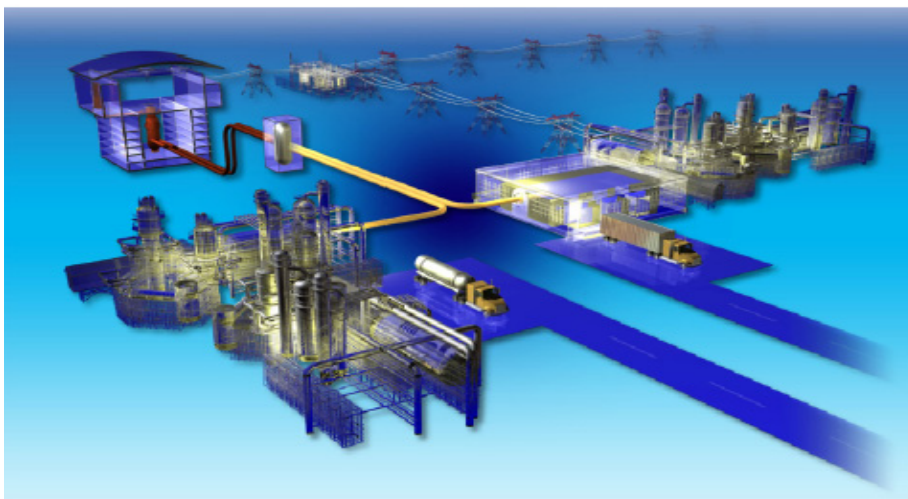


NGNP Data Management and Analysis System Analysis and Web Delivery Capabilities

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M. L. Abbott
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September 2010



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September 2010

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NGNP Data Management and Analysis System Analysis and Web Delivery Capabilities

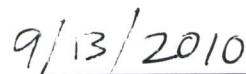
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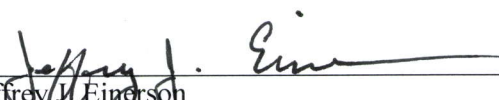
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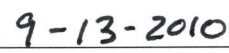
Cynthia D. Gentillon
NDMAS Modeling and Analysis Lead




Date



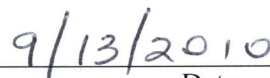
Jeffrey J. Einerson
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Date



for Diane V. Croson
VHTR TDO Deputy Director



Date

ABSTRACT

Projects for the Very High Temperature Reactor Technology Development Office provide data in support of Nuclear Regulatory Commission licensing of the very high temperature reactor. Fuel and materials to be used in the reactor are tested and characterized to quantify performance in high-temperature and high-fluence environments. In addition, thermal-hydraulic experiments are conducted to validate codes used to assess reactor safety. The Very High Temperature Reactor Technology Development Office has established the NGNP Data Management and Analysis System (NDMAS) at the Idaho National Laboratory to ensure that very high temperature reactor data are (1) qualified for use, (2) stored in a readily accessible electronic form, and (3) analyzed to extract useful results.

This document focuses on the third NDMAS objective. It describes capabilities for displaying the data in meaningful ways and for data analysis to identify useful relationships among the measured quantities. The capabilities are described from the perspective of NDMAS users, starting with those who just view experimental data and analytical results on the INL NDMAS web portal. Web display and delivery capabilities are described in detail. Capabilities available to NDMAS developers are more extensive, and are described using a second series of examples. Much of the data analysis efforts focus on understanding how Advanced Gas Reactor fuel irradiation temperature measurements relate to simulated temperatures and other experimental parameters. Statistical control charts and correlation monitoring provide an ongoing assessment of instrument accuracy in currently-running very high temperature reactor irradiation experiments. Data analysis capabilities are virtually unlimited for those who use the NDMAS web data delivery capabilities and the analysis software of their choice.

Overall, the NDMAS provides convenient data analysis and web delivery capabilities for studying a very large and rapidly increasing database of well-documented, pedigreed data.

SUMMARY

Projects for the Very High Temperature Reactor Technology Development Office (VHTR-TDO) provide data in support of Nuclear Regulatory Commission licensing of the very high temperature reactor (VHTR). Fuel and materials to be used in the reactor are tested and characterized to quantify performance in high-temperature and high-fluence environments. Thermal-hydraulic experiments are also conducted to validate codes used to assess reactor safety. The VHTR Program has established the NGNP Data Management and Analysis System (NDMAS) to ensure that VHTR data are qualified for use, stored in a readily accessible electronic form, and analyzed to extract useful results.

This document focuses on the third NDMAS objective. It describes capabilities for displaying the data in meaningful ways and identifying relationships among the measured quantities that contribute to their understanding. The capabilities are described from the perspective of NDMAS users, starting with those who just view experimental data and analytical results on the Idaho National Laboratory (INL) NDMAS web portal. Table S-1 provides an overview of the web page display and analysis capabilities.

Table S-1. Data analysis, display, and delivery capabilities in NDMAS web pages.

Web Page ^a	Capabilities							
	Graphs	Lattice graphs	Tabular drill-down	Data Exploration	Stored processes	Box plots, histograms	ActiveX graphs	Data downloads
AGC-1 → CHR	X	—	X	X	—	X	X	X
AGC-1 → IRR	X	—	X	—	—	—	X	X
AGC-1 → IRR, AGR-1 → Home, AGR-2 → Home	X	X	—	X	—	—	—	—
AGR-1 → FAB	X	—	—	—	—	—	—	X
AGR-1 → FPM	X	X	—	X	—	X	X	X
AGR-1 → FPM, AGR-2 → GG	X	—	—	—	X	—	—	—
AGR-1 → IRR, AGR-2 → IRR	X	—	X	X	—	—	—	X
AGR-1 → PHY	X	—	—	X	—	—	—	X
AGR-1 → Analysis, AGR-2 → Analysis	X	X	—	—	—	X	—	—
HTM → A1	X	—	—	—	X	—	—	X
HTM → A20	X	X	—	—	X	—	—	X

a. Acronyms: AGC, Advanced Graphite Creep; CHR, characterization; IRR, irradiation; AGR, Advanced Gas Reactor; FAB, fabrication; FPM, fission product monitoring; GG, gross gamma; PHY, physics (neutronics and thermal simulations), HTM, high-temperature materials.

Most of the capabilities identified in Table S-1 are self-explanatory. Lattice graphs are graphs with panels that show the data for different groupings, such as different Advanced Gas Reactor-1 (AGR-1) fuel irradiation experiment capsules. Tabular drill-downs allow the data to be expanded or contracted for different levels of detail in the data display, with all graphs and tables in that display linked to respond accordingly. Selecting different time spans for viewing the data is one example of a level of detail that can be changed. Data Exploration tools allow the user to create aggregations and plots of data on the fly. Stored processes perform calculations and access data on a real-time basis, so that the information is

always current. Boxplots and histograms are forms of graphs that show the distributions of data. ActiveX graphs are dynamic, high-resolution, web figures that allow on-the-fly alteration, such as rescaling of axes, subsetting of data, and viewing data values associated with each point. Data downloads to easily-imported text files are available by clicking on an icon at the top of the tabular drilldown and data exploration tables, or by clicking on download links. Together, these capabilities allow the user to view the data and perform data analysis.

The report provides a detailed description of each item in the web pages listed in Table S-1, with references to the analysis and web display and delivery capabilities that they provide. New web pages continue to be developed; the current descriptions apply as of September 2010.

Capabilities available to NDMAS developers are more extensive because the full power of the SAS Institute, Inc. statistical and analysis software, which supports much of the system, is available. An appendix describes some of the data analysis tools. The current capabilities are described through a series of examples.

Much of the modeling effort focused on understanding the AGR-1 fuel irradiation experiment temperature measurements. The temperatures are driven by Advanced Test Reactor operating conditions such as control-cylinder and regulating-rod positions that modulate the neutron flux to the fuel compacts in the experiment test train. The AGR-1 control system adjusts the mixture and flow of neon and helium for each capsule in the experiment test train in order to maintain capsule temperatures in a predefined target range. The gas flow adjustments provide a temperature control function because helium conducts heat away from the fuel capsules at a much faster rate than neon.

The control gas system needs accurate temperature feedback in order to stabilize the temperatures at desired levels. However, nine of 18 thermocouples (TCs) installed in the AGR-1 fuel irradiation experiment are known to have failed during the experiment that began in late 2006. A process for ongoing assessments of TC performance has been added in the NDMAS data review (using statistical control charts and correlation monitoring) to help detect TC problems if they arise in the currently-running Advanced Graphite Creep 1 (AGC-1) and AGR-2 irradiation experiments.

Study of the results from the AGR-1 irradiation experiment continues. Physics-based neutronic and thermal analysis codes have generated simulated estimates of most of the irradiation parameters. The simulated estimates include parameters such as fission power in the fuel and in the graphite that cannot be directly measured in the experiment. These data are also stored in NDMAS. Comparisons of the measured and simulated data lead to additional data analyses. It is possible that some of the TCs that were not declared to be failed in the AGR-1 experiment experienced drift. Studies of differences and possible anomalies in the measured and simulated data are briefly described. There is much to be gained from considering how the many attributes interact in the complex and challenging environment of these experiments.

In addition to data analysis and web display capabilities for NDMAS developers, a third set of analysis capabilities applies to researchers who download data from NDMAS. The web delivery of data to users leads to virtually unlimited data analysis capabilities, since users can apply their own analysis tools or software.

The data analysis and web page creation by NDMAS developers is an ongoing effort. Ideas for extensions of existing analyses and displays are listed. As additional data sets enter NDMAS, still more opportunities for data analysis and web delivery arise. In summary, the NDMAS provides a wide array of capabilities through the INL-NDMAS web portal, interaction with the NDMAS staff, and direct use of downloaded data.

FOREWORD

This document is the first annual update of the Next Generation Nuclear Plant (NGNP) Data Management and Analysis System (NDMAS) modeling capabilities report originally published in September 2009. Although the title has changed, this report follows the same basic pattern as the original report. The update reflects recent analysis and web display/delivery activities. These activities spring from the following changes that have occurred in the last year to the NDMAS:

- More data has accrued:
 - Advanced Gas Reactor (AGR) Test 1 (AGR-1) fabrication data has been added
 - All of the AGR-1 irradiation data has been collected
 - Thermal data from ABAQUS modeling of the AGR-1 experiment such as predicted daily minimum, volume-averaged, and peak fuel temperatures have been stored in NDMAS
 - Neutronics data from JMOCUP modeling of the AGR-1 experiment have also been added (such as estimated maximum, average, and minimum fission power densities, burn-up, and fast neutron fluence in each capsule as a function of effective full-power days of irradiation)
 - Measured data from the first reactor cycle of the AGR-2 irradiation experiment has been input to NDMAS
 - The High Temperature Materials (HTM) data stream is generating experimental data
 - Post-irradiation examination data from AGR-1 is starting to be reported.
- In response to the multiple fuel irradiation experiments, the NDMAS website has shifted to a hierarchical layout that organizes the data by NGNP project or major test and by various data types or streams within each project/test.
- The NDMAS system has shifted to a new version of the SAS statistical software (9.2), which enhances the security of the data and brings additional data analysis and display capabilities

In response to these enhancements to NDMAS, analysis and web delivery capabilities have expanded to cover the additional data streams. The new version of the SAS software has made the Graphics Template Language easier to use, resulting in an increase in the display of plots that allow data to be compared in multiple panels.

Like the previous document, this report is self-contained. The largest section is a description of analyses currently featured on various web pages. Additional data analysis beyond the web page displays includes use of control charts to monitor thermocouple performance and use of simulated and measured data to study possible anomalies in the data. The capability in the SAS JMP software for profiling the effects of modeling choices is illustrated.

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Jeffrey J. Einerson

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CONTENTS

ABSTRACT.....	v
SUMMARY	vii
FOREWORD	ix
ACKNOWLEDGEMENTS.....	x
ACRONYMS.....	xv
1. INTRODUCTION.....	1
2. NDMAS DATA ANALYSIS AND WEB DELIVERY OVERVIEW	3
2.1 Subjects of Analysis—Phenomena of Interest.....	3
2.2 Analysis Process for Various Groups of VHTR Researchers	4
2.2.1 Data Analysis Capabilities via the NDMAS Web Portal.....	4
2.2.2 Data Analysis and Web Delivery Capabilities for the NDMAS Team.....	40
2.2.3 Data Analysis and Web Delivery Capabilities via Analysis Requests.....	41
2.2.4 Data Analysis Capabilities via Downloads	41
2.3 Uses of the Applications	41
3. EXAMPLES OF CURRENT DATA ANALYSIS APPLICATIONS	43
3.1 TC Monitoring	43
3.1.1 Control Chart Monitoring	43
3.1.2 Monitoring Within-Capsule Correlations	44
3.1.3 Monitoring Between-Capsule Correlations.....	44
3.2 Use of the Data to Identify Possible Anomalies	44
3.3 Use of Regression Models for Sensitivity Studies	45
3.4 Potential Use of Regression Models for Experiment Control.....	49
4. ONGOING AND PROPOSED FUTURE DATA ANALYSES AND WEB DISPLAYS.....	52
4.1 Applications	52
4.2 Enhanced Capabilities.....	52
5. SUMMARY AND CONCLUSIONS.....	54
6. REFERENCES.....	55
Appendix A VHTR Experiments and Associated Data Streams	57
Appendix B Use of SAS Tools for Modeling	65

FIGURES

Figure 1. Web hierarchy.	4
Figure 2. AGC-1 graphite characterization data.	6

Figure 3. AGC-1 graphite characterization drill down.	7
Figure 4. AGC-1 graphite coefficient of thermal expansion (CTE) data exploration report.	8
Figure 5. AGC-1 graphite CTE as a function of temperature (sequence) for six graphite grades.	9
Figure 6. Example of use of ActiveX graph toolbar.	10
Figure 7. AGC-1 temperature averages as a function of distance from the ATR midpoint.	11
Figure 8. AGC-1 daily average temperatures for TCs 15.2 cm from the ATR midpoint.	11
Figure 9. AGC-1 daily average compressive stress for the six outer channels in the AGC-1 capsule.	11
Figure 10. AGC-1 Daily average argon and helium gas flows by date (inside shield).	12
Figure 11. AGC-1 Raising Stacks after Cycle 146A (Part I).	13
Figure 12. AGC-1 Raising Stacks after Cycle 146A (Part II).	13
Figure 13. Graphical summary of ATR operating parameters for all cycles of the AGR-1 experiment.	15
Figure 14. ATR core cross section showing reactor internals and the locations of the AGR and AGC experiments (AGR-2 is in flux trap B-12, AGC-1 is in B-11. and AGR-1 was in B-10).	15
Figure 15. Graphical summary of Capsule 6 data for all cycles of the AGR-1 experiment.	17
Figure 16. Graphical summary of AGC-1 TC data.	18
Figure 17. Graphical summary of AGC-1 load and displacement data.	18
Figure 18. AGR-1 fission product R/B ratios for the entire experiment.	19
Figure 19. A part of the AGR-1 Cycle Summary for Capsule 5.	20
Figure 20. SAS "Data Exploration" table for AGR-1 Cycle 143A FPMS R/B data.	22
Figure 21. Box plot of AGR-1 Kr-85m R/B statistics by capsule and reactor cycle.	23
Figure 22. Data distribution histogram and statistics for Kr-85m R/Bs (example from AGR-1 Cycle 143B Capsule 3).	24
Figure 23. "Kr-85m R/B vs TC1 Temp" plot showing differences in capsule and reactor cycle R/B temperature dependencies.	25
Figure 24. Example of linear fit of Kr-85m as a function of temperature from the "TC_1" TCs in three capsules for AGR-1 Cycle 145A, with details of the regression for Capsule 5.	26
Figure 25. AGR-1 example of gross gamma count plot for Detector 4.	26
Figure 26. Example from AGR-1 IRR web page (Capsule 4 gas flow rates across cycles).	27
Figure 27. EFPD as a function of ATR effective power history for AGR-1.	29
Figure 28. Simulated daily average AGR-1 fuel fission power densities by capsule.	29
Figure 29. Overlay showing a smoothed version of the AGR-1 fuel fission power densities for each capsule.	30
Figure 30. Simulated AGR-1 fuel burnup data for each capsule as a function of EFPD.	31
Figure 31. AGR-1 Capsule 5 within-capsule control chart and correlation test for TC drift.	33

Figure 32. AGR-2 Capsule 5 within-capsule control chart and correlation test for TC drift.....	33
Figure 33. AGR-1Capsule 5 between-capsule correlation tests for possible TC junctions (the highest correlations are for the most part with the other Capsule 5 TC).	34
Figure 34. AGR-2 Capsule between-capsule correlation test for possible TC junctions (the highest correlations are for the most part with the other Capsule 5 TC).....	34
Figure 35. Additional information for AGR-2; example of between-capsule correlations for control TCs.	35
Figure 36. AGR-1Capsule 5 box plots of daily within-capsule correlation coefficients by reactor cycle.....	35
Figure 37. AGR-1 Capsule 5 box plots of daily between-capsule correlation coefficients by reactor cycle.....	36
Figure 38. Example of daily TC temperatures with cycle-level average and standard deviation for AGR-1.	36
Figure 39. Example of daily TC temperatures with cycle-level average and standard deviation for AGR-2.	36
Figure 40. .HTM Test Series A-1 tensile testing summary.....	38
Figure 41. HTM Test Series A-1 tensile testing curves for Alloy 800H.	38
Figure 42. HTM Test Series A-20 hysteresis loops for selected elongation/compression cycles.....	39
Figure 43. Four major steps in NDMAS data processing.	40
Figure 44. Measured and simulated AGR-1 TC temperatures.....	46
Figure 45. Daily average data for AGR-1 Capsule 6 at full power.....	47
Figure 46. AGR-1 control chart for TC differences for TC1 and TC4 in Capsule 6.	48
Figure 47. Compendium of plots on possible drift of TC2 in Capsule 6 near end of AGR-1 irradiation.....	48
Figure 48. JMP prediction profiler for predicted fuel temperature in AGR-1 Capsule 6	50
Figure 49. Regression model behind prediction profiler.	51
Figure 50. PMC graphic interface.....	53
Figure B-1. Example EG Process Flow.	67
Figure B-2. Enterprise Guide Query Builder.	68
Figure B-3. Data Task List.....	69
Figure B-4. Data Summary and Statistical Analysis tasks.....	70
Figure B-5. Graphics tasks.....	71
Figure B-6. New Report dialog.....	72
Figure B-7. JMP analysis tools.	74

TABLES

Table S-1. Data analysis, display, and delivery capabilities in NDMAS web pages.....	vii
Table 1. Data analysis and display pages from the hierarchical NDMAS website.....	5
Table A-1. Fuel fabrication data parameters.....	59
Table A-2. Reactor irradiation data parameters and attributes for the AGR (fuel) experiments.	59
Table A-3. Fission product monitoring data parameters and attributes.	59
Table A-4. ATR operating conditions data parameters and attributes.....	59
Table A-5. NGNP neutronics and temperature analysis parameters and attributes.	60
Table A-6. Fuel PIE data parameters and types (preliminary data).....	60
Table A-7. Reactor irradiation monitoring parameters for the AGC (graphite) experiments.	61
Table A-8. Parameters and classification for graphite specimens (characterization).	61
Table A-9. Planned High-Temperature Materials tests.....	62
Table A-10. Parameters for HTM Characterization-Uniaxial Tension Tests (A-1).	63
Table A-11. Parameters for HTM Characterization-Creep-Fatigue Tests (A-20).	63

ACRONYMS

AGC	Advanced Graphite Creep
AGR	Advanced Gas Reactor
AGR-1	Advanced Gas Reactor fuel experiment 1
AGR-2	Advanced Gas Reactor fuel experiment 2
ATR	Advanced Test Reactor
CRADA	Cooperative Research and Development Agreement
CV	coefficient of variation
csv	comma-separated value
DOE	Department of Energy
EBI	Enterprise Business Intelligence
EFPDs	effective full power days
EG	Enterprise Guide
FPMS	Fission Product Monitoring System
INL	Idaho National Laboratory
JMP	JMP Statistical Discovery from SAS (software from SAS, Inc.)
MATLAB	Matrix laboratory software from The MathWorks, Inc.
MPa	megapascals
MW	megawatts
NDMAS	NGNP Data Management and Analysis System
NGNP	Next Generation Nuclear Plant
PIE	post-irradiation examination
Q	gas flow rate (more generally, a heat transfer quantity)
QA	quality assurance
QAPP	Quality Assurance Program Plan
OLAP	online analytical processing
R&D	research and development
R/B	release-to-birth rate ratio
SAS	software from SAS Institute, Cary, NC
SQL	structured query language
TC	thermocouple
TDO	Technology Development Office
UTS	ultimate tensile strength
VHTR	very high temperature reactor

NGNP Data Management and Analysis System Analysis and Web Delivery Capabilities

1. INTRODUCTION

Research and development (R&D) activities are underway to support development of technology for the Generation IV (Gen IV) very high temperature reactor (VHTR). A particular focus of the research is on those activities required to design and license the first Next Generation Nuclear Plant (NGNP). The research is being conducted by an international team of research laboratories, universities, and private companies. The Technology Development Office (TDO) at Idaho National Laboratory (INL) oversees and coordinates this research. In FY 2008, the TDO established the NGNP Data Management and Analysis System (NDMAS) to manage the large body of data being generated by the research. Through the NDMAS, data generated from VHTR research can be stored in a controlled and secure electronic environment that ensures both its integrity and its availability for use by VHTR researchers. The NDMAS provides a significant capability for allowing users to study the data and explore relationships among the attributes and responses being studied. This data analysis and display capability is the subject of this report.

NDMAS can be used to explore relationships in the VHTR research data at a number of levels. At the simplest level, researchers can view graphs of data and think about possible relationships that might exist between various physical quantities in the experiment.

Intuitive models that come from data visualization can be checked by empirical studies. One can estimate parameters, such as averages within groupings of data, and observe which groupings have better outcomes. Formal statistical tests can be performed to identify differences that are beyond the realm of normal variation. At a higher level, one can formulate mathematical relationships that might exist between various attributes or measured quantities, and fit these to the empirical data to see what relationships best represent the data.

More involved data analyses go beyond just empirical patterns and include known physical relationships between the quantities under study. Physical and empirical models can be combined to even better characterize relationships among the measured responses.

A final level of modeling, involving simulation of dynamic conditions as they propagate in a complicated system over a period of time, is not part of the modeling capabilities within NDMAS. NDMAS may support the development of such models, and certainly stores the outputs. Some of the experiments planned for the VHTR will produce data to calibrate and validate such models, and NDMAS analysis capabilities will facilitate the study of those data as well as other data generated by the VHTR R&D program.

A major NDMAS capability that supports such analysis and display is the ability to display analytical results on the internet. NDMAS uses a SAS Enterprise Business Intelligence (EBI) web portal to make the experimental data and analytical results available to the VHTR research community.

In Section 2, NDMAS analysis and web delivery capabilities are described in more detail. Section 3 provides additional data analysis and display examples. Section 4 outlines ongoing applications and possible future studies that might provide further insights from the VHTR experiments. Section 5 provides conclusions and a summary.

This Revision is an update of the report, *NGNP Data Management and Analysis System Modeling Capabilities* (INL/EXT-16327) originally published in September 2009. All of the discussions focus on the status of the NDMAS as of September 2010.

2. NDMAS DATA ANALYSIS AND WEB DELIVERY OVERVIEW

NDMAS data analysis is presented in this section from the standpoint of what the data models describe, how the analyses are performed by different groups of researchers, and how the results are or could be used to improve VHTR research.

2.1 Subjects of Analysis—Phenomena of Interest

Since the data analyses seek relationships between various experimental quantities, knowledge of the available data and associated processes is a necessary prerequisite. The types of data currently stored in NDMAS are described briefly in this section and are itemized in [Appendix A](#). A detailed description of the research data is beyond the scope of this document.

NDMAS has the capability of storing and documenting the qualification of all the data generated in the VHTR research. The data are organized according to data collection project, data stream, and data package. Currently, five projects have been identified:

- Fuel development and qualification
- Materials testing and qualification—graphite technology development
- Materials testing and qualification—high temperature materials
- Design methods and validation
- Nuclear hydrogen initiative.

Data have been input to NDMAS for the fuel development/qualification, graphite technology development, and high temperature materials projects.

Various data streams are generated for each project. A data stream is a set of parameters or measurements collected from one source that can be input into NDMAS together. A data stream may consist of a single set of data that is input just once, or it may be a set of data that is input repeatedly for different time frames or experiments. The set of data submitted in each instance of input for a data stream is called a data package. [Appendix A](#) describes NDMAS data streams and the associated inputs for the fuel and graphite data streams, among others.

At the level of individual data points, each numeric or qualitative value is associated with an experimental unit such as a fuel particle, fuel compact, capsule, or test train. Related records describe additional attributes for these entities. All data in NDMAS are stored in a Structured Query Language (SQL) database. This database has a table that shows the hierarchical relationship between the experimental entities.

NDMAS supports analyses of relationships between quantities in particular data packages. It also facilitates studies of data across data packages, such as from one reactor cycle to another. One can also combine data and study relationships among quantities from more than one data stream. ATR reactor operating conditions data, for example, are combined with VHTR irradiation experiment data for routine plotting and for analyses of controls on temperature. Data from different experimental units, such as different fuel capsules, can also be visually compared using NDMAS. Particular modeling efforts can be geared to the objectives of each VHTR experiment, or to resolve particular questions posed by other VHTR researchers or stakeholders.

An important function that NDMAS provides for the modeling effort is to ensure that data used for the models are captured correctly, are accurate, and are suited for their intended use. These characteristics of the data are the focus of the data qualification section of NDMAS. After data are entered into the SQL database, they are checked to ensure that they are correctly captured, i.e., that they are identical to the raw data files supplied to NDMAS. As applicable, accuracy tests follow. An example of an accuracy test is the

calculation of the coefficient of variation (CV) for a set of data. If the CV is unusually large, the data set is flagged because possible outliers or transcription errors might exist. The overall suitability of the data is ensured by the fact that data marked as qualified were collected under the framework of NQA-1, Part I: “Quality Assurance Requirements for Nuclear Facility Applications” (ASME 2000), as implemented through the *Very-High-Temperature Gas-Cooled Reactor Technology Development Office Quality Assurance Program Plan* (PLN-2690 2010). NDMAS stores references to data reports that document the verification process that was applied for each set of qualified data.

2.2 Analysis Process for Various Groups of VHTR Researchers

NDMAS data analysis capabilities for particular researchers depend on the individual’s level of access to the system. A number of user-specified options allow remote users who view NGNP data using the INL NDMAS web server to customize the displays they obtain for their own analysis needs. A broader range of modeling capabilities exists for members of the NDMAS Development Team, who create the displays that show on the Web. A third analysis capability is for researchers to file requests for particular analyses to be performed by NDMAS team analysts. A fourth level of capability is completely unbounded; users can download data for their own analyses using whatever tools they prefer.

2.2.1 Data Analysis Capabilities via the NDMAS Web Portal

Several data analyses capabilities are part of the NDMAS web portal found at <http://ndmas.inl.gov>. (Note that one must contact the web services administrator to obtain a user ID and password in order to log in and access this web page). The web display capabilities include data visualization, data aggregation (summaries), and data expansion (drilling down to view more detail in the data). The capabilities vary according to the web page the user chooses to display. The modeling capabilities in the web pages showing current VHTR data are noted in subsections below.

The web content changes over time. The current discussion reflects the status of the web pages as of September 2010. The web pages are organized in a hierarchy (Figure 1) with the top level containing links to web pages for the projects and major experiments that have supplied data thus far. For example, the Fuel Development and Qualification project currently has two major experiments with irradiation data from the ATR. Other top-level entries describe other VHTR research projects. To keep the navigation panel on the left side of the screen small, a set of abbreviations has been introduced to describe the various pages. Table 1 explains the acronyms and provides an overview of the pages that are presently available (other than qualification-related pages and help-related pages). The analysis/web display capabilities of each of these pages are described in sections below.

Each “page” (or tab) in the INL NDMAS web portal consists of one or more sections with teal-colored headers. The sections are called portlets. Arrows on the far right in the portlet headers allow the user to display or hide each section. In web pages with lengthy portlets, two scroll bars appear on the right. The rightmost bar scrolls from one portlet to another, while the scroll bar just to the left of that one scrolls within a portlet.

The portlets related to analysis and web display capabilities are discussed below. Note that, in browsing the INL NDMAS web portal, clicking the “Back” arrow causes an error that will require the user to log into the system again. When the “SAS Web Report Viewer” appears, the correct method for moving back to the list of reports is to click above the Viewer or NGNP heading where the word “Portal” appears.

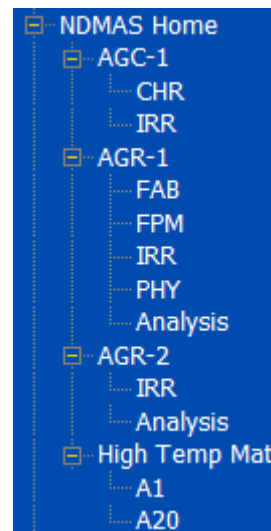


Figure 1. Web hierarchy.

Table 1. Data analysis and display pages from the hierarchical NDMAS website.

Hierarchy			Acronyms	Content	Section References
Level 1	Level 2	Higher Levels			
AGC-1	—	—	Advanced Graphite Creep Test 1	Text	—
	CHR	—	Characterization	Reports, plots, tabular drilldowns	2.2.1.1
	IRR	—	Irradiation	Reports, plots, irradiation summary	2.2.1.2, 2.2.1.3
	PIE	—	Post-irradiation examination	To be supplied (TBS) after Advanced Test Reactor (ATR) irradiation is finished	—
AGR-1	—	—	Advanced Gas Reactor Test 1	Irradiation summary	2.2.1.3
	FAB	—	Fabrication	Reports	2.2.1.4
	FPM	—	Fission product monitoring	Reports and plots. Gross gamma plots	2.2.1.5, 2.2.1.6
	IRR	—	Irradiation	Reports, plots, tabular drilldowns	2.2.1.7
	PHY	—	Physics simulation (neutronics and thermal)	Plots	2.2.1.8
	PIE	—	Post-irradiation examination	TBS, starting in FY-2011	—
	Analysis	—	Analysis [e.g., thermocouple (TC) reliability]	Plots	2.2.1.9
AGR-2	—	—	Advanced Gas Reactor Test 2	Irradiation summary	2.2.1.3
	FAB	—	Fabrication	TBS	—
	FPM	—	Fission product monitoring	Reports and plots	2.2.1.5
	GG	—	Gross gamma counts	Plots, ad hoc plots from "stored processes"	2.2.1.6
	IRR	—	Irradiation	Reports, plots, tabular drilldowns	2.2.1.7
	PHY	—	Physics simulation (neutronics and thermal)	Plots, data downloads	2.2.1.8
	PIE	—	Post-irradiation examination	TBS	—
	Analysis	—	Analysis (e.g., TC monitoring)	Plots	2.2.1.9
HTM	—	—	High temperature materials	Text	—
	A1	—	HTM Test Series A1 (Uniaxial Tension)	Plots, data download	2.2.1.10
	A20	—	HTM Test Series A20 (Creep Fatigue)	Plots, data download	2.2.1.11
Design Methods	—	—	—	Text	—
	Facilities	(Many facilities)	—	TBS	—
	Experiments	(Many experiment types, issues, parameters)	—	TBS	—
	Modeling	(Many subcategories)	—	TBS	—

2.2.1.1 Graphite Characterization Web Page (AGC-1 → CHR)

Graphite is planned for use in the supporting structures in the core of the proposed VHTR. Various graphite formulations have been characterized. Some will be irradiated in the ATR and examined to study performance in a high-temperature, high-neutron-flux environment. Characterization is performed prior to any irradiation, and includes measuring the size of the samples and various properties such as bulk density, elastic modulus, and Poisson's Ratio. The first AGC-1 CHR portlet contains four reports that show data and facilitate the process of data analysis and web display. The second portlet contains a series of plots. The reports and plots are explained below. (Note, though, that the order of reports and displays in the portlets is subject to change, as well as the order of figures within the reports).

Graphite Characterization Drill-down Report

A data table for the basic characterization attributes is displayed in the first report in the first AGC-1-CHR portlet (Figure 2). For 469 graphite specimens, the attributes under study can be viewed individually or in groups according to graphite project, graphite grade, specimen type (piggyback or creep), and orientation (with or against grain).

