

proj. 712



## Global Nuclear Fuel

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Document Control Desk  
U. S. Nuclear Regulatory Commission  
Washington, DC 20555-0001

Attention: Chief, Information Management Branch  
Program Management  
Policy Development and Analysis Staff

Attention: J. Donoghue

Subject: **Presentation Material For GEXL Presentation – Non-proprietary Slides**

Attached is presentation material for the February 11, 2002 meeting requested by the staff to discuss the GEXL correlations for GE12 and GE14 fuel, documented in submitted topical reports NEDC-32464P and NEDC-32851P submitted in September 2001.

This attachment contains the non-proprietary version of the presentation. The proprietary version was transmitted on January 28, 2002, in letter FLN-2002-001.

If you have further questions, please give me a call.

Sincerely,

A handwritten signature in black ink, appearing to read 'Glen A. Watford', with a stylized flourish at the end.

Glen A. Watford, Manager  
Fuel Engineering Services  
(910) 675-5446

cc: R. Caruso (NRC)

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**Global Nuclear Fuel**

A Joint Venture of GE, Toshiba, & Mitsubishi

# **GE12/GE14 10x10 Designs GEXL Critical Power Correlation**

**January 2002**

- **Background**
- **Definition of Issue**
- **Corrective Actions**
  - GE12 recommended uncertainty
  - Proposed testing program
  - Interim corrective actions
  - Preventive actions
- **Double-humped power shape assessment**
- **Staff feedback**

# Critical Power Testing

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- **7x7 design, GETAB basis, GEXL correlation development (1977)**
  - Extensive testing to evaluate sensitivity to axial power shape (inlet, outlet, cosine, uniform, double humped)
  - Basic formulation of correlation developed to account for axial power shape sensitivity
- **Initial 8x8 designs (1977)**
  - Cosine power shape testing only
  - Applied uncertainty from 7x7 testing to account for axial power shape uncertainty
  - Basic correlation capable of predicting axial power shape trends
  - Relied on similarity between designs to extend this conclusion (GETAB basis)
- **Later 8x8 designs, GEXL+ correlation development (1988)**
  - Cosine and inlet peaked testing only
  - Detailed review by PNL/NRC
  - Approved for application over all three power shapes
- **GE11/GE13 9x9 designs (1991, 1993)**
  - Introduction of part length fuel rods
  - Extensive testing with cosine, inlet & outlet shapes
  - COBRAG subchannel code benchmarked to data
  - NRC Amendment 22 audit review - test matrix design review developed as result of audit
- **GE12 10x10 design (1994)**
  - Cosine power shape testing only
  - Supplemented with COBRAG predictions
  - Reviewed by NRC during 1995 Wilmington inspection
- **GE14 10x10 design (1998)**
  - Initially cosine power shape testing
  - Supplemented with COBRAG predictions
  - Subsequent testing with cosine and inlet peaked

**B. Mozafari (USNRC) to G. Van Middlesworth (NMC), "Duane Arnold Energy Center – Request for Additional Information on the Proposed Extended Power Uprate Program (TAC No. MB0543)," dated June 4, 2001.**

**Letter, G. Van Middlesworth (NMC), "Response to Request for Additional Information (RAI) to Technical Specification Change Request TSCR-042 – Extended Power Uprate (TAC # MB0543)," dated July 19, 2001.**

**NEDC-32851P, "GEXL14 Correlation for GE14 Fuel," Revision 2, September 2001.**

**NEDC-32464P, "GEXL10 Correlation for GE12 Fuel," Revision 2, September 2001.**

**Safety Evaluation by the Office of Nuclear Reactor Regulation, Related to Amendment No. 243 to Facility Operating License No. DPR-49, Nuclear Management Company, LLC Duane Arnold Energy Center, Docket No. 50-331, November 6, 2001.**

# Question 1 - Use of COBRAG

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## RAI Question

**“The COBRAG computer code was the critical power ratio (CPR) methodology used to predict critical power behavior throughout the core. The NRC staff has not reviewed this code. The licensee for DAEC has indicated that COBRAG uses first principle models to predict boiling transition and the details of the flow field. Justify the adequacy of the COBRAG code in predicting, from “first principles”, boiling transition phenomena in the upper portion of GE12 and GE14 fuels.”**

