Form 01077 (R7-92)

FORM 101.1	REVISION 14

CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER Oconee Nuclear Station Unit-2

TITLE OF CALCULATION Unit-2 LPT Overpressurization Evaluation (PIP 97-1553)

CALCULATION NUMBER OSC-6547

ORIGINALLY CONSISTING OF:

PAGES 1 THROUGH 14

TOTAL ATTACHMENTS None TOTAL MICROFICHE ATTACHMENTS None

TOTAL VOLUMES _____ TYPE I CALCULATION/ANALYSIS YES ☐ NO ☒

TYPE I REVIEW FREQUENCY N/A

THESE ENGINEERING CALCULATIONS COVER QA CONDITION 1 ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY C. H. Abellana DATE 5/20/97

CHECKED BY RC Gamberg DATE 5/20/97

APPROVED BY S L Nader DATE 5-20-97

ISSUED TO DOCUMENT CONTROL _____ DATE _____

RECEIVED BY DOCUMENT CONTROL _____ DATE _____

MICROFICHE ATTACHMENT LIST: ☐ Yes ☒ No SEE FORM 101.4

REV. NO.	CALCULATION PAGES (VOL)			ATTACHMENTS (VOL)			VOLUMES		ORIG	CHKD	APPR	ISSUE DATE
	REVISED	DELETED	ADDED	REVISED	DELETED	ADDED	DELETED	ADDED	DATE	DATE	DATE	REC'D DATE

Form 101.2 Revision 1
26164 (R9-89)

File/Calculation No. OSC-6547

REVISION DOCUMENTATION SHEET

Revision Number	Review Frequency Changed Yes/No	Revision Description

1.0 PROBLEM:

The purpose of this calculation is to determine if the portions of the Unit-2 "B" LPI piping and components exceeded design parameter(s) resulting from pressurization during heat up. This calculation is performed to resolve PIP 2-097-1553.

2.0 RELATION TO NUCLEAR SAFETY:

This calculation is QA Condition 1. The Low Pressure Injection system is required to mitigate the consequence of design basis accident (LOCA) and provide decay heat removal capability during shutdown.

3.0 DESIGN METHOD:

Low Pressure Injection flow diagram, piping drawings, and equipment manufacturer's drawings will be reviewed to identify line size and pipe schedule(s), design pressure and temperature, and design codes for all equipment that was pressurized. The review will investigate and identify the design limits and determine if any were exceeded.

4.0 APPLICABLE CODES AND STANDARD:

4.1 ANSI N45.2-11

4.2 ASME/ANSI B16.34-1988 (valves)

4.3 ASME VIII 1968, 1969 Winter Addendum (cooler)

4.4 TEMA-R Standards (cooler)

4.5 USAS B31.1.0 1967 Power Piping Code

4.6 USAS B31.7 Nuclear Piping Code

5.0 DESIGN INPUTS:

5.1 ANSI N45.2-11 has been reviewed and all applicable inputs are addressed in the appropriate sections of the calculation.

5.2 Tech. Spec. 3.3.2 states that when the RCS, with fuel in the core, is in a condition with pressure equal to or greater than 350 psig or temperature equal to or greater than 250 deg.F, the following conditions must be met in order to be operable:

1. Two independent LPI trains, each comprised of an LPI pump and a flowpath capable of taking suction from the BWST and discharging into the RCS automatically upon ESPS actuation (LPI segment), together with two LPI coolers and reactor building emergency sump isolation valves (manual and remote-manual) shall be operable.

2. Tests or maintenance shall be allowed on any component of the LPI system provided the redundant train of LPI system is operable. If the LPI system is not restored to meet the requirements of Specification 3.3.2a(1) above within 24 hours, the reactor shall be placed in a hot shutdown condition within 12 hours. If the requirements of Specification 3.3.2a(1) are not met within 24 hours following hot shutdown, the reactor shall be placed in a condition with the RCS pressure below 350 psig and RCS temperature below 250 deg.F within an additional 24 hours.

5.3 Overpressurization events may exceed design rating. However, this does not mean that code stress allowables are exceeded. PIP 2-97-1553 states that the RCS pressure and temperature at the time of the event was 302 psig at 175 F.

6.0 FSAR CRITERIA:

FSAR Chapter 6.3.2.2.2
The Low Pressure Injection System is designed to:

1) Maintain core cooling for larger break sizes

2) Control boron concentration in the core while operating in the recirculation mode.

FSAR Chapter 6.3.2.3.1
The Low Pressure Injection system piping and valves are subjected to more severe conditions during decay heat removal operation than during emergency operation. Table 6.0-4 gives the design pressure and temperature of the Engineering Safeguard piping (Attachment #4).

FSAR Chapter 6.3.2.3.3
LPI Heat Exchangers are designed and manufactured to the requirements of the ASME VIII and TEMA-R (Rigorous) Standards.

7.0 ASSUMPTIONS:

7.1 Assume RCS Low Range transmitter instrument accuracy results in RCS pressure being 9.44 psig higher than indicated. OSC-5596 has calculated that this instrument can be off this much 6 months after calibration. This instrument was calibrated during FEB. 1997 (per Ed Payseur). It is therefore conservative to assume that the instrument has drifted to the maximum value. This will elevate the pressure used for evaluation.

7.2 Assume pumps are within IWP test acceptance criteria. This is acceptable because the LPI pumps are tested quarterly to verify their performance.

8.0 REFERENCES:

8.1 OFD-102A-2.1 Rev.17

8.2 OFD-102A-2.2 Rev.17

8.3 PIP-2-97-1553

8.4 Crane Technical Paper No.410 24th Printing 1988

8.5 OSC-5616 LPI Overpressure/Overtemperature Prevention Analysis Rev.2

8.6 Letter from Ingersoll-Rand pumps to Steve Nader
Requalification of LPI and HPI pumps
P.O. No. C14954-67 dated June 23, 1992

9.0 CALCULATION:

9.1 Calculated pressure at the discharge of "C" LPI pump. (Ref. OSC-5616 Rev.2)

```
  302      psig RCS Pressure
+ 9.44*    psig Low Range Press. X'ter inaccuracy
- 5.82*    psig El. Diff. Between Hot leg and press. Tap
+ 21  *    psig Elevation head
 326.26    psig at the suction of the LPI pump
+ 184**    psig (pump develop head at No flow)

510.26 psig This is the at the "C" LPI pump discharge
            that pressurized the "2B" LPI train
```

* These values are taken from the LPI termination/initiation calculation (OSC-5616).

** This is 425 ft pump develop head at 60 F. At 175 F this is 179 psig. The higher value is used for added conservatism.

9.2 Design review of the LPI instruments:
(Information below provided by ESE/Fred Custer)

ON2LPIPG0008 Ashcroft model 1379S calibrated range 0-400psig, Proof Pressure 520 psig, burst pressure 2800 psig Ref. Product Information Letter from Ashcroft dated 2/17/92

ESE Recommendation: Re-calibrate

ON2LPIPG0022 Barton type 224 model 288A calibrated range 0-200 psid, safe working pressure 500 psig. Ref. Barton Catalog product Bulletin 224-5-16

ESE Recommendation: Re-calibrate

ON2LPIPG0250 Ashcroft model 1379S calibrated range 0-100 psig, Proof Pressure 130 psig, bursting pressure 2400 psig Ref. Product Information Letter from Ashcroft dated 2/17/92

ESE Recommendation: Re-calibrate

ON2LPIPT0012 Bailey Meter Company Type KP2331A Model A1 calibrated range 0-600 psig, Maximum static pressure 1000 psig. Ref. OM-1201C-39-1 Tab 21 Section

P41-8 page19 and IP/0/B/0203/001F data sheet 13 of 17 and OM-1201-28 and OM-1201-342

ESE Recommendation: Re-calibrate

ON2LPIFT0004A Rosemount Model 1151DP5E22B2 upper range limit 27 psid, over-pressure limit 2000 psig. Ref. OM-267A-53

ESE Recommendation: Re-calibrate

ON2LPIFT0004P Rosemount Model 1153DB5RB upper range limit 27 psid, over-pressure limit 2000 psig Ref. OM-267-846

ESE Recommendation: Re-calibrate

9.3 Design review of the LPI Valves: (Provided by Valve Engineering/Jim Kiser)

By examination as shown below, the maximum pressure during this event did not exceed the pressure/temperature rating of any valves. The following table includes all valves exposed to the overpressure.