				Physical Properties and Dimensions					
				Irradiated		No			
				Length (cm)	Diameter (cm)	Hole Diameter (cm)	Mass (g)	Volume (cm ³)	Bulk Density (g/cm ³)
Project_Name	Graphite_Grade	Specimen_Type	Orientation						
AGC-1	A3	Piggyback	WG	0.6301	1.2718	0.0583	1.1023	0.7914	1.3947
	BAH	Piggyback	WG	0.6329	1.2740	0.2401	1.4300	0.7767	1.8411
	H-451	Creep	WG	2.5358	1.2720	0.3251	5.4321	3.1677	1.7149
	HLM	Piggyback	WG	0.6331	1.2740	0.3242	1.3082	0.7548	1.7333
	HLM	Piggyback	WG	0.6335	1.2712	0.2245	1.3742	0.7781	1.7661
	IG-110	Creep	WG	2.5376	1.2709	0.3203	5.5867	3.1657	1.7647
	IG-110	Piggyback	WG	0.6333	1.2708	0.3237	1.3404	0.7511	1.7845
	IG-430	Creep	WG	2.5381	1.2718	0.3205	5.7599	3.1710	1.8165
	IG-430	Piggyback	WG	0.6332	1.2728	0.3236	1.3761	0.7536	1.8262
	HBG-10	Piggyback	WG	0.6329	1.2731	0.2223	1.4029	0.7804	1.7977
	HBG-17	Creep	AG	2.5366	1.2732	0.3176	5.9285	3.1770	1.8661
	HBG-17	Piggyback	WG	2.5373	1.2735	0.3175	5.9264	3.1798	1.8638
	HBG-17	Piggyback	WG	0.6333	1.2729	0.3216	1.4073	0.7544	1.8654
	HBG-18	Creep	AG	2.5368	1.2742	0.3241	5.9672	3.1802	1.8764
	HBG-18	Piggyback	WG	2.5371	1.2737	0.3241	5.9661	3.1781	1.8773
	HBG-25	Piggyback	WG	0.6325	1.2736	0.3229	1.4174	0.7540	1.8799
	PCEA	Creep	AG	2.5386	1.2730	0.3197	5.6819	3.1780	1.7879
	PCEA	Piggyback	WG	2.5382	1.2727	0.3201	5.7524	3.1759	1.8113
	PCIB	Piggyback	WG	0.6341	1.2728	0.3237	1.3732	0.7546	1.8197
	PGX	Piggyback	WG	0.6335	1.2739	0.2266	1.4289	0.7810	1.8297
	PPEA	Piggyback	WG	0.6332	1.2736	0.2221	1.3862	0.7814	1.7741
	S-2020	Piggyback	WG	0.6330	1.2733	0.2264	1.4340	0.7797	1.8391
	S-2020	Piggyback	WG	0.6333	1.2737	0.2265	1.3608	0.7806	1.7433

Figure 2. AGC-1 graphite characterization data.

The graphite characterization data report is an example of a *tabular drill-down report*. Such reports are unique because they display data from SAS EBI online analytical processing (OLAP) *cubes*. Cubes are data structures that allow rapid analysis because the data are hierarchically arranged with precalculated summary data at each hierarchy level. For the characterization data, this means that the data are readily examined for various graphite grades and specimen types. The data can also be easily filtered

to focus on particular graphite grades. For each data attribute, a user can observe averages for the specified grades.

To see all the characterization data, place the cursor in the "Graphite_Grade" column, right click, and select the "Expand All" option. To see the data for just one grade and specimen type, click on the plus ("Expand") sign by the type of interest. The minus sign controls perform a "Collapse" function. The little arrow controls allow the user to "drill down," generating tables that are subsets of the total data at the next level of the hierarchy. For example, in Figure 3, the drill down was from the Graphite Grade column. The drill down initiated from the Specimen Type column leads to a display of data for the individual specimens. The path describing the drilling down appears above the table. To return to a display similar to the original table, click on the left-most item in that path. To return to the original table, click the "portal" block on the left side of the NGNP header and restart the report.

Graphite Grade > NBG-25

Physical Properties and Dimensions							
Irradiated			Ho				
			Length (cm)	Diameter (cm)	Hole Diameter (cm)	Mass (g)	Bulk Density (g/cm ³)
Project_Name	Specimen_Type	Orientation					
AGC-1	Piggyback	WG	0.6325	1.2732	0.2264	1.4400	0.7789
							1.8488

Figure 3. AGC-1 graphite characterization drill down.

The data table can be further rearranged by clicking on the Options in the "Section Data" grouping on the left side of the report. All columns can be removed from the display, and then desired columns can be added. The table will be recreated at the level of aggregation specified by the user. If the user includes "Specimen Number" the table will be detailed, but it could still be a subset of the total data.

An advantage of the tabular drill-down report is that any table created there can be downloaded for further analysis. The file menu allows the user to export the data as a tab-delimited text file, or to export the formatted data directly into Excel.

Report on Graphite Coefficients of Thermal Expansion (CTE) as a Function of Temperature

The second graphite characterization report is an example of a *data exploration* report (Figure 4). It gives a sequence of CTE measurements for selected graphite specimens in six different grades as temperature is raised. This display is similar to the previous one but it is not based on a "cube," and it supports graphs. For example, after taking out all of the selected items and then adding back in, in order, Sequence, Graphite Grade, and Average Linear Thermal Expansion, the table regenerates. Then one can select the view button on the upper left just above the table and request to change the table to a line plot. Figure 5 is the resulting figure. The sequence numbers correspond to temperatures from 100 to 800 °C. As with the tabular drill-down reports, the data can be downloaded.

Report Listing AGC-1 Data by Installed Position in AGC Capsule

The AGC-1 experiment is currently in the ATR in order to study the effects of high temperatures and neutron fluence. Samples are loaded in a single tall capsule with seven channels (stacks) in order to study the performance of several different graphite grades, sample types, and orientations. For the 388 graphite samples being irradiated, the attributes described in the first report are listed together with their associated locations in the AGC-1 capsule. The channels are arranged with one in the center and six spaced evenly around it. Each specimen is in a particular channel, and its midpoint is at a certain elevation in the ATR reactor. As with the previous data exploration report, these data can be filtered, graphed, and downloaded.

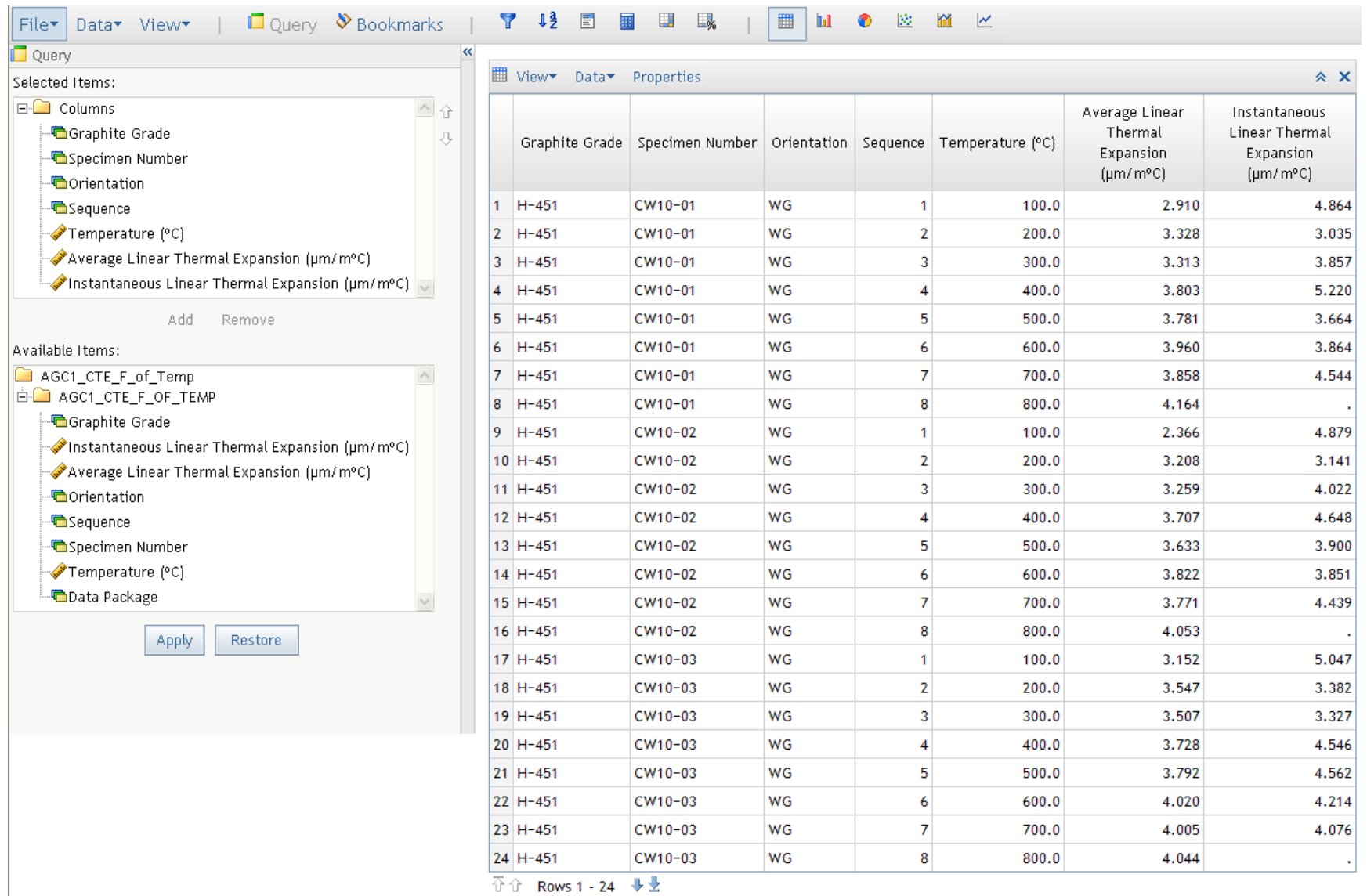


Figure 4.AGC-1 graphite coefficient of thermal expansion (CTE) data exploration report.

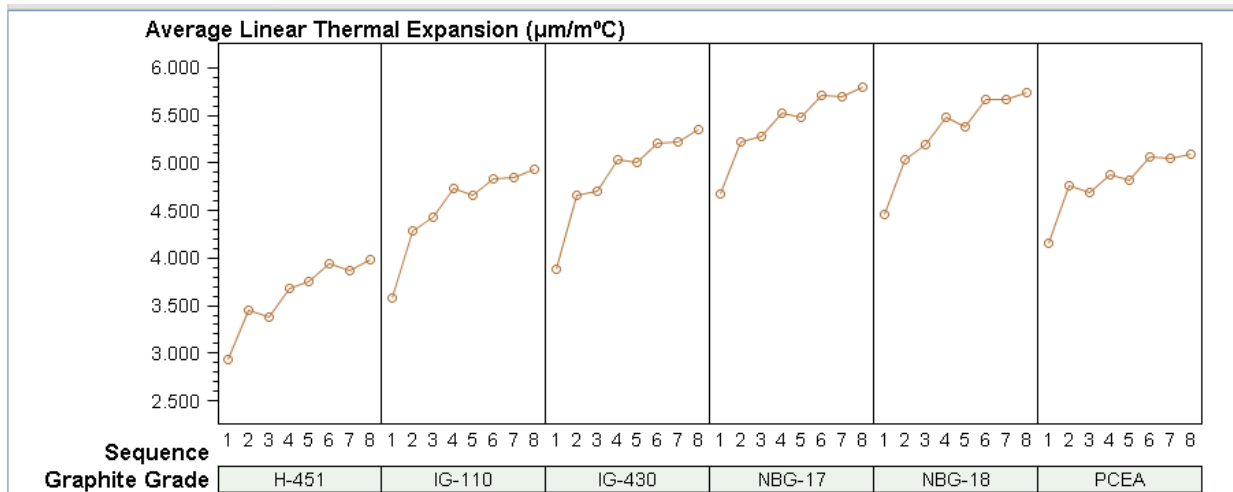


Figure 5. AGC-1 graphite CTE as a function of temperature (sequence) for six graphite grades.

AGC-1 Matched Companion Specimens Data Exploration Report

The final data exploration report associated with the graphite data deals with the study of graphite creep in the high-stress environment of the ATR reactor with its high temperatures and fluence. To study creep, the samples in the outside channels in the upper half of the capsule (from elevation 25.75 inches to elevation 43.25 inches) are subject to pressure. In different channels, three levels of pressure are applied (one constant level of pressure for each channel, with two channels at each level). In the lower half of the capsule, samples are arranged as mirror images of the samples in the upper half of the capsule. That is, the samples are matched in grade, sample type, orientation, and distance from the center line of the ATR core. However, the samples in the lower half of the capsule are not stressed. This design allows post-irradiation study of the effect of the pressure apart from the overall ATR environment stress, which tends to be symmetric around the ATR centerline (with the highest temperatures in the center). In separate rows, the NDMAS report describes the location and 14 characterization parameters for each of 15 graphite sample pairs in each of the six outer channels. A total of 180 graphite samples are described. The report also gives absolute and relative differences for each matched pair of attributes. As with the other data explorations, the data can be filtered and sorted prior to being graphed or downloaded.

Second Portlet: AGC-1 HTML Box Plots

The HTML Box Plots portlet near the bottom of the characterization page provides another web display capability. Plots are given for each of the characterization parameters, for each of the two specimen types. A box plot of the parameter response values appears within a plot, for each graphite grade with data. Any single plot of interest is easily displayed using a Table of Contents section on the left side of the portlet. Unlike the graphs in the reports just discussed, these displayed graphs are ActiveX graphs. Placing the cursor over a box plot or plotted x in these graphs will bring up a little window that lists the value(s) of the data (Figure 6, on left). The graphs can also be customized on the fly, with such actions as filling in the boxes and connecting them. Titles and colors can be changed. A graphic toolbar allows the graph to be moved inside its window, expanded, shrunk, and subsetted (Figure 6, right side). These flexibilities enhance the user's ability to visualize the data and the relationships between different graphite grades across the span of the measured characteristics.

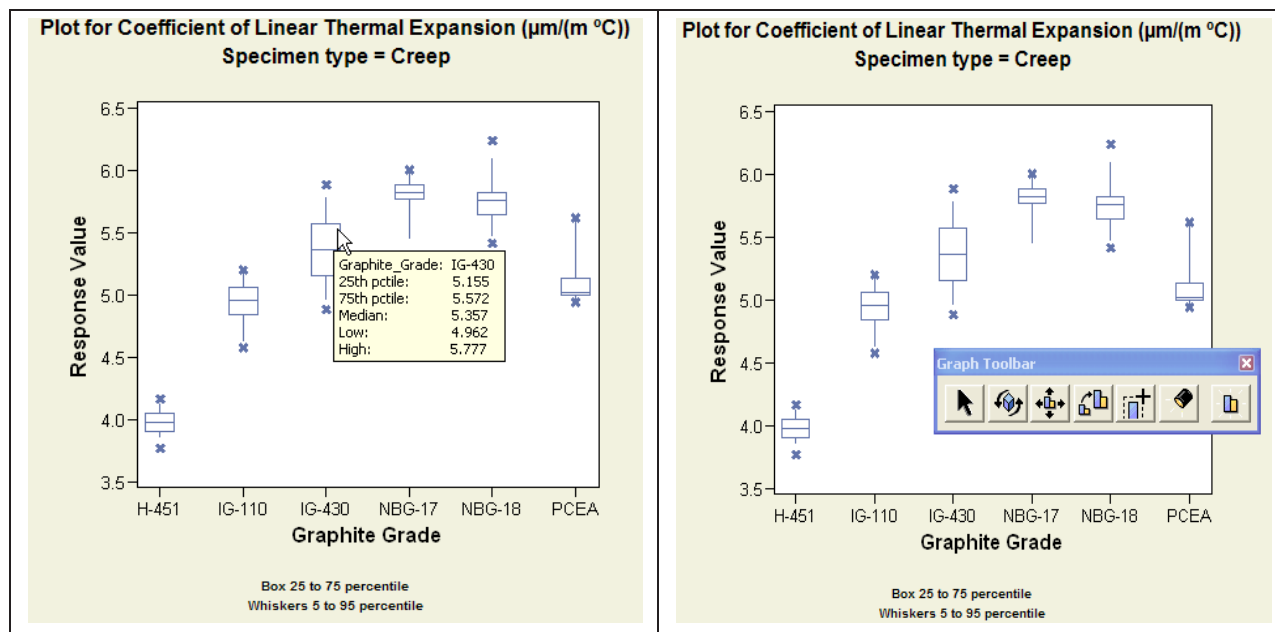


Figure 6. Example of use of ActiveX graph toolbar.

2.2.1.2 Graphite Irradiation Web Page (AGC-1 → IRR)

The AGC-1 irradiation monitoring web page contains two portlets in addition to its introductory portlet. The first has four links and two reports that describe data along with a link to a document describing the test. The links and data reports are described below. The second portlet is a graphical summary, and is described in Section 2.2.1.3.

The graphical displays, which generally show average daily response values as a function of date, are updated by rerunning the SAS "Enterprise Guide" projects that generate them. Each project takes only a few moments to run. The graphs are periodically transferred to the external website. In FY 2011, this process should be automated so that the updates occur as often as desired.

AGC-1 Temperature Monitoring Graphs

The top graph shows average temperatures for each of the 11 thermocouples (TCs) installed in the AGC-1 capsule during the first five ATR cycles (145A, 145B, 146A, 146B, 147A). The TCs are installed at different depths, so the average readings are plotted as a function of distance from the reactor midpoint (Figure 7). The highest temperatures occur near the center of the core.

The remaining graphs in the web display show daily average temperatures as a function of date. Four graphs show the data for different distances from the ATR midpoint, starting with the TC nearest the midpoint. Four TCs are 15.2 cm away, two are around 30 cm away, and four are 45 cm or more away from the center. Figure 8 is an example of one of the graphs. Each graph also has the ATR effective power for the AGC-1 experiment plotted on the right axis.

Ram Pressure, Load Cells, and Stack Position Graphs

A plot shows the load cell compressive stress profile for the six pressurized channels in the upper half of the AGC-1 capsule (Figure 9). Similar plots are presented for ram gas pressure (psig) and stack position in inches.

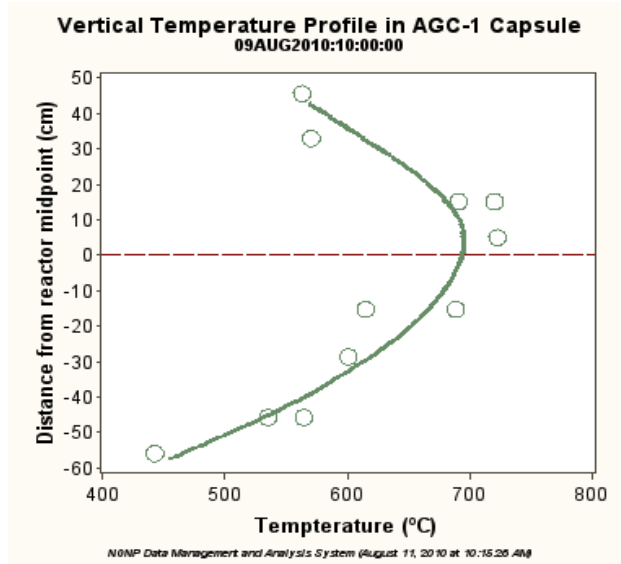


Figure 7. AGC-1 temperature averages as a function of distance from the ATR midpoint.

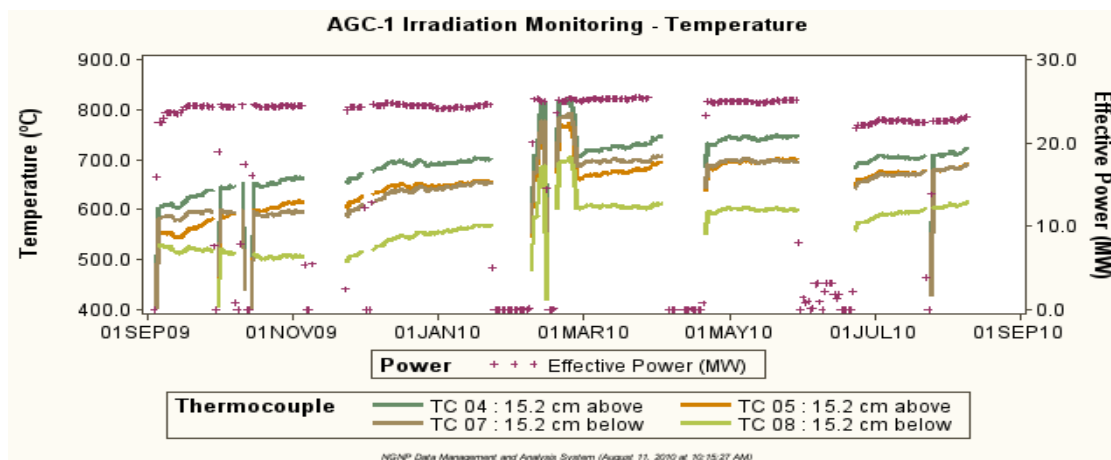


Figure 8. AGC-1 daily average temperatures for TCs 15.2 cm from the ATR midpoint.

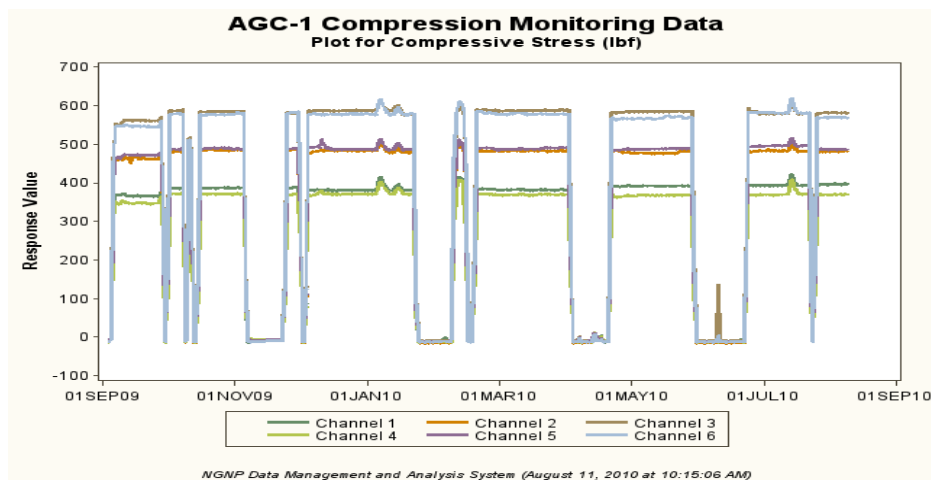


Figure 9. AGC-1 daily average compressive stress for the six outer channels in the AGC-1 capsule.

Argon/Helium Gas Flow Graphs

Plots of daily average argon and helium gas flows in the AGC-1 test are given in time for inlet gas conditions inside the shield and outside the shield (for example, see Figure 10). Argon is used to increase temperatures in the capsule, if needed, since it has a lower heat transfer rate than helium. There is also a plot of outlet moisture content.

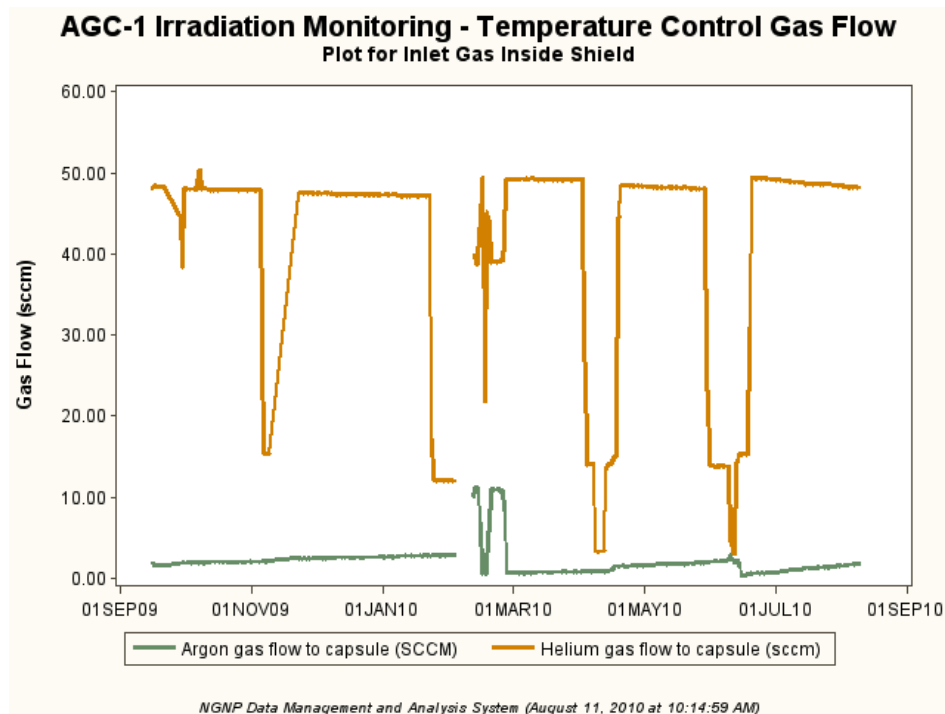


Figure 10. AGC-1 Daily average argon and helium gas flows by date (inside shield).

Graphs of Stack Raising Data

At the end of each ATR cycle, the pressure is removed from the six stacks in the upper half of the AGC-1 capsule and the pressure and position of the tops of the stacks are monitored for a few hours to observe the overall effect of the pressure loadings. During this time, another test removes pressure one channel at a time to observe the raised pressures. Four displays are presented for this monitoring at the end of each cycle: Position (in), Raise Pressure (psi), Load (lbs) and Upper Ram Pressure (psi). Each of these has separate data for each of the six channels, except for Raise Pressure. An example of the plots is in Figure 11 and Figure 12.

AGC-1 Temperatures Report

The AGC-1 temperatures report gives daily average values for all the TCs along with a column for the ATR status and power. The data are organized by ATR cycle. The data can be filtered, sorted, and downloaded.

AGC-1 Creep Response Report

The AGC-1 creep response report gives daily average values for three parameters for each of the six channels that are pressurized. The three parameters are compression stress, ram gas pressure, and the position of the top of the stack. There is also a column for the ATR status and daily average effective power. As with the temperature data, the data are organized by ATR cycle and can be filtered, sorted, and downloaded.

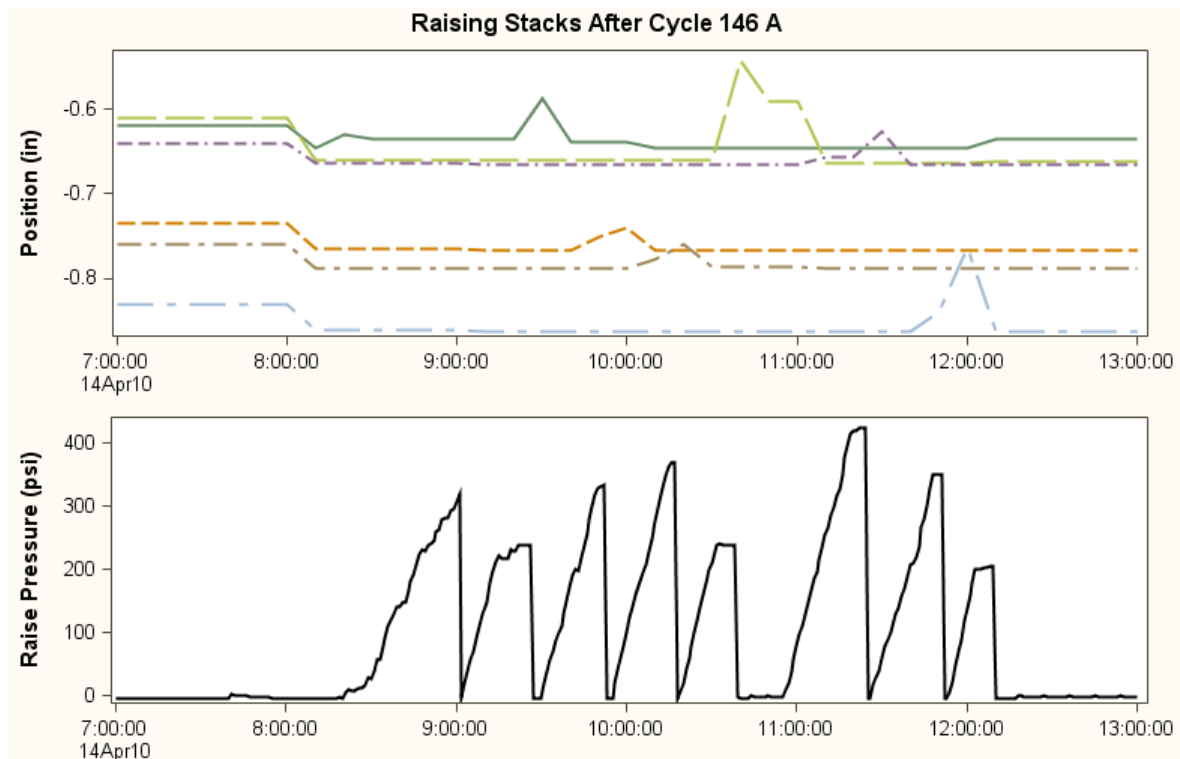


Figure 11. AGC-1 Raising Stacks after Cycle 146A (Part I).

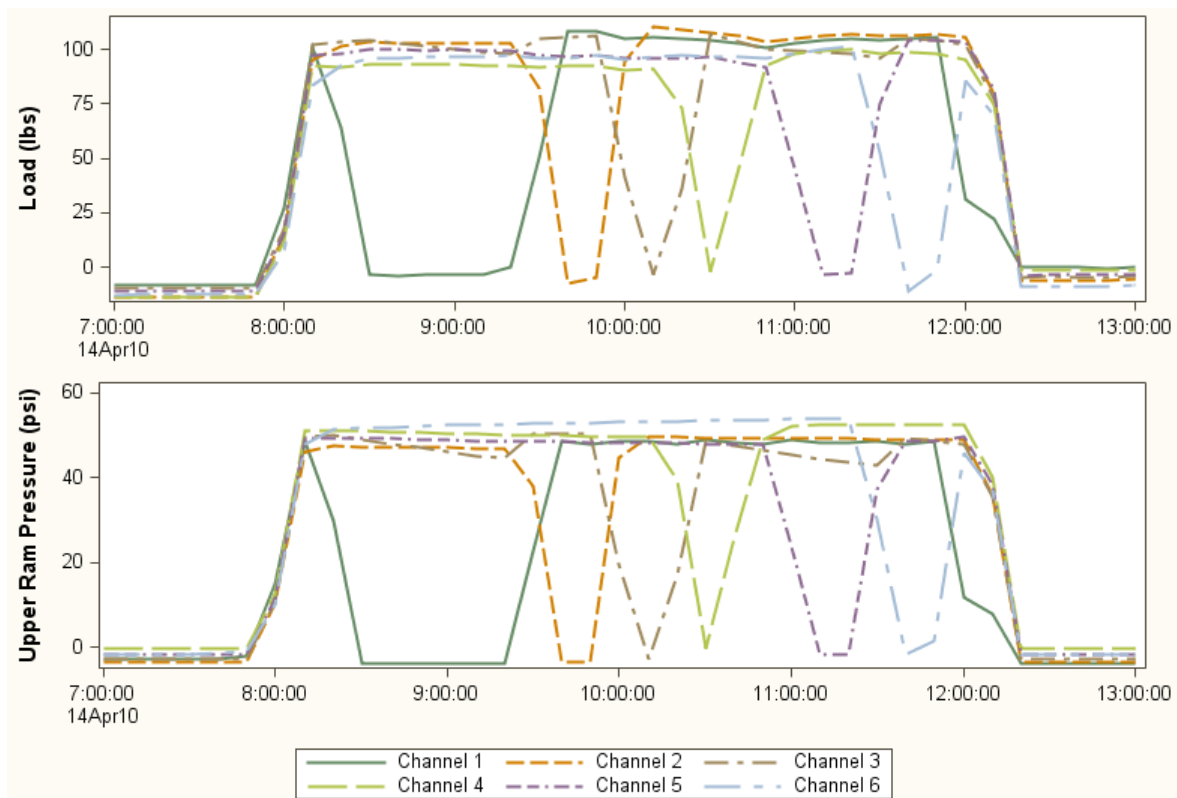


Figure 12. AGC-1 Raising Stacks after Cycle 146A (Part II).