## RAI Response:

**GNF withdrew the use of COBRAG for the determination of the correlation uncertainty**

## NRC SER

**“... GNF has re-correlated the 10x10 fuel design (GE-12 and GE-14) based on experimental data only and included additional GE-14 fuel design testing. The NRC staff is currently reviewing the re-correlation and the additional test data conducted by GNF. In the interim, DAEC (and other similarly situated licensees) can continue to use the revised correlation, as described in and permitted by the approved GESTAR methodology.”**

## Question 2 - Test Data Adequacy



### RAI Question

**“Describe the testing of the new GE14 fuel that was conducted to test the respective CPR correlations. Identify any additional data, available or planned, to substantiate and validate the correlations. Provide upskeew or downskeew data that has been collected to validate the GEXL10 or the GEXL14 correlations for use at DAEC.”**

### RAI Response:

**Description of testing provided, included GE14 inlet and cosine axial power shapes**

### NRC SER

**“... In its response, the licensee stated that the GEXL10 correlation for GE-12 fuel was based on the full-scale ATLAS test points, all of which were cosine power shape. The licensee also discussed the design similarities between the GE-11 and GE-12 fuel lattice designs that affect the CPR performance of the two fuel designs and concluded that the GEXL10 correlation can be considered to be based upon test data points for both the GE-11 and GE-12 designs. The NRC staff evaluated the licensee’s justification that the similarity between the GE-11 and GE-12 fuel lattice designs was sufficient to accept the GE-11 database as representative of the GE-12 fuel in the development of the GEXL10 correlations. Based on the above, the NRC staff has accepted GE’s basis for the development of the GEXL10 correlation in the upskeew and downskeew power profiles ...**

**The licensee also stated that the GEXL14 correlation for GE-14 fuel was based on full-scale ATLAS test points with only a cosine axial power shape. Since the original GE-14 testing was performed, GE has performed additional testing in the ATLAS facility for the GE-14 fuel design for both cosine and inlet-peaked power shape...The NRC staff is currently reviewing the recorrelation and the additional test data conducted by GNF. In the interim, DAEC (and other similarly situated licensees) can continue to use the revised correlation, as described in and permitted by the approved GESTAR methodology.”**

## Question 3 - TDP-0117 and Amendment 22

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### RAI Question

**“Following an NRC Team Audit of GE11 fuel design compliance with Amendment 22 of NEDE-20411-PA, in 1992, GE was encouraged to develop a procedure for implementing Amendment 22 criteria for new correlation development as defined in GESTARII. This procedure is documented in TDP-0117, Rev. 2, page 8. Explain how the procedure was applied in the development of the GEXL14 correlation for use at DAEC, especially with regard to items 3 and 4, given the absence of raw data for upskew and downskew power profiles. Provide technical justification if the criteria of the Amendment 22 process criteria were not met.”**

### RAI Response:

**GE14 tests were performed in accordance with TDP-0117 (later discussions with staff indicated that TDP-0117 was written after completion of the GE14 tests and were written to match the actual testing performed for GE14). With removal of COBRAG data from uncertainty evaluations, GE12/GE14 is in compliance with Amendment 22 criteria.**

### NRC SER

**“... Since GNF has performed additional testing and re-correlated the 10x10 fuel design lattice in accordance with Amendment 22, the NRC staff is satisfied that GE and the licensee have conformed with previously approved methods and NRC staff evaluations.”**



## **Definition of Issues**

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**Further review of GNF submittals (NEDC-32464P and NEDC-32851P) has resulted in the following issues:**

## ***GE12 Correlation Uncertainty***

## GE12 Correlation Uncertainty

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## Location of boiling transition

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**GNF**

## GE11 inlet peaked results

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**GNF**

## GE11 cosine peaked results

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## GE11 outlet peaked results

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**GNF**





## Correlation uncertainties vs power shape

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- **Correlation uncertainties consistent over GEXL history**
- **Consistent between different power shapes**

## GE12 recommended uncertainty

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## Impact of recommended changes

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*Comparison to existing GE12 correlation statistics*

## ***GE14 Additional Testing***





## Proposed test matrix for GE14

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## Summary of test options

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- **Several options available**

