

# **Materials Inventory Database for the Light Water Reactor Sustainability Program**

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August 2013



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Approved by:



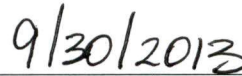
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Date

## ABSTRACT

Scientific research involves the purchasing, processing, characterization, and fabrication of many sample materials. The history of such materials can become complicated over their lifetime – materials might be cut into pieces or moved to various storage locations, for example. A database with built-in functions to track these kinds of processes facilitates well-organized research. The Material Inventory Database Accounting System (MIDAS) is an easy-to-use tracking and reference system for such items.

The Light Water Reactor Sustainability Program (LWRS), which seeks to advance the long-term reliability and productivity of existing nuclear reactors in the United States through multiple research pathways, proposed MIDAS as an efficient way to organize and track all items used in its research. The database software ensures traceability of all items used in research using built-in functions which can emulate actions on tracked items – fabrication, processing, splitting, and more – by performing operations on the data. MIDAS can recover and display the complete history of any item as a simple report.

To ensure the database functions suitably for the organization of research, it was developed alongside a specific experiment to test accident tolerant nuclear fuel cladding under the LWRS Advanced Light Water Reactor Nuclear Fuels Pathway. MIDAS kept track of materials used in this experiment from receipt at the laboratory through all processes, test conduct and, ultimately, post-test analysis. By the end of this process, the database proved to be right tool for this program. The database software will help LWRS more efficiently conduct research experiments, from simple characterization tests to in-reactor experiments. Furthermore, MIDAS is a universal tool that any other research team could use to organize their material inventory.

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## **1. INTRODUCTION**

Nuclear power accounts for about 20 percent of electrical power generation in the United States. As demand for electrical energy grows, advancing the long-term reliability and productivity of existing nuclear reactors is an economical way to meet energy needs. The Light Water Reactor Sustainability (LWRS) Program aims to extend nuclear power plant operating life in the U.S. with multiple research pathways in order to address this goal.<sup>1</sup> This project is part of the Advanced Light Water Reactor Nuclear Fuels Pathway within the LWRS program, which seeks to improve knowledge about nuclear fuel and cladding performance. With this research, LWRS will develop improved fuel and cladding designs for existing nuclear reactors.

Nuclear fuel performance research – and scientific research in general – involves the purchasing, processing, characterization, and fabrication of many sample materials and fabricated components. LWRS proposed creating the Material Inventory Database Accounting System (MIDAS) as a tracking and reference system for such materials used in its research. During development, the database software must demonstrate its value by tracking items used in an experiment under LWRS. MIDAS should ensure traceability of all items used in research, and streamline organization of the program's research inventory.

## **2. INITIAL DATABASE DESIGN**

MIDAS is a Microsoft Access database with supporting code written in Visual Basic for Applications (VBA). Individual parts are listed as rows, known as records, and information about each part is listed in columns, known as fields. Microsoft Access is a better organizational tool than Microsoft Excel for this kind of information for a few reasons. Access has built-in cross-table reference functionality, so it is easy to keep supporting information in separate tables, referencing them when necessary. Access also supports attachments, so documents such as



material certification and analysis reports can be directly referenced in the database. Most importantly, VBA code allows for automation of repetitive database management tasks.

All items tracked by MIDAS start in the Raw Materials table. It contains important information about the material such as serial and lot numbers, the supplier, date received, as well as a description of the material. This is intended to be just an organizational tool for material procurement, listing items as they are purchased (Figure 1). Before any actions are performed on these materials, they must be imported into the Material Inventory table, which is the heart of the database. This table lists descriptive information about items, such as size, quality level, processing performed, etc. (Figure 2). These tables reference supporting information in other tables, such as personnel contact information, storage locations, statements of work, etc.