2.2.1.3 Irradiation Graphical Summary Pages (AGC-1 → IRR, AGR-1, and AGR-2)

An overview of data from three VHTR experiments that have been running in the Advanced Test Reactor (ATR) is presented in the home page for the Advanced Gas Reactor (AGR) experiment series and in the irradiation page for the Advanced Graphic Creep (AGC-1) experiment. The most complete set of information is available for the AGR-1 experiment, which was irradiated in the ATR for 13 fuel cycles, from December 24, 2006 through November 6, 2009. The experiment consisted of six capsules in a vertical test train, inserted in a large B position in the ATR reactor. The capsules and train materials were made primarily of stainless steel. Inside each capsule were three stacks of compacts containing fuel particles, embedded in a graphite support structure. Each stack contained four compacts, and each compact contained low-enriched uranium oxycarbide fuel particles, coated with a porous carbon buffer, an inner pyrolytic carbon layer, a silicon carbide layer, and an outer pyrolytic carbon layer. The purpose of the irradiation part of the experiment was to test the performance of the fuel in a high-temperature, high-fluence environment.

The AGR-2 test train was constructed with six capsules, similar to the AGR-1 test train, but the fuel was made by industrial teams rather than laboratories [one capsule's fuel is from Commissariat à l'Energie Atomique (CEA) (France), another is from the pebble bed modular reactor (PBMR) (South Africa), and the rest are from Babcock and Wilcox (B&W) (United States)]. The web displays reflect the CRADA-based constraint that the French not observe South African fuel fabrication and irradiation data, and the South Africans not observe the corresponding French data. None of the figures in this report show data from the French or South African capsules. The AGR-2 irradiation started June 21, 2010, and continues at this time. This test has less data currently plotted because the fission product monitoring system (FPMS) data are not available until after the end of an ATR cycle, and the first such cycle just ended August 14, 2010. The physics simulation data are also not yet available.

The AGC-1 experiment is also currently in the ATR, as described above, in order to study the effects of high temperatures, fluence, and irradiation-induced creep on graphite. For irradiation monitoring, the parameters are similar to the parameters for the AGR tests. There is no uranium and thus no fission product monitoring. There are additional data streams for the pressure load measurements.

The AGR-1 home page contains four portlets along with its introductory text portlet; similar to the AGR-2 home page. The AGC-1 IRR page has one graphical summary portlet. These are described below.

ATR Operating Conditions Graphical Summary Portlet

The ATR operating condition graphical summary (Figure 13

Figure 13) shows various ATR parameters. The figure applies to AGR-1. Since this test is completed, the focus of the pages is to archive the experiment data. The web pages for the other two experiments focus on monitoring. Therefore, while the AGR-2 and AGC-1 displays have a calendar time axis, the AGR-1 displays are plotted by effective full-power days (EFPD), which are accrued as time passes in the experiment based on the ATR power level. If, for example, the ATR were at 50% power for 24 hours, 0.5 EFPD would accrue. Periods of total down time or less than full power are compressed with the EFPD axis. The EFPD data are mapped to the actual calendar time during the simulation analyses of the fission power densities and expected fuel temperatures. EFPD is the preferred reference because all of the comparisons of the experiment and the codes that model the processes are with regard to this measure of exposure. In all of the graphical summary plots, ATR operating cycles are shown in the background.

The panels in the graph show the status of controls that affect the ATR lobe power levels. ATR power is influenced by three types of controls (see Figure 14). There are 24 neck shims located in an "X" pattern in the center of the reactor. Each shim rod is either fully inserted to absorb neutron flux or pulled out of the core. The number of rods that are inserted in each branch of the "X" is plotted in the first panel. The second control is provided by two regulating rods that can be inserted to various depths as shown in the

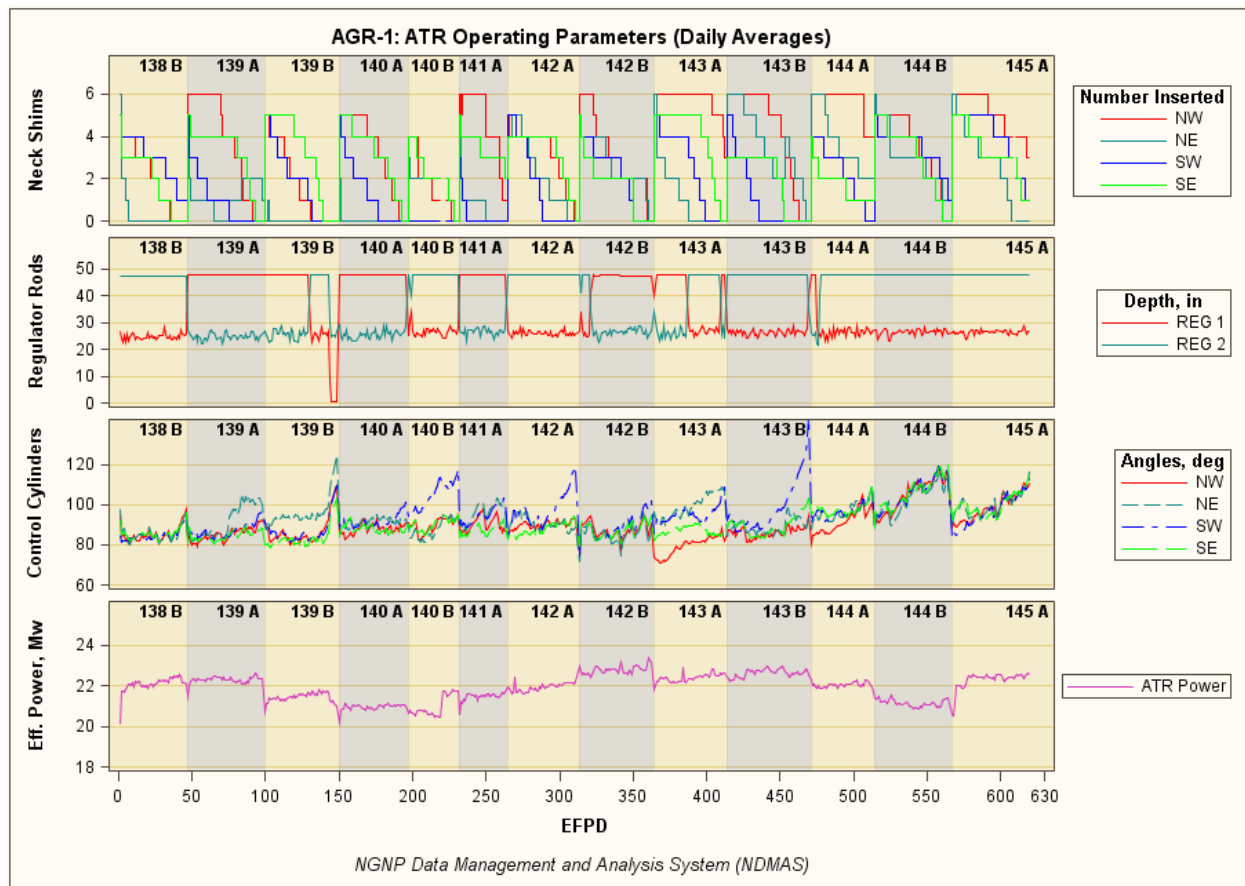


Figure 13. Graphical summary of ATR operating parameters for all cycles of the AGR-1 experiment.

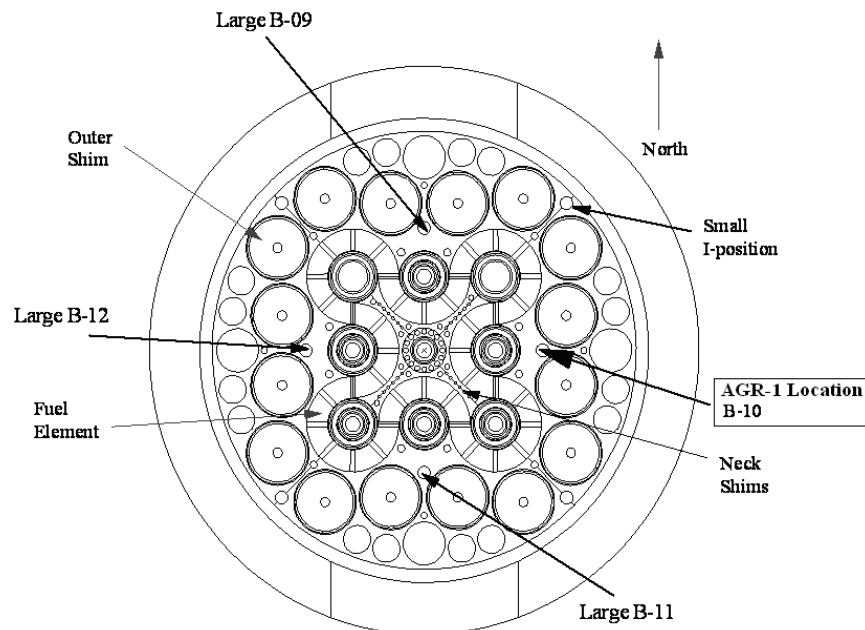


Figure 14. ATR core cross section showing reactor internals and the locations of the AGR and AGC experiments (AGR-2 is in flux trap B-12, AGC-1 is in B-11, and AGR-1 was in B-10).

second panel. Finally, large shim cylinders on the periphery of the reactor can be rotated to reflect or to absorb neutrons. The angular positions of these shims are controlled in a coordinated fashion in each corner (NE, NW, SE, and SW). These positions are shown in the third panel.

The last panel of the graph shows the combined effect of these controls in a plot of the ATR reactor state. The panel shows the ATR effective power. For AGR-1, it is the average of power values from the center, NE, and SE ATR lobes, which are the three of the five ATR lobes closest to the AGR-1 experiment in ATR position B-10. The ATR effective power for the AGR-2 experiment located in position B-12 on the west side of the ATR core is taken to be an average of the center, NW, and SW ATR lobes. Similarly, in the AGC-1 experiment, it is taken to be the average of the SW, SE, and center lobe powers. The effective power applies to all the capsules in an irradiation experiment. It is listed last in the ATR operating condition summary so that it can be visible as one views results from particular capsules.

Experiment-specific Graphical Summary Portlet

For the AGR experiments, the second portlet shows, for each capsule, irradiation parameters over the time frame of the entire experiment. It gives data monitored for each capsule in the experiment. Capsule 6 data sets show first, since Capsule 6 is at the top of the test train (see Figure 15). The data include TC temperatures and neon fraction. Calculated fission power densities in the fuel and in the surrounding graphite are in the third panel since they have a large influence on capsule temperatures. The fourth panel provides insights for temperatures at the TCs by showing differences between measured and simulated values. To complete the temperature overview, calculated (simulated) daily average fuel temperatures, maximums, and minimums are displayed. Release-to-birth (R/B) rate ratios for Kr-85m, Kr-88, and Xe-135 appear in the fifth panel; the birth rates are calculated while the release rates are measured. Finally, measured gross gamma counts for 3.5-second delay times are displayed.

For AGR-2, isotope-specific irradiation R/B ratios and the simulated data will be displayed when they become available. There is or will be a graph like Figure 15 for each capsule, for each experiment.

The plots for some of the graphic summary panels do not go completely across the page. Truncated curves occur primarily because of thermocouple failures. Data that have been disqualified do not appear.

One other note about the AGR summaries is that the calculation of the neon fraction in the control gas is not as easy as one might think. Leadout gas lines flow through the test train. There can be leakage from the leadout into a capsule, or from a capsule into the leadout. Such leakage can be detected when the total outlet gas flow from a capsule does not equal to the sum of the input neon and helium gas flows. When the leakage is outward from a capsule, the neon fraction is not affected. However, if leakage from the leadout into a capsule occurs, the denominator of the neon fraction is increased. The numerator is increased also if the leadout lines carry Ne. The reported neon fractions for the AGR experiments have been corrected for this leakage.

For AGC-1, the second portlet in the "AGC-1 → IRR" web page provides a graphical summary of the irradiation experiment. The experiment has been operating for four ATR reactor cycles thus far. The AGC summary starts with a display of ATR effective powers. The values are daily averages. The single AGC-1 capsule has 11 TCs. TC readings are displayed in the next graph in a panel plot with panels organized according to the distance from each TC to the horizontal centerline of the ATR core. TCs closest to the center of the core show the highest temperatures, as would be expected (see Figure 16). These figures are a compact version of the plots in the first link in the first portlet for AGC-1 irradiation. Temperature is maintained by the mix of Argon and helium in the capsule gas control system, which is plotted in the third link in the portlet above the graphical summary, as already described.

A third graph (Figure 17) in the AGC-1 graphical summary shows the effect of loads that are placed on the graphite samples in the outer six channels in the upper half of the capsule. The six are arranged in three pairs, with each pair having a channel on opposite sides of the center. Three nominal levels of

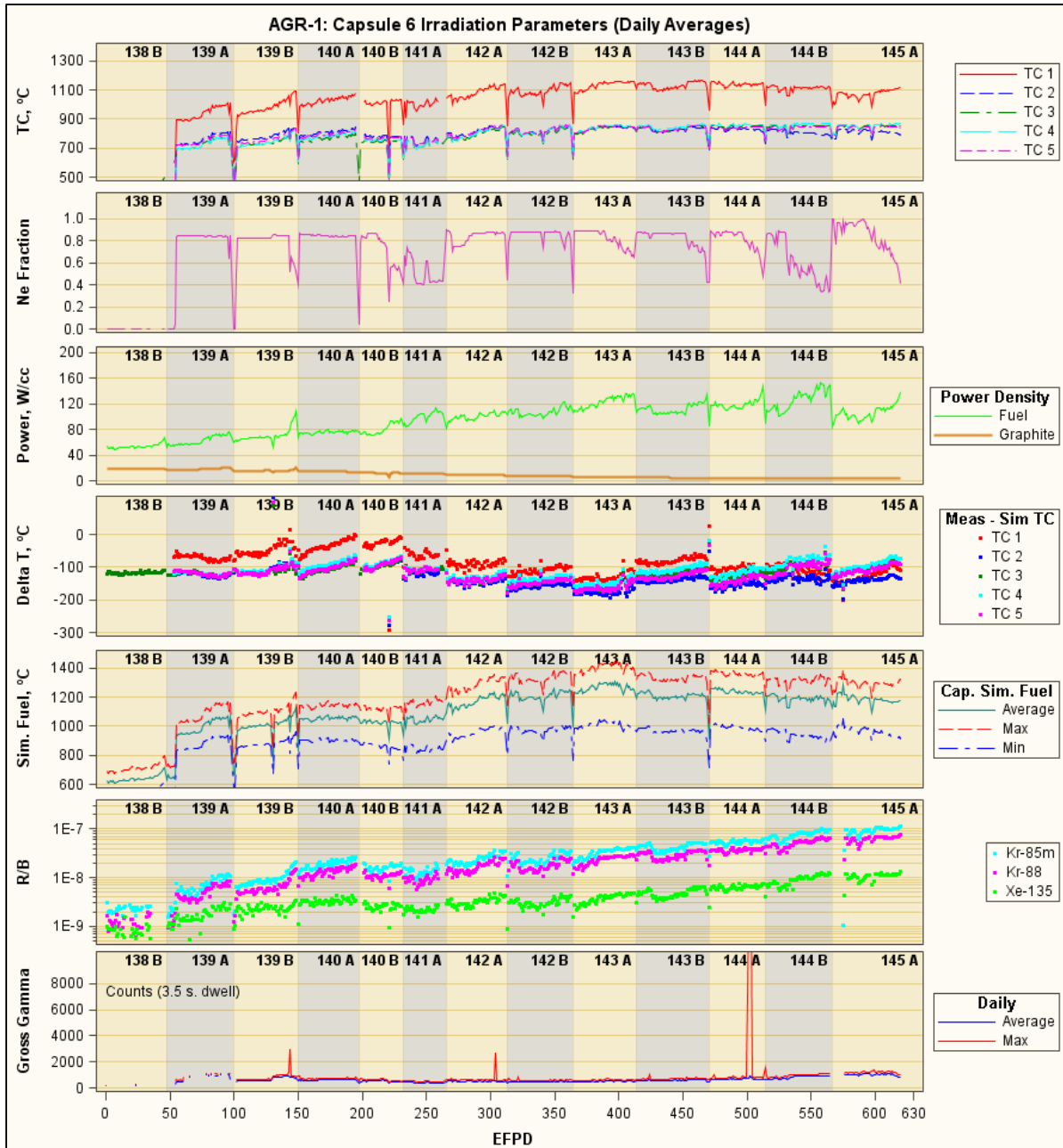


Figure 15. Graphical summary of Capsule 6 data for all cycles of the AGR-1 experiment.

pressure are specified, one for each of these pairs. The top panel in the bottom graphical summary graph shows how well the specified pressures are maintained during the experiment. The panel below shows the effect of the pressure on the graphite. The positions of the tops of the six channels are monitored as the experiment progresses.

AGR-1 "Fission Product R/B Ratios by Capsule and Cycle" Portlet

A third portlet for AGR-1 gives the fission product monitoring R/B ratios by capsule and reactor cycle in a single plot (Figure 18). These are the R/B panels from the capsule-by-capsule graphical summaries, grouped together so that changes from one capsule to another can be shown. Capsule 6 is at the top of the test train as installed in the ATR, nearest to the instrumentation recording devices, and

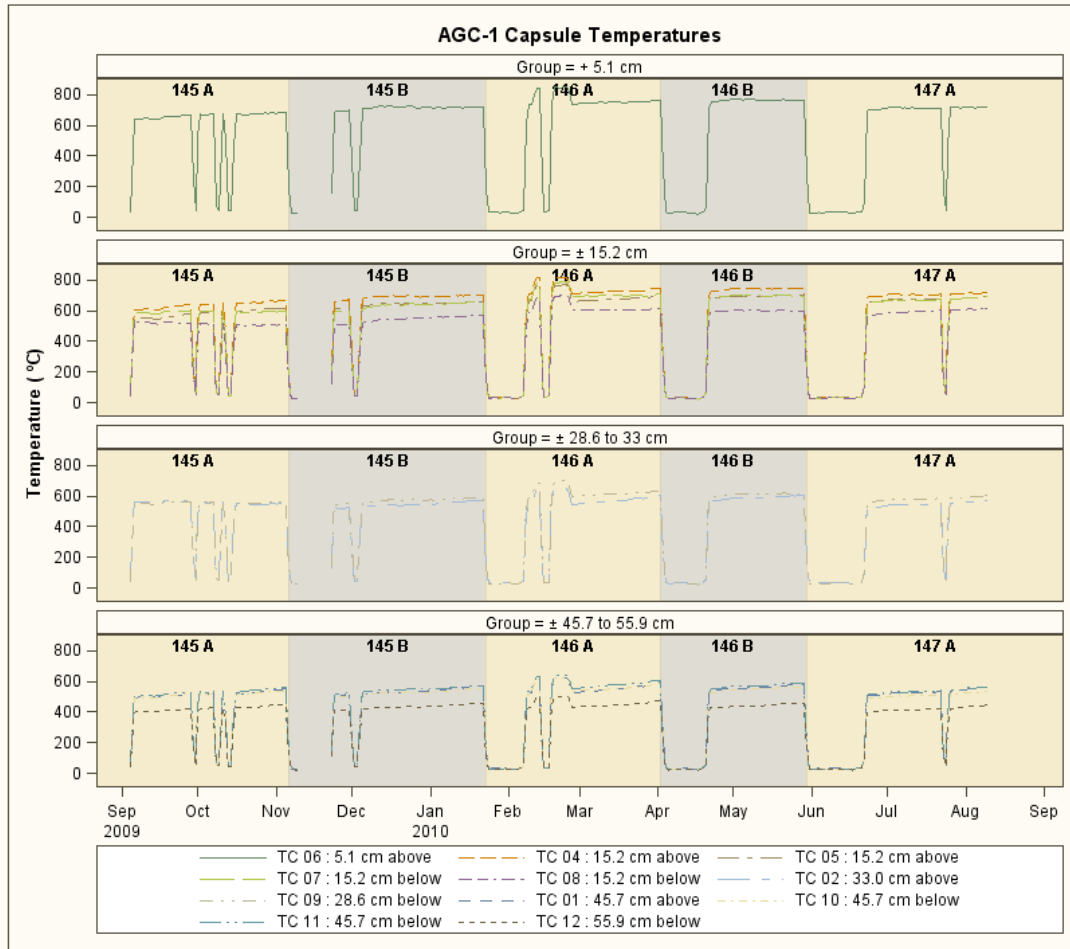


Figure 16. Graphical summary of AGC-1 TC data.

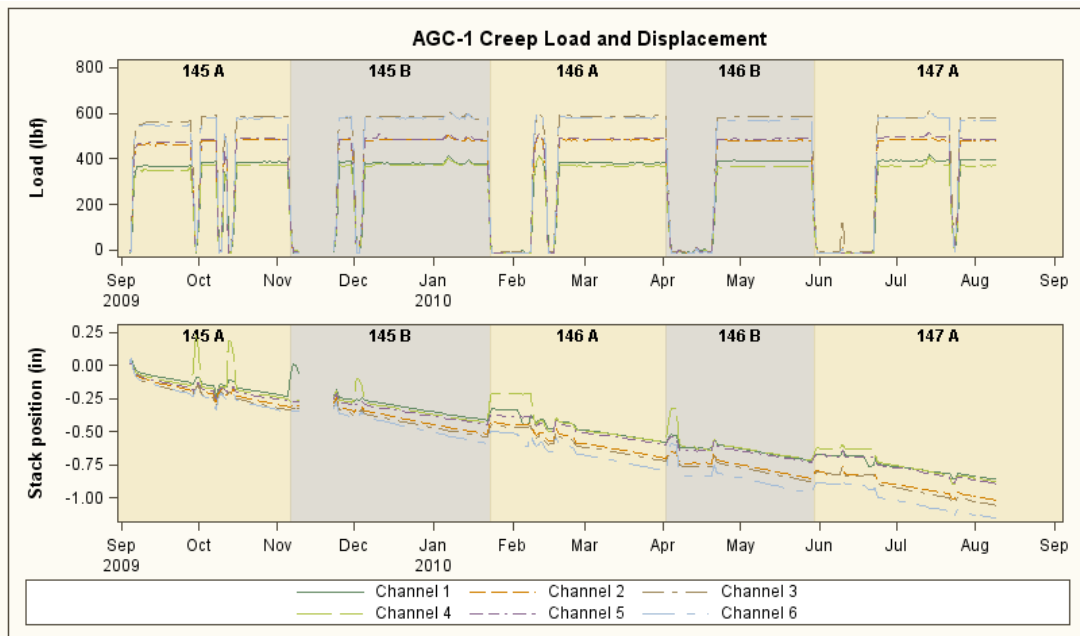


Figure 17. Graphical summary of AGC-1 load and displacement data.

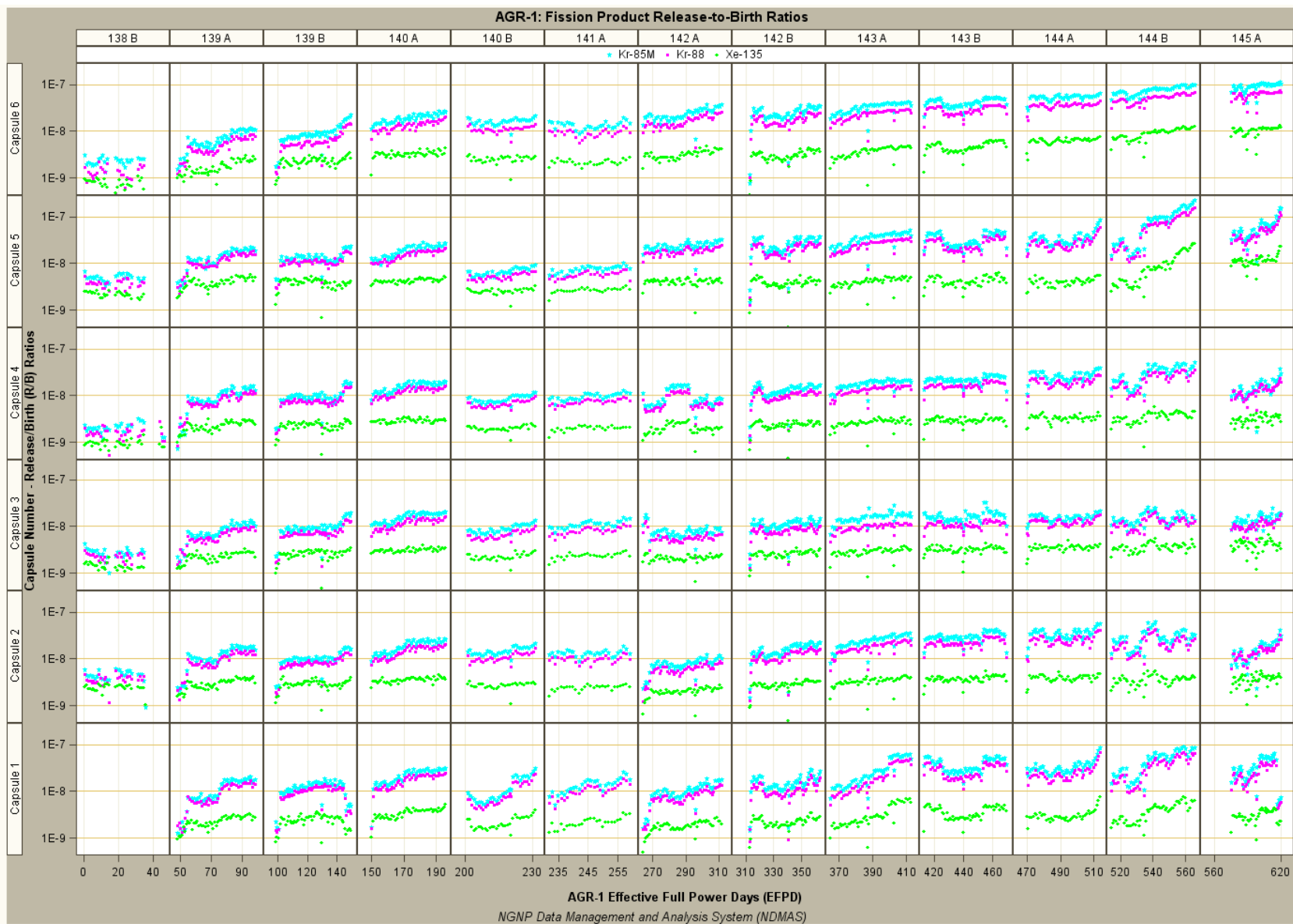


Figure 18. AGR-1 fission product R/B ratios for the entire experiment.

Capsule 1 is at the bottom. Such a portlet will be added for AGR-2 after the data are available and a few ATR cycles have passed by.

AGR-2 "Experiment-specific Graphical Summary for Current Cycle" Portlet

The "Current Cycle" portlet provides the same level of information as the main graphical summary, but it is just for the current cycle for each capsule. The recent values are easier to see here because the time scale is not as compressed. Furthermore, the data are displayed with no averaging unless otherwise stated. For example, the temperature and gas flow data are ten-minute data. A "current cycle" portlet is no longer relevant for the AGR-1 test. As time goes on, such a portlet may be added for AGC-1.

Cycle Statistics Portlet for AGR-1

Graphs showing averages for each cycle in the AGR-1 irradiation are presented in the final AGR-1 home portlet. First there is a graph for effective power. Then, for each capsule, five graphs appear: one for cycle average and cycle maximum TC temperatures, one for helium and neon gas flows, one for neon fraction, one for average and maximum R/B ratios, and a bar chart showing the number of effective full power days with TC data for each TC. Figure 19 is an example of one of the graphs. The graphs include

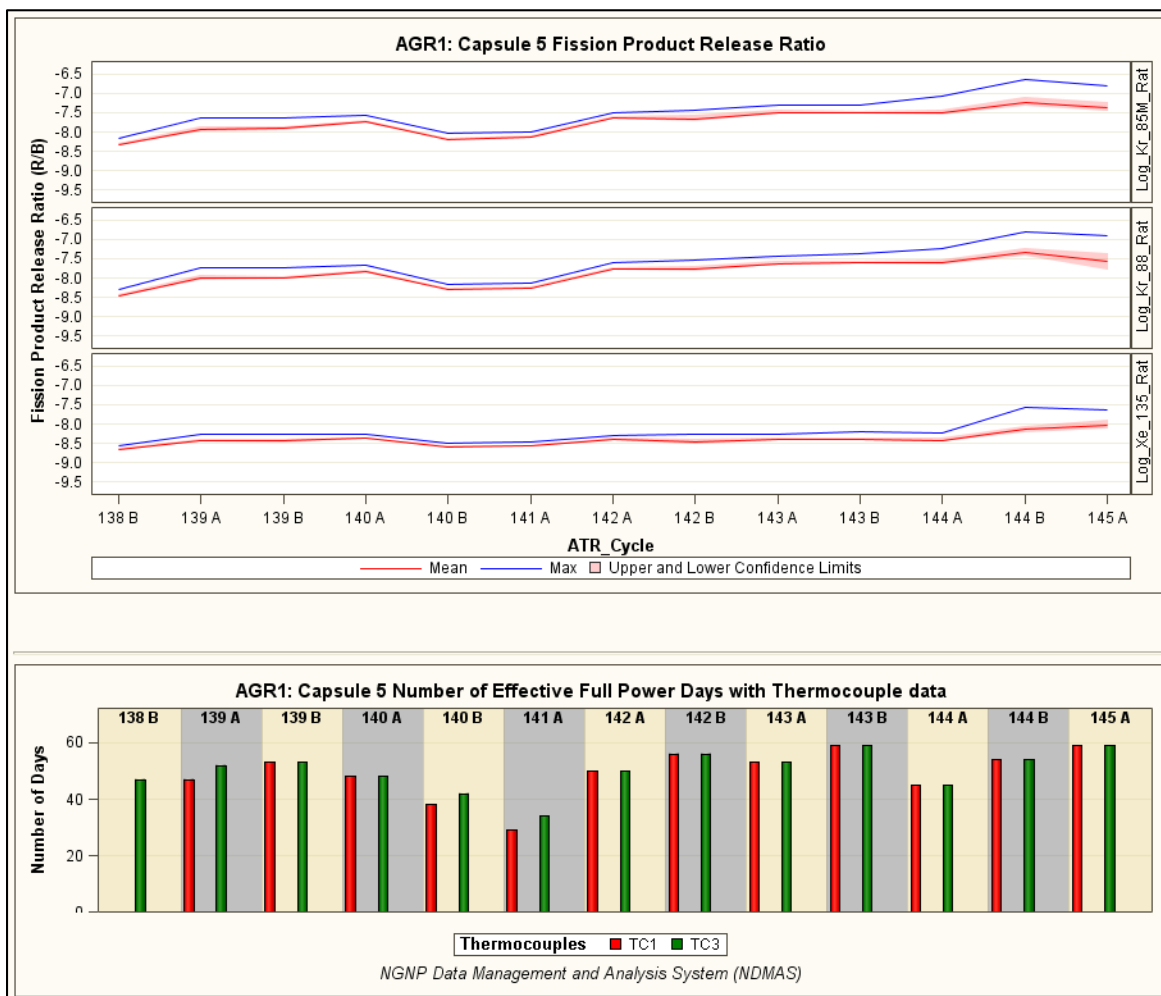


Figure 19. A part of the AGR-1 Cycle Summary for Capsule 5.

upper and lower confidence bands that are calculated using the average of the daily averages and the estimated standard deviation of that cycle average. When the averages are normally-distributed, the confidence bands cover (include) the true mean of the distribution 95% of the time. Thus, the plots not only show the mean values and maxima but give an indication of how the means of the daily means might vary from random variation. A portlet like this one will be added to the AGR-2 home page after a few cycles of data have accrued.

The Graphical Summary web pages do not provide direct access to the irradiation experiment data, nor do they allow the user to manipulate the data for modeling. However, the displays facilitate thinking about relationships between ATR power, thermocouple, control gas flow rates, and fission product data. They allow between-capsule comparisons. For the fuel experiments, they support intuitive modeling about the overall effects of time as fuel burnup increases and graphite boron content decreases from ATR cycle to ATR cycle.