<u>PIP 97-1553 LP Overpressure Event</u>

Valve Evaluation for 523 psig and 175 degrees F

Tag #	Item #	Outline Dwg. OM	Body Material	ANSI Class	Design Code	Allowable P/T
2GWD-033	FS/2/53/007	246-006,001	A182 F316	600	B16.5, 1957	1400 psig/200 F
2GWD-142	FS/2/53/013	246-006,001	A182 F316	600	B16.5, 1957	1400 psig/200 F
2GWD-152	DMV-671	245-158,001	A182 F316	1700	N/A	3505 psig/200 F
2LP-08	2/53/012	245-365 & 367	A351 CF8M	300	B16.5, 1968	700 psig/200 F
2LP-13	2/53/056	245-062,001	A351 CF8M	300	B16.5, 1957	700 psig/200 F
2LP-14	3/53/018R	251-260,001	A351 CF8M	300	B16.34, 1973	620 psig/200 F
2LP-16	2/53/053	201-377,001	A351 CF8M	300	B16.5, 1968	700 psig/200 F
[illegible]-33	2/53/009	245-26A,001	A351	300	B16.5, 1957	700 psig/200 F

			CF8M			
2LP-34	2/53/010	245-062,001	A351 CF8M	300	B16.5, 1957	700 psig/200 F
2LP-37	DMV-709	254-227.004 254-228,001	A351 CF8M body/A182-F316 flange	300 See note:	B16.5, 1988	620 psig/200 F See note:
2LP-39	DMV-299	245-1356,001	A182 F316	1700	N/A	3505 psig/200 F
2LP-40	2/53/028	245-063,001	A351 CF8M	300	B16.5, 1957	700 psig/200 F
2LP-42	FS/2/53/001	246-004,001	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LP-68	2/53/060	245-063,001	A351 CF8M	300	B16.5, 1957	700 psig/200 F
2LP-69	2/53/062	245-605,001	A351 CF8M	300	B16.5, 1968	700 psig/200 F
2LP-73	2/53/063	245-063,001	A351 CF8M	300	B16.5, 1957	700 psig/200 F
[illegible]95	2/53/066	245-620,001	A351 CF8M	300	B16.5, 1968	700 psig/200 F
2LP-96	FS/2/5/084	246-006,008	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LP-102	DMV-6781	248-519,001				
2LWD-272	FS/2/53/074	246-006,006	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LWD-273	FS/2/53/077	246-006,006	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LWD-332	FS/2/53/012	246-006,001	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LWD-347	FS/1/70A/363	246-006,008	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LWD-373	FS/1/70A/515	246-006,008	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LWD-374	FS/1/70A/048	246-006,001	A182 F316	600	B16.5, 1957	1400 psig/200 F
2LWD-411	DMV-300	245-1356,001	A182 F316	1700	N/A	3505 psig/200 F

Assumptions:

1) Valve was built to the Design Code and year that was in effect the year the drawing was originated by the manufacturer unless drawing states something different.

2) Valves that VCRL indicates (x) will be assumed as correct.

Note:

1) Valve body is good for 2160 psig/500 F per OM-254-228, flange rating is the limiting part.

9.4 Design review of the piping and components:

LPI COOLER:

The LPI "B" cooler is designed for 370 psig 300 F. If the cooler where to be hydrotested it would be done at 1.5 times of design. This would be 555 psig for 300 F. The tube side of this cooler was hydrotested to 675 psig at 60 F. This incident pressurized the cooler tubeside to conservatively 511 psig at 175 F. This is less than hydro pressure. It can be considered a hydro test. The LPI cooler manufacturer (Atlas Manufacturing/Ramsey Mahadeen) concurs, this pressurization can be considered a hydro test.

Note: A 16"X 10" reducer is shown on the OFD at the LPI cooler. These are the inlet and outlet nozzles of the cooler. These nozzles are supplied with the cooler and were hydro tested at 675 psig at 60 F.

LPI PUMPS:

The LPI pumps are qualified for:
560 psig at 300 F (Ref.8.10)
580 psig at 250 F (Ref.8.10)

PIPING:

For piping systems the larger diameter pipes will take less pressure than small pipes for a given pipe schedule. Below are the pipes that will be evaluated.

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)}$$ (Ref. B31.1 Section 104.1)

where: Material A-312 TP-304 (Oconee Pipe Spec OS-0243.00-00-0001) PS-301.2 and PS301.3

S = *17050 psi (Ref. B31.7 Table A.8) *interpolated value
E = .85 (Ref. B31.1 1967)
y = .4 (Ref. B31.1 1967)
A = .00 Since the pipe are welded and there are no threaded connection.

10.0 CONCLUSION:

Piping systems are considered safe for operation if the maximum sustained pressure and temperature on any part does not exceed the pressure and temperature allowed by code.

USAS B31.1 Section 102.2.4 acknowledges that system transients will occur. It states that a system can be overpressurized to 115% of code design pressure for 10% of operating life or 120% for 1% of operating life. Only the 10" pipe exceeded the 120% of maximum allowable pressure.

Design review investigated all portions of the LPI system (i.e. instrument, valves, piping and components) affected by the incident. The limiting component in this evaluation is the 10", 8", and 14" LPI piping. The highest pressure the LPI system was exposed to was 511 psig. This pressure did not exceed the design rating of the valves or instruments.

B31.1 Class II (Oconee construction code) required system be hydroed to 1.5 of design pressure. The 1.5 of design is 555 psig. The incident pressurized the piping, components, and instruments to less 1.5 of design (i.e. 511 psig at 175 F). Hydro test is a non destructive examination.

Since the incident was less than hydro pressure, the LPI system was not subjected to any damaging stress. It can be considered a one time hydro and should be tracked as an additional ISI. Therefore, the LPI system is safe for continued operation.