ID	Lot Number	Serial Number	Description	Material Type	Supplier
1	Various 2202000x	2202000x		HI-NICALON Type S	PSI
2	482220	22020001	Spool; <150 m	HI-NICALON Type S	
3	482220	22020003	Spool	HI-NICALON Type S	
4	491237	22020004	Spool; <150m	HI-NICALON Type S	
5	496223	23010303	Spool; 550 m	HI-NICALON Type S	
6	491237	22090105	Spool; 550 m	HI-NICALON Type S	
7	491238	22090106	Spool; 550 m	HI-NICALON Type S	
8	496223	23010301	Spool; 550 m	HI-NICALON Type S	
9	496223	23010302	Spool; 550 m	HI-NICALON Type S	
10	491237	22090104	Spool; 550 m	HI-NICALON Type S	

Figure 1: An excerpt from the raw materials table

ID	LWRS ID	Date	Type	Raw Source	Description	weight / length
376	LWRS-0071	5/20/2013	Consumed	11-135	Watlow resistance heater	
377	LWRS-0072	5/20/2013	Partly Consumed	W58H71 53-3	Zr4 Tube; 12' Length	
378	LWRS-0072-C01	5/20/2013	Consumed	W58H71 53-3	2' tube, SiC 11	2'
379	LWRS-0072-C02	5/20/2013	Consumed	W58H71 53-3	2' tube, SiC 10	2'
380	LWRS-0072-C03	5/20/2013	Consumed	W58H71 53-3	2' tube, SiC 12	2'
381	LWRS-0073	5/20/2013	Consumed	EC-14	End Caps	
382	LWRS-0074	5/20/2013	Consumed	10-480	SiC, 2ply 7 cycle	6"
383	LWRS-0075	5/20/2013	Consumed	10-480	SiC, 1ply 7 cycle	6"
384	LWRS-0069-P	5/20/2013	Consumed	11-135	Modified heater	
385	LWRS-0070-P	5/20/2013	Consumed	11-135	Modified heater	
386	LWRS-0071-P	5/20/2013	Consumed	11-135	Modified heater	

Figure 2: An excerpt from the material inventory table

## 2.1 The ID System

As items undergo changes during research, these changes should be reflected in the database. Database management is time consuming, so MIDAS has a set of VBA functions to perform these changes with minimal user input. MIDAS generates a unique ID for each item imported to the Material Inventory table. When executed, the VBA functions emulate actions taken on a given tracked item – fabrication, processing, cutting, and more – by creating a new record with a modified ID based on the original item ID. Rather than modify the existing record, these functions create a new record in order to maintain the complete history of tracked items. This new ID is marked with a suffix to indicate what led to its generation (Table 1). This system allows the user to understand the history of an item just by looking at its ID; MIDAS also relies on these IDs to determine how it should alter records when its functions are called.

Table 1: Item ID suffixes

Action	Description	Suffix
Cut	A material is divided into pieces	-Cxx
Process	A process is applied to a material, changing it physically	-P
Fabricate	Items are combined together to create a new assembly	-F
Recover	A fabricated item is disassembled, yielding its components	-R

Take an example item which is imported to the Material Inventory table with the ID “Item-0015”. This part is then cut into three pieces – invoking the cut control yields three new records, the third of which would be “Item-0015-C03”. Information about cut dimensions is stored in a separate field. If this item is then processed, another record is created called “Item-0015-C03-P”. The specific type of process is not specified in the ID, but in a separate field. While records and their IDs can be changed manually, it is better to let the VBA code handle the ID system to ensure consistency and code functionality.



## 2.2 The User Interface

Each table in Microsoft Access has a corresponding window where the user can view or change information for one record at a time. Most of the time spent using MIDAS will be in the Material Inventory window, which displays part information and allows the user to call any of the built-in functions available (Figure 3). Cutting and processing materials is simple, as shown in Figure 4 on the next page. The program asks for some information in a new window, then creates new records and populates them automatically. Fabricating and disassembling materials is more complicated and will be explained in more detail.

