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August 9, 1984
REGION V I&E
ANPP-30134-TDS/TRB

U. S. Nuclear Regulatory Commission
Region V
Creekside Oaks Office Park
1450 Maria Lane - Suite 210
Walnut Creek, CA 94596-5368

Attention: Mr. T. W. Bishop, Director
Division of Resident
Reactor Projects and Engineering Programs

Subject: Final Report - DER 83-61
A 50.55(e) Reportable Condition Relating to LPSI Pumps Failure To Start And Do Not Produce The Required Head.
File: 84-019-026; D.4.33.2

Reference: A) Telephone Conversation between P. Johnson and R. Tucker on September 14, 1983
B) ANPP-28001, dated October 13, 1983 (Interim Report)
C) ANPP-28627, dated January 16, 1984 (Time Extension)
D) ANPP-28883, dated February 15, 1984 (Time Extension)
E) ANPP-29293, dated April 13, 1984 (Interim Report)
F) ANPP-29841, dated June 27, 1984 (Time Extension)

Dear Sir:

Attached is our final written report of the Reportable Deficiency under 10CFR50.55(e), referenced above.

Very truly yours,

E E Van Brunt/DBK

E. E. Van Brunt, Jr.
APS Vice President
Nuclear Production
ANPP Project Director

EEVB/TRB:nj
Attachments: CE Doc. No. CEN-285(V)-P
Proprietary Copy #1

cc: See Page Two

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NRC PDR
NSIC
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FINAL REPORT - DER 83-61
DEFICIENCY EVALUATION 50.55(e)
ARIZONA PUBLIC SERVICE COMPANY (APS)
PVNGS UNITS 1, 2, 3

I. Description of Deficiency

The Low Pressure Safety Injection (LPSI) Pumps are supplied by Combustion Engineering (C-E) and are manufactured by Ingersoll-Rand (IR) and include 500 hp Westinghouse motors. They are identified by tag numbers as follows:

1MSIA-P01	2MSIA-P01	3MSIA-P01
1MSIB-P01	2MSIB-P01	3MSIB-P01

While performing preoperational testing at Unit 1 on March 18, 1983, LPSI pump 1MSIB-P01 was run for approximately three minutes with the pump suction valve 1PSIB-UV-652 closed. A restart of the pump was attempted approximately three hours later and the motor failed to start (i.e., tripped out on the time overcurrent protection circuit which was set at 6 seconds). The pump was disassembled and inspection revealed surface damage (galling) to the pump lower case wear ring and mating surfaces of the impeller. Also, the lower case ring was angularly displaced approximately 3/4". This incident was the subject of DER 83-21. The corrective action was to repair the rough surfaces by smoothing with a stoning operation and replace the lower case ring set screws. The pump was then retested successfully.

During the period of May 16 to May 19, 1983, two (2) more failures to start the same LPSI pump occurred due to motor time overcurrent trips. Disassembly and inspection revealed galling had occurred again on the lower case wear ring and impeller mating surfaces and the lower case ring was angularly displaced approximately 3/4". As before, the corrective action was to smooth the impeller and case ring by stoning.

Subsequently, this DER (83-61) documented that on June 14, 1983, LPSI pump 1MSIB-P01 again failed to start during the continuation of the preoperational testing after running for approximately twenty minutes. At this point, the condition was attributed to a motor problem due to the fact that after each failed start, the pump was free to turn but was not coming to speed. Therefore, the LPSI Unit 1 motor was replaced with a Unit 3 LPSI pump motor.

On June 19, 1983, the same LPSI pump with the Unit 3 motor failed to start after running successfully for two hours. On June 21, 1983, with the IR representative present, the pump was disassembled and inspected. Galling of the lower ring surfaces had occurred again and the lower case ring was angularly displaced approximately 3/4". Under the IR representative's direction, the pump was reworked to smooth all galled areas and reassembled. Ten successful test starts were recorded on June 26. On July 6, 1983, the LPSI pump again failed to start.

On October 8, 1983, Unit 2 LPSI pump 2MSIA-P01 failed to start (6-second overcurrent trip) after 41 succcessful starts and accumulation of 66 hours of running time, reference NCR SM-3026. Disassembly revealed heavy galling at the lower impeller to case ring fit and the lower case ring was angularly displaced approximately 3/4", the same as observed after the Unit 1 pump failures to start.

Miscellaneous

1. NCRs SM-2756 and SM-2757 are also included in this DER (83-61) to document that test data indicated pumps 1MSIA-P01 and 1MSIB-P01 did not meet performance requirements for head-capacity (Ref. CESSAR Table 6.3.2-1).

2. On December 3, 1983, the impeller from LPSI pump 3MSIA-P01 was removed for installation in LPSI pump 1MSIB-P01 to replace the damaged Unit 1 impeller. During inspection of the Unit 3 impeller, it was noted that the bore was out of tolerance per vendor drawing C-8X20A3DX1A. The bore should be 2.5005"+.0005". The actual bore measurement is 2.5050" to 2.5015" (Ref. NCR SM-3418). All other LPSI pump impeller bores were within tolerance.

3. Inspection of running clearances on pump 1MSIB-P01 on January 24, 1984, after test runs to evaluate a preloaded bottom bearing and modified running clearances with Nitronic 60 case rings, revealed light contact (Ref. NCR SM-3588).

Equipment Description

The LPSI pumps are 8 x 20 type WDF which are single-stage, centrifugal, vertical, overhung, end-suction type, close-coupled to Westinghouse frame 5010, vertical solid shaft (VSS) 500 hp, 1780 rpm 3/60/4000, squirrel cage induction motors.

The Containment Spray (CS) pumps are IR 8 x 23 type WDF which have a 23" diameter impeller with matching diffuser (optimized for a different head-capacity range than the LPSI pumps) which fit into the same 8 x 20 WDF casing as the LPSI pumps. The motors are Westinghouse frame 5809, VSS, 800 hp, 1780 rpm, 3/60/4000, squirrel cage induction type, with the same upper and lower bearings, mounting fit to pump, and shaft extension dimensions as the LPSI pump motors. The CS pump/motor sets are supplied by C-E and are identified by tag numbers as follows:

1MSIA-P03	2MSIA-P03	3SMIA-P03
1MSIB-P03	2MSIB-P03	3SMIB-P03

Because of the design similarities between the LPSI and CS pumps, the corrective actions address both LPSI and CS pumps, even though CS pumps have never failed to start.

II. Analysis of Safety Implications

The Low Pressure Safety Injection (LPSI) pumps are used to provide core cooling flow in a shutdown cooling mode and also to provide emergency core colling flow if there is a Loss of Cooling Accident (LOCA).

The Containment Spray (CS) pumps are designed to remove heat from the containment atmosphere in the event of a LOCA. They are also used to circulate reactor coolant to remove decay heat following plant shutdown.

Based upon the above, the failure to start condition is evaluated as reportable under the requirements of 10 CFR Part 50.55(e) since, if left uncorrected, it could adversely affect the safety of plant operations.

Also, this condition is evaluated as reportable under the requirements of 10CFR Part 21 since it constitutes a substantial safety hazard and, if left uncorrected, could adversely affect the capability to safely shutdown the reactor.

III. Corrective Action

The cause of the failure to start was theorized to be hard contact between the impeller and casing ring. Accordingly, based on the recommendation of Combustion Engineering and Ingersoll-Rand and with Bechtel Engineering concurrence, the following corrective actions were implemented on the LPSI and CS pumps for Units 1, 2, and 3 to mitigate the effects of the contact. Figure 1, attached, represents a generic cross-sectional view of the LPSI 8 x 20 and CS 8 x 23 WDF pumps and is provided to identify, by item number, the corrective action modifications.

1. The upper and lower K-500 Monel case wear rings (Item 6) were replaced with new rings using Armco Nitronic 60 material which is known for its gall-resistant properties (Ref. 1). The Nitronic 60 is more gall-resistant than K-Monel.

2. (a) The running clearances between the impeller (Item 3) and casing rings (Item 6) on the LPSI pumps were increased to .029"-.036" diametrical, (Ref. 2, Item 3). This was done to reduce startup contact forces and to further reduce startup friction.

   (b) The running clearances between the impeller (Item 3) and the casing rings (Item 6) on the CS pumps were increased to .025"-.032" diametrical (Ref. 3), for the same reason as 2(a).

3. The impeller (Item 3) upper and lower ring fit areas were serrated (grooved) to make them less sensitive to any contact and to minimize possible loss of pump head due to increasing the running clearances (Ref. 2, Item 4).

4. To assure centralization of the upper case wear ring, the allowable run-out on the male rabbet of the stuffing box extension (Item 264) was decreased from .005 inch to .002 inch TIR. Location fits will also be doweled to limit movement after alignment is achieved (Ref. 2, Item 2).

