PNNL-18776

Recovery of Information from the Fast Flux Test Facility for the Advanced Fuel Cycle Initiative

Advanced Fuel Cycle Initiative

Prepared for
U.S. Department of Energy
Reactor Campaign/Advanced Fuel Cycle Initiative
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September 2009
AFCI-TIO-PMO-QA-FM-2009-00052

Summary

The Fast Flux Test Facility is the most recent Liquid Metal Reactor to operate in the United States. Information from the design, construction, and operation of this reactor was at risk as the facilities associated with the reactor are being shut down. The Advanced Fuel Cycle Initiative is a program managed by the Office of Nuclear Energy of the U.S. Department of Energy with a mission to develop new fuel cycle technologies to support both current and advanced reactors. Securing and preserving the knowledge gained from operation and testing in the Fast Flux Test Facility is an important part of the Knowledge Preservation activity in this program.

During Fiscal Year 2009, information associated with the Fast Flux Test Facility was secured and mechanisms for retrieving other information stored on large document storage systems on the Hanford Site were developed. The value of this information lies in its level of detail and depth, which is sufficient to rebuild the reactor plant or to design, construct, and build a similar although not identical reactor.

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Acronyms

AFCI	Advanced Fuel Cycle Initiative
AT Applied	Technology
DOE	U.S. Department of Energy
ECI	Export Controlled Information
ECN Engineering	Change Notice
FFTF	Fast Flux Test Facility
HDTS	Hanford Document Tracking System
IAEA	International Atomic Energy Agency
IDMS	Integrated Document Management System
INL	Idaho National Laboratory
KEF Knowledge	Encapsulation Framework
LMR Liquid	Metal Reactor
LMRTL	Liquid Metal Reactor Technology Library
MASTER	Main Access to Storage and Tracking Engineering Records
OCR	optical character recognition
OSTI	Office of Scientific and Technical Information
OUO Official	Use Only
PNNL	Pacific Northwest National Laboratory
RHA	Records Holding Area
TRIM	Total Records and Information Management
WDC	Westinghouse Drawing Control

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1.0 Background

The Advanced Fuel Cycle Initiative (AFCI) is a research and development program managed by the Office of Nuclear Energy of the U.S. Department of Energy (DOE). The purpose of the program is to develop new fuel cycle technologies to support both current and advanced nuclear power plants. As part of this, the mission of AFCI is to develop proliferation resistant fuel and transmutation technologies leading to an environmentally and economically sound nuclear fuel cycle.

The Fast Flux Test Facility (FFTF) is the most recent liquid-metal reactor (LMR) to operate in the United States, from 1982 to 1992. The technology employed in designing and constructing this reactor, along with information obtained from tests conducted during its operation, can significantly influence the development of a proliferation-resistant transmutation technology. Information from this reactor is currently being archived under a DOE/ Office of Nuclear Energy program. This report summarizes the activities conducted during Fiscal Year 2009 related to securing, preserving, and archiving FFTF information.

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2.0 Information Storage Systems Containing FFTF Information

Several different storage systems on the Hanford Site were used to store information during the design, construction, and operation of FFTF. The information storage systems evolved over time as the storage requirements developed over a period of almost 20 years. The four main storage systems and their principal characteristics are described below.

The oldest storage system is the Main Access to Storage and Tracking Engineering Records (MASTER). This system, which is a metadata-only application, contains engineering documents, non-engineering documents, correspondence, procedures, and other documentation from Westinghouse/Hanford Engineering Development Laboratory. It covers the period prior to contractor consolidation on the site in 1987 and then after consolidation until October 1993.

Entries in the MASTER system typically correspond to a microfilm image (reel and frame number) or microfiche aperture card, which are maintained at Hanford's Central Files. For these microfilmed documents, the microfilm is considered the record and no hard copy of the document was retained in most cases. However, there are also documents tracked in MASTER that have not been microfilmed. In these cases, the physical box location of the document is identified by a Records Holding Area (RHA) number. The RHA Management Information System provides for tracking and retrieving these boxes of records retired by current and predecessor site contractors, including boxes located in the Hanford Central File vault or those that have been retired to the Federal Records Center located in Seattle, Washington. The RHA Management Information System also tracks the reference activity of retired records. When documents are entered into the record system, they are assigned a specific retention period after which it is possible they could be disposed. In many but not all cases, this retention period is 75 years.

