FIPD: EBR-II Fuels Irradiation & Physics Database – FY19 Updates

Chemical and Fuel Cycle Technologies Division

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Summary

FIPD: EBR-II Fuels Irradiation & Physics Database – FY19 Updates

The DOE Advanced Reactor Technology program has supported efforts to recover and preserve metallic fuel data generated throughout the US sodium cooled fast reactor program (SFR). Those efforts have been focused on establishing databases of the experimental data that were mainly generated during the Integral Fast Reactor (IFR) program including data generated at EBR-II, FFTF, and TREAT reactors, as well as out of pile data. The data is essential for future-licensing activities of metallic fuel based advanced fast reactors. This report describes updates to the EBR-II Fuels Irradiation & Physics Database (FIPD) in FY2019. It covers the scientific knowledge available in the database, the logical storage of the data in the database, and the updated web interface used to access the data. Summaries of activities from previous years, the current fiscal year (FY 2019), and future plans are also provided.

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FIPD: EBR-II FUELS IRRADIATION & PHYSICS DATABASE – FY19 UPDATES

1 INTRODUCTION

Sodium fast reactors (SFR) fuels knowledge in the US are related to data collected at Experimental Breeder Reactor II (EBR-II) and Fast Flux Test Facility (FFTF) reactors during their operations starting in the early 1960's for EBR-II and 1984 for FFTF until their shutdown. This experience generated data for both metallic and oxide fuels. In particular, U-Zr based metallic alloy fuel data were generated during the integral fast reactor (IFR) program as well as oxide fuel data generated at FFTF and during the Japanese oxide fuels program at EBR-II. This knowledge base includes general reactor information, Argonne reports, IFR reports, run reports, memos, post irradiation examination (PIE) reports, drawings, experiments qualification reports, publications in journals and conferences, information regarding measured properties (e.g., IFR metallic fuels handbook), and documents of out of pile experiments. Also, measurement documents like micrographs, profilometry data, fission gas release data, and other data are available. At the time, there was development of the IFR Materials Information System (IMIS) database that combined all of that information [1], however it was not completed, as its development was stopped at the end of the IFR program. In particular, detailed data associated with each fuel pin in those experiments (irradiation history) and its association with fabrication and PIE data was not archived. This detailed information is mostly based on a combination of physics and thermal hydraulic information that are generated using reactor run operations data and fuel fabrication information. Other information (e.g., general properties data in the IFR fuels handbook, code calculations, etc.) are not currently available in an accessible form that can facilitate its use by interested analysts.

1.1 Motivation

The above accumulated knowledge represents a large US investment in advanced nuclear power research and development, provides a wealth of information to different groups of interest, and needs to be well archived and maintained so it is easily accessed and utilized in the future. Preserving this detailed fuel and physics knowledge will enable support to reactor designers in their design and evaluation of advanced fast reactor concepts. It will also support reactor vendors and utilities in their effort to make a licensing case for using similar fuel in a fast reactor in the US or abroad. In addition, detailed database information on fuel performance in the reactor support fuel analysts in understand fuel behavior and supporting the development of advanced fuel performance codes for design and licensing purposes.

A fast reactors metallic fuels database that compiles fuel's accurate and detailed operating and performance parameters is important to industry and different institutions who have shown interest in developing metallic fuel based fast reactors (e.g., Terrapower, GE, Oklo, ARC, KAERI, ...). Those potential end-users have interests related to establishing a safety case for this type of fuel within a given operations envelope in a commercial reactor. The database can be used for demonstrating to the licensing authorities the availability of a well-established database that

supports safe reactor operations. In addition, the industry and relevant institutions have interest in developing or using an existing fuel performance code that is well calibrated and validated with the most accurate sets of data to provide best estimate descriptions of fuel behavior in a reactor. Well validated code calculations can be used for the purposes of core design, safety analysis, reactor operations, and satisfying licensing requirements. In general, the database discussed in this report can provide accurate and detailed fuel irradiation and physics data needed for support of future design and licensing activities of metallic fuels based fast reactors. In addition to this main goal, the details and accuracy associated with the database will be useful to other DOE areas of interest related to fuel behavior model development and validation.