**Material Inventory**

**Current Record**

LWRS ID:	LWRS-0074-F	Work Package:	N/A
Date:	5/20/2013	Raw Source:	
Type:	Consumed	Quality Level:	N/A
Description:	SiC-clad internally heated assembly SiC11	Source LWRS ID:	LWRS-0069-P;LWRS-0072-C01;LWRS-0074
weight / length:		Daughters:	LWRS-0069-P-R;LWRS-0072-C01-R;LWRS-
Comments:	2ply SiC	ProcessType:	
		Current Location:	BCTC Bay-4
		Attachments:	
		Certification:	
		Analysis:	
		Green Tag:	

**Item Controls**

Cut      Split      Process      History

**General Controls**

Import      Fabricate      Return

Figure 3: The Material Inventory window

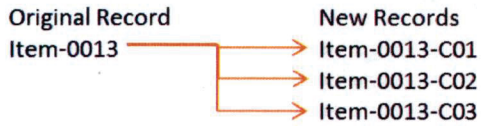
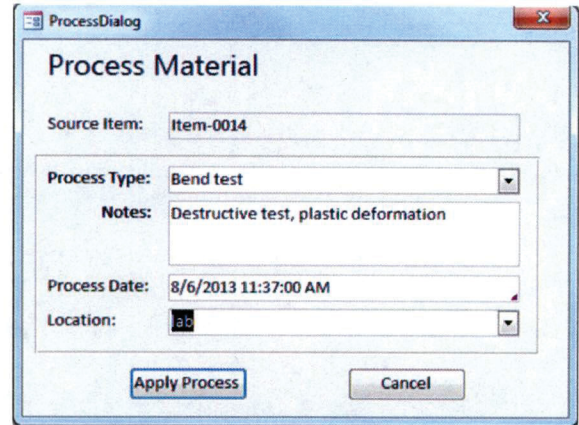
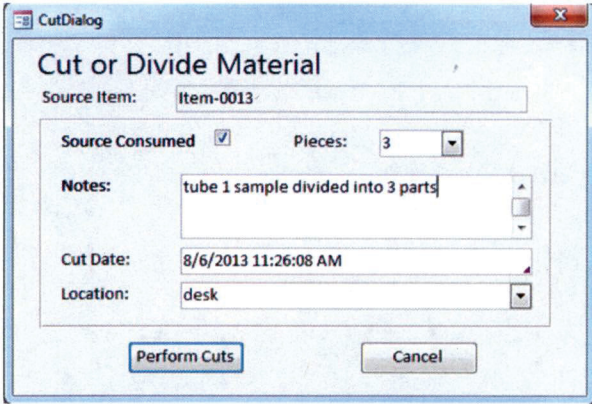


Figure 4: Cutting and processing material

The Fabricate command is used when multiple items are used to assemble a new material. Any number of items can be selected for this process (Figure 5). In this example, a new record will be created with the name “LWRS-0078-F”. This single ID cannot reflect every single part used in the fabrication of the item, so the list of these parts is stored in a separate field.

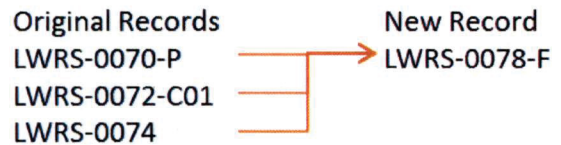
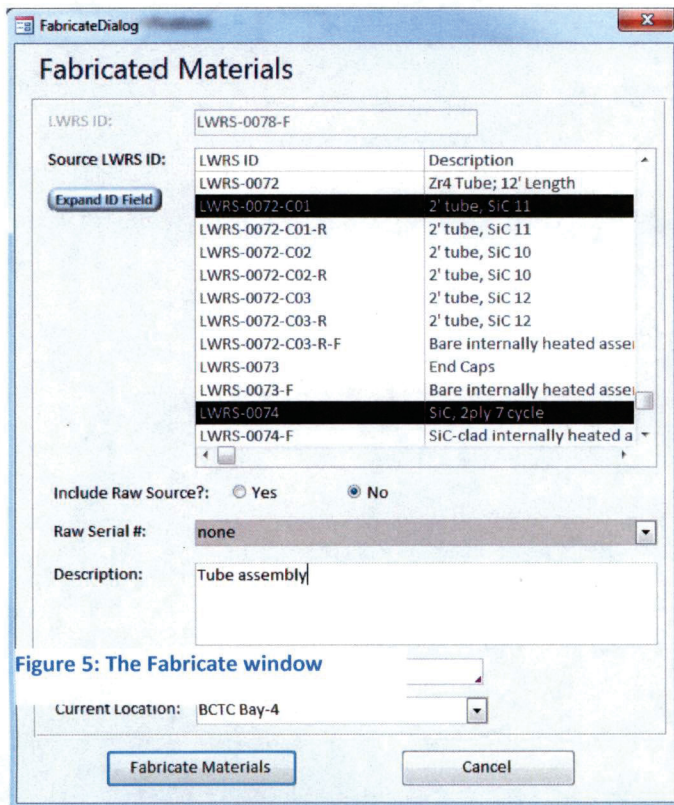


