DCD-016

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 20 1982

Docket No. 50-289

FACILITY: THREE MILE ISLAND, UNIT NO. 1 (TMI-1)

LICENSEE: GPU NUCLEAR CORPORATION (GPUN)

SUBJECT: SUMMARY OF MEETING WITH GPUN ON SEPTEMBER 15, 1982 CONCERNING GPUN'S STEAM GENERATOR (SG) REPAIR PROCESS

Background

As part of their program to recover the SGs from intergranular stress corrosion cracking of the tubes, GPUN has proposed a repair program involving an explosive expansion technique to recover tubes with defects within the upper tubesheet (UTS). The purpose of the September 15, 1982 meeting was to provide a final briefing to the staff prior to start of the actual repair and to resolve any remaining staff or staff consultant concerns regarding the repair itself. A copy of GPUN's presentation is enclosed. A list of attendees is also enclosed.

Discussion

GPUN's proposed repair process consists of kinetically or explosively expanding tubes within the UTS. All 31,000 tubes will be expanded for 17 inches or 22 inches within the 24 inch UTS. In order to establish a qualified seal, there must be a six inch area free of defects. Hence, a 17 inch expansion will recover tubes with defects only within the top 11 inches and a 22 inch expansion will recover tubes with defects only within the top 17 inches of the tube. The process involves use of low level explosives including prima cord, booster, ordance transfer cord and blasting caps. The prima cord and booster are inserted into a polyethylene "candle" and detonated by a blasting cap outside the OTSG via the ordance transfer cord. GPUN will be ready to commence the expansions in mid October 1982. Related actions involve secondary side flush, crevice drying, expansions, debris cleanup, plugging tubes unable to be recovered and testing. GPUN expects to complete these operations by December 1982. The staff issued a Safety Evaluation limited to the steam generator repairs on October 13, 1982. No staff members or staff consultants raised concerns that would postpone or prevent GPUN from commencing the repairs. A meeting has been scheduled October 18 and 19, 1982 (previously October 13 and 14) to discuss remaining aspects of

GPUN's steam generator recovery program.

P. C. Wagner

for Richard H. Jacobs, Project Manager
Operating Reactors Branch #4
Division of Licensing

Enclosures:
1. List of Attendees
2. GPUN's Presentation

cc w/enclosures:
See next page

OFFICE	ORB#4:DL						
SURNAME	RJacobs/cb						
DATE	10/20/82						

ORB#4:DL

MEETING SUMMARY DISTRIBUTION

Licensee: GPU Nuclear Corporation

* Copies also sent to those people on service (cc) list for subject plant(s).

Docket File
NRC PDR
L PDR
ORB#4 Rdg
GLainas
JStolz
Project Manager-RJacobs
Licensing Assistant-RIngram
OELD
Heltemes, AEOD
IE
SShowe (PWR)
Meeting Summary File-ORB#4
RFraley, ACRS-10
Program Support Branch

CRAB, Rm. 542
BGrimes, DEP
SSchwartz, DEP
SRamos, EPDB
FPagano, EPLB

Meeting Participants Fm. NRC:

