UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 16, 1996

MEMORANDUM TO: David B. Matthews, Chief
Generic Issues and Environmental Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

FROM: Claudia M. Craig, Senior Project Manager Claudia M. Craig
Generic Issues and Environmental Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF MEETING WITH WESTINGHOUSE TO DISCUSS ROOT CAUSE DETERMINATION FOR INCOMPLETE ROD CLUSTER CONTROL ASSEMBLY (RCCA) INSERTION

The subject meeting was held at the Nuclear Regulatory Commission (NRC) office in Rockville, Maryland on September 9, 1996, between representatives of Westinghouse and the NRC staff. Members of the Westinghouse Owners Group (WOG) also attended. The purpose of the meeting was for Westinghouse to provide its root cause determination for the incomplete RCCA insertions that have occurred. Attachment 1 is the list of meeting participants. Westinghouse provided both proprietary and non-proprietary versions of the presentation materials in a letter dated September 4, 1996. Attachment 2 is a copy of the non-proprietary presentation material provided at the meeting.

Westinghouse determined the root cause by examining a number of different factors including: results of site testing, review of plant trip history, review of plant operation and fuel management, results of hot cell measurement and testing, review of zircaloy material properties, review of manufacturing process, development of a mechanical model, and review of world-wide experience. During the meeting, Westinghouse provided a brief history of the issue, provided a summary of each of the above factors, and reviewed their conclusions regarding the susceptibility of fuel types to incomplete insertion which were presented to the staff in a June 27, 1996 meeting. Westinghouse stated that results from site testing performed subsequent to the June 27, 1996 meeting, have confirmed their fuel susceptibility conclusions. Westinghouse also indicated that the conclusions discussed during the meeting were specific to Wolf Creek only and the incomplete RCCA insertion issue at South Texas will be addressed separately at a later time.

Based on Westinghouse data and models for Westinghouse fuel, Westinghouse provided the staff the following root cause conclusions:

1) The incomplete RCCA insertions observed at Wolf Creek have been caused by excessive compressive loads on the fuel assembly guide thimble tubes which led to excessive thimble tube distortion.

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RD-8-2 Westinghouse
96-124

1/1 DF03

2) For Wolf Creek, the increased compressive load was caused by unusual fuel assembly growth over and above what would normally be expected as a result of irradiation exposure.

3) The unusual growth component is a combination of growth due to oxide accumulation and accelerated growth, both of which are temperature sensitive.

4) The unusual growth is observed only in high temperature plants on those high burnup fuel assemblies that have certain types of power histories.

During the proprietary portion of the meeting, Westinghouse presented detailed data in support of their conclusions.

Westinghouse also outlined its future plans and schedule: a preliminary report will be submitted to the NRC on October 15, 1996; the South Texas root cause will be completed mid-October; and the final root cause report will be submitted to the NRC on December 31, 1996. Westinghouse will continue to manage areas of susceptibility and plans to review fuel assembly design for possible changes by December 31, 1996.

Attachments: As stated

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WESTINGHOUSE / NRC MEETING
INCOMPLETE RCCA INSERTION
SEPTEMBER 9, 1996 AT ROCKVILLE, MD

MEETING PARTICIPANTS

NAME	ORGANIZATION
Claudia Craig	NRC/NRR/PGEB
Margaret Chatterton	NRC/NRR/SRXB
Eric Weiss	NRC/NRR/SRXB
Robert Jones	NRC/NRR/SRXB
H.F. Conrad	NRC/NRR/EMCB
Howard Menke	Westinghouse
Sumit Ray	Westinghouse
Ron Kesterson	Westinghouse
Ron Knott	Westinghouse
Lynn Connor	for STS
Robert Borsum	FTI
Mike Schoppman	Florida Power & Light
William A. Cross	STS
Satoshi Azumi	Kansai Electric Power
Andrea Keim	NRC/NRR/SRXB
Larry Kopp	NRC/NRR/SRXB
Shih-Liang Wu	NRC/NRR/SRXB
Pete Kokolakis	NYPA
Andrew Drake	WOG Project OFfice
Rick Kohrt	Wisconsin Electric
Vance VanderBurg	AEP/WOG Analysis Subcommittee
Ricahrd Clark	Duke Power
Tom Brookmire	Virginia Power
Harold Scott	NRC/RES
Scott Ferguson	Wolf Creek Nuclear
Ernie Kee	HL&P - South Texas Project
Randy Irwin	Union Electric
Scott Head	HL&P - STP
Stephen Koenick	NRC/NRR/PECB
Don Curet	Siemens Power Corp.
Jan Kozyra	Carolina Power & Light
Steve Katradis	NUS Corp.
John Glamebush	Westinghouse Nuclear Safety
Kris Thomas	NRC/NRR
David McDaniel	Northeast Utilities
Nayeem Farukhi	Westinghouse

