the facts and circumstances surrounding the phenomenon of hydrogen accumulation in the Train A RHR to charging pump suction line (without the benefit of current information) should conclude that management acted prudently during the pertinent time period. Such actions were not indicative of a "significant breakdown in the management controls" of our corrective action program as asserted by

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the Staff. Should the Staff maintain its position that a violation occurred, we conclude that because this phenomenon was discovered, reported and promptly addressed by Alabama Power Company, full mitigation, not escalation, of any civil penalty is warranted.

Alabama Power Company encourages the Staff to give due consideration to its Reply and Answer and after doing so, issue an order in accordance with 10 CFR 2.205(d) dismissing the Notice of Violation.

Alabama Power Company is also concerned that the NRC's August 4, 1988 press release did not present a fair characterization of the facts and issues involved in the subject Notice of Violation. We are distressed that the press release presented the NRC's opinion regarding High Head Safety Injection System (HHSIS) operability without indicating that Alabama Power Company disputed the NRC's conclusions. Further, the NRC press release states "... NRC inspectors identified the fact that the Company had performed an inadequate engineering analysis of the emergency cooling system's operability." This statement implies that the NRC inspectors discovered a condition which Alabama Power Company had overlooked. To the contrary, Alabama Power Company discovered the condition and reported it to the NRC. The press release further stated that "the Company was aware of indications that hydrogen gas coming out of solution in the reactor cooling water was accumulating in pipes to the extent that there was a potential that charging pumps which would be needed to inject cooling water into the reactor during certain abnormal occurrences would not work." This was not the case. The only indication of gas accumulation prior to March 1, 1988 was in the Unit 2 B (2B) charging pump suction piping. The accumulation of gas in the 2B charging pump suction was addressed operationally to ensure the 2B charging pump was maintained operable. Through this operational control, Alabama Power Company ensured the 2B charging pump was operable as far as gas accumulation in the suction piping was concerned. Hydrogen gas had not been vented from the Train A RHR to charging pump suction line. Therefore, the only concern known to Alabama Power Company, the accumulation of gas in the 2B charging pump suction, had been adequately addressed. Additionally, this portion of the press release was worded to convey major safety consequences to the public because of the assertion that "... charging pumps needed to inject cooling water... would not work." This description is misleading because it ignores that only one redundant train was affected, that the injection phase was unaffected by the issue, and that this was only a potential concern for a limited spectrum of small break sizes. Had the press release been more accurate in this regard, an entirely different view of safety significance would have been conveyed. The press release continued to state that "a Company recommendation for a change in the system remained open for six and one-half years and was finally canceled without the recommended analysis being performed." The design change referred to addressed gas accumulation in the Unit 2 B charging pump suction only. It did not state or hypothesize the accumulation of gas at any other location in the system. Finally, the press release states "NRC officials said management controls at Farley resulted in 'the operation of the plants in a degraded condition for an extended period of time'." Alabama Power Company does not believe that the failure to identify the source of the hydrogen, a complex technical issue which is not yet fully understood today, can be construed as "problems in management controls." Instead, the operation of Farley with the accumulation of hydrogen was the result of an inadequate knowledge base throughout the industry. Alabama Power Company was thus not in a position to detect such an off-normal condition.

NRC press releases are often relied upon by the local media as the principal source of information when reporting on enforcement action taken against a licensee. Any mischaracterizations in the NRC press release will likely be repeated and perhaps magnified in local news accounts. This can have a detrimental effect on the general public's perception of a licensee, which ultimately can lead to distrust and lack of cooperation. For these reasons, we urge the NRC to ensure that press releases accurately report the facts and do not judge the guilt or innocence of a licensee prior to the conclusion of the administrative process.

If there are any questions, please advise.

Respectfully submitted,

ALABAMA POWER COMPANY

W. G. Hairston III

W. G. Hairston, III

WGH,III/REM:dst-V8.4

cc: Mr. L. B. Long
Dr. J. N. Grace
Mr. E. A. Reeves
Mr. G. F. Maxwell

SWORN TO AND SUBSCRIBED BEFORE ME

THIS 3rd DAY OF October, 1988

James A. Ripple
Notary Public

My Commission Expires: 8-24-92

ATTACHMENT 1

Alabama Power Company

Joseph M. Farley Nuclear Plant

Reply to Notice of Violation

Enforcement Action 88-113

Inspection Report Numbers 50-348/88-05 and 50-364/88-05

A. Summary of Position

In accordance with the Commission's Rules of Practice and Procedure, as described in the Notice of Violation transmittal letter dated August 3, 1988, Alabama Power Company (sometimes hereinafter referred to as "APCo" or "the Company") hereby replies to the Notice of Violation and Proposed Imposition of Civil Penalty. See, 10 CFR 2.201. As more fully discussed below, Alabama Power Company does not believe that the Train A Emergency Core Cooling System (ECCS) charging pumps on Units 1 and 2 were inoperable for use in the recirculation mode. Instead, Alabama Power Company, having conducted an appropriate evaluation, and consulted with an industry-recognized pump consultant, concludes that the affected systems would have performed their required safety functions. Moreover, Alabama Power Company believes that the heavy reliance which the Staff apparently placed on the Westinghouse letter of March 4, 1988, to support the Notice of Violation was misplaced. That letter identified a worst case, "very improbable" scenario, which appears to form the basis for the Staff's conclusion that the ECCS subsystem was inoperable. APCo asserts that any conclusion based on a very improbable scenario[1] necessarily entails undue speculation and should be rejected.

In the alternative, and assuming that the Staff maintains its position that a violation of Technical Specifications/FSAR requirements has occurred, APCo believes that the alleged violation has minimal safety significance. Thus, any violation should not be issued at more than a Severity Level IV. Moreover, since prompt corrective action was taken by APCo, mitigation, not escalation, of the base civil penalty is appropriate.

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[1] Neither the transmittal letter nor the Notice of Violation provided any other technical analysis to support the Staff's position. Since March 4, 1988, Westinghouse has refined its earlier evaluation and such refinement has been utilized by APCo in preparing both its Reply to the Notice of Violation and its Answer.

B. Discussion

This attachment refers to the Notice of Violation which states:

> During the Nuclear Regulatory Commission (NRC) inspection conducted on February 22 - March 11, 1988, a violation of NRC requirements was identified. In accordance with the "General Statement of Policy and Procedure for NRC Enforcement Actions," 10 CFR Part 2, Appendix C (1988), the Nuclear Regulatory Commission proposes to impose a civil penalty pursuant to Section 234 of the Atomic Energy Act of 1954 as amended (Act), 42 U.S.C. 2282, and 10 CFR 2.205. The particular violation and associated civil penalty is set forth below:
>
> > Technical Specification 3.5.2 requires that two independent emergency core cooling system (ECCS) subsystems shall be OPERABLE in Modes 1, 2, and 3, with each subsystem comprised of, in part, one OPERABLE centrifugal charging pump and an OPERABLE flow path capable of taking suction from the refueling water storage tank on a safety injection signal and transferring suction to the containment sump during the recirculation phase of operation. OPERABLE is defined by Technical Specification 1.18 as, in part, "capable of performing its specified functions."
> >
> > The functions of the charging pumps as high head safety injection (HHSI) pumps are delineated in the Final Safety Analysis Report (FSAR). FSAR Chapter 6, Emergency Core Cooling Systems, Section 6.3.2.2.7, System Operation, paragraph B, Recirculation Mode, states, "[a] portion of each one of the RHR pump's discharge flow would be used to provide suction to two operating charging pumps which would also deliver directly to the RCS cold legs," and, "[this] mode of operation assures flow in the event the depressurization proceeds more slowly so that the reactor coolant system pressure is still in excess of the shutoff head of the residual heat removal pumps at the onset of recirculation."
> >
> > Contrary to the above, the licensee operated the reactors in Modes 1, 2, and 3 and failed to maintain two independent ECCS subsystems OPERABLE as defined in Technical Specification 3.5.2 and FSAR Section 6.3.2.2.7 because the "A" train ECCS subsystems on Units 1 and 2 were rendered inoperable for use in the recirculation mode due to the presence of substantial amounts of hydrogen gas in the crossover piping from the RHR pumps to the centrifugal charging pump suctions. Specifically, on February 26, 1988, approximately fifty-six cubic feet of hydrogen gas was discovered in the crossover piping of Unit 1, and on February 29, 1988, approximately forty cubic feet of hydrogen gas was discovered in the crossover piping of Unit 2.

This is a Severity Level III violation (Supplement I).
Civil Penalty - $100,000

C. Denial of the Alleged Violation

Alabama Power Company denies that, for each unit, the Train A charging pump, or its associated flow path. was inoperable in the recirculation mode during the period that hydrogen gas was entrapped in its RHR to charging pump suction line. Attachment 2, paragraph B.1, and Enclosure 1 provide evidence that the charging pump and its associated flow path were operable in the recirculation mode.

D. Corrective Steps To Avoid Additional Gas Accumulation

Periodic venting of the Train A RHR to charging pump suction line on both units was implemented to limit future hydrogen accumulation. The periodic venting is conducted frequently enough so that any accumulated hydrogen is less than that recommended by the NSSS supplier and pump vendor.

E. Actions Taken to Improve Plant Design and Results Achieved

A loop seal has been installed on the Unit 1 RHR to charging pump suction line at approximate elevation 109. The loop seal is designed to preclude hydrogen migration from the A charging pump suction line towards the Train A RHR to charging pump suction line. Based on the results of subsequent, periodic venting of the subject line, this loop seal has significantly retarded hydrogen accumulation. Alabama Power Company will install a similar loop seal on Unit 2 during its sixth refueling outage.

In order to verify the reduction of hydrogen accumulation, a venting program developed by the NSSS supplier is being implemented. The program will determine the effectiveness of the loop seal under various operating conditions and configurations. The results of the venting program will determine if additional corrective action is required.

ATTACHMENT 2

Alabama Power Company

Joseph M. Farley Nuclear Plant

Answer to Notice of Violation

Enforcement Action 88-113

Inspection Report Numbers 50-348/88-05 and 50-364/88-05

A. Summary of Position

In accordance with the Commission's Rules of Practice and Procedure, as described in the Notice of Violation dated August 3, 1988, Alabama Power Company hereby answers the Notice of Violation and Proposed Imposition of Civil Penalty. See, 10 CFR 2.205. Alabama Power Company denies that the subject violation occurred as stated and contends that the NRC Staff has not provided an adequate basis to justify its NOV, and the associated civil penalty. Based on an evaluation of the as-found condition, Alabama Power Company and its consultant, Dr. Elemer Makay, with system analysis by Westinghouse, have concluded that there was no significant loss of performance of the Train A ECCS charging pump Dr. Makay has determined that if the recirculation mode were initiated the charging pump would shortly purge itself of the hydrogen and then resume normal operation.