In 1995, the Hanford Document Tracking System (HDTS) was created in order to move applications off the Honeywell mainframe computer. The HDTS database includes three separate legacy records management and document control applications: MASTER (discussed previously), the Engineering Change Notice (ECN) database, and the Westinghouse Drawing Control (WDC) database. Based on a database inventory completed in 2008, the estimated inventory of MASTER is approximately 650,000 records associated with microfilm and 130,000 records associated with hard copy. Additionally, the ECN database contains approximately 89,000 records, including ECNs and Field Maintenance Procedures for the Hanford 300 and 400 Areas, and the WDC database contains approximately 275,000 records, including Westinghouse/ Hanford Engineering Development Laboratory engineering and vendor drawings for the 300 and 400 Areas. A significant number of these records relate to design, construction, and operation of the FFTF.

After more than 60 years of only storing official records in hardcopy format, in May 2004, DOE approved storing records in electronic format in the certified Records Management module of the Integrated Document Management System (IDMS). The IDMS provides the Hanford Site with electronic document management, knowledge management, workflow capability, and the records repository. Migration of the HDTS to IDMS was completed in September 2008. A search of the IDMS system using "FFTF" as a search field yields nearly 650,000 records. The MASTER, ECN, and WDC storage systems are now accessed through IDMS. The Hanford Document Control System, also accessible through IDMS, contains a list of the released engineering documentation for the Hanford site. This storage system tracks change information for all engineering documents, drawings, etc., and provides a path for the retrieval of the drawing/document and related change information.

Two additional repositories of FFTF and fast reactor non-record documents exist. One is located at the Liquid Metal Reactor Technology Library (LMRTL) in the 200 East Area of the Hanford Site. The LMRTL focuses on documents and other data specifically related to fuels and materials irradiation testing, although it was recently augmented with other FFTF and fast reactor documentation. The other repository is located at the reactor site in a portable storage module. This module contains FFTF data that may be useful for ongoing 400 area surveillance and maintenance activities and future decontamination and decommissioning of the reactor complex.

3.0 Transfer of Documentation

A significant part of the activity in this program during Fiscal Year 2009 was devoted to securing FFTF information that was at risk because locations where the information was stored were being deactivated and closed. This work is summarized in the paragraphs below.

Two buildings that housed FFTF documentation were at risk: the 4710 Building, which housed the FFTF engineering and support activities; and the 4713-B Maintenance Shop. All documents and files in these buildings were reviewed to determine if they were record or non-record. If determined to be record, they were logged and transferred to the appropriate records management personnel for entry into the records management system.

Non-record materials that were believed to be relevant to the fast reactor data archiving activity were boxed and transferred to the LMRTL for storage. Other materials believed important to ongoing surveillance and maintenance and decontamination and decommissioning work were placed in a portable storage module located adjacent to the reactor. The boxes in LMRTL are in three stages of categorization. Since funding and time available to complete the task were uncertain at the beginning of the effort, initial materials were separated into broad categories according to the International Atomic Energy Agency (IAEA) taxonomy such as “Design and Analysis” or “Fuel.” A complete list of the categories in the IAEA taxonomy that were used is shown in Appendix A.

No effort was made at that time to identify the individual items boxed within these broad categories. As it became apparent that deactivation of the buildings was going to proceed for several months and funding was available to support the activity, items stored in each box were itemized and abstracts for most of the documents were entered into a computer file. Then, as time to be out of the buildings was nearing, materials of potential interest were reviewed to ensure no record materials were present, then boxed unsorted and transferred to the LMRTL for future review and possible retention and categorization.

A total of 485 boxes were transferred from the FFTF, adding to the existing LMRTL inventory of 1,170 boxes, for a total of 1,655 boxes. A set of more than 7,000 microfilm reels of FFTF-specific information was also transferred. Likewise, a complete set of Clinch River Breeder Reactor microfilm reels consisting of more than 61,000 records were also transferred from FFTF to the LMRTL. In addition, approximately 20 boxes of microfilm providing detailed design of the sodium valves, fuels development, and other FFTF subjects were saved.

Examples of the types of material available at the LMRTL include:

- A complete set of FFTF System Design Descriptions
- A complete set of Operations and Maintenance Manuals
- Detailed fuels design and fabrication data
- FFTF Reload and Cycle Reports
- FFTF procurement specifications
- Safety analyses and associated addendums
- Deactivation and decommissioning data

- Environmental data
- Documentation of analyses and operating experience gained over the decade of FFTF operation.

