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Radiation Embrittlement Archive Project: Web Application User's Guide

Prepared by
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Radiation Embrittlement Archive Project: User's Guide

H. B. Klasky, P. T. Williams and B. R. Bass

ABSTRACT

The Radiation Embrittlement Archive Project (REAP), which is being conducted by the Probabilistic Integrity Safety Assessment (PISA) Program at Oak Ridge National Laboratory under funding from the U.S. Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research, aims to provide an archival source of information about the effect of neutron radiation on the properties of reactor pressure vessel (RPV) steels. Specifically, this project is an effort to create an Internet-accessible RPV steel embrittlement database.

The project's website, https://reap.ornl.gov, provides information in two forms: (1) a document archive with surveillance capsule(s) reports and related technical reports, in PDF format, for the 104 commercial nuclear power plants (NPPs) in the United States, with similar reports from other countries; and (2) a relational database archive with detailed information extracted from the reports.

The REAP project focuses on data collected from surveillance capsule programs for light-water moderated, nuclear power reactor vessels operated in the United States. Additionally, REAP contains data from surveillance programs conducted in other countries. REAP is presently being extended to focus on embrittlement data analysis, as well. This document guides readers on the use of the REAP database web application.

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ABBREVIATIONS

ASM	Analysis Service Module
BWR	boiling water reactor
EFPY	effective full-power years
EOL	end-of-licensing
ORNL	Oak Ridge National Laboratory
NRC	United States Nuclear Regulatory Commission
REAP	Radiation Embrittlement Archive Project
PWR	pressurized water reactor
RPV	reactor pressure vessel

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1. Introduction

1.1 Background

From the earliest days of commercial nuclear power generation, it was recognized that over time, neutron irradiation hardens and embrittles the steel from which a reactor pressure vessel (RPV) is constructed. Eventually, embrittlement may degrade an RPV's mechanical properties to a point at which the RPV's steel becomes unacceptable from a regulatory perspective, requiring nuclear power plant operators either to make a significant economic investment in replacing or annealing the RPV, or to shut it down. Current regulatory practice for RPV lifetime prediction relies primarily on information gained from Charpy impact testing, tensile testing, and mechanical testing of other small specimens as part of in-reactor surveillance programs. However, this information is limited to the following: a) materials currently in use (by definition, surveillance information is restricted to the types of materials that are in service today), and b) neutron exposures not greatly exceeding the licensed lifetime. Given that the initial 40-year design life of RPVs are now routinely extended to 60 years, the above-stated limitations can produce real restrictions on the operational lifetimes of the nuclear plants.

Neutron embrittlement of RPV steels is known to be a complex phenomenon. The magnitude of embrittlement depends upon the interplay of a number of environmental variables (e.g., fluence, flux, temperature) and compositional ones (that is, the proportions of copper, nickel, manganese, phosphorus, silicon, etc., in the steel). There are considerable amounts of data regarding the effects of neutron embrittlement on both the mechanical properties (e.g., strength, hardness, impact energy, fracture toughness) and the microstructural properties of RPV steels. However, because working on irradiated materials is an expensive undertaking, individual datasets tend to be limited, rarely including complete information on both mechanical and microstructural properties for the same material exposed in both test and power reactors. Both of these factors (i.e., the complexity of the phenomena that create neutron irradiation damage and the lack of comprehensive datasets to quantify its effects) have inhibited progress toward the development and validation of a comprehensive, physically based model sufficiently robust to enable confident prediction of future embrittlement trends.

1.2 Radiation Embrittlement Archive Project at ORNL

The NRC commissioned the PISA Program at ORNL to develop a web-based database for US surveillance reports and other data related to embrittlement. With that commission came a proposal that the new database should (as a research tool, not a licensing tool) have the following characteristics:

- Web-based
- able to trace the origin of any information contained in the database
- able to maintain a log of changes of values
- able to reflect and describe what individual data values mean (e.g., how the irradiation temperature is measured)
- able to provide the capability to store documents that show legal permission to make the data and document public
- able to produce information that the NRC can use to post on the data.gov website
- able to define the columns of each table
- able to describe the process of entering data from new citations
- capable of downloading citation data in MS Excel format
- include a feedback form
- able to provide data analysis tools
- searchable

The REAP project provides an important tool for RPV integrity assessment within the NRC regulatory environment, especially as it will constitute a crucial research tool for development of future embrittlement predictive models for light-water-reactor (LWR) RPVs. In addition, the REAP project will assemble disparate data, both un-irradiated and irradiated, from surveillance reports that have been submitted to NRC by the U.S.'s 104 commercial nuclear power plants. Finally, the project will contribute to Reg. Guide 1.99 Rev. 2 (1988) and 10 CFR 50 App. H (2005).