## ***GE14 Interim Corrective Actions***

## GE14 interim corrective actions

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## GE14 interim corrective actions

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## GE14 interim corrective actions

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Power shape effect validated with design experiences



## Correlation uncertainties vs power shape

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- **Correlation uncertainties consistent over GEXL history**
- **Consistent between different power shapes**



# Impact of recommended changes for GE14

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*Comparison to existing GE14 correlation statistics*

## ***Safety Evaluation***

- *Various generic conservatisms in current process are adequate to accommodate this variation in SLMCPR*
- *Plant specific conservatisms are also available on case by case basis*
  - *Tech Spec SLMCPR > calculated value, result of utility choosing not to reduce Tech Spec value*

## ***Preventive Actions***



- Continue to track corrective and preventive actions through the GNF corrective action system

***Double-humped Axial Power  
Shape Assessment***

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# Critical power sensitivity to axial power shape

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- **Issue**

- KTH test results leads to observation that boiling length critical power correlation may be non-conservative for double humped axial power shapes

- **Evaluation**

- Boiling length critical power sensitivity to axial power shape
- Controlling physical phenomena

- **Survey of BWR Cores**

- **Benchmarking**

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**Not a Safety Concern**  
**Operating Limit Set by Most Limiting Power Shapes**

# Survey of Actual BWR Cores

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- **Typical core designs surveyed**

$$\text{CPRRAT} = \frac{\text{OLMCPR}}{\text{Bundle CPR}}$$

- **Double humped axial power shapes**
  - Typical for partially controlled bundles or adjacent bundles

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# Evaluation of double humped power shapes

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- **Most severe double humped axial power shapes identified**

## Estimated impact of double humped shape

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## Double-humped shape summary

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**No safety concern has been identified**

# Summary

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- Conservative uncertainties/biases applied to GE12 to develop appropriate correlation statistics
- Several options being investigated for GE14 outlet peaked testing
- Safety evaluation concludes that adequate margin exists in current process, plus plant-specific margin to accommodate GE12 change and GE14 interim penalty
- Double-humped axial power shape investigation still in progress - does not appear to be impact on limiting bundles



## ***Backups***

## ***Additional Test Data***

## BT Location Relative to Top of PLR

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***Note: In this table, spacers are numbered from the top of the core***

### *GE14 Predictions*



## GE14 Inlet Peaked Additional ATLAS Test Data

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## ***COBRAG Description & Qualification***

- **State of the Art Subchannel Analysis Method**

- Two-fluid Three-field thermal hydraulic model
- Transient fuel rod heat transfer
- Critical power
- Pressure drop
- Bundle cross sectional void distribution
- Steady state and transient applications

- **Applications**

- Bundle design studies and optimization
- Extension to ATLAS testing
- Cross sectional void distribution
- Time varying axial power shape (TVAPS)



# Controlling physical phenomena



Critical Power



**Inlet Peaked Power Shape**

Low Heat Flux at Bundle Outlet  
Reduced Film Dryout

**Cosine Power Shape**

**Outlet Peaked Power Shape**

High Heat Flux at Bundle Outlet  
Increased Film Dryout

**Double Hump Power Shape**

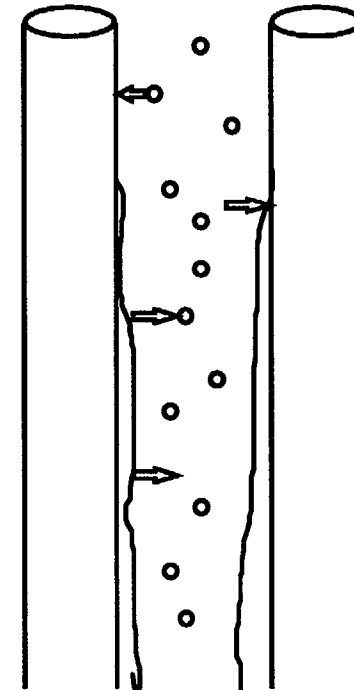
High Heat Flux at Bundle Outlet  
Increased Film Dryout

