CE POWER SYSTEMS

JEFF
Your copy
5/30/84

NUCLEAR POWER SYSTEMS

COMBUSTION ENGINEERING, INC.
COMPONENTS ENGINEERING
Chattanooga, Tennessee

E-2808

PALISADES AUXILIARY FEEDWATER NOZZLE GRINDOUTS

55-31	2966 B
CALCULATION NO.	CONTRACT NO.
CONSUMERS POWER	STEAM GENERATOR
CUSTOMER	COMPONENT

P. L. Anderson	Lead Engineer	5-24-84
PREPARED	TITLE	DATE
N. L. Beard	Structural Engineer	5-24-84
CHECKED (Full Review)	TITLE	DATE
[signature]	SUPERVISOR	5-24-84
REVIEWED	TITLE	DATE
[signature]	MANAGER	5-24-84
APPROVED	TITLE	DATE

P Andersen	5-24-84	COMBUSTION ENGINEERING, INC. Chattanooga Nuclear Operations	
PREPARED	DATE		SHEET 1 OF 6
N. Board	5/24/84	COMPONENT ENGINEERING	CALC. NO. SS-31
CHECKED	DATE		CONTRACT NO.

TITLE

SUMMARY

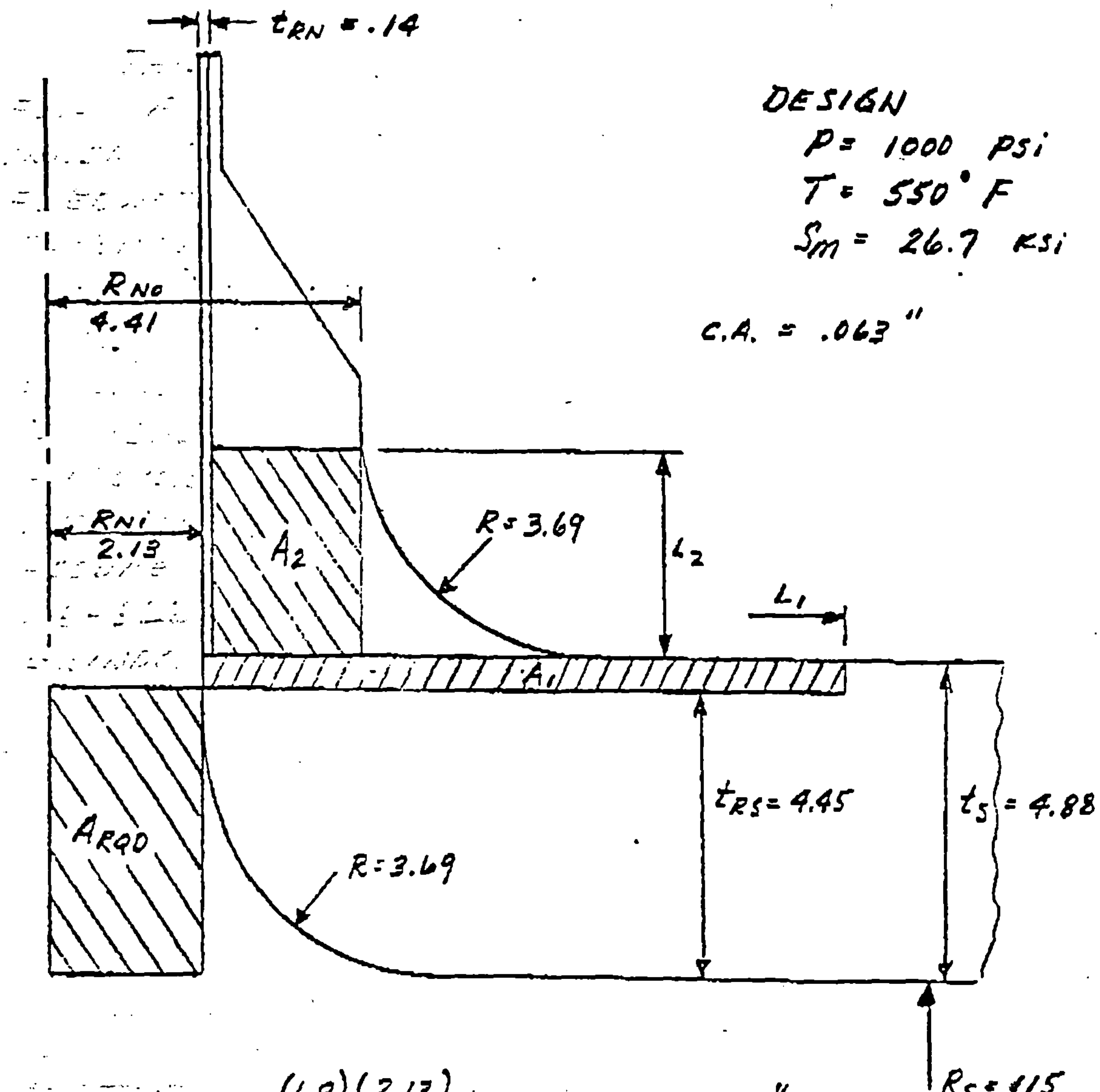
THIS REPORT PROVIDES JUSTIFICATION FOR A WORST CASE GRINDOUT AT THE INNER RADIUS OF THE PALISADES AUXILIARY FEEDWATER NOZZLE. REINFORCEMENT REQUIREMENTS ARE SHOWN TO MEET THE ALTERNATE RULES OF NB-3339 OF THE ASME CODE. BASICALLY, THE NOZZLE OPENING IS SMALL ENOUGH THAT NO REINFORCEMENT IS REQUIRED. FURTHER, THE STRESS ANALYSIS OF THE NOMINAL GEOMETRY INDICATES ADEQUATE STRESS MARGINS TO ASSURE THAT PRIMARY STRESS LIMITS OF NB-3221.2 ARE SATISFIED FOR THE GRINDOUT GEOMETRY.

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

P. Anderson (PREPARED)	5-24-84 (DATE)	COMBUSTION ENGINEERING, INC. Chattanooga Nuclear Operations	SHEET 2 OF 6
N. Baird (CHECKED)	5/24/84 (DATE)	COMPONENT ENGINEERING	CALC. NO. 55-31
			CONTRACT NO.

TITLE

GEOMETRY



DESIGN

P = 1000 psi

T = 550° F

S_m = 26.7 ksi

C.A. = .063"

$$t_{RN} = \frac{(1.0)(2.13)}{26.7 - .5} + .063 = .14''$$

$$t_{RS} = \frac{(1.0)(115)}{26.7 - .5} + .063 = 4.45''$$

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

P. Anderson	5-24-84	COMBUSTION ENGINEERING, INC. Chattanooga Nuclear Operations	SHEET 3 OF 6
PREPARED	DATE		CALC. NO. 55-31
N. Picard	5/24/84	COMPONENT ENGINEERING	CONTRACT NO.
CHECKED	DATE		

TITLE

REINFORCEMENT PER NB-3330 (REF. 1)

$A_{RQD} = (R_{Ni} + C.A.)\, t_{RS} = (2.13 + .063)(4.45)$

$A_{RQD} = 9.76 \text{ IN}^2$

$L_1 = (R_{Ni} + C.A.) + (R_{No} - R_{Ni}) + t_S$

$= 2.193 + 2.28 + 4.88$

$L_1 = 9.35$

$L_2 = .5\sqrt{r_m t_n} + .5R$

$t_n = R_{No} - R_{Ni} = 2.28$

$r_m = (R_{No} + R_{Ni})/2 = 3.27$

$R = 3.69$

$L_2 = 3.21$

$A_1 = (L_1 - R_{Ni} - C.A.)(t_S - t_{RS}) = (7.157)(.43)$

$A_1 = 3.08 \text{ IN}^2$

$A_2 = L_2 (R_{No} - R_{Ni} - t_{RN}) = (3.21)(2.14)$

$A_2 = 6.87 \text{ IN}^2$

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

P. Andrews (PREPARED)	5-24-84 (DATE)	COMBUSTION ENGINEERING, INC. Chattanooga Nuclear Operations	SHEET 4 OF 6
[illegible] (CHECKED)	5/24/84 (DATE)	COMPONENT ENGINEERING	CALC. NO. 55-31
			CONTRACT NO.

TITLE

AREA REMOVED BY GRINDOUTS

CONSERVATIVELY ASSUME 7/16" DEPTH FOR FULL INNER RADIUS PLUS 1" LENGTH INTO BORE OF NOZZLE. SEE GRINDING SKETCH FOR S.G. "A" IN APPENDIX.

$$A_{REM} = \frac{1}{2}\pi R(7/16) + (1)(7/16)$$

$$= \frac{1}{2}\pi(3.69)(7/16) + 7/16$$

$$A_{REM} = 2.97 \text{ IN}^2$$

$$A_{AVAIL} = A_1 + A_2 - A_{REM} = 3.08 + 6.87 - 2.97$$

$$A_{AVAIL} = 6.98 \text{ IN}^2 < A_{RQD} = 9.76 \text{ IN}^2$$

HENCE, THE AVAILABLE REINFORCEMENT IS LESS THAN THE REQUIRED REINFORCEMENT. HOWEVER, ALTERNATE REINFORCEMENT RULES OF NB-3339 INDICATE AN ACCEPTABLE CONDITION.

REINFORCEMENT PER NB-3339 (ALTERNATE RULES)

$$d = 2(R_{Ni} + C.A.) = 2(2.13 + .063) = 4.39$$

$$R = R_S + C.A. = 115 + .063 = 115.063$$

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

P. Anderson 5-24-84 PREPARED DATE	COMBUSTION ENGINEERING, INC. Chattanooga Nuclear Operations	
		SHEET 5 OF 6
N. Kinsch 5/24/84 CHECKED DATE	COMPONENT ENGINEERING	CALC. NO. 55-31
		CONTRACT NO.