The *Probabilistic Pressure Boundary Integrity Safety Assessment (PISA) Program*, sponsored by the U. S. Nuclear Regulatory Commission (USNRC), is the premier research group responsible for assessing structural integrity of reactor pressure vessels (RPVs) utilized by the fleet of 104 commercial nuclear power plants (NPPs) currently providing 20 percent of electricity production in the U. S. The RPV of a NPP provides secure containment for nuclear fuel undergoing fission in an elevated pressure/temperature environment; thus, integrity of the RPV is critical to the public safety and to the well-being of the U. S. electrical grid.

During FY 2013, the PISA Program completed the initial release of the *Reactor Embrittlement Archive Project (REAP)*; funding was from the USNRC Office of Research. For the first time at a single location in the U. S., *REAP* provides the nuclear technology community with a comprehensive, internet-accessible embrittlement database/analytical tool for documenting the effects of neutron irradiation on RPV steels utilized in the U. S. fleet of NPPs. The importance of that information derives from the fact that neutron embrittlement may degrade an RPV's mechanical properties sufficiently to produce real restrictions on the operational lifetime of the NPP (which is currently limited to a total of 60 years). Specific capabilities of *REAP* include (1) a document archive with surveillance capsule reports[1] for commercial NPPs, with similar reports from other countries; (2) a relational database archive with detailed materials data and information extracted from those reports; and, (3) an ***Analysis Service Module*** (ASM) that provides analytical tools for researchers to interpret the embrittlement data. Currently, the REAP archive web application contains data from the U. S., Taiwan, Switzerland, Sweden, Spain, Mexico, South Korea and Brazil. The website for REAP is found at https://reap.ornl.gov; Figure 2 shows the Home Page for that site and Figure 33 an example tool (mechanical test) from the ASM.

It is widely recognized that *REAP* provides an important tool for RPV integrity assessment within the USNRC regulatory environment, especially as it will constitute a crucial research resource for future development of truly *predictive* embrittlement models for legacy RPV steels. In addition, the project is contributing to development of (1) future USNRC regulatory guides and (2) regulations governing operations of NPPs that become part of the U. S. Code of Federal Regulations.

The success and utility of *REAP* is validated by the world-wide group of organizations that are registered users of the website (as of September 2013): Areva (international NPP manufacturer), Babcock & Wilcox (nuclear industry), Electricite de France (French national utility), Electric Power Research Institute (U. S. nuclear industry), European Commission's Institute for Energy and Transport, Exelon Corporation (U.S. nuclear utility), Imperial College of London, Korea Institute of Nuclear Safety (national regulator), National Institute of Standards and Technology (U.S. government technology), Rolls Royce (U.K. nuclear industry), USNRC, ORNL, South California Edison (U.S. utility), Structural Integrity Associates Inc.

[1] Surveillance capsule reports provide material properties data generated from testing of the many specimens contained in large surveillance capsules that are stored in the RPV of an NPP; up to six capsules are extracted over the lifetime of the NPP. Those capsule specimens are exposed to levels of neutron irradiation similar to the RPV steel wall and thus serve as "surrogates" for irradiated RPV material. Test results are published in surveillance capsule reports that serve as source documents for the embrittlement data entered into the REAP archive; legacy capsule reports extending as far back as the 1960s were used to populate REAP.

(U.S. nuclear industry), Swedish Radiation Safety Authority (national regulator), Transwer Enterprises, Inc., and Westinghouse (U.S. nuclear industry).

2. REAP Web Site

The URL for the REAP web site is https://reap.ornl.gov.

In the terminology of the Internet, REAP is a public-facing web-site, but it is not anonymous access. You'll need to be registered first in order to use the web-site.

2.1 Gaining Access

This section describes how to gain access to the REAP web site and how to use each of the functions implemented on it.

2.1.1 How to create an ORNL-XCAMS account to access the REAP Database Web Application

The following steps describe how to create an ORNL-XCAMS account to access the REAP Database Web Application:

1. **Create** an XCAMS account at: https://xcams.ornl.gov/xcams/ There, you will see the web page in Figure 1 Create ORNL XCAMS account. Select the link: *"I need an account*" and follow the instructions on the screen.