Figure 5: The Fabricate window

The database software was initially developed according to this overall design, but without the ability to disassemble



fabricated items, and lacking information and functionality to make viewing and understanding the history of a part a simple process. Testing the ability of the database to track materials used in an actual experiment revealed what features the database lacked and what changes needed to be made. This methodology helps ensure the database is suitable for tracking scientific research.

### **3. TESTING AND DEVELOPING THE DATABASE**

#### **3.1 The Experiment**

MIDAS was tested by tracking materials through the fabrication process for a specific experiment. The LWRS Advanced Light Water Reactor Nuclear Fuels Pathway is investigating the use of Silicon-Carbide Ceramic Matrix Composites (SiC-CMC) as a more accident-tolerant nuclear fuel cladding material. The potential advantages of SiC cladding include increased corrosion resistance and reduced hydrogen generation during accident conditions when the cladding is exposed to steam.<sup>2</sup> Potential cladding material such as SiC-CMC must go through relatively low-cost, nonnuclear mechanical, thermal, and chemical characterization tests; only the best technologies selected by these tests will be used for in-reactor tests.<sup>3</sup> This experiment investigates how Zircaloy-4 cladding tubes surrounded by a SiC-CMC sleeve behave under thermal stress. To simulate the heat generated by nuclear fission, electrical resistance heaters must be installed inside these cladding tubes. The assemblies will be tested in a hot water corrosion flow test loop – to simulate reactor water flow conditions – located at one of the INL facilities. The database would need to keep track of these throughout the sample preparation process: from the point of receipt at the laboratory through cutting, fabrication, test conduct and, ultimately, post-test analysis.

#### **3.2 The Assembly Process**

Test design specifications determined how as-received parts would need to be modified for the assembly of internally heated cladding rods (Figure 6). First, the Zr-4 is cut to an appropriate

size and the appropriate SiC-CMC sleeve is attached to the outside. The stock resistance heaters come with a metal sheath which must be removed. The ceramic coating over the resistor coils in the heater is then removed, and the heater is recast with a new ceramic layer of appropriate diameter. This heater is then coated with a lubricant and placed inside the cladding tube. This entire heater modification process is considered one process in the database.