Even if the hydrogen reached the pump as a solid slug (a condition deemed very improbable by both Westinghouse and Dr. Makay), and such an improbable occurrence resulted in temporary gas binding of the charging pump, Alabama Power Company has determined through engineering evaluation and consultation that such a condition would not cause catastrophic failure of the pump. Westinghouse has calculated that the worst case, maximum time that it is anticipated the pump would be without water for lubrication is 12.5 seconds. Based on Dr. Makay's evaluation and Westinghouse's calculations as described in Enclosure 1, it is shown that the ECCS system performance would have been acceptable.

Therefore, it is Alabama Power Company's position that the accumulation of 56 cubic feet of hydrogen in the Train A RHR to charging pump suction line of Unit 1, would not render this pump "inoperable." It follows that the accumulation of 40 cubic feet of hydrogen in the same suction line of Unit 2 would not render its ECCS subsystem inoperable either.

Additionally, the conclusion reached in the NOV, and its transmittal letter, that the ECCS subsystem was inoperable in the recirculation mode, is not supported by engineering analysis. The Staff apparently placed heavy reliance on the Westinghouse letter of March 4, 1988 to justify the violation and that reliance was misplaced. The letter simply does not afford an adequate basis to conclude that catastrophic pump failure would have occurred.

Alternatively, should the Staff maintain its position regarding the existence of the violation, 100 percent escalation of the base civil penalty is not warranted and, in fact, full mitigation of the civil penalty is appropriate. When the totality of facts and circumstances surrounding this occurrence are reviewed, without the advantage of current knowledge, it is clear that Alabama Power Company neither knew nor should have known of the accumulation of hydrogen in the Train A RHR loop. Additionally, the as-found condition was not safety significant as it relates to a Level III violation, defined by 10CFR Part 2, Appendix C. Mitigation of the civil penalty is also appropriate since Alabama Power Company took prompt and extensive corrective action once the event was discovered and provided prompt reporting to the NRC.

B. Discussion

The following discussion addresses each of the above positions. Alabama Power Company has examined (1) technical specification requirements regarding charging pump operability, (2) the safety significance of the as-found condition, (3) the events which led to the discovery of the alleged deficiency and (4) the Enforcement Policy (10 CFR Part 2, Appendix C) regarding the above issues. The Company has also interviewed numerous people who were associated with this issue during the relevant time period and engaged Dr. Elemer Makay and Westinghouse to perform certain technical evaluations.

1. The Technical Specification/FSAR Operability Requirements Were Not Violated

As discussed below, Alabama Power Company concludes that the Unit 1 and 2 emergency core cooling system subsystems remained operable notwithstanding the existence of hydrogen in the Train A RHR to charging pump suction line. Technical Specification 1.18 defines OPERABLE-OPERABILITY as whenever a system, subsystem, train, component or device is capable of performing its specified function(s) and when all support components are also capable of performing their related functions.

In pertinent part, Section 3.5.2 of the Farley Technical Specifications provides:

> Two independent Emergency Core Cooling System (ECCS) subsystems shall be OPERABLE [in Modes 1, 2, 3] with each subsystem comprised of:
>
> a. One OPERABLE centrifugal charging pump,
>
> b. One OPERABLE residual heat removal heat exchanger,
>
> c. One OPERABLE residual heat removal pump, and

d. An OPERABLE flow path capable of taking suction from the refueling water storage tank on a safety injection signal and transferring suction to the containment sump during the recirculation phase of operation.

While preparing its response to the NOV, Alabama Power Company consulted with Westinghouse to obtain a more precise understanding of operability of the ECCS subsystem as it pertains to this issue. Westinghouse stated in a letter dated September 8, 1988:

> Operability of the ECCS system is addressed in plant T-Spec 3/4.5.2. The LCO requires 1) one operable CCP, 2) one operable RHR heat exchanger, 3) one operable RHR pump and 4) a flowpath capable of taking suction from the RWST and transferring suction to the containment sump during recirculation.
>
> In addition, surveillance requirement 4.5.2.1 requires HHSI - Single Pump Flow $\geq$ 193 gpm (each injection line).
>
> It is the position of Westinghouse that this flowrate applies only to flow requirements during the injection phase. This specification does not address flow requirement during recirculation.
>
> For recirculation, operability is defined as an available flowpath from the containment sump including an operable RHR and charging pump, and an operable RHR heat exchanger.[1]

Alabama Power Company has also consulted with Dr. Elemer Makay regarding the effect of the as-found hydrogen gas on the charging pumps in the recirculation mode. Although APCo acknowledges that the operation of Train A with gas pockets for a limited period of time is not a desired operating condition, the Company does not agree that the charging system was inoperable under the Technical Specification/ FSAR definition. This conclusion has been based on Alabama Power Company's review and consultation with Dr. Makay.

Regarding operability of the charging pumps, recent evaluation has shown that the amount of trapped gas discovered in Train A RHR to charging pump suction line piping (56 cubic feet in Unit 1, 40 cubic feet in Unit 2) would not have caused the destruction of the pump prior to the gas being completely pumped out of the system. In addition, pump testing performed on similar pumps at Palo Verde (1985) and a fossil plant (1980) confirm that this type of pump can operate under similar conditions for at least several minutes without any pump damage. (See Enclosure 1.) Alabama Power Company's evaluation of what the charging pump is expected to

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[1] Flowrate requirements for recirculation are addressed in 10CFR50.46. Specific requirements for Farley Nuclear Plant are addressed in Enclosure 2.

experience as a result of the presence of hydrogen gas in the RHR to charging pump suction header is that although the pump may stall (see Enclosure 1, Reference 4), the system will re-flood the pump suction. This will happen within a relatively short time, estimated to be less than 13 seconds. The system rapidly purges the suction piping of all hydrogen gas, and normal operation resumes without significant loss of performance (or perhaps no loss at all). Enclosure 1 provides a more detailed description and references two test reports that support the conclusion that gaseous flow or gas/water flow is tolerable for a limited period of time. The reports illustrate that gas/water or intermittent gas flow causes instability in the pump, but that the pump can be expected to pass the gas and recover to its full operational capabilities. As stated in a 1970 article by Dr. Makay, "... air trapped in suction and discharge piping is an occasional cause of instability. However, this is not of a permanent nature: eventually it is washed out and smooth operation is restored."[2]

Alabama Power Company maintains that, consistent with the Technical Specification requirements, the flow path was always capable of taking suction from the refueling water storage tank. While we acknowledge that during the recirculation phase intermittent water/gas pockets entering the pump for a short period of time would not be the most preferable or efficient way to operate the pump, the flow path was never blocked sufficiently to render the charging pump "inoperable."

Even assuming that the charging pump failed to deliver its full capacity flow to the reactor coolant system (RCS), Alabama Power Company's analysis of RCS conditions at the time of switchover to recirculation concludes that such full capacity flow as dictated by the initial injection phase is unnecessary during the subsequent recirculation phase. This is because enough time has passed since the initiation of the LOCA such that decay heat levels are greatly reduced. Consequently, the need for HHSI flow into the RCS is greatly reduced. The function of the ECCS subsystem during the recirculation mode is satisfied if the core remains covered at all times. This dictates that either flowrates be maintained at greater than the boil off rate or that flow is not degraded or ceased for long enough periods to allow core uncovery. Enclosure 2 provides a discussion regarding the effect of hydrogen gas accumulation on the Train A RHR to charging pump suction line and its impact on flow requirements. In the enclosure, Westinghouse states, "Given the systems evaluation and assuming the pump continues to operate, Westinghouse has concluded that the hydrogen gas is not capable of degrading HHSI flow for a long enough time to result in core uncovery. Therefore, more than adequate HHSI flow would be available."

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[2] **"Eliminating Pump-Stability Problems"**, by E. Makay, Franklin Research Laboratory, Power, July 1970 at 62.

In the NOV, the Staff implies that the ECCS charging pumps and/or flow path was inoperable solely due to the presence of hydrogen gas in the Train A RHR to charging pump suction line. Based on additional consultations with Westinghouse and Dr. Makay, Alabama Power Company contends that such an implication is incorrect. Indeed, absent in the NOV is any technical analysis or basis for the Staff's summary determination that the mere presence of hydrogen automatically renders the ECCS subsystem inoperable. Alabama Power Company believes now, of course, that such a summary determination is not justified.

The logic referenced in the Staff's transmittal letter was apparently predicated on Westinghouse's March 4, 1988 letter; and more specifically, a "worst case," very improbable scenario. The Staff fails to acknowledge the more likely scenario identified in the letter (and now confirmed by Dr. Makay) that "hydrogen would normally be expected to mix with the water prior to reaching the pump suction." The Staff ignores the important part of the letter where Westinghouse says that in such an event, "enough lubrication is provided to prevent pump failure" and that once the gas is purged, "pump performance will recover." Westinghouse adds:

> Westinghouse believes this is acceptable since pump performance is less stringent during recirculation than during injection. Therefore, a slight degradation of charging pump flow for a short period of time at the initiation of recirculation is acceptable. (Emphasis Added)[3]

Viewed in its proper context, the Staff's conclusion that the charging pump was inoperable is inconsistent with the Westinghouse letter. Westinghouse developed the March 4, 1988 letter in response to the urgent need of Alabama Power Company for quantitative guidelines for hydrogen venting. Therefore, it was necessary that Westinghouse forego a detailed, rigorous evaluation and, instead, develop a conservative, safe criteria for venting by making safe, very conservative assumptions. This approach, while well suited for restoring acceptable operating conditions in the shortest possible time, is not appropriate as the basis for enforcement proceedings. Enforcement action should be based on evaluations which give due consideration to actual pump and system response to the accumulation of hydrogen as opposed to evaluations intended to define a condition for operation which assures no question as to pump and system capability. Enclosure 1 provides the results of a more balanced evaluation of the effects of the hydrogen. Since no other technical basis supporting this conclusion is offered by the Staff, it follows that the conclusion of inoperability is not justified.

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[3] It is readily apparent from Enclosure 1, based on a system response evaluation by Westinghouse and a pump response evaluation by Dr. Elemer Makay, that Alabama Power Company has greatly refined this early evaluation.