For information remaining in the repository in the 400 Area, a general category index was prepared. This repository contains 58 five-drawer file cabinets and 25 two-shelf bookcases. The information includes data pertaining to the Sodium Storage Facility located in files 3 and 4, cold trap data in file 4, etc.

At this time, more than 2,100 linear feet of hard copy materials are stored at the LMRTL and efforts to categorize this material consistent with the IAEA taxonomy format are underway. As the material is categorized, a computer index is being built, which ultimately will contain a complete and searchable inventory of the library and provide not only abstracts of the materials, but their storage locations within the library. In addition, FFTF or related fast reactor documents gathered to support data requests from other sites or groups are being obtained in hard copy from retrievable storage or blown back from microfilm and entered into the Total Records and Information Management (TRIM) system. TRIM is a laboratory-wide electronic database system maintained under contract by the Pacific Northwest National Laboratory (PNNL). This database is described in greater detail in Section 5 and is intended to allow future requests for data and any subsequent retrieval to proceed more quickly and cost effectively.

4.0 Summarizing FFTF Information for Design Data Needs

As an example of the data retrieval process, the following is a summary of a retrieval effort performed in June 2009 for FFTF information at Hanford. Commercial organizations interested in supporting DOE efforts in minor actinide transmutation by becoming providers of liquid metal nuclear steam supply systems requested that certain technological information be made available to them. They requested information in five areas: fixed shielding, control rods and drive mechanisms, gas tagging, fuel handling systems, and HT-9 fuel design. An understanding of these five technology areas was considered essential to the design of any future LMR.

To support this request, a list of approximately 9,000 FFTF document citations was reviewed for pertinence and a further search of available Office of Scientific and Technical Information (OSTI) material was conducted. Those seminal documents essential to understanding the FFTF design and testing process were selected and documents in these five areas of interest were tabulated in a report. The final number of documents selected for citation in this report was 296. This bibliography was provided to DOE for further distribution to the requesting industrial contractors. The number of reports selected by technical area was:

- Fixed shielding (55)
- Control rods and drive mechanisms (41)
- Failed fuel monitoring and gas-tag systems (32)
- Fuel handling systems (55)
- HT-9 fuel design (73)
- Other general fast reactor systems (40).

Open literature documents were provided as electronic copy with the report and restricted use documents, available in the various databases, were only identified since OSTI is currently the authorized supplier of non-public information in the LMR realm.

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5.0 Retrieval and Storage of FFTF Information

As indicated earlier, a document containing information related to FFTF can be stored in any one of several document storage systems. In response to a client request for a document, the document storage systems are searched in an orderly manner designed to minimize the search effort. If the document exists only as a hard copy, it is scanned and a copy forwarded to the client while an electronic copy is stored in TRIM for subsequent expedited retrieval. The original hard copy is returned to the Hanford storage system it was obtained from, which has responsibility for retaining this document. The logical flow of this activity is illustrated in Figure 5.1.

The overall process provides a disciplined approach by which: (a) documents are retrieved, (b) documents are provided to the interested participants in the AFCI program, (c) originals are not lost in the process, and (d) a consolidated electronic database is built in TRIM for more efficient and cost-effective retrieval for future requests. As shown in the figure, a classification review to determine if the information is Applied Technology (AT), Official Use Only (OUO), or Export Controlled Information (ECI) is an integral part of the process.

Two distinct document management/knowledge management systems are currently in use for FFTF data archiving and knowledge preservation purposes:

- TRIM is a commercial off-the-shelf document management solution developed by Hewlett Packard and used by PNNL to manage project records. It provides keyword searching of the full document text and version control, supports folders (e.g., for use in implementing an organizing taxonomy), and in the PNNL implementation, provides DOE-approved security controls adequate for AT and ECI documents. It is used to preserve an archival copy of documents related to FFTF along with project-specific metadata including IAEA subject taxonomy headings and a subject matter expert prepared abstract. TRIM is the main "production" document management system used in support of the Knowledge Preservation for the FFTF.
- Knowledge Encapsulation Framework (KEF) is a knowledge management tool developed by PNNL under the aegis of the Technosocial Predictive Analytics Initiative (laboratory-directed research and development) effort. It is based on the open-source Semantic MediaWiki project, which involved a world-wide network of developers and is led by Karlsruhe University, Germany. KEF is being used in a prototyping effort to demonstrate the utility of "semantically aware" document management software tools. A "semantically aware" uses formal relationships between data or documents (e.g., "this document supports hypothesis A" or "HT-9 is a type of alloy") to facilitate more expressive search capabilities.
- The primary reason for the dual system is expediency. While TRIM provides a robust document storage and retrieval solution that is well-supported by both the commercial vendor and PNNL's own document management organization, it lacks many features that can be used to add value to the documents. KEF provides many of these features, but is still in development; hence it is being used to test and demonstrate key concepts related to knowledge preservation on a pilot basis.