2.2.1.4 AGR Fuel Fabrication Web Page (AGR-1 → FAB)

The fabrication of coated fuel particles and compacts for the AGR-1 experiment was performed at B&W and ORNL. The introductory portlet provides a description of the fuel along with references to documents that describe it in more detail. A second portlet contains three reports. The first two of these contain data tables that present fuel attributes. These are just simple tabular listings that could be summarized or graphically displayed (for example, in box plots) if there were a need to do so.

2.2.1.5 AGR Fission Product Monitoring Web Page (AGR-1 → FPM)

The FPMS for both AGR experiments has gamma spectrometers in the sweep-gas flow lines for each capsule in addition to gross gamma counters. The spectrometers measure five Kr isotopes (85m, 87, 88, 89, and 90) and seven Xe isotopes (131m, 133, 135, 135m, 137, 138, and 139). NDMAS stores three quantities for each of these radionuclides: release rate, R/B ratio, and error estimates. The accumulated counts are recorded over a nominal 8-hour sampling period during the irradiation experiment in the ATR.

The birth rates used to calculate R/B ratios at each 8-hour time interval are themselves calculated quantities. Currently, the main calculations are performed at the start and end of a reactor cycle and at two points in between. Eight-hour values to match the release rate sampling periods are obtained by interpolation. Because the birth rate estimates are calculated at the end of each reactor cycle, the post-processed release and R/B data are not available for loading into NDMAS until the end of each ATR reactor cycle.

The "FPM" web page for AGR-1 has two data table portlets that provide direct access to the isotope-specific FPMS data by reactor cycle. One portlet (FPMS Release Data) lists the release data, with capsule-specific isotope data for each cycle. The other portlet (FPMS R/B Data) lists the R/B ratio data.

The FPM data table portlets use the SAS EBI *Data Exploration* tool, which provides a significant modeling visualization and downloading capability. The user can select and order available "categorical" and "measurement" variables to develop a customized table (Figure 20). Then the data can be filtered and sorted as desired by the user. In the query capability of these portlets, one can even add totals, percentages, and other calculated fields (e.g., the ratio of two isotopes). Ranking the data according to a specified field is another capability. Simple line plots of the data can also be made within the display or the data can be downloaded to Excel and plotted using other scientific plotting software.

Three additional portlets exist on the FPM web page: Release Rates Plots and Distributions, R/B Plots and Distributions, and FPMS – Irradiation Data Analysis. A fourth portlet (Other Analysis/Modeling), reserved for future additional modeling work, is currently empty.

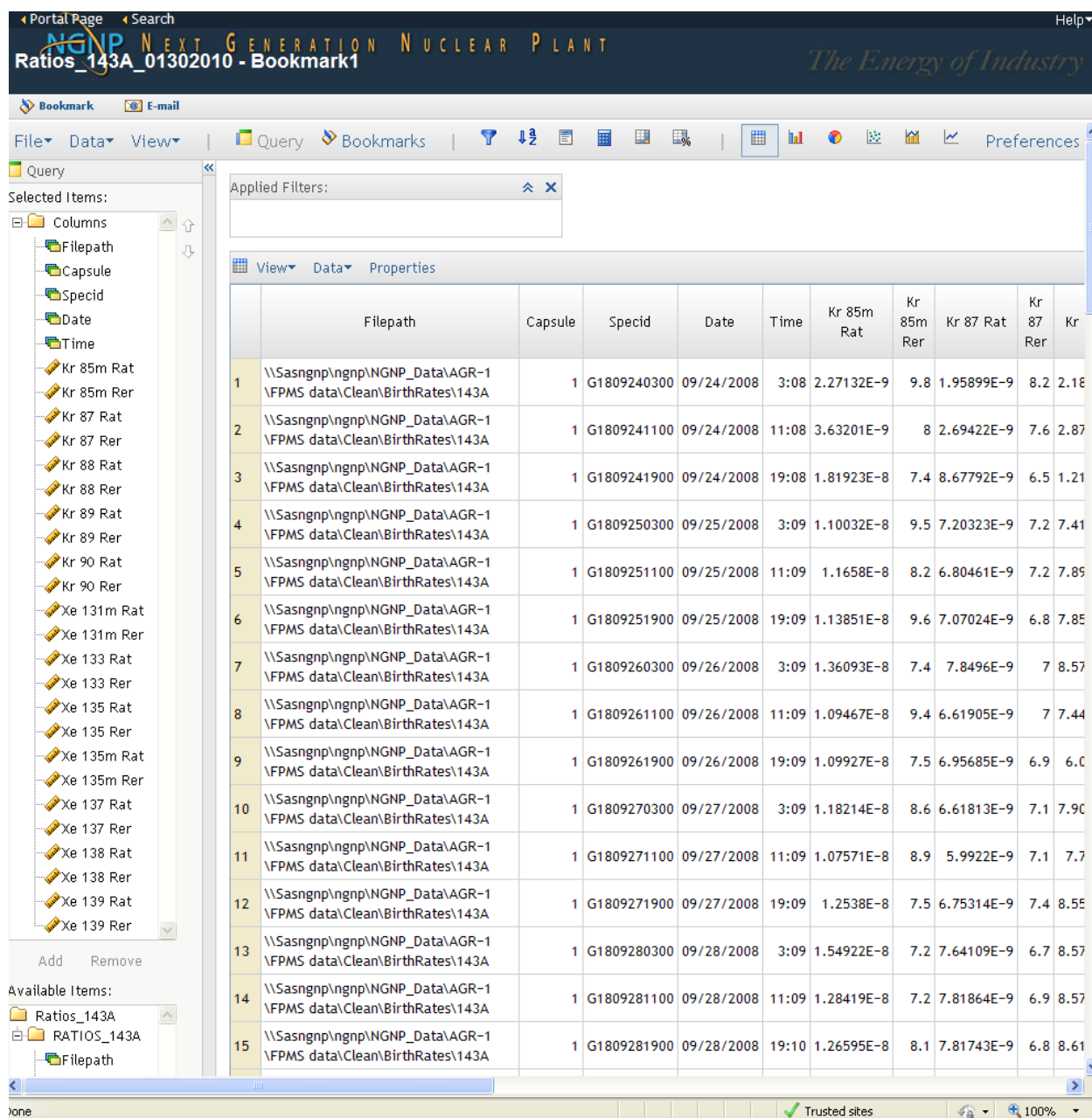


Figure 20. SAS “Data Exploration” table for AGR-1 Cycle 143A FPMS R/B data.

The Release Rates and R/B Plots and Distribution portlets provide information to summarize and better visualize the FPMS data sets by capsule and reactor cycle. Each portlet contains a stacked scatter plot of R/B data as a function of EFPD for all capsules and reactor cycles (e.g., Figure 18). JMP software generated two additional plot types: one with box plots that compare medians, quartiles, and data ranges by capsule and reactor cycle (Figure 21), and a series of plots with histogram/distribution statistics by capsule and cycle (Figure 22).

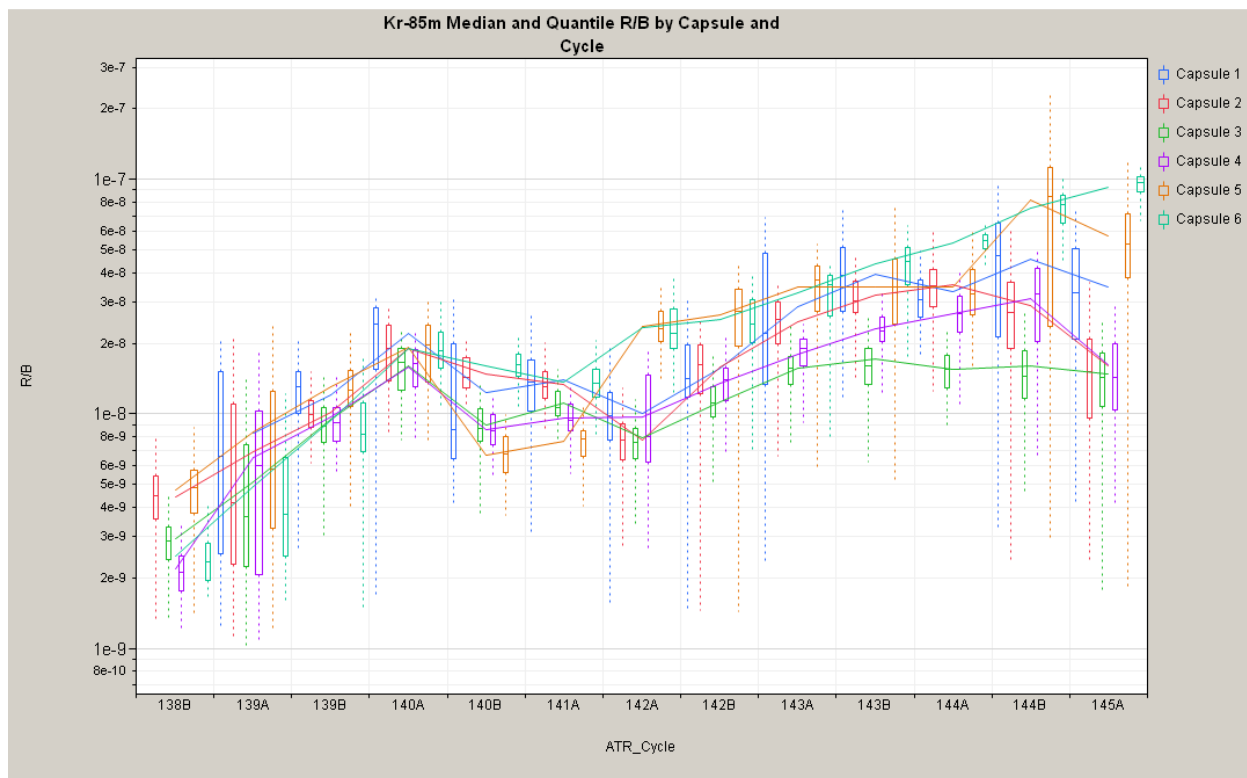


Figure 21. Box plot of AGR-1 Kr-85m R/B statistics by capsule and reactor cycle.

The last portlet on the FPMS web page, FPMS-Irradiation Data Analysis, provides two plots comparing Kr-85m R/Bs with thermocouple temperatures and a data table that has been filtered to exclude highly uncertain FPMS measurements that occurred during periods of instrument problems (cycle 138B) or when the reactor or experiment were not at optimum conditions (effective power < 20 MW, helium flow rate > 20 sccm, TC1 < 600°C). The first plot, “Kr-85m R/B vs TC1 Temp,” shown in Figure 23, provides a good visualization of the linear relationship between the log Kr-85m R/B and capsule temperature, and the difference in this relationship across capsules and reactor cycles. The second plot, “Fit_Kr85m_Rat_TC1,” shown for one cycle in Figure 24, gives the linear regression results for the R/B-temperature relationship.

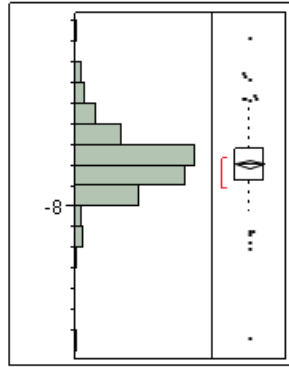
2.2.1.6 AGR Gross Gamma Data (AGR-1 → FPM, AGR-2 → GG)

A sodium iodide detector in the sweep-gas flow line for each capsule in the AGR-1 and AGR-2 experiments was designed to monitor the associated gross gamma level. A seventh detector functions as an online spare. The detectors record the accumulated gamma count over a nominal detector dwell time of 3.5 seconds. During normal operation (i.e., with no fuel particle failures), the radiation comes from stray or ‘tramp’ releases from heavy metal contamination on the fuel particles and compacts. In addition, the gross gamma recorders pick up fluctuations associated with perturbations in the instrumentation and recording system. The system is not intended to provide quantitative estimates of fission product releases, but rather to provide an early indication of any fuel leakage that might occur in the experiment.

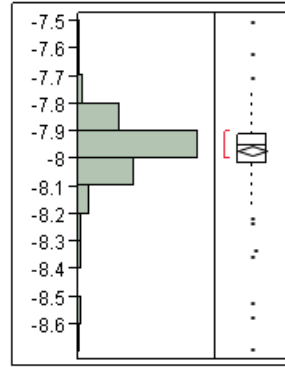
A web page (AGR-2 → GG) exists for AGR-2 that is dedicated to the gross gamma data. The data are included in the FPM page for AGR-1, since the data there are present more for archival purposes than for monitoring.

Distributions ATR_Cycle=143B, Capsule=Capsule 3

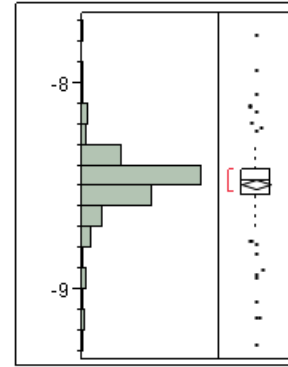
Log_Kr85m_RB



Log_Kr88_RB



Log_Xe135_RB



Quantiles

100.0%	maximum	-7.188
99.5%		-7.188
97.5%		-7.461
90.0%		-7.598
75.0%	quartile	-7.721
50.0%	median	-7.797
25.0%	quartile	-7.874
10.0%		-7.951
2.5%		-8.125
0.5%		-8.636
0.0%	minimum	-8.636

Quantiles

100.0%	maximum	-7.506
99.5%		-7.506
97.5%		-7.788
90.0%		-7.865
75.0%	quartile	-7.909
50.0%	median	-7.951
25.0%	quartile	-8.018
10.0%		-8.078
2.5%		-8.337
0.5%		-8.694
0.0%	minimum	-8.694

Quantiles

100.0%	maximum	-7.766
99.5%		-7.766
97.5%		-8.116
90.0%		-8.356
75.0%	quartile	-8.422
50.0%	median	-8.471
25.0%	quartile	-8.543
10.0%		-8.640
2.5%		-8.960
0.5%		-9.271
0.0%	minimum	-9.271

Moments

Mean	-7.791627
Std Dev	0.1568195
Std Err Mean	0.0111729
Upper 95% Mean	-7.769592
Lower 95% Mean	-7.813661
N	197

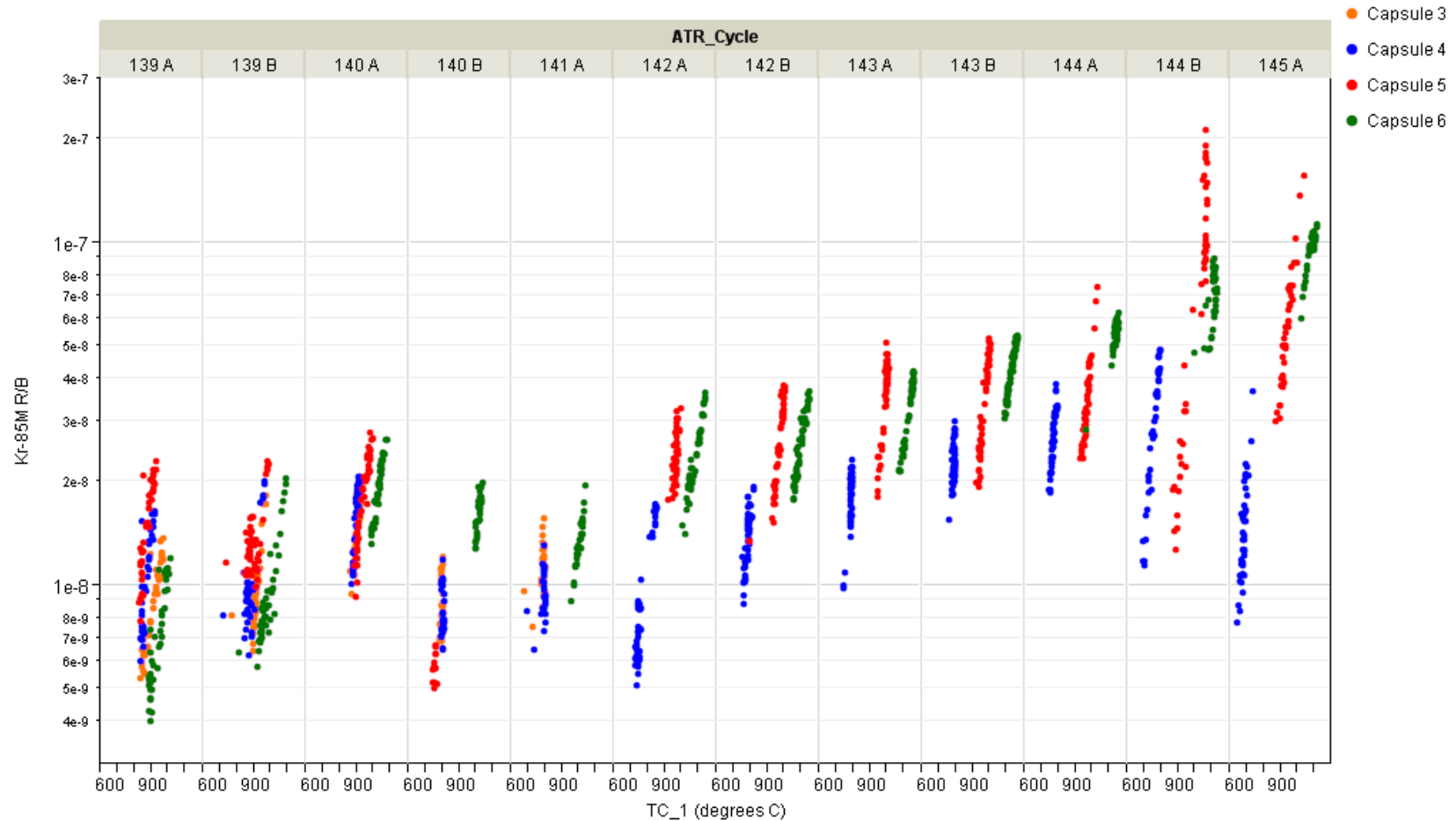
Moments

Mean	-7.971281
Std Dev	0.1259795
Std Err Mean	0.0089985
Upper 95% Mean	-7.953534
Lower 95% Mean	-7.989028
N	196

Moments

Mean	-8.490968
Std Dev	0.1701557
Std Err Mean	0.0122165
Upper 95% Mean	-8.466873
Lower 95% Mean	-8.515063
N	194

Figure 22. Data distribution histogram and statistics for Kr-85m R/Bs (example from AGR-1 Cycle 143B Capsule 3).



NGNP Data Management and Analysis System (NDMAS)

Figure 23. “Kr-85m R/B vs TC1 Temp” plot showing differences in capsule and reactor cycle R/B temperature dependencies.

Bivariate Fit of Log_Kr85m_Rat By TC_1 ATR_Cycle=145 A

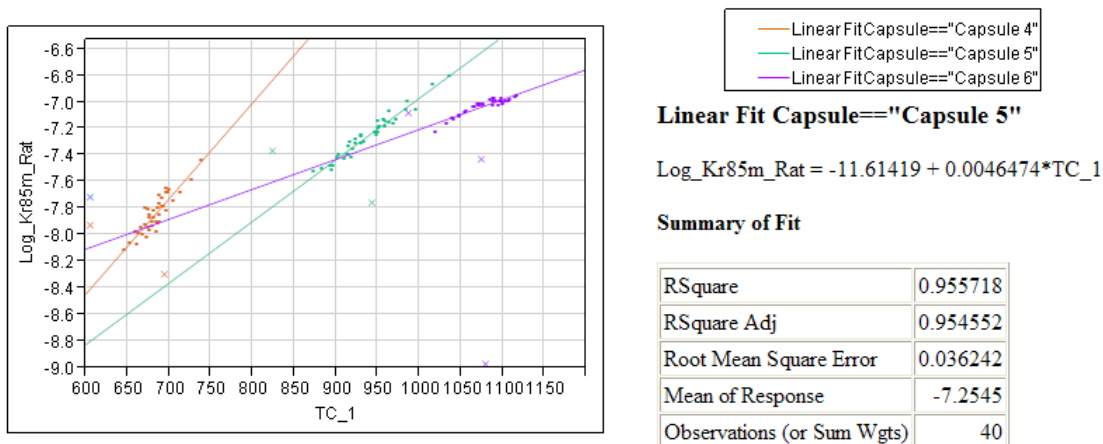


Figure 24. Example of linear fit of Kr-85m as a function of temperature from the "TC_1" TCs in three capsules for AGR-1 Cycle 145A, with details of the regression for Capsule 5.

Two types of displays can be viewed in the FPM Gross Gamma portlets. In the first portlet (Interactive Gross Gamma Plots), users can view graphs of gross gamma counts for any specified less-than-24-hour period or for any specified day or range of days during an experiment. Users also specify the detector of interest for this plot. This capability is provided by the *Stored Process* feature in the INL NDMAS web portal. The stored process directs the system to retrieve and format the data and then create the plots "on the fly." In the second type of display, a standard set of plots shows Detector 3 data for the most recent 7 days, the most recent day (less than 24 hours), and since the start of the most recent ATR cycle (see the example in Figure 25). Detector 3 is associated with Capsule 3, near the center of the

Nal Gross Gamma - ATR Cycle 144B - Detector 4

From cycle start --05/11/09 to 07/22/09

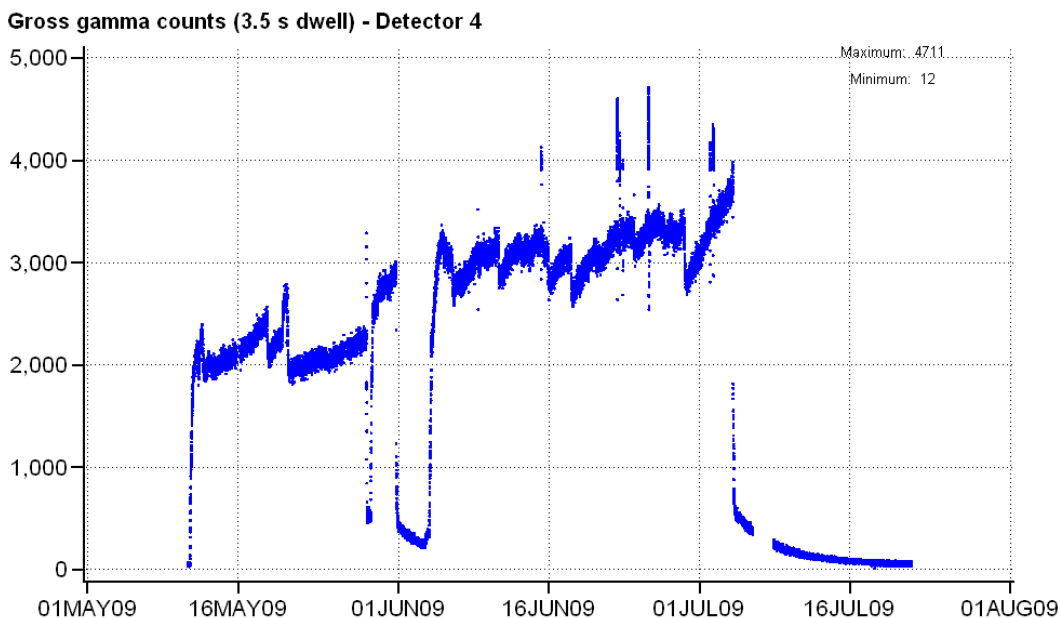


Figure 25. AGR-1 example of gross gamma count plot for Detector 4.

AGR-1 experiment train. Users with access restrictions will see gross gamma count data from their own capsule in this standard display.

The use of gross gamma data in modeling is limited because it is subject to numerous instrument perturbations and does not account for changes in gas flow rates. However, it does respond to changes in the irradiation experiment such as increases in neutron flux, and the data are available almost immediately after collection. Therefore it has considerable potential for real-time analysis of experimental data. The more accurate isotope-specific spectrometer results, which are displayed as release rates (atoms/s) and R/B rate ratios, are probably more suitable for modeling (see the previous section).

2.2.1.7 AGR Irradiation Web Page (AGR-1 → IRR, AGR-2 → IRR)

The AGR IRR web pages contain information about the same measured fuel irradiation attributes as the graphical summaries. Information can be accessed on reactor power measures, gas flow rates, thermocouple temperatures, and logarithms of R/B ratios. A series of reports in the first portlet display the data by ATR cycle, with capsule results grouped together as panels in one graph. A series of reports in the second portlet display the data for separate capsules across all cycles. An example from one of the reports is presented in Figure 26.

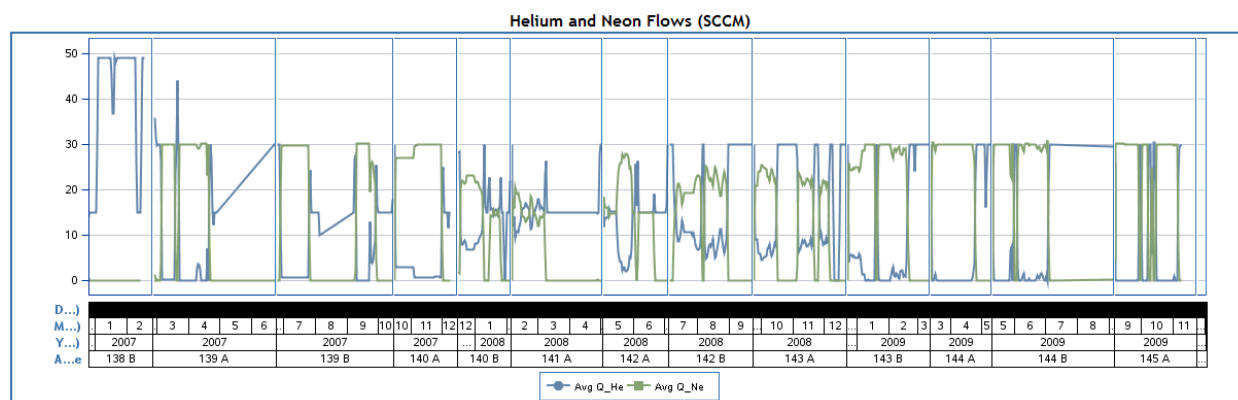


Figure 26. Example from AGR-1 IRR web page (Capsule 4 gas flow rates across cycles).

The reports in these web pages display data from SAS cubes, like the AGC-1 data characterization cubes. The IRR cubes allow rapid analysis because the data are hierarchically arranged with precalculated summary data at each hierarchy level. The data are readily examined at various time intervals, from daily to monthly, yearly, and by ATR cycle.^a The data can also be easily subsetted to focus on particular intervals of time. For each data attribute, a user can observe averages and maximums for the specified time periods.

The time selections are controlled by clicking on particular entities (years, for example) in the X axis of the graph. Expand and drill-down options are provided. Both lead to more detailed displays, but the drill down option also subsets the data to focus on the period selected. Expanding or drilling down on a specific year reveals monthly data. Clicking on a specific month allows further expansion of the associated data as daily values are shown for each calendar day in the month. The data can be reaggregated to return to previous displays showing a broader expanse of time by clicking on particular dates or months and selecting the “Collapse” option. When only daily data appear, aggregation to the month level can be requested by clicking on the Day label on the left side of the X axis.

a. Note that the most detailed data (e.g., 5-minute temperature data) are not accessible through the cubes. Also, since cubes combine different data streams, some interpolation of the raw data occurs to get the data on a uniform daily time scale. Therefore, cube data downloads differ slightly from downloads of source data from single data streams.

Whatever is done in each manipulation to the graph being examined affects all the other graphs in the same report. One option accessed by the time labels on the left side of the X axis allows drilled-down data to be sorted by the attribute being displayed (right click to see these options). This capability is useful for data analysis because one can observe patterns in how other attributes increase or decrease as the studied variable changes.

Further support for data analysis comes from the Section Data options in the box on the left side of the graphs. Different fields can be selected, for example. Exporting the data is accomplished using the right-most icons next to the File/View/Data menu on the left, just below the NGNP header.

For AGR-1, tabular data tables follow the graphs. For AGR-2, there are plot portlets and separate data portlets. The data can be downloaded using the reports in the "_DATA" portlets by ATR cycle for all capsules in an experiment, or for the whole irradiation time for particular capsules. Currently, the AGR-2 reports lack FPM data because these data have not yet been received for the first reactor cycle.

Sometimes a page takes time to load in the browser. A "Working" icon appears in a horizontal bar just under the NGNP main header during this delay time. A "cancel" button is provided next to the working icon so that the user may exit out of the process if desired.

2.2.1.8 AGR Neutronics/Thermal Simulations Web Page (AGR-1 → PHY)

The AGR-1 Neutronics/Thermal Simulation Data ("PHY" for physics) web page contains JMOCUP model "as-run" neutronics simulation results for (1) average fission power density (FD in W/cc and MW) by capsule; (2) maximum, minimum, and average fuel burnup for each capsule [in fissions of initial metal atoms (%FIMA)]; and (3) maximum, minimum, and average fast neutron ($E > 0.18$ MeV) fluence (in neutrons/cm²) for each capsule. The Lillo fast neutron fluence data (e.g., AGR1_Lillo_S1) are end-of-cycle cumulative values, while the Sterbentz data (e.g., AGR1_Sterb_S1) are daily averages. Detailed descriptions of these data and how they were calculated can be found in ECAR-958 (Sterbentz 2010) and INL/EXT-10-17943 (Abbott et al. 2010).

Thermal data on the web page includes daily ABACUS model simulations of AGR-1 fuel temperatures (SFT, in °C), averaged over compacts (AGR1_Hawk_Compact), stacks (AGR1_Hawk_Stack), and capsules (AGR1_Hawk_CAP). Simulated thermocouple temperatures (STC, in °C) also appear. Each fuel temperature data set includes (1) maximum, minimum, and average daily simulated fuel temperatures and (2) time-averaged maximum, minimum, and average daily simulated fuel temperatures (SFT-TA, in °C). The thermal data are documented in ECAR-968 (Hawkes 2010) and in Abbott et al. (2010). Both the thermal and neutronics data table links on the web page are in a "SAS Data Exploration" format, which allows the user to customize the tabular online presentation (e.g., by filtering, sorting, removing/adding variables) and also to download the data to Excel.

Also included on the web page are links to plots of (1) ATR power history with EFPD estimates by calendar day (Figure 27), (2) fuel fission power density (Figure 28), (3) fuel fission power density trend (Figure 29), (4) fuel burnup (Figure 30), and (5) cumulative fast neutron fluence. These NDMAS plots combine a large amount of information using the advanced plotting capabilities of the JMP software and were used by the data generators in their ECARs (ECAR-958 and ECAR-968).

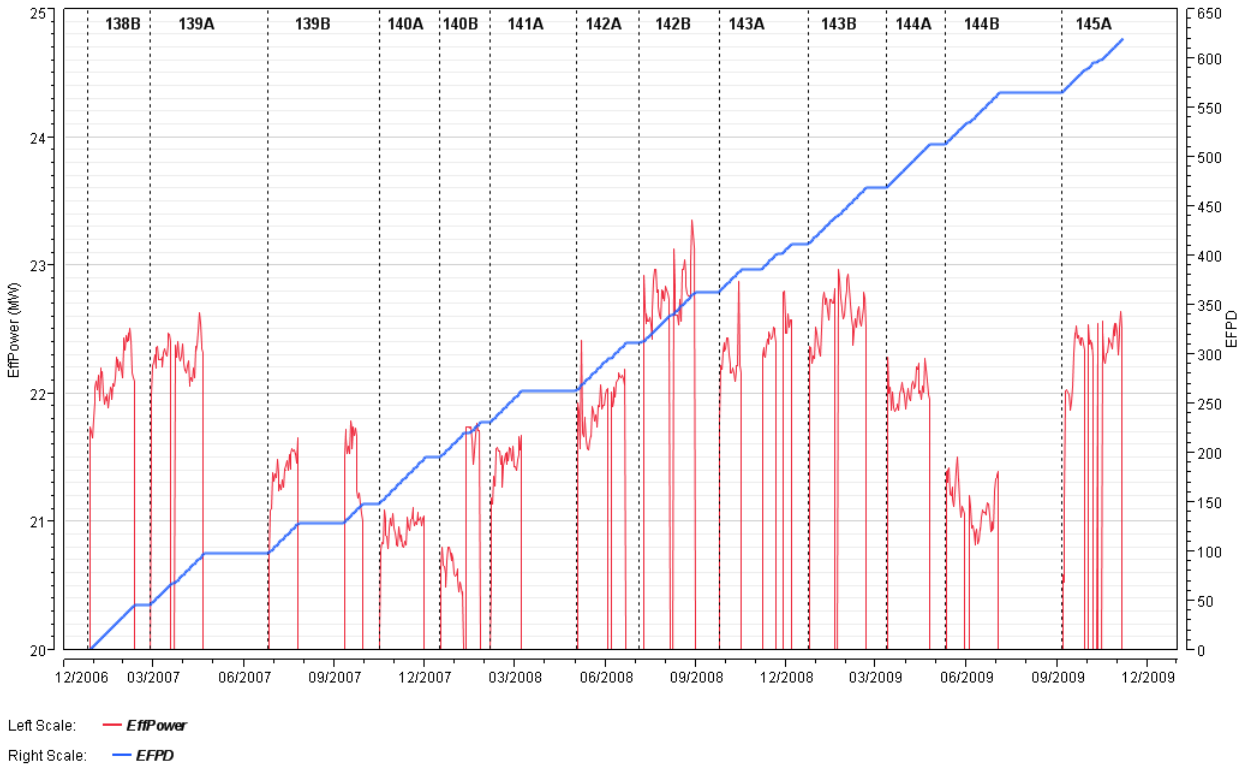


Figure 27. EFPD as a function of ATR effective power history for AGR-1.