During testing of LPSI 1B (with its 500 hp motor and with above Items 1-4 implemented) another failure to start occurred on January 29, 1984 (the unit was tripped manually after two seconds). As with previous failed starts, the shaft rotated slowly prior to the trip and was free to rotate by hand thereafter. Unlike previous failed starts, the unit was successfully restarted six times on January 30, 1984. Subsequent disassembly and inspection disclosed light contact at the lower clearance, and the lower case ring was radially displaced approximately 1/4".

III.B. <u>Corrective Action, LPSI Pump Motors</u>

As documented and presented in detail in the C-E report (Ref. 9), it was concluded that due to the shaft flexibility in combination with transient electromagnetic starting forces, this particular 500 hp motor (frame 5010) is unsuited for reliable use with the WDF type pump, in spite of the mitigating effects of Corrective Action Items 1-4 above.

Contact between impellers and case rings during startup does not in itself cause failure to start, but has been demonstrated to be a precondition of the failure-to-start mechanism.

Measurements of startup shaft and impeller deflections in air have shown that impeller-to-case ring contact consistently occurs with the original 500 hp LPSI pump motors and does not occur with the stiffer shaft 800 hp CS pump motors in combination with either LPSI or CS pump impellers, (Ref. 4). Therefore, to minimize the startup shaft and impeller deflections, the stiffer shaft 800 hp CS pump motor was installed on the LPSI pump.

It was determined that a 100 start test with no failures would demonstrate adequate reliability with 95% confidence for a pump/motor set (Ref. 5). The following items were therefore implemented.

1. An 800 hp CS pump motor from Unit 3 was installed on the LPSI 1B pump (Ref. 6).

   The pump/motor set was operated for 3 hours to stabilize bearing temperatures. It was then restarted 5 times (20 minutes run time for the first four starts to satisfy motor cooling requirements). Subsequent disassembly and inspection on March 3, 1984, revealed light contact at the lower impeller clearance (360°) with corresponding contact at approximately 270° of the lower case ring on the side away from the pump discharge connection.

2. The pump was reassembled and 100 additional starts were made. All runs were approximately 20 minutes duration and at 2000 to 2100 gpm valve setting. The first run (after refilling and venting) started at approximately 100 gpm through the minimum flow line, the same as in Paragraph 1 above. Subsequent disassembly and inspection (March 8, 1984) disclosed no evidence of contact at the upper ring clearance and no obvious additional contact at the lower ring clearance, as noted in Item 1 above. The contact surfaces of the Nitronic 60 case rings were smooth with a light intermittent film transfer to the four impeller running surface lands.

   At a March 9, 1984 meeting, APS, Bechtel, C-E, and IR agreed that the light rubs were normal and within acceptable limits (Ref. 7). The significance of no evidence of contact on 90° of the lower case ring indicates startup deflections are not resulting in contact. The 270° contact resulted from the brief operation at minimum flow where pumps characteristically run rougher than at higher flows. It was further agreed that the test showed this particular 800 hp motor (frame 5809 with a 6" diameter shaft between bearings) would operate reliably in combination with the WDF type pump (either 8 x 20 or 8 x 23 sizes).

3. All six LPSI pump motors from Units 1, 2, and 3 will be replaced by six new Westinghouse frame 5809 800 hp motors. These new motors will be duplicates of and interchangeable with the original CS pump motors (Ref. 4). This motor replacement is proceeding in accordance with DCP 1, 2, 3 SM-SI-117.

   The increased startup inrush current (800 vs 500 hp) is within the capacity of the diesel generators. The LPSI breaker settings were changed to accommodate the 800 hp motor. In addition, the original current transformer (100/5 amp.) was replaced (150/5 amp.) and the ammeter was changed from a 0-100 to 0-150 scale meter.

4. SAR Change Notice 1180 has been initiated to revise affected sections of the FSAR for the change in LPSI pump motors.

5. As of August 8, 1984, Unit 1 LPSI pumps A and B have been started 36 times and 46 times, respectively, since completion of the 100 start test, without any difficulties. Disassembly and inspection of these pumps during the time period of additional starts have not disclosed any abnormal wear patterns.

   Also, CS pump A has been started 48 times and CS pump B, 46 times. Inspection after additional operation revealed no abnormal wear patterns. These particular pump/motor sets have never had a failure-to-start problem.

III.C. Corrective Action, Miscellaneous

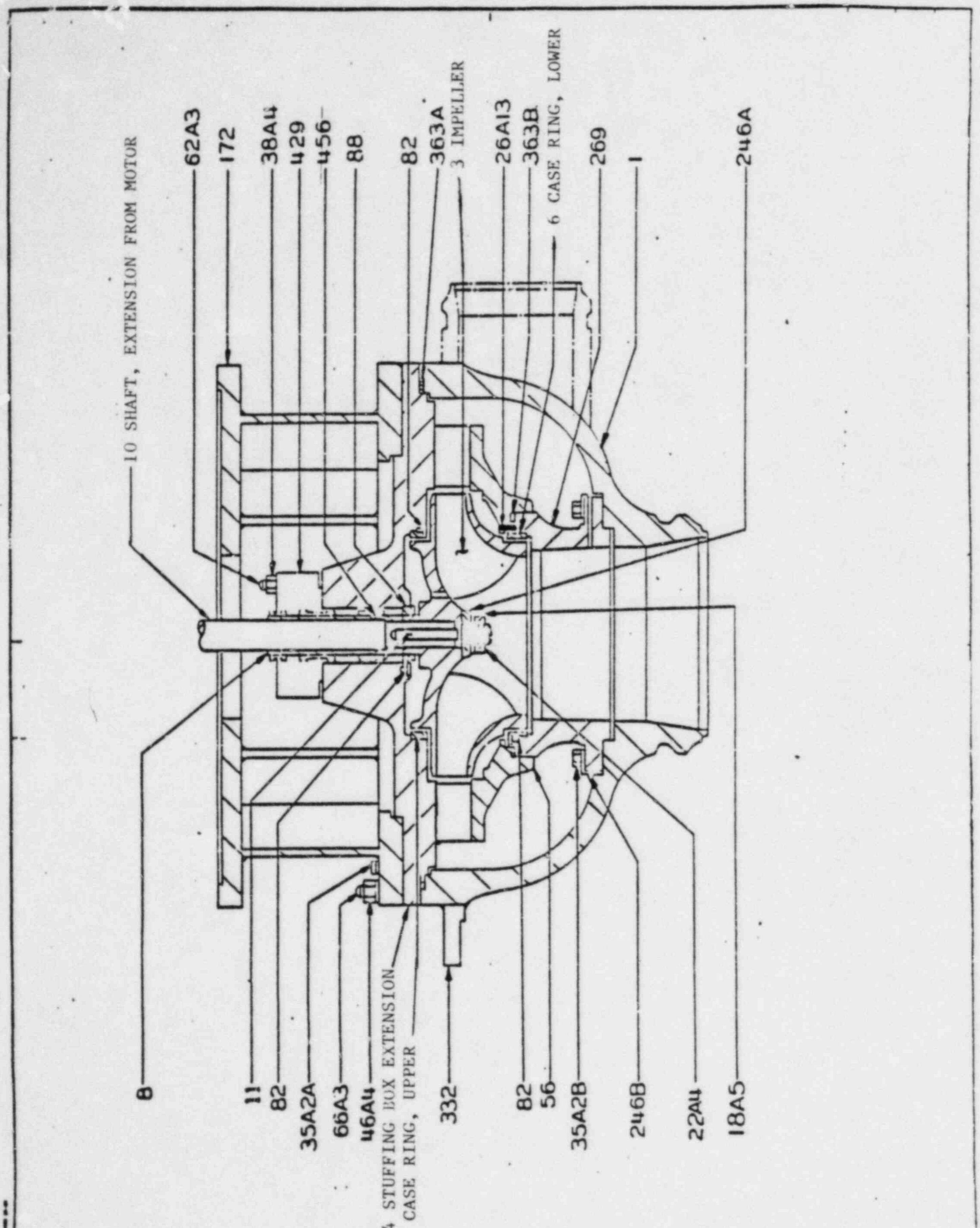
1. Regarding NCRs SM-2756 and 2757, additional field performance tests after final modifications of both Unit 1 LPSI pumps have verified that the head-capacity characteristics from minimum flow to runout are acceptable.

2. NCR SM-3418 was dispositioned to have the impeller returned to IR for rework to correct the bore dimension.

3. NCR SM-3588 was dispositioned to cleanup the impeller and replace the lower case ring after rubs had occurred while operating with a 500 hp motor on January 18, 1984.