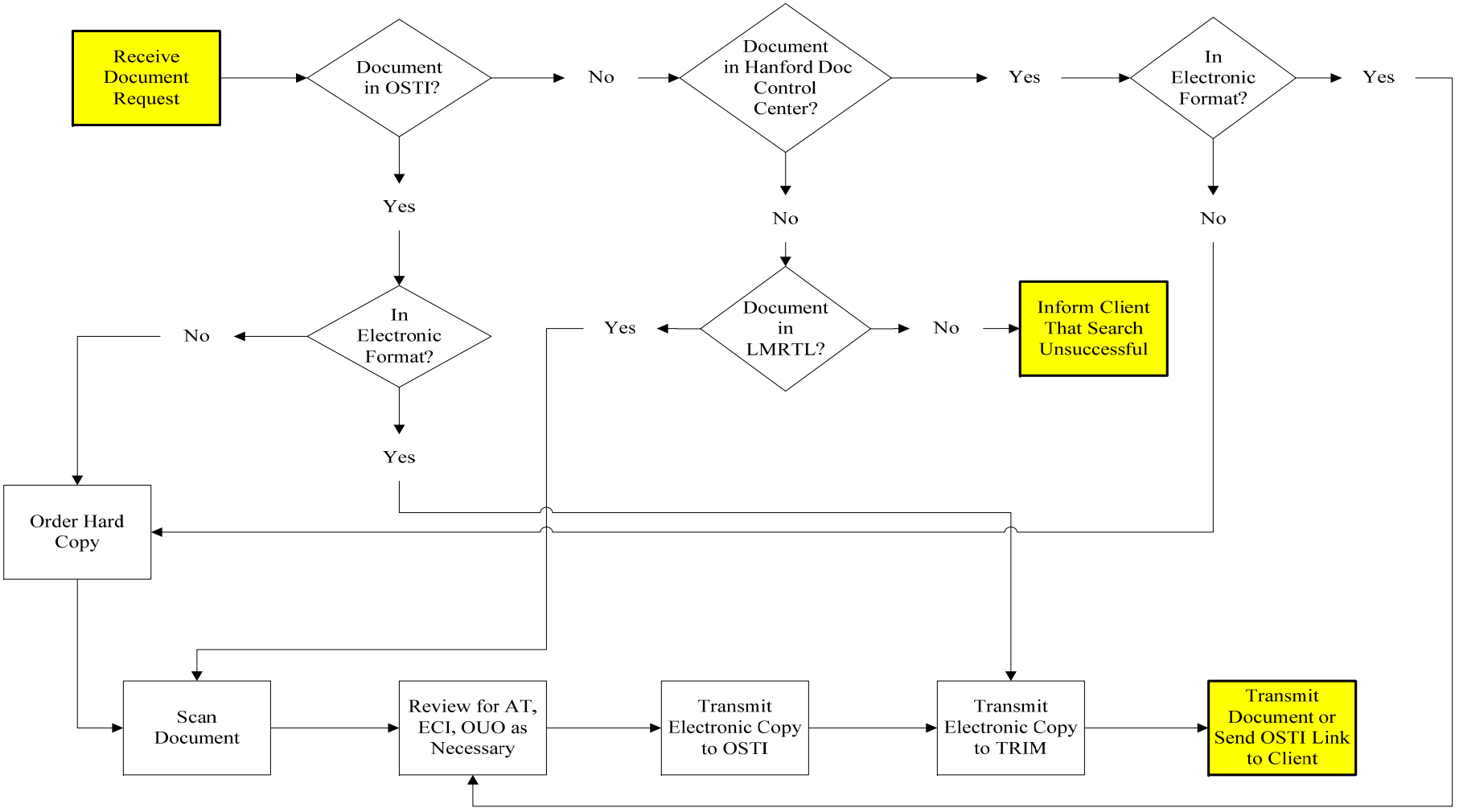

Figure 5.1. Flow Diagram for Searching FFTF Databases

As indicated in Figure 5.1, documents are entered into each system primarily in response to customer requests for data. To date, 28 documents ranging in length from five to several hundred pages have been entered. Each document is saved as an image file (typically, a TIFF graphic embedded in a PDF file) along with associated optical character recognition (OCR) data that allows the full text of the document to be indexed and searched. The image of the document is preserved due to the large number of graphics, tables, and charts that typically do not translate well into OCR data, and because many of the documents contain significant number of text recognition errors (fonts used for many of the FFTF reports prove to be difficult for current OCR software to convert effectively). This approach allows the reader to see the document as it was actually prepared (including, at times, any hand-written marginal notes) while still preserving a reasonable quality text-search capability.

Once documents have been entered into the TRIM system, they can be searched using the standard TRIM search capabilities or retrieved in response to one or more standardized reports, which provide the ability to summarize TRIM metadata fields (e.g., title, author, publication year, abstract) in response to user-defined queries. Documents may also be "browsed" using the abbreviated (high-level) IAEA taxonomy, as shown in Figure 5.2.