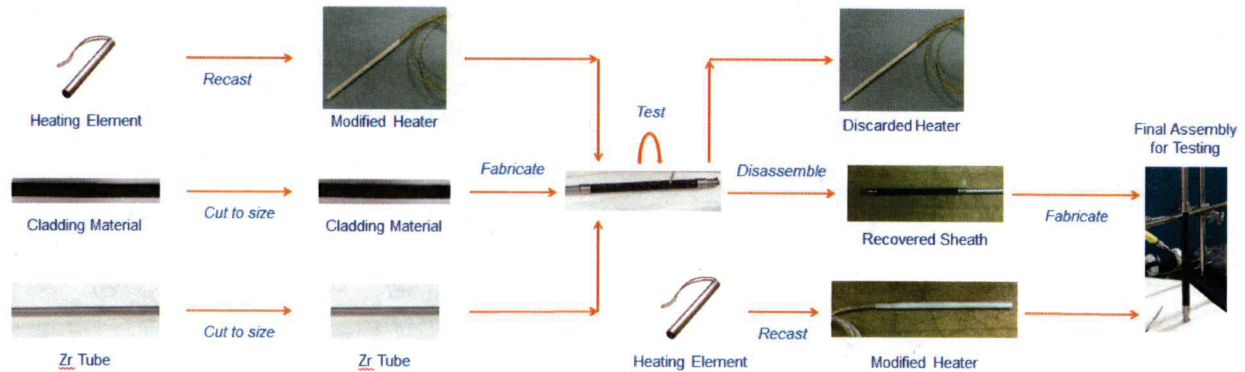


Figure 6: The internally-heated fuel cladding assembly process

Initial testing of these assemblies revealed an electrical issue. The internal thermocouples of the heaters were contacting the metal sheaths, which created significant error in temperature measurements. Even when isolated, the Zr-4 sheaths acted like antennae, altering the thermocouple voltage reading. The cladding assemblies had to be disassembled to address this issue. The Zr-4 and SiC-CMC cladding was saved, and the old heaters set aside. New heaters were recast with the same process, but with the thermocouple slightly adjusted. The total assemblies were fabricated again, using the same cladding tubes, but with the newly recast heaters.

### 3.3 Modifications to MIDAS

The sample preparation process for this experiment revealed the need for new features in MIDAS. Fabricated parts like the first internally heated cladding assembly might need to be taken apart, and their components recovered. In cases like this, using the cut control does not



make intuitive sense, as one single material is not being divided. The database required a function that could emulate the disassembly of a fabricated material, so the split function was developed. This takes the list of all materials that were combined into a fabricated part, and creates new records for these pieces, which are considered “recovered” (Figure 7). This function tracked the disassembly of the first internally heated cladding rods. Their recovered parts, with the heater replaced, could then be fabricated into new internally heated cladding tubes.

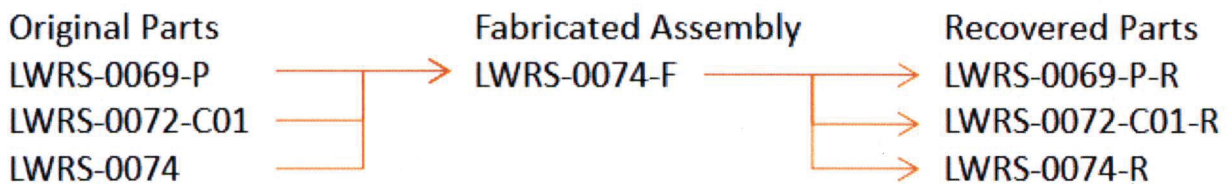
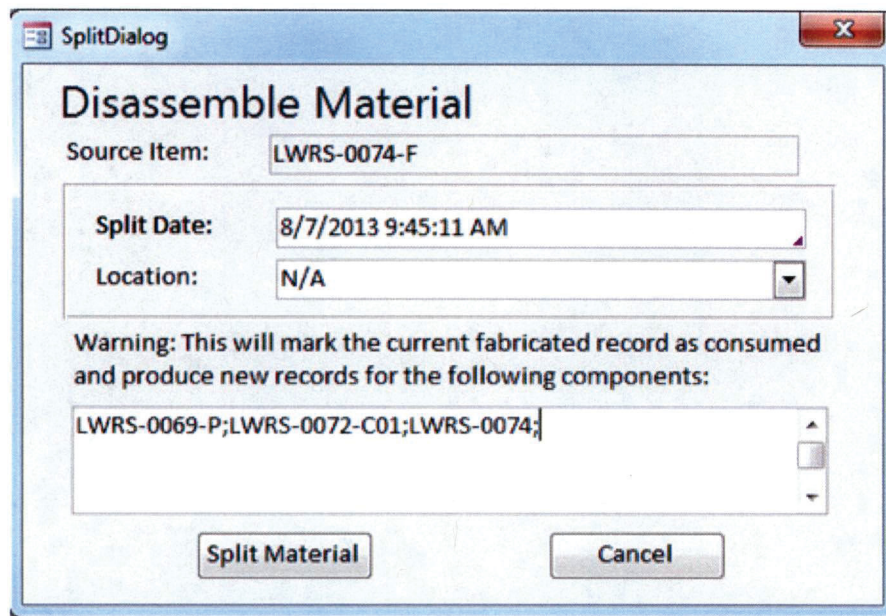