C. McCracken
J. Rajan
E. Brown
R. Major
F. Young, TMI Site
L. Frank
H. Gray, Reg. I
H. Brammer

Enclosure 1

LIST OF ATTENDEES

NRC

G. Lainas

J. Stolz

C. McCracken

R. Jacobs

J. Rajan

E. Brown

R. Major

F. Young, TMI Site

L. Frank

H. Gray, Reg. I

H. Brammer

NRC Consultants

L. Leonard, FRC

T. Shook, FRC

V. Luk, VRC

C. Davey, FRC

GPUN

P. Clark

D. Slear

E. Wallace

J. Colitz

R. Neidig

J. Fidler

M. J. Graham

S. Giacobbe

GPUN Consultants

B. Barratt, F.W.

D. Pai, F.W.

J. Pearson, B&W

R. Kosiba, B&W

S. Weems, MPR Assoc.

J. Concklin, B&W

Other

S. Maingi, Pa. BRP

L. Connor, NRC Calendar

A. Manik, PANE

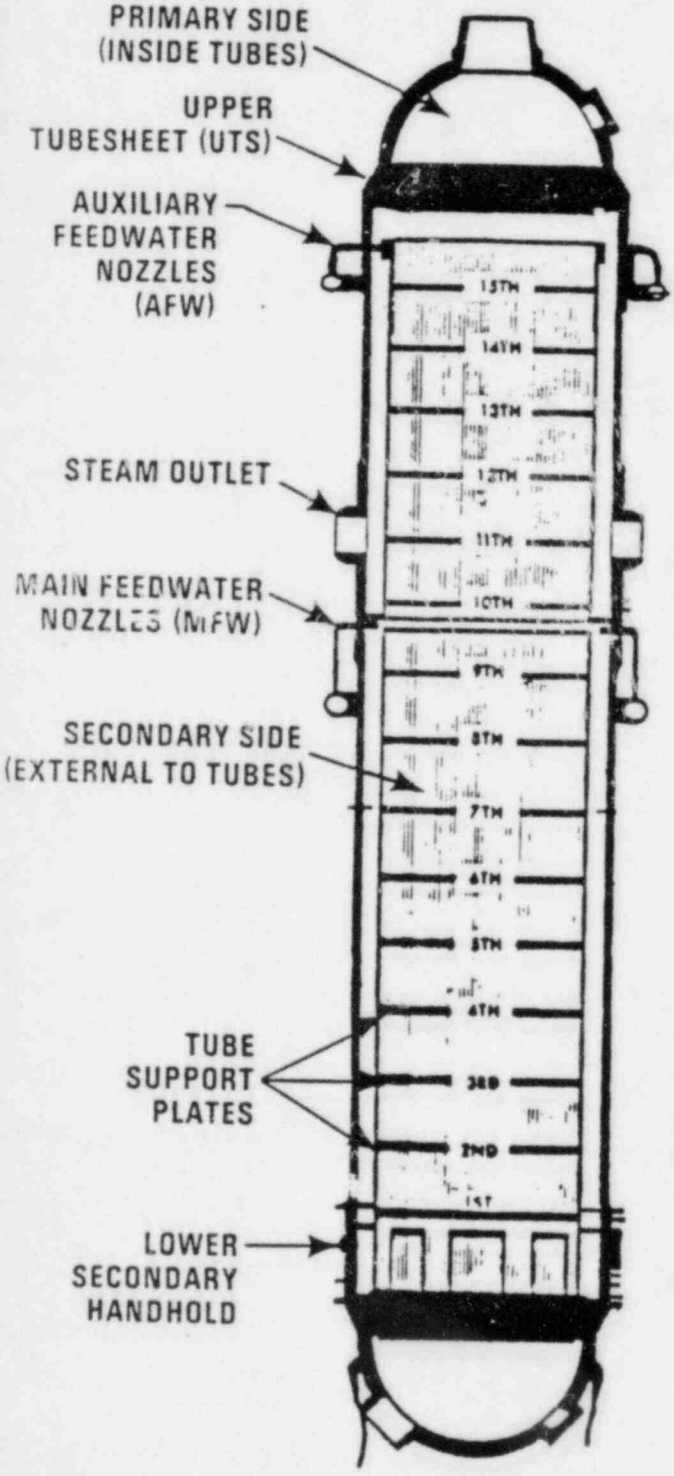
GPU Nuclear

TMI-1 OTSG Repair Process Description/ Qualification

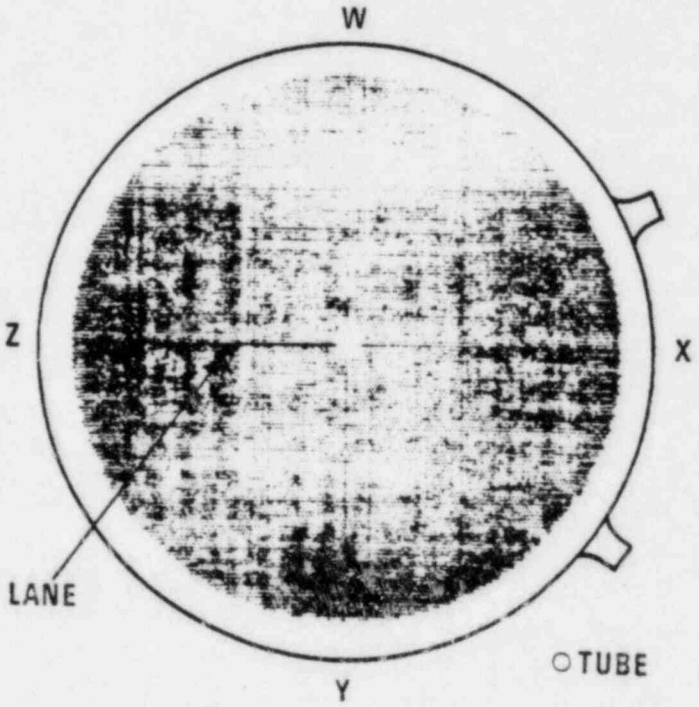
September 15, 1982

TMI-1 Steam Generator

ELEVATION



CROSS SECTION



Weight, operating	637 tons
Height	73 feet
Primary flow	69×10^6 #/hr.
Steam flow	6.1×10^6 #/hr.
Number tubes	15531
Tube size, material	0.625" od, .034 wall inconel 600
Manufacture date	5/69 to 11/70

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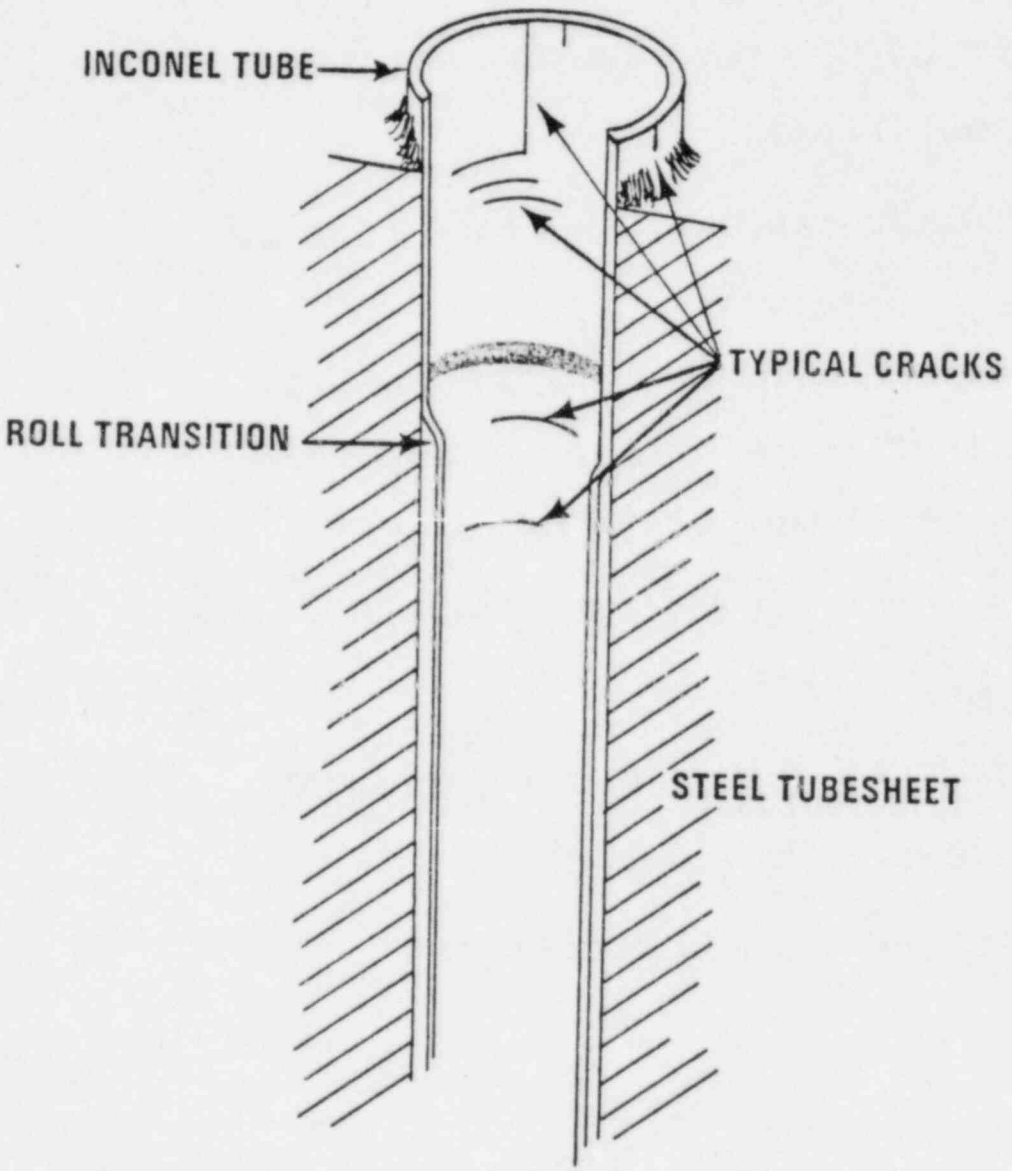
TMI-1 Steam Generator
Typical Cracks



CRACK CHARACTERISTICS:
- CIRCUMFERENTIAL BELOW FILET WELD
- NOT FULL ARC
- GENERALLY VERY TIGHT
- PRIMARY SIDE INITIATED

TMI-1 OTSG Repair Process (Steps/Sequence)

1. Flush secondary side tube/tubesheet crevice (complete)
2. Heat crevice to drive out moisture (in process)
3. Pre-coat OTSG surfaces
4. Kinetically expand tubes for 17" or 22"
5. Cleanup debris
   A. Organic residue on RCS surfaces
   B. Explosive particulate residue
   C. Pieces of polyethylene candle
6. Plug tubes with defects below UTS + 8"
7. Leak tests
8. Plug or roll leaking tubes (if required)
9. RCS cleanup (if required)
10. Pre-critical operational testing

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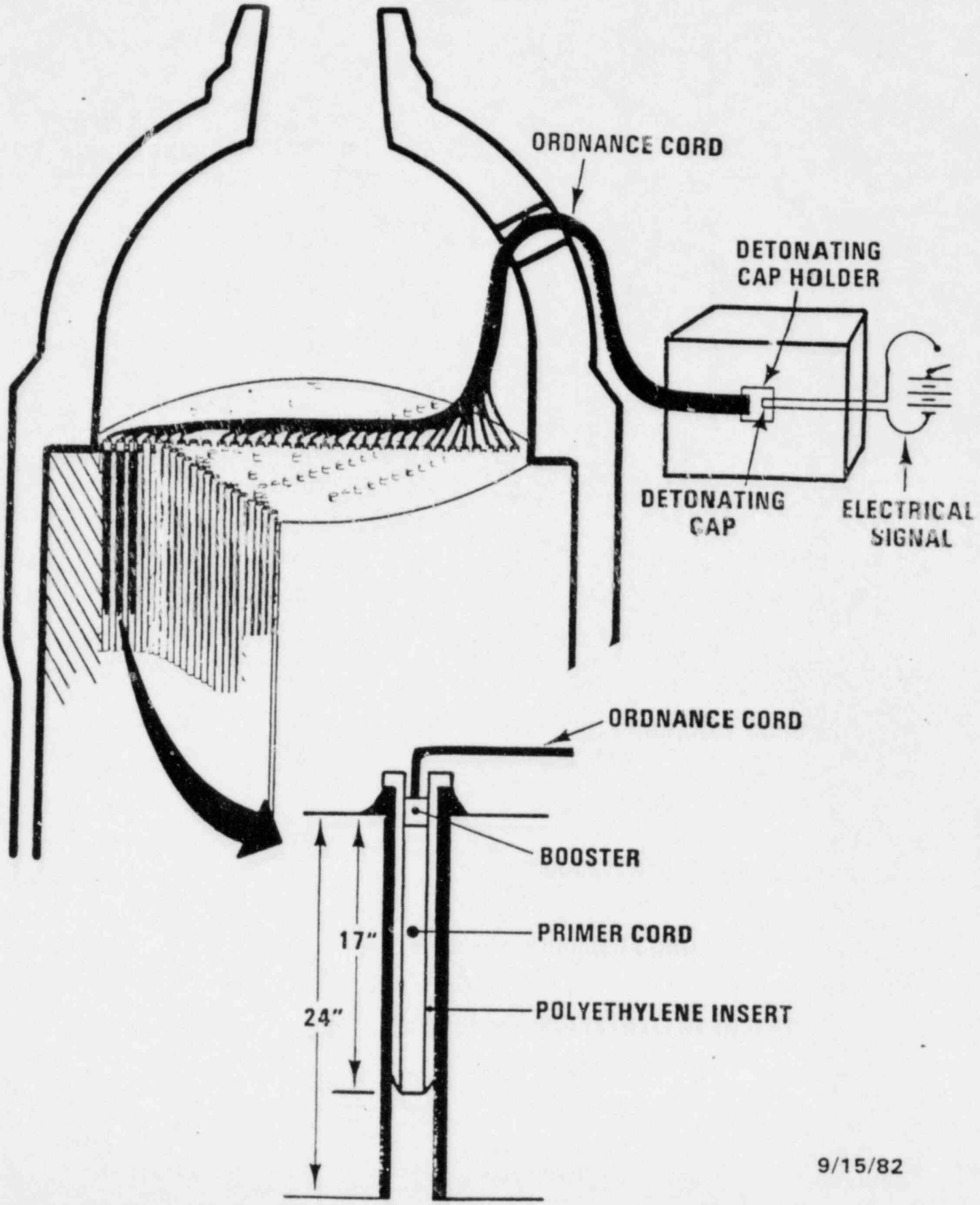
KINETIC EXPANSION PROCESS



