DATE ISSUED: 12/13/83

ACRS FLUID DYNAMICS SUBCOMMITTEE
MEEITNG MINUTES
DECEMBER 8, 1983
WASHINGTON, DC

Purpose: The purpose of the meeting was to discuss the recent flow-related incidents at the Palo Verde Unit 1, St. Lucie, Unit 1, and Millestone Unit 2 reactors that resulted in equipment damage to the plants' primary systems.

Attendees: Principal meeting attendees included:

ACRS

D. Ward, Chairman
J. Ebersole, Member
H. Etherington, Member
C. Michelson, Member
I. Catton, Consultant
R. Dillon, Consultant
V. Schrock, Consultant
C. L. Tien, Consultant

Florida Power & Light

D. Chaney

Northeast Utilities

M. Cass
C. Gladding

NRC

M. Licitra
K. Heitner
D. Sells

Arizona Public Service (APS)

E. Van Brunt
C. Andognini

Combustion Engineering

C. Ferguson
J. Mullooly
R. Longo
E. Scherer

A complete list of meeting attendees is attached to the office copy of these minutes.

Meeting Highlights, Agreements, and Requests

1. Mr. E. Van Brunt (APS) outlined the presentations and introduced the speakers for the APS discussion of the damage found at Palo Verde (PV) Unit 1.

2. The APS hot functional test program for PV Unit 1 was outlined by Mr. C. Andognini. Immediately following its completion, the test was considered successful in that there were few problems seen. Upon inspection of the coolant pumps after the test, damage was found. Further damage was found upon inspection of the primary system internals. In response to Mr. Ebersole, APS said the dissassembly of the RCP had been scheduled prior to the test, because it was a first-of-a-kind type.

3. C. Ferguson (CE) detailed the damage seen to the Palo Verde RPS. There were four areas (components) of damage: (1) resistance temperature detector (RTD) thermowells, (2) safety injection nozzle thermal sleeves, (3) RC pumps, and (4) control element assembly (CEA) shroud assembly of the upper guide structure.

   The original RTD installation with the failure locations is shown on Figure 1. These failures showed up during the pre-core hot functional tests. The failure mode is as follows: (1) the thermowells experienced high cycle vibration, (2) the vibrations were in a plane perpendicular to the flow direction, indicative of vortex shedding, (3) failure was initiated by fatigue, and (4) extensive wearing was found on the thermowell at the annular interface between the inconel thermowell and the inconel pipe nozzle. All failures were seen in the cold leg RTDs. Figure 2 shows the redesigned RTD thermowell. The redesign increased the natural frequency from 1000 to 2800 cps, putting it well out of the region of potential excitation from plant operating conditions. Figure 3 shows the modified pipe nozzle fitting.

   The details of the RTD thermowell test program were described (Figure 4). In response to Dr. Schrock, Mr. Ferguson said that the hgher flow velocities in Palo Verde caused a problem here that has not been seen in other CE plants. In response to Dr. Catton, CE noted that the Palo Verde flow is ~10% higher than what is seen in CE's operating plants. Test results on the redesigned thermowell as of 11/30/83 showed no wear or evidence of vortex shedding after 6-8 hours of flow tests. There were several questions from the Subcommittee centering on the reproducability of the plant conditions as mocked up at the CE test facility. Dr. Catton requested information from CE on their measured versus calculated frequencies for the thermowell.

CE discussed the failure mode for the thermal sleeves located in the cold-leg ECCS injection nozzles (Figure 5). One of the four sleeves was ejected into the cold-leg pipe and another one was partially dislodged from its normal position. Failure was vibration initiated causing the sleeve to loosen, twist, and dislodge from the nozzle. The source of vibration was RC pump flow velocity and mechanical vibration. A possible contributing factor was the design reduction of the explansion* groove depth from 0.125 in. to 0.100 in. for this size thermal sleeve. In response to Mr. Michelson, CE said the vibration that caused the thermowell failures also affected the thermal sleeves. CE has elected to remove the sleeves. Analysis indicated that the thermal fatigue usage factor for the injection nozzle will not be signfiicantly affected by sleeve removal. In response to Mr. Ward, Mr. Ferguson indicated that the usage factor analysis is quite conservative. In response to Mr. Michelson, CE indicated that they have not felt it necessary to advise its customers to inspect their operating plants for loose or missing sleeves.

Mr. Ferguson detailed the damage to the RC pumps (Figure 6) and the modifications made to resolve the problem. The pumps are of German design and are "first-of-a-kind" components. There was damage seen

*Note - explansion designates an explosive expansion process used to secure the sleeve in the nozzle.

to the pump internals (broken diffuser bolts, broken and cracked diffuser vanes) found upon inspection after the hot functional test. Mr. Michelson asked if the loose parts monitor (LPM) was able to detect anything. CE said it was in an on-again, off-again mode and the failures occurred rather quickly, with no parts continually moving around the RCS. APS is analyzing the LPM data they do have, vis-a-vis this event, to help baseline this system. In response to Mr. Michelson, Mr. Scherer (CE) said the LPM is not a cure-all for problems of this kind.

As a result of a series of tests on the pump, the cause of the damage was found to be due to flow pulsations. The fix elected was to increase the clearance between the impeller and diffuser from 2.3% to 6.0% by cutting back the diffuser vanes, without resulting in significant hydraulic impact. Head losses due to increased gap, removal of suction pipe rings, and cutting back the leading edges of impeller were recovered by backfiling the impeller. Radial hydraulic forces on the diffuser were reduced by a factor of 3.3 by increasing the gap to 6.0 percent. The measured stress levels on the impeller and diffuser vanes were at acceptable levels. Metallurgical tests show the cause of the RCP damage was due to flow pulsations. Metallurigical tests show the cracking mode for the impeller is fatigue. There was no evidence of corrosion. Similar examination of the diffuser bolts again indicated fatigue was the most likely failure mode and no evidence of corrosion or hydrogen embrittlement was seen. Details of the diffuser modifications were also noted.

The test program to confirm the modified pump design was discussed. This is a four phase program which will be complete this week (Figure 7). Preliminary results to date show significant reductions in the strains and accelerations seen in the pump internals of the original design.

CE discussed the cracking seen in the upper region of the CEA shroud assembly. Figure 8 shows the shroud and the upper guide structure and Figure 9 shows the location of the cracking in the upper structure region. Most of the cracking was in this location. The failure mode was by high cycle fatigue. In response to Mr. Dillon, BE said there was no evidence of corrosion seen. Further questions brought out the fact that the CEA shroud design is first-of-a-kind for Palo Verde. Vibration and excitation tests have been done since the damage was observed. These tests showed that there was a problem with vibration induced cracking.

Figure 10 shows the modified upper guide assembly. CE has cut off the top 8 inches of the CEA which includes the shaft guides. Lateral snubbers were also added between the CEA and upper guide structure collandria to further dampen any vibrations. In response to Dr. Schrock, Mr. Scherer said that loss of CEA integrity does not threaten core cooling in the event of a LB LOCA. He also said there is a potential safety issue here and CE will assure there is a free path for control rod insertion given a DBA. In response to Mr. Dillon, Mr. Ferguson said there were several sources of vibrations that could have induced cracking, including a lack of upper support and cross flow in the collandria surrounding the CEA.

Mr. Andognini discussed the planned integrated test program after all the above modifications are in place. This program is under development and will be reviewed by the NRC Staff. Units 2 and 3 will be equipped with the above modifications prior to their pre-core hot functional tests.

Mr. Van Brunt briefly outlined the APS involvement in the repair program. APS has filed a 10 CFR 50.55(e) notice with the NRC Staff. Interim notification to NRC is due in January 1984. All items will be closed out via 50.55(e) notification.

Mr. Ward asked if there is any relationship to the recent pump impeller failure at the CE Palisades plant and the pump problems discussed today. Mr. Scherer indicated no correlation based on preliminary information received to date.

4. Mr. M. Licitra (NRC) discussed the NRC Staff review of the Palo Verde event. He began by noting the NRC review requirements that define the design and test requirements impacted by the Palo Verde problems. Dr. Catton requested a copy of the report on flow induced vibration testing required by Regulatory Guide 1.20, when it is available. Mr. Licitra said the pre-operational test program required by NRC worked, in that it brought out the problems noted above.