OSC-6547 Performed CGA
Date: 5/18/97
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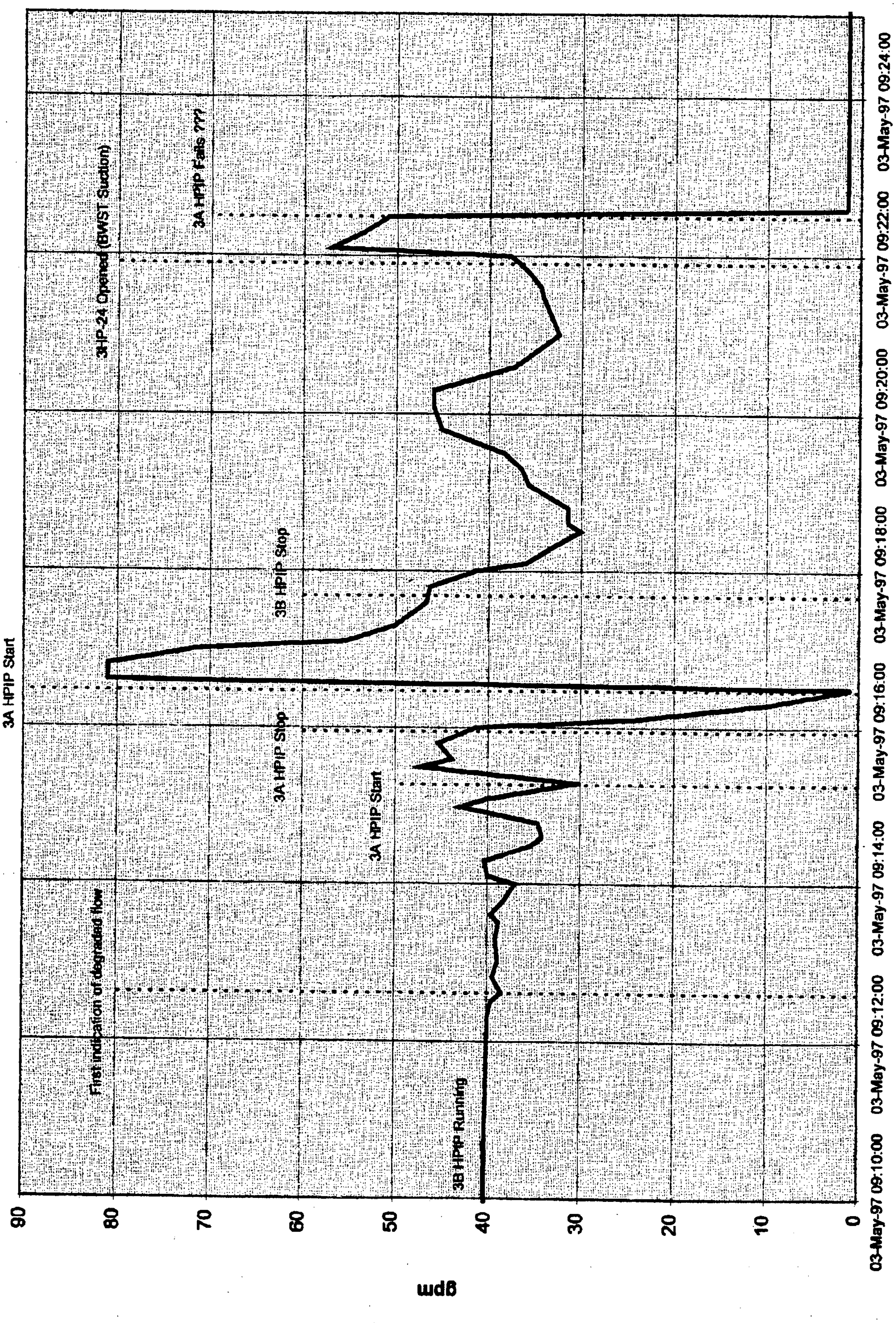
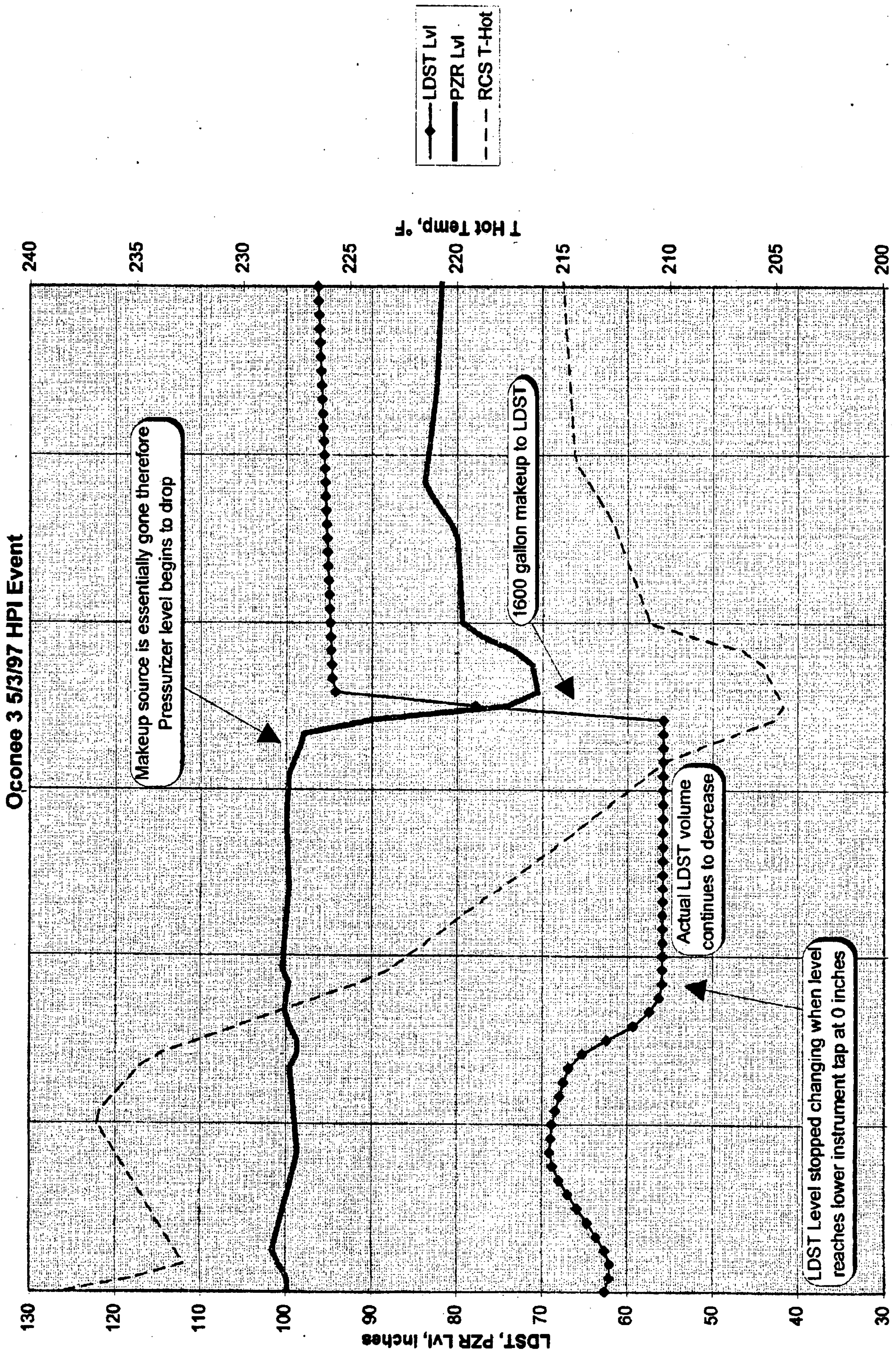
t_m = 87.5% of Nominal Wall thickness (Manufacturers Standard)

Pipe Size	Pipe Schedule	Diameter (D_o)	Nominal Wall	t_m Min. Wall	Max. Pressure psig	Max Hydro 1.5 P
¾"	S-40s	1.05	.113	.099	2955.85	555
1"	S-40s	1.315	.133	.116	2750.99	555
2"	S-40	2.375	.154	.135	1726.05	555
3"	S-40s	3.5	.216	.189	1635.86	555
4"	S-10s	4.500	.120	.105	689.18	555
6"	S-10s	6.625	.134	.117	519.22	555
8"	S-10s	8.625	.148	.1291	438.25	555
10"	S-10s	10.750	.165	.144	392.47	555
14"	S-10	14.00	.250	.219	457.03	555

By inspection only the 8", 10", & 14" pipe have a "maximum pressure" less than the overpressure seen during the event. The overpressure event was of a short duration (less than 30 mins). It is appropriate to use a "transient" (B31.1 section 102.2.4) overpressure allowance of 120% since it is well below 1% of operating life. Based on this, ONLY the 10" pipe doesn't meet the code equation (392.47x1.2)=470.96) and it misses by approximately 40 psig. This overpressure seen during this event was less than the hydro pressure of 555 psig (370psigx1.5).