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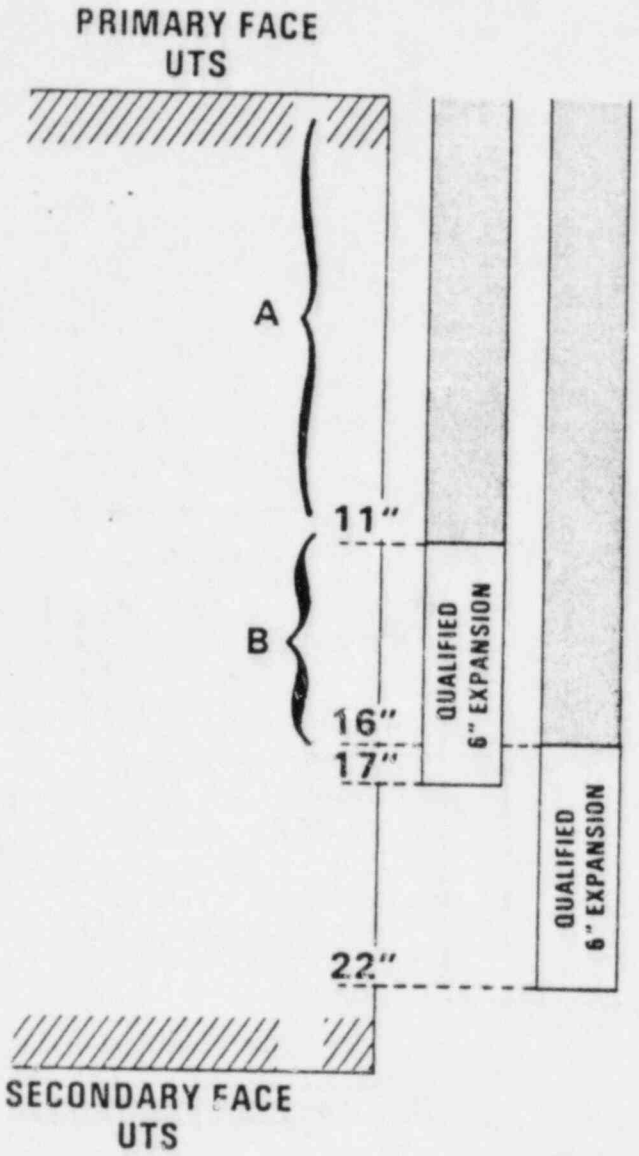
Kinetic Expansion Length
(Repaired Tubes)



ZONE WITH DEFECTS*	LENGTH OF EXPANSION
A	17
B	22

*TUBES WITH MULTIPLE DEFECTS IN THESE ZONE COMBINATIONS TO RECEIVE 22" EXPANSIONS

AB

15TH TSP

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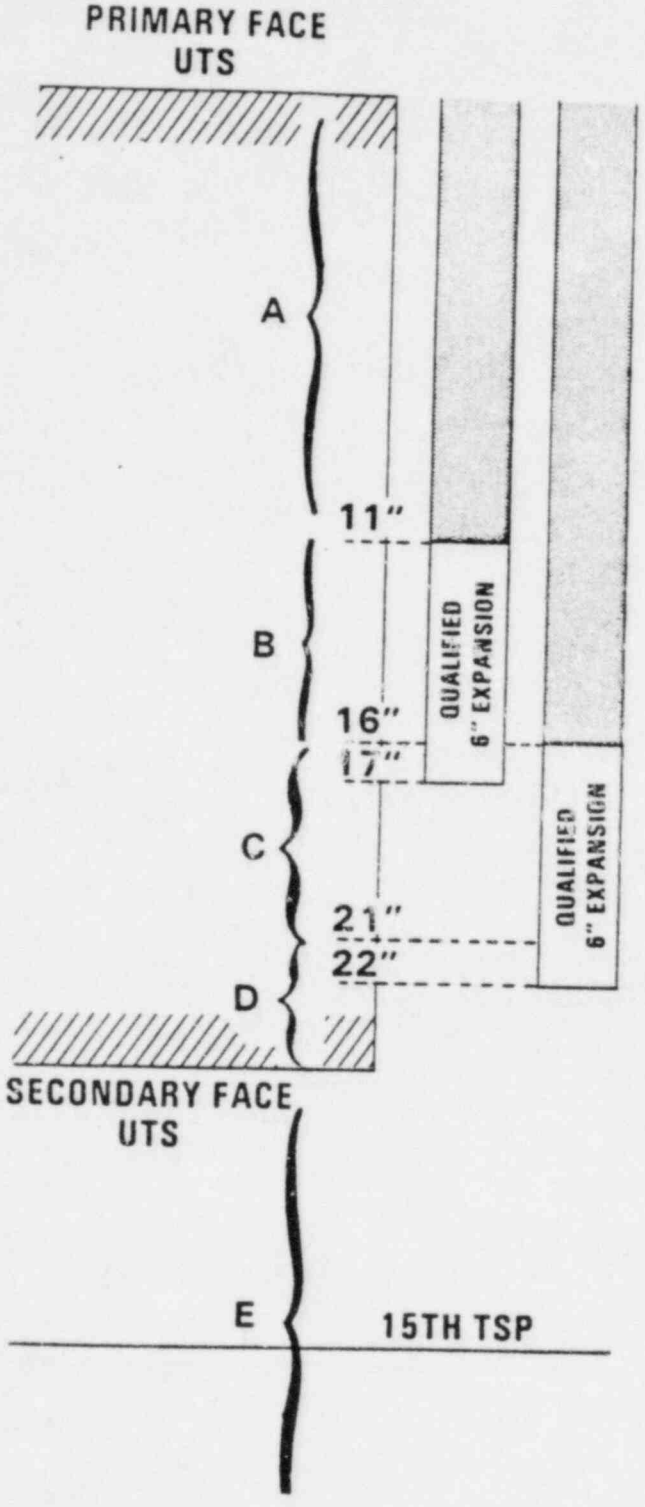
Kinetic Expansion Length
(Plugged Tubes)



ZONE WITH DEFECTS*	LENGTH OF EXPANSION
C	22
D	17
E	17

*TUBES WITH MULTIPLE DEFECTS IN THESE ZONE COMBINATIONS TO RECEIVE 22" EXPANSIONS

AC
BC
CE

*ALL REMAINING TUBES WITH MULTIPLE DEFECTS AND NON-DEFECTIVE TUBES TO RECEIVE 17" EXPANSIONS

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Kinetic Expansion Experience

Foster Wheeler

- Expanded over 5,000,000 tubes in heat exchangers over last 20 years
- CRBRP intermediate heat exchanger (17,100 expansions)
- Repaired MSR's at Salem 1 and 2 (17,640 expansions)

B&W

- Tested as manufacturing process - 3 tubes inservice at Oconee III with 24" expansions at both ends

W

- Used in field to close tube to tubesheet crevice on steam generators

CE

- Used to close steam generator tube to tubesheet crevice during manufacture

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Repair Criteria

(1) The maximum allowable primary-to-secondary leakage rate for normal operation shall be as low as reasonably achievable and allow plant operation within the radioactive effluent limits of the technical specifications.