IV. References

(1) V-CE-19299 dated Nov. 11, 1983
(2) V-CE-19218 dated Oct. 28, 1983
(3) V-CE-19298 dated Nov. 11, 1983
(4) V-CE-30175 dated Apr. 30, 1984
(5) V-CE-20584 dated Jan. 26, 1984
(6) V-CE-19784 dated Feb. 20, 1984
(7) V-CE-21628 dated Mar. 9, 1984
(8) V-CE-21710 dated June 11, 1984
(9) V-CE-30704 dated Aug. 2, 1984, Combustion Engineering Report CEN-285(V)-P, "Palo Verde Nuclear Generating Station Low Pressure Safety Injection Pumps Failure to Start"



Ingersoll Rand WDF Type Pump

Figure 1 , DER 83-61

C-E Power Systems
Combustion Engineering, Inc
1000 Prospect Hill Road
Windsor, Connecticut 06095

Tel 203/688-1911
Telex 99297

217542
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POWER SYSTEMS

November 11, 1983
V-CE-19299

Mr. G. C. Andognini
Arizona Public Service Company
P.O. Box 21666 - Sta. 4015
Phoenix, Arizona 85036

Subject: Palo Verde LPSI and Containment Spray (CS) Pumps

Dear Mr. Andognini

Combustion Engineering has been asked to provide additional information on the Nitronic 60 material that C-E and I-R are currently recommending for use in the LPSI and CS Pumps. This letter provides such technical information.

cc R. WELCHER
cc K. STWEETNIK
cc B. MORE

Anti-Galling Properties

Nitronic 60 is formulated to be an anti-galling material. It contains 3.50 to 4.50% Silicon which reduces galling tendency. Published galling resistance data by Armco and data from I-R tests indicate that Nitronic 60 is compatible with steels similar to CA6NM (impeller material).

I-R is in the process of testing the Nitronic 60/CA6NM combination, although even without this data, I-R says that the Nitronic 60 will be superior to the existing K-Monel.

Corrosion resistance

Nitronic 60 compares with 304 stainless steel for corrosion resistance and is non-corroding in borated water. I-R does not anticipate any corrosion problems for this application.

Thermal Expansion

The coefficient of thermal expansion for Nitronic 60 between 75 and 400°F is $8.8 - 9.2 \times 10^{-6}$ in/in °F. The ring is pressed into a 304 stainless steel suction nozzle which has a coefficient of expansion of 9.4×10^{-6}. The effect of the thermal transient has been reviewed and the Nitronic 60 material is suitable.

Please advise if you require any additional information.

Very truly yours,

C. Ferguson

C. Ferguson
Project Manager

CF/CDB:rre
V-PCE-2792
F43615
Distribution on Attached Sheet

DISTRIBUTION
V-CE-19299

cc: Messrs:
E. E. Van Brunt, Jr.
J. Vorees
W. H. Wilson
W. G. Bingham
R. H. Holm
J. W. Dilk
G. A. Butterworth
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J. Kirby
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C-E Power Systems
Combustion Engineering, Inc.
1000 Prospect Hill Road
Windsor, Connecticut 06095

Tel. 203/688-1911
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216824

POWER SYSTEMS

V-CE-19218
October 28, 1983

Mr. G. C. Andognini
Arizona Public Service Company
411 North Central
Phoenix, Arizona, 85036

Subject: LPSI Pumps Failure to Start

Reference: (A) V-CE-20488 dated 10/17/83
(B) V-CE-20397 dated 07/29/83

Dear Mr. Andognini:

To date ANPP Palo Verde has experienced the failure of two LPSI Pumps to start, Unit I Pump B and Unit II Pump A. These failures and some of the actions taken are described in References (A) and (B). Although all the contributing factors to the root cause for the failure to start have not been completely defined, contact between the impeller and casing ring does occur which prevents the start. The possible contributing factors identified are shaft stiffness, radial bearing assembly, impeller centralization, casing ring materials and clearances, and motor performance. This letter presents C-E's recommended plan of action to eliminate this failure to start problem.

LPSI Pumps

1. Limit Shaft Movement

A. Our vendor advises that "a review of the pump and motor design does not indicate any areas for gross shaft movement or misalignment" and that "shaft loads and deflections have been reviewed with the conclusion that the shaft is adequately sized to limit deflection due to bending." Investigation is continuing in this area as is examination of motor bearing clearances.

B. A program is under way to check the axial and radial shaft movement vs. load for the 1B motor at the Westinghouse Phoenix facility and for the 2A motor on site. If axial and/or radial play is excessive, the radial bearing internal clearance can be reduced by replacing the radial bearing. The thrust bearing O.D. to bearing housing I.D. clearance can be reduced by reworking the bearing housing. Radial bearings are readily available and a drawing is being made to show the reduced thrust bearing clearance if that also is required. I-R Engineering and Service personnel are on site to accomplish these checks.

An initial verbal report of examination of the original 1B motor now at Westinghouse's Phoenix facility indicates mechanical problems with the upper (radial) bearing assembly. Examination of the upper bearing

assemblies in the LPSI 1B replacement motor and 2A motor is recommended.

2. Assure Centralization of Impeller in Casing Ring

A. The casing ring I.D. will be checked for concentricity to the casing stuffing box extension rabbet fit to check for machining accuracy, distortion due to excess heat at pipe welding, and excess nozzle loads. An I-R serviceman is on site working with C-E/APS to make the necessary tooling. Completion is expected by October 28.

B. Westinghouse is to review the air gap for motor/rotor centralization and to comment by October 28.

C. At pump reassembly, the allowable run-out on the male rabbet of the stuffing box extension will be decreased from .005 inches to .002 inches TIR. Locational fits will also be doweled to limit movement after alignment is achieved.

3. Casing Rings

A. Material

C-E and I-R recommend the use of Nitronics 60 in lieu of the Monel K-500. The Nitronics 60 material has been evaluated as an acceptable wear ring material for this application. The Nitronics rings can be made available to the site within ten days. C-E and I-R recommend that they be installed in the LPSI 1B pump prior to the testing recommended in item 6.

B. The ring impeller clearance should be within a range of .029" - .036" inclusive.

4. Serrate Impeller

It is recommended that the impeller ring fit areas be serrated to make this area less sensitive to any contact and to minimize the effect on pump head and capacity in the event of a larger clearance between this area and the casing ring for any reason. I-R can provide the necessary machining information by November 1st.

5. Check Motor Torque

Existing data does not conclusively prove that the motor output is correct. I-R and Westinghouse are reviewing the existing data and investigating possible ways to perform a locked rotor test.

6. Testing

C-E recommends that the changes outlined above be made on the Unit I LPSI Pumps, and that 100 starts be performed on LPSI 1B pump to verify ability to start. The number and sequence of starts to be made at miniflow and thru the 6 inch bypass line as well as defining an acceptance criteria, are to be determined prior to the test.

C-E also recommends that the seal piping be vented prior to each test start and results of venting recorded. After four successive ventings occur that indicate that no air is present, then venting operations may be suspended until every 10th start.

Containment Spray Pumps

C-E and I-R will continue to evaluate the containment spray pumps for determining if the modifications recommended for the LPSI pumps should be considered for these pumps.

Nitronic 60 casing rings can be made available as replacement rings for the Unit I and II LPSI Pumps approximately ten days after receipt of your concurrence with these recommendations.

We wish to proceed as expeditiously as possible on the above. Should you have any questions and or any objections to our recommendations, please inform us as soon as you are able.

Very truly yours,

Dave Amerine

for C. Ferguson
Project Manager

CF/CDB:rre
V-PCE-2759
F43565

cc: Messrs:
E. E. Van Brunt, Jr.
J. Vorees
W. H. Wilson
W. G. Bingham
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POWER SYSTEMS

November 11, 1983
V-CE-19298

Mr. G. C. Andognini
Arizona Public Service Company
P.O. Box 21666 - Sta. 4015
Phoenix, Arizona 85036

POTENTIAL DCP

Subject: PNVGS Containment Spray (CS) Pumps

Reference: (A) V-CE-19218, dated 10/28/83, LPSI Pumps Failure to start

Dear Mr. Andognini

Reference (A) addressed the LPSI Pumps in detail and also stated that C-E and I-R would continue to evaluate the CS Pumps with regard to recommending any modifications. The CS Pumps have not experienced any failures to start, and, based on their engineering analysis, to date, I-R informs C-E that no changes are required to ensure pump starting capability.

cc W.J.S
cc R. Welker
cc K. Sweeten
cc E. Murray

However, since the pumps are disassembled it would be an opportune time, if APS so chooses, to implement some currently available modifications that would provide component enhancement. The modifications are as follows:

1. install Nitronics 60 casing rings
2. maintain the ring clearance within a range of .025 -.032 inches inclusive.
3. serrate the impeller ring areas.

C-E and I-R also suggest that the following checks be made to determine the current status of the CS Pumps:

1. casing concentricity (boring bar)
2. motor shaft radial movement (200 lb. push-pull).

C-E feels that implementation of the above modifications would provide assurance of greater margin in the area of any problem similar to that experienced on the LPSI Pumps. The modifications would be relatively simple to perform at this time. The Nitronic 60 rings can be made available for the Unit 1 & 2 CS Pumps in approximately one week.

We wish to proceed as expeditiously as possible on the above. Should you have any questions and or any objections to our recommendations, please inform us as soon as you are able.