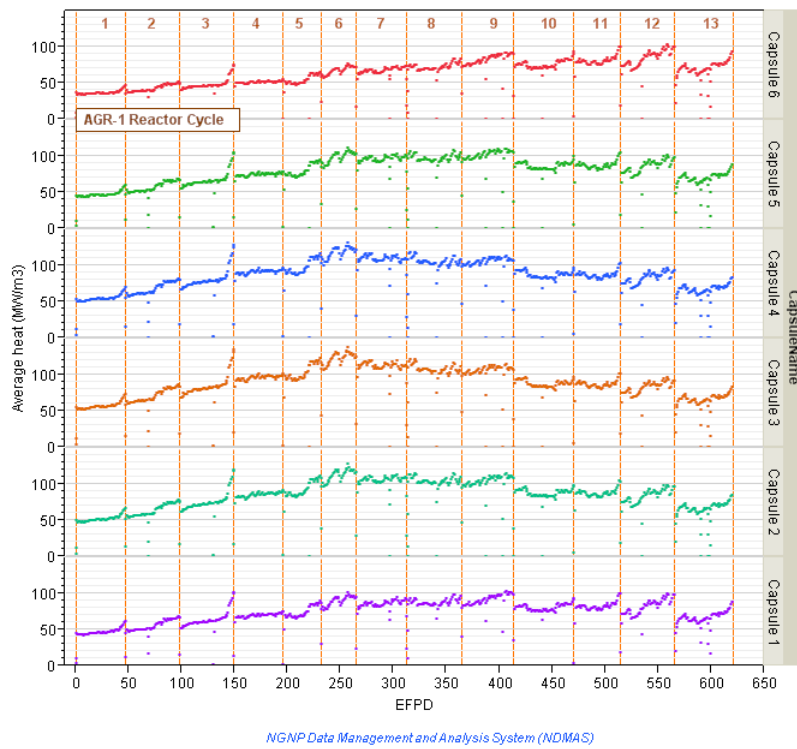


Figure 28. Simulated daily average AGR-1 fuel fission power densities by capsule.

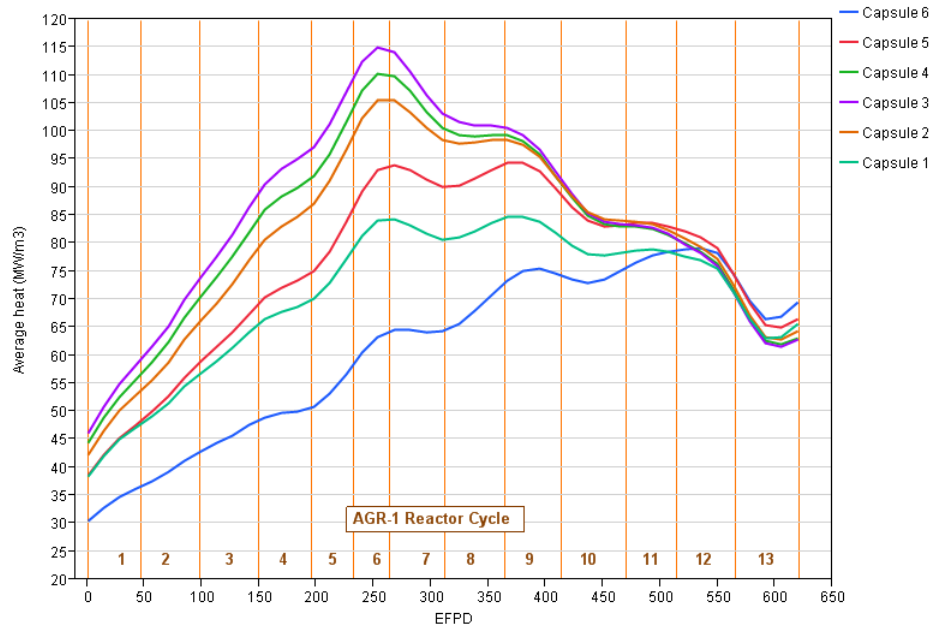


Figure 29. Overlay showing a smoothed version of the AGR-1 fuel fission power densities for each capsule.

2.2.1.9 Analysis Web Pages (AGR-1 → Analysis, AGR-2 → Analysis)

The AGR Analysis web page shows data analyses that are intended to assess potential data anomalies in the fuel irradiation experiment TC readings. Knowledge of the temperatures experienced by the fuel, along with the neutron flux, is important for assessing experimental results. A primary purpose of the fuel irradiation experiments is to determine which fuels perform best in the high-temperature, high-flux environment of a VHTR.

The temperature data sets provide an important indication that an experiment is progressing as planned. The data streams are also important for experiment control, because the gas transport system uses these data to adjust the mixture of neon and helium in each capsule to control temperatures in the experiment. Helium has a higher thermal conductivity than neon, and thus transfers thermal energy more rapidly between the capsule and the much colder water in the reactor vessel, leading to decreased capsule temperatures. Neon has a significantly lower thermal conductivity, so capsule temperatures can be increased by increasing the neon/helium ratio of the gas flow mixture.

A primary means of assessing the accuracy of the TC data relies on numerical simulations conducted by the AGR-1 technical staff. Measured temperatures are compared to calculated TC temperatures to help evaluate the integrity of the TCs. During the irradiation, the calculated temperatures are determined for one or more times during each reactor cycle. Eventually, daily average values are computed. Steady-state fission power heating rates are calculated for the test fuel stacks, using a combination of the MCNP and ORIGEN2 nuclear reactor simulation codes (Chang and Lillo 2007). These calculations employ reactor operating conditions data stored in NDMAS. The heating rates are then used as source terms in a 3-D heat transport model of the AGR-1 experiment capsules (Ambrosek 2005), to calculate temperatures in the fuel stacks and at the thermocouples. These complex evaluations are beyond the scope of NDMAS modeling. They have the advantage of accounting for a wide range of evolving conditions in both the ATR and in the experiment itself, including changes in power levels induced by changes in the configuration of the ATR, fuel burnup within the capsules, and boron depletion in the graphite holder

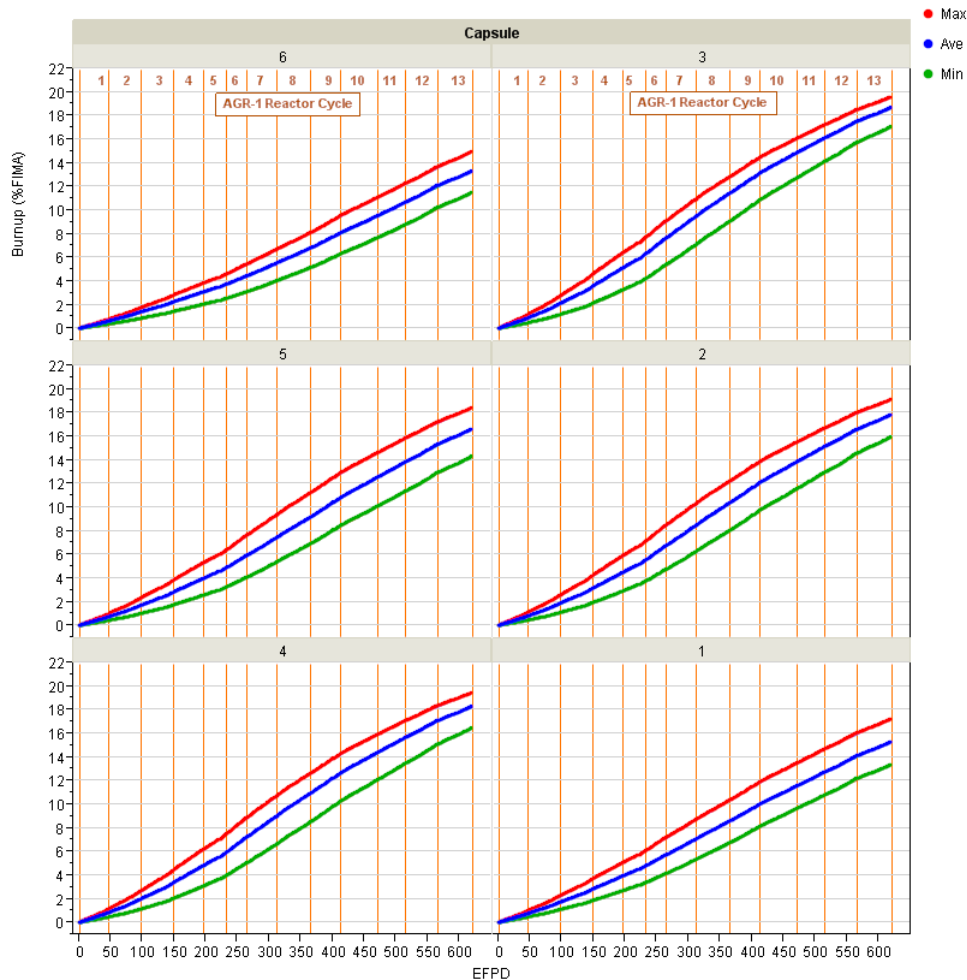


Figure 30. Simulated AGR-1 fuel burnup data for each capsule as a function of EFPD.

assembly. When TCs record temperatures significantly different from readings predicted by numerical simulation, the TCs may be judged to have failed.

For AGR-1, measured temperatures have been supplied by the TCs every hour during the first cycle in the experiment, every 10 minutes during the second cycle, and every 5 minutes during the rest of the experiment. Measured temperatures are supplemented and checked against temperatures calculated via simulation of neutron transport and heat transport.

Because of the importance of the TC readings, much of the current NDMAS analysis effort has focused on how to determine whether or not they are accurate. The “Analysis” web pages show the results of some of these analyses. Like the graphical summary pages, they do not provide direct access to the data, nor do they allow the user to manipulate the data. However, the displays facilitate thinking about relationships in the data, allow between-capsule comparisons, and support intuitive modeling about the overall effects of time on temperature as fuel burnup increases and boron content decreases from ATR cycle to ATR cycle.

The first portlet in the Analysis web pages provides TC information. The 18 TCs installed in the AGR-1 irradiation experiment test train are described for AGR-1, including their design and where they are installed. Half of the TCs have experienced failure. The portlet provides failure dates and other information about the failures. The introductory AGR-2 analysis web page is similar. Each capsule in the

AGR-2 experiment has two TCs except for Capsule 6, on the top of the test train, which has five. One TC in Capsule 2 is not reporting data and appears to have failed in fabrication or installation. In the analyses that follow, all of the data are filtered to time spans when the ATR effective power (the average of the power in the nearest three ATR lobes) was at least 20 MW. The analyses use daily data (e.g., 5- or 10-minute data) to compute daily correlation coefficients. Temperature plots show daily averages.

For AGR-2, to support current monitoring of TC performance, the next two portlets give historical data about the temperatures and gas flows. The gas flows show also the total outlet gas flow and the sum of the neon and helium flows. Gas leakage into a capsule can be inferred when the outlet gas flow rate exceeds the sum of the neon and helium flow rates.

For both tests, the main display shows within-capsule evaluations. It contains two of the three main tools for TC evaluation. The first is plotting control charts of differences in daily average TC readings in the same capsule. While the temperatures change in response to process condition changes such as ATR power changes and changes in the neon fraction for a capsule, the temperature differences for TCs in the same capsule might be expected to remain fairly constant. Such TCs are exposed to the same set of process variations, particularly if they are in similar positions in a capsule. From the start of the experiment, differences were monitored and their sample standard deviations were computed. The standard deviations were evaluated to identify the point in time when they stopped changing as more data were added to the calculation. The period from the start to this point in time is called the baseline period. More recent data are in the "monitoring period." If the more recent differences follow the same normal distribution as the differences in the baseline period, they will stay between the estimated baseline period average plus three standard deviations and the average minus three standard deviations over 99% of the time. Noticing whether the monitoring period data stay within their control limits is the first TC monitoring tool.

The second tool is an examination of the series of daily correlation coefficients between TCs in the same capsule. Five-minute readings provide 288 data pairs each day for a correlation calculation. These readings should be highly correlated since they see the same variation in ATR power loading and the same neon fraction in the control gas. Drops in the within-capsule daily correlation coefficients are not expected when the TCs are operating properly. This test and the control chart method are both ways of possibly detecting instances of instrument drift for a single TC.

Figure 31 and Figure 32 provide examples of these plots for AGR-1 and AGR-2, respectively. The displays for AGR-1 also have a panel that shows differences from the simulation model calculated data. These differences help identify which TC in the pair is failed; for example, in Figure 31, the green dots in the second panel show that TC3 readings were decreasing compared to the simulated values as the experiment proceeded. For AGR-2, just one cycle of data is available.

Correlations are expected to be lower for TCs from different capsules, especially since the control gas mixture is administered to each capsule separately. Another possible TC failure mode is the forming of a junction in the lead wires for two TCs. Such a junction is most likely to occur for a TC in a lower capsule connecting with one from a higher capsule, since the TC wiring comes out of the top of the test train. If such a failure occurred, the TC in the lower capsule might have readings like the TC in the upper capsule. To test for this possibility, between-capsule TC daily correlation coefficients were evaluated. For each TC, for each day, daily correlation coefficients are evaluated for all the other TCs. The TC with the highest such correlation is identified. For the third evaluation tool, the number of the capsule containing the highest-correlated other TC is monitored. This capsule is expected to be the same capsule as the subject TC. The formation of a pattern for which the highest correlated other TC remains consistently in some other capsule provides evidence of a possible junction problem. Figure 33 and Figure 34 show examples of these plots for AGR-1 and AGR-2, respectively. Each graph shows the capsule of the subject TC as a solid line, and the capsules of the TCs with daily maximum correlations to other TCs as circles.

Capsule 5: Control Chart for Daily Average of TC Differences, and Daily Correlations of TC1, TC3

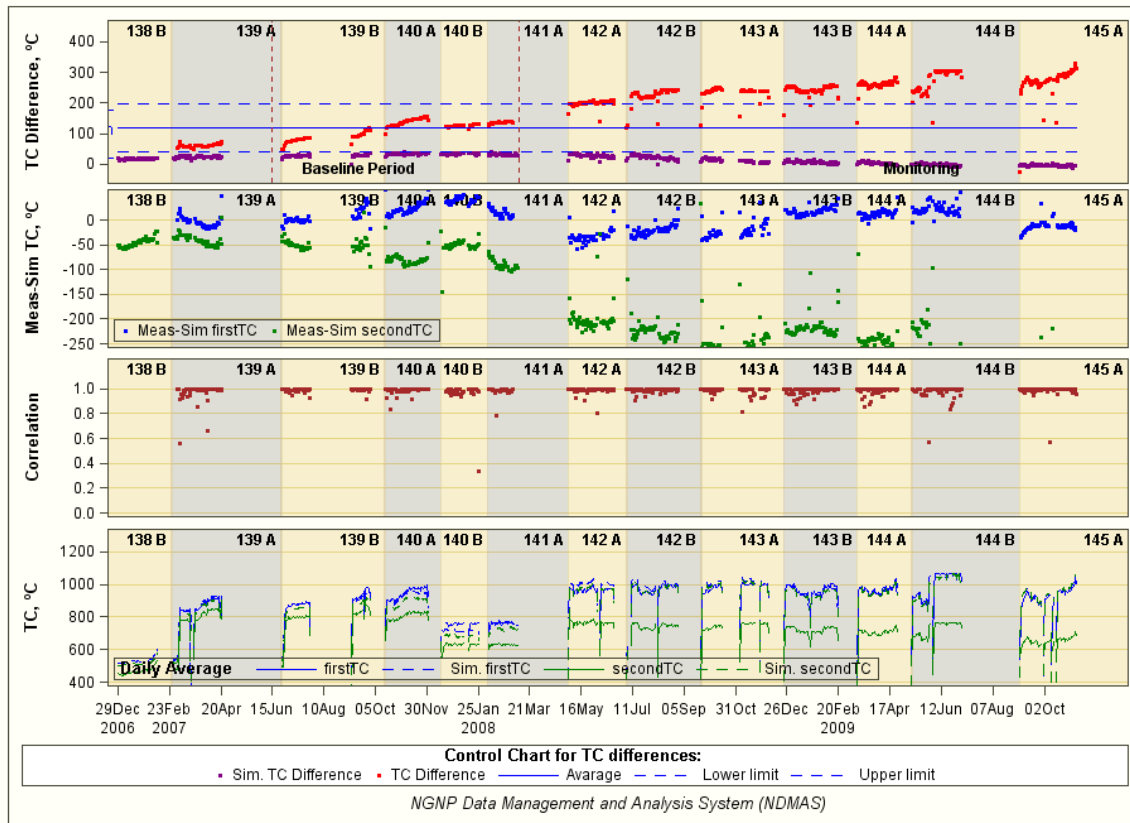


Figure 31. AGR-1 Capsule 5 within-capsule control chart and correlation test for TC drift.

Capsule 5: Control Chart for Daily Average of TC Differences, and Daily Correlations of TC1, TC2

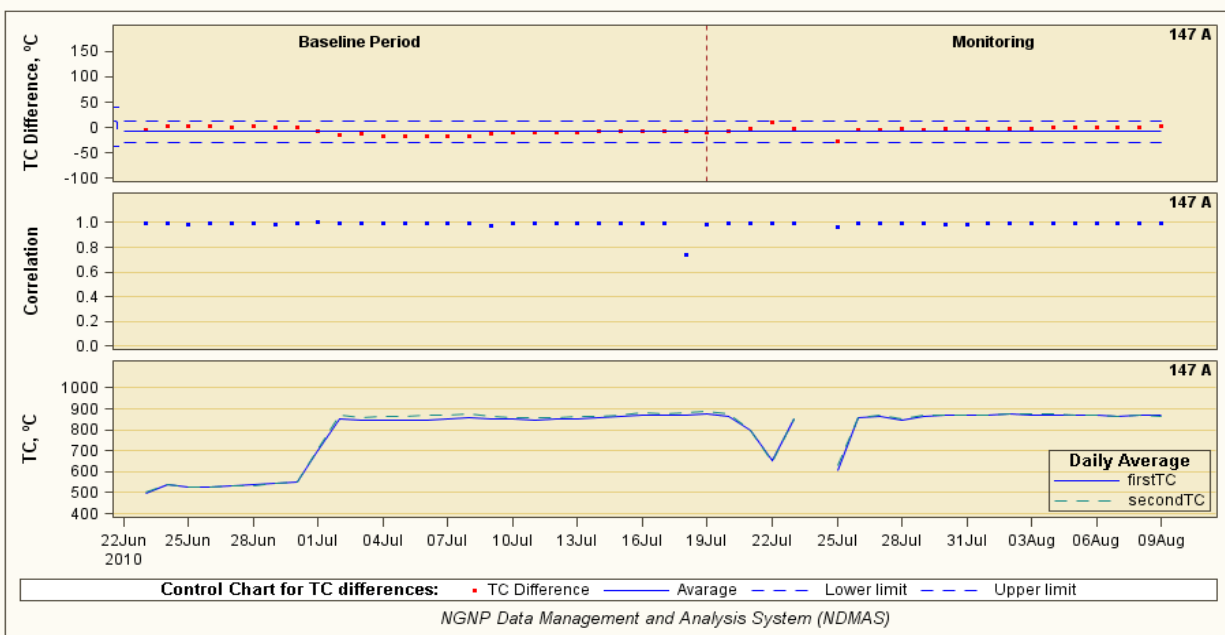


Figure 32. AGR-2 Capsule 5 within-capsule control chart and correlation test for TC drift.

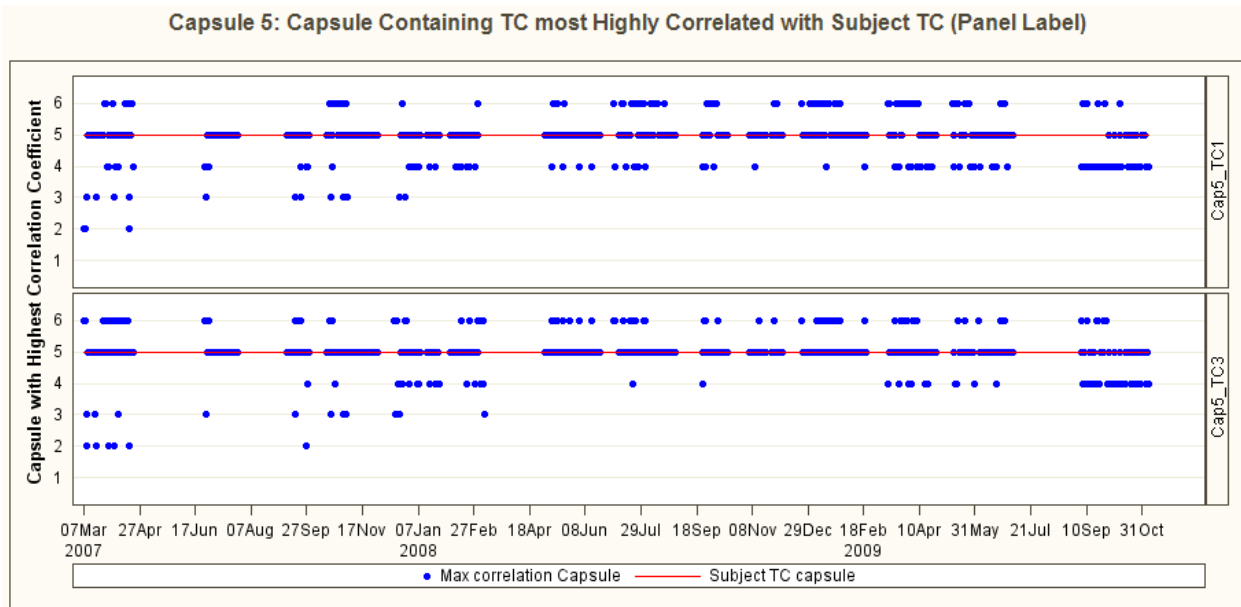


Figure 33. AGR-1 Capsule 5 between-capsule correlation tests for possible TC junctions (the highest correlations are for the most part with the other Capsule 5 TC).

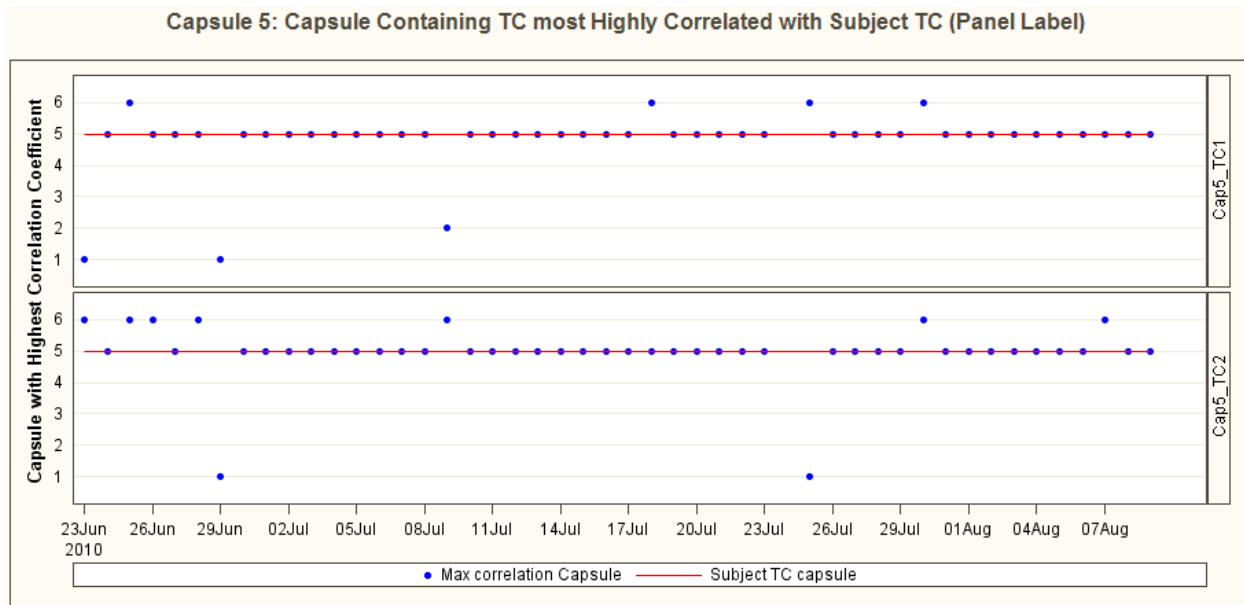


Figure 34. AGR-2 Capsule 5 between-capsule correlation test for possible TC junctions (the highest correlations are for the most part with the other Capsule 5 TC).

To supplement the between-correlation maximum capsule plots, a portlet is present for each test with the actual between-capsule correlations plotted. The form of the plot for AGR-2 is a simple display of daily correlation coefficients for pairs of control TCs (for example, see Figure 35). Since each capsule has such a TC, there are 15 such pairs.

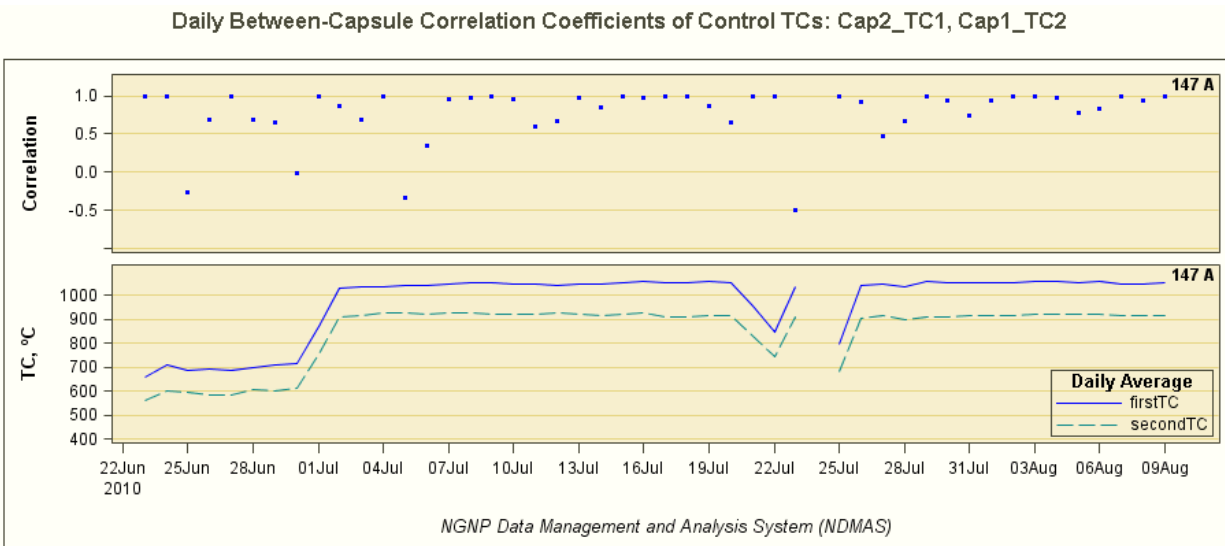


Figure 35. Additional information for AGR-2; example of between-capsule correlations for control TCs.

For AGR-1, which has much more historical data, box plots were used to show the correlations. For each individual TC, both within- and between-capsule correlations are shown in separate portlets. The daily correlations with all the other TCs during a cycle provide the data going into the plots. For example, AGR-1 Capsule 5 has two TCs and thus one within-capsule correlation coefficient on each day. If a cycle has 40 days of operation, then 40 points are summarized in the box plot above that cycle in the within-capsule plot (see the example in Figure 36). Seven working TCs lay outside Capsule 5, so each day of operation provides seven between-capsule correlations. Thus, much more data for a cycle go into the between-capsule correlation box plots (see Figure 37). The box plots show the center 50% of the data in the box itself (from the 25th percentile to the 75th, which is the interquartile range). The lines in the boxes show the median of the data and the circle shows the mean. Points lying 1.5 or more interquartile ranges beyond the box are flagged. Comparing Figure 36 and Figure 37 shows that the within-capsule correlations are much higher than the between-capsule correlations, especially in the last few ATR cycles.

The last portlet contains daily average capsule TC temperatures plotted with cycle averages and standard deviations (see the AGR-1 example in Figure 38 and the AGR-2 example in Figure 39).

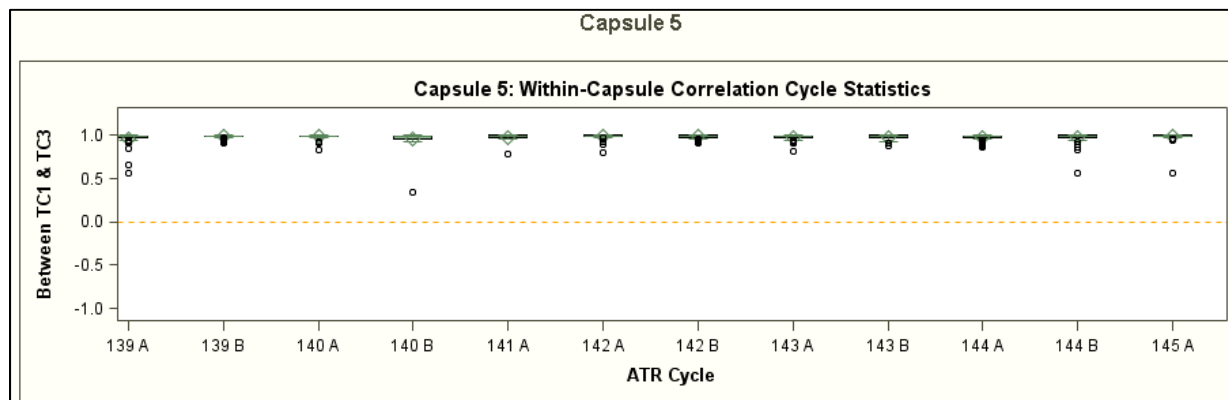


Figure 36. AGR-1 Capsule 5 box plots of daily within-capsule correlation coefficients by reactor cycle.

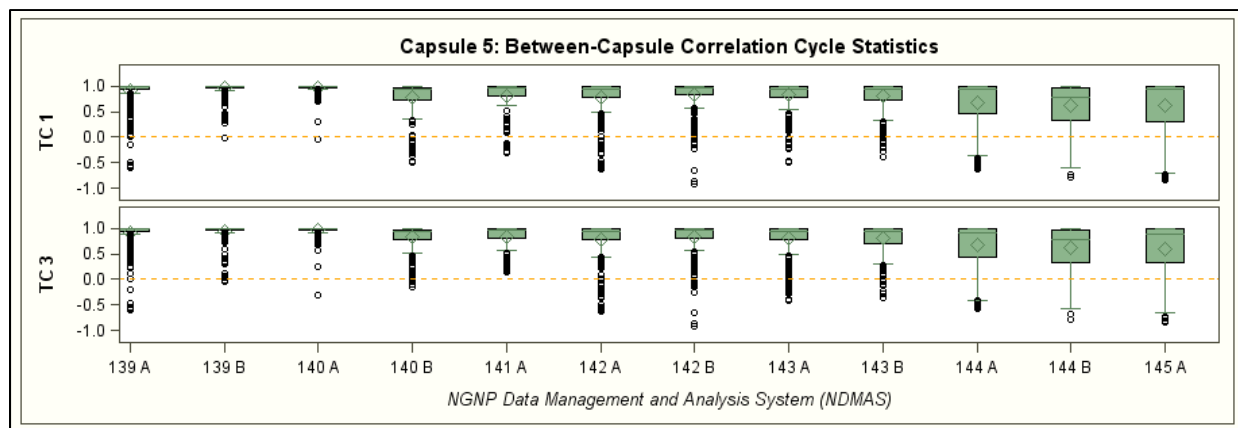


Figure 37. AGR-1 Capsule 5 box plots of daily between-capsule correlation coefficients by reactor cycle.