**Observed Double Humped and Outlet Peaked Critical Power is Lower than Critical Power for Cosine Axial Power Shape**

**Critical power for Inlet Peaked Axial Power Shape is Higher**

**Boiling Length Correlation Characterize Single Peaked Axial Power Shapes Well**

**Potentially Non-conservative for Double Humped Axial Power Shape**



Deposition

Film dryout

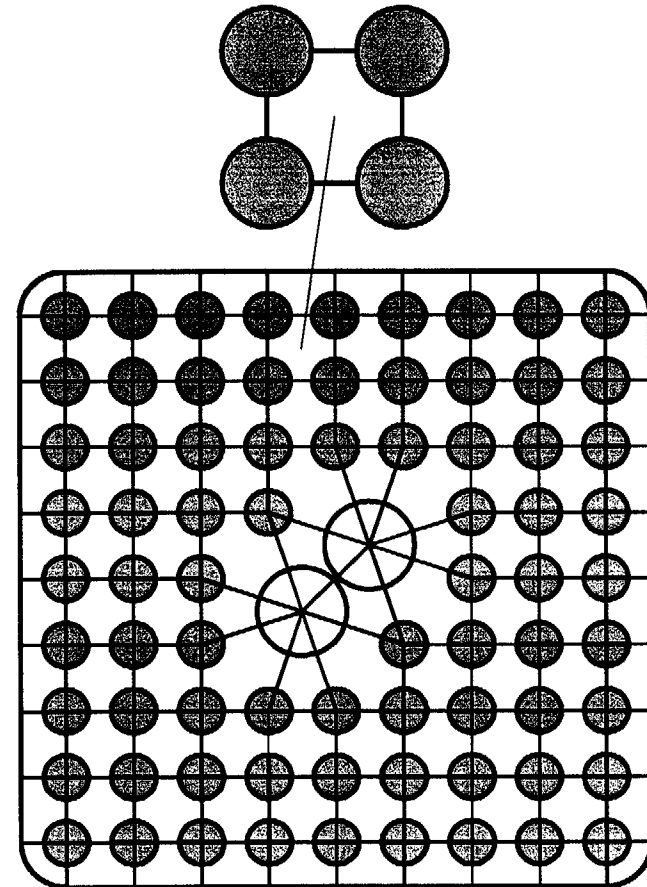
Entrainment

Evaporation

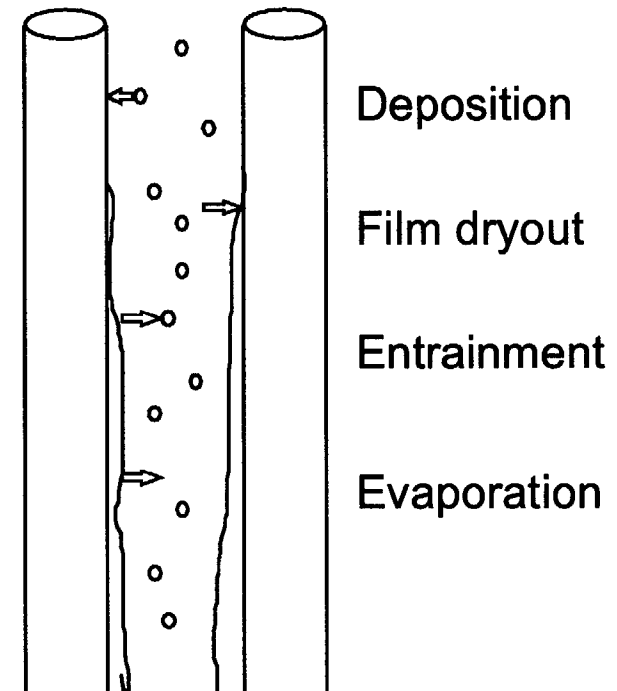
**Boiling transition calculated from film dryout**

$$\frac{dW_f}{dz} = \text{Dep} - \text{Ent} - \text{Evap}$$

- **Conventional Subchannels**
- **Two-fluid three-field thermal hydraulic model**
  - Conservation equations for mass momentum and energy
  - Steam, films and droplets
- **Fuel rod transient heat transfer**
  - Radial heat conduction
  - Heat transfer
- **Models and correlations**
  - Shear and heat transfer
  - Entrainment and deposition
  - Void drift and mixing
  - Spacer effects