1.2 Background

Since its start, EBR-II hosted experiments in support of different US fast reactor programs to test the behavior and performance of different types of fuels including metallic, oxide, mixed oxide, and mixed carbide fuels. A wealth of information was generated from those experiments where most of the existing metallic fuels database is associated with the IFR program that ran from 1984 to 1994. The IFR metallic fuel experiments looked at one or more of the following;

- prototypic fuel behavior
- run beyond cladding breach behavior (RBCB)
- fuel swelling and restructuring
- lead IFR experiment
- fabrication parameters
- design parameters
- high temperature behavior
- large slug diameter
- blanket safety
- fuel qualification
- fuel impurities

PIE data from those experiments included fission gas release, fuel volumetric and fuel length change, cladding diametral change, and cladding wastage. Axial profiles are available for fuel radial growth at low burnup (prior to and including initial fuel-cladding contact) and for cladding radial growth for a wide range of burnups and fast fluences. Some data that are available on a more limited basis are radial and axial variations in U, Pu, Zr; fission gas porosity; axial variations in fraction of porosity filled (logged) with Na; as well as the depth of C-depleted and Ni-depleted zones in HT9 and D9 cladding materials, respectively. The intent of this database effort is to create a web-accessible relational database as an archive of information from EBR-II fuels irradiation experiments, combine it with other forms of information that are based on calculations, and make it available in a form that is appropriate for use by fuels and reactors analysts/modelers.

The database development is an ongoing effort over the past few years [1, 2, 3, 4, 5, 6, 7], and continues to the present (FY 2019). The database structure, interface, and current status are described in the subsequent sections.

2 DATABASE CONTENT ADDITIONS

This section describes additions and improvements to the content of the database. Improvements to the web interface are discussed in a later section.

2.1 Operating Parameters

The pin-level operating parameters available in FIPD are summarized below in Figure 1. These parameters are calculated using a series of computational codes, described in more detail in a previous report [7]. While the available dataset has not been extended, there have been several corrections to the existing dataset based on ongoing quality assurance efforts. These updates are describe in detail in a separate report [8].

Temperatures	Power/Burnup	Isotope Densities
<ul style="list-style-type: none">•Coolant flow•Cladding outer surface•Cladding midwall•Cladding inner surface•Fuel outer surface•Fuel centerline	<ul style="list-style-type: none">•Linear power•Power density•Cycle DPA•Burnup•Fast fluence•Total fluence	<ul style="list-style-type: none">•Uranium (U-234, U-235, U-236, U-238)•Neptunium (Np-237)•Plutonium (Pu-236, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242)•Americium (Am-242, Am-243)•Curium (Cm-242, Cm-254, Cm-244, Cm-245, Cm-246)

Figure 1: Calculated data available in FIPD. Data is given as axial distributions for each pin in the assembly.

2.2 Measured Data

2.2.1 Bulk Measurements

Fabrication and post-irradiation measurements were performed on a subset of fuel pins. Even on pins that were analyzed, not all pins were subject to the same analysis. If a pin was measured in some way, the associated measured data is presented in the database. The available data is given in Figure 2. Since the last report, the pin irradiated weights have also been added, where available.

Dimensional Measurements	Plenum Gas Measurements	Plenum Gas Chemistry (gas fraction)	Isotopic Gamma Scans	Profilometry Measurements
<ul style="list-style-type: none"> • Irradiated fuel length • Irradiated fuel weight 	<ul style="list-style-type: none"> • Backfill volume • Pressure • Temperature 	<ul style="list-style-type: none"> • Hydrogen • Helium • Water • Nitrogen • Carbon monoxide • Carbon dioxide • Oxygen • Argon • Krypton • Xenon 	<ul style="list-style-type: none"> • Gross activity • Element-wise activity 	<ul style="list-style-type: none"> • Clad outer diameter • Peak clad outer diameter • Minimum clad outer diameter • Clad strain • Peak clad strain • Minimum clad strain

Figure 2: Measured data available for select pins. Not all data is available for all pins.