Based on the above, Alabama Power Company concludes that (1) the Train A charging pump would have remained operable throughout gas/water flow conditions and (2) gas entrapment in the Train A RHR to charging pump suction line did not render the flow path inoperable. Therefore, Technical Specification conditions were always satisfied in that the pump and flow path were operable, and further, FSAR provisions were not violated.[4]

2. <u>Alternatively, Assuming A Violation Occurred, It Was Not Safety Significant And Does Not Justify A Severity Level III Violation And A $100,000 Civil Penalty</u>

Should the Staff remain convinced that a violation occurred as stated in the NOV, Alabama Power Company maintains that the alleged deficiency does not warrant escalated enforcement action because the as-found condition lacks the requisite safety significance. Farley Emergency Event Procedures (EEP) and operator training would have guided operators to assure adequate core cooling with or without HHSI pumps.

As more fully explained in Enclosure 1, a 4 inch or above loss of coolant accident (LOCA) results in such a rapid depressurization of the RCS that RHR injection occurs before the recirculation mode is initiated. For small break (SB) LOCAs of 1 inch or below, no containment spray initiation is assumed and operator action will result in the RCS reaching cold shutdown before the RWST reaches the setpoint for recirculation. Therefore, a SBLOCA that assumes ECCS subsystem operability is in the range of 1-4 inches, since it is only there that the RWST would reach its setpoint for recirculation before the RCS pressure decreased to less than RHR discharge pressure for RCS injection. Switchover to the recirculating mode is performed well into the accident scenario after decay heat has lessened; therefore, time is not as much a critical factor and procedural guidance specifies manual operator actions.

In such a case, Farley operator procedures for both units, which are based on and consistent with NRC-approved Westinghouse Owner's Group guidelines, provide specific instructions for cooldown and depressurization of the RCS both with or <u>without</u> HHSI pumps. Specifically, the Westinghouse Owner's Group guidelines as described in a letter to the NRC state:

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[4] FSAR 6.3.2.2.7 provisions are substantially the same as those appearing in Technical Specification 3.5.2.

> For LOCA scenarios characterized by RCS pressures greater than the shutoff head of the RHR pump, EEP-1 transitions the operator to procedure ESP 1.2. This procedure provides guidance to cooldown (at rates up to 100°F/hr.) and depressurize the RCS to cold shutdown conditions. For the more probable case where the HHSI pumps are running, procedure ESP 1.2 provides guidance to reduce and terminate HHSI pump flow in combination with the plant cooldown and depressurization. For the case where HHSI pumps are not operating, procedure ESP 1.2 functions to cooldown and depressurize the RCS. Since RCS pressure will follow saturation pressure for RCS temperature, this RCS cooldown will result in delivery of the safety injection accumulator contents followed by delivery of the RHR flow.[5]

Because these guidelines address the scenario of a complete absence of HHSI charging pumps and still effectively resolve the SBLOCA, safety significance is minimal. Even assuming inoperability of the charging pumps, there never has been any unacceptable risk that endangered the public health and safety. For this reason an escalated Severity Level III Civil Penalty is not warranted. The determination that the HHSI charging pump was inoperable would justify at most a Severity Level IV Violation.

3. Alabama Power Company Had Neither Actual Nor Constructive Knowledge of Hydrogen Accumulation in the RHR Line

The NOV is based upon the assumption that the Company "performed an inadequate engineering analysis of system operability based on indications of hydrogen gas coming out of solution for reactor coolant in the HHSI system." The Staff increased the base civil penalty by 100%, "because of the failure of Alabama Power Company management to act on available information concerning the occurrence of gas generation and its potential accumulation in the crossover piping." Alabama Power Company believes that its position was adequately stated in the Enforcement Conference, but it appears that the Staff may not have had a clear understanding of

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[5] This quote (with Farley procedure nomenclature substituted for generic nomenclature) is taken from a letter dated August 29, 1985 to D. G. Eisenhut, Director, Division of Licensing, NRR, from L. D. Butterfield, Chairman, Westinghouse Owner's Group. In response to the guidelines referenced here, the NRC, in a supplemental SER dated December 26, 1985, said: "Based on our review of the above guidelines, we conclude that the Revision 1 ERGs provide adequate guidance for the loss of high pressure makeup before the occurrence of inadequate core cooling."

our position and the relevant facts. We therefore will set out our position and the facts more clearly below. This review shows actual hydrogen accumulation in the RHR line had never been previously identified as a concern and that there was no actual or constructive knowledge of a problem with hydrogen in the RHR line until March 1988.

a. Unit 2 Startup

At the time of Unit 2 startup in 1979, Alabama Power Company and Westinghouse were investigating generic concerns with shaft failures in charging pumps. During this period, an Operating Change Request (OCR) was initiated to address "Problems associated with proper venting of the charging/HHSI pumps." This OCR identified the following actual problems: (1) gas accumulation on the 2B charging pump suction loop when the 2B charging pump was idle; and (2) venting arrangements with pump seal coolers and mini-flow piping. Specifically, the OCR reported on the cold hydro test on Unit 2 where "gas was found to accumulate in the suction loop of idle 'B' charging pump." However, in addition to these actual problems, the OCR speculated that the inability to vent the suction of the "A" pump back to the VCT was a "potential problem ... during safety injection operation." There was also more speculation and hypothesis about gas accumulation in the "A" and "C" charging pump suctions when the pumps were idle and in the "A," "B," and "C" charging pump suctions when the pumps were running.[6]

Alabama Power Company has recently discussed these events with the author of the OCR who stated that his concern was caused by finding gas in all three charging pump suctions prior to starting the pumps; however, only accumulations in the 2B charging pump suction were identified in the OCR. The author attributed the gas collection to the extensive maintenance being done on the system prior to startup, and noted that the charging pumps had no significant run time when the OCR was written. The author also hypothesized that the gas accumulation would be a problem in the running pumps because the fluid velocity in the pump suctions would not be high enough to sweep any gases not in solution through the pumps. The result would be that the gas would accumulate in the pump suction high points during operation, which could impair the performance of the pump. As indicated in the OCR, the only documented evidence of gas accumulation was in

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[6] It is important to observe that the OCR was prepared by a startup engineer involved in pre-operation testing and maintenance. In it, he hypothesized "potential" problems that were later never seen when actual operations began.

the 2B charging pump suction line. Since the configuration of the 2B charging pump suction piping is significantly different from that of the other two charging pumps, the gas accumulation can be justifiably attributed to the unique configuration. Consequently, when the maintenance on the system was completed and the charging pumps were run for significant periods of time, gas was not found to accumulate in the suctions of the running charging pumps. Therefore, the major problem identified was gas accumulation in the 2B charging pump suction, a problem that was eliminated by running the 2B charging pump continuously.

To place the OCR in proper context, several considerations must be borne in mind. First, the state of knowledge within the industry at the time was such that the potential for hydrogen stripping (see paragraph 3.d) was not considered to be a technical concern. For example, a report prepared in September, 1979 by Dr. Elemer Makay, a recognized independent consultant on pump operation, to address pump shaft concerns at Farley did not identify the formation of gas pockets in suction lines as a factor contributing to pump shaft damage.[7]

Westinghouse also circulated a questionnaire to utilities in October, 1979 which, among other things, asked the question: "Does the suction piping from VCT, RWST or the makeup control system contain gas traps..." Significantly, the questionnaire did not mention the need to consider the RHR system piping. In any event, Westinghouse did not indicate that any further potential concerns needed to be addressed as a result of the response to the questionnaire.

Moreover, in September, 1980 the NRC itself inspected the design, installation and operation of the charging pumps at Farley and found no violations or deviations.[8] The NRC reviewed a wealth of documents associated with the charging pump issues and did not identify hydrogen accumulation as a potential issue affecting charging pump operability. According to the Inspection Report, the NRC Inspection Specialist from the Performance Appraisal Branch

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[7] **Determination of the Causes of the "Charging and Safety Injection" Pump Failures and Operating Difficulties in Westinghouse "PWR" Nuclear Units, (September 4, 1979)**. This report included an Appendix I which contained the results of a telephone survey with Westinghouse "PWR" plant owners using charging pumps similar to those at Farley. Nothing in this survey identified hydrogen accumulation in the Train A RHR to charging pump suction line as either an actual or potential problem. See also, Makay, **"Eliminating Pump-Stability Problems,"** Power, July 1970 at 62.

[8] Inspection Report No. 50-348/80-28, dated November 14, 1980

reviewed "various correspondence between NRC (NRR), Westinghouse, Pacific Pumps and the Licensee concerning pump problems and corrective action" and did not identify the problem which Alabama Power Company is now cited for failing to resolve.

It is our belief that this is convincing evidence that the state of knowledge at the time, including the NRC's own reviews, was such that hydrogen accumulation was not considered a concern. Given the state of knowledge and the fact that only the 2B charging pump showed any evidence of gas accumulation, it is not reasonable to conclude that Alabama Power Company knew or should have known of a concern regarding gas accumulation in the Train A RHR to charging pump suction line.

At the time the OCR was initiated, Unit 2 was in startup. During startup, a tremendous number of issues are discovered or hypothesized and are brought to management's attention. Considering the level of activity during startup and the absence of objective evidence that gas accumulation was a significant problem, the approach taken in response to the OCR was reasonable.

b. <u>The 1981 PCR</u>

On June 5, 1981, while performing a routine surveillance test procedure (STP) on the 2B charging pump, plant personnel started the pump and noticed low running amps. The pump was secured immediately and a procedure change was initiated that required venting the suction piping. After such venting, the STP was performed satisfactorily. All three pumps for each unit were then evaluated and no gas accumulation was found other than on 2B charging pump. Since only this pump had the unique piping configuration, the event served to re-enforce the conclusion that gas accumulated in only the 2B charging pump suction loop and only when it was idle. On June 6, 1981, operations night orders were written as follows:

> <u>Unit 2</u>
>
> 2B charging pump has gas trap -- pipe with vertical U in suction. Hence run 2B charging pump as on service pump. If secure it then vent suction vent to floor drain prior to starting.

On June 10, 1981 Production Change Request 81-2-2064 was initiated and accordingly focused on this known problem. The OCR was considered superseded after initiation of the PCR. This is clear evidence that no deficiencies existed "in the design deficiency review process or the production change request process..." as suggested by the August 3, 1988 transmittal letter.