ATTACHMENT 1

Westinghouse Presentation to the NRC:

"Incomplete Rod Cluster Control Assembly (RCCA) Insertion, Root Cause Determination"

September 9, 1996

Westinghouse Presentation to the NRC:

"Incomplete Rod Cluster Control Assembly (RCCA) Insertion, Root Cause Determination"

September 9, 1996

AGENDA

- Background
- Program Status Overview
- Root Cause Conclusions
- Future Plans and Schedule

- Proprietary Portion -

- Root Cause Determination Process
- Site Testing Results
- Materials Investigations
- Hot Cell Examinations and Tests
- Model Development
- Root Cause Conclusions
- Future Plans

BACKGROUND

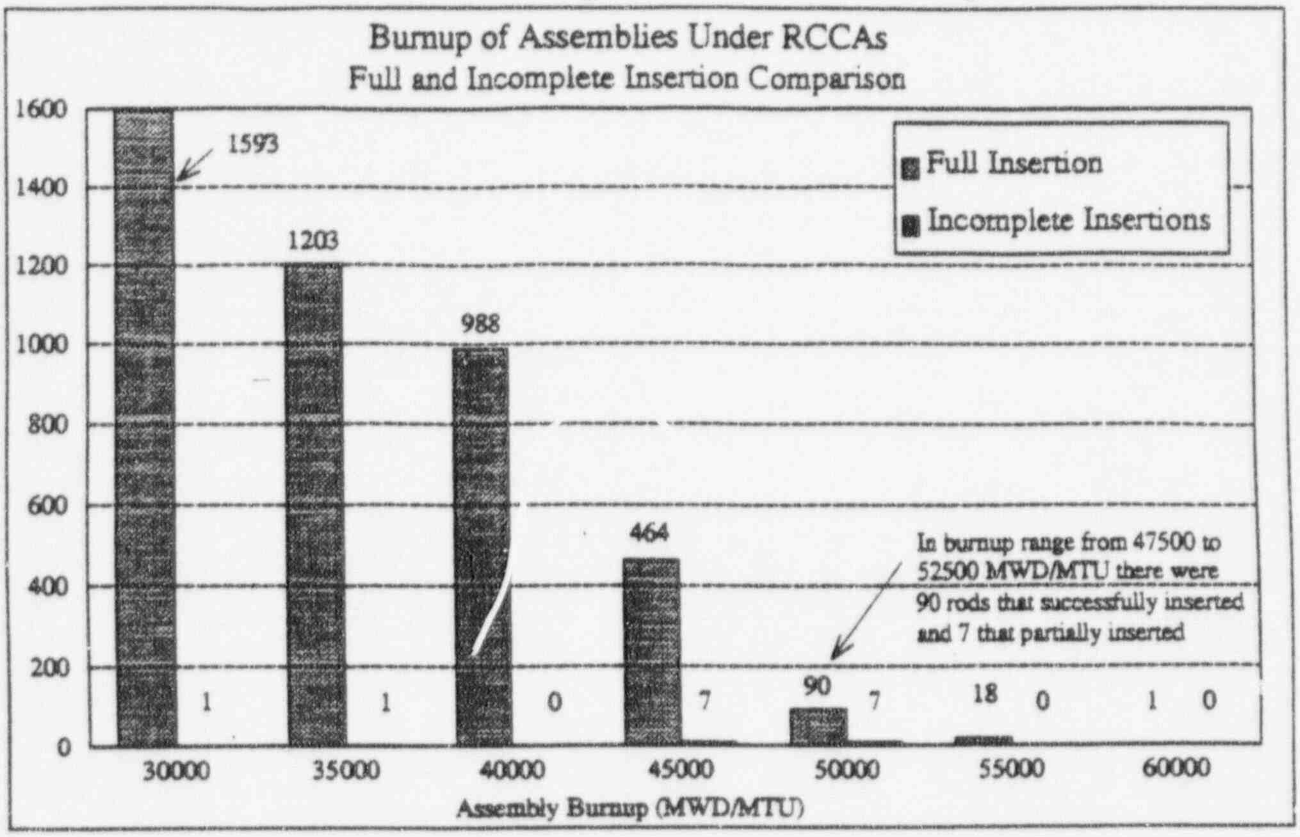
- South Texas Event 12/95
- Wolf Creek Event 01/96
- NRC Contacted WOG/ WOG Responded to 14 NRC Questions 02/96
- W/WOG/NRC Meeting 02/96
- Bulletin 96-01 Issued 03/96
- NRC/W/WOG Meeting 03/96