   NRC is expecting reports from APS on the four components where problems were found. The reports will address problems that were found, efforts to determine the cause of the problems, design changes made, followup testing, and results. Mr. Licitra said that at this point, the applicant's program seems to be progressing in the right direction. Any generic implications of this event on CESSAR-80 plants are still being evaluated by the Staff. Non-CESSAR plants are not impacted by this concern.

   There was extensive discussion of the generic aspects of thermal sleeve failures.

5. Ms. L. Beruabei representing the Government Accounting Project (GAP), interveners in the Palo Verde licensing process, made a brief public statement. GAP believes a more thorough review of this issue is warranted by NRC. She cited a number of issues that have been raised since the above problems surfaced and that could have potential safety impact. Mr. Licitra took issue with Ms. Beraubei's comment that she has not been kept fully informed of the Palo Verde problems.

6. Mr. D. Chaney (FP&L) introduced the agenda for the discussion on the St. Lucie and Millstone plants thermal shield (TS) problem. He noted CE has four operating plants with thermal shields. Figure 11 notes these four plants as well as outlines the TS problem seen at Maine Yankee. FP&L is maintaining a close liaison with the NRC Staff vis-a-vis their recovery program (Figure 12).

Mr. M. Cass (Northeast Utilties) introduced the Northeast Utilities representatives and noted they would follow FP&L with a ddtailed presentation.

7. Mr. J. Mullooly (CE) detailed the reactor vessel internals focusing on the thermal shield assembly. He also detailed the thermal shield connection to the core support barrel (Figure 13). CE also showed slides of photographs of the thermal shield damage at St. Lucie Unit 1 and Millstone Unit 2.

9. D. Chaney (FP&L) discussed the plant specific aspects of the St. Lucie TS damage. He showed slides taken in the vessel of the damage seen. Two of the support lugs were torn off, one of these tore a hole through the core support barrel wall. NDE was performed on the core support barrel to determine the location and extent of cracking. In response to Mr. Ebersole, Mr. Chaney said the high radiation field (~200,000 rad/hr.) made the NDE quite difficult. No welding repair is planned as noted below.

Support barrel repair included machining away the damaged area for non-through wall cracks. For through wall cracks, crack arrestor holes are machined. Lug tear out areas require machining and/or patch preparation. Expandable plugs will be used to hold the patch in place (Figure 16).

FP&L has maintained close contact with NRC during the recovery program. Presently, FP&L is in the process of machining the core support barrel repair and is in preparation for plugging and patching the through-wall holes. The earliest estimated return to power date is April 1984.

10. Northeast Utilities (NU) discussed their program for removing the TS and repairing any damage to the core barrel. After removing the TS/core

barrel assembly from the RPV NU severed the thermal shield at the support lugs and then cut it up for removal. Only two of the 9 support barrel lugs were damaged. Slides of the damaged lugs were also shown. Eddy current and ultrasonic inspections were performed to dentify any support barrel cracking. NU will machine out and repair all flaws detected. Crack arrester holes will be machined to avoid any further crack propagation.

Analysis by NU of the effect of TS removal on NDTT and PTS considerations were noted. Key points are:

° Removal of thermal shield will increase fast neutron fluence to the vessel by approximately 73%.

° Limiting locations in the Millstone Unit No. 2 beltline has a new predicted end-of-life RT_{NDT} of 197°F (plate C-505-2) and 205°F (weld 9-203).

° The NRC established PTS limitation (SECY 82-465) is 290°F for longitudinal welds and plates and 300°F for girth welds.

° Both values are well within acceptable limits.

° The holes in the core barrel will cause a local peak of vessel fluence and hence a peak RT_{NDT} in plate C-505-3.

° RT_{NDT} in plate C-505-3 at end of life is bounded by the lead plate.

° P-T limit curve, for 10 efpy is based upon the RT_{NDT} of 140°F.

° The increase in fluence will cause the RT_{NDT} to reach this value in 5.3 efpy.

° Ten year P-T limit curves are thus limited to 5.3 efpy .3 additional efpy.

° Revised technical specifications are being prepared for the 10 efpy curve which will reflect the higher fluence.

In repsonse to Mr. Ward, NU noted that the man-rem exposure for the repairs is similar to exposures seen during a normal shutdown. FP&L's experience here is also similar.

NU safety analyses were reevaluated for any impact of the core support repair and TS removal. The impact was negligible. The current repair schedule calls for startup on January 3, 1984. Presently, fuel load is in progress.

11. Mr. D. Sells (NRC) discussed the evaluation of the St. Lucie TS problem. He reviewed the history of NRC/FP&L interactions on this matter. FP&L will prepare a formal report of the entire problem (Figure 17) for review by NRC. The report should be submitted the week of January 9, 1984. The key item of concern is the continued integrity of the core support barrel. NRC also needs to decide what future monitoring and inspection programs will be required.

Mr. K. Heitner discussed the NRC review of the NU analysis and recovery program. The critical review areas include: core support barrel repair, Q/A of inspection and repair process, revised PTS calculations, revised reactor thermal hydraulics, and effects of by-pass flow. NU submittals are now under Staff review. For Maine Yankee (MY), the following points were noted. Maine Yankee performed its ten year ISI in October-November 1982. At that time, three upper position pins were discovered to have dislodged. The pins were recovered. Interim plant operation without the position pins was initially justified based on visual inspection. Subsequent actions established that the St. Lucie failure analysis indicated failure did not occur in one cycle, thus operation of MY until March 1984 is justified. Accident consequences of a thermal shield drop were analyzed and found to be acceptable. In April 1984 MY will inspect the core support barrel and

TS. In response to Mr. Ward, Mr. Heitner indicated MY has not seen alot of zero power operation in recent years. Ft. Calhoun has thoroughly inspected their TS and CSB and has not found any problems. As with Maine Yankee, Ft. Calhoun has not had alot of zero-or-low-power operation in recent years. NRC, in response to Mr. Ward, indicated they will analyze low- and zero-power operation data from these plants and will provide this information to the Subcommittee. Ft. Calhoun plans to upgrade their loose parts monitor system. In response to questions from Mr. Michelson, Mr. Scherer indicated that LPM systems are most useful for analysis of long-term trends in plant operations.