Very truly yours,

C. Ferguson

C. Ferguson
Project Manager

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Windsor, Connecticut 06095

Tel 203/688-1911
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MAY 7 '84

POWER SYSTEMS

V-CE-30175
April 30, 1984

Mr. E. E. Van Brunt, Jr.
Arizona Nuclear Power Project
P.O. Box 21666 - Sta. 3003
Phoenix, Arizona 85036

Subject: LPSI Recovery Program

Attachment: Summary of Shaft Motion

Dear Mr. Van Brunt:

This letter provides shaft deflection data from Westinghouse tests at Buffalo and additional information relative to the resolution of the LPSI failure to start problem.

cc WSS
cc J BLACK

Test Data: Three motors were tested by Westinghouse at their Buffalo plant between March 28 and March 30, 1984; a Palo Verde LPSI motor, a Duke LPSI motor, and a Palo Verde containment spray motor. Deflection measurements were taken with the pump end of the motor shaft exposed. Two configurations for each motor were tested, one with the impeller removed, the other with the impeller installed. The summary of data, Attachment 1, was received from Westinghouse at a meeting on April 13, 1984. A final report from Westinghouse has been promised for May 18, 1984.

C-E concludes from this data that the Duke LPSI motors have little deflection at the shaft impeller end during the starting transient compared to the Palo Verde LPSI motor. Also, it is clear that the measured deflections are well within the minimum radial wear ring clearance of .013 inches.

Replacement Motors for Units 2 & 3

As we advised you on April 25, IR/Westinghouse has verbally recommended that the remaining LPSI pump motors be replaced with Containment Spray (CS), motors. They proposed a July 1, 1984 shipment date for the first two motors to be used for Unit 2 with four (4) additional CS motors to ship at the end of 1984 for Unit 3.

Based upon our discussions with you and J. Houchen - IR was advised that the first two must be on site June 15, 1984. Furthermore, the shipment dates for the last four motors need to be more definitive. We are waiting their formal response which they say will be forthcoming early this week. We will keep you advised.

We have been advised by Ingersoll Rand that the containment spray (2B) motor which was returned to Westinghouse for repair is scheduled for shipment to the site no later than June 13, 1984.

Duke Motor Shipment: Two Duke LPSI motors were shipped April 27, 1984 from the Westinghouse facility in Charlotte, North Carolina. They can be installed in Palo Verde Unit 2 as replacements for the present LPSI motors in the event that the replacement CS motors are not available in time to support the schedule. Please advise us prior to any decision on the installation of these motors.

Note that the Duke LPSI motors and the new containment spray configuration motors will incorporate the latest bearing lubrication modifications to preclude oil leakage.

Please contact me or Dave Amerine, should you have any questions.

Very truly yours,

Glenn L. McCoy

C. Ferguson,
for Project Manager

CF/TEF:jlb
V-PAK-628
F47838
cc: Messrs:
G. C. Andognini - w/e
J. Vorees - w/e
W. H. Wilson
W. G. Bingham - w/e
R. H. Holm
J. W. Dilk
G. A. Butterworth
S. N. Mager
D. B. Amerine - w/e
W. L. MacDonald
J. R. Bynum
G. D. Houchen - w/e

DATA SUMMARY

	LPSI B	CS/LPSI Imp.	Duke/LPSI Imp.	CS/CS Imp.
Palo Verde				
No Impeller				
Min.	11.93	2.098		2.098
Ave.	12.9	2.42		2.42
Max.	14.02	2.636		2.636
With Impeller				
Min.	17.76	7.95		3.889
Ave.	20.18	9.8		5.83
Max.	22.61	14.3		6.175
Buffalo				
No Impeller				
Min.	20.7	2.58	3.48	
Ave.	22.8	3.50	5.43	
Max.	24.3	3.96	8.15	
With Impeller				
Min.	26.5	4.94	4.6	
Ave.	29.4	6.62	7.0	
Max.	34.9	8.33	9.5	

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POWER SYSTEMS

January 26, 1984
V-CE-20584
V-SF-1663

Mr. W. G. Bingham
Bechtel Power Corporation
12400 East Imperial Highway
Norwalk, California, 90650

Subject: Statistical Basis for LPSI Pump Starts

Reference: V-CE-20568, dated January 12, 1984, "LPSI Pump Recovery Program Meeting"

Attachment: LPSI Pump Reliability

Dear Mr. Bingham:

Comment #6 of the Reference requires a statistical basis for the number of test starts during Phase III of the LPSI Pump Recovery Program. The Attachment provides that basis and is provided per our discussion and agreement on January 25, 1984. Due to the agreement between the C-E and BPC analyses, Table 3-1 provided by BPC is substituted for that in the C-E analysis as it more clearly identifies confidence levels.

Very truly yours,

C. Ferguson
C. Ferguson
Project Manager

226376
JOB 10407
FILE N.9.02
FEB 2 '84
KMS
WJS
B. MURRAY

CF/SLS:plk

cc: D. B. Amerine
G. C. Andognini
D. Arrigan
G. A. Butterworth
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R. H. Holm
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W. H. Wilson

LPSI PUMP RELIABILITY

1.0 SYSTEM RELIABILITY REQUIREMENT

In the absence of an industry standard or regulation specifying a required system reliability goal for the Low Pressure Safety Injection System (LPSI), a survey was performed of reported PRA results to determine a range of system reliability values which are typical of operating plants. This range of system reliability values was used to determine a minimum "acceptable" value for the Palo Verde LPSI System.

Seven PRAs were reviewed to determine the calculated unreliability of LPSI. Results of the survey are presented in Table 1-1. Following the methodology of WASH 1400, the highest and lowest values from the survey were averaged in order to calculate a log normal median value. This median value is used below as the criterion to determine the minimum number of LPSI pump start-up tests that are required to demonstrate adequate pump reliability. The log normal median value between the highest value (4.7×10^{-3}) and the lowest value (2.5×10^{-4}) is 1.1×10^{-3}.

2.0 LPSI SYSTEM RELIABILITY MODELS

Fault tree analysis was employed to determine the reliability of the PVNGS LPSI System. The methodology employed in this analysis is consistent with and is described in CEN-239 Supplement 3. The fault tree models were used to determine the PVNGS LPSI System reliability for various LPSI pump failure rates. A system description and list of the assumptions made in performing the fault tree analyses are provided. The results of the fault tree analyses and probabilistic evaluation are used as input to determine the LPSI pump reliability requirements and are discussed in Section 3.0.

2.1 System Description

A schematic of the PVNGS LPSI System (Injection Mode) is presented in Figure 2-1. The injection mode of operation is initiated upon receipt of a Safety Injection Actuation Signal (SIAS). A SIAS is produced upon any two coincident low pressurizer pressure (1700 psia) or high containment pressure signals. The SIAS may also be initiated manually in the control room. Upon a SIAS, the LPSI pumps automatically start and the LPSI header isolation valves open. During injection mode, the minimum flow lines downstream of each pump are kept open to prevent possible dead head operation. The pumps take suction from the Refueling Water Tank (RWT) and the discharge through four LPSI header isolation valves via two redundant LPSI headers. The safety injection water then flows to the reactor vessel through a safety injection nozzle on each of the four RCS cold leg pipes. If offsite power (normal AC) is unavailable, the ESF buses are connected to the diesel generators and safeguard loads (the LPSI System) are then started in a preprogrammed time sequence.

When the RWT level drops to its predetermined low level at the end of the safety injection phase, a recirculation actuation signal (RAS) is generated. The RAS signal stops the LPSI pumps and ends LPSI System operation.

2.2 Assumptions

The LPSI System fault tree analysis is based on the methodology employed in CEN-239, Supplement 3. Component failure data used in the probabilistic evaluation of the fault tree was also derived from CEN-239. The following additional assumptions were made in performing the fault tree analysis for Failure to Deliver Sufficient LPSI Flow:

1. System failure is defined as the inability to deliver sufficient LPSI flow to the reactor core. Sufficient LPSI flow is defined as one LPSI pump flow to two RCS loops. (Two flowpaths are required to deliver the flow from one pump.)

2. Isolation of the pump mini-flow lines could result in dead head operation and damage to the pumps.

3. The only operator action considered was manual backup of SIAS from the control room.

4. It is assumed that components on Train A receive SIAS-A and components on Train B receive SIAS-B.

5. To facilitate tree construction and evaluation, it was assumed that components on Train A are aligned to Train A electrical supply buses and components on Train B are aligned to Train B electrical supply buses.

6. Maintenance error resulting in the advertent isolation of a LPSI pump has been included in the analysis.

7. Palo Verde's periodic test and maintenance program is assumed to preclude wear-out type failures.

8. Palo Verde's pump modifications are assumed to be adequate to prevent the failure mode described by this Recovery program.