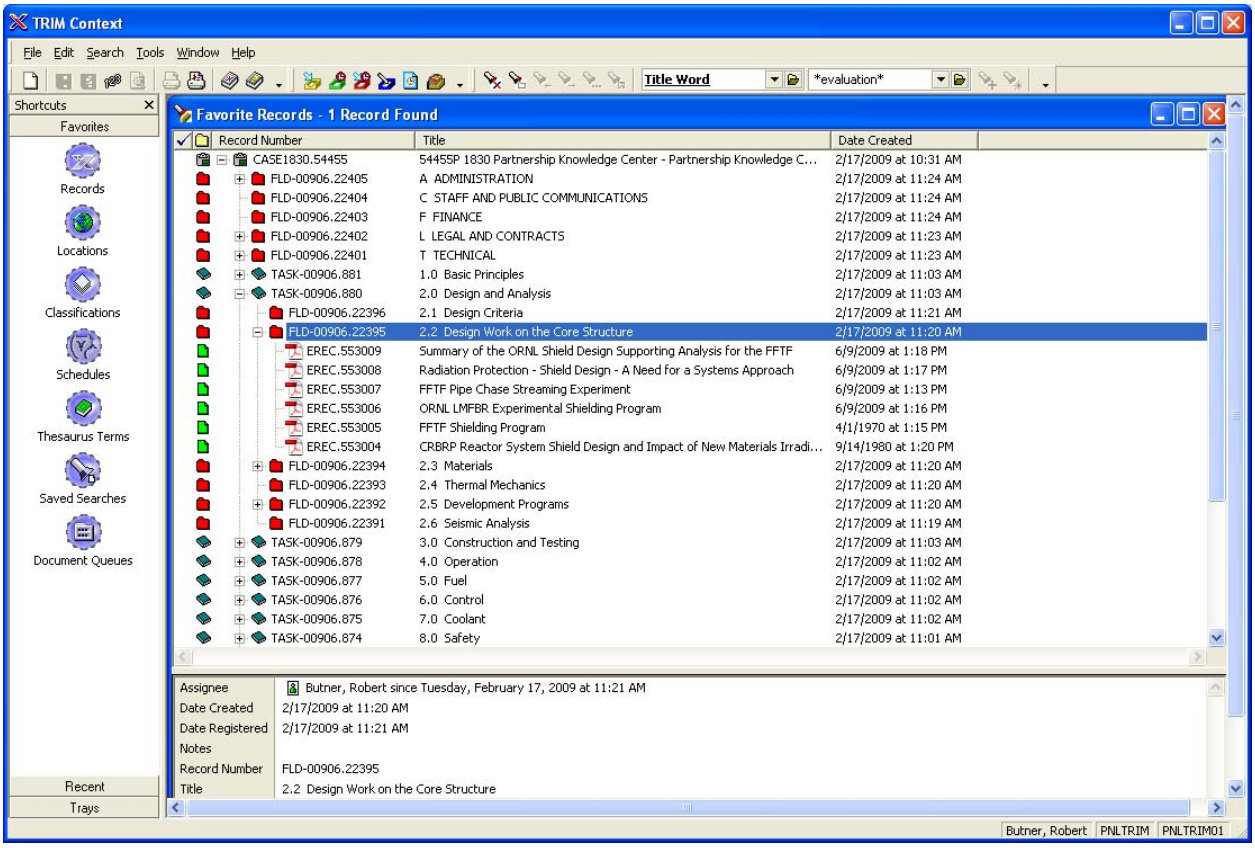

Figure 5.2. High-level IAEA Taxonomy

Initial retrieval tests done by searching for "unique" key phrases or terms (e.g., technical terms that occur in the documents but are unlikely to be used frequently) have indicated that retrieval rates are satisfactory (of 10 technical terms used in a preliminary test, all were found in the document index). The ability to retrieve documents via keyword searches will be monitored as a wider range of document ages, formats, and document lengths are encountered, each of which is expected to be an important factor in determining the quality of the OCR text conversion.

While TRIM is useful for day-to-day production archiving of documents, much of the knowledge about FFTF is in the form of so-called "tacit knowledge"—knowledge about documents, their historical and technical context, and undocumented programmatic knowledge. In an effort to capture some of this knowledge, PNNL developed the KEF, an open-source Semantic MediaWiki project that uses a semantically-enhanced version of MediaWiki. While "wiki" conjures up the image of "anyone can edit or create content," Wiki tools are simply a form of document management system. In KEF, only approved users can access content and user editing of the original document is not allowed, although users can annotate the document so their comments can be shared with the rest of the technical community.

The primary reason for using KEF, however, is not to use the wiki features, but to take advantage of very powerful "semantic search" capabilities that are supported by the tool. In a KEF version of an FFTF document for instance, each figure, table, or graphic is stored as a separate information object, which allows a search to be conducted specifically for documents containing a figure with the term "HT9" in the figure title. Author relationships are also made more explicit, for instance KEF allows us to click on any author's name, and find all of the reports that list the author as a contributor. As FFTF "ontology" (similar to a taxonomy) continues to develop, more sophisticated relationships are expected between documents. For instance, KEF allows the knowledge that "HT9" refers to a type of alloy used in cladding of fuel pins to be preserved; this knowledge can then be used to search for all documents dealing with alloy testing and retrieve relevant HT9 documents, even if the user does not know that HT9 is an alloy.

Currently, all documents that have been entered into TRIM have also been replicated in KEF, a simple KEF user interface has been created, and efforts continue to illustrate some of the semantic search capabilities of KEF with practical use cases. The KEF home page is presented in Figure 5.3.