12. The meeting was adjourned at 4:40 p.m.

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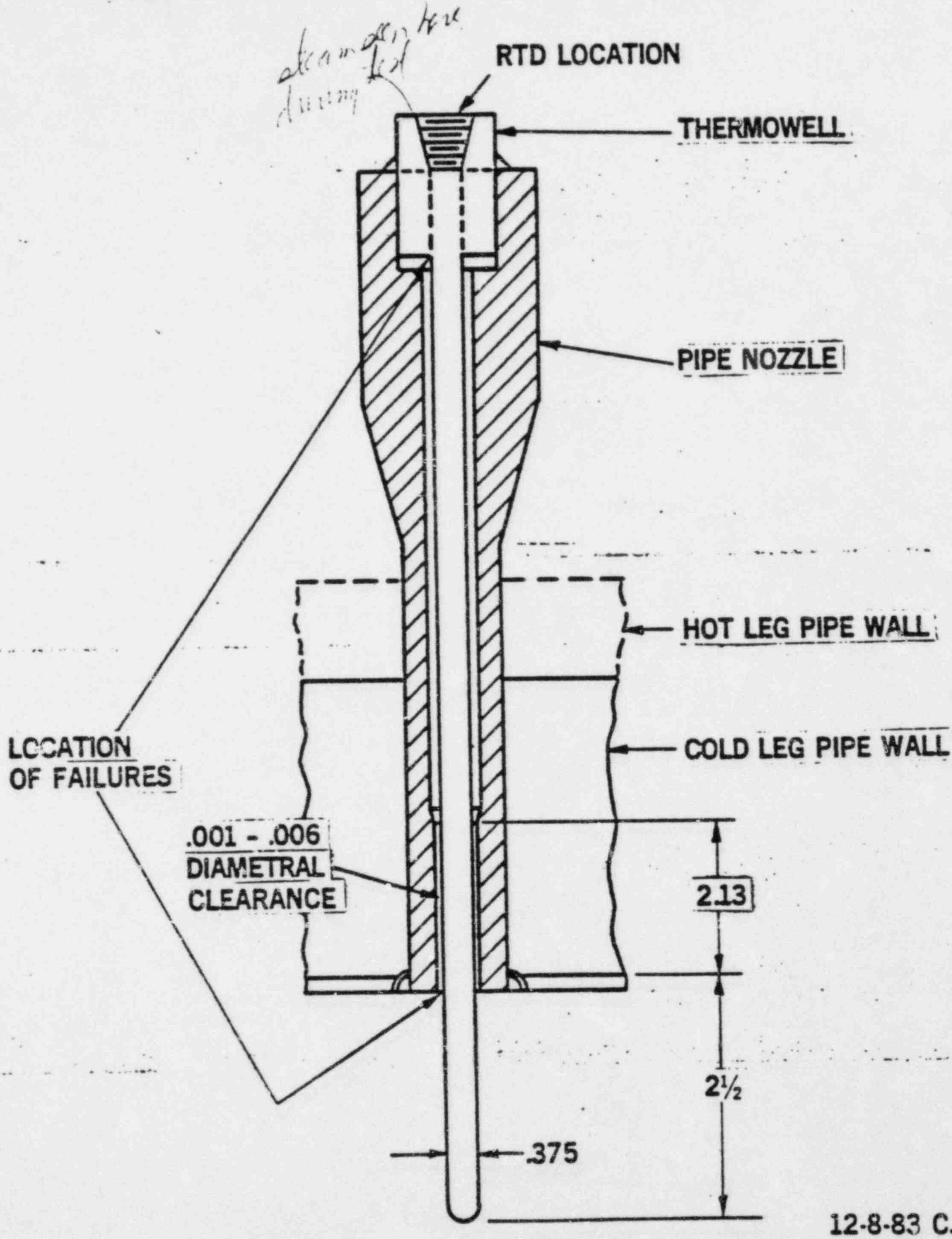
NOTE: Additional meeting details can be obtained from a transcript of this meeting available in the NRC Public Document Room, 1717 H Street, NW, Washington, D.C., or one can be purchased from Tayloe Associates, 1625 I Street, NW, Suite 1004, Washington, DC 20006 (202-293-3950).

RTD/TW INSTALLATION ORIGINAL DESIGN



12-8-83 C.F.