TITLE

$t = 4.45$

$d/\sqrt{Rt} = \underline{.19 < .20}$

THEREFORE, REINFORCEMENT IS NOT REQUIRED FOR THE SMALL NOZZLE.

PRIMARY STRESSES

REINFORCEMENT IS NOT REQUIRED IF IT CAN BE SHOWN THAT PRIMARY STRESS LIMITS OF NB-3221.2 ARE MET.

A FINITE ELEMENT STRESS ANALYSIS OF THE NOMINAL NOZZLE GEOMETRY WAS PERFORMED AND REPORTED IN CENC-1588 (REF. 2). RESULTS OF THE LEAK TEST CONDITION (1000 psi) ARE PRESENTED ON PAGES A-46 AND A-47 OF CENC-1588 FOR THE HIGHEST STRESSED SECTION. THE MAX. LOCAL HOOP MEMBRANE STRESS IS 15.0 KSI. THE CORRESPONDING STRESS INTENSITY

$S.I. = 15.5 \text{ ksi}$

IS SIGNIFICANTLY BELOW THE $1.5 S_m$ ALLOWABLE OF 40 KSI. SLIGHT VARIATIONS IN THE LOCAL GEOMETRY WOULD NOT SIGNIFICANTLY AFFECT THIS STRESS; THEREFORE THE INDICATED GRINDOUT IS ACCEPTABLE ON THE BASIS OF STRESS ANALYSIS.

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

P. Anderson PREPARED	5-24-84 DATE	COMBUSTION ENGINEERING, INC. Chattanooga Nuclear Operations	SHEET 6 OF 6
[illegible] CHECKED	5/24/84 DATE	COMPONENT ENGINEERING	CALC. NO. SS-31
			CONTRACT NO.

TITLE

REFERENCES

1. ASME BOILER AND PRESSURE VESSEL CODE, SECTION III FOR NUCLEAR VESSELS AND ADDENDA THROUGH SUMMER 1983.

2. CENC-1588, ADDENDUM TO THE ANALYTICAL REPORT FOR CONSUMERS POWER STEAM GENERATOR, APRIL 1983.

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

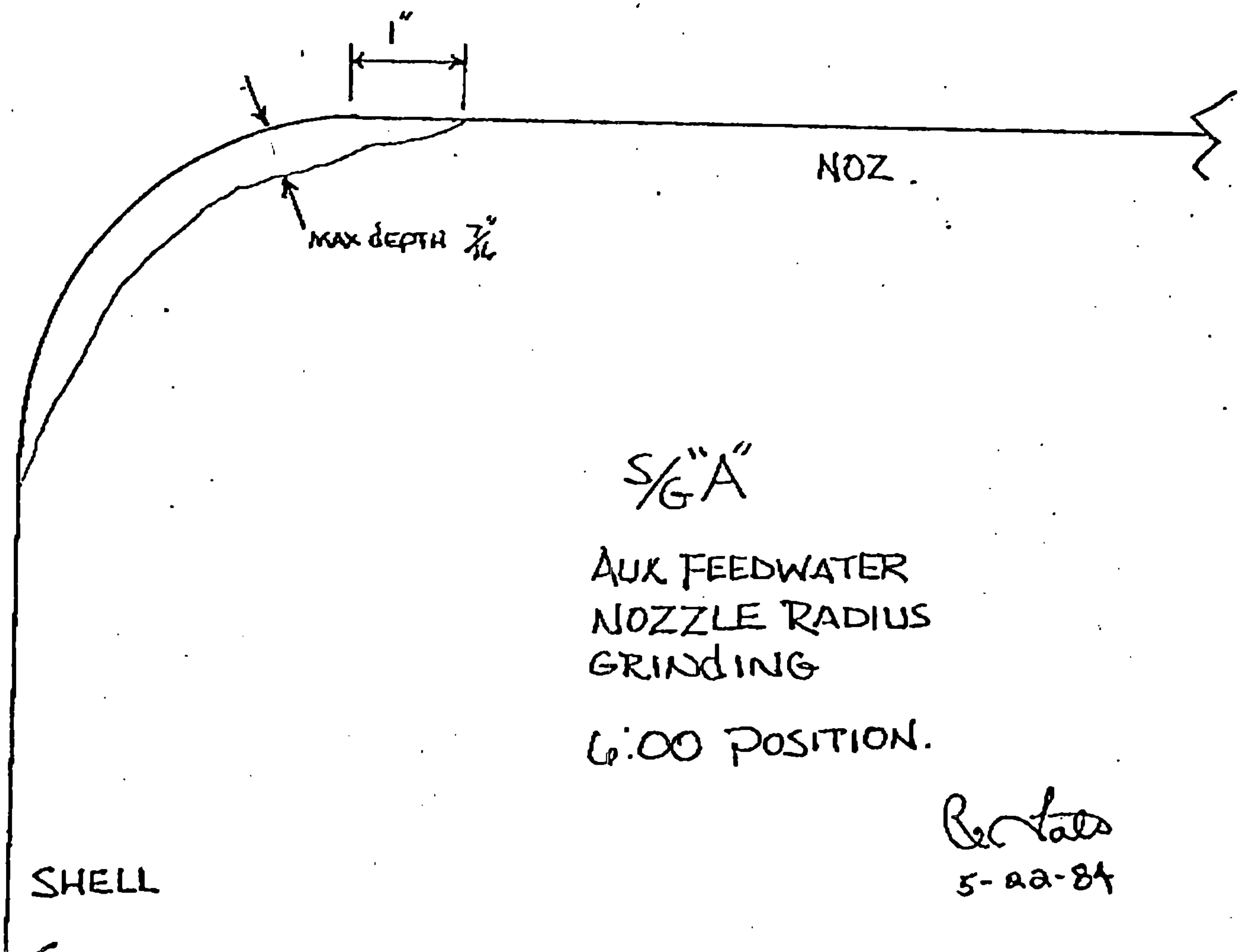
PREPARED	DATE	**COMBUSTION ENGINEERING, INC.** Chattanooga Nuclear Operations	SHEET OF
CHECKED	DATE	COMPONENT ENGINEERING	CALC. NO. CONTRACT NO.

TITLE

APPENDIX

(3 PAGES)

REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK	REV.	DATE	BY	CHECK

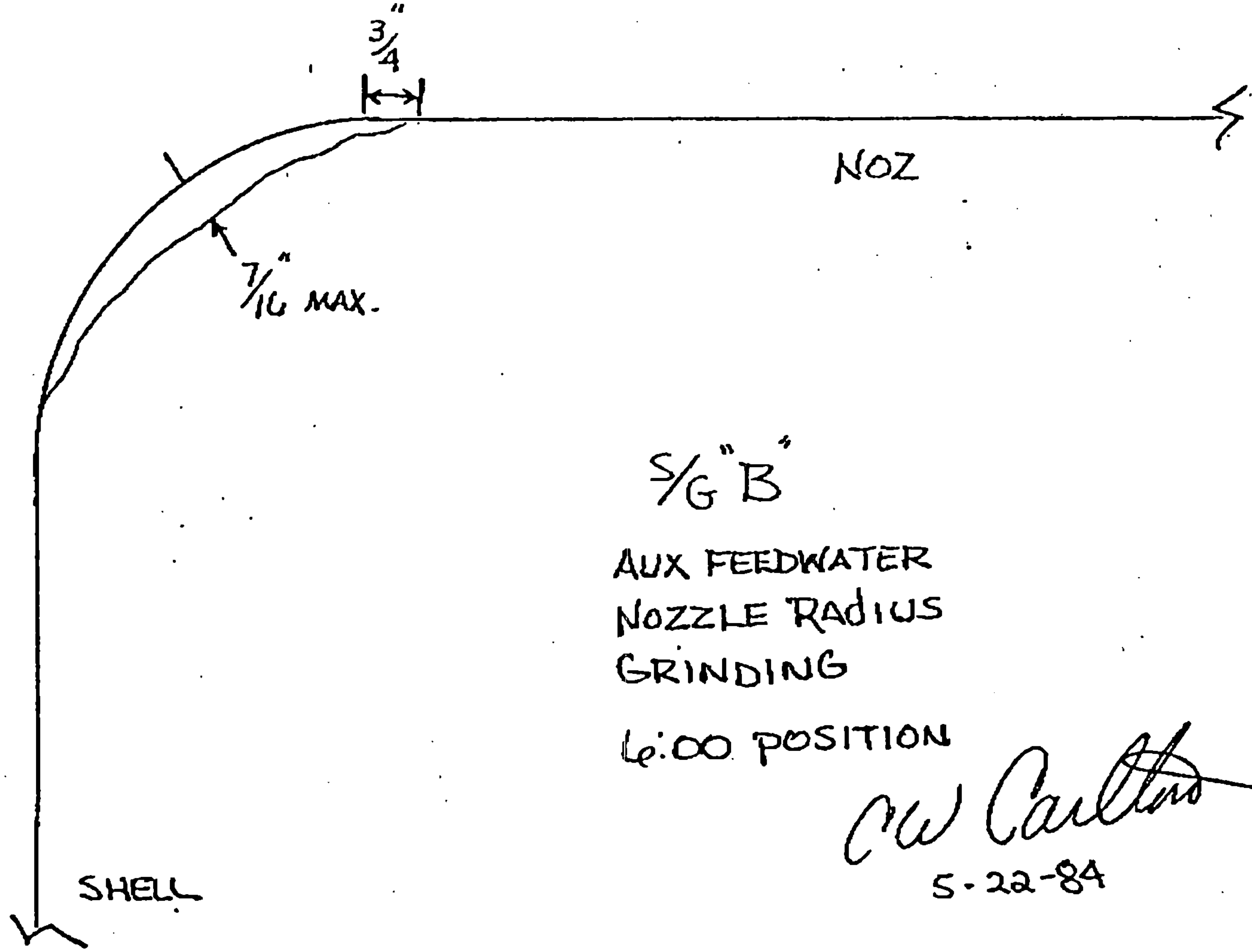


S/G "A"

AUX FEEDWATER
NOZZLE RADIUS
GRINDING

6:00 POSITION.