Figure 7: Disassembling a fabricated part

Although the ID system provides a way to manually trace the history of a part, this can still be time consuming. The sample assembly process for the internally heated cladding tube experiment revealed the potential complexity of item histories. Tracing items back through processing or cutting is simple, but fabrication and disassembly are much more difficult to

follow. The part history function addresses this issue – it recovers an item’s complete history and displays it as an Access report (Figure 8).

This function starts with the ID of the item to be investigated. If the part is cut or processed, it simply finds the record for the item’s previous state by removing the suffix. If an item has been fabricated, it checks the source item field for the list of all its components, and follows their individual histories by calling itself for each of those components. The function will also include the fabricated item that a recovered part came from. In Figure 8, the source field lists the components of a fabricated assembly, and the fabricated item that yielded a given recovered item upon disassembly. Furthermore, the daughter field contains the list of parts that result from applying a function to a given part.

Part History						
LWRS ID	Date	Type	Description	Comments	Source LWRS ID	Daughter Material
LWRS-0072	5/20/2013	Partly Consum	Zr4 Tube; 12' Length			LWRS-0072-C01;LWRS-0072-C02;LWRS-0072-C03;
LWRS-0072-C01	5/20/2013	Consumed	2' tube, SiC 11			LWRS-0074-F;
LWRS-0074	5/20/2013	Consumed	SiC, 2ply 7 cycle			LWRS-0074-F;
LWRS-0074-F	5/20/2013	Fabricated	SiC-clad internally heated assembly SiC11	2ply SiC	LWRS-0069-P;LWRS-0072-C01;LWRS-0074;	LWRS-0069-P-R;LWRS-0072-C01-R;LWRS-0074-R;
LWRS-0076	6/24/2013	Consumed	Watlow resistance heater			LWRS-0076-P;
LWRS-0076-P	7/1/2013	Consumed	Modified heater			LWRS-0076-P-F;
LWRS-0072-C01-R	7/15/2013	Consumed	2' tube, SiC 11		LWRS-0074-F	LWRS-0076-P-F;
LWRS-0074-R	7/15/2013	Consumed	SiC, 2ply 7 cycle		LWRS-0074-F	LWRS-0076-P-F;
LWRS-0076-P-F	7/17/2013	Fabricated	SiC-clad internally heated assembly SiC11	2ply SiC	LWRS-0072-C01-R;LWRS-0074-R;LWRS-0076-P;	

Figure 8: The history of a fabricated part

## 4. CONCLUSION

By the end of the cladding tube assembly process, MIDAS proved to be a suitable tool for tracking materials used in scientific research. This experiment revealed essential features that needed to be added to the database software. The ability to cut, process, fabricate, or disassemble items should allow users to represent any changes made to materials. Most importantly, MIDAS

has the ability to identify any part's parents and children, as well as the complete history of the part. This ensures traceability of items used in research, makes it easy to verify the testing history of parts, and more. In the future, some additional functions could be made to further simplify database management. The need for such functions might become apparent as new experiments are conducted.

As the amount of data being tracked grows, the database might be converted to an SQL server. Compared to a simple Access file, server design has increased security and transaction logging – this is good for a project-wide file which multiple people may need to view and modify. For now, the streamlined material inventory organization will help LWRS more efficiently conduct research experiments, from simple characterization tests to in-reactor experiments. Since material states and the actions that can be applied to materials are universal in nature, MIDAS is suitable for tracking any kind of research – a generic version of the database is available for any research team to use.

## **5. ACKNOWLEDGEMENTS**

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  - Shannon M. Bragg-Sitton
  - Kristine E. Barrett
  - Susan M. Case
- Creation of first incarnation of database
  - Steven R. Bryan



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