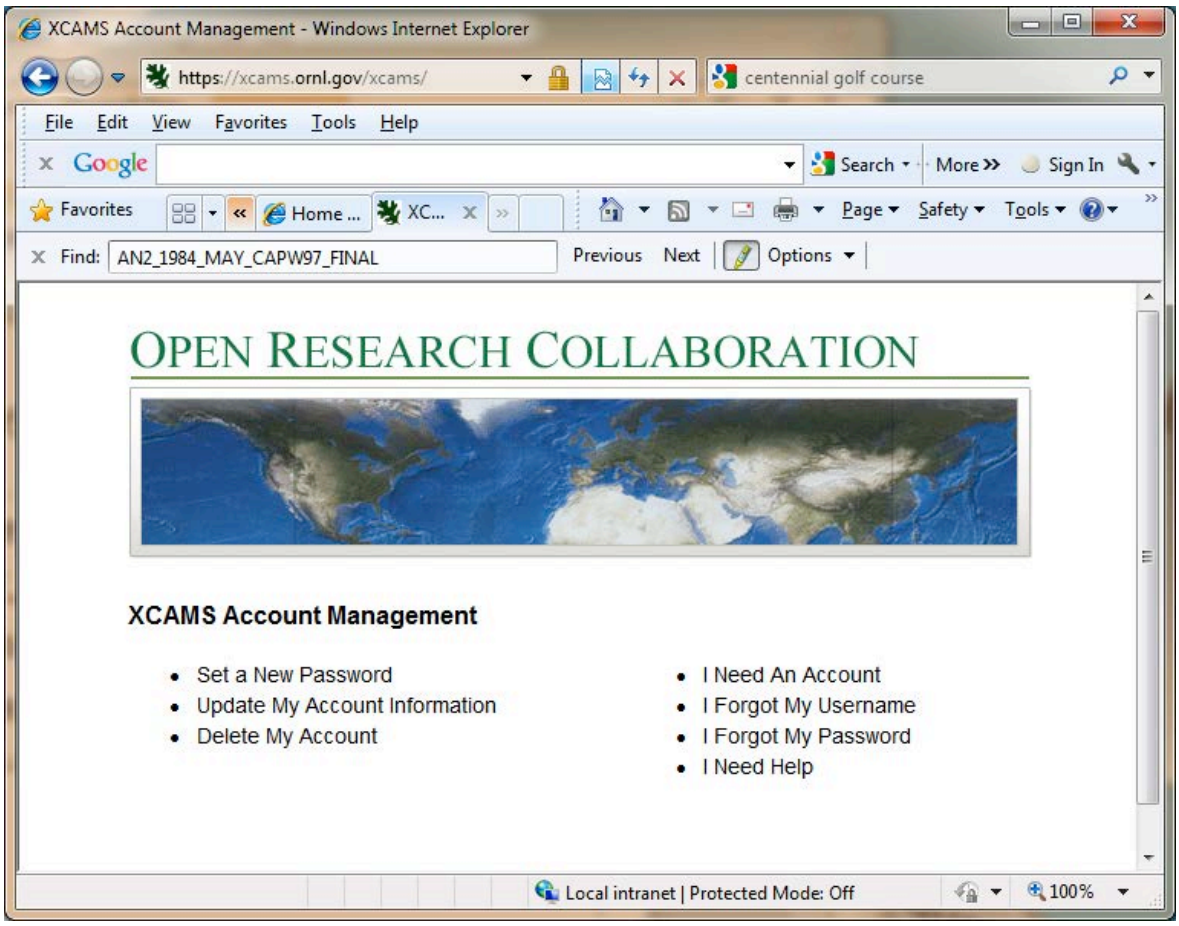


Figure 1 Create ORNL XCAMS account.

2. **Save** your **user name, PIN and password on a safe place**, so you can retrieve it later, when needed.

3. **Request** access to the REAP Database Web Application, by sending an email with your new *User-Name* to Hilda Klasky at klaskyhb@ornl.gov.

4. **Receive** email notification from Hilda Klasky at ORNL when your account has been granted access to the REAP Database Web Application.

5. **Access** the REAP Database Web Application at https://reap.ornl.gov/. When prompted, type in the user name the suffix: '**extranet\'** followed by your user name. Then, type in your password.

6. If you forget your XCAMS user name, password or pin number, you can retrieve this information at: https://xcams.ornl.gov/xcams/ or send an email to: helpline@ornl.gov. To obtain a faster response; you can also contact the ORNL helpline at: 865.241.6765.