  Commitment for:

  - Susceptible Fuel 06/15/96
  - Root Cause 08/31/96
- W/WOG/NRC Meeting 05/96
- W Meeting with NRC on Susceptible Fuel 06/27/96
- WOG/NRC meeting 08/96

SUMMARY OF PLANT TRIP INFORMATION

- Data From 50 Plants (Westinghouse & Non-Westinghouse Fuel)



BU (GWD/MTU) Range Under	Number FAs Showing Full	Number FAs Showing Incomplete
27.5 - 32.5	1593	1
32.5 - 37.5	1203	1
37.5 - 42.5	988	0
42.5 - 47.5	464	7
47.5 - 52.5	90	7
52.5 - 57.5	18	0
57.5 - 62.5	1	0

SKELETON ASSEMBLY COMPARISON

Isolation of the Population that may be Susceptible

Spent Fuel Pool Testing Program
(F/A length measurements, RCCA drag tests, Single tube probe drag tests, Top and bottom fuel rod gap measurements)

Manufacturing and material time period 1 (Pre Wolf Creek)	Manufacturing and material time period 2 (Wolf Creek vintage)	Manufacturing and material time period 3 (Post Wolf Creek)
14x14, 15x15 OFA	14x14, 15x15 OFA	14x14, 15x15 OFA
17x17 V5H	17x17 V5H	17x17 V5H
17x17 OFA	17x17 OFA	17x17 OFA

RCCA Insertion Experience
Complete collection of past trip data
Monitor spring shutdown rod drop testing

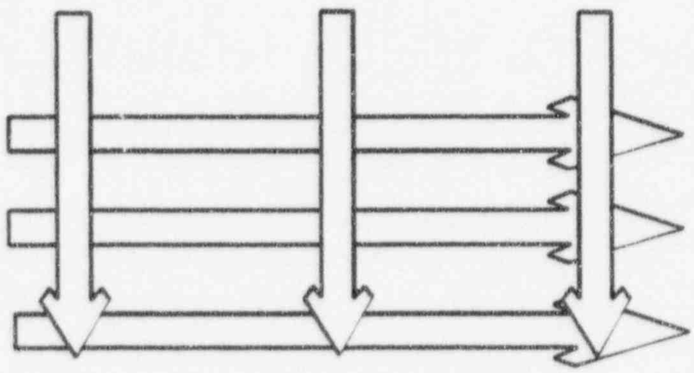
17x17 OFA

17x17 V5H

17x17 XL

15x15 OFA

14x14 OFA



PROGRAM STATUS OVERVIEW

- The site testing program has been completed

Plant	Fuel Type	Visuals	Drag Testing	Growth	Probe	Boroscope
Wolf Creek	17x17 V5H	✓	✓	✓	✓	✓
	17x17 V5H w/IFM	✓	✓	✓	✓	NP
	17x17 STD	✓	✓	✓	NP	NP
Millstone 3	17x17 V5H w/IFM	✓	✓	✓	✓	NP
South Texas	17x17 XL	✓	✓	✓	✓	✓
Point Beach	14x14 OFA	✓	✓	✓	✓	NP
Surry	15x15 OFA	✓	✓	✓	✓	NP
VC Summer	17x17 OFA w/IFM	✓	✓	✓	✓	NP
Sequoyah	17x17 V5H	✓	✓		✓	NP
Diablo Canyon	17x17 OFA w/IFM	✓	NP	✓	✓	NP
North Anna	17x17 V5H	NP	✓	✓	✓	NP
Vogtle	17x17 OFA w/IFM	✓	✓	✓	✓	NP