Fig. 1

ANPP-1 THERMOWELL DESIGN COMPARISON

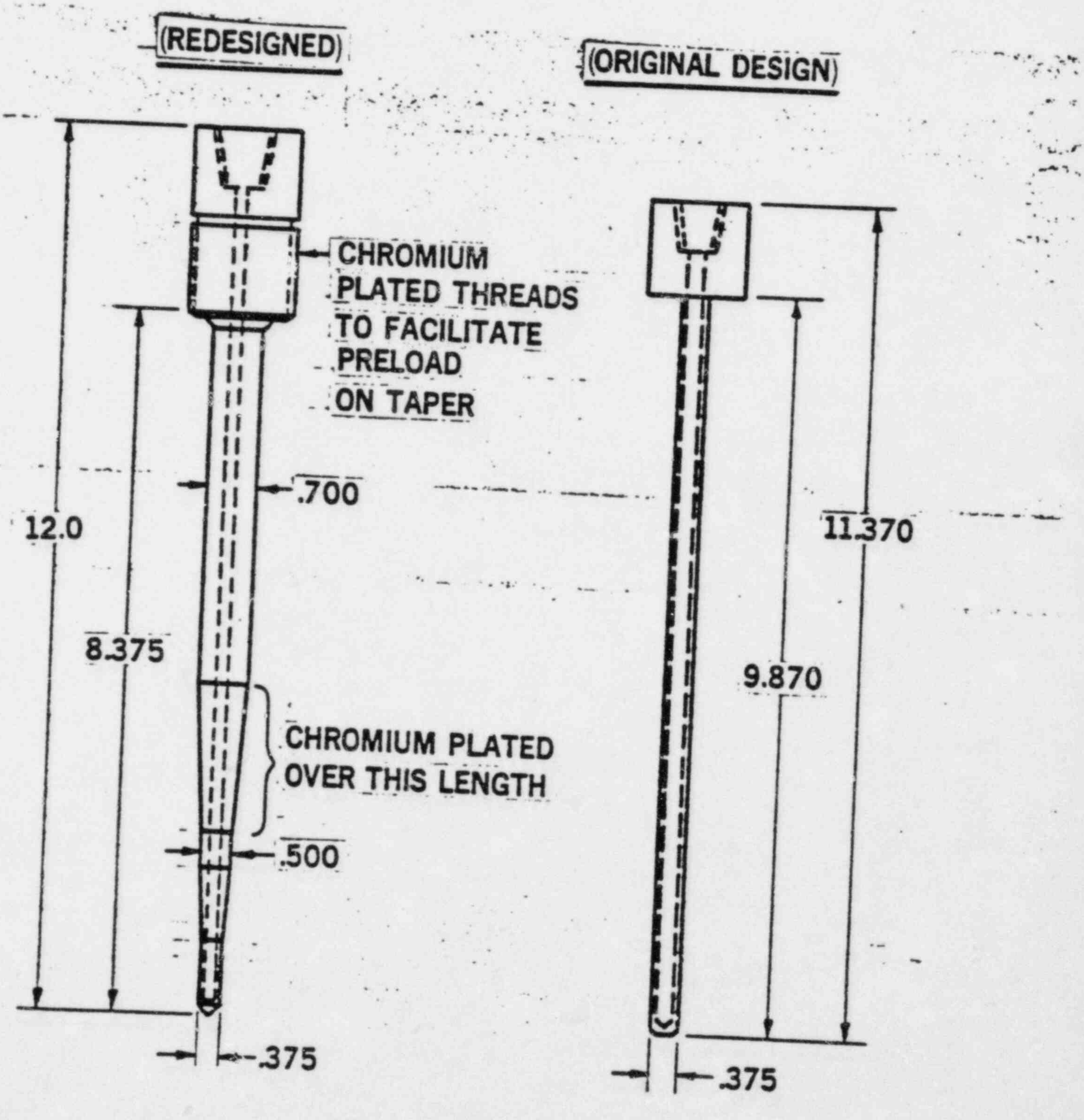


FIG. 2

MODIFIED THERMOWELL & PIPE NOZZLE

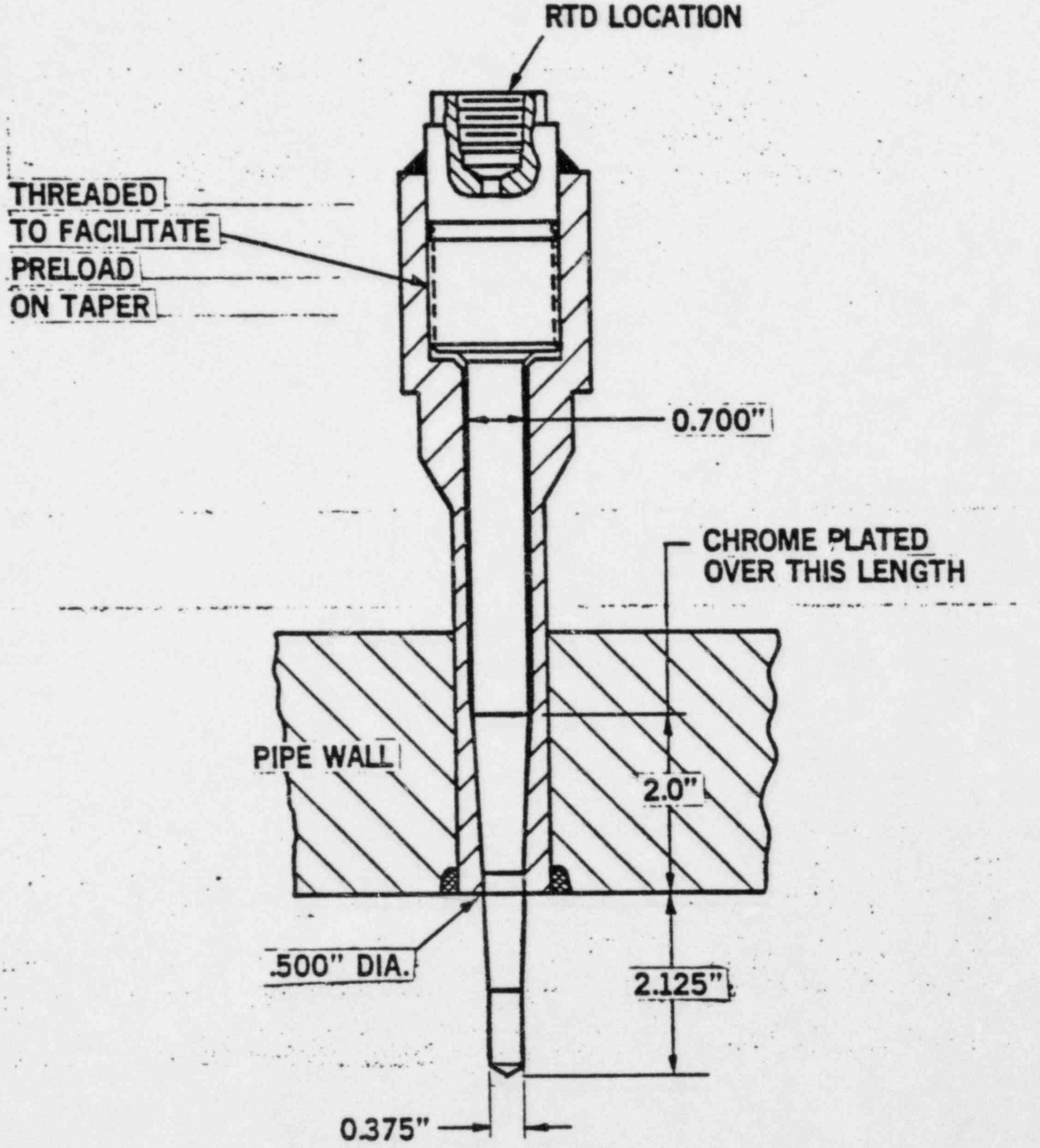


FIG. 3

FIG. 4

RTD/THERMOWELL TEST PROGRAM

TEST	LOCATION	STATUS
1. VORTEX SHEDDING TESTS OF THE SYSTEM 80 DESIGN AND THE NEW TAPERED DESIGN	CE-W	COMPLETED*
2. SHAKE TABLE TESTS OF THE RTD, THERMOWELL, PIPE NOZZLE AND ATTACHMENTS	CE-W	12-83