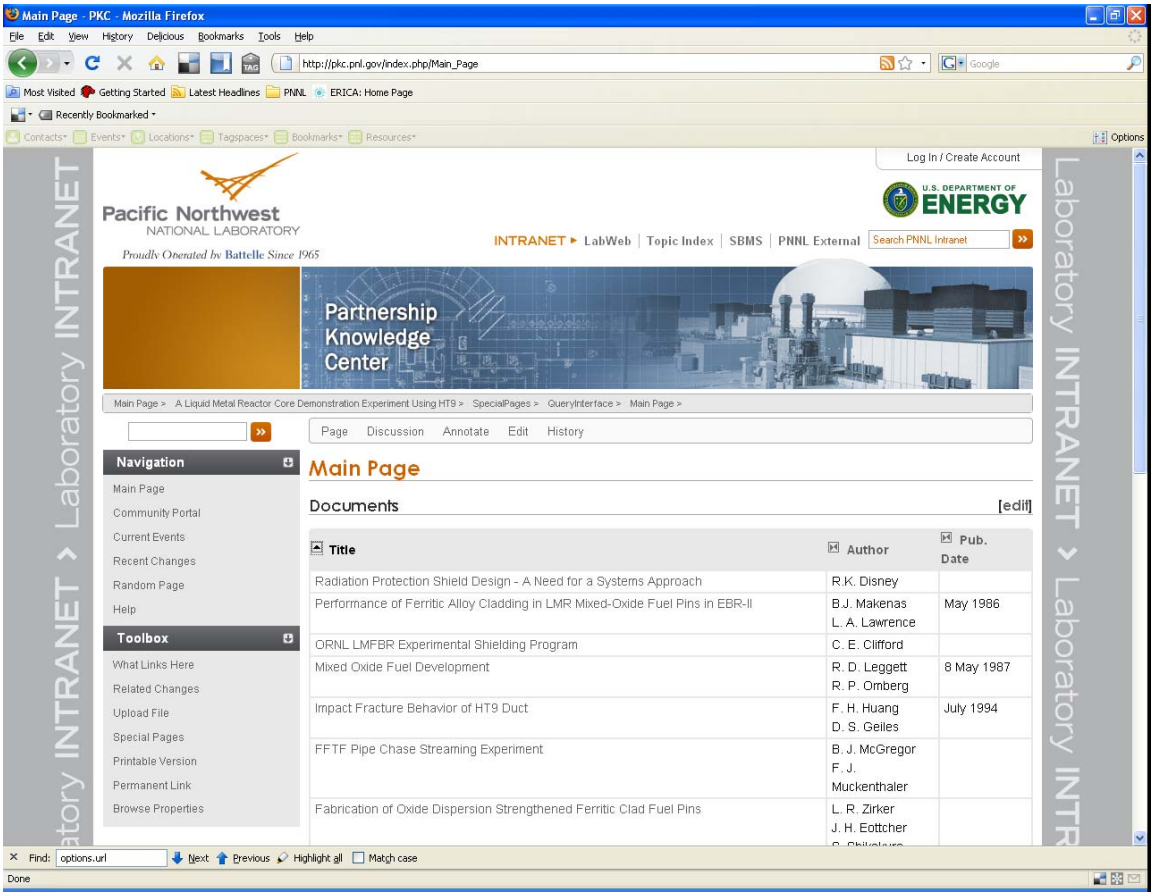

Figure 5.3. KEF Home Page on PNNL's Intranet

6.0 Retrieval of Information for Data Assessment Packages

Information about FFTF operations, components, operating parameters, and irradiation tests is of considerable value to the AFCI program, as evidenced by recent requests for specific information related to potential modeling and simulation benchmarks and interpretation of metal fuel irradiation test data. The practical application of this information is dependent on having ready access to the archive data and reports and having knowledgeable individuals who can identify, locate, and interpret the information. Current efforts to catalogue and index the preserved documents and data will allow more efficient response to such requests.

6.1 Metal Fuel Tests

A series of binary U-Zr metal fuel test assemblies were irradiated in FFTF to provide performance data and to qualify this fuel as prototypic LMR driver fuel. These irradiated test assemblies were shipped to Idaho National Laboratory (INL), where post irradiation examinations are currently being planned for two of these assemblies, MFF-3 and MFF-5. INL has requested PNNL to provide FFTF test information and key reactor operational data of the irradiation environment relevant to these two test assemblies to assist in the planning and interpretation of post irradiation examinations. PNNL is in the process of generating a complete data package report, similar to that provided for other test assemblies in the past, including material compositions, irradiation history, fission powers, fast and total neutron fluxes, sodium temperatures, and sodium flow rates.

Major tasks include:

- Identify and retrieve relevant reports, data, and codes
  - Cycle reload design reports
  - Test design descriptions
    - As-built dimensions and compositions
    - Component drawings
  - Physics codes and data
  - Thermal hydraulic codes and data
- Scan test reports to pdf files
- Generate detailed axial and radial flux and power distributions by cycle
- Extract and compile burnup-dependent material compositions
- Extract and compile temperatures and flow rates
- Review for AT, ECI, and OUO before off-site release
- Convert documents and drawings to electronic format
- Return originals to storage location
- Duplicate electronic copies stored in TRIM for later retrieval as needed.

6.2 FFTF Initial Criticality Benchmark

PNNL is collaborating with INL on the joint development of a draft evaluated integral benchmark specification for the initial, fully-loaded, isothermal, core-critical configuration of FFTF as measured on March 8, 1980. This project requires detailed information on the core components in order to construct an accurate benchmark specification that could be used for verifying reactor analysis and design codes and verifying modeling and simulation efforts.

Major tasks include:

- Identify and retrieve relevant reports and data
- Approximately 200 component drawings were identified and retrieved
  - Driver fuel
  - Control rods
  - Radial reflectors
  - Radial shield
  - In-core shims
  - Tests (in-reactor thimble, vibration open test assembly)
- Review for AT, ECI, and OUO before off-site release
- Convert documents and drawings to electronic format
- Return originals to storage location
- Duplicate electronic copies stored in TRIM for later retrieval as needed.