2.2.2 Digitized Profilometry Data

The profilometry measurements were performed as a non-destructive examination of the cladding dimensional changes. All of the profilometry measurements were recorded in hard-copy documents, where the quality of data varies for different experiments. In order to include digital data in the FIPD database, these plots were digitized using the Fast Reactor Data Digitalization System (FRDDS) code [6]. This digitization process is described in detail in a previous report [7]. At this point all available hardcopy contact profilometry data have been digitized. For quality assurance purposes, all digitized data needs to be examined by a subject matter expert (SME) before they are added to the database [8]. As of the current reporting period, 12 experiments have been reviewed and added to the database. There are current a total of 360 digitized profilometry datasets in the database. Table 1 summarized the current archiving status of the contact profilometry data.

Table 1: Current archiving status of the contact profilometry data.

Experiment	Number of images in hard copy	Number of Digitized images	Number of Datasets Examined by SME	Number of Datasets Uploaded in FIPD web
X419	61	61	61	61
X419A	9	9	9	9
X419B	60	60	60	60
X420A	57	57	57	57
X421	61	61	61	61
X421A	7	7	7	7
X423	6	6	6	6
X423A	6	6	6	6
X423B	9	9	9	9
X423C	37	37	37	37
X425A	54	54	-	-

X425B	26	26	-	-
X425C	60	60	-	-
X430	37	37	-	-
X435	16	16	-	-
X438	6	6	-	-
X441	53	53	-	-
X441A	49	49	-	-
X447A	47	47	47	47
X448	7	7	-	-
X452A	23	23	-	-
X483	12	12	-	-
X486	6	6	-	-
X489	7	7	-	-
X492	4	4	-	-
Total:	720	720	360	360

2.2.3 Digitized Gamma Scan Data

Among all types of PIE data, the amount of isotopic gamma spectroscopy data is the largest in terms of the number of scanned images in archived documentations. The isotopic gamma spectroscopy data of each fuel element usually contain gamma scan data for specific isotopes (e.g., Cs-134, Cs-137, Mn-54, Nb-95, Rh-106, and Zr-95), and a measurement of gross activity. All of the isotopic gamma scan legacy data were preserved in hardcopy, and have since been scanned into PDF files. As with the profilometry data, the digitization of the gamma scan hard-copy files was performed using FRDDS. For quality assurance purposes, all digitized data needs to be examined by an SME before being added to the database [8]. As of the current reporting period, 11 experiments have been examined and added to the database. There are currently a total of 1434 digitized gamma scan datasets in the database. Table 2 summarized current archiving status of the isotopic gamma scan data.

Table 2: Current archiving status of the isotopic gamma scan data.

Experiment	Number of images in hard copy	Number of Digitized images	Number of Datasets Examined by SME	Number of Datasets Uploaded in FIPD web
X419	378	378	378	378
X419A	125	125	125	125
X419B	27	27	27	27
X420	154	154	-	-
X420A	91	91	-	-
X420B	170	170	-	-
X421	217	217	-	-
X421A	163	163	-	-

X423C	285	285	-	-
X425	149	149	-	-
X425B	248	248	-	-
X425C	110	110	-	-
X430B	49	49	-	-
X431	65	65	65	65
X435	202	202	-	-
X441	277	277	277	277
X441A	240	240	-	-
X447	3	3	-	-
X447A	91	91	91	91
X448	119	119	119	119
X483	105	105	105	105
X489	118	118	118	118
X492	93	93	93	93
X492A	32	32	32	32
Total	3511	3511	1434	1434

2.3 GLASS Data

The GLASS dataset is a new addition to FIPD. The Germanium-Lithium Argon-Scanning System (GLASS) was installed in EBR-II to monitor and analyze the gamma activity of the reactor cover gas and the reactor building air. When applied to the reactor cover gas, this gave the ability to identify the sources of fission-gas leakage from fuel elements. This GLASS dataset contains daily 1-minute resolution recordings for Kr-85m, Kr-87, Kr-88, Xe-133, Xe-135, Xe-135m, and Xe-138, as well as the total reactor power. The dataset added to FIPD contains 2785 daily records from May 12, 1986 (~Run139A) through January 2, 1994 (~Run167A). These datasets are presented in the application in both plot and table formats.