3.0 LPSI PUMP RELIABILITY REQUIREMENTS

The results of the fault tree analyses for the LPSI System are shown in Figure 3-1. The results are presented as a plot of the unreliability of the LPSI System as a function of LPSI pump failure rate. The LPSI pump failure rate for failure to start on demand was varied from 10^{-3}/demand to 10^{-1}/demand. The curves generated are used to relate the LPSI System unreliability to a LPSI pump reliability requirement. The number of tests required to demonstrate a certain LPSI pump unreliability was then determined using a binominal distribution shown in Table 3-1.

For example, for the LPSI System function, a survey of PRA literature was used to determine a median LPSI System unreliability (1.1×10^{-3}). Using the curve in Figure 3-1, a corresponding LPSI pump unreliability requirement of approximately 3×10^{-2} is found. The best estimate number of tests required to demonstrate a failure rate of 3×10^{-2} is found using Table 3-1 and is approximately 24 tests for a 50% confidence level and 99 tests for a 95% confidence level.

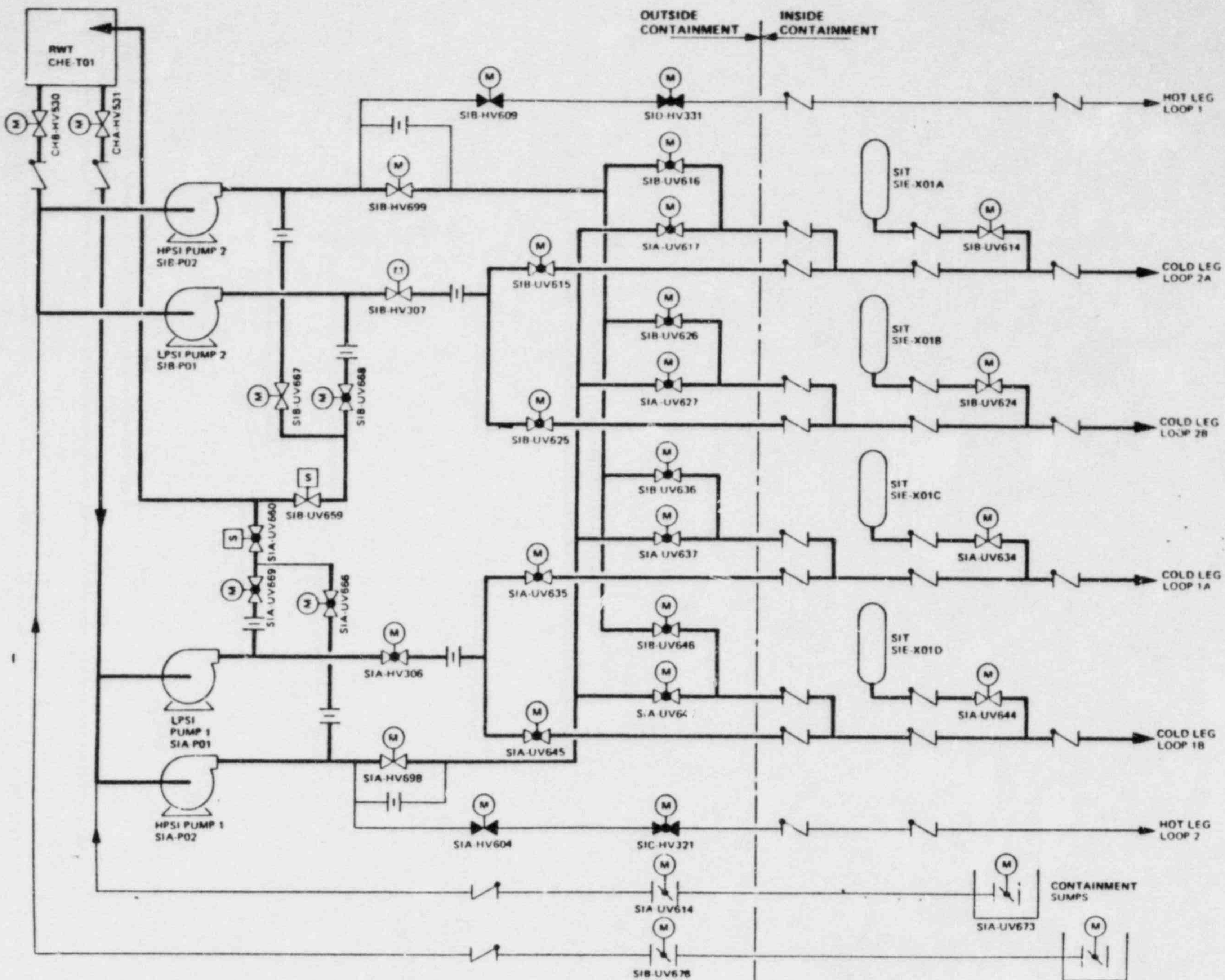
4.0 CONCLUSION

With the performance of 100 LPSI pump start-up tests with no failures, the LPSI pumps will have demonstrated sufficient reliability with 95% confidence that the reliability of the LPSI function will be adequate.

Table 1-1

LPSI UNRELIABILITY

PRA	UNRELIABILITY	REFERENCE
Reactor Safety Study	4.7×10^{-3}	Wash-1400 Page 11 - 137
German Risk Study	1.7×10^{-3}	The Federal Minister of Research and Technology, August 15, 1979
Zion Safety Study	2.5×10^{-4}	Commonwealth Edison Study, Page 1.5 - 4-12
Sequoyah RSSMAP	1.9×10^{-3}	NUREG/CR-1659/1 of 4 Page B.7 - 10
Oconee Unit 3 RSSMAP	2.4×10^{-3}	NUREG/CR-1659/2 of 4 Page B.6 - 14
C-E Generic PWR	1.0×10^{-3}	CEN-156



SAFETY INJECTION SYSTEM
INJECTION MODE

FIGURE 2-1

FIGURE 3-1

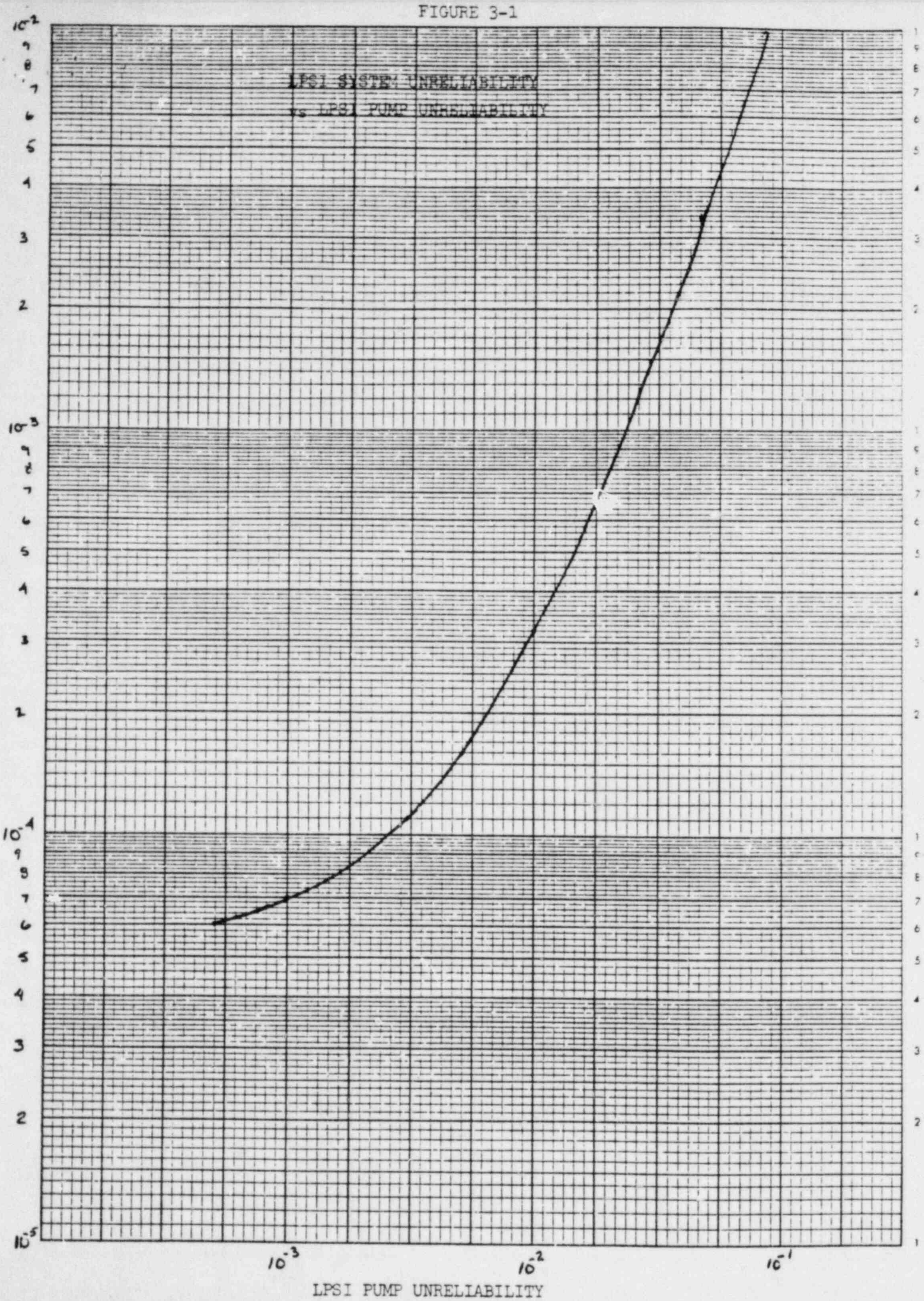

LPSI SYSTEM UNRELIABILITY
vs LPSI PUMP UNRELIABILITY
LPSI SYSTEM UNRELIABILITY
LPSI PUMP UNRELIABILITY
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-1}