3. STRUCTURAL RESPONSE	CE-N	12-83
4. VORTEX SHEDDING FREQUENCY	CE-N	12-83
5. VELOCITY MEASUREMENTS AT RTD/ THERMOWELL	CE-N	12-83

NOTES: 1. TESTS AT CE-NEWINGTON, NEW HAMPSHIRE ARE CONDUCTED IN THE FULL SCALE RC PUMP TEST FACILITY
2. CE-W IS C-E WINDSOR
3. STATUS AS OF 12-2-83

*DATA REDUCTION AND EVALUATION IN PROGRESS.

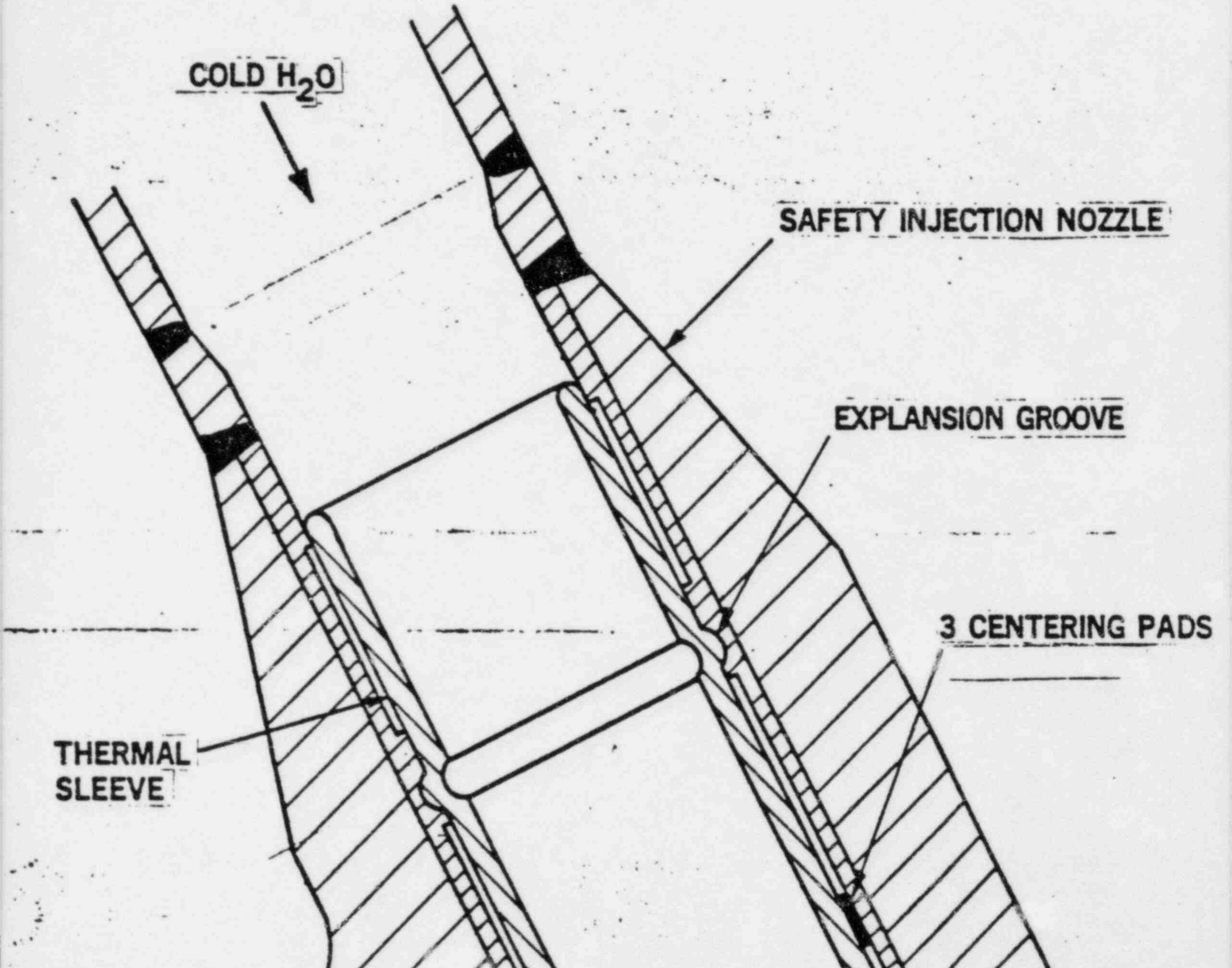
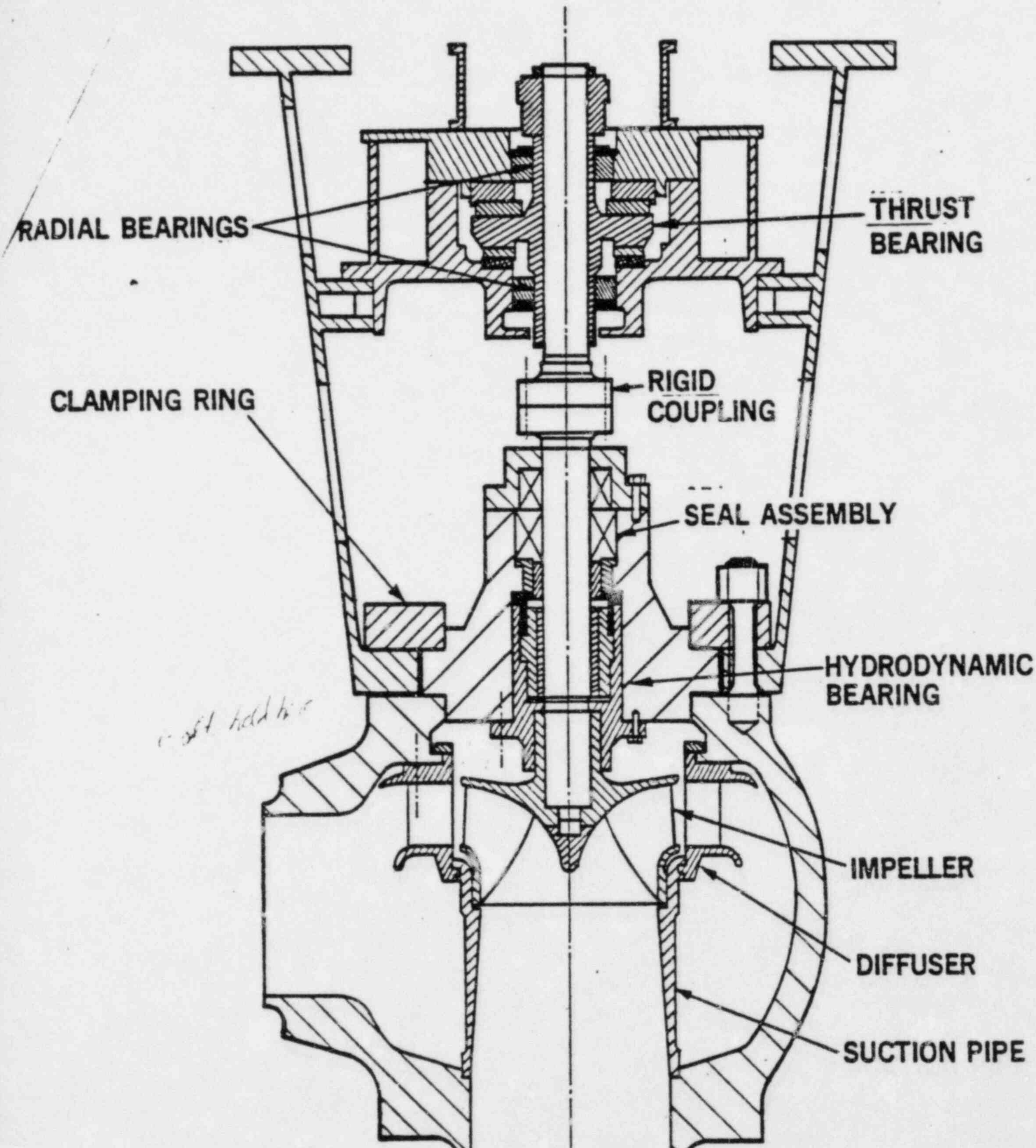