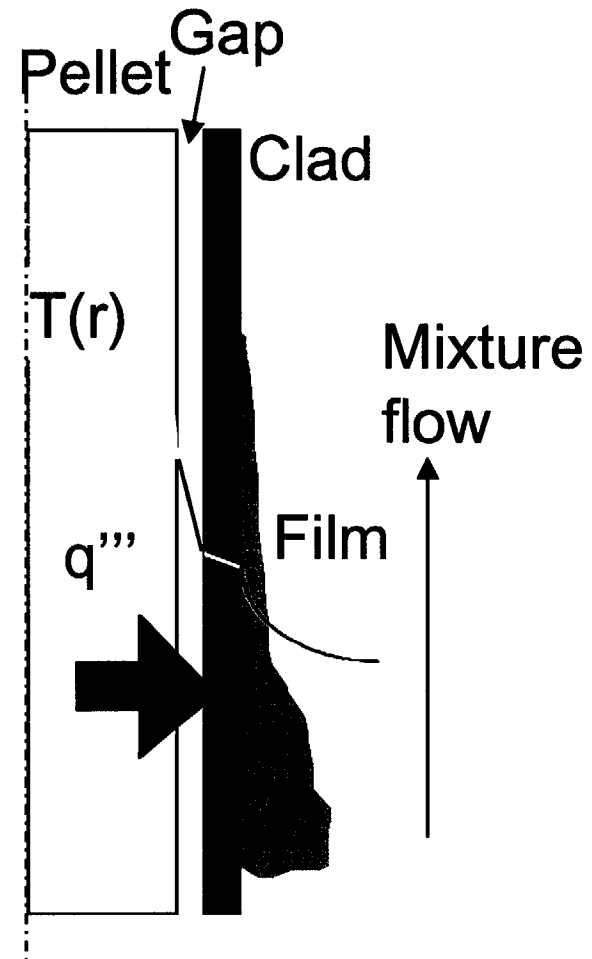
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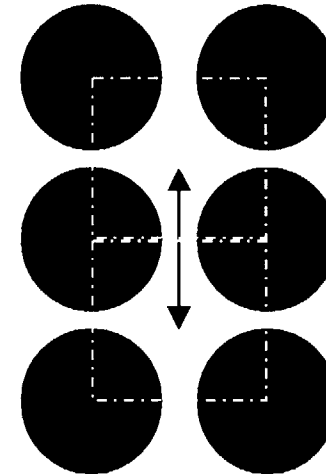
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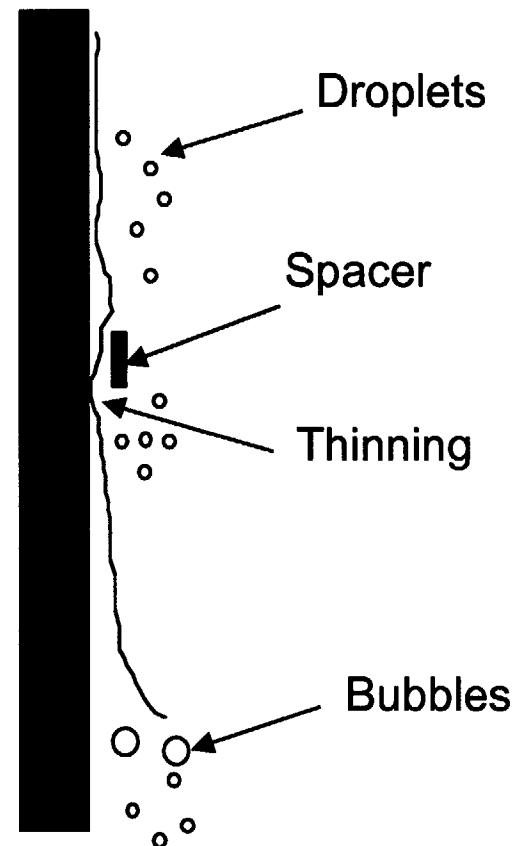
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**Void drift toward high velocity region will create non-uniform void distribution**

**Mixing will create uniform void distribution**

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# Qualify COBRAG with ATLAS

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**ATLAS 9X9 Data**

**ATLAS 10X10 Data**