2.2 Logging onto web site

To access the REAP Database Web Application open a browser window at: https://reap.ornl.gov/.
When prompted:

A) type in the user name the suffix: '**extranet\'** followed by your user name.
B) Then, type in your password.

2.2.1 Preferred browsers

We have tested the production release REAP Changeset (i.e. revision number): 17535 on the following browsers:

- Microsoft Internet Explorer 9 and newer
- Firefox 20.0 and newer
- Google Chrome 26.0.1410.65 and newer

Other browsers and/or previous versions of the above have not been tested, thus are not recommended for use of the REAP Changeset: 17535 or newer builds.

2.3 Navigating the Home Page

After login in, users can see the REAP home page.

This project, conducted by the Oak Ridge National Laboratory (ORNL) under funding from the United States Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research, aims to provide an archival source of information concerning the effects of neutron radiation on the properties of reactor pressure vessel steels. This website provides access to information in two forms:

1. A Document Archive, which provides access to files in PDF format of original source documents (e.g., technical reports), and
2. A Data Archive, which provides access, in a relational database format, to information extracted from the document archive.

This initial release of REAP focuses on data collected as part of surveillance programs for light-water, moderated, nuclear power reactor vessels operated in the United States. This includes data on Charpy V-notch energy, tensile properties, composition, exposure temperature, flux, and fluence. Additionally, REAP contains some data from surveillance programs conducted in other countries. Depending on the availability and accessibility of data, REAP may be expanded to include the following:

- Data from accelerated irradiations performed in test reactors,
- Fracture toughness data,
- Hardness data, and/or
- Microstructural data.

The document archive and the data archive can both be accessed via the Search/Download Single Citations & Data link under the Search & Analyze Data section to the left. Here, copies of individual documents can be downloaded from the document archive, and the data from each document can be downloaded into a separate Excel workbook.

The Analyze Data section is currently under construction. When completed users, will be able to access data from multiple documents at the same time. Additionally, by using the advanced analysis methods, users will be able to perform calculations using data (e.g., Charpy transition temperatures can be calculated from Charpy V-notch energy vs. temperature transition curves).

Please Read Cautionary Notice!
Caution: REAP is still under development and the information in the data archive is still being checked. This version is provided to users for review and comment. Users are cautioned to not use the data in the data archive without first checking its accuracy relative to the information in the document archive. Users assume full responsibility for the use of any information found on this website.

The left navigation panel is the starting point for your searches of the database.