NP = not planned

Susceptibility Conclusions

- Based on data and analysis, fuel with IFMs is not susceptible to incomplete insertion
- The manufacturing period does not affect susceptibility to incomplete insertion
- Twelve-foot Westinghouse fuel is not susceptible below a burnup of 40,000 MWD/MTU
- Based on data to date, while it appears that 14x14 and 15x15 fuel are less susceptible, it is difficult at this time to make a definitive conclusion

Subsequent site testing results have confirmed susceptibility conclusions

Testing conducted after 6/27 NRC meeting

• Millstone 3	17x17 V5H w/IFM
• Sequoyah	17x17 V5H
• Diablo Canyon	17x17 OFA w/IFM
• South Texas	17x17 XL

Conclusions

- IFM assemblies show similar characteristics as those previously tested, and confirm that IFM assemblies are not susceptible to incomplete insertion

- 40,000 MWD/MTU threshold for exceeding both F-spec drag criteria continues to remain valid for 12-foot W fuel

- Thimble tubes in other plants from same lot and similar burnups as Wolf Creek did not show unusual growth confirming that this is not a manufacturing- related issue

Hot cell testing program required for incomplete insertion has been completed

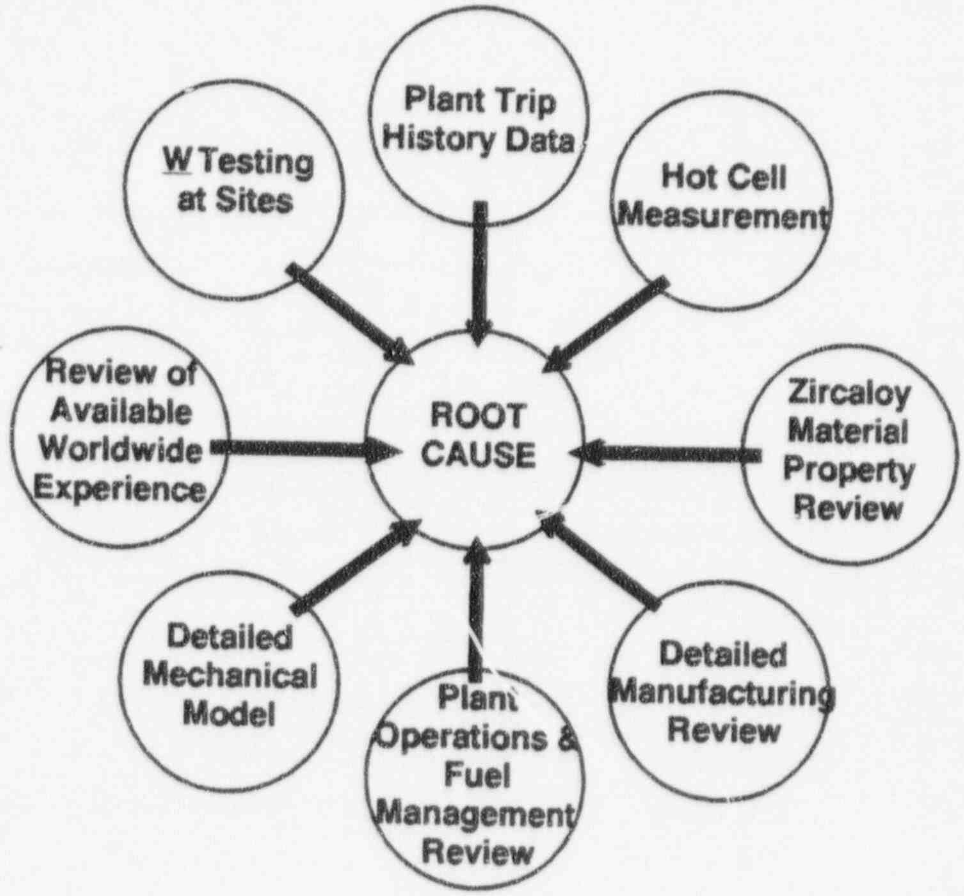
Purpose of Hot Cell Examination

- To perform an in-depth testing of the characteristics of the skeletons of two of the incomplete insertion assemblies (H50 & H38) observed at Wolf Creek

Testing Program

- Visual examination
- Thimble tube dimension measurements
- Metallography examination
- Oxide measurements
- Hydrogen measurements
- Tensile tests