[signature]
5-22-84



S/G "B"

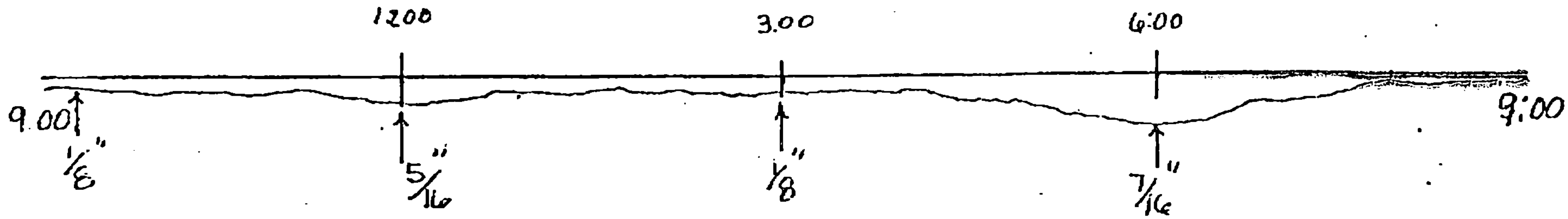
AUX FEEDWATER
NOZZLE RADIUS
GRINDING

6:00 POSITION

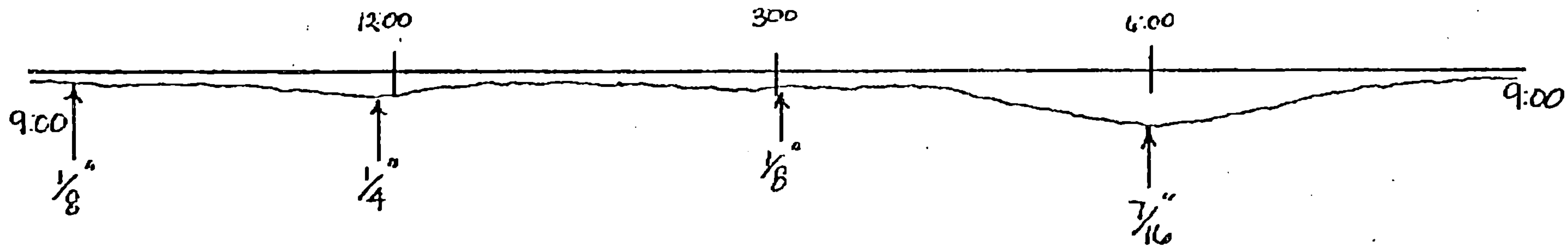
CW Carlton
5-22-84

PALISADES
PLA

S/G "A" AUX FEEDWATER NOZ. RADIUS GRINDING.



S/G "B"



GRINDING DEPTHS ARE MAX. DEPTH AT LOCATION INDICATED.
NO LOCAL GRINDOUTS EXIST AS THE TOTAL RADIUS SURFACE
WAS GROUND WITH TAPERED TRANSITION BETWEEN
HIGH AND LOW AREAS.

R. Nato 5-22-84

FORM QA-16 REV 8- 6/78

outage PAGE 1 OF 1 Befn Rt HU

Consumers Power Company DEVIATION REPORT

4/2/84

R/CHG/REMC/DWR

R/CHG DGMM/GY 3/12/84

i DEVIATION REPORT NO	D-PAL-84-015
ii TIME OF OCCURRENCE	Date 3-9-84 Hour 1800
iii SAFETY RELATED	(Yes) No

IDENTIFICATION & DESCRIPTION — PART 1

A TITLE: MISSING PIECE OF AUXILIARY FEED RING HANGER 'A' STEAM GENERATOR

B PLANT SYSTEM (UFI) 02320 EQUIPMENT - CLASS (UFI) 13370 EQUIPMENT NUMBER E-50A

C DESCRIPTION OF OCCURRENCE OR CONDITION: UPON INSPECTING THE AUXILIARY FEEDRING IN 'A' STEAM GENERATOR IT WAS DISCOVERED THAT A PIECE OF ONE AUX FEEDRING HANGER WAS MISSING.

D IMMEDIATE ACTION: VIDEO AND STILL PHOTOS WERE TAKEN. COGNIZANT ENGINEER WAS NOTIFIED.

E REFERENCES: EPal 84-015

F PREPARED BY: [signature] DATE: 3-12-84

DEPT/PLANT: Palisades SECTION: Tech.

APPROVED BY: [signature] DATE: 3/12/84

G NONCONFORMING ITEM: YES [✓] NO [ ] IDENTIFY: E50-A

DETERMINED BY: P-CARB DATE: 3/12/84

H DR FORWARDED TO: P-CARB DEPT/PLANT: Pal SECTION:

REPORTABILITY — PART 2

A TECH SPEC REPORTABLE: YES [ ] NO [X] ER #:

DETERMINED BY: P-CARB DATE:

B EVALUATOR: JDS

DEPT/PLANT: Pal SECTION:

APPROVED BY: P-CARB DATE: 3/12/84

EVALUATION DUE DATE: 3/31/84

PRIORITY: 8 7 6 5 4 3 2 1

(Provide as inspection info on B S/G Reportable item)

EVALUATION AND DISPOSITION — PART 3

A DESCRIBE CAUSE OF DEVIATION:

~~Transferred to EPAL 84-015 on 3-12-84~~
~~(copy attached)~~

ignore this information [signature]

Failure of fasteners holding sparger hanger together due to vibration/ water hammer during use.

B CONSIDERED TO BE REPORTABLE UNDER 10CFR21: YES ___ NO ___

(IF YES, NOTIFY NLA FOR FINAL DETERMINATION) DETERMINED BY: DATE:

COMPLETION — PART 4

APPROVED BY: DATE:

COMPLETION REVIEW — PART 5

REVIEWED BY: QA Representative DATE:

(Gold) - COPY 4 - FORWARD TO QA UPON COMPLETION OF PART 2.
(Pink) - COPY 3 - FORWARD TO QA UPON COMPLETION OF PART 3.
(Canary) - COPY 2 - FORWARD TO THE ORIGINATING DEPARTMENT UPON COMPLETION OF PART 5.
(White) - COPY 1 - FILED IN DOCUMENT CONTROL CENTER UPON COMPLETION OF PART 5.

FORWARD ALL CORRECTIVE ACTION DOCUMENTS THROUGH YOUR CORRECTIVE ACTION COORDINATOR.

FORM QA-16
FORM QA-17
FORM QA-19
REV 4- 6/78

CORRECTIVE ACTION SHEET

PAGE ___ OF ___

i	REPORT NO.
ii	TIME OF OCCURRENCE Date ______ HOUR ______
iii	SAFETY RELATED YES ____ NO ____

EVALUATION — PART 3

PROPOSED REMEDIAL CORRECTIVE ACTION:
Inspect secondary side of steam generator and remove materials

PRC: YES ✓ NO ____
MEETING
PRIOR TO PLACING RELIANCE YES ✓ NO ____
ASSIGNED TO R+C
DEPT/PLANT Pal
SECTION
APPROVED BY [signature]
DATE APPROVED 4/2/84
REQD COMPLETION DATE ~~5/15/84~~ 5/31/84 PCARB
JSC/CHG-(WCF/ONX) 5/16/84
PRIORITY: 8 ___ 7 ___ 6 ___ 5 ___ 4 ___ 3 ✓ 2 ___ 1 ___

DETERMINED BY *Jeff Terpstra* DATE 3/31/84

COMPLETION — PART 4

REMEDIAL ACTION TAKEN:
Combustion Engineering cleaned and inspected the ~~Annulusr~~ Anulus of the 'A' Steam Generator and removed the following pieces: one U-clamp, two U-clamp straps, one Drager tube, one jackknife blade, one spacer and one bolt.
Combustion Engineering says that the anulus has no more debris in it and any further missing pieces cannot be retrieved.

COMPLETED BY *Ronald Narrier* DATE 5/22/84
APPROVED BY P-CARB DATE 5/22/84

A

PROPOSED CORRECTIVE ACTION TO PREVENT RECURRENCE:
None applicable (This is being covered in E-PAL-84-015)

PRC: YES ____ NO ____
MEETING
PRIOR TO PLACING RELIANCE YES ____ NO ____
ASSIGNED TO
DEPT/PLANT
SECTION
APPROVED BY [signature]
DATE APPROVED 4/2/84
REQD COMPLETION DATE
PRIORITY: 8 ___ 7 ___ 6 ___ 5 ___ 4 ___ 3 ___ 2 ___ 1 ___

DETERMINED BY *Jeff Terpstra* DATE 3/31/84

ACTION TAKEN TO PREVENT RECURRENCE:
N/A

COMPLETED BY ______ DATE ______
APPROVED BY [signature] DATE 4/9/84

(Gold) - COPY 4 - (FOR ERs) FORWARD TO NUCLEAR LICENSING ADMINISTRATOR UPON COMPLETION OF PART 3; (FOR DRs AND NRs - DISCARD).
(Pink) - COPY 3 - FORWARD TO QA UPON COMPLETION OF PART 3.
(Canary)- COPY 2 - FORWARD TO ORIGINATING DEPARTMENT UPON COMPLETION OF PART 5.
(White) - COPY 1 - FILED IN DOCUMENT CONTROL CENTER UPON COMPLETION OF PART 5.