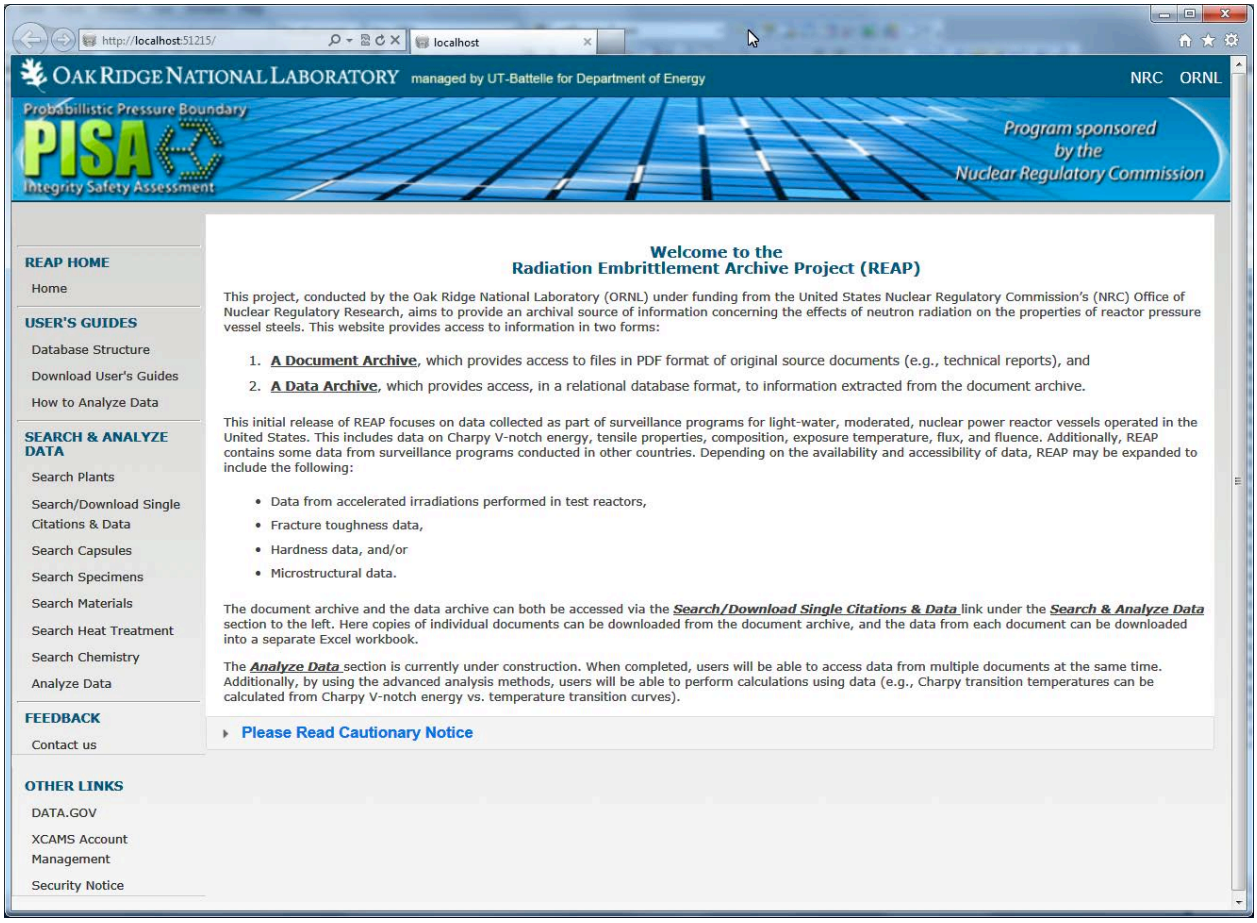


Figure 2 REAP home page

2.4 Providing Feedback

We welcome your feedback! Please select from the subjects below (Figure 3), enter your message, and then press the Send Email button.

Our postal mailing address is Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN, 37831 (USA). Please mark "Attn: Ms. Hilda Klasky." If you're sending mail by carriers other than the U.S. Postal Service, replace the "P.O. Box 2008" with "One Bethel Valley Road."