As a result of the experience of June 5, 1981, a walkdown of both units' charging pump suction loops occurred. The suction line for the 2B charging pump was the only line identified where there was evidence of a problem and the only line with the unique piping configuration. Therefore, the focus of the PCR was properly on resolving this apparent problem. At that time, nothing in the experience of Alabama Power Company, Dr. Makay, Westinghouse, Bechtel or the NRC suggested that gas accumulation was occurring in an area other than that of the unique piping configuration. Accordingly, it was within that framework that Alabama Power Company considered the solutions proposed by Bechtel and Westinghouse over the next few months. This is additional evidence of the prudence of Alabama Power Company's actions in 1982.

By letter dated March 22, 1982, Westinghouse proposed permanent modifications which included installation of vent lines on the 2B charging pump and 2C charging pump suction lines and a water seal and a vent line for the 2A charging pump suction line. While Westinghouse's proposal included modifications for all three pumps, no evidence was cited of gas accumulation for charging pumps other than 2B. In fact, the Westinghouse letter stated that the water seal modification was not necessary for Train A in Unit 1. This implied to Alabama Power Company that the problem was isolated to the 2B charging pump, because the design of the Train A is similar in both units, with the exception of a slight difference in elevation.

After the Westinghouse proposal was evaluated by Alabama Power Company, it was determined that the permanent modifications would not be beneficial. The technical reasons for this were twofold: First, it was not clear that gas would vent back to the VCT given the pressure differential between the VCT and the suction lines. Second, the modifications would have introduced the risk of faulty automatic valve actions and would have entailed installing a check valve in the common vent line--a change that was considered by plant management to be undesirable from the standpoint of reliability of a safety related system. In addition, the modifications were determined to entail considerable cost without a corresponding safety benefit. Given what was believed about the lack of safety significance of the issue and the ability to control the 2B charging pump accumulation by having the 2B charging pump on service, the modifications were determined to be unjustified and the PCR was eventually voided.[9]

---

[9] The PCR was held in abeyance (along with a number of others) beginning in 1983 while better means to modify the system were sought. Eventually the PCR was voided on February 11, 1988.

It is evident, therefore, that far from failing to perform an adequate evaluation of the issue, the known problem was appropriately pursued, and prompt corrective action was taken. Contrary to the NOV, plant management did not perform an inadequate engineering analysis of the known problem nor did it fail to act on available information.

c. 1987 Incident Report

On March 2, 1987 an Incident Report was filed to report cavitation of charging pump A in Unit 1. Cavitation of the pump was found to be due to gas or air in the suction line. Subsequent analysis, as described in the Incident Report and LER No. 88-006-01, dated April 25, 1988, determined that the probable cause of the gas accumulation in the suction piping was due to a VCT pressure drop resulting from failure of the VCT hydrogen pressure regulator (dropping from 20 psig to 15 psig). It was believed that the pressure drop resulted in gas coming out of solution.

The NOV faults Alabama Power Company for not implementing the corrective actions of Incident Report 1-87-88 which, in part, recommended that PCR 81-2-2064 be considered for implementation on Unit 1. On the contrary, Alabama Power Company did repair the hydrogen pressure regulator, which was thought to be the cause of the condition. The addition of a PCR similar to 81-2-2064 to the "Permanent Corrective Action" recommendation was made because the Farley Staff was not absolutely sure that the hydrogen regulator was the root cause for the gas accumulation. What was known was that gas did accumulate in the 2B charging pump when it was idle and, in this instance, gas accumulated in the 1A charging pump when it was idle. It was also known that the Westinghouse proposed resolution for PCR 81-2-2064 included vents for each Unit 2 charging pump suction. Consequently, it was proper to suggest that a similar PCR be evaluated for Unit 1. However, operating for almost eleven months with no gas accumulation in any idle pump other than the 2B charging pump confirmed for the Farley Nuclear Plant Staff that the reason for the gas accumulation in the 1A charging pump was the failure of the hydrogen pressure regulator. Therefore, the voiding of PCR 81-2-2064 and the failure to write a similar PCR for Unit 1 was proper.

d. Source of Hydrogen

The NOV states that it is a particular concern to the NRC Staff that no detailed engineering analysis was performed to evaluate why hydrogen was being stripped[10] from the fluid in the HHSI system. Use of the term "stripping" here by the NRC is based on hindsight,

---

[10] Hydrogen stripping was only hypothesized and used by Alabama Power Company after the March 1, 1988 discovery of the hydrogen accumulation.

since that term was not used until after Alabama Power Company's discovery of the accumulation. Additionally, the Staff was concerned that tests were not performed to determine how much gas was being generated or the location of the gas. Alabama Power Company would like to reconstruct the facts surrounding this issue in belief that these concerns are only reasonable in view of what is now known; that it is only with the benefit of hindsight that this criticism can be levied. Consideration of the available observations at the time Alabama Power Company had to evaluate the situation yields a different perspective.

Alabama Power Company discovered during Unit 2 startup testing that gas would accumulate at the high point location of the Unit 2 B charging pump suction. In evaluating this finding, it stood to reason that if gas was desorbing at widespread locations in the suction system or if gas entrainment were occurring from the VCT, it would be accumulated at the C charging pump suction high point when the C charging pump was idle. The accumulation would be due to buoyancy. The fact that the suction header is horizontal would allow for migration of gas toward the C charging pump, for example when the A charging pump is running. However, accumulation was not occurring in the C charging pump suction, thereby indicating that there was something unique about the 2B charging pump that caused gas to be formed.

Since the aforementioned observation indicated that gas accumulation was not occurring at widespread suction locations but rather at the 2B charging pump and due to the fact that accumulation in the 2B charging pump could be understood in terms of buoyancy effects and 2B's charging pump unique physical arrangement, it naturally followed that Alabama Power Company's concerns were with addressing the 2B charging pump accumulation. Additionally, given the fact that gas accumulation had not been observed at any other locations, except as a result of perceived equipment problems, on either unit despite numerous opportunities to be detected, there appeared to be no justification for pursuing further the difficult question of why the gas was accumulating at the 2B charging pump. Nor did there appear to be indications that the problem spanned beyond the 2B charging pump.

The source of the hydrogen gas which accumulates in the Train A RHR to charging pump suction remains only a hypothesis. Following the March 1988 discovery of the hydrogen gas, Westinghouse and Bechtel were requested to assist in determining the source of the hydrogen. To date, although fully cognizant of the fact that hydrogen accumulates, neither has conclusively determined the source.

Although the source of hydrogen has not been concretely identified, one primary source has been hypothesized. "Hydrogen stripping", characterized by hydrogen desorbing at localized high velocity, low pressure points within the charging pump supply piping, is believed to be the primary source. Fluid supplying the charging pump suction from the Volume Control Tank (VCT) is saturated with dissolved hydrogen. This is accomplished by spraying the fluid into the VCT through a hydrogen atmosphere, maintaining a 15-20 psig hydrogen overpressure in the VCT, and by bubbling makeup hydrogen through the liquid in the VCT. As the hydrogen saturated fluid exits the VCT, the parameter keeping the hydrogen in solution is increasing pressure due to the decreasing elevation of the suction piping, i.e., the VCT is higher than the charging pumps. Based on engineering experience, it is expected that the additional pressure due to elevation would keep hydrogen from desorbing. The installed piping configuration is not just a straight run of pipe. System requirements, such as connecting the RHR pump discharge and the VCT to the charging pumps suction header and NRC requirements such as train separation, require the use of elbows and T-connections. System operation requires the use of valves for the recirculation mode. As the fluid traverses the charging pump supply piping, it flows through numerous elbows, T-connections, and valve bodies. It is hypothesized that these mechanical members cause flow perturbations in the fluid. These perturbations may result in high velocity, low pressure points which offset the pressure increase due to elevation. Consequently, some hydrogen could be desorbed at localized sites and become entrained in the fluid. As the entrained hydrogen flows through the charging pump supply piping, it collects at the system high points, such as the 2B charging pump suction piping or the Train A RHR to charging pump suction piping, or is pumped through the charging pumps where it is forced into solution by the large pressure increase.

Alabama Power Company did not know, nor do we now know, the source of the hydrogen accumulating in the 2B charging pump suction piping. Our only conclusion is that once it is there, buoyancy will cause it to accumulate in the high point of the 2B charging pump suction. It was not until after gas was discovered in the Train A RHR line that speculation developed that localized pressure effects at various locations in the suction system could cause some hydrogen to desorb, thereby suggesting that accumulations would not be unique to the 2B charging pump.

This illustrates why the original Westinghouse resolution to the problem (four air operated valves, a loop seal, and associated piping) was considered an unnecessary design, i.e., went beyond the conditions that were known to exist. Consequently, Alabama Power Company's reluctance to implement a design change of major proportions which complicated a safety-related system, and introduced additional failure modes, can be better understood. Of even greater significance is the fact that the source of the hydrogen is still not fully understood today. Therefore, it is unreasonable to fault Alabama Power Company for inability to identify the initial condition or for the lack of industry knowledge on hydrogen desorption over nine years ago.

e. Summary

From the above discussion, it is apparent that once deprived of the advantages of clear hindsight, it is neither fair nor reasonable to say that because a concern with hydrogen accumulation in the B charging pump of Unit 2 was recognized in 1979, all other potential pockets for trapping gas should have been recognized and action taken to foreclose any possibility of gas accumulation. The hydrogen accumulation phenomenon was not recognized as a significant concern at the time, nor was the presence of gas in the 2B charging pump suction line considered a problem for pump operability. Given the state of knowledge at the time within the industry and the NRC and the fact that concerns were properly focused on the 2B charging pump, Alabama Power Company's actions were reasonable and should not now--in the light of subsequent events--be second-guessed and considered unreasonable.

Accordingly, Alabama Power Company believes that escalation of the civil penalty for the alleged failure to act on available information was not appropriate.

4. Mitigation of the Civil Penalty is Warranted

a. Prompt and Extensive Corrective Actions

Upon discovery, at approximately 1700 on March 1, 1988, that a hydrogen gas entrapment condition existed which resulted in hydrogen accumulation in the Train A RHR to charging pump suction line, Alabama Power Company promptly instituted corrective actions that remedied the problem. At approximately 1620 on March 2, 1988, Alabama Power Company implemented a periodic venting program on the RHR to charging pump suction lines of both trains on both units to minimize the quantity of hydrogen allowed to accumulate.

b. Prompt Identification and Reporting

Once the existence of the accumulation of hydrogen gas was originally recognized on March 1, 1988, Alabama Power Company promptly alerted the NRC Resident Inspector. Alabama Power Company also notified the industry of its finding in a Nuclear Network notification. Significant research into the effects of this finding was performed and provided in a promptly issued and detailed LER dated April 25, 1988.