Repair Criteria

(2) Repaired tube shall sustain, with adequate margins, the design basis loads

Loads	Generic 177FA	TMI-1
LOCA	+ 2641 lb	+ 2641 lb
MSLB	+ 3140 lb	+ 3140 lb
FWLB	- 620 lb	- 620 lb
Normal cooldown:	+ 1107 lb	+ 1107 lb

+ = tension

- = compression

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Repair Criteria

(3) The effects of both repaired and plugged tubes on the thermal and hydraulic performance of the plant and on the structural and vibrational adequacy of the steam generator shall be evaluated and shall be within the acceptance criteria for both normal operating and design basis accident conditions as specified in the licensing basis documents.

Third Party Review

Purpose

To provide a timely, independent, objective, safety evaluation of all activities defined in (the scope of) this charter for conformance to:

1) the NRC rules and regulations governing the operation of TMI-1
2) the adequacy of the steam generator repair program that will allow safe operation of the nuclear unit

Scope

- Failure analysis program
- Eddy current examination program
- OTSG performance evaluation
- Repair criteria
- OTSG repair program

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Qualification Program Elements

Foster Wheeler

- Load carrying capability and leak tightness

Babcock and Wilcox

- New transition stresses
- Chemical constituents of kinetic expansion device and residue
- OTSG cleanup - use of precoat and final OTSG surface residue concentrations

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Other Program Elements

Technical support considerations

- OTSG design basis
- Presence of IGSCC

Site preparations

- Crevice dry
- Explosive handling
- Effect of process on other equipment

Quality control

- Manufacturing facilities
- During implementation at TMI-1

ALARA

Third Party Review

MEMBERSHIP	SPECIALITY AREA
Stephen Brown -EPRI NDE Center	Non Destructive Examination
S.A. Holland -Duke Power Co.	Plant Operations
Arturs Kalnins -Lehigh University	Stress Analysis
W.H. Layman -NSAC	Safety Analysis
David J. Morgan -Penn. Power & Light	Chemistry
E.J. Wagner* -Burns & Roe	Steam Generator Design and Performance
Dick Weeks -Argonne National Lab	Materials

*Chairman

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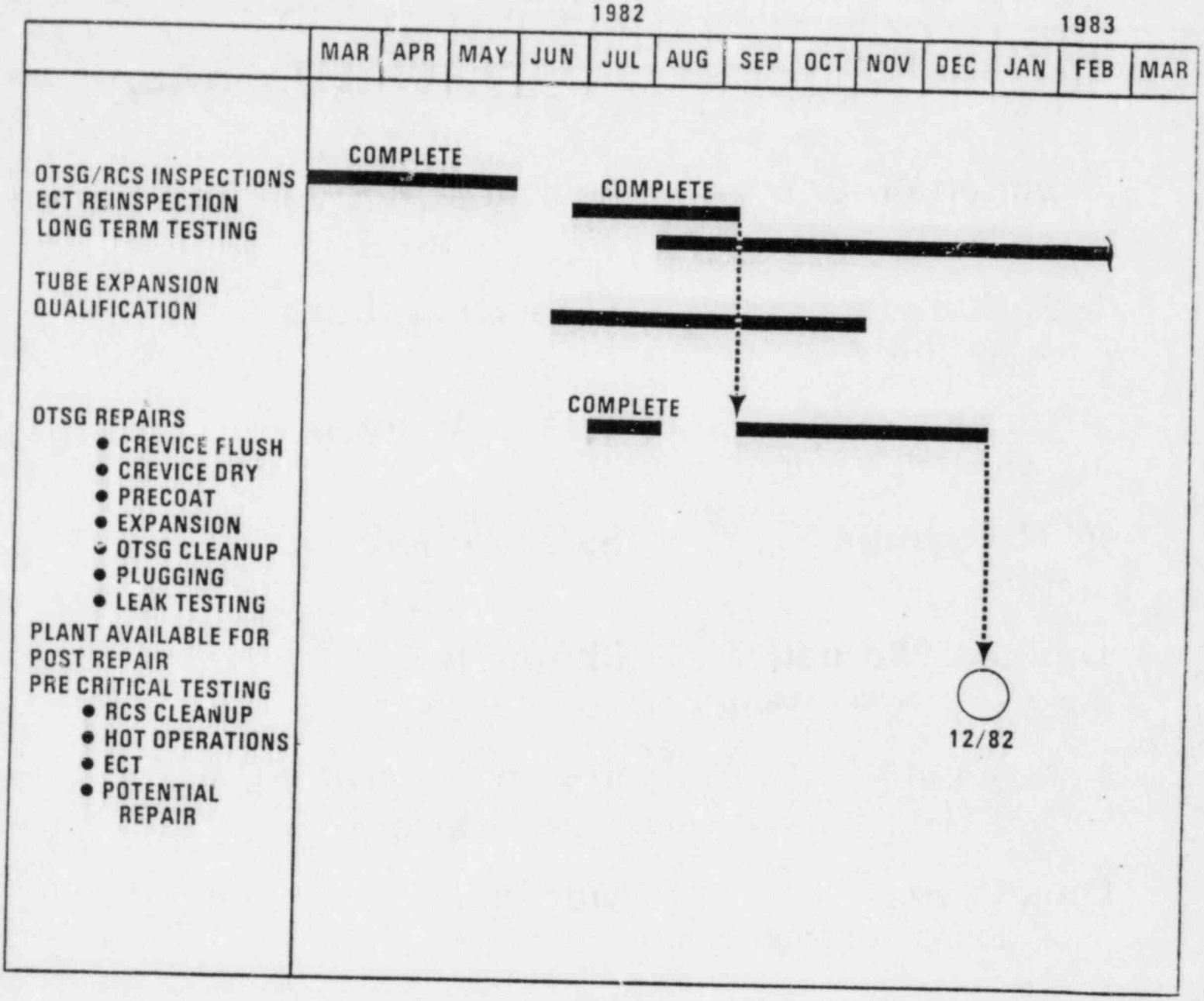
OTSG Repair Program Plan/Schedule



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Key Elements of Qualification Program

I. Joint qualification

- Prototypical kinetic expansions
- Proof test expanded joints
- Thermal cycle condition joints
- Axial load condition joints
- Determine water leak rates
- Determine joint pullout strength

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Key Elements of Qualification Program Continued

II. Supporting tests

- Evaluate residual stress at joint transition
- Determine adjacent shot effects
- Determine double expansion effects
- Evaluate joint integrity with different crevice corrosion
- Determine joint strength with different annulus size
- Determine induced strain effects
- Evaluate tubesheet ligament distortion