TABLE 3-1 Binomial Tables

Number of Tests Without Failure Vs Reliability and Confidence Level

Reliability (R)	Confidence Level, Percent											
	50	60	70	75	80	85	90	95	97.5	99	99.5	99.9
0.999999	693150	916290	1203970	1386290	1609440	1897120	2302590	2995730	3688889	4605170	5298320	6907760
0.99999	69315	91629	120397	138629	160944	189712	230259	299573	368889	460517	529832	690776
0.9999	6932	9163	12040	13863	16094	18971	23026	29957	36889	46052	52983	69078
0.999	693	916	1204	1386	1609	1897	2303	2996	3689	4605	5298	6908
0.998	347	458	602	694	805	949	1152	1493	1845	2303	2650	3454
0.997	231	305	401	462	537	632	768	999	1230	1535	1766	2303
0.996	173	229	301	346	401	473	575	747	920	1149	1322	1723
0.995	138	183	241	277	321	379	460	598	737	920	1058	1379
0.994	115	152	201	230	267	315	383	498	613	765	880	1148
0.993	99	130	174	198	229	270	328	427	526	657	755	985
0.992	86	114	150	173	200	236	287	373	460	574	660	860
0.991	77	101	134	153	178	210	255	332	408	510	586	764
0.99	69	92	120	138	160	188	229	298	367	459	527	688
0.98	34	45	60	69	80	94	114	149	183	228	263	342
0.97	23	30	40	45	53	62	76	99	121	151	174	227
0.96	17	23	30	34	39	46	57	74	91	113	130	170
0.95	14	18	24	27	31	37	45	58	72	90	103	135
0.94	11	15	20	22	26	31	37	49	60	75	86	112
0.93	10	13	17	19	22	26	32	42	51	64	74	96
0.92	9	11	15	17	19	23	28	36	45	55	64	83
0.91	8	10	13	15	17	20	25	32	39	49	57	74
0.9	7	9	12	13	15	18	22	29	35	44	51	66
0.8	3	4	6	6	7	9	11	14	17	21	24	31
0.7	2	3	4	4	5	6	7	9	11	13	15	20
0.6	2	2	3	3	4	4	5	6	8	9	11	14
0.5	1	1	2	2	3	3	4	5	6	7	8	10

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221503
JOB 10407
FILE N.9.02
FEB 27 '84

POWER SYSTEMS

V-CE-19784
February 20, 1984

Mr. W. G. Bingham
Bechtel Power Corporation
12400 East Imperial Highway
Norwalk, CA 90650

Subject: Preparation for Interim Use of Containment Spray Motors with LPSI Pumps

Reference: (A) V-CE-19720, dated February 8, 1984

Dear Mr. Bingham:

Reference (A) identified four steps in the testing to evaluate the ~~use of the~~ CS motors on the Unit 1 LPSI pumps. The second of the steps was the evaluation of the air test results and the decision for interim use of containment spray motor on the LPSI pumps. The following is a summary of C-E's evaluation concluding that a CS pump motor should be transfered to Unit 1 for installation on the 1B LPSI pump.

The CS motor operation without the impeller and with the LPSI pump impeller show significant improvements over previous tests with the LPSI pump motors.

The maximum and mean deflections for the CS motor are:

No Impeller		LPSI Impeller		CS Impeller	
Max.	Mean	Max.	Mean	Max.	Mean
2.6	2.4	14.3	9.8	7.4	5.8

These compare with LPSI motor deflections of:

Max.	Mean	Max.	Mean
15.7	14.3	29.2	26.4

The W analysis was reviewed at a meeting in Pittsburg on February 14, 1984. The results imply that the shaft end deflection with the LPSI impeller is reduced by using the CS motors. The comparative deflections are; LPSI motor 15.7 mils and CS motors 12.7 mils. This improvement is less than tests have shown, but the trend is similar.

Results from analysis performed by an independent consultant indicate a 3 to 1 improvement between the LPSI motors and the CS motors.

Further supporting analysis is being done by C-E. The results are expected by February 24, 1984.

As there has not been a failure to start with the CS motor and pump, and the above results support the contention that failure would not occur to that motor/pump combination, the concensus of test results, analysis and engineering judgement supports CS motor installation in the Unit 1 LPSI pump for final evaluation of this motor as an interim resolution for the failure to start problem.

The following test program is recommended to provide documented test results which will be used for justfication to allow the interim use of these motors on the LPSI pumps through fuel load in Unit 1.

1. Transport one Unit 3 CS pump motor to Unit 1 and install on LPSI pump 1B.
2. Conduct the two hour motor run-in required after previously completed bearing housing modification to resolve oil leakage problem.
3. Conduct a series of 5 instrumented water tests measuring shaft deflection at the upper bearing and below the lower bearing. (Using Neolube blue the impeller and wear ring). A flowrate of 2100 ± 100 gpm is to be used.
4. Inspect the wear ring and impeller surfaces for comparison with inspection results from previous water tests conducted with the original LPSI motor.
5. Conduct 100 start test using a flow rate of 2100 ± 100 gpm.
6. Disassemble, inspect and evaluate.
7. If the results thru step 4 are satisfactory install a second containment spray motor on LPSI A.

In addition, either before or after the above tests, the radial play of the upper bearing in the two CS motors used in the test program should be measured for comparison.

C-E recommends that the containment spray motors be used with the existing bearings.

The above use of the CS motors is recommended as an interim measure to allow fuel load to proceed in Unit 1 without further delay while final resolution details are developed.

Very truly yours,

For T. E. Ferguson,
Project Manager

CF/TEF:jlb
V-PAK-540
F47748
cc: Messrs:

E. E. Van Brunt, Jr.	G. A. Butterworth
G. C. Andognini	S. N. Mager
J. Vorees	D. B. Amerine
W. H. Wilson	W. L. MacDonald
R. H. Holm	J. R. Bynum
J. W. Dilk	

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222284
JOB 10407
N. 9.02

POWER SYSTEMS

March 9, 1984
V-CE-21628
V-SF-1790

Mr. J. D. Houchen
Arizona Public Service Company
P. O. Box 21666
Phoenix, Arizona, 85036

Subject: LPSI Pump 1B 100 Start Test

Reference: PVNGS-LGP-M83-171, dated December 30, 1983

Dear Mr. Houchen:

On March 7, 1984, LPSI Pump 1B successfully completed 100 starts using a Containment Spray Pump motor per the LPSI Pump Recovery Program described in the Reference. The pump was disassembled on March 8, 1984, for visual observation of the upper and lower casing rings and impeller wear surfaces. A meeting was held on site on March 9, 1984, to discuss the results of the test and inspection.

It was agreed by all attendees that the LPSI pump had successfully completed the 100 starts portion of the test. Since evidence of contact was observed, a comparison against a visual standard was required to verify acceptance of the test. Before that inspection was conducted, some of the evidence was mistakenly cleaned on the impeller and part of the lower casing ring. Sufficient evidence remained on the casing ring for the Ingersoll-Rand metallurgist to determine that the contact mechanism was identical to that observed in laboratory testing, and that using the photographs of the laboratory testing as a standard, the amount of contact was acceptable. The APS Operations Engineering representative concurred with that assessment. In addition, BPC reported that, based on photographs taken prior to the 100 start test and personal observation following the test but before the surfaces were touched, there was no evidence of additional contact during the 100 start test. It was, therefore, the conclusion of all attendees that the 100 start test was successful and the inspection was acceptable.

C-E will provide APS Startup with a written report of the inspection and follow up with a formal report submitted through C-E Engineering.

Very truly yours,

Dave Amerine

D. B. Amerine
C-E Startup Manager

DBA/SLS:plk

cc: G. C. Andognini
W. G. Bingham
J. R. Bynum
C. Ferguson
J. D. Houchen
T. Mack
S. N. Mager
J. C. Moulton
W. J. Stubblefield
E. E. Van Brunt, Jr.