FIG. 5

TYPICAL: 4 COLD LEGS



C-E - KSB PUMP DESIGN

FIG. 6

RC PUMP TEST PROGRAM

TEST	TIME	STATUS
1. Phase 1		
A. 95 to 130% FLOW DATA	50 hours	Complete
B. BASE LINE DATA FOR INSTRUMENTATION. NO MODIFICATIONS. GAP 2.3 PERCENT.		
2. Phase 2		
A. 130 to 150% FLOW DATA	100 hours	Completed
B. CONTINUATION OF BASELINE DATA. NO MODIFICATIONS. GAP 2.3 PERCENT		
3. Phase 3		
A. 130 to 150% FLOW DATA	150 hours	Complete
B. ALL MODIFICATIONS INCORPORATED. GAP 6.0 PERCENT.		
4. Phase 4		
A. 95 to 130% FLOW DATA	30 hours	12/83
B. ALL MODIFICATIONS INCORPORATED. GAP 6.0 PERCENT.		

NOTES: 1. All Tests to be Conducted in the Full Flow RC Pump Test Facility at C-E-Newington, New Hampshire.

2. Status as of 11-30-83

F. 7

FIG. 7

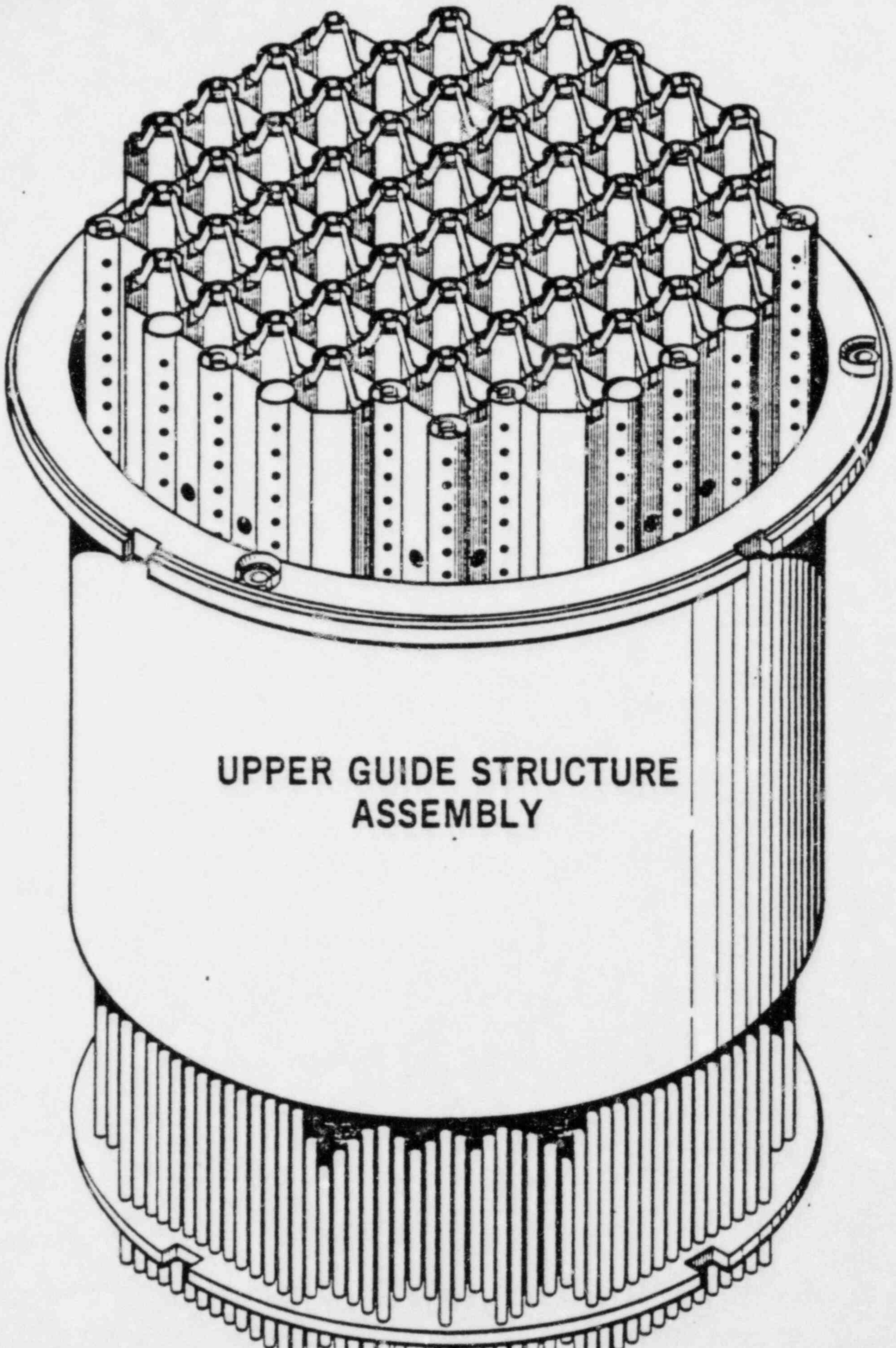


FIG. 8

TOP CRACK SUMMARY

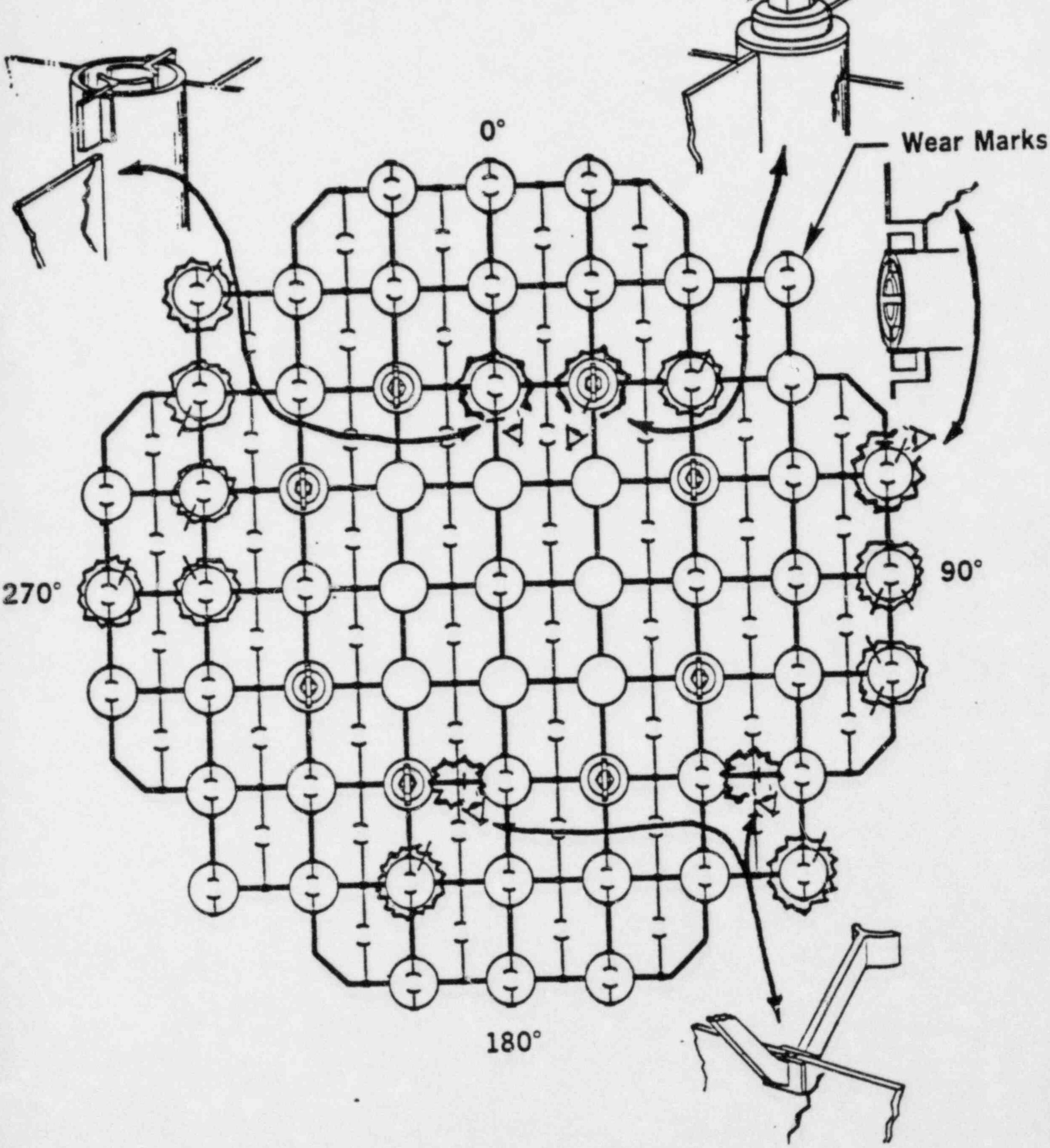


FIG. 9

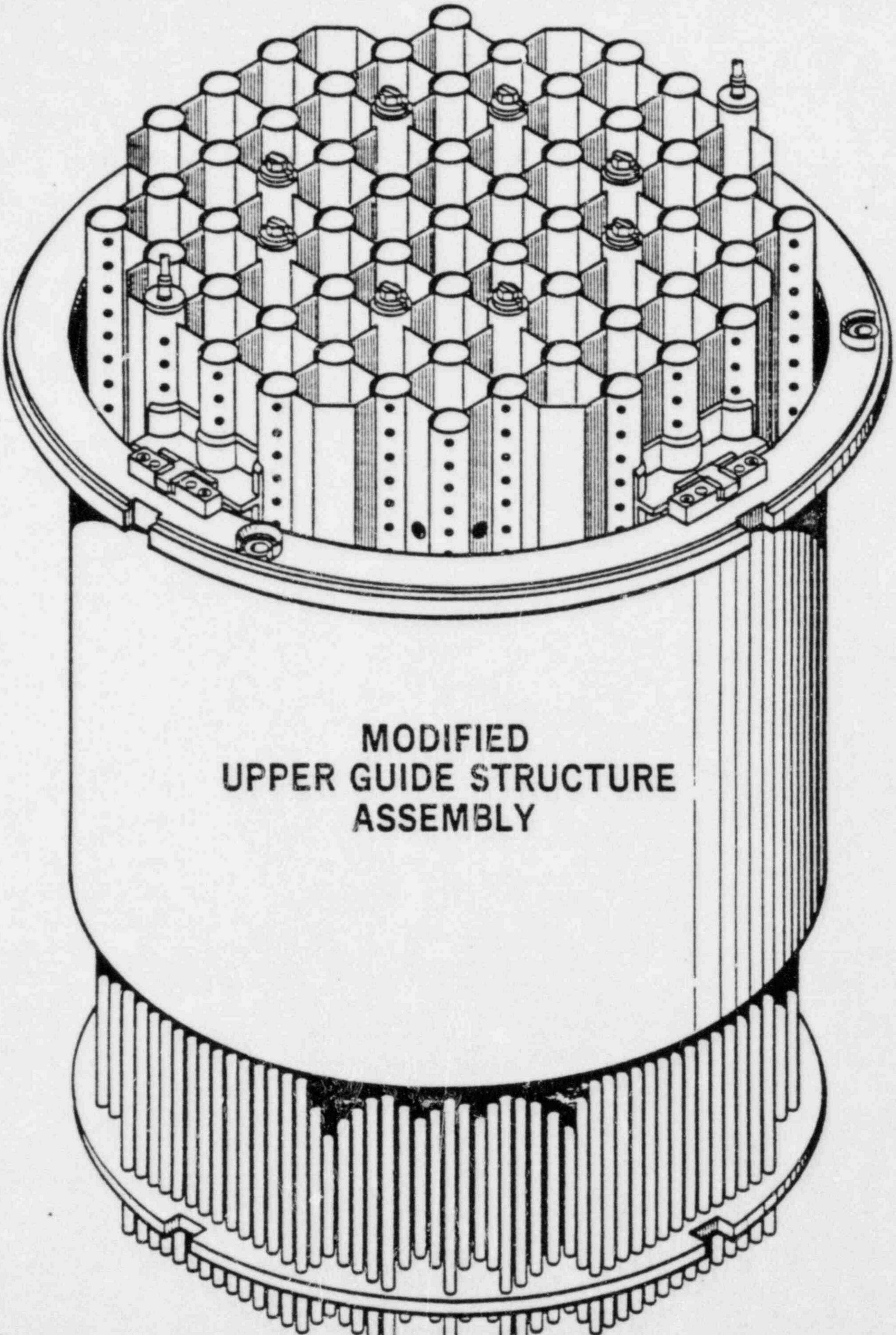


FIG. 10

FLORIDA POWER & LIGHT - ST. LUCIE 1

OPENING REMARKS

- OPERATING COMBUSTION ENGINEERING (C-E) NSSS PLANTS WITH THERMAL SHIELDS
  - MAINE YANKEE
  - FT. CALHOUN - 1
  - MILLSTONE - 2
  - ST. LUCIE - 1
- MAINE YANKEE INSPECTION (OCTOBER 1982)
  - C-E AVAILABILITY DATA PROGRAM (ADP) INFO BULLETIN 82-12 (TRANSMITTED TO FPL - DECEMBER 82)
    - 1 LOOSE/2 DISPLACED UPPER POSITIONING PINS (OF 9 TOTAL)
    - NO EVIDENCE OF WEAR, LOOSENESS OR EXCESSIVE MOTION AT ANY SUPPORT LUGS OR OTHER POSITIONING PIN INTERFACES.
    - STEADY STATE AND TRANSIENT RESPONSE ANALYSIS - NO CHANGE
    - 3 POSITIONING PINS RETRIEVED, BUT NOT REPLACED
- ST. LUCIE 1 INSPECTION (MARCH 1983)
  - 2 DISPLACED UPPER POSITIONING PINS
  - THERMAL SHIELD AND CORE SUPPORT BARREL DAMAGE - 35 MM SLIDES