2.4 Documents

The document library in FIPD has been significantly improved. The library has been extended to include the EBR-II operational run reports for runs from 133 through 170, which can be used to gain additional operation insight into the experiments present in FIPD.

To make the document library more searching and cross-linked, each document in the library has been individually reviewed and tagged according to the material shown in Figure 3. This explicit tagging and categorization of documents allowed for significant improvements to the web application, as discussed in a later section.

Document Tagging	Content Categories	PIE Types
<ul style="list-style-type: none"> • Document type • Authors • Contents categories • PIE categories (if PIE) • Related subassemblies • Related pins (if any) 	<ul style="list-style-type: none"> • General planning & preparation • Design / construction • Fuel description • Quality Assurance • Loading Diagram • Safety • Fabrication Data • Analysis of data / observations • Calculations (from simulation) • Post-irradiation exam data • PIE planning • Drawing • Test specs • Run Report 	<ul style="list-style-type: none"> • Visual exam photos/data • Weight data • Neutron radiography • Gamma scans • Laser profilometry • Profilometry • Bow measurements • Length Measurements • Metallography data • Fission gas analysis data • Fission gas chemistry data • Swelling data • Strain data • Fuel redistribution

Figure 3: Document tagging, content, and post-irradiation examination (PIE) categories.

2.5 Pin Design Descriptions

Pin design descriptions and as-built design specifications for each experiment have been extracted from FIPD documentation and added to the relational database. Designs were available in the existing FIPD documentation for all experiments except for X429, as shown in Table 3. Effort is ongoing to locate a reference for X429 pin designs and complete the design set.

Table 3: Number of pin design descriptions extracted for each experiment.

Experiment	Designs	Experiment	Designs
X419	3	X451	1
X420	3	X452	1
X421	3	X453	1
X423	6	X454	1
X425	3	X455	1
X430	4	X482	2
X431	6	X483	1
X432	6	X484	1
X435	1	X485	1
X441	11	X486	1
X447	2	X489	7
X448	1	X492	4
X449	1	X496	1
X450	1	X501	2

For each pin design contains a nominal design description, generally from the experiment design description and safety analysis, as well as more detailed as-built specifications, generally from the quality assurance / as-built documentation. The fields for each pin design are given in Figure 4. Values were not always provided for all fields in every experiment, but all values that were provided have been included.

Nominal Description	As-built Specification
<ul style="list-style-type: none"> • Fuel composition • Cladding type • U-235 enrichment • Fuel O.D. • Fuel length • Fuel:Plenum ratio • Cladding O.D. • Cladding Thickness • Element length • Smeared density • Wire wrap diameter/pitch • Sodium level above fuel 	<ul style="list-style-type: none"> • Fuel length • Fuel weight • Fuel O.D. • Cladding O.D. • Cladding thickness • Element length • Fuel/cladding diametral gap • Fuel density • Smeared density • Plenum/sodium volume • Plenum:Fuel ratio • Plenum gas composition • U/Pu isotopic compositions

Figure 4: Pin design description fields for nominal description and as-built specification.

With the pin design descriptions available, FIPD documentation and fabrication data were also reviewed to relate every pin in the database to one of the design descriptions. With the exception of X429 pins, for which design descriptions have not yet been located (65 pins), and several pins from the X431/X432 experimental set (7 pins), all other pins in the database have been related to a specific pin design (1914/1986 pins).