C. Conclusion

There is objective scientific evidence that supports the finding that the Train A ECCS charging pumps on Units 1 and 2 were operable for use in the recirculation mode. The assertions in the NOV that Alabama Power Company suffered a significant breakdown in management controls is unjustified and unsupported. Instead it is apparent that if tested against the state of knowledge in the nuclear industry and the NRC during the pertinent time frame, Alabama Power Company acted prudently, responsibly, utilized good engineering judgment, and adhered to NRC Regulations. Accordingly, the Staff should enter an order, in accordance with 10 CFR 2.205(d), dismissing the Notice of Violation.

ENCLOSURE 1

EVALUATION OF HYDROGEN GAS IN THE RHR TO CHARGING PUMP SUCTION LINE

Objective:

The goal of this evaluation is to outline the fluid systems evaluation as to what the charging pump is expected to experience as a result of the presence of hydrogen gas in the RHR to charging pump HHSI suction header. This gas is pulled into the charging pump at the start of cold leg recirculation. Therefore, the discussion provided will address that time from just prior to alignment for cold leg recirculation until the time that the gas is entirely purged from the system.

Transients of Consideration:

The worst case scenario is a solid slug of gas reaching the charging pump with no mixing occurring. Because of the piping configuration, the A pump is expected to have the least mixing (i.e., highest void fraction) at its suction. The B pump, with approximately twice as many elbows and T-connections as the A pump to promote mixing, is expected to have a much lower void fraction at its suction. Consequently, this analysis is based on the A pump as the worst case.

A 4 inch or above Loss of Coolant Accident (LOCA) results in such a rapid depressurization of the RCS that RHR injection occurs before the recirculation mode is initiated. For Small Break (SB) LOCAs of 1 inch or below, no containment spray initiation is assumed and operator action will result in the RCS reaching cold shutdown before the RWST reaches the setpoint for recirculation. Therefore, a SBLOCA that requires ECCS recirculation subsystem operability is in the range of 1-4 inches, since it is only there that the RWST would reach its setpoint for recirculation before the RCS pressure decreases to less than RHR discharge pressure for RCS injection. The SBLOCA that results in the highest RCS pressure and therefore lowest HHSI flow is the one inch LOCA that results in a RCS pressure of 600 psig with a HHSI flowrate of 550 gpm, based on operator action approximately 2 hours following the break when the RWST level reaches the setpoint for recirculation.

Initial Conditions and Key Parameters:

- Refer to the attached sketch No. 1
- Valve 8706A closed
- RHR pump is not operating
- Flow from RWST to charging pump = 550 GPM
- Pressure at point D = 10-20 psig
- Discharge head of charging pump = 1680 psig

- 56 ft^3 of hydrogen exists in pipe section A to B. Note this represents an almost 100% void of this section
- Reactor Coolant System pressure is > 600 psig
- The maximum developed head of the RHR is 150 psid
- The maximum developed head of the charging pump is 2680 psid
- Charging pump minimum flow paths will be isolated

Evaluation:

The effect of switchover to recirculation on the charging pumps is presented in phases. Following is a discussion of each stage.

Phase 1:

Initial Conditions

Phase 2:

Valve 8706A is opened

Phase 3:

The RHR pump is turned on

- As the pump comes up to speed, the pump begins to deliver water in section A to F towards the charging pump suction.
- As water traverses from point A to B, it has the effect of compressing the gas and carrying the gas from point B to point C.
- While the gas is being carried and compressed, the charging pump will continue to deliver 550 GPM flow. Suction flow will be drawn from both the RWST and the RHR pump supply lines.

Phase 4:

When the gas front reaches point C, a mixture of gas and water will have been created. This mixture will represent some void fraction. If this void fraction is less than 20%, the pump performance actually improves as reported in Ref. 1 and the gas will be purged in a short time period. The case when the void fraction is above 20%, which is the most pessimistic case, is discussed below.

Phase 5:

This mixture of gas and water reaches point D (Inlet to the charging pump).

Phase 6:

When the void fraction becomes higher than 20%, the charging pump generated head will be lowered, but pumping continues. When the void fraction reaches a very high number, say approaching 100% due to the amount of gas present in the pump, the pump developed head will fall off, such as during the Palo Verde Nuclear Auxiliary Feedwater pump test, shown as test point No. 11 in Reference 2. Once the discharge pressure of the charging pump falls below Reactor Coolant System pressure (600 psig) the pumping process will stop and the flow in the suction piping will stagnate. The charging pump will continue to run. Some water is contained inside the pump passages that will provide adequate lubrication to all close clearance surfaces such as the wear-rings at the impeller eye, and the balancing drum. Since the RHR pump is running, the suction pressure will increase to near the shut-off head of the RHR pump (150 psig). At this time the gas is compressed to approximately 12 ft^3. Check valve 8926 closes due to a positive closing head.

Phase 7:

A review of the piping layout for the charging pump suction notes the pump suction piping to be self venting. During the time that the system is not pumping, some amount of gas will escape back up to the higher points and the lower elevation piping will be re-flooded. This results in re-flooding/priming of the first stage of the charging pump. As this occurs, the pump developed head will begin to increase and the charging pump will start pumping again. An excellent example is shown in Figure 3 of Reference 3 during a start-up operation of the Martins Creek Power station, where the start-up boiler feed pump is similar in design. The large amount of turbulence is expected to result in a fairly homogeneous gas/water mixture. This mixture could be postulated in sections A-B, B-C, C-D and E-C. The void fraction of this homogeneous mixture is predicted to be less than the initial void fraction the pump experienced in Phase 5. The amount of gas trapped inside the charging pump hydraulic passages is purged out of the charging pump into the discharge piping.

Phase 8:

As the pumping process is re-initiated, the charging pump will pull this homogeneous mixture back into the charging pump suction. The charging pump will continue to run, thereby purging the system of gas. The pump performance may fall again due to the presence of gas in the pump; however, each time the pump stalls (see Reference 4), the system will self correct itself by venting and re-flooding the pump inlet. Such case was demonstrated at the Palo Verde Nuclear plant with the Auxiliary Feedwater (AFW) pumps that are of comparable design. After re-flooding the AFW pump, normal operation of the pump resumed without any damage to the AFW pump internals, and without any loss of performance.

Each time the pump is pumping fluid, a significant amount of gas passes through the pump and is purged from the system. Following each occurrence of pump stall and re-initiation, the volume of gas to purge from the system decreases. Eventually, the amount of gas present will decline to an acceptable pumping level.

Key Points:

- Some water or water-gas mixture is always present inside the charging pump which provides lubrication to the close clearance wear surfaces. The charging pump is not expected to see a solid slug of hydrogen gas.

- The charging pump may stall; however, if this occurs the system will re-flood the charging pump suction. Reflooding will happen within a relatively short time period, estimated to be within 12.5 seconds. When compared with the Palo Verde test in which AFW pumps of similar design were operated in the run-out mode with loss of head for 8 minutes, including total loss of head for 2 minutes, with no mechanical damage to the pump, no damage to the charging pumps is expected. (See Reference 2)

- Eventually the system purges the suction piping of all hydrogen gas, and normal operation resumes, without significant loss of performance (or perhaps no loss at all as presented in Reference 2 after Test Point No. 12 and 13 and the Palo Verde nuclear plant). Starvation of the pump for longer time periods is reported in Reference 3 without failure. Martins Creek pump speed is 5900 rpm. The pump experienced a complete loss of head several times for "several minutes" (once for 7.5 minutes, twice for 5-6 minutes, several times for over 1 minute). See Figure 3 of Reference 3.

References:

1. "1/3 Scale Air-Water Pump Program Analytical Pump Performance Model", EPRI Report No. NP-160, October 1977.

2. "Performance Behavior Of The Auxiliary Feedwater Pumps In The Normal And Extreme Run-Out Operating Modes: Actual Testing Performed On The Motor Driven Pump Of Unit 1 At The Palo Verde Nuclear Station" by E. Makay, March 28, 1985.

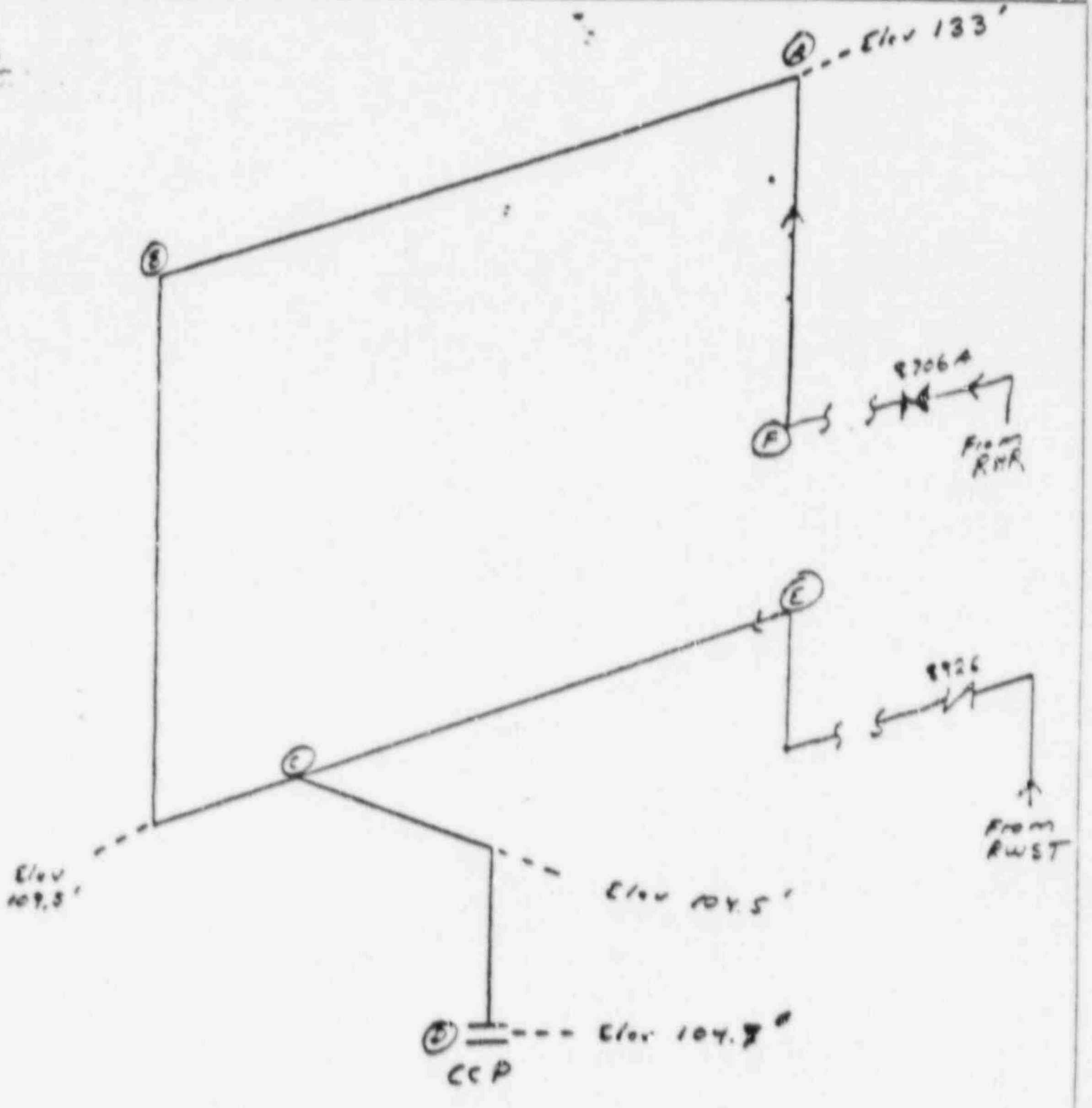
3. "Start-Up Pump: System Vibration Study." DeLaval Technical Report No. RP-36 by Soete and Peck; January 26, 1979 (Prepared for PA. P & L Co., Martins Creek Power Station.).