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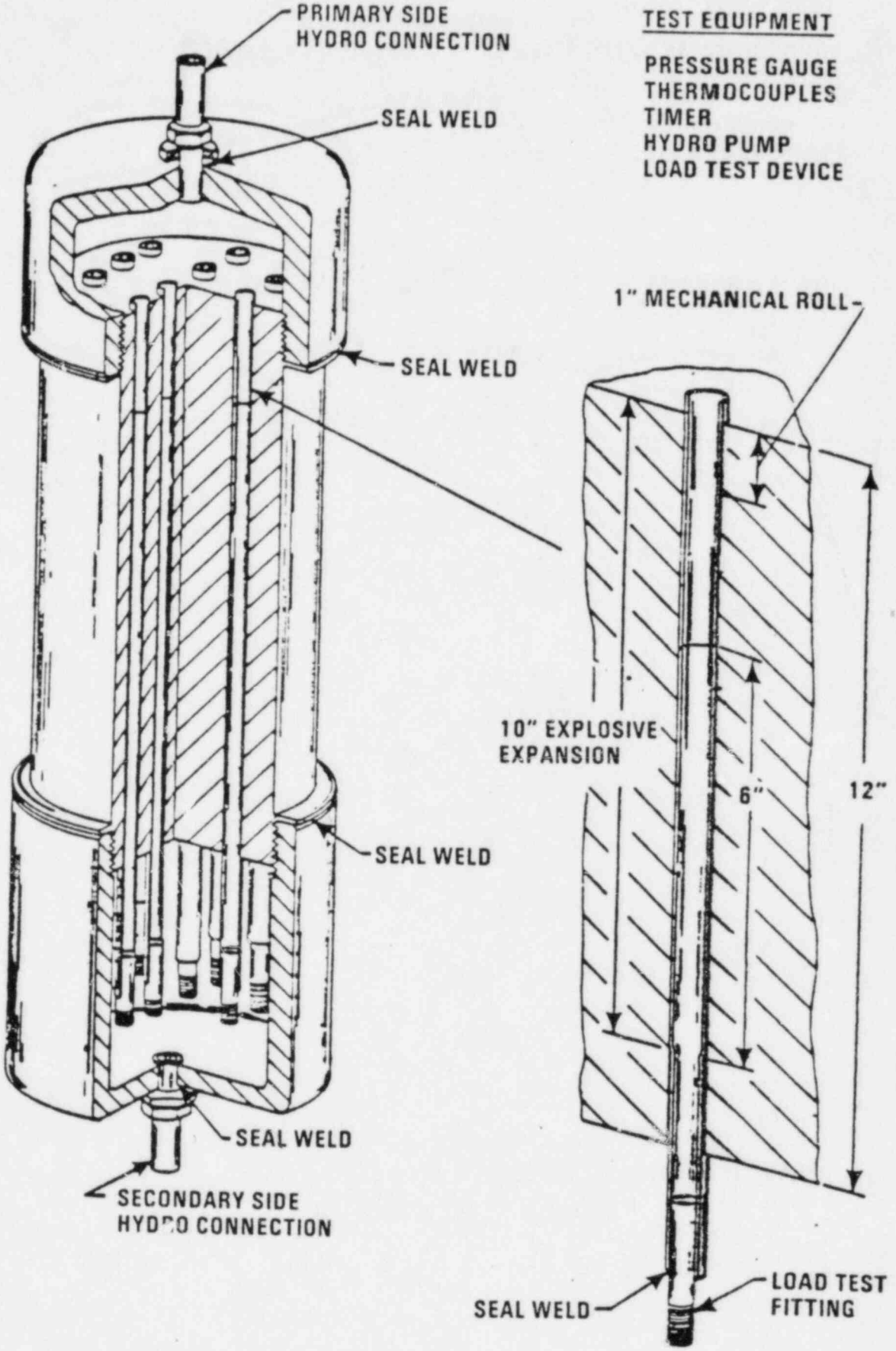
10 Tube
Leak and Load Test Fixture



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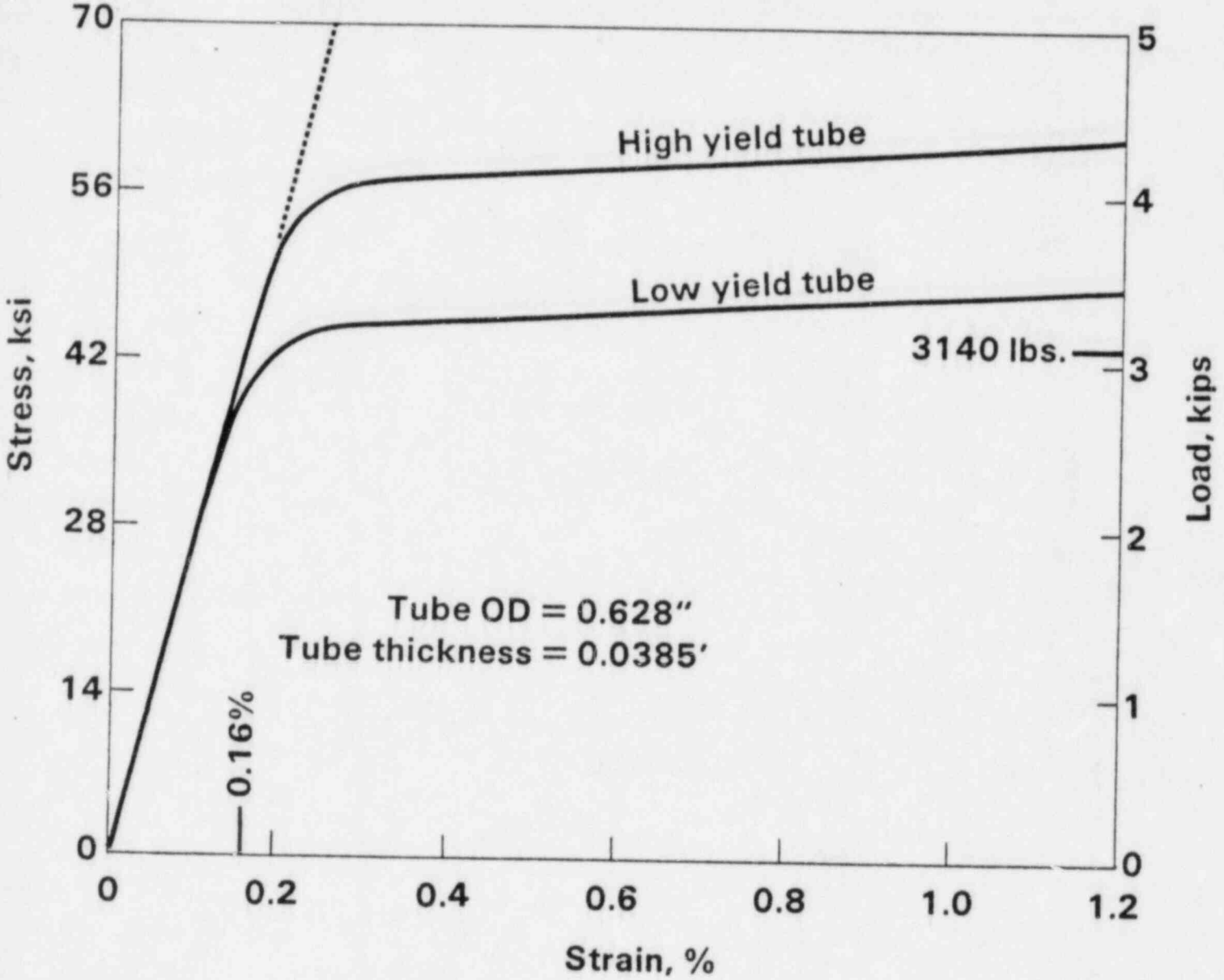
Pullout Load Design Basis