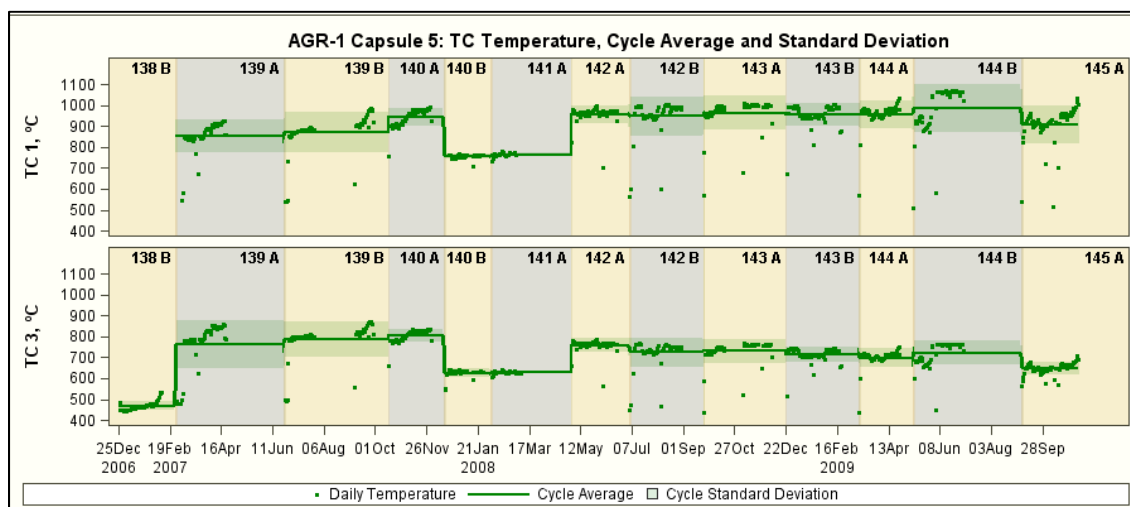


Figure 38. Example of daily TC temperatures with cycle-level average and standard deviation for AGR-1.

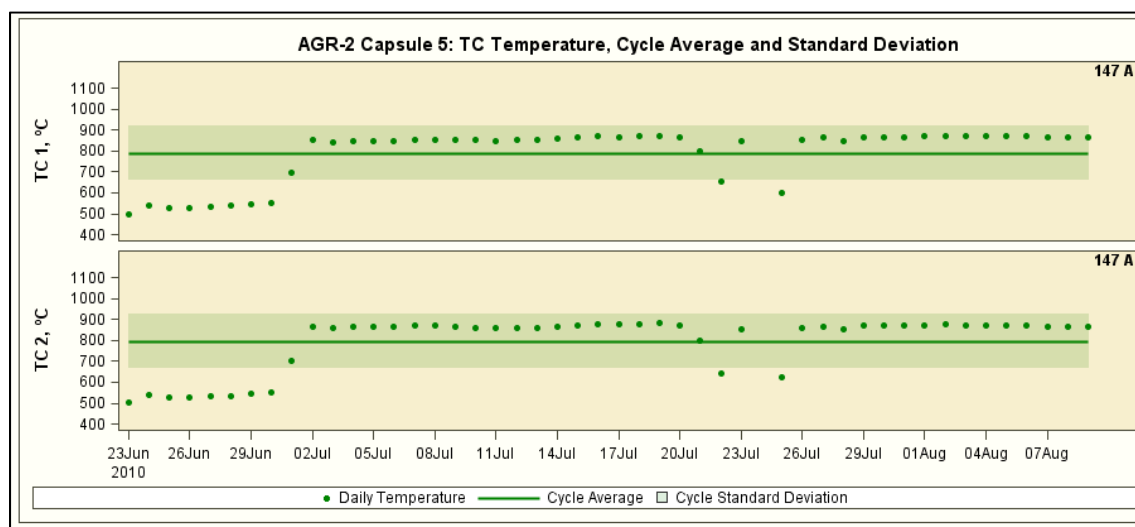


Figure 39. Example of daily TC temperatures with cycle-level average and standard deviation for AGR-2.

2.2.1.10 High Temperature Materials Tensile Testing Web Page (HTM → A-1)

The high-temperature material (HTM) home page lists the test series that are planned to identify materials for supporting systems and components that will withstand the high temperatures associated with the VHTR. The first test series to submit data to NDMAS is the "A-1" tensile test. In this test, samples from plates of Alloys 617 and 800H were pulled in uniaxial tension over a period of time with increasing stress until they broke. The test was performed at a variety of temperatures. During each process, the elongation was measured and the applied stress and strain (elongation as a percentage of the original length) were recorded.

For each trial, researchers recorded the following strength parameters:

- the maximum elongation (%)
- the percent reduction in cross-sectional area
- the yield strength (point at which permanent deformation is experienced) (MPa)
- the ultimate tensile strength (UTS) (MPa) (maximum stress prior to necking).

The first portlet for this test series displays these strength parameters as a table. The second portlet contains graphical summary plots, starting with a plot (Figure 40) of these values.

The additional plots in the graphical summary provide further details. A plot exists for each alloy. In each plot, traces of stress as a function of strain are shown for each temperature. The initial linear portion of each trace is the elastic region; the middle section of each trace is the strain hardening region; and the final section of decreasing stress is the necking region, where the local cross-sectional area decreases rapidly until the sample ruptures. Figure 41Figure 40 is the plot for Alloy 800H. The summary strength parameters can be inferred from the graph traces, except for the change in area.

Data from these tests will be used to identify time-independent design allowable stress limits.

The A1 web page also supports downloading the data. The last portlet contains a small table with alloy sample numbers. Clicking on one of the numbers initiates the downloading of the data for that sample. The comma-separated value (.csv) file that is transferred opens directly in Excel, or the file can be saved on the user's hard drive.

2.2.1.11 High Temperature Materials Creep-Fatigue Testing (HTM → A-20)

In the A-20 test series, samples from Alloy 617 plates are subject to fully-reversed strain cycles. To achieve a 0.3% strain range, for example, the sample is pulled until it reaches 0.15% strain. This position is held for a specified "hold" time before the sample is pushed until it reaches 0.15% compression. This process, called a cycle, was performed repeatedly in a high-temperature environment (950 °C). The experiment is being performed in an air environment, but will be repeated in a helium environment more like the VHTR. In the data received thus far, the specified strains have been 0.3%, 0.6%, and 1%, and the hold times have varied from 0 minutes (no hold time) up to 3 minutes, 10 minutes, and 30 minutes. The cycles were repeated until researchers determined the sample had failed.

For each cycle, the maximum and minimum stresses applied were recorded, along with the times. For select cycles, the time, stress, temperature, elongation and strain values are recorded. Only the "logarithmic" cycles (1, 2, 5, 10, 20, 50, 100, etc.) are recorded in the NDMAS system. The graphical summary portlet in the A-20 web page shows the hysteresis loops corresponding to the logarithmic

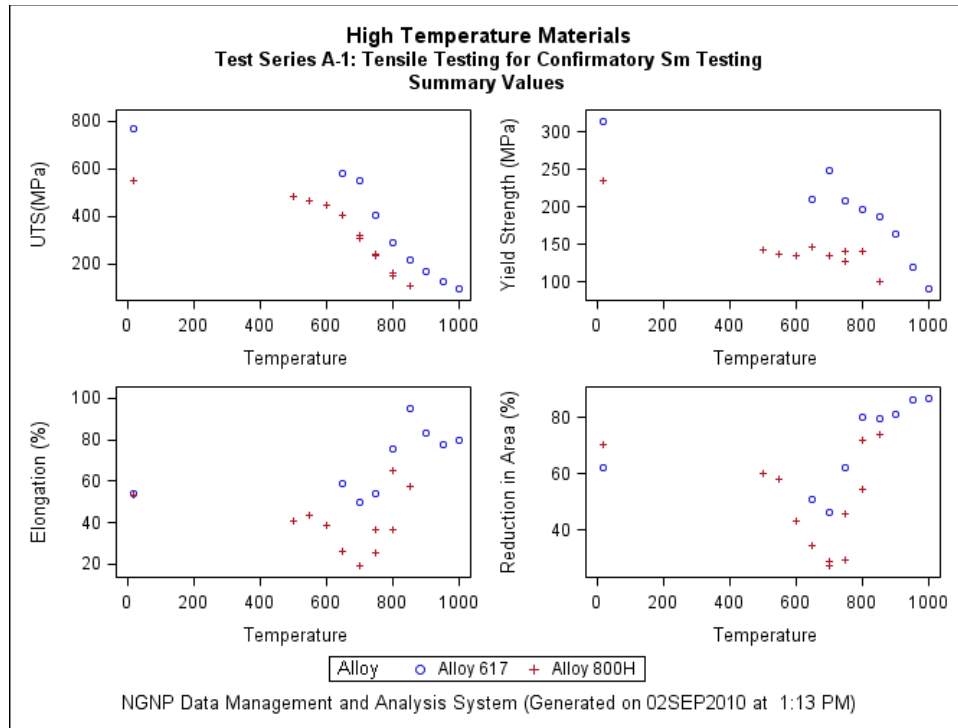


Figure 40. .HTM Test Series A-1 tensile testing summary.

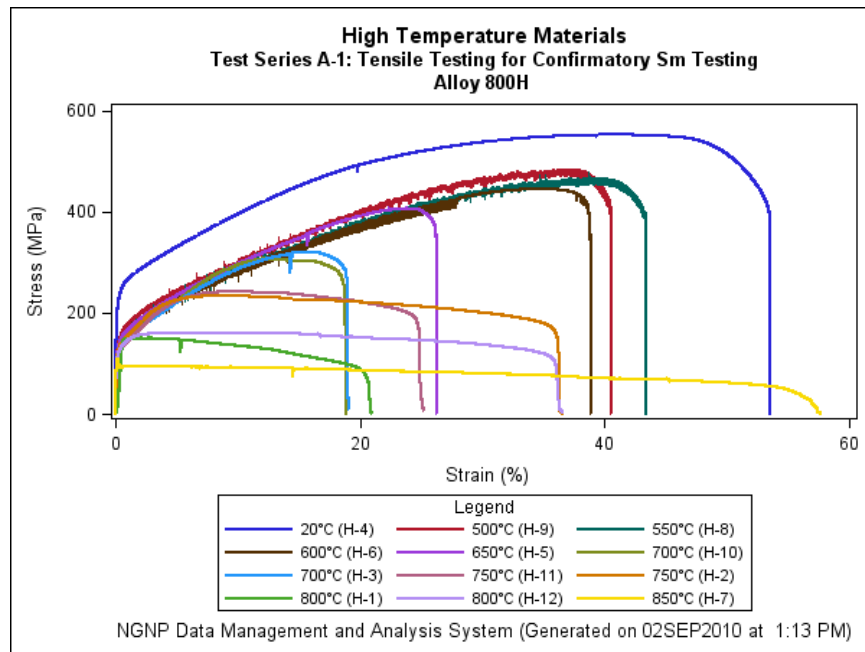
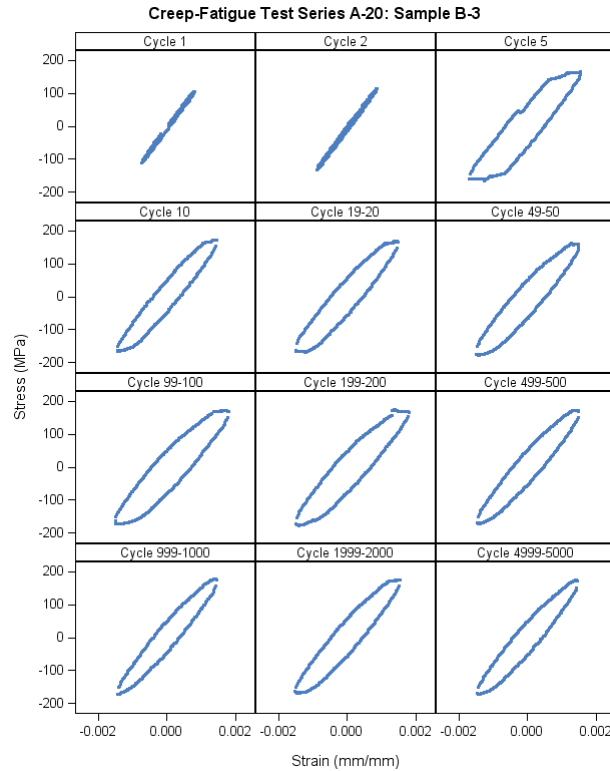


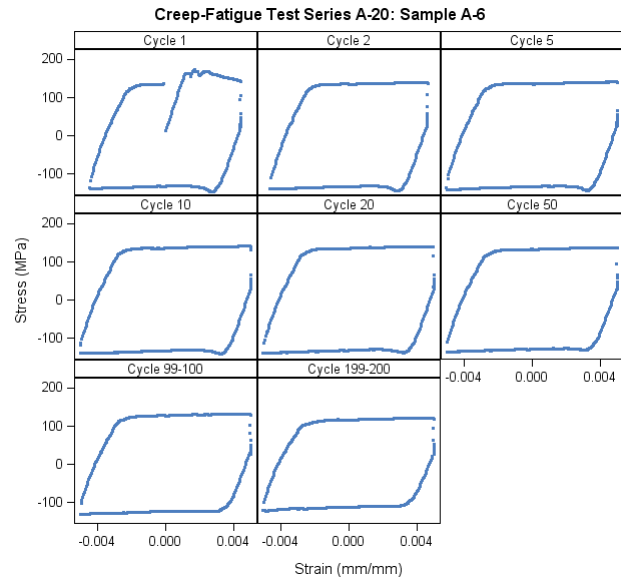
Figure 41. HTM Test Series A-1 tensile testing curves for Alloy 800H.

cycles. Figure 42 shows the results from a 0.3% stress range test with no-hold time on the left and a 1% strain range test with a 3-minute hold time on the right.

The A-20 web page also supports downloading the data. Clicking a link directly above the graphs will initiate the downloading of the sample's cycle data or peak stress data (ratios of high and low stresses for



Air, 0.3% strain, no hold



Air, 1% strain, 3 min. hold

Figure 42. HTM Test Series A-20 hysteresis loops for selected elongation/compression cycles.

each cycle) to the user's hard drive as a comma-separated value (.csv) file that will, if desired, open in Excel.

2.2.1.12 Summary of Data Analysis and Delivery from the INL NDMAS Web Portal

The examples discussed above presented several capabilities for website users to view data and visually explore relationships. The primary data analysis and web display capabilities are:

- Data visualization through ordinary graphs
- Data visualization through lattice graphs that show several plots grouped according to a common attribute. The differences that define the groupings (such as different experiment capsules) can be compared.
- Tabular drill-down views of the data using SAS EBI “cubes”
- Data exploration panels that allow the user to select particular variables, observe aggregated results, and download data
- Customized graphs for particular time periods, obtained using stored processes
- Box plots and histograms that show data distributions
- ActiveX graphs that allow additional customization of the observed displays.

Web delivery/data download capabilities are integrated in the tabular drill-downs, and data explorations. Data are also provided through the use of stored processes.

2.2.2 Data Analysis and Web Delivery Capabilities for the NDMAS Team

The NDMAS team has direct access to the data in the SQL “Vault.” Data sets judged most useful are shown in the INL NDMAS web portal, but all the data in the system are accessible to the NDMAS development team.

The data are stored in NDMAS as described in Figure 43. The vast majority of the data enter the system from electronic records such as text files or Excel spread sheets. In Figure 43, these are schematically shown in the “Source” rectangle. Enterprise Guide (EG) is a tool provided by SAS for data manipulation and analysis. “Projects” have been created in EG to process each data stream and load it into an SQL Server database. This data repository is represented in the “Storage” box in Figure 43 as a tall cylinder, because ultimately, each datum is placed in a separate record. There are literally millions of short records in the main data table. Isolating each data value allows the data qualification activities of the database to flag and resolve individual problems. The Vault also provides for data security and change control.

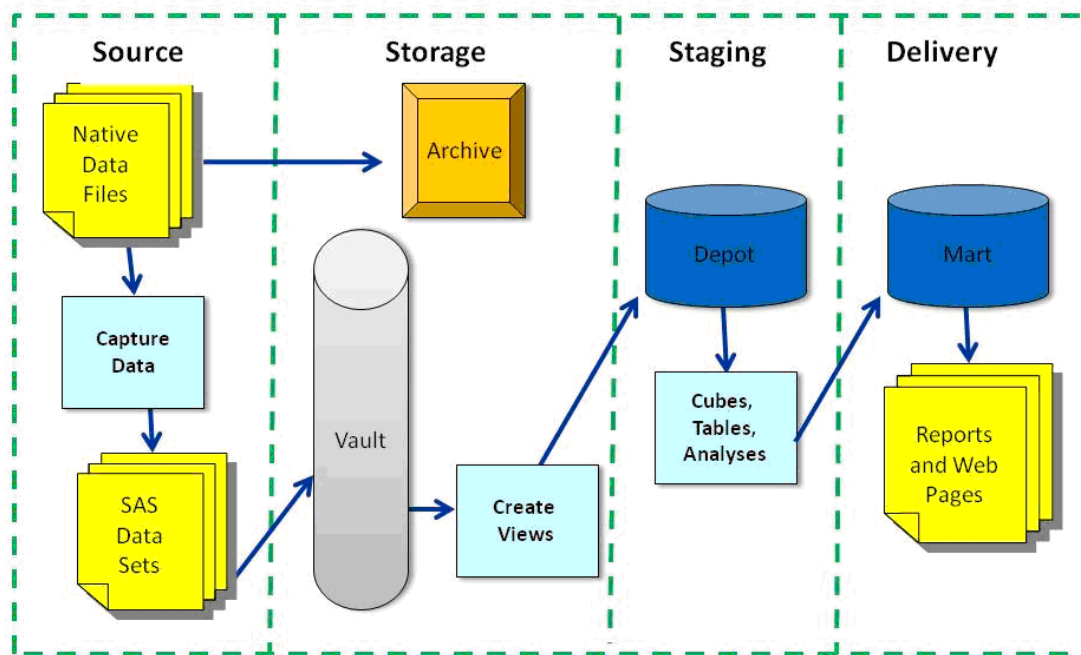


Figure 43. Four major steps in NDMAS data processing.

NDMAS developers extract the data from the Vault as tables, generally with multiple measurements in each record such as experiment parameters (temperatures and gas flows) in a particular capsule at a specific point in time. These more “horizontal” data views are contained in the “Depot” shown in the Staging box in Figure 43. These are the primary data sets used by NDMAS team members for modeling and analysis. The “Mart” in the Delivery box is a mirror image of the external NDMAS server, and provides the production capabilities described in Section 2.2.1. The Mart is separate from the Depot in order to ensure that errors or problems that occur in developing models will not affect the reliability of the production web pages. Results of the modeling are displayed from the Mart.

Some general guidelines for using Enterprise Guide to create models using the NDMAS data are given in [Appendix B](#). Additional modeling capabilities are provided by the SAS “JMP” product. These are also described further in this appendix.

2.2.3 Data Analysis and Web Delivery Capabilities via Analysis Requests

The ready-to-download data tables and analysis results in the web pages are structured based on the best knowledge of NDMAS staff. The most detailed levels of data for some of the VHTR projects contain millions of records. Web display of detailed data (such as individual 5-minute temperature readings) is not practical because the time required for such displays to render would be prohibitive. However, users who need particular studies to be performed using the VHTR data can request these analyses from the NDMAS staff.

In addition to making new or different calculations with the most detailed data, the requests may involve combining different types of data from different data streams. The data streams from various sources are organized in NDMAS in a linkable manner based on specific component, variable, and data package identifiers. An example of a recent request was the joining of AGR-1 fuel fabrication data with the physics simulated data describing conditions at the end of the experiment. The average fuel temperatures, burnup, and fluence data for each compact were associated with the compact's fabrication identifier. The traceability of attributes from the PIE data to the fabrication data will also be preserved when the PIE data are loaded into NDMAS.

Results can be displayed on the INL NDMAS web portal and/or in reports, as desired by the person making the request. For the reports displayed in the portal, user group security options may be employed to restrict access if needed. Data analysis reports can thus be distributed to particular users on the Internet based on assigned groupings.

2.2.4 Data Analysis Capabilities via Downloads

The INL NDMAS web portal provides several options for downloads of the data. Users can also request particular data sets and the NDMAS team will deliver them (pending appropriate release approvals). The results can be in Excel spreadsheets or many other formats, as desired by the user. Such data can be combined by the user with other data and used for data analysis to further the state of VHTR research in whatever way the user has in mind.

2.3 Uses of the Applications

NDMAS data analysis and web display capabilities have many potential uses, including:

- Scientific understanding is, of course, a fundamental reason for any attempt to identify relationships between variables.
- Data visualization for web page outputs helps researchers grasp the patterns in the observed data. In the web pages, these patterns are distilled from sometimes thousands of records.
- Accuracy tests for input data streams are a current use for many of the analyses. Some of the tests are based on simple calculations, such as the idea that the coefficient of variation (the standard deviation divided by the mean) should remain within certain bounds. Others are based on functional relationships established by a regression analysis. Once a pattern has been established, significant deviations from the pattern give rise to alerts for increased data review. Such deviations either indicate errors in the data collection process, or significant changes in experimental conditions.
- The alerts or early warnings of possible anomalies or instrument failure based on departure from prior patterns can be useful during the experiments. In some cases, experimental conditions can be adjusted or corrected as a result of the accuracy tests. The timeliness of data processing in NDMAS also facilitates this potential use of the analyses and web monitoring displays.
- The analyses can be used for experiment control.

- Hypothesis tests of the experimental results can be developed and evaluated. The tests can help identify the features of the experimental design that make a difference, or the features that lead to the best performance. Random variation is always present. The statistical analyses can help distinguish whether the measurement results of one process are really likely to be an improvement over the measurements from a different process, even in the presence of this variation.
- The analyses can help identify limits defining envelopes for safe operation.
- Alternately, the data can be used to characterize reliability, given particular operating limits.
- The statistical analyses can lead to response surfaces that allow users to predict future phenomena based on operating conditions that have been studied in prior ATR reactor cycles or VHTR experiments.
- The statistical analyses can support VHTR licensing.

3. EXAMPLES OF CURRENT DATA ANALYSIS APPLICATIONS

This section contains examples of data analysis applications (rather than web delivery). The development of these applications is an ongoing process. NDMAS will be expanded and sections will be added to future versions of this report as more data streams enter the database and more analyses are performed.

For this version of the report, the following four applications are discussed: TC monitoring, use of the data to identify possible anomalies, use of regression models for sensitivity studies and potential use of regression models for experiment control.

3.1 TC Monitoring

Three methods were described in Section 2.2.1.9 for monitoring TC performance: control charts, within-capsule correlations, and between-capsule correlations. Subsections below provide additional information about these tools.

3.1.1 Control Chart Monitoring

The purpose of statistical control charts is to allow simple detection of events that are indicative of actual process change. This simple decision can be difficult when the process characteristic is continuously varying. The control chart provides statistically objective criteria for detecting change. When change is detected and considered valid, its cause should be identified. The AGR and AGC experiment TCs and AGC-1 load cells, are subject to a harsh environment and could degrade or fail during the experiment. Control charts provide an objective contribution to the process of deciding when instruments fail or when the possibility of a process change needs to be investigated.

The first step in constructing an ordinary control chart is to identify a quantity that is expected to be constant during the process being monitored. For the VHTR experiments, temperatures and loads may fluctuate but differences in readings from nearby instruments would be expected to be fairly stable. Daily average differences are charted for the TCs and load cells.

The next step to constructing a control chart is to select a baseline period. The average and standard deviation of the daily average differences are estimated. When there are few data points, a large variation is seen in the standard deviation estimates. This variation drops as more data are obtained. A “baseline period” is defined as the period of initial data collection to characterize how the daily average differences behave. When the estimates become stable, the data are considered for the baseline period. The data in that period also need to be fully representative of the process, since data collected during the baseline period are used to define the expected performance of the data time series.

The mean of the response value in the baseline period is calculated using all of the observations. This mean is used to draw the center line of the control chart. The standard deviation of the observations is calculated and used to draw the upper and lower control limits at 3 standard deviations above and below the mean. If the time series is normally-distributed, 99.7% of future points will plot between the upper and lower control limits. Note that, even if the original data is not normally-distributed, the averages tend to be so.

Data falling outside the control limits tend to indicate a change in the process, such as instrument drift. However, isolated points outside the limits are to be expected. A more specific criterion is needed. For use in monitoring the TCs and load cells, an ad hoc criterion is that 10% of the values must fall outside the band in order to generate an "out-of-control" flag.

In addition to data falling outside the control limits, patterns of data within the control limits can also indicate a change in the process generating the data. Including the "out-of-control" rule, the three rules are used to apply control charts to the AGR and AGC-1 monitoring data. They are listed below.

1. Out-of-control rule:
 - a. Out of control: >10% of the days in the monitoring period have differences lying outside the control limits
 - b. Out of control warning: >30% of the days in the monitoring period have differences lying outside warning limits, which are defined as the baseline mean value ± 2 standard deviations.
2. Prolonged bias rule:
 - a. Bias up: >75% of the days in the monitoring period have differences greater than the baseline mean value.
 - b. Bias down: >75% of the days in the monitoring period have differences less than baseline mean value.
3. Time trend rule:
 - a. Strong trend: the correlation between differences and run time is >0.8 or <-0.8.
 - b. Moderate trend: the correlation between differences and run time is between 0.6 and 0.8 or between -0.6 and -0.8.

When a control chart generates one of these flags, the data are suspect. However, professional judgment is applied to making the decision about whether the data are still valid. The flagged conditions become the subject of a Data Review Committee meeting, for example.

If the flagged data are judged valid, a new baseline period is instituted that includes these data.

3.1.2 Monitoring Within-Capsule Correlations

As stated in the earlier text, TCs that are near each other are expected to be highly correlated. A daily correlation plot of such data shows high correlations. When a sequence of such values consistently trails away from 1.0, a potential problem exists with the data. This test is not quite as formal as the control chart method.

3.1.3 Monitoring Between-Capsule Correlations

This tool, which involves considering other instruments to identify which is most correlated with an instrument being monitored, has also been described in the web page discussion. Proximity for the AGR experiments involves being in the same capsule in the test train. When instruments are performing as expected, their readings are most correlated to the readings from other nearby instruments that measure the same quantity. An irregularity has entered a data stream when the location of the most correlated responses to the response being evaluated is no longer nearby. A TC junction failure would be indicated by a maximum correlation estimate that is consistently (for several days) in a higher capsule (nearer the top of the test train) than the capsule of the subject TC.

3.2 Use of the Data to Identify Possible Anomalies

The VHTR experiments study complex phenomena under conditions that, in many cases, have not been investigated before. The phenomena are modeled using detailed computer codes, and a goal of the

research is to adjust the parameters in the codes so that they correctly describe the phenomena. The codes need to be "calibrated" so that they best simulate the data. On the other hand, the high temperatures and neutron flux may cause instrument degradation. Many TC failures were seen in the AGR-1 experiment. A challenge in the research is to sort out the differences and decide which stream of information is the most accurate.

A strength of NDMAS is that the data is in one place, with tools to investigate these issues and delineate where the greatest differences are to be found. For example, in the AGR-1 experiment differences were seen in between the "valid" TC measurements and the estimated temperatures at the TC locations that came out of the detailed neutronics and thermal modeling. The data are plotted in Figure 44. Figure 45 shows simulated minus measured TC differences in the top three panels for TC1, TC2, and TC3 in Capsule 6. The simulated and measured temperatures for TC1 depart from one another after 230 EFPD. The blue dot temperature differences in the fourth panel show TC1 simulated-measured values increasing by approximately 70°C from 230 EFPD to the end of the experiment. Figure 46 shows that the measured differences between TC1 and TC4 (the purple dots) are higher than the simulated differences (gray dots) by approximately 50°C at the beginning, then end up around 20°C lower at the end of the experiment. Again, these data show a possible drift of 70°C. So, although TC1 in Capsule 6 has not been declared to be failed, it may have experienced a drifting problem.

The same could be true for TC2 in Capsule 6 in the last few cycles of the AGR-1 experiment. The plots assembled in Figure 47 show departures from a regression model, points falling out of bounds on a control chart, much wider variations in the distributions of daily within-capsule correlations between TC2 and TC5 near the end of the experiment, and a dropping off of the TC readings in a plot of the readings themselves. All of these deviations occur in the last two cycles of the irradiation.

Many other examples of peculiarities are possible. In the panel showing simulated and measured temperature differences in Figure 45, there is a repeating pattern in the data within most of the ATR cycles. Also, the bottom panel shows an increase in the Kr-85M R/B ratio in the last cycle of the irradiation. The NDMAS provides the capability to bring together the different sources of data and investigate trends and patterns.

3.3 Use of Regression Models for Sensitivity Studies

The availability of both measured and simulated data from the fuel irradiation experiments allows a high-level study of relationships among the entities that most affect fuel temperatures. The SAS software product, JMP, has a process that facilitates this exploration. The capability is called "prediction profiling." The capability is illustrated here through use of an example involving EFPD, simulated fission power, simulated graphite fission density, and the neon fraction. The quantities that change most during the experiment are the fuel fission power and neon fraction. The EFPD is fixed at some particular time of interest, and the graphite fission density changes fairly slowly. In the example, a goal is to maintain the average fuel temperature at, say, a target value of 1050 °C, by manipulating the neon fraction as particularly the fuel fission power changes.

The process is as follows:

- Fit a regression model to the simulated average fuel temperature ("SFT_AVE") using the EFPD, simulated fuel fission power ("FD_W"), simulated graphite fission density ("GR_CD"), and measured neon fraction ("Ne_Frac"). Note that the EFPD term, while not significant in the fuel temperature model, is significant in a measured TC temperature model and in a simulated TC temperature model. It provides an overall trend for changes that span the experiment irradiation time.

$$SFT_AVE = a_0 + a_1 EFPD + a_2 FD_W + a_3 GR_CD + a_4 Ne_Frac$$

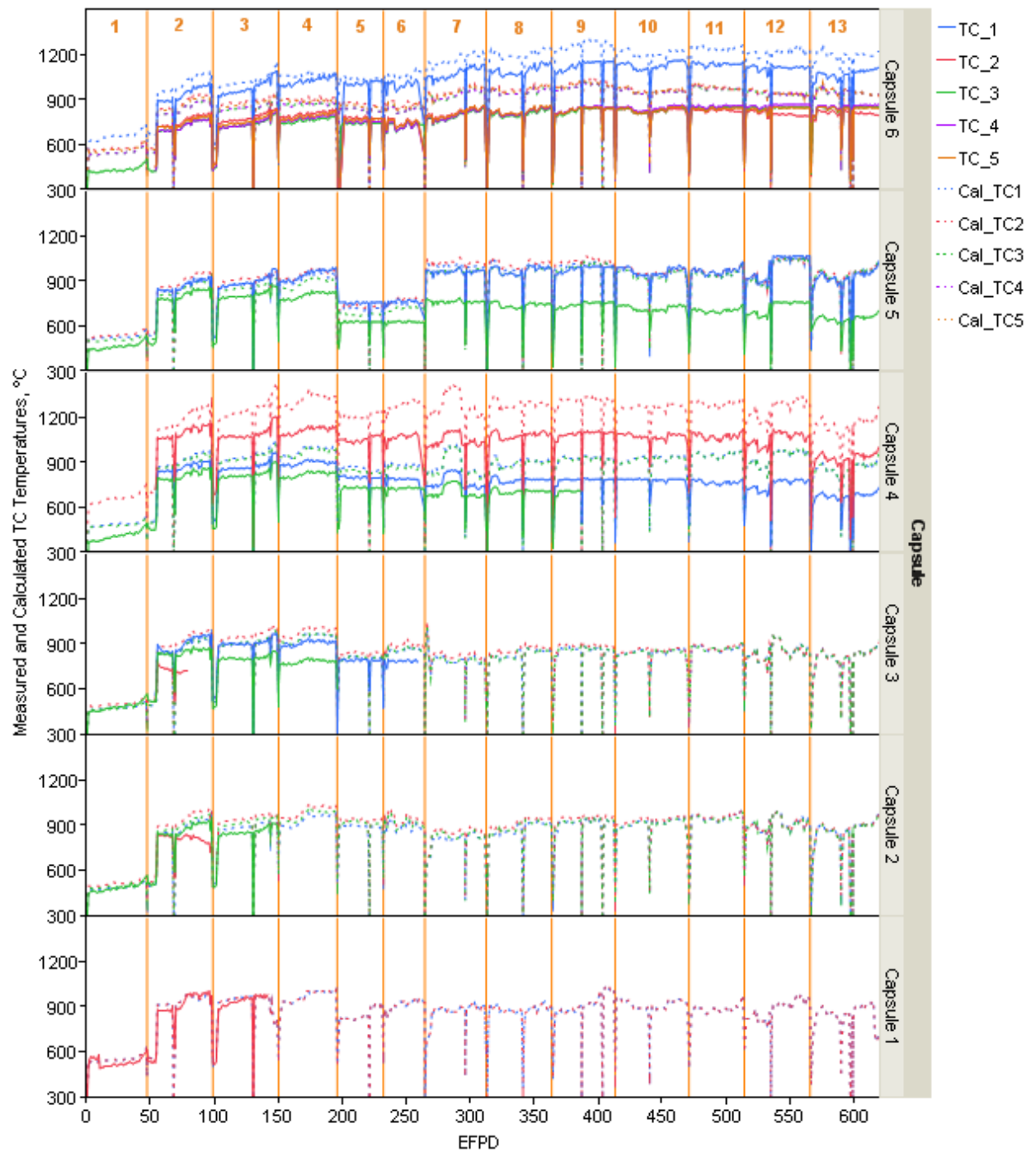


Figure 44. Measured and simulated AGR-1 TC temperatures.