3 APPLICATION UPGRADE

This section covers the redesign of the FIPD web application. The previous version of FIPD was a Perl script which had been extended over the years as new content had been added to the database. While this was working for the database at it was, the script and its related database often relied on implicit relationships and naming between material, which limited the cross-linkage potential of the application, and resulted in some undesirable behavior when the implicit relationships were challenged.

To solve these problems and move forward with a more maintainable code infrastructure, the web application and related relational database were completely redesigned and rewritten. The redesigned application is based on the Django web application framework [9] for Python:

Django is a high-level Python Web framework that encourages rapid development and clean, pragmatic design. Built by experienced developers, it takes care of much of the hassle of Web development, so you can focus on writing your app without needing to reinvent the wheel. It's free and open source. [9]

There are many important benefits to using an established framework over working with an in-house solution as had been the case:

- Fully featured components are already available – Django includes dozens of extras you can use to handle common Web development tasks. Django takes care of user authentication, content administration, site maps, database interaction, and many more tasks, right out of the box.
- The ever-expanding problems of security are handled by professionals in the field
- General design allows applications to be versatile and scalable
- Complete and detailed documentation is available for the entire platform, along with a sizable development community available to help.
- The platform is actively developed and maintained, keeping the system up to date with modern web design and security standards.
- Model-View-Controller framework design separates data, presentation, and business logic, so that each can be logically documented and updated.

The frontend is also based on the Bootstrap frontend design framework [10], which helps make styles consistent throughout the application, and with elements that users recognize and understand from elsewhere on the internet. Bootstrap is also responsive and mobile-friendly, so designs can be expected to look reasonable on operating systems, different browsers, and different display sizes.

The combination of redesigned database, Django backend framework, and Bootstrap frontend framework, allows for significant improvement in the user interface, which are described in the following section.

4 MAJOR INTERFACE IMPROVEMENTS

This section covers several of the more significant improvements to the user-facing FIPD interface, made possible by the database extensions and application redesign discussed in earlier sections.

4.1 Modern design and layout

By basing the redesigned frontend on the Bootstrap front-end framework and following modern design guidelines, the overall styling and page layouts have been significantly improved. For general comparison, the original home page is shown in Figure 5, and the redesigned home page is shown in Figure 6.

Figure 5: Original FIPD Home page.

Figure 6: Redesigned FIPD Home page.

4.2 Experiment listings

The main experimental listings page has been significantly improved, providing descriptions, fuel and cladding types, and key operating data for each experiment in the set. This makes it significantly easier for users to find experiments that match their particular design case. The experimental listing from the original application is shown in Figure 7, and the experimental listing from the upgraded application is shown in Figure 8.

Figure 7: Experiment listing in original application.

Experiment	Brief Description	Fuel Compositions	Cladding Types	Peak Power (kW/ft)	Peak Clad Temp (°C)	Peak Fuel Temp (°C)	Peak Burnup (a/o)	Fast Fluence (x10 ²² n/cm ²)
X421	IFR prototype, fuel behavior, failure mode	U-10Zr, U-19Pu-10Zr, U-8Pu-10Zr	D9	14.60	547	706	18.95	19.68
X423	Fuel swelling and restructuring, large-diameter fuel	U-10Zr, U-19Pu-10Zr, U-22Pu-10Zr, U-26Pu-10Zr, U-3Pu-10Zr, U-8Pu-10Zr	316SS	13.50	501	691	5.21	8.08
X425	Lead IFR, U-Pu-Zr/HT9	U-10Zr, U-19Pu-10Zr, U-8Pu-10Zr	HT9	14.70	607.40	728	19.90	20.66
X429	Fabrication variables and strain prediction	U-10Zr, U-19Pu-10Zr, U-8Pu-10Zr	316SS, HT9	14	571	713	13.78	13.45
X430	HT9, peak cladding	U-10Zr, U-19Pu-10Zr	HT9	18.90	626	808	11.83	18.10

Figure 8: Experiment listings in upgraded application.