FORWARD ALL CORRECTIVE ACTION DOCUMENTS THROUGH YOUR CORRECTIVE ACTION COORDINATOR!

FORM QA-16
FORM QA-17
FORM QA-19
REV 4- 6/78

CORRECTIVE ACTION SHEET

PAGE ___ OF ___

i REPORT NO. D-PAL-84-025
ii TIME OF OCCURRENCE Date 3/9/84 HOUR 1800
iii SAFETY RELATED YES X NO ___

B

EVALUATION — PART 3

PROPOSED REMEDIAL CORRECTIVE ACTION: Conduct an evaluation of the affect of leaving the un retrieved material in the steam generator including the impact of periodic ECT testing at Refout intervals

PRC: YES X NO ___
MEETING ___
PRIOR TO PLACING RELIANCE YES X NO ___
ASSIGNED TO R T Carrier
DEPT/PLANT Pal
SECTION TECH
APPROVED BY P Corb
DATE APPROVED 5/22/84
REQD COMPLETION DATE 6/18/84
PRIORITY: 8 ___ 7 ___ 6 ___ 5 ___ 4 X 3 ___ 2 ___ 1 ___

DETERMINED BY P Corb Cleg DATE 5/22/84

COMPLETION — PART 4

REMEDIAL ACTION TAKEN: C-E says that leaving parts in the Generator for another re-fueling cycle will not be detrimental to the system. C-E Recommends doing another inspection of the annulus during the next refueling outage. (See attached letter). ECT can locate wall thinning on periphery tubes due to loose parts but its accuracy for actually locating loose parts cannot be guaranteed. If the loose part is not against the tube, the signal will not be of good quality.

COMPLETED BY [signature] DATE 6/13/84
APPROVED BY [signature] DATE 6/14/84

PROPOSED CORRECTIVE ACTION TO PREVENT RECURRENCE: ___

PRC: YES ___ NO ___
MEETING ___
PRIOR TO PLACING RELIANCE YES ___ NO ___
ASSIGNED TO ___
DEPT/PLANT ___
SECTION ___
APPROVED BY ___
DATE APPROVED ___
REQD COMPLETION DATE ___
PRIORITY: 8 ___ 7 ___ 6 ___ 5 ___ 4 ___ 3 ___ 2 ___ 1 ___

DETERMINED BY ___ DATE ___

ACTION TAKEN TO PREVENT RECURRENCE: ___

COMPLETED BY ___ DATE ___
APPROVED BY ___ DATE ___

(Gold) - COPY 4 - (FOR ERs) FORWARD TO NUCLEAR LICENSING ADMINISTRATOR UPON COMPLETION OF PART 3; (FOR DRs AND NRs - DISCARD).
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(White) - COPY 1 - FILED IN DOCUMENT CONTROL CENTER UPON COMPLETION OF PART 5.

FORWARD ALL CORRECTIVE ACTION DOCUMENTS THROUGH YOUR CORRECTIVE ACTION COORDINATOR!

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

Tel. 203/688-1911
Telex: 99297

POWER SYSTEMS

P-CE-7647

June 8, 1984

Consumers Power Company
Palisades Plant

Mr. C. Gilmor
Palisades Nuclear Plant
Consumers Power Company
Route 2, P.O. Box 154
Covert, MI 49043

Subject: Palisades Steam Generator Loose Parts

Dear Mr. Gilmor:

As we previously recommended, the candeck region of the Palisades A steam generator has been reinspected for loose parts. None were found. In addition, an attempt was made to examine the downcomer region of the steam generator for loose parts. This was not practical using the inspection equipment available at this time. Significant difficulty was encountered in controlling video camera movement underwater, with the result that both the primary and backup video inspection equipment was damaged. After reviewing the situation, recognizing that the missing auxiliary feedwater sparger clamp assembly may never reach the tubesheet, even if it is currently lodged in the downcomer region, a decision was made to abort further efforts to perform a downcomer inspection. After reviewing the available information, it was concluded that it was not absolutely necessary to perform an inspection of the tubesheet for the missing sheared bolt head, prior to plant startup. This conclusion was reached based on the similarity in geometry to other loose parts for which flow tests have been conducted. For the parts tested, these flow tests showed that no significant damage should result from a single cycle of operation.

If practical to do so, C-E feels it is always desirable to remove any loose parts in the steam generator.

At the next refueling outage C-E recommends that a tube sheet annulus inspection be conducted to search for the sheared bolt head and to check for any other loose parts which might have been dislodged from the downcomer region. If workable techniques and equipment are available at that time, an inspection of the downcomer region is recommended to provide additional assurance that no potentially damaging loose parts are located there.

The above is submitted in response to your verbal inquiry to Bob Taylor, requesting C-E's recommendations regarding what further action should be taken with regard to the subject unaccounted for loose parts, and to confirm our discussions on this subject yesterday (June 7, 1984).

Very truly yours,

COMBUSTION ENGINEERING, INC.

W.D. Meinert

W.D. Meinert
Palisades Project Manager

WDM/jbn

cc: J.P. Pomaranski
D.R. Hughes
V.A. Anderson
M.D. Turnmire
R.W. Taylor
J.W. Matton

FORM QA-16 REV 8- 6/78

Outage - Heatup

JAT:84*021

Consumers Power Company

DEVIATION REPORT

CARB Review required after evaluation

Reviewed by CARB Date 6/18/84 CHG/DGM/REMC

D- Pal -84 -137 (DEVIATION REPORT NO)

TIME OF OCCURRENCE Date N/A Hour

SAFETY RELATED (Yes) No

IDENTIFICATION & DESCRIPTION — PART 1

A] TITLE: Auxiliary Feedwater Piping Immediately Adjacent to Steam Generator B

B] PLANT SYSTEM (UFI) 03430 EQUIPMENT - CLASS (UFI) 15113 EQUIPMENT NUMBER DBB-2-4"

C] DESCRIPTION OF OCCURRENCE OR CONDITION: Ultrasonic measurement of the wall thickness on the auxiliary feedwater piping immediately adjacent to steam generator B has shown the actual piping wall thickness in some areas to be less than the nominal wall thickness shown within piping tables for schedule 40 4" piping.

D] IMMEDIATE ACTION: Transmitted results of ultrasonic test to plant management; Phil Flenner of Operating Services Department, and Denny Hughes of Nuclear Plant Support.

E] REFERENCES: Ultrasonic test results for auxiliary feedwater piping immediately adjacent to E-50A (attached)

F] PREPARED BY: Jeff Terpstra JAT DATE: 4/28/84

DEPT/PLANT: TECH/PALISADES SECTION: PROJECTS

APPROVED BY: [signature] FOR CHK DATE: 5/4/84

G] NONCONFORMING ITEM: YES ☐ NO ☒ IDENTIFY:

DETERMINED BY: [signature] DATE: 5/4/84

H] DR FORWARDED TO: DEPT/PLANT: SECTION:

REPORTABILITY — PART 2

A] TECH SPEC REPORTABLE: YES ☐ NO ☒ ER #:

DETERMINED BY: [signature] DATE: 5/4/84

B] EVALUATOR: JRHuble

DEPT/PLANT: NOD SECTION: NPS

APPROVED BY: PCart DATE: 5/7/84

EVALUATION DUE DATE: ~~5/25/84~~ 6/15/84 Schedule per CHG.

PRIORITY: 8 7 6 X 5 4 3 2 1

Date change approved by JSR for RWM 5/25/84

EVALUATION AND DISPOSITION — PART 3

A] DESCRIBE CAUSE OF DEVIATION: The cause of the observed wall thinning is believed to be inherent in the design and failed condition of the steam generator auxiliary feedwater sparger. Under such conditions, Combustion Engineering describes the possibility of steam bubble collapse within the failed sparger (see P-CE-7597, Combustion Engineering Auxiliary Feedwater Sparger Study, Paragraph 1, Page 4 of 7, Attachment 1). During steam bubble collapse large differential pressures are realized which accelerate the incoming cold auxiliary feedwater to velocities which result in erosion of the nozzle liner and pressure boundary piping.

B] CONSIDERED TO BE REPORTABLE UNDER 10CFR21: YES ___ NO X

(IF YES, NOTIFY NLA FOR FINAL DETERMINATION) DETERMINED BY: CHG DATE: 6/18/84

COMPLETION — PART 4

APPROVED BY: DATE:

COMPLETION REVIEW — PART 5

REVIEWED BY: QA Representative DATE:

(Gold) - COPY 4 - FORWARD TO QA UPON COMPLETION OF PART 2.
(Pink) - COPY 3 - FORWARD TO QA UPON COMPLETION OF PART 3.
(Canary) - COPY 2 - FORWARD TO THE ORIGINATING DEPARTMENT UPON COMPLETION OF PART 5.
(White) - COPY 1 - FILED IN DOCUMENT CONTROL CENTER UPON COMPLETION OF PART 5.

FORWARD ALL CORRECTIVE ACTION DOCUMENTS THROUGH YOUR CORRECTIVE ACTION COORDINATOR.

FORM QA-16
FORM QA-17
FORM QA-19
REV 4- 6/78

CORRECTIVE ACTION SHEET

PAGE ___ OF ___

REPORT NO. D-PAL-84-137

TIME OF OCCURRENCE
ii Date ______ HOUR ______

SAFETY RELATED
iii YES ____ NO ____

EVALUATION — PART 3

PROPOSED REMEDIAL CORRECTIVE ACTION:
Remove piping.