4. "Eliminating Pump-Stability Problems" by E. Makay, POWER, July 1970, p. 62.

WESTINGHOUSE POWER SYSTEMS DIVISION

SKETCH NO. 1

TITLE			PAGE OF
PROJECT	AUTHOR DATE	CHK'D BY DATE	CHK'D BY DATE
S.O.	CALC NO	FILE NO	GROUP



Volumes A-B = 58 ft^3
B-C = 7.5 ft^3
C-D = 3.95 ft
E-C = 8.09 ft

REV NO	REV DATE	AUTHOR DATE	CHK'D BY DATE	CHK'D BY DATE

WESTINGHOUSE FORM 55213C (8/68)

REFERENCE I

1/3 SCALE AIR-WATER PUMP PROGRAM, ANALYTICAL PUMP PERFORMANCE MODEL

EPRI NP-160
(Research Project 598)

Key Phase Report

Volume 1

OCTOBER 1977

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single-phase characteristics through the pump average void fraction. It was proposed that the difference between the single- and two-phase characteristics could be calculated by applying a multiplier to the single-phase homologous curves. The multiplier, to be a function of the pump average void fraction α, was defined as

$$M(\alpha) = \frac{(C)_1 - (C)_2}{(C)_1} \tag{1}$$

where

$(C)_1$ = single-phase characteristic: h/v^2, b/α_N^2, etc.,
$(C)_2$ = two-phase characteristic: h/v^2, b/α_N^2, etc.

It was presumed that the variation of M with void fraction would depend on flow direction. Consequently, separate correlations were undertaken for the first and second quadrant data. Furthermore, the approximate characteristics reported in Reference 1, reproduced here for the first quadrant as Figures 2-2 and 2-3, exhibited a difference in trends between the positive and negative characteristics. Head and torque were observed to decrease with increasing void fraction in the region where the characteristics were positive for all void fractions. However, where the head and torque curves were negative for both single- and two-phase flows, the magnitudes of head and torque at two-phase operating points actually showed an increase at void fractions less than 20%. Therefore, it was considered necessary to develop $M(\alpha)$ separately for positive and negative performance characteristics in the first quadrant.

Values of $M(\alpha)$ were computed for first- and second-quadrant two-phase performance characteristics using the reduced homologous data and polynomial fits to the single-phase head and torque curves.

Each multiplier was assumed to be a polynomial in the average void fraction, α, of the form

$$M(\alpha) = B_0 + B_1\alpha + B_2\alpha^2 + \ldots + B_n\alpha^n. \tag{2}$$

The coefficients, B_i, were determined by least-squares fits to the calculated values of M. The Babcock & Wilcox ROMP curve-fitting program (Reference 3) was used.

EPRI PUMP TWO-PHASE PERFORMANCE PROGRAM REPORTS

1. C-E Quarterly Technical Progress Report No. 1, January 1 - March 31, 1975, EPRI RP301.
2. C-E Quarterly Technical Progress Report No. 2, April 1 - June 30, 1975, EPRI RP301.
3. C-E Quarterly Technical Progress Report No. 3, July 1 - September 30, 1975, EPRI RP301.
4. Two-Phase Pump Performance Program, Preliminary Test Plan, W. G. Kennedy et. al., EPRI NP-128, September 1975.
5. C-E Quarterly Technical Progress Report No. 4, October 1 - December 31, 1975, EPRI RP301.
6. Review and Analysis of State-of-the-Art of Multiphase Pump Technology, P. W. Runstadler, Jr., EPRI NP-159, February 1976.
7. C-E Quarterly Technical Progress Reports No. 5 & 6, January 1 - June 30, 1976, EPRI RP301.
8. Two-Phase Pump Performance Program, Pump Test Facility Description, J. D. Fishburn et. al., EPRI NP-175, November 1976.
9. C-E Quarterly Technical Progress Report No. 7 & 8, July 1 - December 31, 1976, EPRI RP301.
10. 1/20 Scale Model Pump Test Program, Preliminary Test Plan, P. W. Runstadler, Jr. and F. X. Dolan, EPRI NP-292, February 1977.
11. 1/20 Scale Model Pump Test Program, Facility Description Report, P. W. Runstadler, Jr. and F. X. Dolan, EPRI NP-293, March 1977.
12. Analytical Models and Experimental Studies of Centrifugal Pump Performance In Two-Phase Flow, D. G. Wilson et. al., EPRI NP-170, January 1977.
13. 1/3 Scale Air-Water Pump Program, Test Program and Pump Performance, R. W. Winks, EPRI NP-135, February 1977.

REFERENCE 2

Technical

Report

REPORT NO: ERCO-10,756.

MARCH 28, 1985

PERFORMANCE BEHAVIOR OF THE AUXILIARY FEEDWATER PUMPS IN THE NORMAL AND EXTREME RUN-OUT OPERATING MODES: ACTUAL TESTING PERFORMED ON THE MOTOR DRIVEN PUMP OF UNIT 1 AT THE PALO VERDE NUCLEAR STATION.

BY

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TEST PT	TIME	FLOW* GPM	PRESSURE-PSI		ΔP PSI	H FT	MAX VIB** MILS	MOTOR AMPS
			SUC.	DISCH.				
1	18:58	0	24.5	1790	1766	4078	0.5	72
2		740	22	1480	1458	3370	0.4	125
3		990	21	1270	1249	2885		135
4	19:21	1070	20	1190	1170	2703		138
5		1200	19	1080	1061	2451		140
6		1270	18.5	998	979	2262		140
7	19:23	1380	18	870	852	1968	0.8	142
8.		1470	16.5	690	673	1556	1.5	138
9	8 MIN	1510	16.5	520	503	1163		132
10		1510	16.5	410	393	909		130
11	APPROX 2MIN	1520	16	300	284	656	2.5	128
12		750	22.5	1470	1447	3343	0.5	125
13	19:34	0	26	1785	1759	4063	0.6	72
14	COAST DOWN TIME: 1 MIN. 25 SEC.							0

* ADD 250 GPM FOR CONTINUOUSLY RECIRCULATING MINIMUM FLOW TO GET TOTAL PUMP FLOW AT HIGH PRESSURES.

** VIBRATION WAS MONITORED IN THE X-Y-Z DIRECTIONS. ONLY MAX. AMPLITUDES SHOWN.

TABLE 1: AUXILIARY FEEDWATER PUMP (AFB-P01) RUN-OUT FLOW TESTING AT THE PALO VERDE NUCLEAR GENERATING STATION UNIT NO. 1 ON MARCH 6, 1985.