Design basis: 0.16% strain at 3140 lb. load for
0.625" OD X 0.034" wall tube

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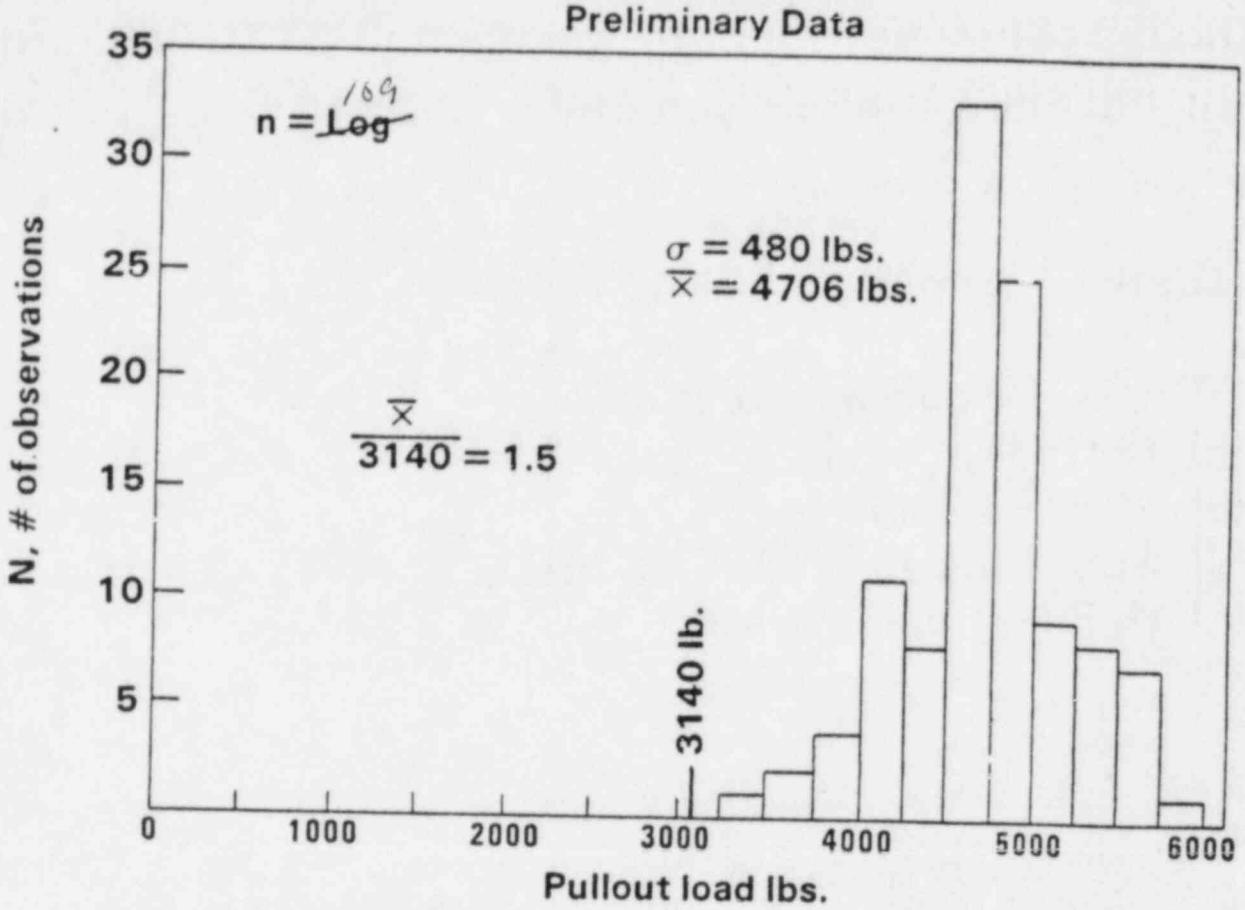
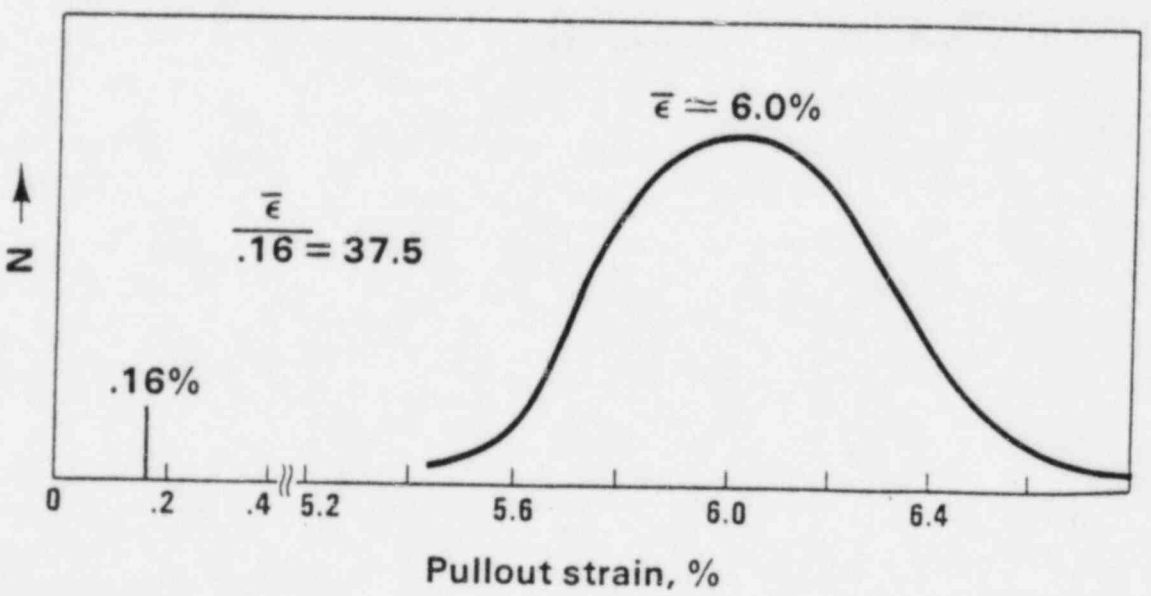
Pullout Load Qualification Criterion

Pull-out load of 3140 lb. with 99% probability at 99% confidence level



The above assumes a load-controlled behavior
Actual event is thermally induced (strain-controlled)



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Water Leak Rate

Design objective: 1 lbm/hr. per plant ($3.2X10^{-5}$ lbm/hr./tube)

Qualification program objective : $3.2X10^{-6}$ lb./hr./tube

Qualification data points for

(a) 10 tube average/test block
(b) Corroded blocks
(c) 6" Expansion
(d) 360° fully severed tube (defect)
(e) Demineralized water

- ~ $2.4X10^{-6}$ lb./hr./tube
- ~ $10.5X10^{-6}$ lb./hr./tube
- ~ $23.3X10^{-6}$ lb./hr./tube (after thermal cycling, equivalent of 5 year life)
- ~ $30.3X10^{-6}$ lb./hr./tube (after thermal cycling, equivalent of 5 year life)

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Water Leak Rate Measurement

Leak rate is measured using pressure decay of an enclosed water volume under pressure

$$\text{Leak Rate} = \rho V \left[\underbrace{(K+K') \frac{dP}{dt}}_{\text{Pressure Effect}} + \underbrace{(\beta'-\beta) \frac{dT}{dt}}_{\text{Temperature Effect}} \right]$$

Where,

- ρ = Density of water
- V = Water volume
- K = Isothermal compressibility of water
- K′ = Structural elasticity of enclosure
- β' = Coeff. for enclosure volume change due to temperature
- β = Coeff. of volumetric expansion for water due to temperature

$\frac{dP}{dt}$ = Rate of water pressure change

$\frac{dT}{dt}$ = Rate of water temperature change

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Error Analysis for Leak Rate

Physical constants	~ 5%
Temperature correction	~ 20%
Other measurements	~ 3%

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B&W Presentation

- Qualification Program
  - Kinetic expansion transition
  - Control of materials
  - Process residue characterized
  - Immunol precoat
  - Clean Up
- Technical Support Activities - Effect of Process
  - Existing crack-indications
  - Pressure vessel integrity
- Site Preparations
  - Crevice drying tests
  - Maintaining crevice dry
  - Mt. Vernon test
  - Explosive handling
- Quality Activities
  - Off-site preparation efforts
  - Site effort
- ALARA

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B&W Presentation

- Qualification Program
- Technical Support Activities
- Site Preparations
- Quality Activities
- ALARA Update

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Qualification Program

Kinetic Expansion Transition

- Design Objectives:
  - Transition length
    - Required $> 0.1''$
    - Goal $> 0.125''$
- Verification Program
  - Prequal mockups $\geq 0.15''$
  - Residual stress measurements/Penn State x-ray defraction
  - Mt. Vernon test - 0.3" to 0.45"
  - Accelerated corrosion test in 10% NaOH -kinetic/hard roll
- Transition produced more gradual than those with sat. service
  - Years of sat. operation with stress relieved hard roll
  - Kinetic expansion transition is longer than hard roll
  - $>$ 100 unstress relieved roll transitions remain in service after 9 years/Oconee I