PRC: YES ___ NO X
MEETING ___
PRIOR TO PLACING RELIANCE YES X NO ___
ASSIGNED TO JAT/CHG
DEPT/PLANT PAL
SECTION TECH
APPROVED BY PCaw
DATE APPROVED 6/18/84
REQD COMPLETION DATE 6/18/84
PRIORITY: 8 ___ 7 ___ 6 ___ 5 ___ 4 X 3 ___ 2 ___ 1 ___

DETERMINED BY Jeffrey R. Dienke JCB DATE 6/15/84

COMPLETION — PART 4

REMEDIAL ACTION TAKEN:
Completed per FC-613

COMPLETED BY JAT by clg DATE 6/18/84
APPROVED BY [signature] DATE 6/18/84

PROPOSED CORRECTIVE ACTION TO PREVENT RECURRENCE:
See FC-613.

PRC: YES X NO ___
MEETING ___
PRIOR TO PLACING RELIANCE YES X NO ___
ASSIGNED TO JAT
DEPT/PLANT PAL
SECTION TECH
APPROVED BY Chg-PCaw
DATE APPROVED 6/18/84
REQD COMPLETION DATE 6/18/84
PRIORITY: 8 ___ 7 ___ 6 ___ 5 ___ 4 X 3 ___ 2 ___ 1 ___

DETERMINED BY Jeffrey R. Dienke JCB DATE 6/15/84

ACTION TAKEN TO PREVENT RECURRENCE:
Complete

COMPLETED BY clg for JAT DATE 6/18/84
APPROVED BY [signature] DATE 6/18/84

(Gold) - COPY 4 - (FOR ERs) FORWARD TO NUCLEAR LICENSING ADMINISTRATOR UPON COMPLETION OF PART 3; (FOR DRs AND NRs - DISCARD).
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FORWARD ALL CORRECTIVE ACTION DOCUMENTS THROUGH YOUR CORRECTIVE ACTION COORDINATOR!

CONSUMERS POWER COMPANY
SYSTEM PROTECTION AND LAB SERVICES DEPT
NONDESTRUCTIVE TESTING SERVICES
THICKNESS MEASUREMENT
EXAMINATION REPORT

EXAMINER R. THOMAS HUERTER LEVEL II DATE 4-27-84 SHEET NO RTH-02

EXAMINER N/A LEVEL N/A NDT COMPANY CPCo

PROJECT NO 238415-225077 REQUESTING DEPT TECH

JOB LOCATION PALISADES TOTAL HOURS WORKED ______

NDT PROCEDURE NDT-UT-02 REV 0

N/A

ULTRASONIC EQUIPMENT NORTEC 131D SN#

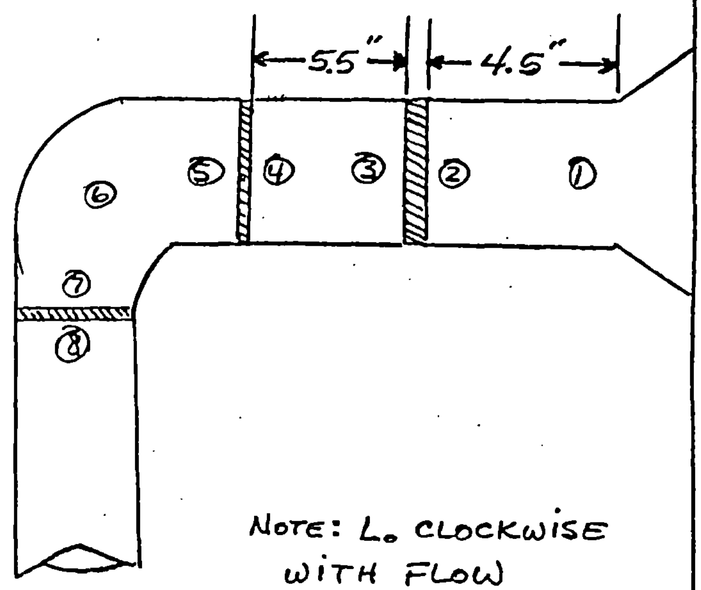
PANAMETRICS (3743-00285) 5MHZ X .50 ULTRAGEL II BATCH 8120

COMPONENT IDENTIFICATION AUX FEEDWATER 4" OFF S/G 'B'

ITEM	THICKNESS 1	2	3	4	5	6	7	8	9	10	
CLOCK POSITIONS	0200		0400		0600		0800		1000		1200
POSITION # 1	278		272		270		273		274		286
2	236		243		225		222		236		218
3	250		358		380		383		222		336
4	260		372		386		364		290		320
5	212		218		226		221		220		235
6	233		240		231		220		233		250
7	241		251		236		231		240		256
8	238		243		250		246		238		253

SKETCH/REMARKS

S/G 'B'



NOTE: L0 CLOCKWISE WITH FLOW

EXAMINER ______ PAGE ___ OF ___ REVIEWED BY ______

REV 2/83

To	Technical Superintendent, Palisades	
From	PM&MP Resident Engineer, Palisades	CONSUMERS POWER COMPANY
Date	May 4, 1984	
Subject	Auxiliary Feedwater Piping	Internal Correspondence
CC	ADMullholand, P13-213B JGGose, PM&MP/Palisades Doc. Control 950*42*10*06	TEM 13-84

Upon being informed of a possible problem in the auxiliary feed lines DBB-1 and DBB-2 installed by the plant during the 1981 outage a review of the drawings, piping class sheets and pipe class summary sheets was made. The possibility of a pipe wall thickness problem arose as a result of UT examination performed on the pipe. The examination provided wall thickness readings greater than the wall thickness of schedule 40 pipe with which the line was constructed. This resulted in speculation that possibly a short section of schedule 80 pipe had somehow been installed immediately adjacent to the Steam Generator nozzle.

Isometrics M101-2937(Q) R/8 and M101-2938(Q) R/8 contain details of an engineered adapter piece manufactured from a section of 5-inch XXS pipe machined on one end to fit-up with the S.G. nozzle and on the other end to fit-up with the schedule 40 pipe. This adapter piece is what was mistakenly thought to be a piece of schedule 80 pipe installed erroneously.

Following the above, questions arose in various quarters regarding the propriety of lines DBB-1 and DBB-2 being schedule 40. To check this situation, copies of the appropriate pipe class sheets and pipe class summary sheets were obtained. Minimum wall calculations per ANSI B31.1, 1980 were made to check the adequacy of the design. Copies of the pipe class sheets, pipe class summary sheets, and check calculations are attached.

The conclusions based upon the checks made are; that no schedule 80 pipe was wrongfully installed adjacent to the vessel nozzle; the line schedule is adequate for the design pressure and the remaining wall thickness based upon UT is greater than the calculated minimum wall including a 14% margin for bending, even though this system appears to be made up of straight sections and fittings.

References:

- M101-2937(Q) R/8
- M101-2938(Q) R/8
- 5935-M-260 Sh. 35 R/1 (Copy attached)
- 5935-M-259 Sh. 100 R/1 (Copy attached)
- Check Calc. 5-3-84 - TEM (Copy attached)

Former Drawing No. M-260 SH. 89

CLASS 900 PRESSURE – TEMPERATURE RATING CARBON STEEL CODE: ASME B&PV CODE, SECTION III, CLASS 2			CLASS : DBB
ITEM	**MATERIAL SPECIFICATION**	**SIZE**	**REMARKS**
PIPE:	ASME SA-106, GR. B (SEAMLESS)	6" 4" thru 2 1/2" 2" & smaller	Schedule 80 Schedule 40 Design P = 1100 Schedule 80
FITTINGS:	ASME SA-234, GR. WPB ASME SA-105	2½" and larger 2" & smaller	SEAMLESS, BUTT WELDING, WALL THICKNESS TO MATCH PIPE. 3000# Socket Welding
FLANGES:	ASME SA-105, F&D, BORED TO MATCH PIPE	2½" & larger	900# WELDING NECK, SMALL T&G
PLATE:	ASME SA-515, GR. 70	----	----
VALVE BODY:	ASME SA-216, GR. WCB	2½" & larger	CASTINGS
BOLTING:	ASME SA-193, GR. B7 ASME SA-194, GR. 2H	----	AN STANDARD STUD BOLTS WITH HEAVY HEXAGON NUTS.
GASKETS:	"FLEXITALLIC" OR APPROVED EQUAL	2½" & larger	STYLE R-4, STYLE CG FOR 26" & LARGER

VALVES:		GATE	GLOBE	CHECK	BUTTERFLY
2½" & larger	900# BW:	DBB-GT	DBB-GB	DBB-CK	

FIELD WELD END PREPARATION AND TRANSITION: DRAWING 12447-G-84(Q)
Attachment C, Sheet 2

BRANCH CONNECTIONS: 2½" & larger BRANCHES: GROUP A, DRAWING Sheet 62
2" & Smaller Branches: Drawing Sheet 63

CORROSION ALLOWANCE: None

FIELD WELDING PROCEDURE: DRAWING 12447-G-84(Q)

WELD JOINT NDE: DRAWING 12447-G-84(Q)

NO.	DATE	REVISIONS	BY	CH'K	APPR.
1		CHGD. DWG. No. FORM. M-260 SH. 89 & REV. BRANCH CONN. REF. SH. No's.	JGD	TPV	DIB

BECHTEL	PIPING CLASS SHEET	JOB NO. 12447	
	CONSUMERS POWER COMPANY, PALISADES PLANT SOUTH HAVEN, MICHIGAN	Drawing 5935-M-260	REV. 1
		SHEET 35	

P-DBB 3/78 TCW

CLASS & SERVICE NO.	SERVICE *CRITICAL SERVICES P&ID NO. (______)	SEISMIC CLASS	DESIGN RATING PSIG	DESIGN RATING °F	SERVICE CONDITION NORMAL PSIG	NORMAL °F	MAXIMUM PSIG	MAXIMUM °F	INSUL. CLASS	SAFETY RELATED (S)
DBB-1	Aux. FW from EBB-1 ctmt. pene. #9 to stm. gen. E50A nozzle (207)	I	1,100	550	850	435	1,200	550	-	S
DBB-2	Aux. FW from EBB-2 ctmt. pene. #73 to stm. gen. E50B nozzle (207)	I	1,100	550	850	435	1,200	550	-	S

No.	DATE	REVISIONS	BY	CH'K	DESIGN SUPV	ENG'R	PROJ ENGR	APPR
1	5/6/82	ISSUED FOR RECORD	[signature]	[signature]	—	[signature]	[signature]	—
0	4/14/82	ISSUED FOR USE	[signature]	[signature]	—	[signature]	[signature]	—

SCALE | DESIGNED | DRAWN | CHIEF ENGR

ORIGIN: AAO

BECHTEL

PIPING CLASS SUMMARY
CONSUMERS POWER COMPANY
PALISADES NUCLEAR PLANT

JOB No. 12447

DRAWING No. 5935-M-259 | REV.