ROOT CAUSE DETERMINATION PROCESS



ROOT CAUSE CONCLUSIONS

All conclusions are based upon Westinghouse data and models for Westinghouse fuel

- The incomplete RCCA insertions observed at Wolf Creek have been caused by excessive compressive loads on the fuel assembly guide thimble tubes leading to excessive thimble tube distortion.
- For Wolf Creek, the increased compressive load was caused by unusual fuel assembly growth over and above what would normally be expected as a result of irradiation exposure.
- The unusual growth component is a combination of growth due to oxide accumulation and accelerated growth, both of which are temperature sensitive.
- The unusual growth is observed only in high temperature plants on those high burnup fuel assemblies that have certain types of power histories.

FUTURE PLANS & SCHEDULE

Schedule

•	Preliminary report to NRC	10/15
•	South Texas root cause	mid-October
•	Final report to NRC	12/31

Corrective Actions

•	Manage areas of susceptibility	Immediately
•	Review fuel assembly designs for possible changes	12/31

PROPRIETARY PORTION

ROOT CAUSE DETERMINATION PROCESS

Process & testing logic used to determine root cause

Determine extent of problem

- Plant trip history data

Related to design (V5H) or manufacturing?

- Materials and process review
- Testing program at ten sites

Related to plant operations?

- Chemistry
- Temperature/flow/power
- Fuel management

Material property related?

- Unirradiated tests
- Hot cell exams
- Literature review
- Consultant experts including General Electric

Root cause hypothesis

- Data analysis
- Analytical model

SITE TESTING RESULTS

RECENT SPENT FUEL POOL TESTING

- All planned tests have been completed
  - Diablo Canyon
  - Millstone 3
  - North Anna
  - Point Beach
  - Sequoyah
  - Surry
  - South Texas
  - Vogtle
  - VC Summer
  - Wolf Creek

- During this testing no abnormal growth was detected at plants other than Wolf Creek

- Drag testing results showed consistency between different fuel assembly types at various sites

- Probe results consistent with [ ][a,b,c]

RECENT ASSEMBLY GROWTH DATA

- Data consists of Zircaloy fuel assemblies only
- Data from measurements at
  - Diablo Canyon
  - Millstone 3
  - North Anna
  - Point Beach
  - Surry
  - South Texas
  - Vogtle
  - VC Summer
  - Wolf Creek
- Other than Wolf Creek "H" and some VC Summer assemblies, data are consistent with existing Westinghouse database
- Low growth seen in all fuel with [ ][a,b,c]

Recent Assembly Growth Zr-4 Grid Data Only

a,b,c

[ ]

Recent Assembly Growth Inconel Grid Data Only

a,b,c

Assembly Growth Data (Zircaloy Grid Only)

a,b,c

DASHPOT AND UPPER GUIDE THIMBLE DRAG DATA (SPENT FUEL POOL TESTING)

- Data from 12 units
  - 17x17 V5 (OFA)
  - 17x17 V5H
  - 14x14 OFA
  - 15x15 OFA
- Data obtained from measurement of fuel stored in spent fuel pool for at least two months
- All fuel assemblies which contained RCCAs during operation had full insertion
  - [ ]a,b,c

Dashpot and Upper Guide Thimble Drag Data (Spent Fuel Pool Testing)

a,b,c

Dashpot Drag and Fast Fluence Data
(Spent Fuel Pool Testing)

a,b,c

Upper Guide Thimble Drag and Fast Fluence Data (Spent Fuel Pool Testing)

a,b,c

DASHPOT AND UPPER GUIDE THIMBLE DRAG DATA
(DRAG MEASURED AFTER REACTOR TRIP)

- Data from 12′ fuel assemblies at 10 different sites
  - 17x17 V5 (OFA)
  - 17x17 V5H
  - 17x17 XL
  - 14x14 OFA
  - 15x15 OFA

- Data obtained from measurements either in reactor vessel or shortly after fuel assemblies transferred to spent fuel pool

- Other than Wolf Creek and South Texas, none of these plants have had incomplete RCCA insertion

- Both F-spec criteria [ ]^{a,b,c} need to be exceeded to produce incomplete RCCA insertion in W 12′ fuel

- For 14′ fuel, [ ]^{a,b,c} upper guide thimble drag and [ ]^{a,b,c} dashpot drag were observed, consistent with expectations