Attendees:
D. Hayes, APS S/U
A. McCabe, APS S/U
C. Crane, APS S/U
G. Sullivan, APS S/U
J. Van Wyk, APS S/U
K. Schroeder, APS S/U
R. Kropp, OPS ENG
D. Sachs, OPS ENG
D. Amerine, C-E S/U
S. Schey, C-E S/U
W. Kuntz, C-E S/U
D. Blanchard, C-E
E. Stoma, I-R
R. Miller, I-R
V. Najarian, BPC
R. Gross, BPC
T. Mack, BPC
W. Murray, BPC
M. Winsor, NUC ENG
R. Badsgard, NUC ENG

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POWER SYSTEMS

June 11, 1984
V-CE-21710
V-SF-2073

2268-41
N.9.02
JUN 18 '84
RMS
MURRAY

ATTACHMENTS RECEIVED 6-26-84

Mr. W. G. Bingham
Bechtel Power Corporation
12400 East Imperial Highway
Norwalk, California, 90650

Subject: Unit I LPSI and Containment Spray Performance Data

Reference: 91SU 1SI06 - SI Pump Curve Data Test

Attachment: 1) LPSI 1A and 1B Performance Curve
2) Containment Spray 1A Performance Curve
3) Containment Spray 1B Performance Curve

Dear Mr. Bingham:

Combustion Engineering has reviewed the data for Unit I LPSI and Containment Spray performance provided per Appendices C, D, E and F of the reference and finds the data acceptable. Attached are performance curves generated from that data. Data runs on June 2, 1984, for LPSI 1B and May 22, 1984, for the remaining pumps, were used for curve developement. If you have any questions, please contact Bill Kuntz of this office.

Very truly yours,

Dave Amerine

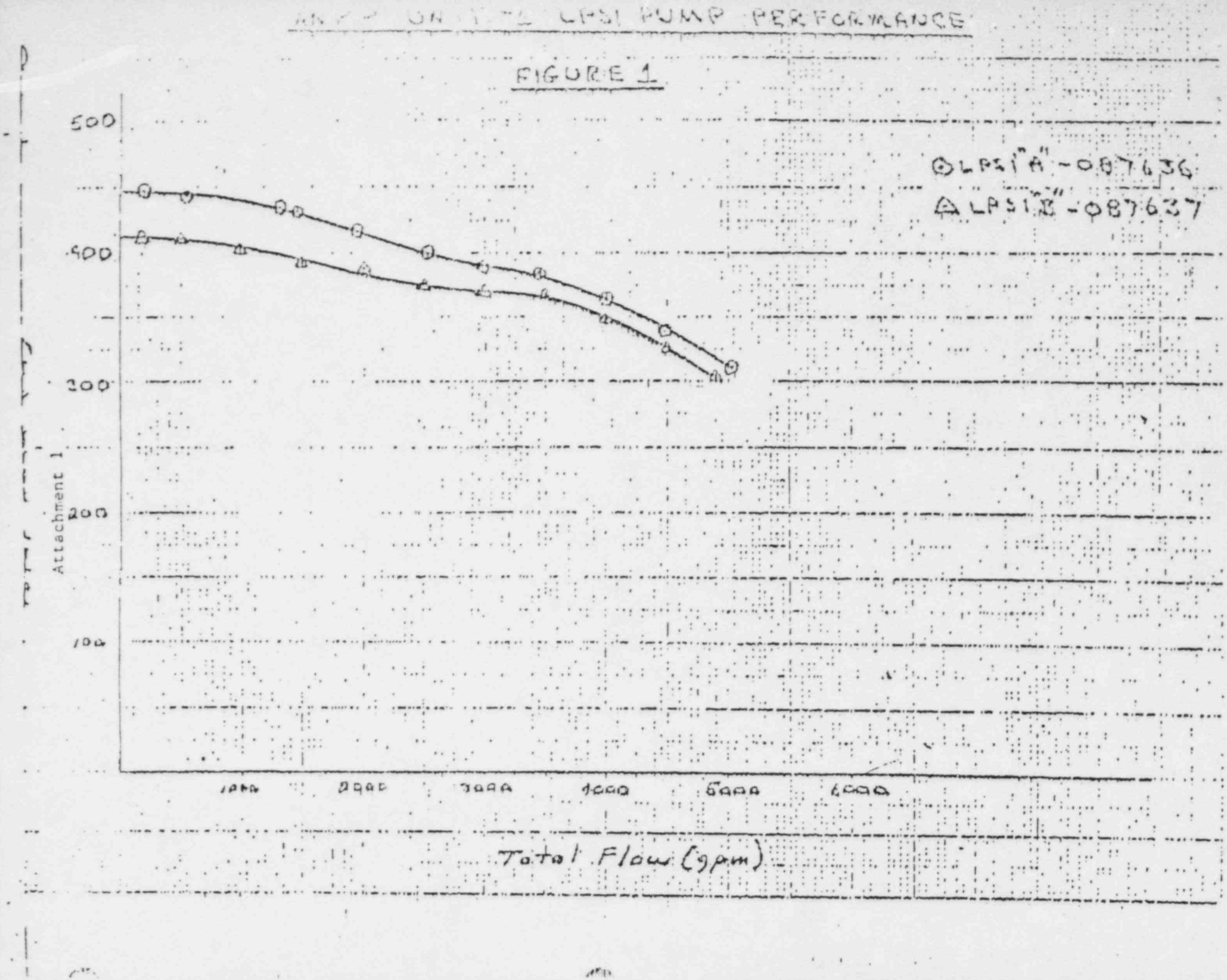
D. B. Amerine
C-E Startup Manager

DBA/WDK:kjr

cc: J. M. Allen
J. Black
J. R. Bynum
S. Day
C. Ferguson
J. D. Houchen
J. Kirby
T. Mack
S. N. Mager
A. J. McCabe
R. Papworth
W. J. Stubblefield
E. E. Van Brunt, Jr.
R. Vaughan