M-081073

5-3-84 TE [illegible]

1) Check Min. wall requirement for DES-1
Per B31.1 1980 5935-M-260 R-5 sh 89 of 95

$$t_m = \frac{P D_o}{2(SE + Py)} + A$$

line = SA106 Gr. B 4-inch ∴ D_o = 4.50
P = 1100 from M-259 sh 100 of 106
T = 550 " " " " " "
SE = 15,000 from Appendix A, Table A-1 B31.1, 1980
y = 0.4 from B31.1, 1980
A = 0 – designers discretion

$$t_m = \frac{1100 \times 4.5}{2(15{,}000 + (1100 \times .4))} = \frac{4950}{30880} = \underline{0.1602979}$$

(1100 X .4 = 440)

Wall allowance for bending – Assume 4 diam. bend – 14% (¶102.4...)
0.1602979 X 1.14 = 0.1827396 < 0.237 = sch 40 wall ∴
sch 40 is acceptable

2) Check Min wall requirement for DBB –
5935-M-9260 R-5 sh 6 of 19

Per B31.1 1980

$$t_m = \frac{P D_o}{2(SE + Py)} + A$$

line = SA106 G.B 4-inch ∴ D_o = 4.5
P = 1685 From M-9259 sh 3 of 20
T = 120 " " " " " "
SE = 15,000 from Appendix A, Table A-1 B31.1, 1980
y = 0.4 from B31.1, 1980
A = 0 – designers discretion

$$t_m = \frac{1685 \times 4.5}{2(15{,}000 + (1685 \times .4))} = \frac{7582.5}{31348} = \underline{0.2418814} > \text{sch } 40$$

(1685 X .4 = 674)

Wall allowance for bending – Assume 4 diameters – 14%
1.14 X .2418814 = 0.2757447 < 0.337 = sch 80 wall ∴
sch 80 is acceptable

C-E Power Systems
Combustion Engineering, Inc.
1000 Prospect Hill Road
Post Office Box 500
Windsor, Connecticut 06095-0500

Tel. 203/688-1911
Telex: 99297

POWER
SYSTEMS

P-CE-7597

Consumers Power Company
Palisades Plant

Mr. D. R. Hughes
Consumers Power Company
1945 Parnall Road
Jackson, Michigan 49201

SUBJECT: AUXILIARY FEEDWATER SPARGER REPAIR

References: (A) W. D. Meinert to D. R. Hughes, "Auxiliary Feedwater Sparger Repair," P-CE-7573, dated March 29, 1984.

(B) Corrective Action Review Board Meeting, April 5, 1984.

Attachments: (1) Auxiliary Feedwater Sparger Study.

(2) Response to Consumers Power Company Questions, received April 19, 1984.

(3) C-E Calculation, SS-801, "Evaluation of Palisades Auxiliary Feedwater Piping For A Postulated Water Hammer Event", dated April 19, 1984.

(4) C-E Position on the Palisades Steam Generator Auxiliary Nozzle Sparger Repair, April 16, 1984.

Dear Mr. Hughes:

This letter has been prepared to address the Palisades auxiliary feedwater sparger repair effort. The enclosed attachments discuss the sparger design, damage and repair based on the information presently available.

Attachment (1) has been revised to clarify Reference (A), incorporation of new information, and address items that were discussed during a meeting at Palisades site, Reference (B).

On April 19, 1984, C-E received a list of questions to be answered for Consumers Power Company safety evaluation on the auxiliary feedwater sparger modification. The responses to these questions are provided in Attachment (2). Additionally, C-E has performed a calculation Attachment (3) "Evaluation of Palisades Auxiliary Feedwater Piping for a Postulated Water Hammer Event", that should address some of your concerns.

Attachment (4) is C-E's position on the Palisades steam generator auxiliary feedwater nozzle sparger repair as a result of an internal meeting in Chattanooga, Tennessee, on April 16, 1984.

C-E is also reviewing normal plant operating and emergency procedures that could be affected by auxiliary feedwater flow rate restrictions to help preclude water hammer. A marked-up copy of these procedures will be forwarded to Consumers by Friday, April 27, 1984.

In summary, C-E recommends that the sparger be removed. A new thermal liner with splash shield assembly should be installed to protect the auxiliary feedwater nozzle from direct impingement of cold auxiliary feedwater. Auxiliary feedwater flow rate restrictions will be required when the level in the steam generator is below the auxiliary feedwater nozzle to prevent water hammer in the first horizontal pipe until testing can be performed to provide a basis to relax these restrictions. The modification and flow restrictions will remove the potential for a damaging water hammer to occur inside the steam generator. The external piping will remain full of water during normal operating conditions. Further action to keep the external piping as full of water as possible when the steam generator water level is below the auxiliary feedwater nozzle could be considered. Periodic testing, to demonstrate that a significant portion of the external piping would not void within a reasonable time for operator action, could be performed. This would require installation of a means for monitoring the external piping for line voiding.

If you have any further questions regarding any of the attached information, please let me know.

Very truly yours,

COMBUSTION ENGINEERING, INC.

W.D. Meinert

W. D. Meinert
Palisades Project Manager

WDM/CJG:jcp

xc: G. B. Slade
W. J. Beckius
R. W. Montross
C. Gilmor
J. P. Pomaranski
J. W. Matton
R. W. Taylor

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Combustion Engineering
Auxiliary Feedwater Sparger Study

Background

During a recent inspection of the steam generators, damage was observed to the internal auxiliary feedwater piping in both units. C-E personnel have inspected both steam generators. In one unit the nozzle liner was sheared off and the first support bracket was broken. In the second unit, the weld was cracked between the nozzle liner and the elbow allowing the pieces to separate and the first support bracket was twisted. It is our understanding that a visual inspection of the external auxiliary feedwater piping has been performed and that no significant damage was found.

Investigation

C-E has reviewed the results of the water hammer test that was conducted after the auxiliary feedwater spargers were installed. During the test no water hammer was observed at the test conditions. However, a review of the raw data (strip chart recorder traces) reveals evidence of periodic water hammer(s), between the tests run at steam generator pressures of 200 psi and 900 psi at flow rates of approximately 40 gallons per minute (below the range of test conditions). The indications stopped when the flow rate was raised to 50 gallons per minute, with the steam generator at 900 psi.

Additional verbal information has been received from the site. Based on interviews with the site operating staff and information obtained during the site meeting, Reference (B), it is understood that small water hammers may have occurred during sodium recovery operations during the last cycle of operation. These indications were reported to have been observed when the steam generator level was below the auxiliary feedwater nozzle with estimated flow rates of 15 to 30 gallons per minute. The water hammers were cyclic in nature and stopped when auxiliary feedwater flow was increased above 50 gallons per minute.

Present Auxiliary Feedwater Sparger Design

The present sparger design incorporates the design features presently used in the industry to preclude water hammer. Top discharge J tubes are used to keep the sparger full of water when steam generator water level is below the sparger. If the sparger becomes partly drained, a water slug formation can occur during the refilling of the sparger. Large vent area to sparger volume ratios were incorporated to minimize the probability of water slug formation. This sparger design compares favorably with the design of other units. An anti-siphon gooseneck was incorporated to prevent sparger draining through the thermal sleeve clearances when steam generator level is below the nozzle for extended periods of time. Consistent with standard PWR practice, every effort was made to maintain the sparger full of water to minimize the probability of water hammer when auxiliary feedwater flow was initiated. Due to the location of the existing supports, the auxiliary feedwater spargers at Palisades were installed close to the normal water level. These supports have limited load carrying capability that prevents hanging the sparger lower in the steam generator. This location results in the top of the anti-siphon gooseneck being in the steam space, at normal steam generator water levels. A small steam void would, therefore, be present in the gooseneck during plant operation.

Postulated Water Hammer Mechanism(s)

System configuration, operation and physical damage have all been studied to determine a mechanism that could produce the damage observed. A number of different conditions can be postulated that could have resulted in several types of water hammer events of varying severity.

A comparatively large water hammer event would have been required to cause the damage observed in the steam generator. This belief is supported by the inspection of the damaged parts. A large tensile load had to occur to break the nozzle liner and shear the support bracket. There is no known evidence of cyclic failure of these components. The water hammer test conducted following the sparger installation produced pressure spikes of several hundred psi. These water hammers are not believed capable of causing the physical damage observed to the spargers. The sparger damage probably occurred during subsequent plant operation.