Oconee 3 HPI Event HPI Total RCP Seal Injection




Oconee 3 5/3/97 HPI Event
LDST Lvl
PZR Lvl
RCS T-Hot
LDST, PZR Lvl, inches
T Hot Temp, °F
Makeup source is essentially gone therefore Pressurizer level begins to drop
1600 gallon makeup to LDST
Actual LDST volume continues to decrease
LDST Level stopped changing when level reaches lower instrument tap at 0 inches
130
120
110
100
90
80
70
60
50
40
30
240
235
230
225
220
215
210
205
200
6:00
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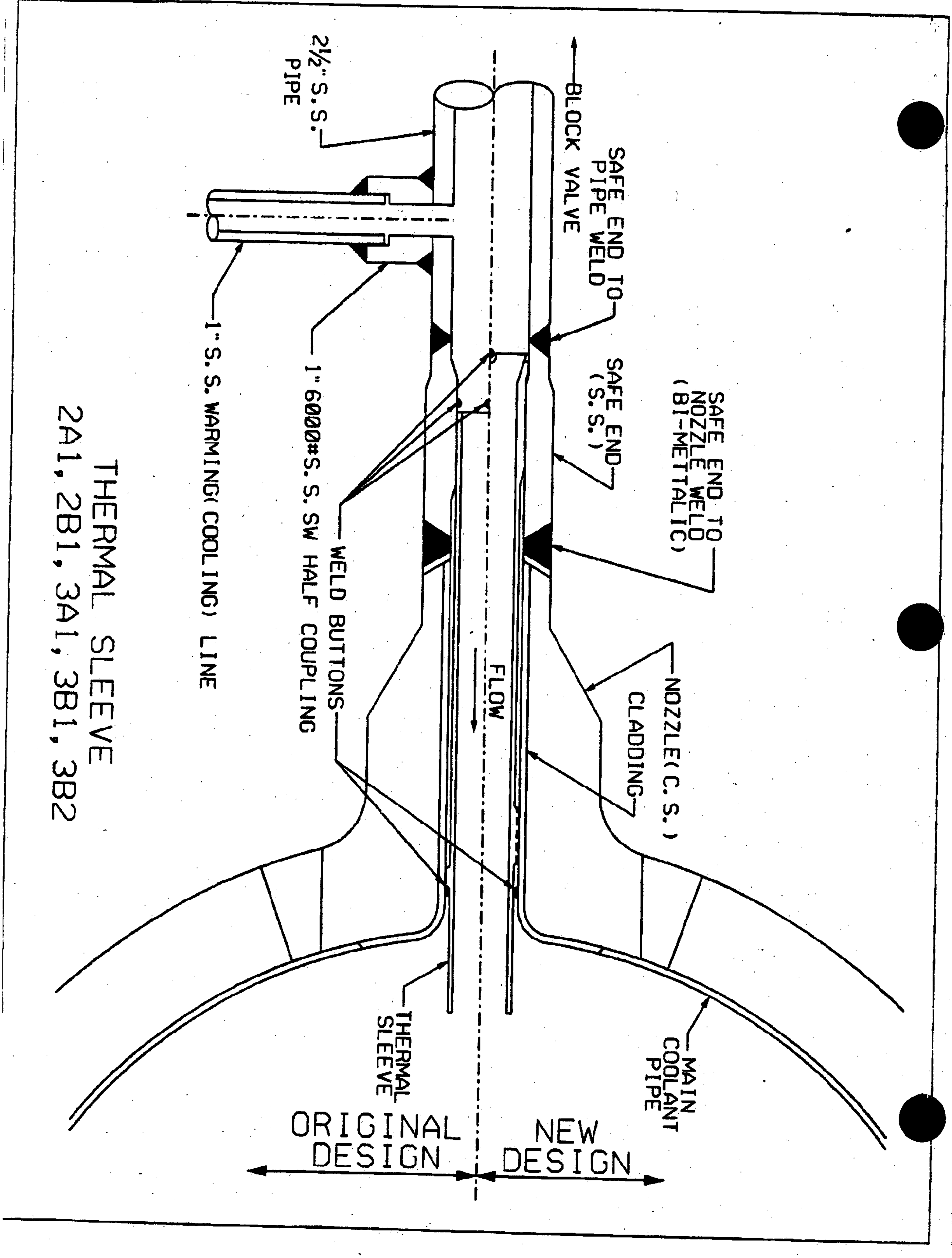
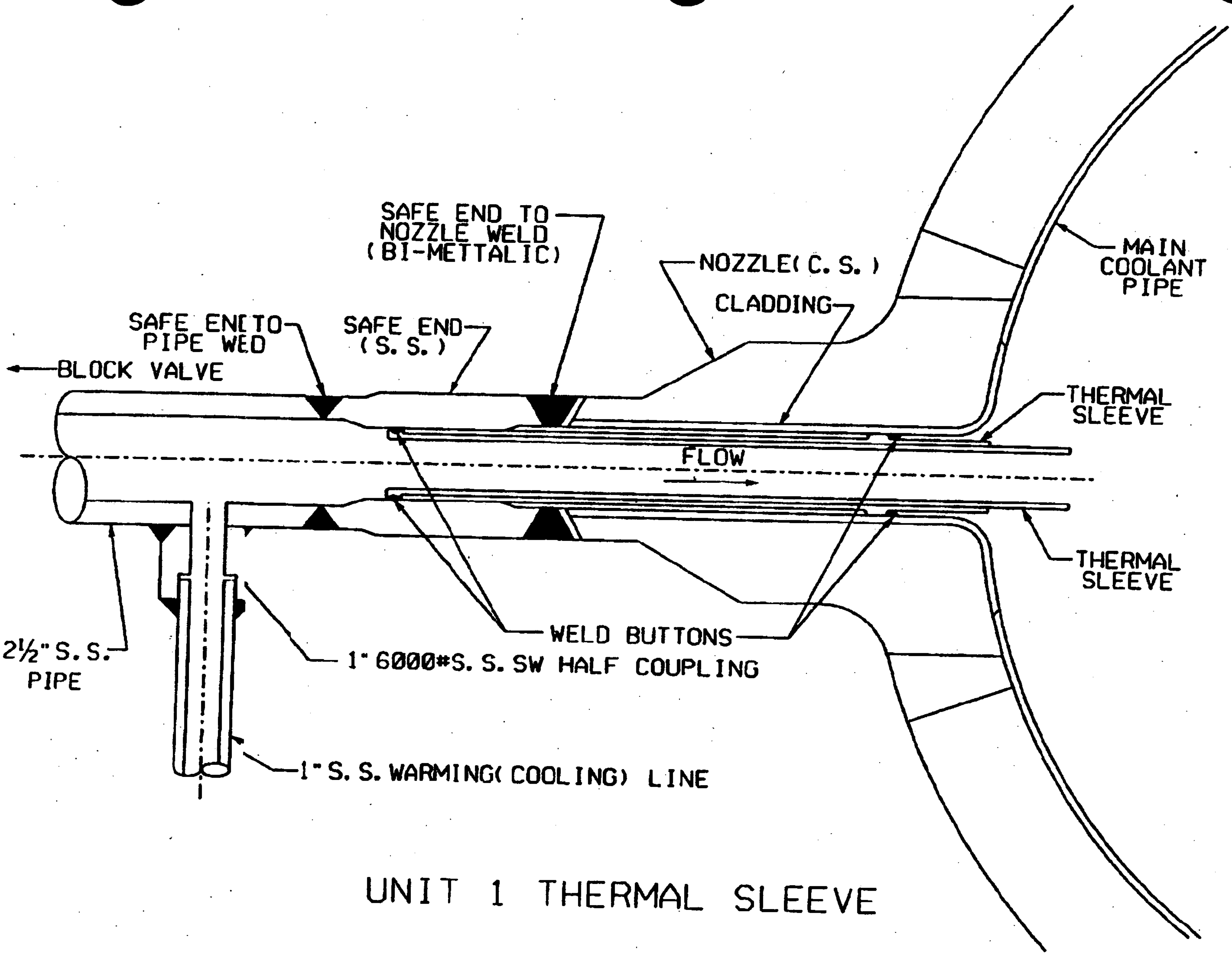
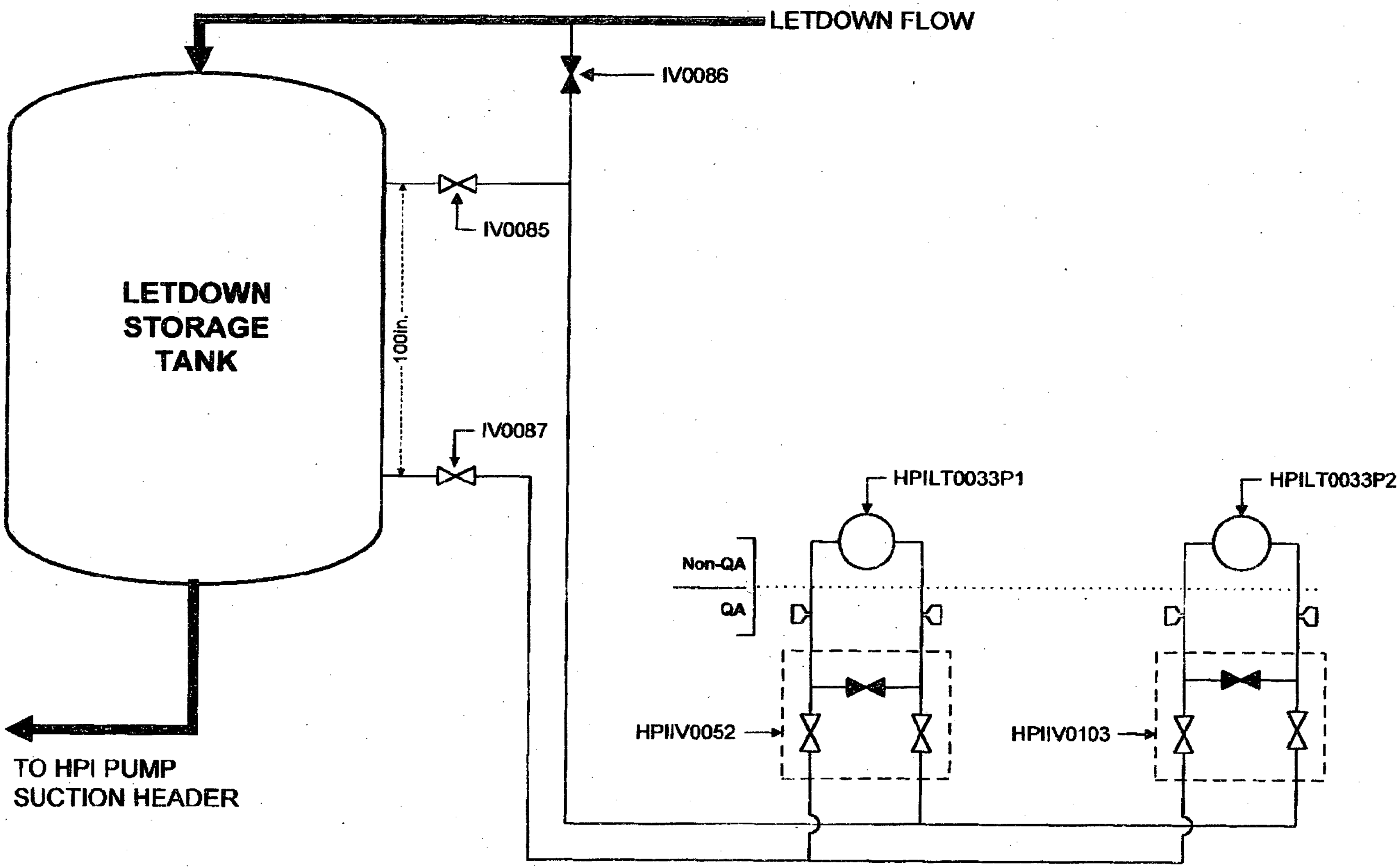
10:00
11:00
12:00