Energy Research & Consultants Corp.
900 OVERTON AVENUE - MORRISVILLE, PA. 19067

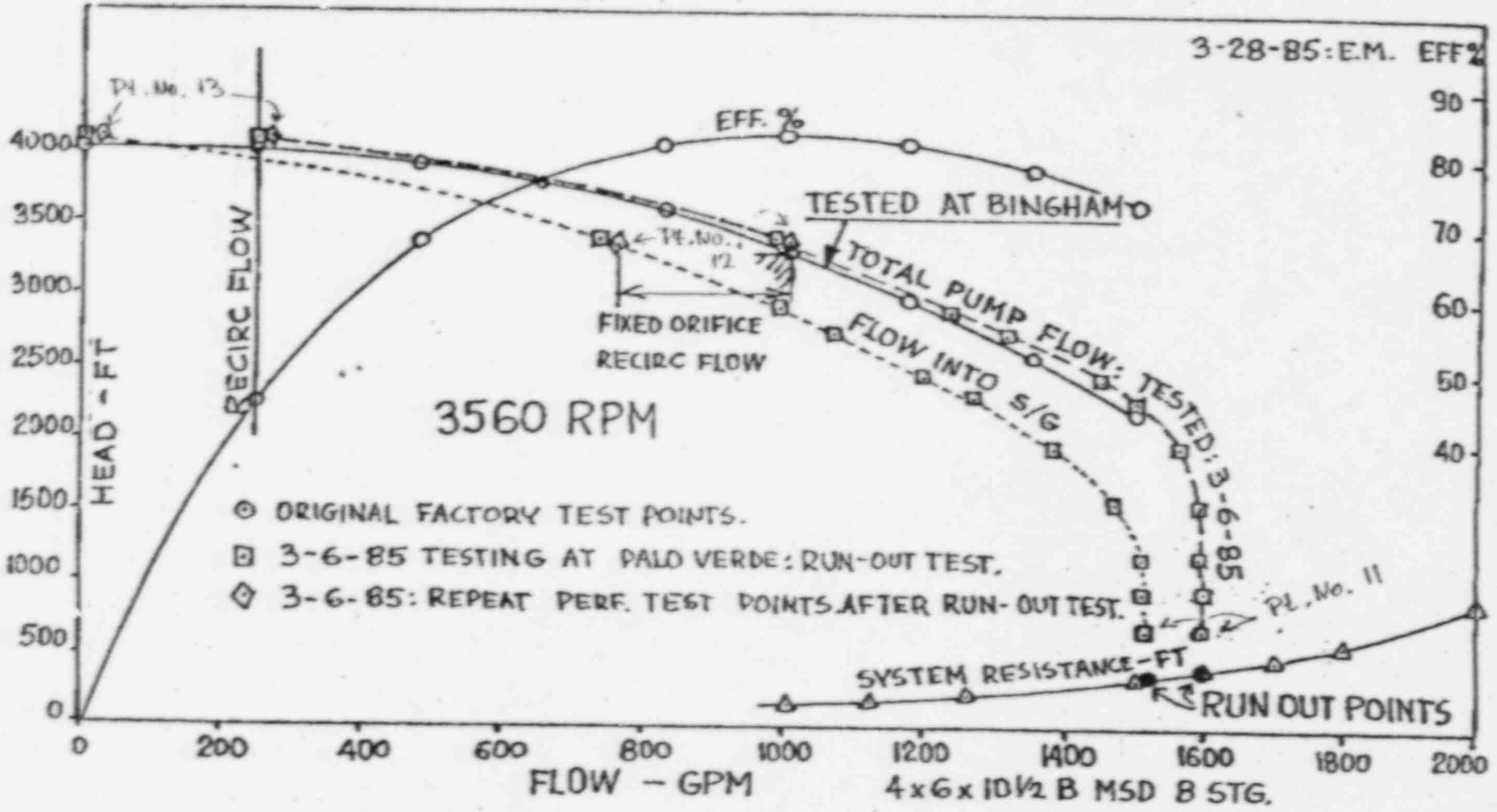

FIGURE 7: BINGHAM-MADE NUCLEAR AUXILIARY FEEDWATER PUMP TESTING AT THE PALO VERDE NUCLEAR GENERATING STATION, UNIT 1.

REFERENCE 3

DELAVAL TURBINE INC.
TRENTON, N.J. 08602

AUTHOR: G. W. SOETE / R. J. PECK		UNITERM CLASSIFICATION:
TITLE: Start-Up Pump - System Vibrations Study Pa. Power & Light, Martins Creek Sta., 705812-13		
ENG'G DIV. REPORT: RP-36	DATE: Jan. 26, 1979	NO. PAGES: 10 APPLICABLE TO: Pumps

ABSTRACT:

During start-up and shutdown, on a daily basis, severe cavitation occurs on the motor/gear driven pumps in a routine manner. Proper instrumentation can be installed and, with surveillance, will prevent this.

These instruments may also be used to automate the opening and closing of the recirculation valve at proper flow points to more positively protect the pump.

Cavitation and failure to properly operate the non-automatic recirculation valves were the major contributors to the failures experienced by these pumping units.

Future monitoring of shaft vibration and axial position is a positive step towards measuring the operating pump characteristics in terms of a preventative maintenance program.

PREPARED FOR: Pennsylvania Power & Light

TESTS MADE BY: G. W. Soete, R. J. Peck, W. A. Mc Crea AUTHOR:

COUNTERSIGNED: R P Kolb R. P. Kolb Manager of Engineering DEPARTMENT: Pump Engineering

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No. 283 (R-2) 4/73

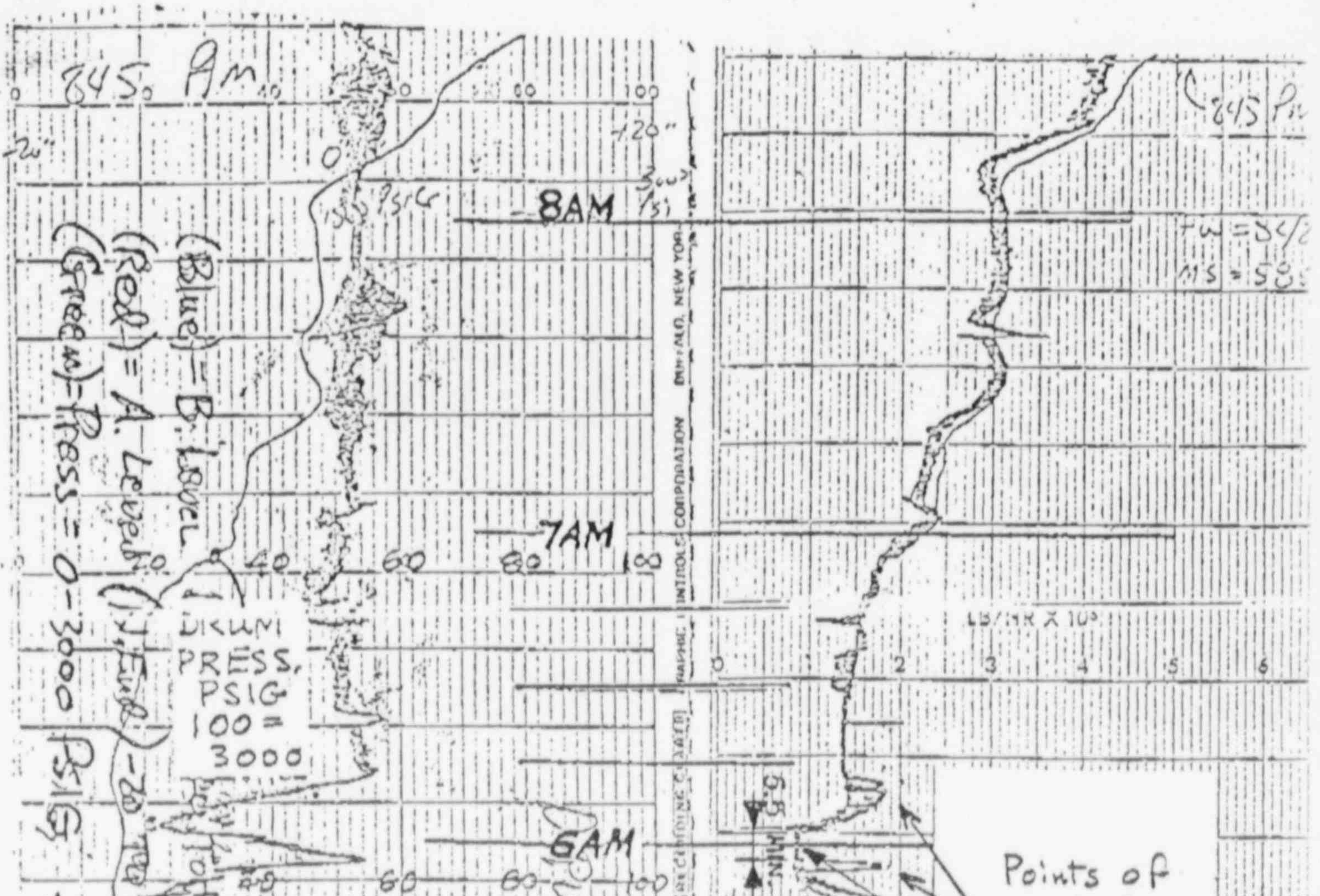

FIG. 3
DRUM LEVEL, DRUM PRESSURE, PUMP FLOW

Reprinted from Power
THE
JULY 1970
ISSUE
A McGraw-Hill Publication
330 West 42nd Street
New York N.Y. 10036

REFERENCE 4

Eliminating pump-stability problems

Boiler feed pump vibrations can be reduced considerably, perhaps eliminated, by selecting hydrostatic bearings over conventional hydrodynamic bearings

Competition in the boiler feed pump (BFP) market has created a situation where desired pump efficiencies are exceeding current technological capabilities. Though performance figures appear somewhat inflated now, competitive position in the future demands that higher efficiencies be delivered without creating operational problems.

Many phenomena tax safe operation, especially at partial loads. They include vibration from hydraulic forces, higher noise levels, larger and unpredicted axial thrust, damping effects on critical speeds and nonsynchronous response of the flexible rotor. Further, pressure pulsations in the impeller and hydraulic passages have been greatly magnified in high-output, high-speed pumps. A frequent result of these [illegible]ons is fatigue failure of the impeller.

Although research continues, no concrete solutions for pump-vibration problems have yet been found. The total problem of pump instability involves complex interactions among hydraulic, geometric and mechanical features of a particular unit.

To locate the causes and solve vibratory problems, you must examine carefully both the failure mechanism and pump geometry. Several mechanisms leading to intolerable vibrations are: (1) rotating stall in the impeller, (2) stall in the diffuser and guide channels, (3) secondary flows, (4) cavitation from a low net-positive-suction head (NPSH), and (5) oscillations caused by rotor dynamics.

The first four situations are generally observed during low NPSH conditions and transient partial-load operation. The fifth, somewhat independent of flow and NPSH, is strongly dependent on speed variation and bearing characteristics. Pump tests at varying speeds have shown that, at any flow and NPSH condition, there is at least one critical speed where pressure oscillations are most pronounced. Frequency of these oscillations depends on design quality.

A thorough understanding of *stall* is important if you have excessive BFP vibration (figure, lower right). Rotating stall in impellers occurs this way: When the load condition of a centrifugal machine changes, direction of flow also changes in the cascade of blades. That is, as the incidence angle—difference between flow angle and pump-impeller or diffuser-vane inlet angle—increases, you get flow separation first, then stalling. However, because of nonuniform flow upstream of the blades or manufacturing inaccuracies, one channel stalls before the others.

Breakdown of flow in this passage causes a deflection of the inlet fluid stream. Thus, one neighboring passage receives fluid at a smaller incidence angle and another at a larger angle. Result: Passage with the larger incidence angle stalls, and cyclic rotation of the phenomenon begins. For centrifugal pumps with blades bent backward (where inlet angle is less than 90°) stall rotates in the direction of impeller rotation at high loads and in the opposite direction at low loads. Similarly, stall can occur in diffuser channels from a change in incidence angle during low-load conditions. If diffuser is not properly designed, stall also will be evident at full load.

Vibration is strongly influenced by pump-stage geometry (figure in center of column at right). Conclusion based on many laboratory and field tests is that the following areas should be carefully designed if induced vibration, cavitation and general instability are to be reduced:

- Geometry of the inlet guide vanes
- Impeller-eye geometry and shaft size
- Impeller-discharge geometry, exit angle and vanes
- Wearing-ring clearance
- Radial gap between the impeller and the diffuser
- Impeller/diffuser alignment
- Diffuser geometry
- Axial gap between the impeller and stator.

Also, air trapped in suction and discharge piping is an occasional cause of instability. However, this is not of a permanent nature: eventually it is washed out and smooth operation is restored.