When the plant is at power, the auxiliary feedwater system is usually in a standby configuration, i.e., it is only operated monthly for surveillance testing. The sparger gooseneck high point vent is in the steam space during normal plant operation. As a result of back leakage through the auxiliary feedwater system over this extended period of time, steam could have entered the high point vent in the gooseneck and displaced the water in the nozzle liner and some of the external piping. This displacement of water would continue until the system leak rate was balanced by the condensation rate of steam in the uninsulated piping. When the auxiliary feedwater system was manually initiated at a very low flow rate, a region of two phase flow developed in the external horizontal run of piping. When the steam came in contact with the cold auxiliary feedwater, the condensation rate exceeded the venting capacity of the vent on top of the gooseneck, producing a low pressure void in the horizontal pipe. Steam generator pressure would then accelerate a slug of water from the sparger over the gooseneck impacting the piping near the nozzle liner. C-E believes this slug of water would have had enough energy to produce the damage observed.

Several mechanisms have been postulated to explain the small periodic noises reported by the site operating staff. None of the following theories can be definitely proven analytically but are based on the information currently available to C-E. One mechanism assumes the sparger is intact, the other two mechanisms assume the sparger is damaged.

The periodic banging during the original testing could have been due to two-phase flow in the gooseneck section of the sparger. At normal steam generator water level, there is a small steam void in the top of the gooseneck. When cool auxiliary feedwater flow is introduced to the steam generator at very low flow rates, cold water cascades over the gooseneck. Steam rushes in through the high point vent to replenish the steam that is condensing in contact with the cold water. At a critical flow rate, the steam void collapses causing a small differential pressure that pulls a small slug of water up the gooseneck from the sparger. The water then redistributes and a small void of steam is recreated in the top of the gooseneck. Conditions have then been reset to allow this small banging to reoccur. Because the steam space involved is small, the resulting pressure differential would also be small. This mechanism should not result in a damaging water hammer that creates enough energy to damage the sparger. The observed pressure spikes from the test data were a few hundred psi which is consistent with this theory.

Two other theories have been postulated which would produce periodic banging after the sparger had been damaged. A banging noise could have been the result of auxiliary feedwater flow pushing on the internal piping causing it to strike the steam generator internals. Secondly, after the sparger had been damaged, the first horizontal run of auxiliary feedwater piping would drain if the steam generator level was below the nozzle. If auxiliary feedwater flow was initiated manually at a low flow rate, two-phase flow conditions could exist in the first horizontal pipe run outside the steam generator. As the pipe refilled, steam in contact with cold auxiliary feedwater would condense in the pipe. Steam would rush in to replace the condensed steam. At some point during the filling of this horizontal pipe, the steam velocity would increase to a point where it caused a wave to form blocking off the steam flow. The entrapped steam bubble would collapse producing a low pressure zone in the horizontal pipe. Water would then be accelerated into this low pressure zone. When these columns of water collide in the low pressure zone their kinetic energy is transformed into potential energy and is manifested in a pressure pulse. This energy is dissipated as the pressure wave radiates through the auxiliary feedwater piping. It is believed that this mechanism produced the water hammer observed by the operators during the sodium recovery operations during the last cycle of operation.

Safety Implications

While the auxiliary feedwater spargers were damaged, the safety function of the system was not impared.

- Decay heat removal capability was not degraded. Auxiliary feedwater flow capability was demonstrated each month during the surveillance test.

- The steam generator pressure boundary integrity is not believed to have been degraded. The thermal liner stayed in place protecting the thick wall section of the nozzle from cold water induced thermal stress. While not considered likely, the inner radius of the nozzles could have been subjected to cold water splashing. This splashing could give rise to surface cracking of this portion of the nozzle. Visual inspection of the nozzle inner radius will be performed during the sparger repair work to confirm the present condition of the inner surface of the nozzle.

- The external auxiliary feedwater piping is not believed to be damaged. A visual inspection of the external auxiliary feedwater piping was performed and we understand that no significant damage was found.

- Radiographic inspection of the nozzle weld and horizontal piping to the first elbow has been performed. No cracking of the welds or pipe has been reported, however, we understand that some loss of wall thickness near the top of the pipe may have occurred.

Design Alternatives

Several design alternatives have been considered to reduce the probability of water hammer in the system. Lowering the sparger would prevent steam from entering the gooseneck and the external piping while the steam generator is at normal water level. This had been evaluated previously. The existing brackets can not support the load induced by this design. Based on the apparent successful operation of the plant for some period of time in the existing configuration, the recommended modification is to remove the sparger and install a modified nozzle liner and splash shield to protect the nozzle.

Removal of the sparger and gooseneck eliminate several of the conditions believed to have contributed to the large water hammer. When the steam generator is at normal water level, back leakage through the auxiliary feedwater system will be made up with water from the steam generator. By maintaining the nozzle and external piping full of water, the mechanism to produce a large differential pressure is eliminated. If the steam generator level is below the nozzle, the thermal liner and the first horizontal pipe run of external piping immediately outside the steam generator will drain. C-E has performed a calculation to evaluate the conditions under which water hammer might occur during the refill of this pipe. This analysis assumed that only the first horizontal length of auxiliary feedwater piping is voided. If steam generator level is maintained below the auxiliary feedwater nozzle for a sufficient length of time, there is the potential to void the next horizontal run of piping. A void in the second horizontal pipe run could produce a large water hammer event when auxiliary feedwater flow is initiated.

As discussed during the meeting, Reference (B), water hammer may have occurred in the first horizontal pipe during sodium recovery operations. During this operation, steam generator water level was allowed to drop below the auxiliary feedwater nozzle and auxiliary feedwater flow rates were very low. It is recommended that any time the auxiliary feedwater nozzle is not submerged, auxiliary feedwater flow be initiated at a flow rate that would prevent two-phase flow in this pipe (i.e., >70 gpm).

Operational Testing

Calculations indicate that water hammer can occur in the first horizontal pipe run. The potential for water hammer exists when steam generator level is below the auxiliary feedwater nozzle and auxiliary feedwater flow is below 70 gallons per minute. For flow rates above 70 gallons per minute the horizontal pipe will flow water solid and will not be susceptable to two-phase flow induced water hammer. When the auxiliary feedwater nozzle is completely submerged in water the horizontal pipe will remain full of water and no restrictions are imposed on the auxiliary feedwater flow rate. As a minimum, flow testing should be performed to verify that water hammer will not occur within the flow restrictions indicated above. With the plant at hot standby conditions, the steam generator level should be quickly dropped below the auxiliary feedwater nozzle. Auxiliary feedwater flow should then be initiated rapidly at a rate of 150 gallons per minute. This test would simulate plant operation for expected transients that would automatically initiate the auxiliary feedwater system. Auxiliary feedwater flow should be slowly throttled from 150 gallons per minute to 70 gallons per minute while the auxiliary feedwater nozzle is uncovered to confirm that water hammer will not occur in the recommended flow range.

More extensive testing could be performed to minimize the operational limitations. This testing would be performed over the entire auxiliary feedwater flow range at reduced steam generator pressures. Reduced steam generator pressures would minimize the magnitude of the water hammer that could occur and would provide a basis for relaxing operational restrictions.

Conclusion

In conclusion, C-E recommends that the sparger be removed. A new thermal liner with splash shield assembly should be installed to protect the auxiliary feedwater nozzle from direct impingement of cold auxiliary feedwater. Auxiliary feedwater flow rate restrictions will be required when the level in the steam generator is below the auxiliary feedwater nozzle to prevent water hammer in the first horizontal pipe until testing can be performed to provide a basis to relax these restrictions. The modification and flow restrictions will remove the potential for a damaging water hammer to occur inside the steam generator. The external piping will remain full of water during normal operating conditions. Further action to keep the external piping as full of water as possible when the steam generator water level is below the auxiliary feedwater nozzle could be considered. Periodic testing, to demonstrate that a significant portion of the external piping would not void within a reasonable time for operator action, could be performed. This would require installation of a means for monitoring the external piping for line voiding.

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RESPONSES TO LIST OF ITEMS TO BE ANSWERED FOR CPCO SAFETY EVALUATION ON AUXILIARY FEEDWATER SPARGER MODIFICATION

1. Justify acceptability of design

Question 1 (a): Why if forces are greater than stress allowable is design acceptable?

Question 1 (b): Why is deviation from normal design practice acceptable?

Question 1 (c): Calculation

See the SUMMARY AND CONCLUSIONS, C-E calculation SS-801, EVALUATION OF PALISADES AUXILIARY FEEDWATER PIPING FOR A POSTULATED WATERHAMMER EVENT. If worst calculated waterhammer pressure pulses of 4000 psi (see Figure 1) were actually experienced, the calculted stress produced at the minimum cross section would slightly exceed the mimimum yield stress at temperature. Using ASME fatigue curves a total of approximately 2000 cycles of this transient pressure pulse would be allowable. For 25 cycles (pulses) the fatigue usage factor would be negligible.

There is no normal design practice for waterhammer. SS-801, based on the ASME code, is considered a reasonable approach to evaluate this postulated transient. In view of the ductility of the carbon steel material the stress of 31 KSI (52% of Su) is considered to be well below a damaging stress.

It should be noted that this calculation presupposes undamaged material and a willingness to accept operational restrictions to avoid/limit water hammer occurrences until experimental or theoretical justification is available to provide a basis for relaxing the restrictions.

Question 1 (d): How much certainty does C-E have in the calculation, any tolerance?