4.3 Experiment details

The experiment and subassembly detail views have been greatly improved, providing pins names in the subassembly hex grids, color-coding of pins based on pin design, and filters to highlight pins with specific PIE documents or digitized results. This makes it significantly easier for users to identify the location and designs of all pins, and to identify which pins have specific PIE of interest available, in either document or digitized form. The experiment detail listing from the original application is shown in Figure 9, and the experiment detail listing from the upgraded application is shown in Figure 10.

Figure 9: Experiment detail view in original application.

Figure 10: Experiment detail view in upgraded application. The digitized gas release data filter is selected, highlighting pins with said data available.

4.4 Pin detail view

The pin detail page has been extended to aggregate all of the related design data, fabrication data, operating conditions, available PIE (document or digitized form), and related documents, all provided in a single location.

4.5 Document listings

The document listings views have been significantly improved, displayed as interactive filterable and sortable tables, and including document and content types for each document. This makes it easier for users to determine at a glance which documents will likely contain the material they are looking for. A sample document listing from the original application is shown in Figure 11, and a sample listing from the upgraded application is shown in Figure 12.

Steady State Data	Out-of-pile Transient Data	Documents	Contact	Logged in as: aoaks
Documents				
Experiment: X419				
10/22/1985, 12 Elements from S/A X419 Isotopic gamma scan				
08/16/1985, 18 Elements from S/A X419 Bow measurements and Length measurements				
08/12/1985, 18 Elements from S/A X419 Profilimeter traces				
08/12/1985, 18 Elements from S/A X419 Profilimeter traces				
08/10/1985, 2 Elements from S/A X419 Isotopic gamma scan				

Figure 11: Document listing in original application.

Type	Title	Authors	Date
As-Built Loading Diagram	As-built Loading Diagram for X419 Fabrication Data Loading Diagram Post-irradiation exam data	Steinman, W.	Feb. 7, 1985
Data	Microprobe Examination RESULTS, t T179, X419 Post-irradiation exam data		
Design Description	Design Description and Safety Analysis for X419, X420 and X421 Design / construction Drawing Fabrication Data Fuel description Safety	Lahm, C. Pahl, R.	Dec. 1, 1984
HFEF Data Transmittal	12 Elements from S/A X419 Isotopic gamma scan Post-irradiation exam data	Franklin, E.	Oct. 22, 1985
HFEF Data Transmittal	18 Elements from S/A X419 Bow measurements and Length measurements Post-irradiation exam data	Franklin, E.	Aug. 16, 1985
HFEF Data Transmittal	18 Elements from S/A X419 Profilimeter traces Post-irradiation exam data	Franklin, E.	Aug. 12, 1985

Figure 12: Document listing in upgraded application.

4.6 Cross-linked documents

A document detail view has been added to the upgraded application to all tagged and cross-referenced information about a document before downloading. This allows users to see at a glance all related material for the document, and follow those relations immediately (e.g., browsing to related pin data). A document detail view from the upgraded application is shown in Figure 13.

Document Details

[Document List](#)

Download Link	Download PDF
Title	Destructive Examination of IFR Elements T-11 and T-179 (Subassembly X419)
Date	Aug. 22, 1985
Authors	Beck, W. 23 docs Hofman, G. 11 docs
Document Type	Memo 596 docs
Document Contents	Drawing 15 docs Fabrication Data 51 docs Fuel description 41 docs Post-irradiation exam data 402 docs
Related Post Test Exams	Metallography data 71 docs
Related Subassemblies	X419 75 docs
Related Pins	T011 11 docs T179 11 docs

Figure 13: Document detail view in upgraded application, showing all cross-references available for the given document.

5 EXTERNAL ACCESS

5.1 Multi-factor Authentication (MFA)

In accordance with Argonne's Cybersecurity Office's requirements, users accessing potentially sensitive content are required to use multi-factor authentication (MFA). DOE lab employees who are authorized to view such content are able to obtain HSPD-12 smartcard badges, and are required to authenticate to their client computers before accessing the application. It is typically not possible (or at least not easy) for industry/university partners to obtain this level of credential. Argonne's Cybersecurity Office has approved the Duo multifactor authentication service [11] for use in these situations.