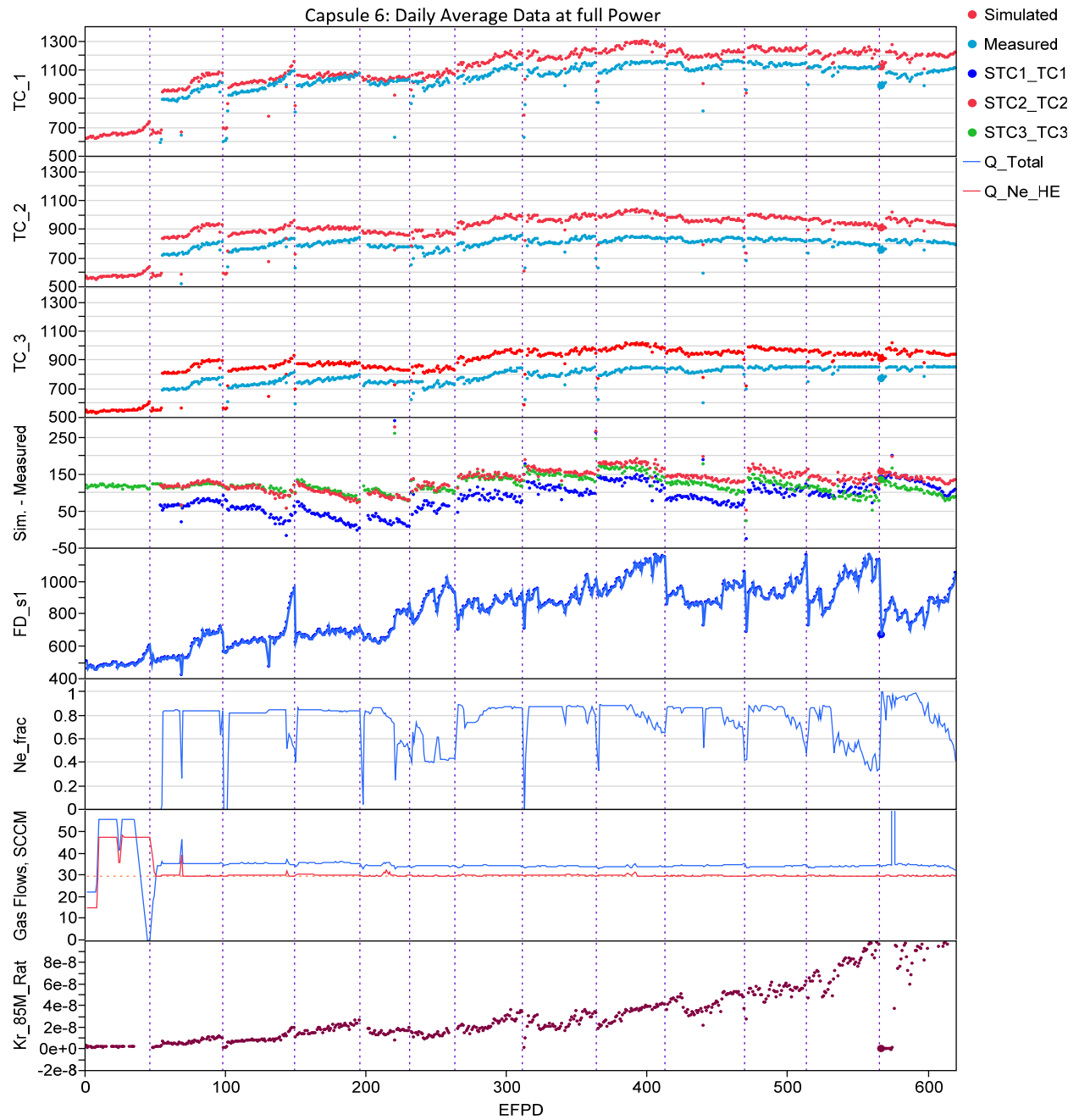


Figure 45. Daily average data for AGR-1 Capsule 6 at full power.

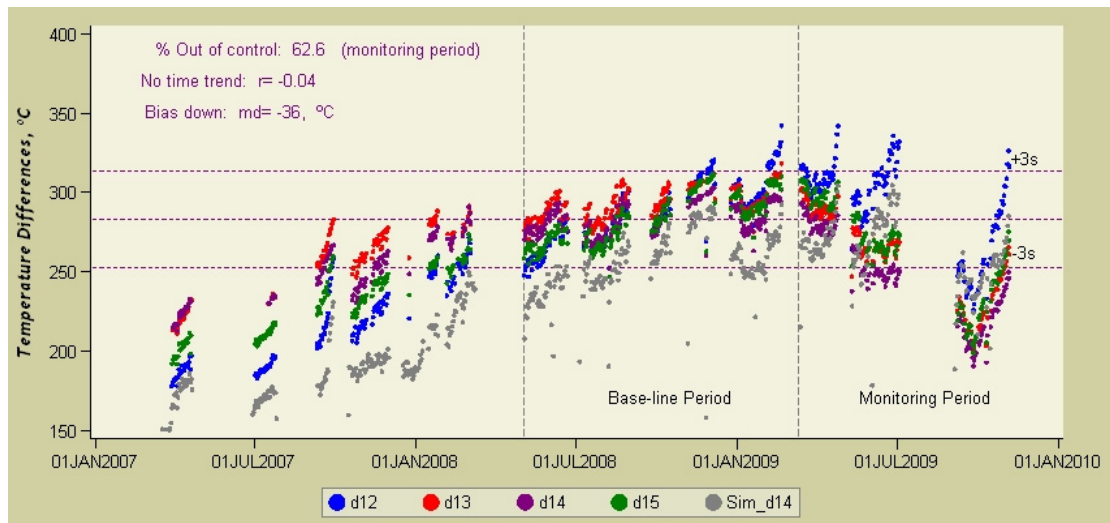


Figure 46. AGR-1 control chart for TC differences for TC1 and TC4 in Capsule 6.

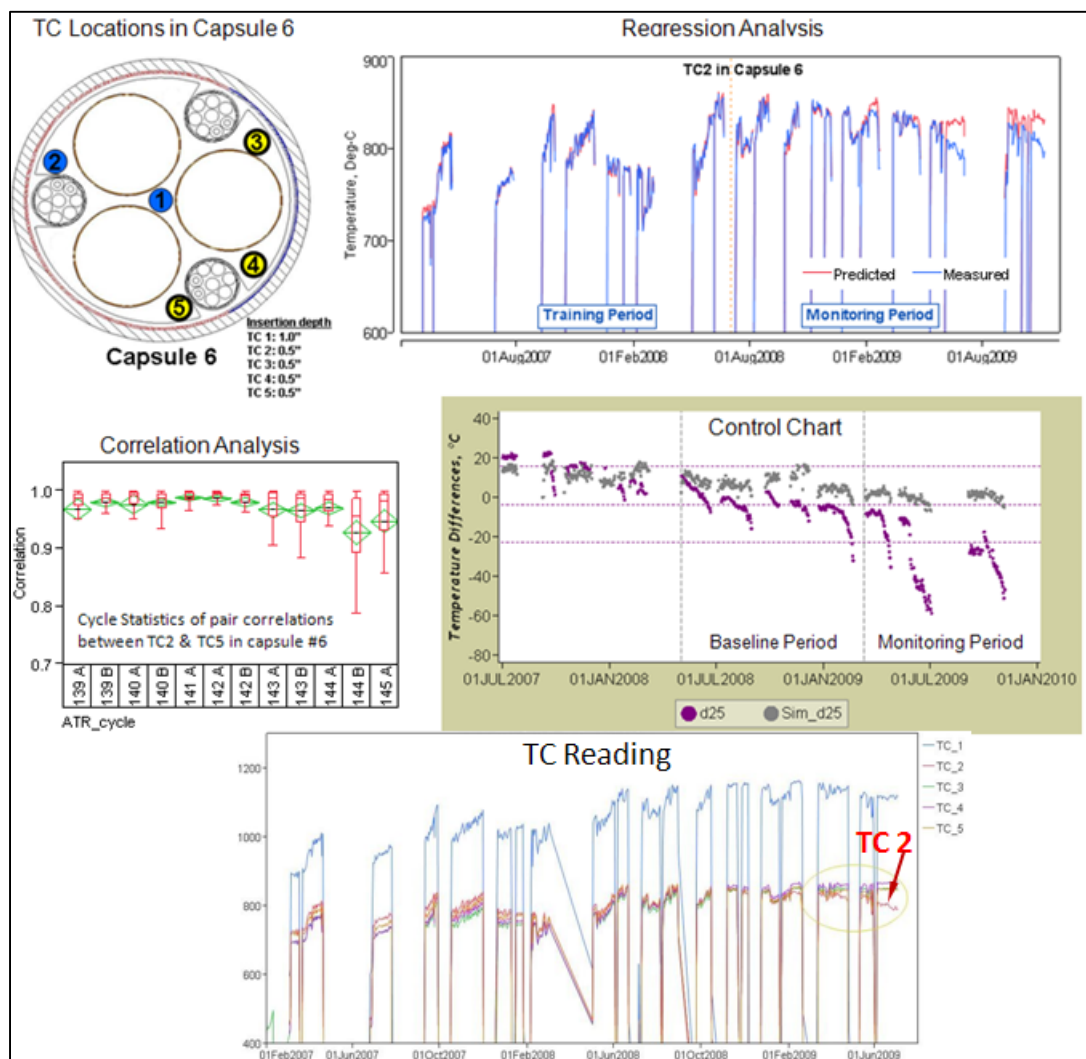


Figure 47. Compendium of plots on possible drift of TC2 in Capsule 6 near end of AGR-1 irradiation.

- Estimate the five coefficients.
- Solve the equation for Ne_Frac:

$$Ne_Frac = [SFT_AVE - (a_0 + a_1 EFPD + a_2 FD_W + a_3 GR_CD)] / a_4$$

- Substitute nominal values for EFPD and GR_CD. Substitute a series of values for FD_W and observe how the neon fraction changes as to maintain SFT_AVE at the target level.

The SAS JMP prediction profiling tool facilitates this process by displaying a matrix of little dynamic graphs, shown in each of the panels in Figure 48. The matrix has a row for each response variable (in the current example, one such row). It also has exactly one row for the input variables. It has columns for each input variable and for a quantity called "desirability."

The profile user first selects a "desirability function" for the quantity of interest (average fuel temperature) by specifying a target value along with upper and lower bounds and associated tail probabilities. The regression generates the rest of the little figures. The blue curves show the sensitivities of the output fuel temperature to the four input parameters. Each blue curve is a plot of output fuel temperature as a function of a particular input variable, with the other variables held constant at specified values. These specified input values are plotted in the vertical red lines in the display, which can be dragged to select other values.

After picking nominal values for EFPD and GR_CD, one can observe the effect of changes in fuel fission power on the Ne_Frac needed to achieve the target fuel temperature by inputting fission power values using the red dotted line slider in the second box on the bottom row. For each fission power value, an adjustment to the slider in the Ne_Frac box (dragging it with the mouse) allows the system to find the Ne_Frac setting that gives the desired fuel temperature. Figure 48 shows the state of the profiler and how it responds as the user moves through this process. At each stage, the display retains the regression relationship shown in Figure 49.

Models such as the example can also be studied using subsets of the data. For example, if performance during ATR Cycle 143B is under study, the input data could be restricted to the three or four cycles preceding Cycle 143B. After a regression model is developed that fits the data, the profiler can be used to study the relationships.

3.4 Potential Use of Regression Models for Experiment Control

The fuel temperature in the AGR irradiation experiments is controlled by setting a target temperature for a capsule's control TC. Given such a value, the control system automatically adjusts the neon fraction in the control gas to either increase the control TC's reading to reach its target, or to lower the temperature reading to reach the target.

An issue is the selection of an appropriate target value for the control TC that will produce desired fuel temperatures. When an experiment has progressed so that two or three cycles of simulated fuel and TC temperature data are available, one can evaluate the differences and factor that information into the process of determining the control TC target. Cycle-average differences in readings from TC1 and the simulated fuel temperature in Capsule 6 in AGR-1 varied from approximately 26 °C in Cycle 139A to approximately 134 °C in Cycle 143A. Characterizing these differences and making predictions from the model for future cycles can assist in experiment control. For example, if the model showed that the expected difference (fuel temperature minus the measured control TC temperature reading) is 100 °C, then the control TC target temperature would be set at the target fuel temperature minus 100 °C. Even if the control TC were drifting, the statistical data modeling could account for the drift in identifying the new setting. This evaluation would be performed after each reactor cycle.

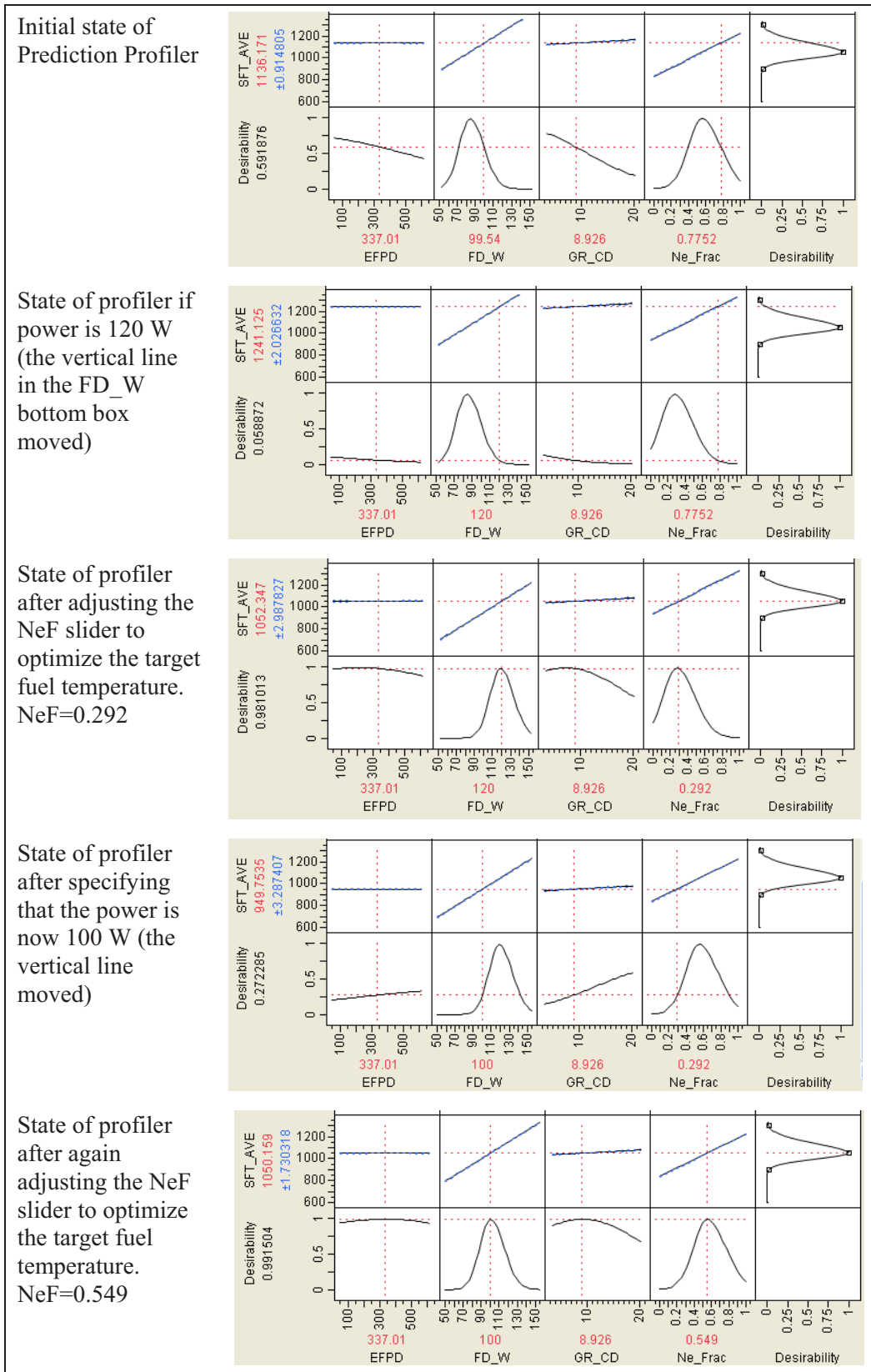
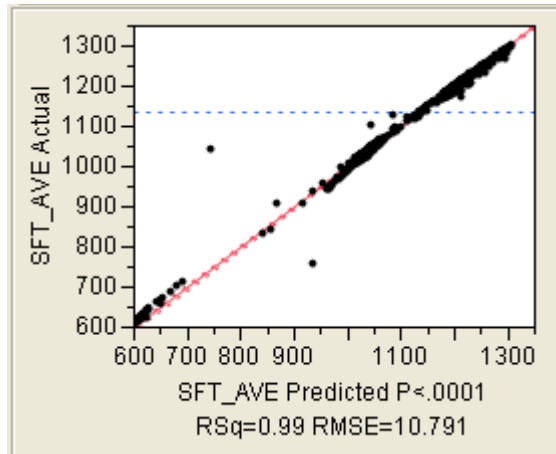


Figure 48. JMP prediction profiler for predicted fuel temperature in AGR-1 Capsule 6



Equation:

Simulated Avg. Fuel Temp
(SFT_AVE) =

$$\begin{aligned}
 &298.631864724172 \\
 &+ 0.0029132001312 * \text{EFPD} \\
 &+ 5.12969694548567 * \text{FD_W} \\
 &+ 2.58695179808901 * \text{GR_CD} \\
 &+ 390.681673009338 * \text{Ne_Frac}
 \end{aligned}$$

Figure 49. Regression model behind prediction profiler.

4. ONGOING AND PROPOSED FUTURE DATA ANALYSES AND WEB DISPLAYS

Ongoing and future data analysis and web display capabilities can be viewed from two perspectives: the applications that may be developed and the new capabilities that come from enhancements in the set of tools available to support those applications.

4.1 Applications

The primary ongoing modeling effort for NDMAS is to add displays to the website that will show each new data stream as it is identified and added to the database. The fuel irradiation project will be generating post-irradiation examination data in FY 2010.

Another priority for ongoing work is to look into models and relationships that might exist based on requests received from the community of VHTR researchers.

4.2 Enhanced Capabilities

One capability that will be enhanced during the next year is the automation of transfer of content to the external website. The data there will be more current as the data acquisition systems from the ATR improve and the reports that generate plots from Enterprise Guide are updated automatically. Also, the use of the Phoenix Modeling Center (PMC) software should bring some enhancements to the existing work processes. The remaining paragraphs in this section describe the PMC.

The PMC is a tool to enhance workflow automation. It provides a graphical environment for process integration as shown in Figure 50. The little boxes in the model schematic at the upper right in the figure (with a purple background), are called plug-ins. Each plug-in provides an interface to a particular product or tool. Plug-ins are being developed to allow PMC to read data directly from SAS and store results directly back to SAS. Currently, these capabilities must be tailored to particular data sets. A proof-of-concept application was developed that read AGR-1 TC data from SAS into PMC where it was passed on to a MATLAB plug-in. In MATLAB, the data were analyzed using an empirical method to predict TC readings later in a cycle, given the readings and other parameters during the first 20 days or so of a cycle. The predicted TC values were then written back to SAS. Plots generated in MATLAB were viewable after the MATLAB process had run. However, the plots are currently not stored as part of the PMC model, and MATLAB must be rerun for them to be displayed again.

Additional PMC plug-ins will aid analysts in setting up a PMC model using data from SAS. The SQL queries that will be needed will be generated automatically. Also a plug-in will take care of SAS user authentication and will pass a user's credentials to SAS so that no additional passwords or logins will be needed.

NDMAS developers expect to be using PMC to facilitate the process of adding analysis results to the NDMAS web portal. A Java script is being developed that will allow a user to invoke the PMC application programming interface from the web portal. This capability will allow PMC to run on a server and will allow easier system maintenance. Decisions are still being worked out about how to display the data returned from a PMC analysis and how to store the PMC models.

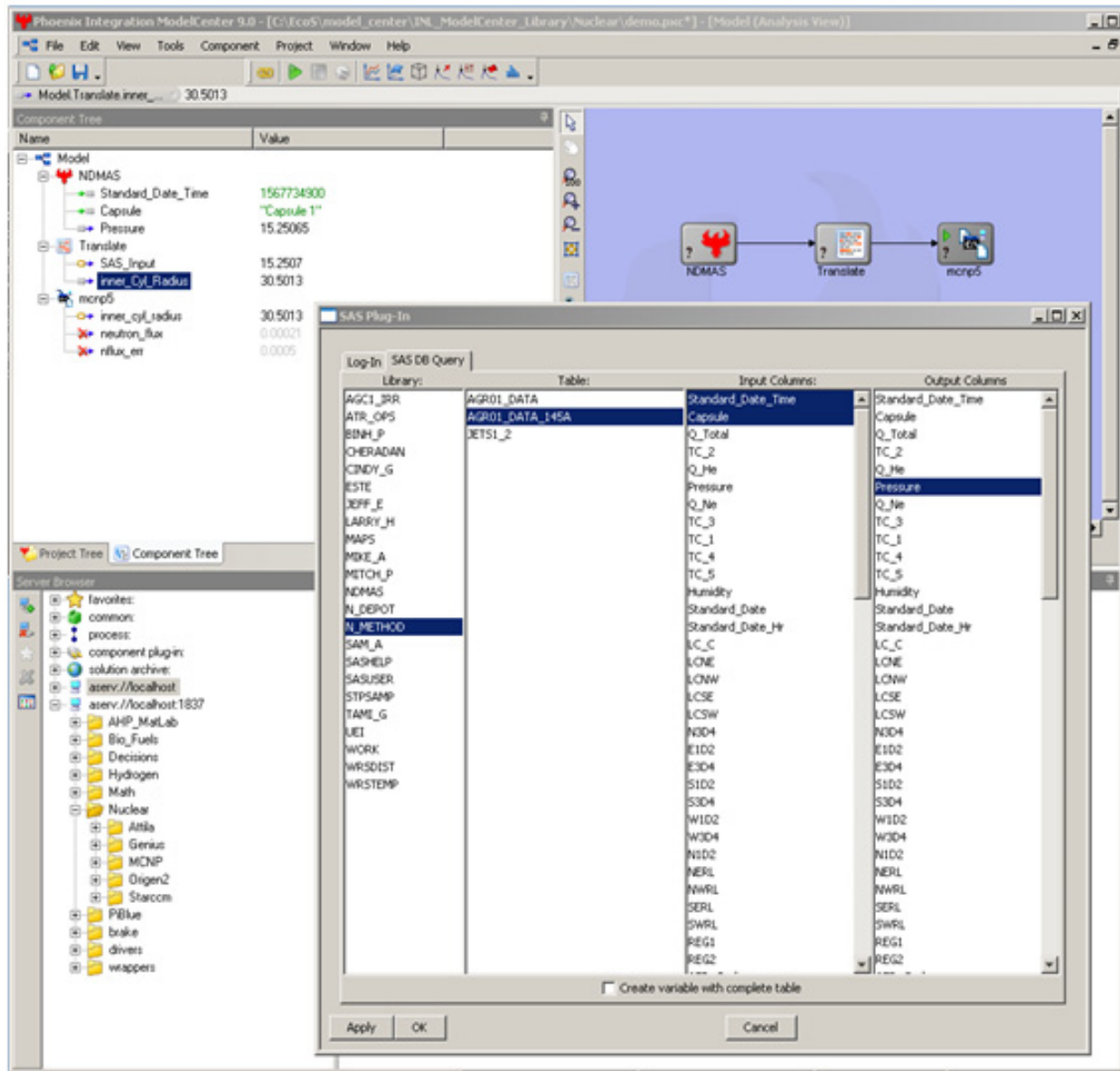


Figure 50. PMC graphic interface.

5. SUMMARY AND CONCLUSIONS

NDMAS provides many powerful data analysis and web display capabilities. Users accessing the INL NDMAS web portal can study relationships between key attributes of the experiment and various experimental conditions using such features as:

- Scatter plots, line plots, and bar charts or a combinations of these
- Histograms and box plots that show distributions for the sample data
- Lattice plots that break the data into subsets such as data from different capsules, and show each in successive panels having a common time or other axis
- Matrix plots that show all the pair-wise relationships within a set of variables
- ActiveX graphs that allow the user to manipulate many of the features of the graph to enhance understanding
- Plots and data displays based on hierarchical cubes, allowing users to drill down and display more detailed levels in the data
- Data exploration portals that allow users to perform their own variable selection, sorting, filtering, data display, and downloading
- Stored processes that, for example, allow users to view gross gamma counts for the time frame and capsule that they select.

This report describes these website features as they are implemented as of September 2010. Because the website is updated frequently, the content that can be studied using tools such as these will continue to evolve.

Even more data analysis tools are available for developers creating content for the website. All of the statistical power of SAS, Inc.'s SAS/STAT statistical software is available, in addition to the SAS/QC software for control charts and complete access to SAS/GRAPH for data visualization. The SAS/STAT regression procedures, in particular, provide modeling frameworks that can be tailored to the nature of the data being analyzed. In the process of fitting a parametric model to data, the researcher makes assumptions about how the data set was generated, whether certain quantities are independent, etc. The SAS procedures allow many of these assumptions to be relaxed. Nonlinear regression is supported, so that functional relationships established from physical models can be accommodated. Different distributional forms can be considered, as well as a variety of variance structures. Ultimately, empirical data modeling is about separating process variation that can be understood and to some extent controlled from the random "noise" that is always a part of observed data. The flexibility and power of the SAS system for data analysis optimizes the possibility of deriving useful information from the data modeling efforts.

This report has provided examples of current applications of some of these technologies. Many of the applications deal with describing temperatures during the AGR-1 irradiation experiment and applying that information to the AGR-2 irradiation data currently coming into the system.

Since all VHTR researchers can request the NDMAS team to investigate and display particular relationships between variables on the web, or download data and investigate these relationships themselves, the data analysis and web delivery capabilities of NDMAS are virtually unlimited.

6. REFERENCES

- Abbott, M. L., L. C. Hull, B. T. Pham, and M. A. Plummer, 2010, *AGR-1 Data Qualification Report*, INL/EXT-10-17943, March 2010.
- Ambrosek, R. G., 2005, "Thermal Analyses for Design of AGR-1," EDF-5138, Idaho National Laboratory, October 3, 2005.
- ASME, 2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Nuclear Quality Assurance (NQA-1), ASME International, New York, NY.
- Chang, G. S., and M. A. Lillo, 2007, "Confirmatory Neutronics Analysis of the AGR-1 Experiment Irradiated in ATR 8-10 Position," EDF-7120, Rev 1, Idaho National Laboratory.
- Hawkes, G., 2010, "AGR-1 Daily As-run Thermal Analyses," ECAR-968, Idaho National Laboratory, May 20, 2010.
- Hull, L. C., 2010, *AGC-1 Irradiation Data Qualification Interim Report: Data from ATR Cycles 145 A, 145 B, 146 A and 146 B*, INL/EXT-10-19630, September 2010.
- INL, 2010, *Very High Temperature Gas Reactor Program Data Management and Analysis Plan*, PLN-2709, Rev. 2, Idaho National Laboratory.
- INL, 2010, *Very High Temperature Gas Reactor Technology Development Office Quality Assurance Program Plan*, PLN-2690, Rev 5, Idaho National Laboratory.
- Krusch, S., 2009, *General Software Management Plan for the VHTR TDO*, PLN-2247, Rev 0, Idaho National Laboratory.
- Lillo, M. A., G. S. Chang, 2007, *Neutronics Projection Analysis to Support the End of Irradiation Determination for the AGR-1 Experiment*, ECAR-515, Idaho National Laboratory.
- Sterbentz, J.W., 2010, *JMOCUP As-Run Daily Depletion Calculations for the AGR-1 Experiment in ATR B-10 Position*, ECAR-958, Rev 0, May 14, 2010.

Appendix A

VHTR Experiments and Associated Data Streams

Appendix A

VHTR Experiments and Associated Data Streams

Data streams currently being processed or developed for very high temperature reactor (VHTR) research are briefly described below. They are organized according to the data collection projects currently described in the Next Generation Nuclear Plant (NGNP) Data Management and Analysis System (NDMAS) Program Plan (PLN-2709^a).

A-1. Fuel Development and Qualification Project

A series of Advanced Gas Reactor (AGR) experiments are planned to study the performance of possible fuels for the VHTR. The two designs under consideration for the VHTR are a prismatic block design with low-enriched uranium oxycarbide (UCO) fuel particles and a pebble bed design with low-enriched uranium dioxide (UO₂) fuel particles. Within these two major groupings, a variety of fabrication methods and coatings are possible for the fuel. The experiments are designed to identify fuel that can, among other things, endure the operating conditions of the VHTR, including high temperatures, without leaking or deforming. The experiments will provide data to justify Nuclear Regulatory Commission (NRC) licensing of the selected fuel design.

In the AGR-1 experiment, approximately 300,000 fuel particles were fabricated and loaded into compacts (approximately 4150 per compact), which were installed in capsules. The capsules were loaded in a test train that was installed in the Advanced Test Reactor (ATR) at Idaho National Laboratory (INL). There were 12 compacts per capsule and six capsules total. In the ATR, the capsules were irradiated over a period of nearly 36 months, at temperatures generally exceeding 1000 °C. Conditions in the experiment were recorded frequently (e.g., every 5 minutes) until the last irradiation in November of 2009. The test train was removed from the ATR area in March, 2010, and post-irradiation examination (PIE) to provide more information about the fuel performance is underway.

The second experiment in the AGR series is currently underway in the ATR reactor. AGR-2 has a configuration similar to AGR-1, and is testing additional fuel variants including fuel fabricated in France and in South Africa.

Additional experiments will test other fuels, and fuels at higher temperatures, and fuels sized at a scale comparable to the fuel planned for the demonstration VHTR.

The fuel experiments give rise to such data sets as:

- Fuel fabrication data (see Table A-1)
- Irradiation data (see Table A-2)
- Fission product monitoring system data (see Table A-3)
- ATR reactor operations data (see Table A-4)
- Neutronics and temperature analysis data (see Table A-5)
- PIE data (see Table A-6)

a. PLN-2709, "VHTR Program Data Management and Analysis Plan," PLN-2709, Rev. 2, Next Generation Nuclear Plant Project, June 2010.

The tables below list attributes measured in the experiment by component or experimental unit. Components are structured in a hierarchical fashion in the database so that the data can be associated with the level of entity that is being monitored.

Table A-1. Fuel fabrication data parameters.