6.3 Observations/Issues

- Relevant documents and drawings were successfully identified and retrieved.
- Relevant computer files were successfully identified and retrieved.
- Information was located and retrieved from the LMRTL or Hanford Central Files.
- The LMR knowledge preservation effort was essential in searching, identifying, and locating reports and drawings. The successful retrieval effort was made possible by utilizing personnel familiar with FFTF technology and documentation. The ongoing indexing and cataloguing process for the holdings in the LMRTL will make it much easier to respond to future requests.
- A process for review of documents and drawings for off-site release was developed and utilized.
- All information not marked as having been reviewed for AT/ECI was reviewed and some was determined to be AT/ECI.
- Most information was marked restricted release internal to Hanford, requiring review for ECI/AT before any off-site release.
- AT documents were routed through OSTI for off-site access.

- OSTI currently does not handle drawings, so these were transmitted by the Hanford document release station.
- Computer codes and data have configuration control/quality assurance requirements. They are handled separate from documents and reports. Consistent preservation efforts for these codes should be considered.
- Ongoing cataloging/indexing/electronic storage of documents is increasing ease of use and will make future retrieval efforts more efficient.

The staff involved in responding to these data requests has a developed process in place and are prepared to efficiently handle future requests.

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7.0 Summary and Conclusions

At the beginning of Fiscal Year 2009, information pertaining to the design, construction, and operation of FFTF was at serious risk of being irretrievably lost. All of this information has been secured and initial efforts are underway to categorize it logically by the IAEA LMR taxonomy. In addition, a detailed understanding of the four major Hanford Site storage systems and the FFTF information contained within them was developed. Documents from these systems have been successfully retrieved to meet major AFCI program milestones. In addition, documents, computer programs, and prints have been retrieved to meet AFCI program specific commitments. The general scope of the activities in the FFTF data archiving were presented at professional society meetings to acquaint the LMR community with the information available for their use [1-3]. And finally, a preliminary electronic search tool was developed so that information from the Hanford Site storage systems can be more easily retrieved in the future.

Throughout the FFTF program, the responsible organizations thoroughly supported extensive efforts to archive all documents, drawings, and specifications related to the reactor and its operations. The information storage systems evolved over the 20 years that the activity occurred and is stored in different locations and systems on the Hanford Site. This in no way diminishes the value of the information, but only the difficultly in retrieving it. Assessment of this program concludes that the available information is sufficient to rebuild the reactor plant or alternatively to build a similar reactor should the decision be made to do so.

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8.0 References

(1) S. BUTNER, D.W. WOOTAN, R. P. OMBERG, B. J. MAKENAS, "Preservation of FFTF Testing, Design, and Operating Information," *Transactions American Nuclear Society*, 98, 715 (June 2008).

(2) S. BUTNER, D.W. WOOTAN, R. P. OMBERG, B. J. MAKENAS, "Secure Retrieval of FFTF Testing, Design, and Operating Information," to be published in the *Transactions American Nuclear Society,* ANS Winter Meeting, Washington D.C., (November 2009).

(3) B. J. MAKENAS, *Inventory of Liquid Metal Reactor Information in the Hanford 3717C Building,* FFTF-27592, Fluor Hanford, Richland, Washington, (September 2005).

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Appendix A - IAEA LMR Data Taxonomy

1.0 BASIC PRINCIPLES
- 1.1 Fast Fission
- 1.2 Physics Methods
- 1.3 Basic Design and Safety Variations

2.0 DESIGN AND ANALYSIS
- 2.1 Design Criteria
- 2.2 Design Work on the Core Structure
- 2.3 Materials
- 2.4 Thermal Mechanics
- 2.5 Development Programs
- 2.6 Seismic Analysis

3.0 MANUFACTURING AND CONSTRUCTION
- 3.1 Site Selection
- 3.2 Reactor Building
- 3.3 Peripheral Plant
  - 3.3.1 Heat Exchangers
  - 3.3.2 Pumps
  - 3.3.3 Storage Tanks
- 3.4 Inspection – Codes and Standards
- 3.5 Design Analysis and Licensing
- 3.6 Commissioning

4.0 OPERATION
- 4.1 Operating Procedures
- 4.2 Operating Experience
- 4.3 Failure Detection
- 4.4 Charge/Discharge
- 4.5 Decontamination and Decommissioning

5.0 FUEL
- 5.1 Basic Principles
- 5.2 Design and Supporting Research and Development
- 5.3 Materials – Testing and Selection
- 5.4 Manufacture
  - 5.4.1 Cladding and Wrappers
  - 5.4.2 Fuel Compounds and Mixtures
  - 5.4.3 Fuel Fabrication
  - 5.4.4 Cluster Assembly