The FIPD application was designed to support Duo authentication to satisfy the MFA requirement for non-HSPD-12 cardholders. After initial authentication using password credentials (either with an Argonne employee account or a collaborator account), secondary authentication is performed using the Duo service, which can be satisfied with the Duo smartphone application, text message, or phone service. On first login, users perform a one-time registration, which is then used in subsequent logins. Duo licenses are covered by Argonne so FIPD users using the Duo service do not incur any cost.

5.2 External Launch

The upgraded user interface has been officially launched, and is now the FIPD application that all users see.

The breakdown of current users is shown in Figure 14. FIPD is accepting requests for new users, with information about how to obtain access provided on the login page.

Figure 14: Distribution of current FIPD users, between Argonne, other DOE national labs, and industry entities.

6 FUTURE ACTIVITIES

Currently, the FIPD contains majority of the key metallic fuel experiments data needed for supporting fuel behavior analysts and reactor designers, as well as supporting industry licensing activities for fast reactor designs that are based on metallic U-Zr fuels. The current mature state of the database will allow its immediate utilization to support those areas, as activities in both areas are expected to accelerate in the near future. This is especially important as the NRC is currently evaluating a QAPP (Quality Assurance Program Plan) developed through the ART program that aims at qualifying the SFR metallic fuel data, especially data included in the FIPD.

For example, adaptation of the advanced fuel performance code BISON to metallic fuel is at the state where it will require detailed validation and verification effort, especially as it is identified as a code of interest to both NRC and industry. The detailed data provided through the database is the type of data needed for BISON V&V activities, as well as, supporting improvements in the code's physics-based models. In addition, the recent consideration of the deployment of a US test fast reactor (Versatile Test Reactor – VTR) that is based on metallic U-Zr alloy based fuel, highlights the importance of the database and the quality of its data.

Recently, there has been industry stake holders who are promoting different types of advanced fast reactor designs that are based on the US experience with metallic fuels in fast reactors. Those industries include TerraPower, GE Hitachi Nuclear Energy, Oklo Inc., and Advanced Reactor Concepts (ARC), where some are already engaged in licensing discussions with the NRC. For example, Oklo Inc. is currently engaged in pre-application activities with the NRC for licensing their specific design, where metallic fuel performance and qualification of metallic fuel data in the FIPD are directly relevant to the licensing activities.

Based on the above discussion, it is clear that the quality of the data accumulated in the FIPD is important to both analysts and industry, and Quality Assurance (QA) will need to be a major part of future database related activities. The following is a summary of potential future FIPD activities:

- Database maintenance and security activities:
 - Maintenance of the database software as described in the SQAPP (software quality assurance program plan).
 - Continue security improvements of the database and access control activities to provide the database to wider audience.
- Database Improvements and additions:
 - Improvements to database interface through custom queries and addressing users' requests and comments
 - Continue revising data, including PIE images and graphs, in the database as original images become available from the original databooks at Argonne and INL (INL continues to collaborate with Argonne providing original images of PIE measurements)
 - Continue adding databooks for all available experiments from the Alpha Gamma Hot Cell Facility (AGHCF) and request and add databooks from Hot Fuel Examination

Facility (HFEF) (as it become available), and QA related documents (especially HFEF related documents).

- Request revision of neutronics calculations as needed to issues that are identified in some the binary files produced during the IFR program.
- Respond to other Programs and Industry Requests:
 - Make data available to analysts in NEAMS, VTR, or other DOE supported programs (in FY 2019 requests for detailed data and improvements to the database were made by NEAMS personal from different labs as part of BISON code validation effort)
 - Respond to specific industry requests including establishing separate web access route that better support their interests (e.g., a dedicated route or page can be established for an industry partner tailored to meet industry needs')

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