The above discussions center around the structural analyses which C-E has performed to demonstrate that the piping system has sufficient structural strength to withstand the calculated worst case loadings due to waterhammer. However, the prediction of the onset of waterhammer and the resultant magnitudes is a very difficult calculational process. To minimize the uncertainity in these calculations, C-E has chosen to use experimental empirical correlations wherever possible.

These correlations are broken down into two areas, the prediction of the onset of wave formation, which is the necessary precondition for waterhammer, and the prediction of the magnitude of the resultant waterhammer. Wave formation occurs due to the counterflow of steam across the surface of auxiliary feedwater within the thermal sleeve. As the level of water within the sleeve increases due to an increase in auxiliary feedwater flow or the refill of the steam generator, the available flow area for steam to enter the sleeve from the steam generator is reduced. Since the condensation rate remains relatively constant during this period, the velocity of the steam must continually increase to compensate for the reduced flow area. At some point during the recovery process, the steam velocity reaches a point where the drag forces on the surface of the feedwater cause a wave to form. Once this occurs, the available flow area for the steam is rapidly reduced resulting in total blockage.

When blockage occurs, the necessary preconditions for waterhammer are present. The steam that is trapped within the sleeve continues to condense. This depressurizes the steam pocket creating a differential pressure across the wave. This pressure difference accelerates the wave of water away from the steam generator into the auxiliary feedwater system piping where it impacts the column of water within the pipe. This creates the pressure impulse associated with waterhammer.

The calculation concerning the onset of wave formation is based on a MIT paper, reference A. This paper uses the dimensionless Taitel-Dukler Criteria, which has been correlated to experimental test data, to predict wave formation. A computer code is used to calculate this number at various points along the thermal sleeve, while taking into account the condensation rate, the auxiliary flow rate and the height of the water level within the pipe. From these runs, a curve is plotted, Figure 1, which shows the onset of wave formation as a function of auxiliary flow rate and water level at the exit to the thermal sleeve.

The pressure rise following the collapse of the trapped steam bubble is determined using correlations documented in the Creare waterhammer report, reference B. An attempt has been made to verify this method by comparing the predicted pressure with experimentally obtained Tihange test data. When using this method, the impact velocity of the slug is first computed as a function of the water level within the pipe and the available steam generator pressure. The pressure rise is then calculated using classic waterhammer theory involving the accoustical velocity of the water, its density and the slug velocity. This information is also plotted on Figure 1 as a function of the water level within the pipe.

The maximum pressure rise is determined by the intersection of the wave formation and the pressure rise curves. For other flow conditions the pressure rapidly decreases. Hence, a very unique set of conditions are required before pressure increases of the magnitude assumed in the stress analyses can be achieved.

Recent discussions with plant staff indicate that water hammers have not been detected during low flow conditions, such as during sodium recovery operations, indicating that if waterhammer occurred it was of much lower magnitude than the worst case predicted by the waterhammer calculation. Recently conducted radiograph tests, which identified no pipe wall cracks, provide additional support for this belief.

Question 1 (e):1 List of assumptions.

There are relatively few key assumptions made in these calculations. It is assumed that waterhammer does occur once wave formation is predicted. In reality, these waves may be broken up before complete blockage occurs, thus further limiting the flow conditions under which waterhammer can occur. Another critical assumption is a one-dimensional temperature profile within the auxiliary feedwater. Under actual flow conditions, the surface of the feedwater would heatup more rapidly, creating a temperature profile through the feedwater. If the profile were considered, the rate of heat transfer and hence the condensation rate would be reduced. This would reduce the amount of steam being drawn into the thermal sleeve and further limit the flow conditions under which wave formation is possible.

The magnitude of the pressure impact is very dependent on the condensation rate within the trapped steam pocket. In this analysis, it is assumed that rapid condensation of the magnitude believed to occur at Tihange takes place. However, for this to occur, the surface of the water must be broken up into small droplets, which greatly amplify the condensing area. If the surface doesn't breakup, the pressure within the steam pocket remains relatively high, reducing the slug velocity and ultimately the peak pressure.

Question 1 (f): Degree of conservatism.

In general, this is a best estimate calculation, since all critical correlations are based on empirical data. If wave formation and rapid condensation do occur, significant waterhammers are possible. If these conditions are not present or they are significantly reduced, the magnitude of the waterhammers will be much less. The fact that no waterhammers have been reported during the most recent low flow operations indicates that these calculations are conservative and that other mitigating factors are coming into play.

Question 1 (g): Under what conditions do we have severe waterhammer?

The most severe waterhammer is predicted to occur when the pipe is approximately 60% full. Under these conditions, a worst case waterhammer of approximately 4000 psi is predicted. If wave formation occurs at higher or lower water levels within the pipe, and/or flow rates are either smaller or greater, the predicted pressure pulse is reduced significantly. This has prompted C-E to recommend that an interim minimum auxiliary flow restriction of 70 gpm be placed on plant operations when the level in the steam generator is below the top of the auxiliary feedwater nozzle. Both tests and analytical calculations indicate that, for this flow, the sleeve will flow full, thus preventing the formation of a steam pocket which must be present before waterhammer can occur.

References: (A) R.W. Bjorge, "Intiation of Water Hammer In Horizontal or Nearly-Horizontal Pipes Containing Steam and Subcooled Water," Ph.D. Thesis, MIT, 1983.

(B) TN 251, "An Evaluation of PWR Steam Generator Water Hammer" Creare Incorporated, February, 1977.

Question 1 (h): Will the pipe fracture?

The pipe should not fracture provided the assumptions delineated in the discussion of 1.(a), (b), (c) above are valid.

Question 1 (i): If the chances are greater for a fatigue type failure-how many cycles are allowable?

Using ASME fatigue curves, approximately 2000 cycles of the postulated pressure pulse would be allowable. If a single violation of the operating restrictions did not result in the accumulation of over 25 water hammer pulses the cumulative usage factor would be negligible (u=0.0125). See also calculation SS-801 and the discussion under 1.(a), (b), (c) above.

NOTE: Experimental measurements would be required to determine the rate (waterhammer pulses/time) at which cycles are accumulated if the operating restrictions are violated.

Question 1 (j): Do you recommend NDE on the auxiliary feedwater piping after the modification is complete and the plant has run for awhile?

Yes. Baseline NDE data should be taken before startup. This would provide a basis for comparison should something unforeseen occur. Repeat of the NDE inspection at the next refueling outage would provide confirmation that no degradation had taken place during the operating cycle.

2. Operational restrictions

Question 2 (a): If above a certain pressure and below a given steam generator level, what flows are forbidden? What flows should be avoided? What are postulated consequences?

To avoid waterhammer in the auxiliary feedwater system piping adjacent to the steam generator the following restrictions are recommended.

If SG level is below 60% (NR) AFW should only be initiated at flow rates greater than 70 gpm. If auxiliary feedwater flow is initiated manually a flow rate above 70 gpm should be established as quickly as possible to avoid waterhammer while passing through the restricted flow range. Flow should not be reduced below 70 gpm until SG level is recovered and maintained at on above a level of 60% (NR).

Question 2 (b): Is there a tolerance on your calculated flow values? If so, what?

As shown on the attached figure there is a theoretical possibility of water hammer over a range of flows of 5 gpm (when the auxiliary feedwater nozzle is being recovered) to 60 gpm. The recommended operational restriction is 70 gpm.

Based on reported operators' recollections, waterhammer (when it was observed) occurred at flow rates of 30 to 40 gpm and ceased when the flow rate was increased to 50 gpm. This is in excellent agreement with our calculations as shown on the attached figure. Based on the operators' observations the actual upper limit for observable water hammer to occur may be approximately 50 gpm.

Question 2 (c): Calculations

See discussions under 1 above.

Question 2 (d): Procedural requirements

The operational requirements mentioned in 2(a)should be incorporated into every procedure that may require that the AFW system be used. SOP 12 Feedwater System and EOP 1 Reactor Trip are being reviewed and changes recommended in the appropriate areas. The additional procedures listed below will also be reviewed.

Plant Heatup
Plant Cooldown
Loss of Main Feedwater
Loss of Off Site Power
Turbine Trip
Loss of Condenser Vacuum

3. Can we justify continuing to operate after having experienced a short interval of operation at low auxiliary feedwater low steam generator level?

Question 3 (a): How long can we stay in this region of low flow/low level?

As indicated above, until justification (experimental or theoretical) can be provided for relaxing the recommended operating restrictions the restricted operating region should be administratively avoided. Should operation in this region occur the following questions would need to be addressed:

(1) Did waterhammer occur, i.e. was detectable waterhammer observed?
(2) What was the severity of the water hammer?
(3) How many cycles (pressure pulses) were accumulated?

As discussed above and delineated in SS-801 the ASME fatigue curves would permit up to approximately 2000 cycles of the worst postulated (calculated) pressure pulse. For 25 cycles the cumulative usage factor is essentially negligible. Experimental measurements would be required to ascertain the rate at which water hammer cycles would actually be accumulated if the recommended operating restrictions are not addressed too. These same experimental measurements could be used to measure the actual magnitude of the pressure pulses and provide a basis for possible relaxation of the restriction.

adhered to.

To put this in better perspective, if the period of the water hammer is once per second and the operator responded to correct the situation within 5 minutes, 300 cycles would be accumulated. If the period was 20 to 30 seconds between waterhammer, consistent with some of the operators' recollections as reported to C-E, the number of cycles accumulated would only be 10 to 15 for the same period of time.

Question 3 (b): What corrective action should be taken?

If a flow rate less than 70 gpm occurs at a steam generator level below 60% (NR) the flow rate should be promptly increased to greater than 70 gpm, or terminated.

PALISADES REGION OF POTENTIAL WATERHAMMER AND IMPACT PRESSURE RISE RELATION