THERMAL SLEEVE
2A1, 2B1, 3A1, 3B1, 3B2
BLOCK VALVE
2½" S.S. PIPE
SAFE END TO PIPE WELD
SAFE END (S.S.)
SAFE END TO NOZZLE WELD (BI-METTALIC)
1" S.S. WARMING (COOLING) LINE
1" 6000#S.S. SW HALF COUPLING
WELD BUTTONS
FLOW
NOZZLE (C.S.)
CLADDING
THERMAL SLEEVE
MAIN COOLANT PIPE
ORIGINAL DESIGN
NEW DESIGN

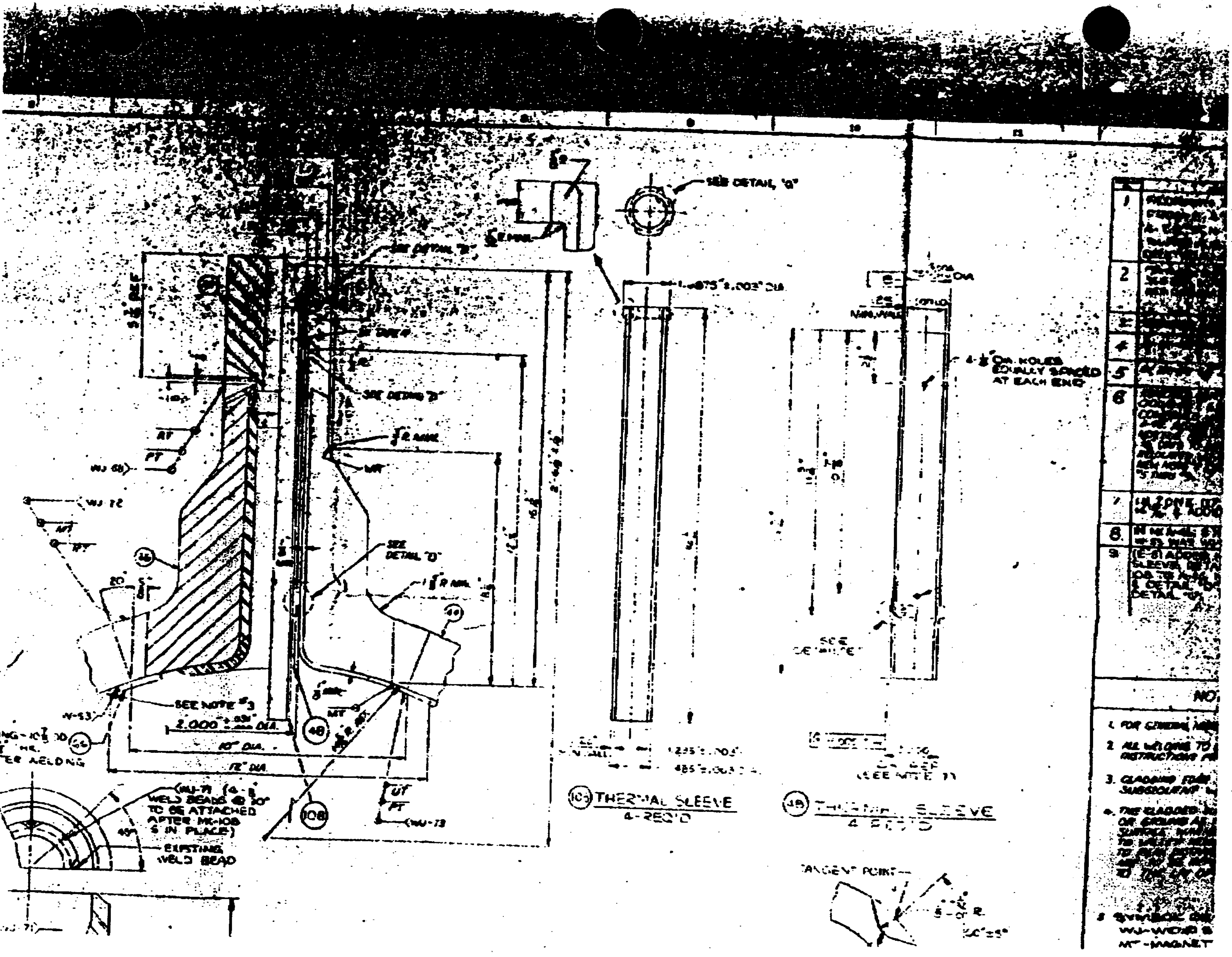


UNIT 1 THERMAL SLEEVE



NOTE:
SKETCH FOR INFORMATION ONLY

OCONEE NUCLEAR STATION - UNITS 1, 2, & 3		
LETDOWN STORAGE TANK LEVEL INSTRUMENTATION SKETCH		
MAY 12, 1997	FILE: LDSTSKCH.VSD SHEET 1 OF 1	REV. 0


SEE DETAIL "G"
1.4875" ±.003" DIA
4-⅜" DIA. HOLES EQUALLY SPACED AT EACH END
SEE DETAIL "B"
SEE DETAIL "D"
SEE DETAIL "D"
SEE NOTE #3
2.000
10" DIA.
12" DIA.
WELD BEADS
TO BE ATTACHED AFTER MK-108 IS IN PLACE)
EXISTING WELD BEAD
THERMAL SLEEVE
4-REQ'D
TANGENT POINT
FOR GENERAL
ALL WELDING TO
INSTRUCTIONS
CLADDING
WJ-WELD
MT-MAGNET

METALLURGICAL EXAMINATION OF OCONEE-2A2 HPI COMPONENTS

From: Kevin Redmond (DPC Project Engineer), and Tim Smith, Paul Ledwith & Scott Harding (FaAA Consultants)

To: Craig Tompkins, FIP Team Leader

Re: Met Lab Data Compilation

SUMMARY OF WORK COMPLETED:

1. Samples were received at the LRC on April 28th (make-up line with cracked safe-end to pipe weld and attached warming line) and May 2nd (safe-end and thermal sleeve); initial unpacking and radiation surveys were completed shortly thereafter. Results of these inspections are as follows:

   - contact radiation levels were slightly over 1 R/hr, with a high, soft β component;
   - smearable contamination levels were extremely high (e.g., > 3 M dpm/100cm^2)

2. All components were subjected to thorough visual inspections, augmented by stereovisual and liquid penetrant inspections as deemed appropriate by the lab team. In general, these inspections were performed on both exterior surfaces and interior surfaces after sectioning. In addition, dimensional inspections of the safe-end and thermal sleeve were performed to characterize the wear damage and material loss of the sleeve as well as assess the fit between the safe-end and sleeve in the contact region. All visual, stereovisual, liquid penetrant and dimensional inspections have been completed. Results of these inspections are as follows:

Note: *Dimensional data should be considered preliminary, since a careful review has not yet been performed due to the intense work schedule in lab.*

- **Make-up line to safe-end weld crack** - a circumferential crack was verified at the root of the pipe to safe-end weld; the crack was located along the weld centerline and had a circumferential extent of 360°; the weld root exhibited some minor concavity; the crack broke the OD surface of the weld near the top, with a circumferential extent of ~77° (-16° to +61° relative to top-dead-center);

- **ID cracking of components** - a high concentration of multi-directional cracks were observed on the inside surfaces of the make-up line, safe-end and thermal sleeve, extending from about mid-length on the rolled region of the thermal sleeve back to about 2 inches beyond the warming line penetration; cracking patterns in the make-up line correlated with flow from the warming line penetration, axial cracks were also identified at the outlet end of the thermal sleeve, some of which were throughwall, and a few discrete, short, axial cracks were observed on the ID surface near the collar location.

- **Material loss on thermal sleeve** - there was obvious material loss along the RCS downstream side of the thermal sleeve, consisting of an irregular-shaped pattern approximately 4-1/4 inches long through a maximum 150° arc; long, axial cracks were associated with the material loss area, extending from the outlet end of thermal sleeve through the collar region and ending approximately mid-length on the sleeve (i.e., about 7-1/2 inches from inlet end); the longest crack appeared to have propagated in the axial direction from the outlet end toward the inlet end and exhibited signs of blunting at the tip.