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Qualification Program

Control Of Materials

- Specifications
  - Sulfur $\leq$ 250 ppm
  - Chloride and fluoride $\leq$ 250 ppm
  - Heavy metals $\leq$ MDC*
- Process materials analyzed at source
- Cleanness controls implemented - from source to OTSG
  - Manufacturing
  - Assembly
  - Site handling & storage
- Changes made in materials to avoid introducing harmful elements
  - Transfer cord for detonator cord
  - Organic booster substituted
  - Eliminated resin coating in detonator cord
- Only acceptable materials introduced into OTSG
- Cold leg and hot leg plugs utilized to contain debris

*MDC - Minimum Detectable Concentration

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Qualification Program

Post Expansion Residue

- Bulk Material
  - Readily removable by hand/vacuuming
- Surface Contamination
  - Harmful elements controlled to acceptable levels by specifications for materials used in OTSG
  - Adherent semi-transparent film with carbonaceous residue deposited on surfaces

    May affect heat transfer
    May affect sulfur removal
- Desirable to reduce quantity
  - Minimize net accumulation in RCS
  - Prevent interference with sulfur removal

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Qualification Program

Immunol Precoat

Precoat - facilitates removal of surface contamination

- Immunol - a cleaning agent
  - water soluble
  - acceptable chemistry
  - extensive data available
- Effectiveness visually confirmed
  - Mt. Vernon tests
  - Mockups
- Evaluating - interaction with sulfur
  - effect on H_2O_2 process

- Application
  - Manual spray - dome, tubesheet & tubes
    - Flood ID of tubes
  - Barrier at hot/cold leg to confine precoat

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Qualification Program

Clean Up

- Bulk Material Removal
  - Manual - debris in heads
  - Air assist ejection of candles from tubes
- Surface Contamination
  - Wipe head and tubesheet
  - Felt plugs blown thru tubes
  - Rinse
- Acceptance Criteria - surface swipes to meet
  - B&W established standard halogen levels

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Process Effect On Cracks/Indications

- Test Results (30 gr./ft)
  - 100% through wall crack opened slightly
  - No ductile growth axially
  - No ductile growth circumferencially
  - Conclusion: crack did not grow
- Leakage Tends to be Self Sealing
  - CR-3 operating experience
  - ARC model boiler test results
    - ~ 5 tubes defected/1 to 2 gph leakage
    - After 1000 hrs operation - no leakage
    - CRUD & corrosion products seal leaks
    - Tubesheet corrosion insignificant by inspection

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Pressure Vessel Integrity

Assessment

- Requirements of satisfactory repair
  - Maintain structural integrity
  - Maintain acceptable leak rate
- Structural integrity criteria - meet ASME code stress limits
  - Residual stresses in transition below acceptable past practice
  - Tube preload change controlled within acceptable limits
  - Process does not structurally degrade vessel
- Leakage design objective - total ≤ 1 lbm/hr
- Demonstration of meeting the criteria
  - Repair tested for maximum faulted tube load
  - Original design analyses remain valid
  - Residual stresses in the transition region are minimized

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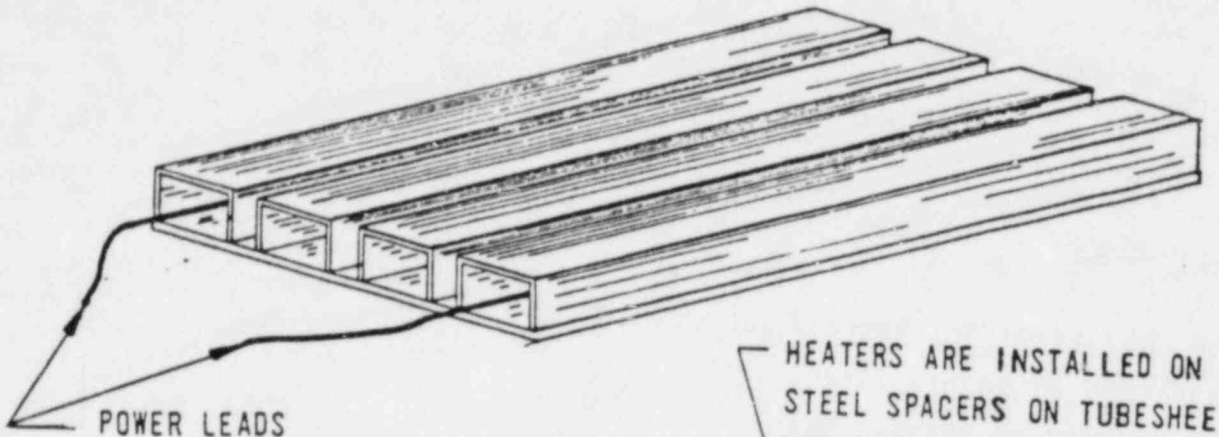
Pressure Vessel Integrity
(Continued)

- Mt. Vernon test results (132 tubes)
  - Dynamic stress for tubesheet and shell < yield stress
  - Change in axial tube load < 30 lbs
  - Dynamic pressure wave is small
  - PT examination of tube-to-tubesheet weld shows no damage
- Test shows no measurable ligament distortion
- Analysis of crevice drying procedure indicates acceptable stresses

- Demonstration of meeting the criteria (continued)
  - Qualification leak testing conservatively performed at room temperature

- Conclusions
  - The OTSG's continue to meet the requirements of the ASME Code

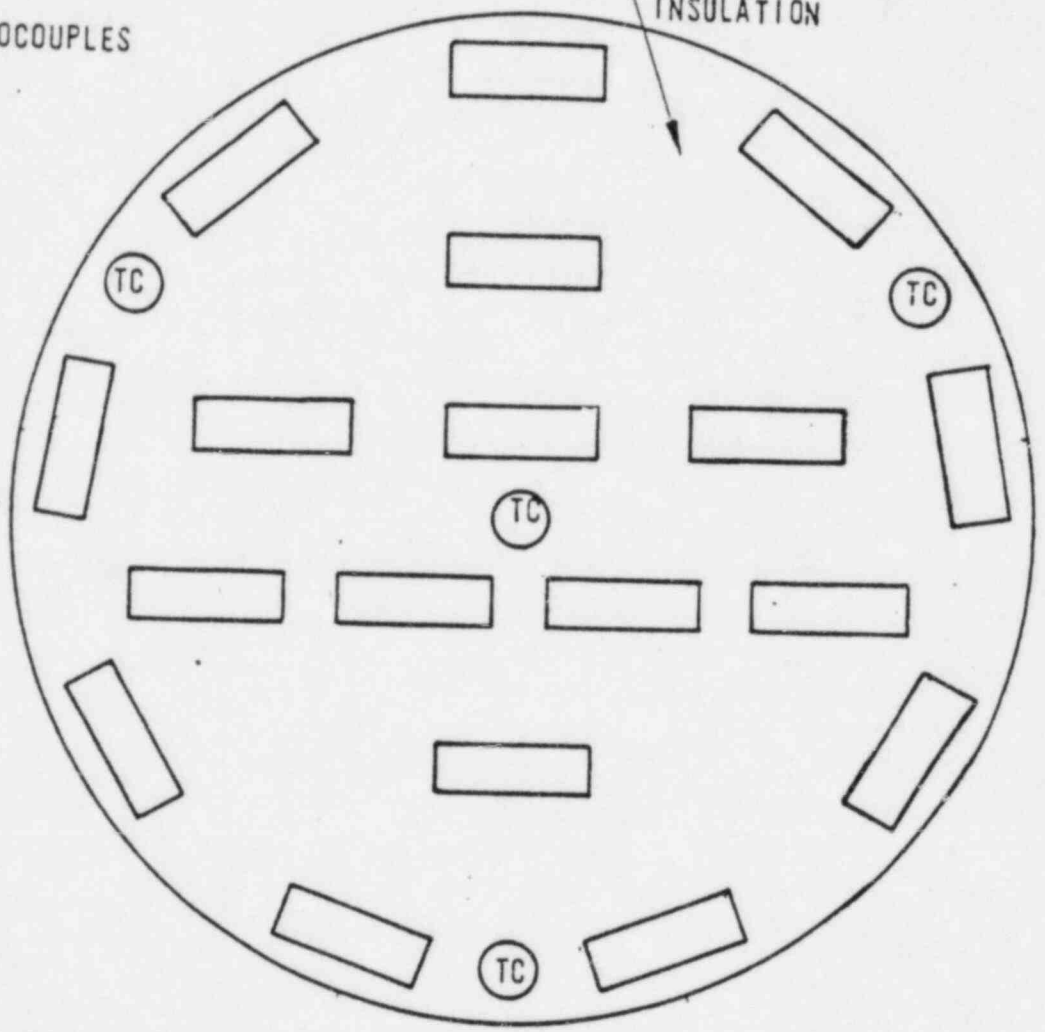
Crevice Drying



POWER LEADS

HEATERS ARE INSTALLED ON STAINLESS STEEL SPACERS ON TUBESHEET AND ENTIRE TOP SURFACE OF HEATERS IS COVERED WITH INSULATION