Dashpot and Upper Guide Thimble Drag Data
(Drag Measured after Reactor Trip)

a,b,c

[ ]

Dashpot Drag and Fast Fluence Data
(Drag Measured after Reactor Trip)

a,b,c

Upper Guide Thimble Drag and Fast Fluence Data
(Drag Measured after Reactor Trip)

a,b,c

SOUTH TEXAS EXAMINATION RESULTS

- [ ]a,b,c observed for all incomplete insertion assemblies and some complete insertion assemblies
- All upper guide thimble tube drags are [ ]a,b,c
- Drag at [ ]a,b,c
- Single tube probing [ ]a,b,c
- Growth measurements are [ ]a,b,c

South Texas 1 Dashpot and Upper Guide Thimble Drag Data (Drag Measured after Reactor Trip)

a,b,c

South Texas 1 Dashpot and Fast Fluence Data
(Drag Measured after Reactor Trip)

a,b,c

South Texas 1 Guide Thimble Drag and Fast Fluence Data (Drag Measured after Reactor Trip)

a,b,c

THIMBLE TUBE PROBE TESTING

Objective

- Determine nature and extent of thimble tube distortion

Method

- Probe dashpots and guide tubes [

  ]a,b,c

PROBE PLAN/SEQUENCE

[

•

•

•][a,b,c]

TUBE PROBE INDICATIONS

[

-
-
-
-
-
-
-

]a,b,c

THIMBLE TUBE PROBING

Results/Conclusions

- At any given span, [
  ]a,b,c

- Distortion is primarily due to [
  ]a,b,c

- Locations/extent of distortion [
  ]a,b,c

SITE TESTING CONCLUSIONS

- High growth seen for Wolf Creek "H" assemblies
- Region "H" assemblies in Wolf Creek are unique in
  - Fuel assembly growth
  - [ ][a,b,c]
- South Texas has [ ][a,b,c]
- In all 12-foot assemblies distortion is evidenced as bow, not cross section distortion
- The manufacturing period does not affect susceptibility to incomplete insertion
- Based on data and analysis, fuel with IFMs is not susceptible to incomplete insertion
- 12' Westinghouse fuel is not susceptible below a burnup of 40,000 MWD/MTU

EMPIRICAL OBSERVATIONS OF GROWTH DATA

For assemblies where lengths were measured, operating history information was collected in database

Characteristics such as cycles, cycle time, power, temperatures and flow were analyzed

Evaluations of the data indicates that the following conditions exist with abnormal growth

- [
-
-
-][a,b,c]

Growth vs Fluence - 3 Cycle data

a,b,c

Growth vs Fluence - 2 cycle data

a,b,c

OBSERVATIONS RELATED TO GROWTH DATA

- Fuel assemblies showing high growth are only seen in high temperature plants
- High temperature seems to be a necessary but not sufficient condition for high growth
- For high temperature plants specific power histories may promote high growth
- Number of cycles appears to affect growth

POWER HISTORY

- [ ][a,b,c] are needed for high growth

[a,b,c]

[ ]

- Data from Vogtle, Wolf Creek and Summer
- Low growths seen for [ ][a,b,c]

MATERIALS INVESTIGATIONS

- Materials testing
- Manufacturing process
- Hot cell examination and tests
- Oxide/hydride growth factors

MATERIALS TESTING

- Testing performed on archive samples
  - [
  -
  -
  -
  -][a,b,c]

MANUFACTURING PROCESS

- Process/product change timeline indicates no impact from changes
- Original test results were within expected limits
- [ ][a,b,c] of the thimble tube production lots were used for non-Wolf Creek assemblies
- Diablo Canyon and Vogtle assemblies with thimble tubes from the same lots as Wolf Creek show no abnormal growth
- All planned activities are complete no anomalies in process or material were found

RECENT ASSEMBLY GROWTH DATA

a,b,c

LOT SEQUENCE

a,b,c

- Material from eleven ingots were used to produce the "H" assembly thimble tubes.
    - No specific ingot impact on the high growth
- 68 thimble tube lots were produced during the same time window of the Wolf Creek thimble tube production, 23 of these lots were associated with Wolf Creek. Of these 23 lots, more than 50% of the individual tubes from the 23 lots were used to fabricate skeletons other than Wolf Creek
- No specific lot impact on the high growth