Component	Response Variables and Attributes
Kernel batch, fabricated fuel kernels	Envelope density, diameter, and sphericity
Kernel composite	Enrichment, composition, impurity levels, diameter, density, sphericity
Surrogate particle batch, kernels coated with buffer and IPyC layers.	Buffer and IPyC layer densities
Fully coated particle batches	Layer thicknesses, missing OPyC layer defect fraction
Coated particle composite, kernels coated with buffer, IPyC, SiC, and OPyC layers.	Layer thickness, density, defect fraction, aspect ratio, pyrocarbon layer anisotropies, SiC layer microstructure
Individual compact, particles encapsulated into fuel compact.	Diameter, length
Compact composite ^a	Purity, strength, U loading, defects
Particle and compact	Manufacturing conditions—gas ratios during coating, temperatures during coating, compact molding pressure, compact carbonization and heat treatment conditions
Compact	Irradiation position—stack, capsule

Table A-2. Reactor irradiation data parameters and attributes for the AGR (fuel) experiments.

Component	Response Variables and Attributes
Capsule	Temperature from thermocouples, helium, neon, and total gas flow
Capsule and leadout	Gas pressure and moisture content

Table A-3. Fission product monitoring data parameters and attributes.

Component	Response Variables and Attributes
Capsule	Fission product concentrations in sweep gas Calculated release to birth ratios of fission products Gross gamma monitoring data

Table A-4. ATR operating conditions data parameters and attributes.

Component	Response Variables and Attributes
Reactor	ATR lobe power ATR shim cylinder position ATR core inlet temperature

Table A-5. NGNP neutronics and temperature analysis parameters and attributes.

Component	Response Variables and Attributes
Fuel compact or graphite specimen	Neutronics analysis data, calculated fluence Thermal analysis data, prediction of specimen temperatures

Table A-6. Fuel PIE data parameters and types (preliminary data).

Component	Response Variables and Attributes
Test train	Pictures, observation notes, gamma scans, metrology, graphite holder dimensions
Graphite holder, capsule components	Detailed gamma scan and radioisotope inventories
Flux wire, melt wire, capsule liner	Estimated maximum temperature, neutron flux data, and emissivity values used in modeling
Thermocouples	Metallographic images and other data to examine chemical interactions and microstructure
Fuel compact	Physical dimensions, detailed gamma scan, radioisotope inventories, selected photos to support fuel qualification, fuel particle failure by leach-burn-leach, post-irradiation safety testing Photos, notes, irradiation
Fuel particles	Radioisotope inventory, metallography, inspection of layer integrity, photos, spatial distribution of fission products

A-2. Materials Testing and Qualification— Graphite Technology Development Project

The nonfuel components in the VHTR reactor core will be primarily graphite. As with test fuels, various graphite formulations will be irradiated in the ATR and examined to study performance in a high-temperature, high-neutron-flux environment. In a separate series of experiments, properties of the graphite materials will be studied for different graphite grades.

For the graphite that is tested in the ATR, many of the data streams are like the fuel data. In particular, the data streams will include the following:

- Irradiation data (see Table A-7)
- ATR reactor operations data (the data streams are the same as for the fuel; see Table A-4)
- Neutronics and temperature analysis data (same data streams as for the fuel; see Table A-5)
- PIE data (data to provide characterization and safety analysis of graphite after irradiation in the ATR will be stored, but a detailed list of response variables has not yet been developed)

The graphite characterization part of the project will generate the data described in Table A-8.

Table A-7. Reactor irradiation monitoring parameters for the AGC (graphite) experiments.

Component	Response Variables and Attributes.
Capsule, test train	Same parameters as for the fuel experiments, plus...
Channel	Compressive stress applied to graphite specimens for analysis of radiation induced creep
Capsule, leadout	O ₂ concentration measured in the inflow gas; CO and CO ₂ monitored in the effluent gas

Table A-8. Parameters and classification for graphite specimens (characterization).

Component	Response Variables and Attributes.
Specimen	Physical properties. thickness, diameter, mass, volume, bulk density Elastic modulus. modulus by time of flight, fundamental frequency, Poisson's ratio Electrical properties. electrical resistivity Thermal properties. instantaneous and mean coefficient of thermal expansion, thermal diffusivity, specific heat, thermal conductivity. Mechanical properties. tensile strength, compressive strength Grade, orientation, type, location within billet Irradiation location information: position within capsule, channel

A-3. Materials Testing and Qualification— High Temperature Materials Project

The High Temperature Materials (HTM) data project involves the performance of materials outside the reactor core. A particular focus will be on heat exchanger materials to be used in the design of the reactor-hydrogen interface. Guidelines for approving materials for high-temperature applications ask for tensile strength, yield strength, reduction of area, and elongation at 50°C-increments from room temperature to 50°C above the maximum intended use temperature and over a range of strain rates. Weld strength rupture factors will be determined for two welding processes as a function of time and temperature. Other properties to be measured at elevated temperatures (T up to 1,000°C) include elastic modulus, Poisson's Ratio, linear thermal expansion, thermal conductivity, thermal diffusivity, and density. Additional lab investigations will characterize weld creep-fatigue, effect of helium impurities, and aging effects on fracture toughness. Table A-9 gives a list of the test series planned for the HTM project. Each series consists of multiple experiments.

Data have been received in NDMAS from the A-1 and A-20 test series. Parameters for these tests are listed in Tables A-10 and A-11, respectively.

A-4. Design Methods and Validation Project

Data collection activities in support of code development and validation include measurement of nuclear interaction cross sections. Nuclear cross-section measurements relevant to the harder neutron spectrum of the VHTR will be made for selected isotopes, particularly ²⁴⁰Pu, ²⁴¹Pu, and ²⁴²Pu. These data will ultimately be incorporated into the Evaluated Nuclear Data Files, but may be retained in NDMAS if deemed appropriate. Other data to be collected include criticality, reactivity feedback coefficients, kinetics parameters, peak power, conversion ratio of sustainable cores, transmutation potential, maximum displacement per atom, decay heat, and radiation levels.

Table A-9. Planned High-Temperature Materials tests.

Test Series	Description
A-1	Tensile Tests for Sm Confirmatory Testing
A-2	Weld Strength Rupture Factor Determination Test
A-3	Creep-Fatigue Tests for Alloy 617 Welds
A-4	Aging Effects on Fracture Toughness of Alloy 617 Wrought Metal
A-5	Tensile Tests to Determine Strain Rate Sensitivity in Support of Unified Constitutive Model
A-6	Torsion Tests for Validating Von Mises Criterion to Support Unified Constitutive Model
A-7	Stress Dip Tests in Support of Unified Constitutive Model
A-8	Short-term (Days) Creep Tests to Support Unified Constitutive Model
A-9	Uniaxial Ratcheting Tests to Support Unified Constitutive Model
A-10	Torsional Cycling with Constant Axial Strain to Support Unified Constitutive Model
A-11	Loading-Unloading-Creep Sequence to Support Unified Constitutive Model
A-12	Thermomechanical Cycling to Support Unified Constitutive Model
A-13(a)	Creep Curves to Qualify Unified Constitutive Model
A-13(b)	Stress Relaxation Tests for Qualifying Unified Constitutive Model
A-14	Uniaxial Tests on Thermally Aged Alloy 617 to Support Unified Constitutive Model
A-15	Tube Burst Tests for Alloy 617 and Alloy 800H
A-16	Creep-Fatigue Tests for SMT Specimens
A-17	Long Term Alloy 617 Creep Rupture Tests for Qualification
A-18	Thermal Aging Tests for Strength Reduction Factors
A-19	Fatigue Tests to Support Design Curve Development in Alloy 617 Code Case
A-20	Creep-fatigue Test Matrix to Support Determination of Creep-Fatigue Interaction Diagram
A-21	Tests to Determine "C" Factor in Multiaxial Creep Rupture Strength Criterion for Alloy 617
A-22	Interrupted Creep Tests
A-23	Creep-Fatigue Saturation with Hold Time
A-24	Exploration of Creep Mechanisms for Alloy 617
A-25	Determination of Grain Size Rupture Factors for Alloy 617
A-26	Tensile Tests Supporting Unified Constitutive Model for Alloy 800H
A-27	Weld Strength Rupture Factor for Alloy 800H Weldments
A-28	Strain Rate Effect on Yield and Tensile Strength for Alloy 800H
A-29	Exploration of Creep Mechanisms of Alloy 800H
A-30	Qualification of Yield and Tensile Strength Reduction Factors for Alloy 800H Due to Thermal Aging
A-31	Tests to Validate "C" Factor in Multiaxial Creep Rupture Strength Criterion for Alloy 800H

Table A-10. Parameters for HTM Characterization-Uniaxial Tension Tests (A-1).

Component	Response Variables and Attributes
Specimen	Physical properties
Specimen	Time, stress, strain
Specimen	Crosshead displacement , force, extensometer 1 displacement, extensometer 1 strain, extensometer 2 displacement, extensometer 2 strain, average displacement, average strain, estimated strain rate, corrected strain
Specimen	Test temperature, yield strength, ultimate tensile strength, percent elongation, percent reduction in area
Specimen	Final specimen length
Specimen	Photographs

Table A-11. Parameters for HTM Characterization-Creep-Fatigue Tests (A-20).

Component	Response Variables and Attributes
Specimen	Physical properties
Specimen	Time, axial count, corrected stress, axial strain, thermocouple (more recent files)
Specimen	Axial displacement, axial force, thermocouple (older files)
Specimen	Diameter at testing temperature
Specimen	Inelastic strain range @ midlife, stable load range, initial/stable stress max, cycles for initial /stable, cycles to initiation, cycles to failure
Specimen	Stress min/max at 2 points per cycle, stress ratio per cycle
Specimen	Strain min/max at 2 points per cycle
Specimen	Photographs
Experiment	Procedure File

Thermal-hydraulic experiments are aimed at producing validation for computational fluid dynamics and systems analysis codes. The experiments will focus on core heat transfer, fluid behavior in core plenums, reactor cavity cooling, air ingress, and combined effects experiments. Two types of experiments are planned: isothermal fluid dynamics measurements, and heated flow studies. Approximately 20 to 50 new experiments will be required to validate software. Data to be collected include temperature, velocity, and pressure. Optical data collection techniques will also be employed. Very large data files will be created by these experiments to capture the spatial and temporal variation in fluid movement and temperature necessary to validate codes. Specific parameters and data types will be defined for these data streams as the research continues.

A-5. Nuclear Hydrogen Initiative Project

Hydrogen initiative activities focus on development of hydrogen production options to use the high temperature gases generated by the VHTR. High temperature electrolysis requires low-cost, efficient electricity and an energy source that can produce high temperature steam. The Hydrogen project's focus is on design of nuclear hydrogen systems, optimization of solid-oxide electrolysis cells, and catalysis of hydrogen production using sulfur-based cycles. Response variable lists and data types for data streams associated with the nuclear hydrogen initiative project will be developed as further details of the research are defined.

Appendix B

Use of SAS Tools for Modeling

Appendix B

Use of SAS Tools for Modeling

Most of the data displays and statistical data modeling described in this document were created using the SAS software product, Enterprise Guide (EG). This product provides an environment for accessing data, building queries that provide desired views of the data, including adding and removing fields and filtering the data, and performing a series of statistical analyses. The product also provides tools to graph the data and the model outputs.

Enterprise Guide comes with the SAS Business Intelligence software package. It is installed on the ISASAPP server. The Next Generation Nuclear Plant (NGNP) Data Management and Analysis System (NDMAS) team members access EG using a client interface on their PCs. EG also provides access to the underlying SAS Foundation, which includes an open-ended language for manipulating data and invoking SAS statistical procedures. The Base SAS product also includes a macro language that allows repetitive processes to be easily automated.

A second tool from SAS that provides modeling capabilities is the “JMP” product. This tool is a stand-alone product that also interacts with the SAS EBI (Enterprise Business Intelligence) software. It is licensed and installed on individual PCs. It is designed to provide an interface for intuitive data exploration.

The use of each of these products in NDMAS is discussed further in sections below.

B-1. Enterprise Guide

EG provides a workspace where data manipulation tasks, statistical analyses, and graphic display tasks are shown in a project view that gives the user an overview of the steps being performed to achieve results. Figure B-1 is an example of the EG “Project Designer” workspace. Here, an existing data set is referenced, then a query selects particular fields (variables, columns) of interest. Tasks such as the query are each referenced in a box in the diagram. The query boxes have little icons that look like one table on top of another. The diagram also shows examples of Summary Statistics blocks that perform data aggregation, and Line Plot blocks that provide an interface for specifying details for output plots. Double clicking on these boxes brings up wizards that let the user specify how a particular analysis is to be done. Each type of task box invokes a particular SAS procedure to perform the calculations.

The table blocks with little red dots in the lower right-hand corner link to data sets. Most steps in EG projects either manipulate data or use it to produce output data, so it is not surprising that nearly every other block in the figure is a data block. Some tasks produce more than one data set, and some use more than one.

The fourth block in the figure is different from the others. It has an icon of a little person running. Such blocks are “code” blocks where data can be manipulated using the SAS language. Beginning users will not have these types of blocks, usually. However, each of the task blocks generates SAS code. Therefore, the automatic code can be modified to achieve specified differences in the outputs, such as changing certain formats or labels. Eventually, one can observe the pattern and create SAS code directly, if desired.

The other symbols in the flow diagram in Figure B-1 are HTML outputs. These contain tables, graphs and any printed output that the procedures might generate.

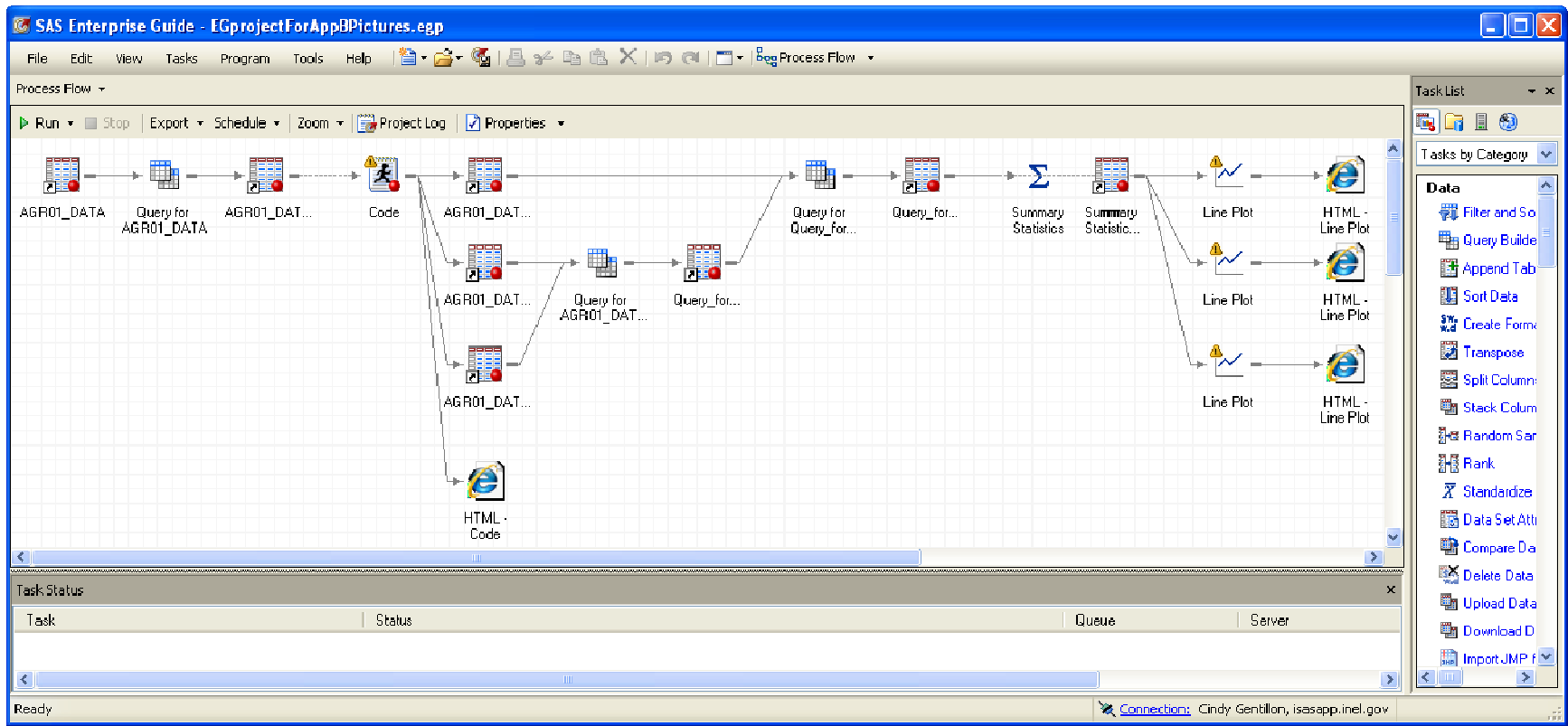


Figure B-1. Example EG Process Flow.

A few more summary observations about the workspace, data manipulation tasks, analysis tasks, graphical tasks, and how the modeling efforts connect to the INL NDMAS web pages are in sections below. The last section provides references for further information.

B-1.1 Project Designer

In one EG project file, one can have several “Process Flows” such as Figure B-1. Task boxes are created in a process flow using Menu items such as “Data,” “Describe,” “Graph,” and “Analyze.” A Task List, discussed further below, is also available. In addition to different icons on the blocks for different tasks, each block can be labeled to show its contents. The first 18 characters of the label show directly on the diagram; longer labels can be viewed individually by right-clicking on the task boxes. The “Tools” menu at the top of the screen provides a set of options that allows a user to customize the interface. After a task is selected and the associated menus are completed, EG generates a SAS program that uses the SAS language and Procedures to perform the task. The user can execute the task by clicking, for example, the triangle icon button below the “Process Flow” on the second toolbar. A Task Status window is available, if desired, to view notes about the task progress. The program runs and produces the desired output. If any problems occur, a “log” window will open with error messages. Another block that can be displayed with each task is a “Last Submitted Code” block. Changes can be entered here that will customize the results for any items that are not directly supported by the wizard. Then the modified task block can be run to obtain the desired outputs.

B-1.2 Data Manipulation Tasks

The “Query Builder” task that was described in the introduction is the second item on the Tasks/Data Menu. Figure B-2 shows the resulting window, using one of the AGR-1 Fuel Irradiation data sets. The fields are listed in the panel on the left and there are tabs to describe the data desired for the output, any data filters, and how the data should be ordered on output.

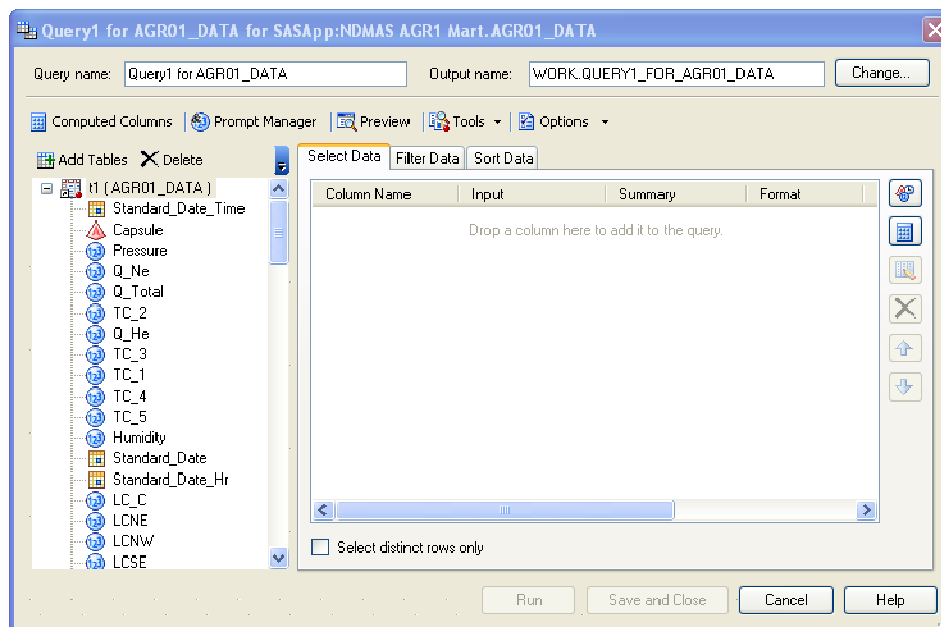


Figure B-2. Enterprise Guide Query Builder.

Several other data manipulation tasks are also available. Figure B-3 shows the Data tasks from the Task List window. These tasks are also listed in the Data Menu. For example, the Transpose task

transforms a data set so that category labels in specified columns in the input set become columns in the output data set. This action can be performed in groups, as specified by the values of other column variables (that remain so in the output data). The operation is similar to making a “Pivot Table” in Structured Query Language (SQL) or in many spreadsheet or database packages. The NDMAS team uses this capability extensively because the data as stored in the SQL “Vault” has one data item per record where its qualification status can be tracked. But for outputs, values in the associated “parameter” column become column headings and the various measurements collected at the same time become columns in wide single records instead of multiple short records.

It is beyond the scope of this overview to discuss each Data task individually. Figure B-3 shows that EG provides tools to manipulate the data as needed to support modeling and data display.

The File/Open/Data option allows direct access to the rows and columns of a data table (if the table is not locked).

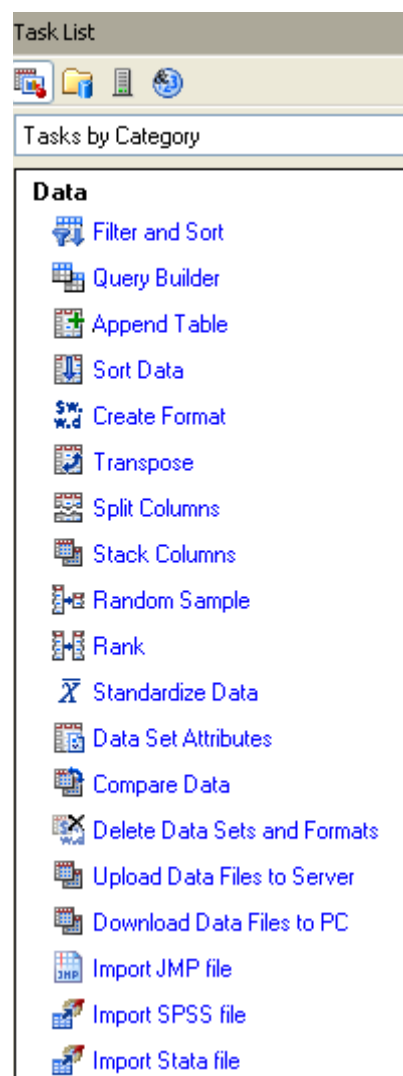


Figure B-3. Data Task List.

B-1.3 Data Summary and Statistical Analysis Tasks

Figure B-4 shows various data summary and statistical analysis tasks that can be performed in EG. The “Describe” tasks provide summaries of different types of data. For example, the Frequency task deals with counts. The Table Analysis task also deals with counts. It will tally data and create tables based on categorical data, for example. It also provides statistical tests of the hypothesis that the pattern of counts in various columns is the same from one row to another in a table. The Summary Statistics task computes averages, standard deviations, coefficients of variation, minimums, maximums, percentiles, and several other measures for the numeric columns in a data set. The computations can always be performed in groups, based on other categorical or numerical variables.

The statistical tasks in the right-hand column of Figure B-4 are for various types of modeling. One can test hypotheses, look for linear or other relationships in the data, identify groupings of data, and so forth. Many of the tools work with categorical data as well as numerical data. The nonparametric methods deal with data that is not normally-distributed.

The Control Charts group is provided by the SAS/QC product. It allows one to establish control limits and monitor stationary processes to see if they continue to perform within established bounds.



Figure B-4. Data Summary and Statistical Analysis tasks.

B-1.4 Graphics Tasks

As shown in Figure B-5, several styles of graphs are available for displaying the results of the analysis. These are in addition to the output generated by many of the procedures discussed above, which themselves create graphical output. The graphs are provided by the SAS/GRAPH product.

The Capability graph tools listed in the figure generate graphs, but are also themselves statistical tools for exploring data and comparing probability distributions.

Graph	Capability
 Bar Chart [use wizard]	 Histograms
 Pie Chart [use wizard]	 Probability Plots
 Line Plot [use wizard]	 P-P Plots
 Scatter Plot	 Q-Q Plots
 Area Plot	 CDF Plots
 Bar-Line Chart	
 Bubble Plot	
 Donut Chart	
 Contour Plot	
 Box Plot	
 Radar Chart	
 Surface Plot	
 Tile Chart	
 Map Graph	
 Create Map Feature Table	

Figure B-5. Graphics tasks.

B-2.5 Delivering Output to the Web

There are several ways to deliver output from EG to the INL NDMAS web portal. Three are mentioned here.

First, one can create a report that can be linked to the INL NDMAS web portal. From the menu bar, one can select File/New/Report. Within the dialog (Figure B-6), one can create text blocks and enter text explaining the data, and one can enter graphs and other displays. Then, using the SAS Portal software, one can display the report on the web.

A second method is to create a Stored Process by selecting File/New/Stored Process. The interface presents a series of seven-panels that are not shown here. To define the process, one specifies SAS code, which can be extracted from previous EG steps using the “View Last Submitted” option. One also specifies prompts for particular conditions that might influence the process. For example, one could have a prompt that lets a person specify the name of the input data set. Later, when the process is run, the set specified at run time is accessed. Another input for the process is to specify where it will be stored on the INL NDMAS web server. After the process is created and runs successfully in EG, it is automatically made available to the web where it can be added in a portlet.

A third method comes from the “OLAP” option on the main menu bar. Here, wizards allow the EG user to create a “multidimensional data set,” or “cube,” that can later be displayed in an “OLAP Table Viewer” portlet on the SAS web. These portlets allow the web user to drill down into the data and view different levels of detail.

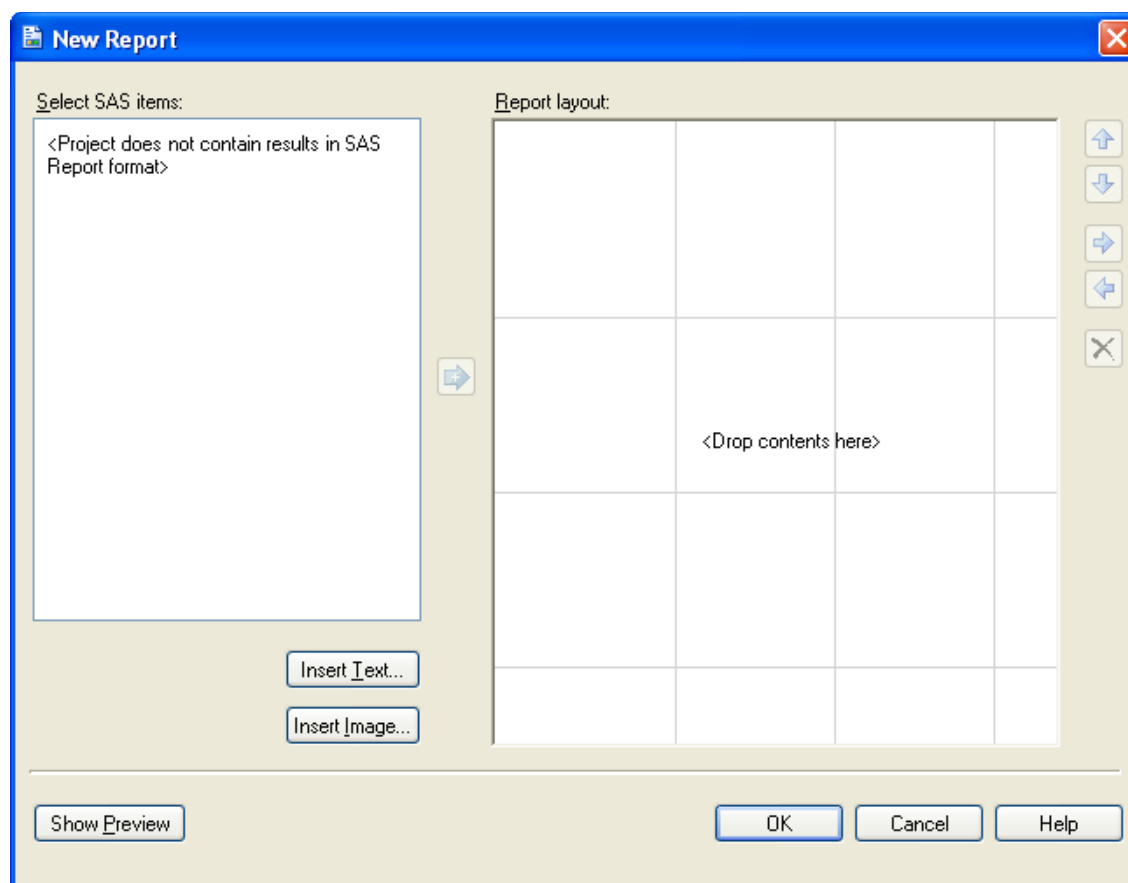


Figure B-6. New Report dialog.

B-1.6 Use of Help Files

EG contains a help file that describes its use. SAS products are documented further at http://support.sas.com/documentation/cdl_main/index.html.

The page provides a box for searching for particular words, but the links below the search box are generally more useful. Particularly the Quick Links lead to useful information. Details about any particular SAS procedure can be found by clicking the "SAS Procedures by Name and Product" link. These procedures come from various SAS products. Just the procedures associated with products that are licensed for a particular site will execute. For NDMA, procedures associated with Base SAS, SAS/ACCESS, SAS/GRAPH, SAS/STAT, and SAS/QC are licensed.

The list below shows links to follow in the SAS help page to learn about particular SAS features that might be used from EG:

- For details about Base SAS procedures that manipulate the data, pick

SAS Procedures by Name and Product — SAS Procedures by Product — Base SAS — Then select a procedure.

- For details about Statistical Procedures, pick

SAS Procedures by Name and Product — SAS Procedures by Product — SAS/STAT — Then select the procedure of interest.

- For details about SAS Version 9.2 graphing procedures, pick

SAS Procedures by Name and Product — SAS Procedures by Product — SAS/GRAPH — Then select the procedure of interest;

(note that the Graphic Template Language procedures start with "SG")

- For details about the Base SAS language, pick

SAS 9.2 Language Reference by Name, Product, and Category — Statements — Then select a statement.

- For details about functions in the Base SAS language, pick

SAS 9.2 Language Reference by Name, Product, and Category — Functions — Then select a function.

B-2. JMP

JMP is a stand-alone product that is used for graphics and data analysis by the NDMAS team. These graphs differ from the ordinary EG graphs (from “SAS/GRAPH”) because they show more than one set of axes and data in a single graph. The SAS NDMAS data tables can be imported directly into JMP after a link to the SAS metadata library is established using the SAS\Server Connections option from the JMP File menu. The major advantage of JMP is that it provides an easy to use graphical exploratory data analysis capability to rapidly identify underlying statistical relationships in large data sets.

For example, a single graph can contain a panel with data for each capsule. Such graphs can be produced using the SAS graphic template language (GTL), but this process requires SAS programming skills. Using JMP, the “Capsule” variable, for example, is dragged with the mouse into a region in the graphic user interface and the collection of small graphs inside a larger graph appears instantly. These graphs are called “lattice” plots or “trellis” plots because the classification variable(s) that characterize the individual little plots are like a framework for the little plots. The process of generating these types of graphs is often called “conditioning,” because they allow an examination of the data with regard to (or “conditioned on”) the different values of the lattice variable.

Another type of graph that JMP produces quickly and easily is a matrix graph. Here, scatterplots of pairs of variables in a multivariate data set are generated inside a larger “matrix” of plots. For example, if the user selects three numeric quantities, A, B, and C, in a data set, the matrix plot will have three rows and three columns. The variable names appear in the diagonal cells. The other cells have small scatterplots, with the X axis corresponding to the column variable for the matrix and the Y variable corresponding to the row.

These graphs can be saved as HTML files on the server. They can then be displayed in a “URL Display Portlet” on the INL NDMAS web portal.

Many analysis options are available within JMP. As with EG, data can be manipulated, many statistical analyses can be performed, and many graphical outputs can be generated. Figure B-7 is a list, from the JMP help file, of the statistical “platforms” that can be invoked from JMP. Most of them create graphs that illustrate the results. Thus, the modeling capability in JMP is virtually unlimited. JMP is described in more detail at <http://www.jmp.com>.



Figure B-7. JMP analysis tools.