w/a O. J. Zeringue
C. Churchman
w/a C. Crane

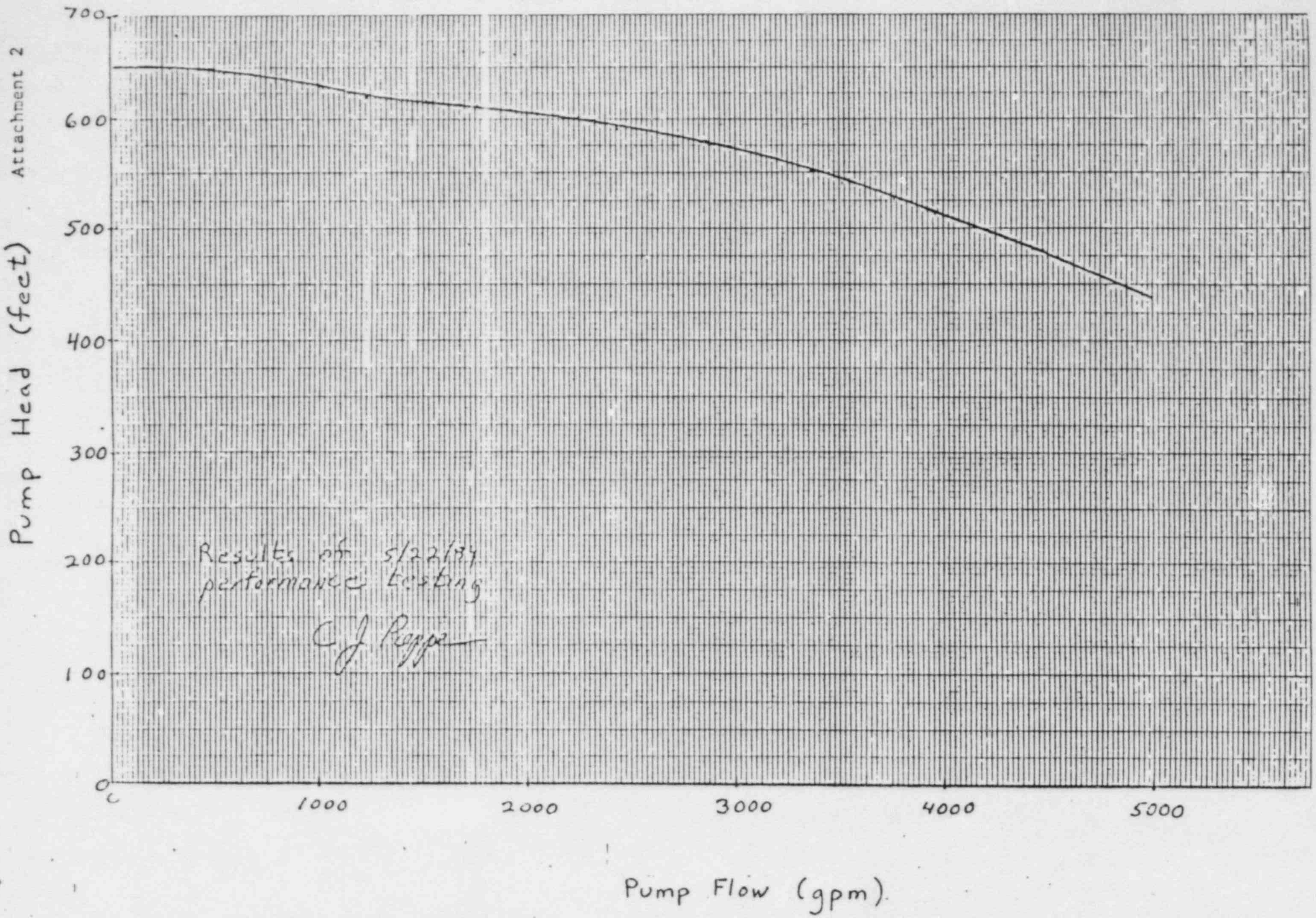
FIGURE 1



Attachment 1

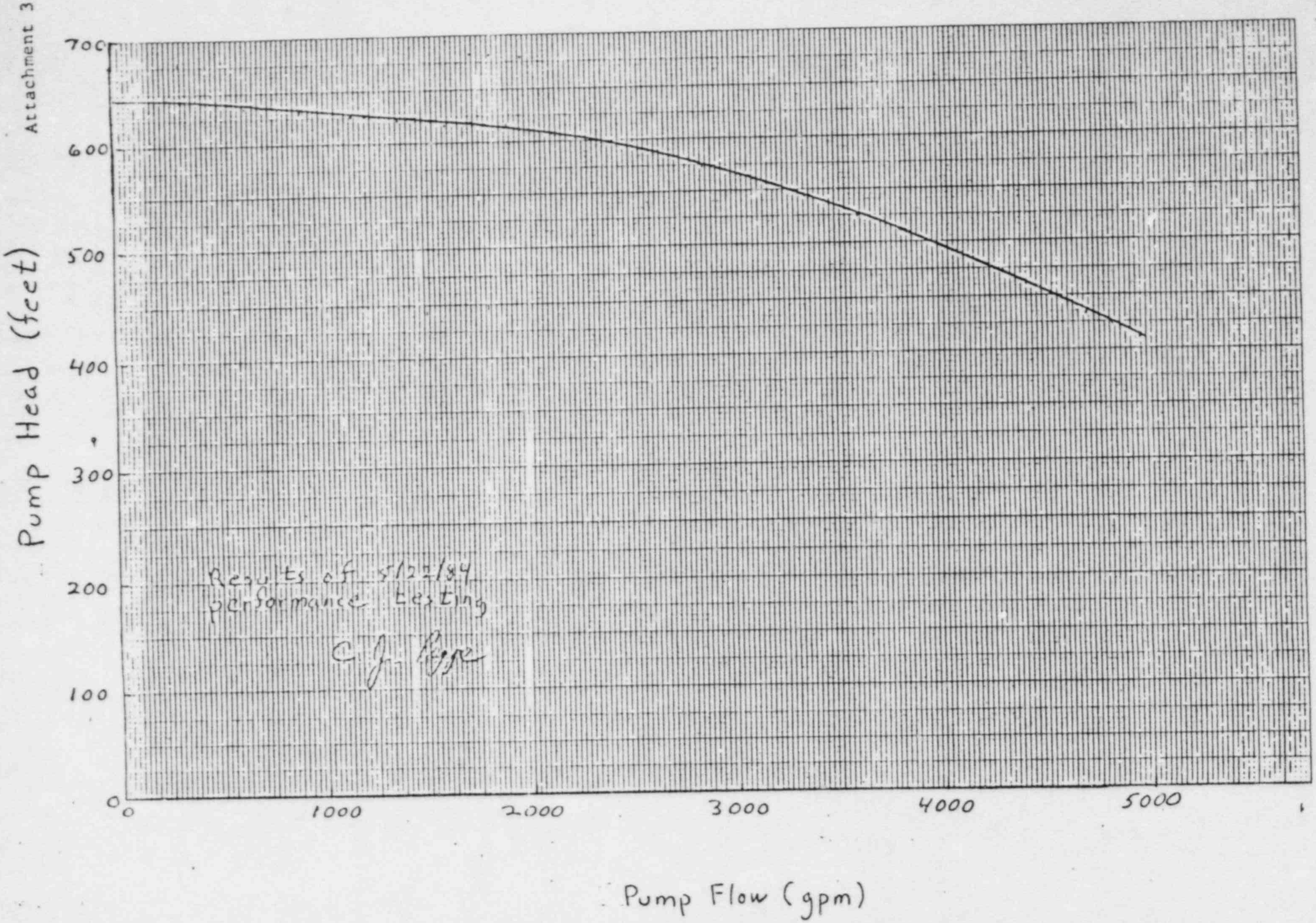
Attachment 2

Palo Verde Unit 1
Containment Spray Pump "A"



Attachment 3

Palo Verde Unit 1
Containment Spray Pump "B"



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POWER SYSTEMS

August 2, 1984
V-CE- 30704

Mr. E. E. Van Brunt, Jr.
Arizona Nuclear Power Project
P.O. Box 21666 - Station 3003
Phoenix, Arizona 85036

Subject: 10 CFR 50.55(e) Report on Low Pressure Safety Injection Pump Failure to Start

Dear Mr. Van Brunt:

Enclosed for your submittal to the Nuclear Regulatory Commission is the 10 CFR 50.55(e) report on Low Pressure Safety Injection Pump Failures to Start along with the proprietary affidavit. Copies 1 through 25 of the proprietary report are intended for submittal to the NRC. Copies 26 through 43 are provided for APS use. In addition, thirty-five copies of the non-proprietary version are also enclosed. This report is a Final report and is considered complete.

If you have any questions feel free to call.

Very truly yours,

C. Ferguson

C. Ferguson
Project Manager

CF/TJC:jld
Enclosure
cc: D. B. Amerine w/Copy 45
W. G. Bingham w/Copy 44
G. A. Butterworth
J. R. Bynum
J. W. Dilk
R. H. Holm
W. L. MacDonald
S. N. Mager
W. H. Wilson
W. F. Quinn

AFFIDAVIT PURSUANT

TO 10 CFR 2.790

Combustion Engineering, Inc.)
State of Connecticut)
County of Hartford) SS.:

I, A. E. Scherer, depose and say that I am the Director, Nuclear Licensing, of Combustion Engineering, Inc., duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.790 of the Commission's regulations, and in conjunction with the construction permit of Arizona Public Service Company, for withholding this information.

The information for which proprietary treatment is sought is contained in the following document:

CEN-285(V)-P, Report on Palo Verde Nuclear Generating Station Low Pressure Safety Injection Pump Failure to Start, August 1984.

This document has been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by Combustion Engineering in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1. The information sought to be withheld from public disclosure are testing and analysis done to resolve the Palo Verde Low Pressure Safety Injection Pump failures to start, which is owned and has been held in confidence by Combustion Engineering.

2. The information consists of test data or other similar data concerning a process, method or component, the application of which results in a substantial competitive advantage to Combustion Engineering.

3. The information is of a type customarily held in confidence by Combustion Engineering and not customarily disclosed to the public. Combustion Engineering has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The details of the aforementioned system were provided to the Nuclear Regulatory Commission via letter DP-537 from F.M. Stern to Frank Schroeder dated December 2, 1974. This system was applied in determining that the subject document herein are proprietary.

4. The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.790 with the understanding that it is to be received in confidence by the Commission.

5. The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.

6. Public disclosure of the information is likely to cause substantial harm to the competitive position of Combustion Engineering because:

a. A similar product is manufactured and sold by major pressurized water reactor competitors of Combustion Engineering.

b. Development of this information by C-E required thousands of manhours of effort and hundreds of thousands of dollars. To the best of my knowledge and belief a competitor would have to undergo similar expense in generating equivalent information.

c. In order to acquire such information, a competitor would also require considerable time and inconvenience related to testing and analysis of the Palo Verde Low Pressure Safety Injection Pumps.

d. The information required significant effort and expense to obtain the licensing approvals necessary for application of the information. Avoidance of this expense would decrease a competitor's cost in applying the information and marketing the product to which the information is applicable.

e. The information consists of testing and analysis done to resolve the Palo Verde Low Pressure Safety Injection Pump failures to start, the application of which provides a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with Combustion Engineering, take marketing or other actions to improve their product's position or impair the position of Combustion Engineering's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

f. In pricing Combustion Engineering's products and services, significant research, development, engineering, analytical, manufacturing, licensing, quality assurance and other costs and expenses must be included. The ability of Combustion Engineering's competitors to utilize such information

without similar expenditure of resources may enable them to sell at prices reflecting significantly lower costs.

g. Use of the information by competitors in the international marketplace would increase their ability to market nuclear steam supply systems by reducing the costs associated with their technology development. In addition, disclosure would have an adverse economic impact on Combustion Engineering's potential for obtaining or maintaining foreign licensees.

Further the deponent sayeth not.

A. E. Scherer
Director
Nuclear Licensing

Sworn to before me
this 2nd day of August

Diane J. Windecker
Notary Public
DIANE J. WINDECKER
NOTARY PUBLIC
MY COMMISSION EXPIRES MARCH 31, 1989