HOT CELL EXAMINATIONS AND TESTS

HOT CELL EXAMINATIONS

- H50 and H38 skeletoı. at Westinghouse hot cell
- Visual examination
  - OD appearance vs length
  - Grids and instrumentation tube
  - No spalling or anomalous condition
- Length measurements
  - Performed on sections with two grids in place - 3 sections plus dashpot
  - [

    ][a,b,c]

MEASURED SPAN GROWTH
H-50 ASSEMBLY

a,b,c

Note: Parenthesis show estimated growth

Laser Profilometry

[

-

-

-

][a,b,c]

a,b,c

THIMBLE TUBE DIAMETER MEASUREMENTS

[•

•

•

]a,b,c

a,b,c

• Profilometry data characterizations are continuing

METALLOGRAPHY

- Initial results indicate OD and ID oxide is [ ][a,b,c]

- Oxide thickness varies with [length, with fluence, and with temperature profile][a,b,c]

- Maximum measured oxide thickness was [ ][a,b,c]

- Wall thickness variations are [ ][a,b,c]

- Hydride platelet density corresponds to [ ][a,b,c]

H50 ASSEMBLY PROFILE WITH OXIDE, HYDROGEN AND DIMENSIONAL CHANGES

a,b,c

[ ]

Note: % values are based on nominal drawing dimensions

OXIDE/HYDROGEN GROWTH EFFECTS

- Samples tested in autoclave show [ ][a,b,c]

- [ ][a,b,c] water for accelerated corrosion results in [ ][a,b,c]

a,b,c

a,b,c

- Dimensional changes measured on samples hydrided in [ ]a,b,c

- Hydrided samples had [ ]a,b,c

- Hydride growth factor is about [ ]a,b,c

- Measured autoclave sample growth were [ ]a,b,c

a,b,c

a,b,c

- Oxide/hydride impact is related to [ ]a,b,c and function of temperature and time

- Impacts on Wolf Creek "H" assembly growth [ ]a,b,c are predicted to be [ ]a,b,c

ESTIMATE OF OXIDE AND HYDRIDE IMPACT ON H-50 MEASURED GROWTH

a,b,c

Note: Values in parenthesis represent growth difference between measured and estimated oxide/hydride impacts

MODEL DEVELOPMENT

- Material growth model
    - Accelerated growth
    - Mechanical model

ACCELERATED GROWTH

- Total growth = normal saturation growth + accelerated growth

- Normal saturation growth term is primarily a function of fluence

- Accelerated growth term is a function of fluence and temperature and material condition

- Temperature dependent accelerated growth mechanisms

    - Higher temperature leads to:
        - Formation of C-loop dislocations
        - Dissolution of precipitates such as iron and chrome into the zirconium matrix
    - Iron/chrome dissolution stabilizes C-loop dislocations
    - Increasing number of stabilized C-loop dislocations enhances growth; including stresses from hydride and oxide

- Evaluated industry data and reviewed information with non-W experts (including GE)

- Developed best estimate curve with fluence and temperature variables

Irradiation Growth vs Fluence

a,b,c

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MECHANICAL MODEL - THIMBLE TUBE DISTORTION

A mechanical model has been developed that calculates thimble tube distortion. Input to the model includes:

a,b,c

• Assembly BOL holddown spring force	• Fuel rod weight
• Assembly buoyancy	• Grid drag force
• Assembly holddown spring fast flux	• Grid fast flux
• Assembly holddown spring rate	• Mid-span fast flux
• Assembly hydraulic lift	• Mid-span temperature
• Assembly weight	• Rod-to-bottom nozzle BOL gap
• Clad ID	• Skeleton thimble bow prior to rod loading
• Clad OD	• Thimble ID
• Cycle length	• Thimble OD
• Fuel rod buoyancy	• Thimble span length
• Fuel rod hydraulic lift	• Irradiated growth model
• T_{cold}, T_{Hot}	• Oxide growth model
• Fuel Assembly power distribution	

The model is constructed to account for [

]a,b,c. These properties are then used to calculate [

]a,b,c.