- **Wear damage on the thermal sleeve & safe-end** - Significant wear was noted along the RCS downstream side of the sleeve extending from its deepest (~0.048 inch) and widest (~150°) point about one inch downstream of the collar, tapering out to the

nominal OD surface about 5 inches in back of the collar; a deep circumferential wear groove was observed adjacent to the collar on the downstream side (i.e., correlating to location of downstream weld pads); at its deepest point, this groove extended nearly through the wall of the sleeve; circumferentially oriented cracks were also observed in these thinned regions adjacent to the collar; significant wear was observed at the rolled end of the thermal sleeve to approximately 2-1/4 inches from the inlet end; the deepest portion was approximately 0.040 inches on the RCS downstream side.

Note: *No other degradation was noted on the exterior surfaces of the make-up line or other make-up line welds, as determined by an ASNT Level II inspector from FTI; no other degradation was noted on the exterior surfaces of the safe-end; no cracking was identified on the interior surfaces of the warming line and socket region.*

4. Several cracked regions, including the make-up line to safe-end weld, make-up line near the warming line penetration, safe-end upstream of the thermal sleeve, and thermal sleeve near the inlet and outlet ends have been flattened and/or bent open to expose the fracture surfaces for visual, stereovisual and SEM fractographic examination. Nearly all of the planned examinations have been completed except for one axial crack sample from the outlet end of the thermal sleeve. The results of these examinations are summarized below:

- **Throughwall circumferential crack at the make-up line to safe-end weld** - the majority of the crack face exhibited a dark brown oxide film; SEM examination showed that the crack had propagated in a transcrystalline mode with evidence of cyclic loading (i.e., striations from the ID to the OD surfaces); the fatigue striations were frequently observed to bow toward the OD surface; although precise measurements of striation spacings were not possible, generally the shortest spacings were on the order of one micron or less.

- **Other ID initiated cracking** - the fracture surfaces of all cracks examined to date have been generally consistent with the throughwall circumferential crack in the make-up line to safe-end weld, although the safe-end, and thermal sleeve cracks have tended to be somewhat more oxidized and have required cleaning in the lab; although not well-formed, there is some evidence of faint fatigue striations on most of these surfaces.

5. Several cracked regions, including the make-up line to safe-end weld, make-up line near the warming line penetration, safe-end upstream of the thermal sleeve, thermal sleeve near the inlet and outlet ends have been mounted and prepared for metallographic examination. Most of the planned examinations have been completed, although photographic documentation is still in progress. The results of these examinations are summarized below:

   - **Circumferential crack at the make-up line to safe-end weld** - the crack was contained within the weld fusion zone and had propagated in transcrystalline fashion exhibiting little branching.

   - **Make-Up line, safe-end & thermal sleeve cracking** - all cracking was found to be transgranular and most of the cracking exhibited little branching; crack depths in the make-up line were generally less than 30% throughwall

PRELIMINARY CONCLUSIONS:

1. ID surface cracking observed in the make-up line, safe-end and thermal sleeve was predominantly the result of thermal fatigue; these cracks, in general, appeared to be slow growing.

2. The throughwall circumferential crack in the make-up line to safe-end weld probably initiated at the weld root by thermal fatigue, but other sources of high-cycle/low-amplitude loading most likely propagated the crack to failure; this crack was slow growing and had probably been present for an extended period of time.

Note: *Aside from in-service thermal fatigue cracking, the weld appeared to be in good condition; a slight concavity condition was observed at the weld root.*

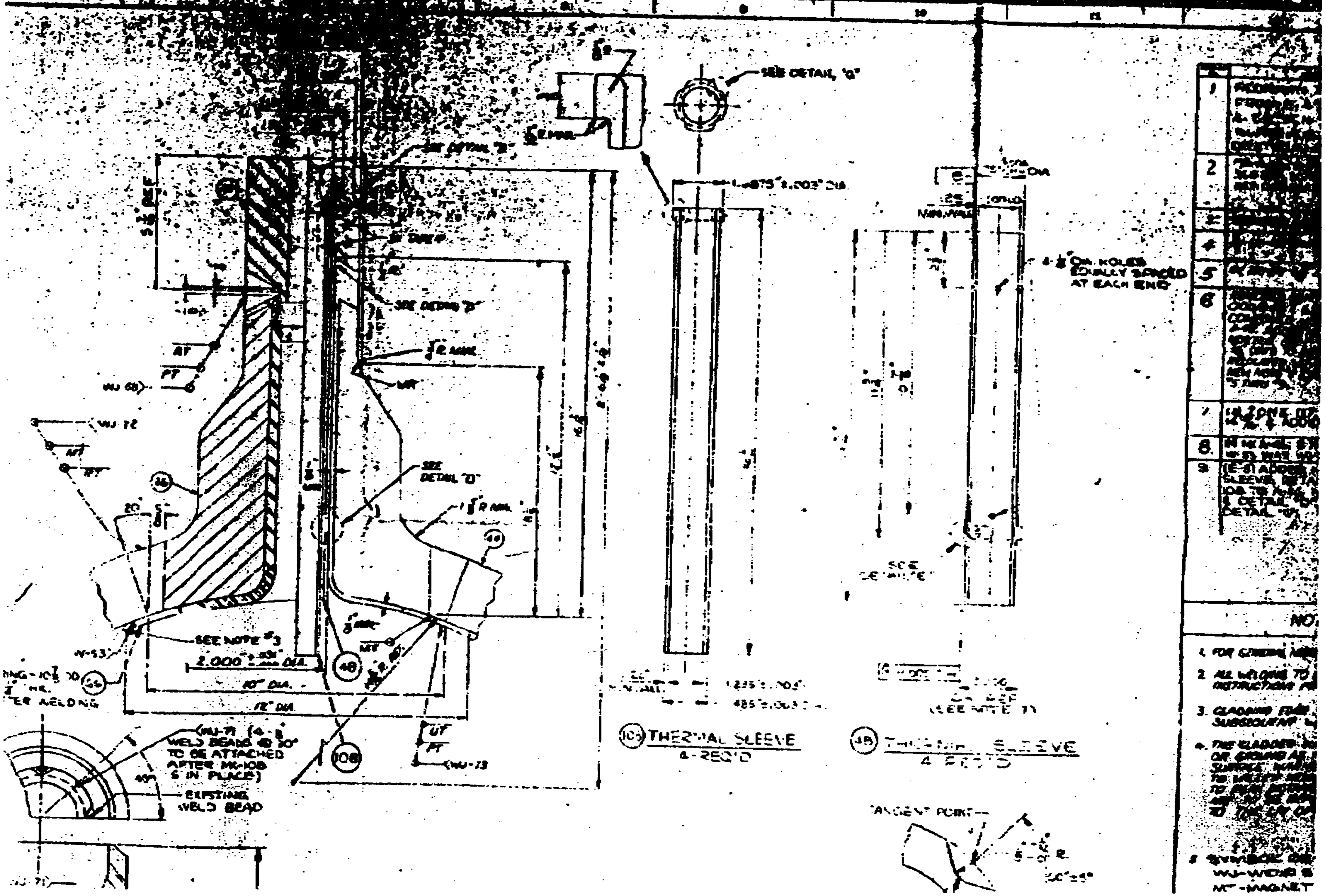
3. The wear damage, material loss and long axial cracking observed near the outlet end of the thermal sleeve is more likely the result of flow induced vibration (FIV) from RCS cross-flow excitation, although initiation of the long axial cracks may have been due to localized thermal fatigue in this region. Wear in the rolled region is also consistent with FIV.

Submitted by:

5/5/97
Kevin R. Redmond, DPC

Reviewed by:

Scott Harding, FaAA


SEE DETAIL "G"
SEE DETAIL "D"
SEE NOTE #3
2.000"
10" DIA.
12" DIA.
SEE DETAIL "D"
WELD BEADS
TO BE ATTACHED
AFTER MK-108
S IN PLACE
EXISTING
WELD BEAD
4-1/8" DIA. HOLES
EQUALLY SPACED
AT EACH END
THERMAL SLEEVE
4-REQ'D
TANGENT POINT
UT
PT
MT
RT
48
108

METALLURGICAL EXAMINATION OF OCONEE-2A2 HPI COMPONENTS

From: Kevin Redmond (DPC Project Engineer), and Tim Smith, Paul Ledwith & Scott Harding (FaAA Consultants)

To: Craig Tompkins, FIP Team Leader

Re: Met Lab Data Compilation

SUMMARY OF WORK COMPLETED:

1. Samples were received at the LRC on April 28th (make-up line with cracked safe-end to pipe weld and attached warming line) and May 2nd (safe-end and thermal sleeve); initial unpacking and radiation surveys were completed shortly thereafter. Results of these inspections are as follows:

    - contact radiation levels were slightly over 1 R/hr, with a high, soft β component;

    - smearable contamination levels were extremely high (e.g., > 3 M dpm/100cm^2)