FIG. 11

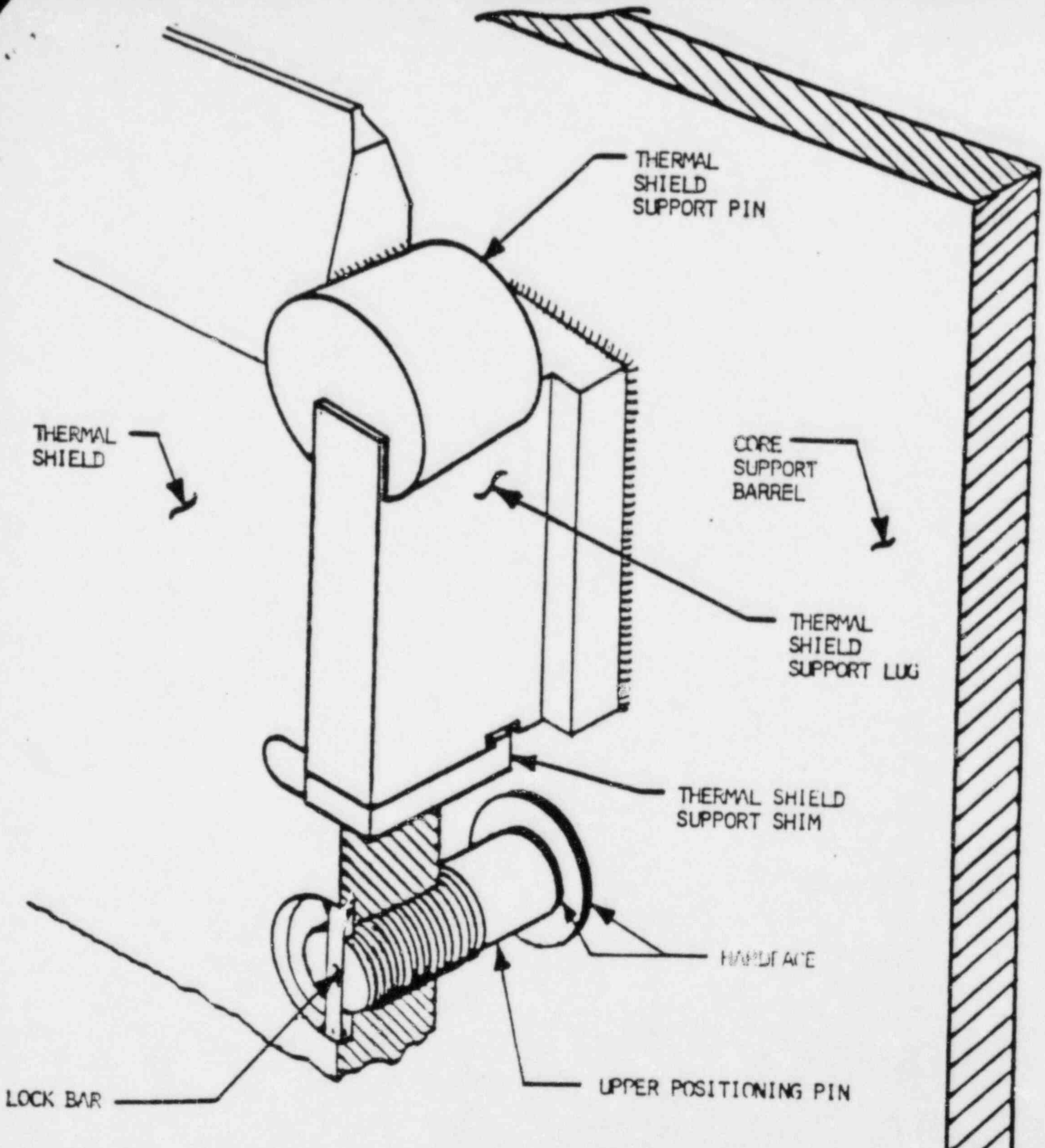
NRC MEETING

(1)	PRELIMINARY ASSESSMENT	4-12-83
(2)	RECOVERY PLAN PRESSURIZED THERMAL SHOCK CONSIDERATIONS	4-25-83
(3)	LOOSE PARTS MONITOR (LPM) AND EXCORE DETECTOR DATA (IVM) (INCLUDING ANALYSES CONDUCTED)	6-3-83
(4)	THERMAL SHIELD/CORE SUPPORT BARREL/ INTERNALS INSPECTION RESULTS	8-16-83
(5)	FPL PROPOSED FINAL REPORT CONTENT	9-22-83
(6)	NRC REGION II PROJECT RECOVERY PLAN REVIEW	11-4-83
(7)	FAILURE MECHANISM ANALYSIS RESULTS PRESENTATION	11-10-83

FUTURE

(8)	INTEGRITY AND STABILITY OF INTERNALS/ POST-MACHINING FINAL NDE INSPECTION RESULTS	WEEK OF 1-23-84 (SUBMITTAL WEEK OF 1-9-84)