(TC) — THERMOCOUPLES



PRIMARY MANWAY →

- UPPER SURFACE $\leq$ 300°F
- LOWER SURFACE $\geq$ 10° ABOVE T_{SAT} (~ 125°F)
- TIME REQUIRED $\simeq$ 4 HOURS
- PERFORMANCE CONFIRMED BY MT. VERNON TEST

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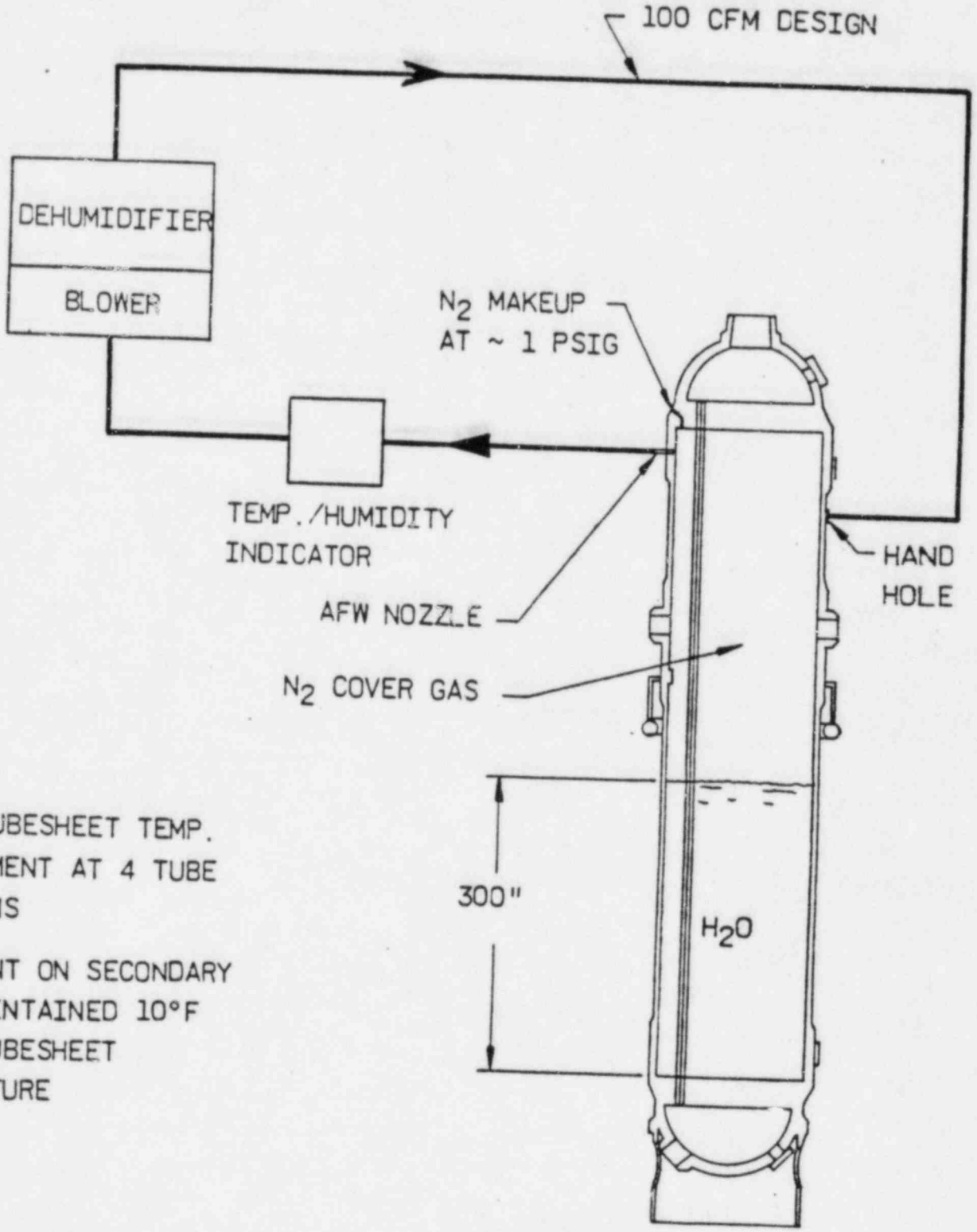
Maintaining Crevice Dry

Forced Circulating System



NOTES:

- UPPER TUBESHEET TEMP. MEASUREMENT AT 4 TUBE LOCATIONS
- DEW POINT ON SECONDARY SIDE MAINTAINED 10°F BELOW TUBESHEET TEMPERATURE

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Mt. Vernon Test

Accomplishments

- Verified shock to tubesheet is within acceptable limits
- Allowed full dress mockup training, testing of installation tool and procedures
- Provided verification of the reliability of support systems
- Allowed refinement of expansion process resulting in estimated exposure savings of 200 manrem
- Assessed magnitude of post expansion cleaning
- Performed expansion pull test

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Site Preparations

Explosive Handling

- Established procedures for handling operations
- Trained technicians, licensed explosives handler
- Approved storage containers
- Insert storage outside containment
- Activities regulated/monitored by the state of Pennsylvania
- Minimal quantity of inserts in containment
- Inventory under concurrent control of plant security and FWEA licensed explosives handler
- Handling operations directly supervised by licensed handler and inspector
- Class C explosive
  - Least hazardous explosives rating
  - Requires high energy shock for detonation
  - Can be shipped by commercial carrier

Quality Activities

Off Site-Qualification Program

- GPUN & B&W specifications for qualification program
- Coordinated test plan
- FWEA QA verify test control (Monitored by B&W and GPUN)
  - FWEA specs and procedures for testing
  - Trained technicians
  - Calibrated instruments
  - Documented results

Quality Activities

Off Site - Manufacturing

- B&W approved FWEA specifications to subvendors
- Chemical analysis of components
- Cleanliness requirements applied in process
- In-process verification of dimensional requirements
- In-process overchecking of components supplied by subvendors
- FW overcheck verification of grains/foot

Kinetic Expansion
ALARA Estimates

Man-rem Exposure Estimates

Crevice drying	20
Manual tube marking	10
Pre-coating tubes	*
In-generator testing	10
Process expansion	
-insert installation	70
-insert removal	100
-debris removal	5
Tube/tubesheet/dome cleaning	*
Closeout inspection	2
Total	217

(excluding precoating of tubes and cleanup)

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Quality Activities

Site Effort

- Shipping and storage in approved containers
- Receipt inspection for shipping damage
- Comply with state of Pennsylvania explosives handling and storage requirements
- In-process QC monitoring includes
  - Verification of procedure compliance
  - Plant condition prerequisites
  - Process control to separate high and low charge density inserts
  - Expansion in whole row "lots"
  - Physically mark tubes to be expanded to 22"
  - Random performance sampling by E/C, tube ID measurements and periodic tube expansions outside OTSG
- Video overview and record of operations

Summary

- Testing and analysis continues to indicate that kinetic expansion is practical for application to TMI-1
- We can conclude that implementation of the kinetic expansion process will not do irreparable damage to the OTSG
- Preliminary and final qualification testing and analysis confirms with reasonable assurance that the process fulfills specification requirements
- Planning, training and rehearsal are essentially completed
- Implement repair process at TMI-1