2. All components were subjected to thorough visual inspections, augmented by stereovisual and liquid penetrant inspections as deemed appropriate by the lab team. In general, these inspections were performed on both exterior surfaces and interior surfaces after sectioning. In addition, dimensional inspections of the safe-end and thermal sleeve were performed to characterize the wear damage and material loss of the sleeve as well as assess the fit between the safe-end and sleeve in the contact region. All visual, stereovisual, liquid penetrant and dimensional inspections have been completed. Results of these inspections are as follows:

Note: *Dimensional data should be considered preliminary, since a careful review has not yet been performed due to the intense work schedule in lab.*

- **Make-up line to safe-end weld crack** - a circumferential crack was verified at the root of the pipe to safe-end weld; the crack was located along the weld centerline and had a circumferential extent of 360°; the weld root exhibited some minor concavity; the crack broke the OD surface of the weld near the top, with a circumferential extent of ~77° (-16° to +61° relative to top-dead-center);

- **ID cracking of components** - a high concentration of multi-directional cracks were observed on the inside surfaces of the make-up line, safe-end and thermal sleeve, extending from about mid-length on the rolled region of the thermal sleeve back to about 2 inches beyond the warming line penetration; cracking patterns in the make-up line correlated with flow from the warming line penetration, axial cracks were also identified at the outlet end of the thermal sleeve, some of which were throughwall, and a few discrete, short, axial cracks were observed on the ID surface near the collar location.

- **Material loss on thermal sleeve** - there was obvious material loss along the RCS downstream side of the thermal sleeve, consisting of an irregular-shaped pattern approximately 4-1/4 inches long through a maximum 150° arc; long, axial cracks were associated with the material loss area, extending from the outlet end of thermal sleeve through the collar region and ending approximately mid-length on the sleeve (i.e., about 7-1/2 inches from inlet end); the longest crack appeared to have propagated in the axial direction from the outlet end toward the inlet end and exhibited signs of blunting at the tip.

- **Wear damage on the thermal sleeve & safe-end** - Significant wear was noted along the RCS downstream side of the sleeve extending from its deepest (~0.048 inch) and widest (~150°) point about one inch downstream of the collar, tapering out to the

nominal OD surface about 5 inches in back of the collar; a deep circumferential wear groove was observed adjacent to the collar on the downstream side (i.e., correlating to location of downstream weld pads); at its deepest point, this groove extended nearly through the wall of the sleeve; circumferentially oriented cracks were also observed in these thinned regions adjacent to the collar; significant wear was observed at the rolled end of the thermal sleeve to approximately 2-1/4 inches from the inlet end; the deepest portion was approximately 0.040 inches on the RCS downstream side.

Note: *No other degradation was noted on the exterior surfaces of the make-up line or other make-up line welds, as determined by an ASNT Level II inspector from FTI; no other degradation was noted on the exterior surfaces of the safe-end; no cracking was identified on the interior surfaces of the warming line and socket region.*

4. Several cracked regions, including the make-up line to safe-end weld, make-up line near the warming line penetration, safe-end upstream of the thermal sleeve, and thermal sleeve near the inlet and outlet ends have been flattened and/or bent open to expose the fracture surfaces for visual, stereovisual and SEM fractographic examination. Nearly all of the planned examinations have been completed except for one axial crack sample from the outlet end of the thermal sleeve. The results of these examinations are summarized below:

- **Throughwall circumferential crack at the make-up line to safe-end weld** - the majority of the crack face exhibited a dark brown oxide film; SEM examination showed that the crack had propagated in a transcrystalline mode with evidence of cyclic loading (i.e., striations from the ID to the OD surfaces); the fatigue striations were frequently observed to bow toward the OD surface; although precise measurements of striation spacings were not possible, generally the shortest spacings were on the order of one micron or less.

- **Other ID initiated cracking** - the fracture surfaces of all cracks examined to date have been generally consistent with the throughwall circumferential crack in the make-up line to safe-end weld, although the safe-end, and thermal sleeve cracks have tended to be somewhat more oxidized and have required cleaning in the lab; although not well-formed, there is some evidence of faint fatigue striations on most of these surfaces.

5. Several cracked regions, including the make-up line to safe-end weld, make-up line near the warming line penetration, safe-end upstream of the thermal sleeve, thermal sleeve near the inlet and outlet ends have been mounted and prepared for metallographic examination. Most of the planned examinations have been completed, although photographic documentation is still in progress. The results of these examinations are summarized below:

- **Circumferential crack at the make-up line to safe-end weld** - the crack was contained within the weld fusion zone and had propagated in transcrystalline fashion exhibiting little branching.

- **Make-Up line, safe-end & thermal sleeve cracking** - all cracking was found to be transgranular and most of the cracking exhibited little branching; crack depths in the make-up line were generally less than 30% throughwall

PRELIMINARY CONCLUSIONS:

1. ID surface cracking observed in the make-up line, safe-end and thermal sleeve was predominantly the result of thermal fatigue; these cracks, in general, appeared to be slow growing.

2. The throughwall circumferential crack in the make-up line to safe-end weld probably initiated at the weld root by thermal fatigue, but other sources of high-cycle/low-amplitude loading most likely propagated the crack to failure; this crack was slow growing and had probably been present for an extended period of time.

Note: *Aside from in-service thermal fatigue cracking, the weld appeared to be in good condition; a slight concavity condition was observed at the weld root.*

3. The wear damage, material loss and long axial cracking observed near the outlet end of the thermal sleeve is more likely the result of flow induced vibration (FIV) from RCS cross-flow excitation, although initiation of the long axial cracks may have been due to localized thermal fatigue in this region. Wear in the rolled region is also consistent with FIV.

Submitted by:

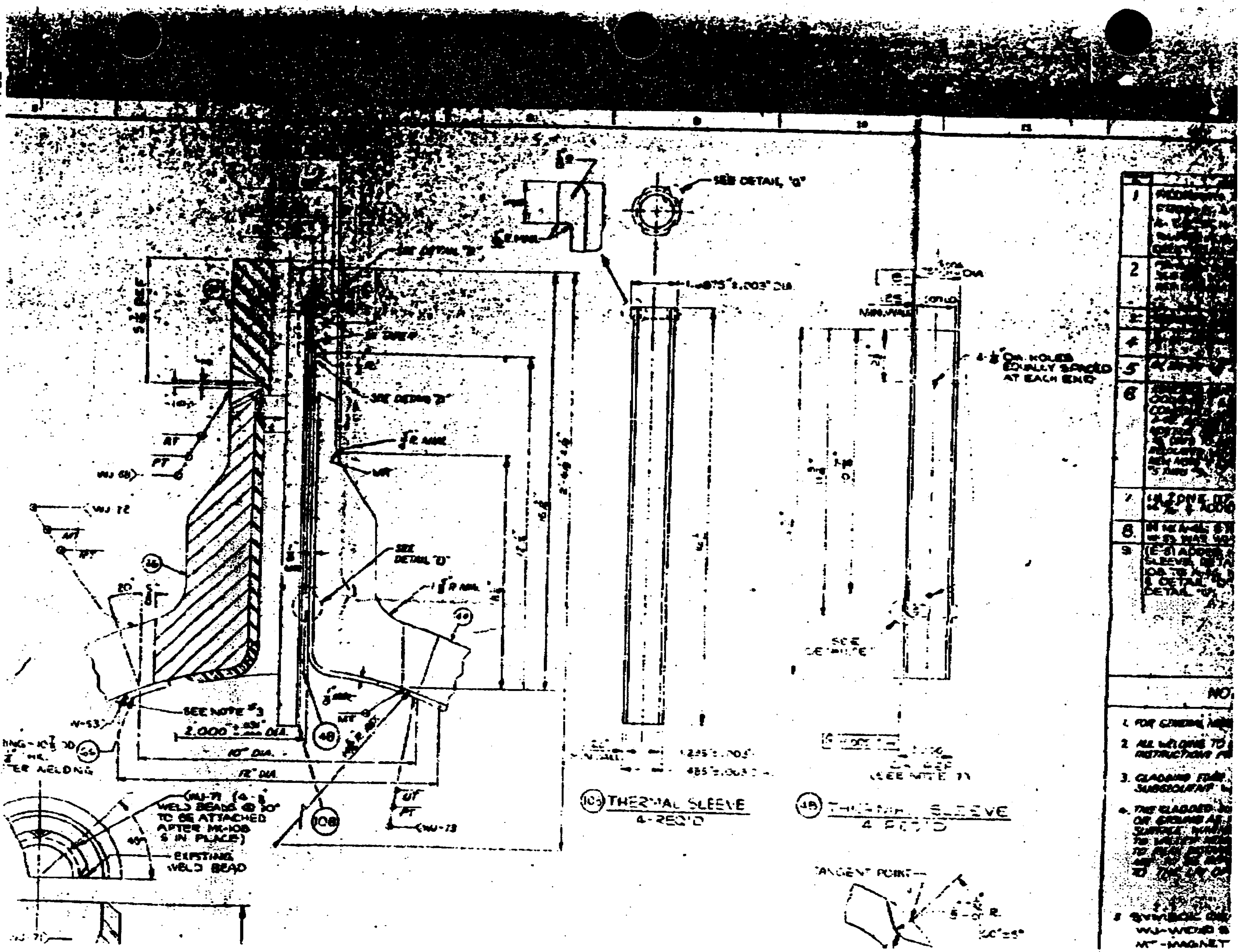
5/15/97

Kevin R. Redmond, DPC

Reviewed by:

Scott Harding, FaAA

01-04-0900 12:18PM P.02



METALLURGICAL EXAMINATION OF OCONEE-2A2 HPI COMPONENTS

From: Kevin Redmond (DPC Project Engineer), and Tim Smith, Paul Ledwith & Scott Harding (FaAA Consultants)

To: Craig Tompkins, FIP Team Leader

Re: Met Lab Data Compilation

SUMMARY OF WORK COMPLETED:

1. Samples were received at the LRC on April 28th (make-up line with cracked safe-end to pipe weld and attached warming line) and May 2nd (safe-end and thermal sleeve); initial unpacking and radiation surveys were completed shortly thereafter. Results of these inspections are as follows:

   - contact radiation levels were slightly over 1 R/hr, with a high, soft β component;
   - smearable contamination levels were extremely high (e.g., > 3 M dpm/100cm^2)

2. All components were subjected to thorough visual inspections, augmented by stereovisual and liquid penetrant inspections as deemed appropriate by the lab team. In general, these inspections were performed on both exterior surfaces and interior surfaces after sectioning. In addition, dimensional inspections of the safe-end and thermal sleeve were performed to characterize the wear damage and material loss of the sleeve as well as assess the fit between the safe-end and sleeve in the contact region. All visual, stereovisual, liquid penetrant and dimensional inspections have been completed. Results of these inspections are as follows:

Note: *Dimensional data should be considered preliminary, since a careful review has not yet been performed due to the intense work schedule in lab.*

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- **ID cracking of components** - a high concentration of multi-directional cracks were observed on the inside surfaces of the make-up line, safe-end and thermal sleeve, extending from about mid-length on the rolled region of the thermal sleeve back to about 2 inches beyond the warming line penetration; cracking patterns in the make-up line correlated with flow from the warming line penetration, axial cracks were also identified at the outlet end of the thermal sleeve, some of which were throughwall, and a few discrete, short, axial cracks were observed on the ID surface near the collar location.

- **Material loss on thermal sleeve** - there was obvious material loss along the RCS downstream side of the thermal sleeve, consisting of an irregular-shaped pattern approximately 4-1/4 inches long through a maximum 150° arc; long, axial cracks were associated with the material loss area, extending from the outlet end of thermal sleeve through the collar region and ending approximately mid-length on the sleeve (i.e., about 7-1/2 inches from inlet end); the longest crack appeared to have propagated in the axial direction from the outlet end toward the inlet end and exhibited signs of blunting at the tip.

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nominal OD surface about 5 inches in back of the collar; a deep circumferential wear groove was observed adjacent to the collar on the downstream side (i.e., correlating to location of downstream weld pads); at its deepest point, this groove extended nearly through the wall of the sleeve; circumferentially oriented cracks were also observed in these thinned regions adjacent to the collar; significant wear was observed at the rolled end of the thermal sleeve to approximately 2-1/4 inches from the inlet end; the deepest portion was approximately 0.040 inches on the RCS downstream side.

Note: *No other degradation was noted on the exterior surfaces of the make-up line or other make-up line welds, as determined by an ASNT Level II inspector from FTI; no other degradation was noted on the exterior surfaces of the safe-end; no cracking was identified on the interior surfaces of the warming line and socket region.*

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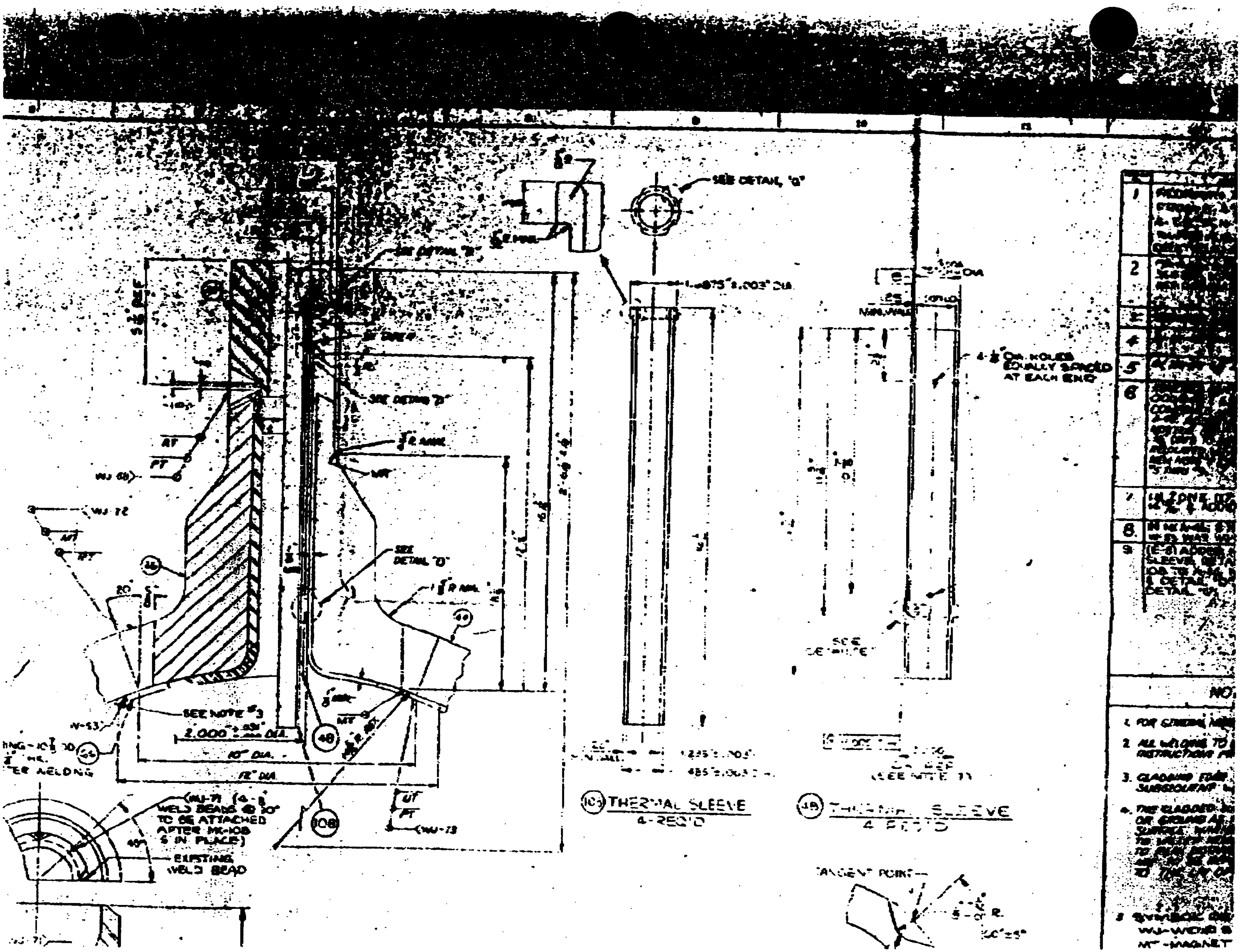
Submitted by:	Reviewed by:
5/15/97	
Kevin R. Redmond, DPC	Scott Harding, FaAA


SEE DETAIL "Q"
1.4875" ±.003" DIA.
4-3/8" DIA. HOLES EQUALLY SPACED AT EACH END
SEE DETAIL "B"
SEE DETAIL "D"
SEE DETAIL "D"
SEE NOTE #3
2.000" DIA.
10" DIA.
12" DIA.
(WJ-71 (4-1/8" WELD BEADS @ 90° TO BE ATTACHED AFTER MK-108 IS IN PLACE)
EXISTING WELD BEAD
108
48
49
36
THERMAL SLEEVE
4-REQ'D
THERMAL SLEEVE
4-REQ'D
TANGENT POINT
NO
1. FOR GENERAL
2. ALL WELDING TO
3. CLADDING EDGE
4. THE CLADDED
WJ-WELD
MT-MAGNET

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