Parameters calculated at each time step include:

a,b,c

• Assembly growth	• Thimble axial creep per span
• Assembly holddown spring load	• Thimble axial growth due to oxide per span
• Assembly lateral bow per grid	• Thimble axial load per span
• Clad elastic modulus per span	• Thimble axial stress free irradiation growth per span
• Fuel rod axial load per span	• Thimble elastic modulus per span
• Fuel rod growth per span	• Thimble lateral bow per span
• Grid drag per grid	
• Thimble oxide thickness per span	

MECHANICAL MODEL

- Model developed and correlated to [
  ]a,b,c
    - [
    -]a,b,c
- Other inputs to model
    - [
    -]a,b,c
- Model verified to field measurements from plants
    - [
    -
    -]a,b,c

KEY CONCLUSIONS OF GROWTH RESULTS FROM MECHANICAL MODEL

- Predicts fuel assembly growth differences between Wolf Creek "H" and "J" assemblies as well as South Texas
- Axial span growth agrees well with hot cell results
- Relative magnitude of span bow agrees with drag/probe results

Measured vs Predicted Assembly Growth

a,b,c

Predicted and Measured Assembly Growth

a,b,c

The open data points are the measured values and the closed data points are the predicted values

MECHANICAL MODEL THIMBLE BOW

- Three typical assemblies analyzed
  - Wolf Creek H50 and J32
  - South Texas F26

- Relative span bow magnitudes agree well with drag/probe results

- Fuel assembly H50 results illustrate [ ][a,b,c]

Wolf Creek F/A H50

a,b,c

Wolf Creek F/A J32

a,b,c

South Texas F/ F26

a,b,c

INCOMPLETE RCCA INSERTION IFM SUSCEPTIBILITY

Both Vogtle and VC Summer (high burnup and temperature) drag tests indicate:

- All RCCAs inserted
- Drag is [ ]^{a,b,c}
- Drag [ ]^{a,b,c}

- Mechanical model - Wolf Creek H & J analysis, J32 assembly analyzed with H50 power history
  - Growth is [ ]^{a,b,c}
  - [ ]^{a,b,c} are significantly lower in bow

a,b,c

ROOT CAUSE CONCLUSIONS

CONCLUSIONS

- Incomplete RCCA insertion is caused by thimble tube distortion which results from high compressive loads
- For 12′ Westinghouse fuel assemblies, high growth is necessary in order to cause sufficient distortion to initiate incomplete RCCA insertion
- High temperature is necessary but not sufficient for high growth for 12′ Westinghouse
- Only fuel assemblies with certain types of power histories show unusual growth in high temperature plants
- Unusual growth component is a combination of growth due to oxide accumulation and accelerated growth
  - [ ][a,b,c] saturation growth
  - Accelerated and oxide growth
- Oxide growth and accelerated growth components are dependent on temperature and power history

ROOT CAUSE CONCLUSIONS

All conclusions are based upon Westinghouse data and models for Westinghouse fuel

- The incomplete RCCA insertions observed at Wolf Creek have been caused by excessive compressive loads on the fuel assembly guide thimble tubes leading to excessive thimble tube distortion
- For Wolf Creek, the increased compressive load was caused by unusual fuel assembly growth over and above what would normally be expected as a result of irradiation exposure
- The unusual growth component is a combination of growth due to oxide accumulation and accelerated growth, both of which are temperature sensitive
- The unusual growth is observed only in high temperature plants on those high burnup fuel assemblies that have certain types of power histories

IMPLICATIONS OF ROCT CAUSE ANALYSIS

- For 12′ Westinghouse fuel assembly designs within currently licensed burnups, potential problem only if all conditions below are met
  - Zircaloy 4 thimble tubes
  - >40K MWD/MTU burnup [ ][a,b,c]
  - No IFM grids
  - High temp plant [ ][a,b,c]
- Data to date shows high growth in high temperature plants [ ][a,b,c]

FUTURE PLANS

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- Schedule
  - Preliminary report to NRC — 10/15/96
  - South Texas root cause — mid-October
  - Final report to NRC — 12/31/96

- Ongoing Program
  - Expand database
  - Continue refinement of mechanical and growth models
  - Support South Texas root cause
  - Investigate high burnup 12′ design
    - Zirlo in hot cell for evaluation

CONSIDERATIONS FOR CORRECTIVE ACTIONS

- Use of low growth materials for thimble tubes (Zirlo)
- Specific fuel management for high temperature plants to control susceptibility
- Investigate additional possible changes to fuel assembly design