Degree of instability is determined by observing: (1) frequency and amplitude of flow-pressure oscillations, (2) lateral vibration, which induces pressure waves, (3) axial vibration—this, too, induces pressure waves, and (4) variations in axial thrust induced by pressure oscillations.

Poor design or wear at any one of the locations listed above may be responsible for these oscillatory disturbances. Realize that frequency range and peak-to-peak amplitudes depend on magnitude of axial thrust, level of efficiency and head stability.

Pressure pulsations can be defined as low- and high-frequency response of fluid particles to complex, unsteady, nonlinear forces. Low-frequency, high-amplitude pressure pulsations result in visually observable movement of pump

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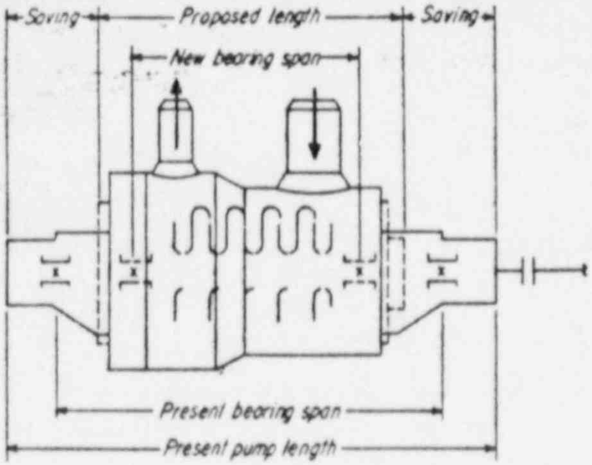
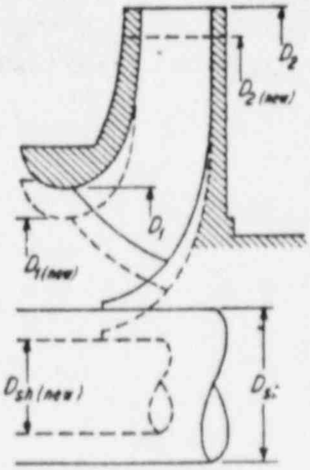




Hydrostatic bearings offer significant reduction in boiler feed pump size and cost. Their load-carrying capacity is maintained by an externally pressurized fluid. Hence, fluid film separates shaft from bearing even at zero speed.

Bearings must be pressurized: Speed of rotation is too slow to give sufficient load-carrying capacity from hydrodynamic action alone—recall, viscosity of water is very low at high temperature.

In hydrodynamic bearings, fluid pressure supporting a load is generated within the bearing by relative motion of bearing and shaft.

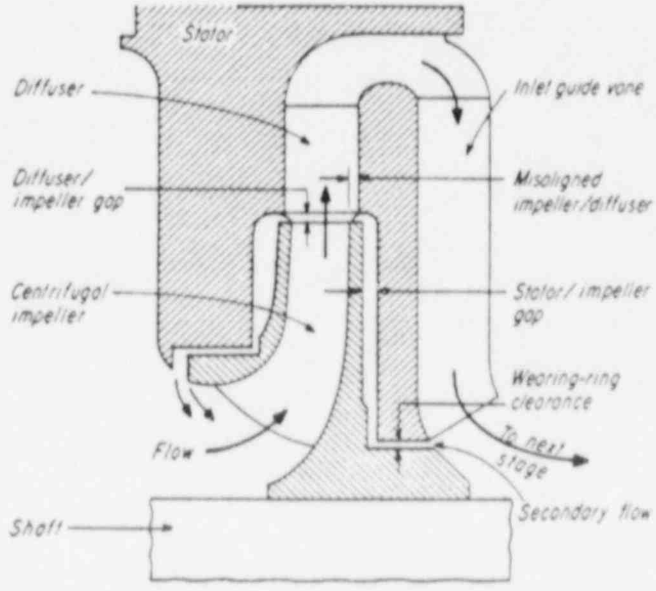
and connecting pipe. They also cause gross fluctuation in discharge flow. High-frequency, high-amplitude pressure pulsation degrades pump performance somewhat; more important, it causes accelerated damage to the rotating and stationary cascades.

Many pump-instability problems can be eliminated, or at least reduced, if hydrodynamic, oil-lubricated journal bearings are replaced by hydrostatic bearings using pressurized boiler feedwater as the lubricant. There are many advantages to be gained by selecting hydrostatic bearings. For example, overall length of a feed pump can be shortened by approximately 40%. Reasons: Water-lubricated bearings can be enclosed within the pump barrel, and seals can be eliminated (figures in tinted area).

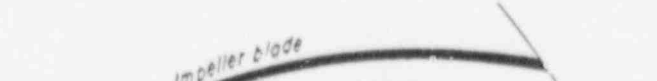
Further, when a shorter bearing span is employed, shaft deflection does not dictate the shaft diameter; it is determined by stress levels alone. To illustrate: For an 80,000-hp, five-stage unit, shaft diameter is estimated at 9.5 in. when hydrodynamic bearings are used. Hydrostatic bearings permit an 8.25-in. diam shaft with its favorable influence on pump performance and life. Other advantages:

- Smaller impeller eye produces a better flow path, yielding increased efficiency and NPSH
- Longer blade path offers more favorable blade loading
- Smaller diameter wearing ring causes less leakage, giving higher pump efficiency
- Smaller clearances at the wearing surfaces give better partial-load performance and less danger of instability
- Secondary flow at the impeller eye during low loads is decreased, reducing vibration caused by pressure pulsation
- Smaller impeller produces the same head, lowers disc friction and reduces barrel stresses
- Higher speeds are possible, reducing unit size
- Oil lubrication system is eliminated
- Capital cost is reduced.

Although most BFP-bearing experience has been with hydrodynamic journals in the laminar regime, the technology for turbulent bearings is well established and has been applied successfully to other demanding applications in rotating machinery. Recently developed computer programs solve hydrostatic bearing problems to improve performance predictions for both dynamic and static loading, and determine the effects of turbulence in the bearing film. These programs have been verified experimentally for general modes of operation. ●



Vibration, cavitation, and instability can generally be traced to one of several possible locations in a centrifugal pump stage. For example, wearing-ring clearance might be excessive or perhaps the impeller/diffuser is out of alignment



Stalling occurs when the incidence angle—difference between flow angle and pump-impeller or diffuser-vane inlet angle—increases above a specific critical value. Stalled area, which eventually washes out, reforms as rotation continues

ENCLOSURE 2

The following discussion provides information regarding the effect of hydrogen gas accumulation on the RHR to CCP suction line and its impact on flow requirements.

Operability of the ECCS system is addressed in plant Technical Specification 3/4.5.2. The LCO requires 1) one operable CCP, 2) one operable RHR heat exchanger, 3) one operable RHR pump and 4) a flowpath capable of taking suction from the RWST and transferring suction to the containment sump during recirculation.

In addition, surveillance requirement 4.5.2.1 requires HHSI - Single Pump flow $\geq$ 193 gpm (each injection line). However, this flowrate applies only to flow requirements during the injection phase. This flowrate does not address flow requirements during recirculation.

However, requirements for flowrates during recirculation are addressed in 10CFR 50.46. In general terms, it is necessary that the ECCS operation be able to support long-term cooling of the reactor core. This includes limiting PCT and providing for decay heat removal. In specific terms, demonstrating complete coverage of the core during the time period of interest will ensure acceptable long-term cooling.

The operative parameters for evaluating adequate core coverage include flow delivered to the core, water inventory in the core, and decay heat levels. A calculation was performed which focused on that period of time after the accident when recirculation might be required until such time that the RCS pressure could be reduced below the RHR cut-in pressure. This evaluation determined (1) flowrate required to maintain a steady state water level, (2) initial excess inventory available to prevent core uncovery, (3) total tolerable loss of all ECCS flowrate, and (4) total tolerable partial loss of ECCS flowrate.

The key parameter in maintaining a steady state water level is the decay heat present in the core. To maintain a constant water level, inventory must be added to account for water inventory lost due to boil off. Of course, as the decay heat is diminished, the flow requirement decreases.

The ANS 1971 + 20% decay heat was used, in keeping with the decay heat model employed in the Farley SBLOCA analysis of record. The question, then, was to establish the flow that would have to be made up to compensate for potential boil off and thus assure the core would remain covered long-term. Several very conservative assumptions were taken with respect to general cooling of the vessel water inventory.

With this basis established, the following table was developed to show flow versus time after an accident.

TIME	FLOW (LBM/SEC)	FLOW(GPM)
1 hr.	57.2	428.1
2 hrs.	45.5	340.6
3 hrs.	40.0	299.4
4 hrs.	36.6	273.5

The second issue was to identify the amount of excess inventory available prior to recirculation. Excess inventory is defined as the amount of water available above the top of the core. It was verified based on analysis trends that the reflooding of the core/vessel during injection would be sufficient that the water level would reach the hot leg elevation prior to the initiation of recirculation. The water above the core up to the hot leg elevation would represent an inventory that could be boiled off in dissipation of decay heat before the core would be in jeopardy of being uncovered.

Knowing the available water inventory and decay heat levels, it is possible to determine the total tolerable loss of all ECCS Flowrate. This evaluation was conservative in nature taking no credit for hot leg filling above the hot leg (bottom) elevation nor was downcomer filling factored in. The total tolerable loss of all ECCS was calculated to be as follows:

TIME	TOLERABLE HHSI INTERRUPTION TIME (SEC)
1 hr.	272
2 hrs.	349
3 hrs.	400
4 hrs.	440

The final issue was to evaluate the total tolerable partial loss (degradation) of HHSI flow. This would occur if the gaseous void reduces the delivered HHSI flowrate, but does not result in total cut-off. This evaluation defined a family of curves which would look like the following curve defined for the 2 hour time point. (This represents the most limiting curve due to the highest decay heat level).

As previously identified the minimum expected flowrate during switchover to recirculation is expected to be approximately 550 GPM (RCS pressure = 600 psig). Based on the curve below, two extremes of the curve can be evaluated for comparison (flow delivered equals 50 GPM and 400 GPM). The first case (50 GPM) represents a 91% reduction in flow and can be tolerated for 5.1 minutes. The second case (400 GPM) represents a 27% reduction in flow and can be tolerated indefinitely.

Given the systems evaluation and assuming the pump continues to operate, Westinghouse has concluded that the hydrogen gas is not capable of degrading HHSI flow for a long enough time to result in core uncovery. Therefore, more than adequate HHSI flow would be available.