FIG. 12



THERMAL SHIELD CONNECTION

F

FIG. 13

PROGRAM PLAN - THERMAL SHIELD FAILURE MECHANISM ANALYSIS

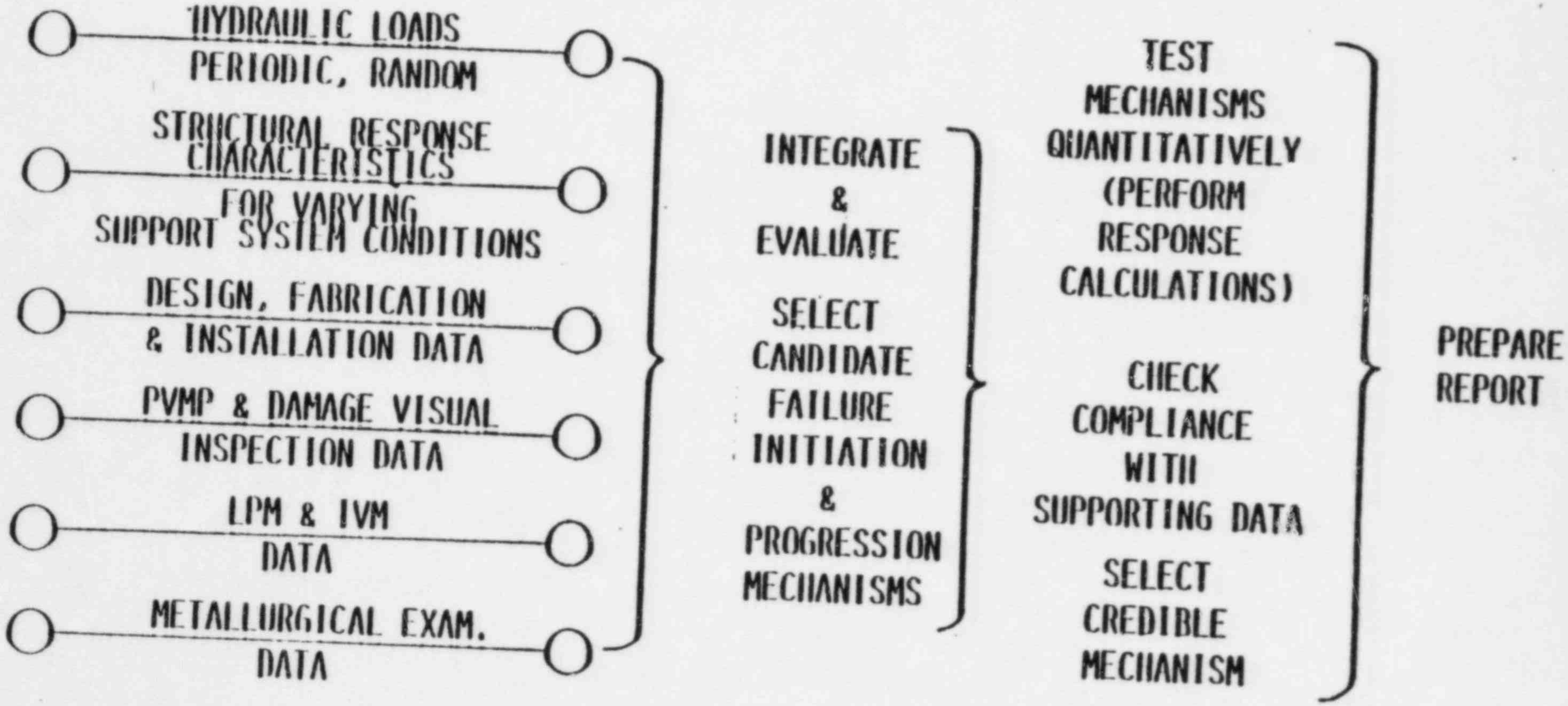


FIG. 14

ST. LUCIE 1 EXCORE DETECTOR LOCATION
AND IVM SYSTEM

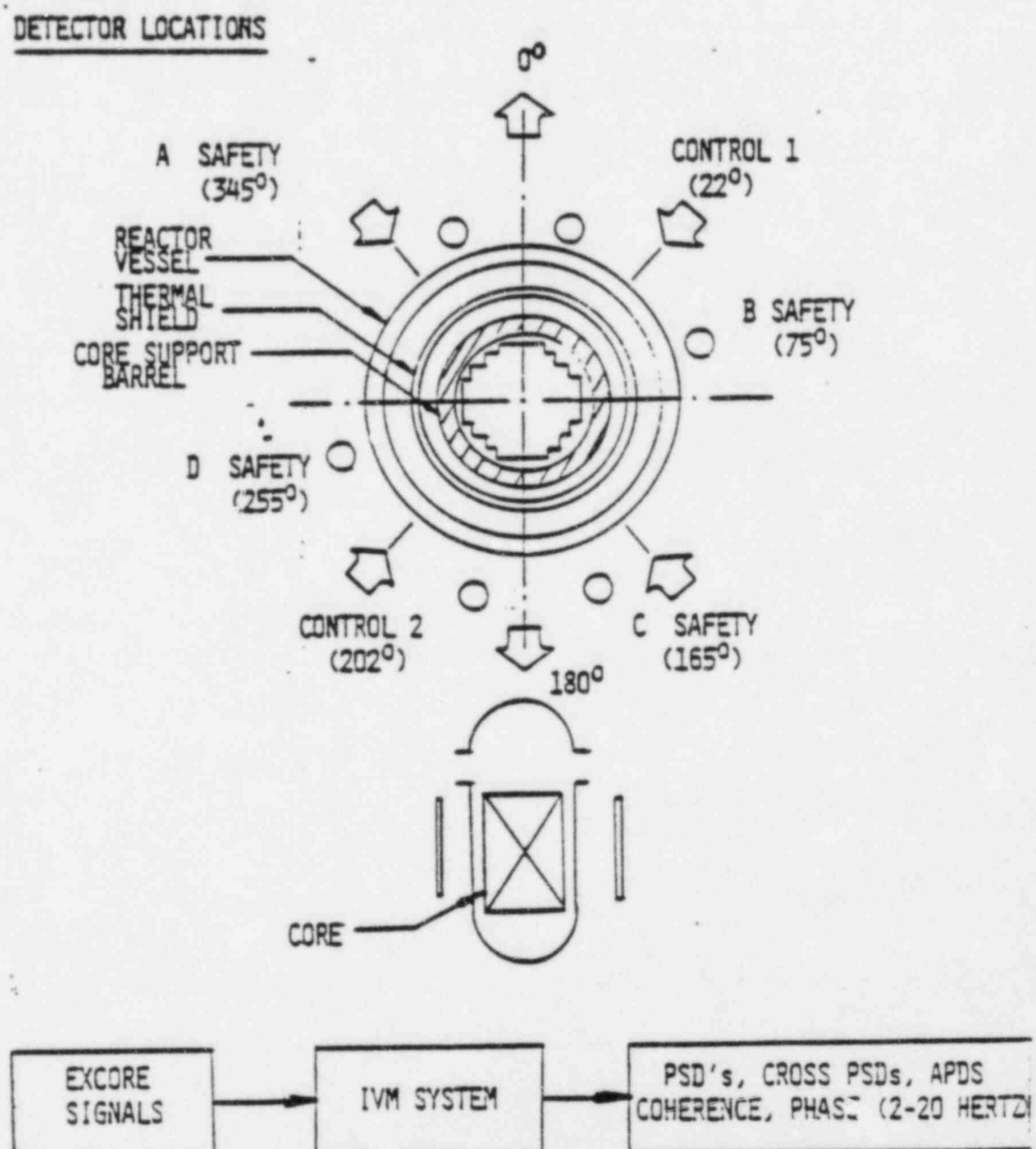
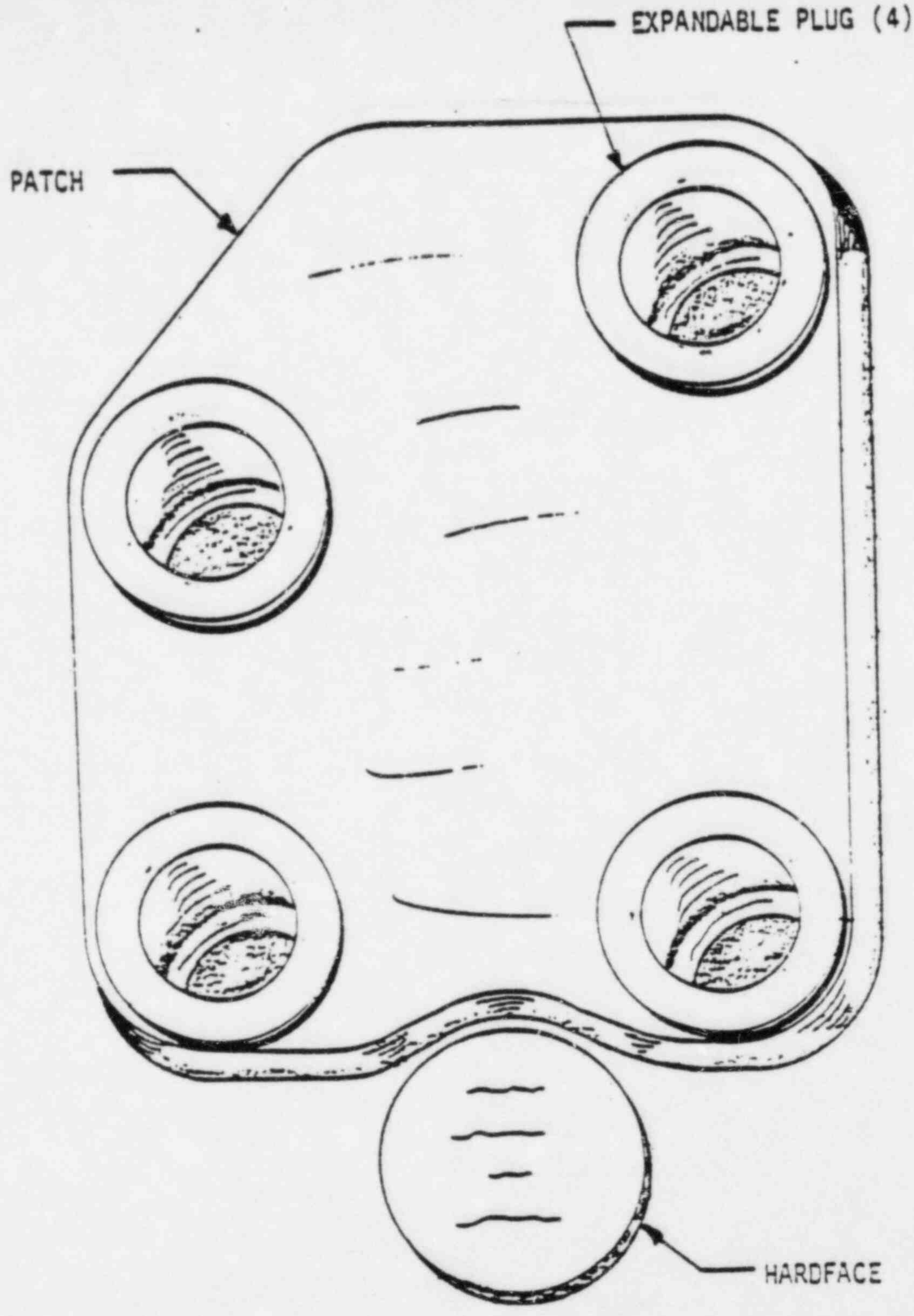


FIG. 15



TYPICAL PATCH

FIG. 16

Don 5 - IV

REPORT OVERVIEW

FIG. 17