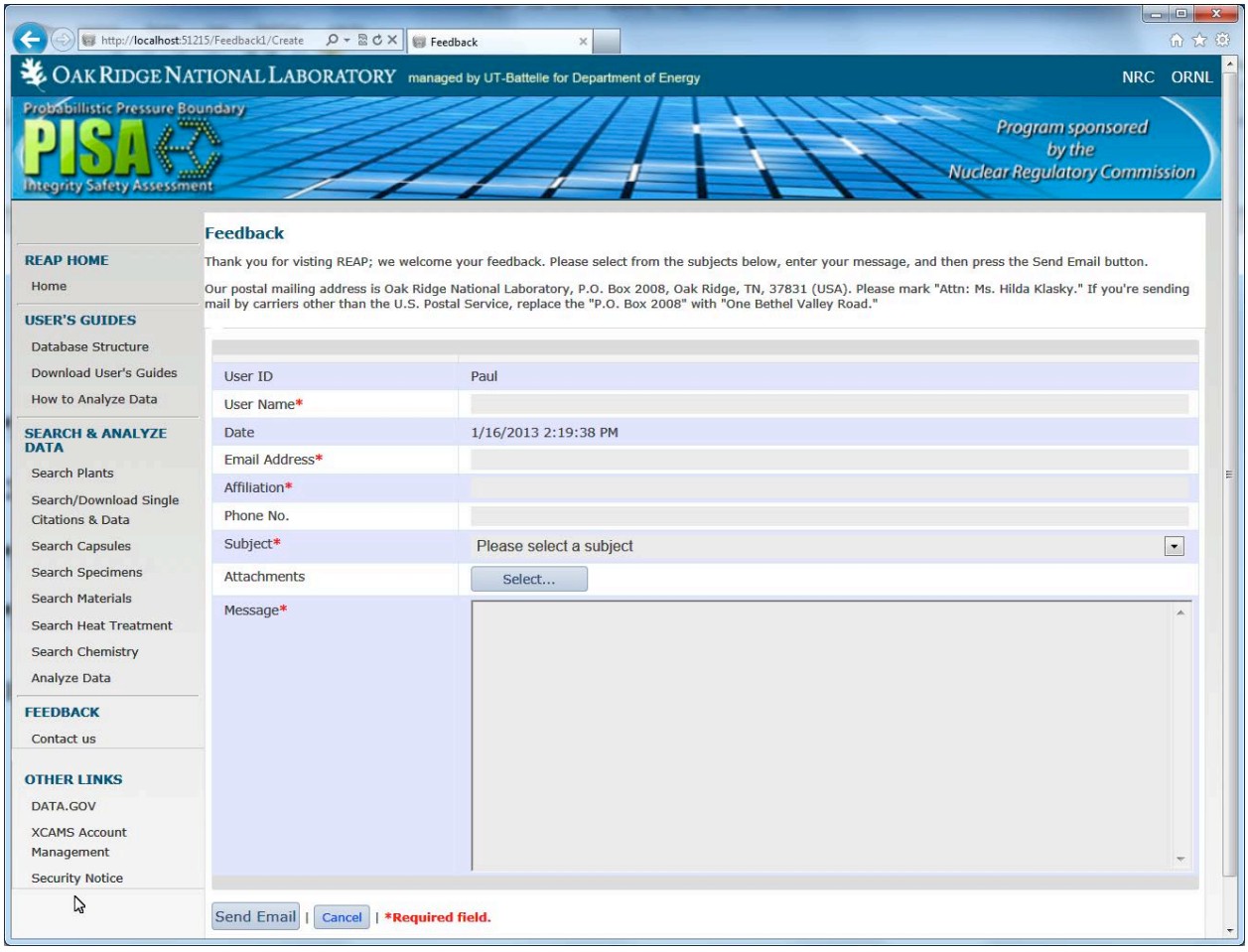


Figure 3 Feedback Form

2.5 Searching the Database for Nuclear Power Plants

The left navigation panel is the starting point for any searches in the REAP database. The left-navigation panel provides users with other methods of accessing information in the REAP database. Searching the Plants data is shown on Figure 4.

The Plant's table contains information from all Nuclear Power Plants in the world, either active, no longer active or in construction. Information contained in this table comes from the original Embrittlement Database Project EDB [2] (predecessor of REAP), the International Atomic Energy Agency (IAEA) 2006 Nuclear Power Reactors in the World [3] and the US NRC NUREG-1350, Volume 22, Information Digest 2010-2011[4].

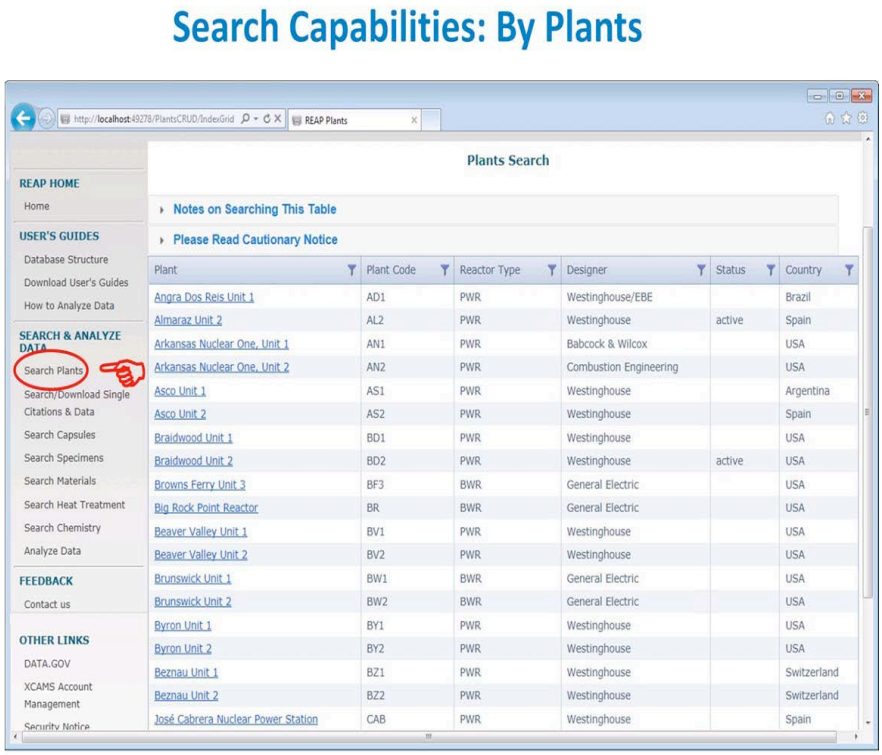


Figure 4 Search By Plants

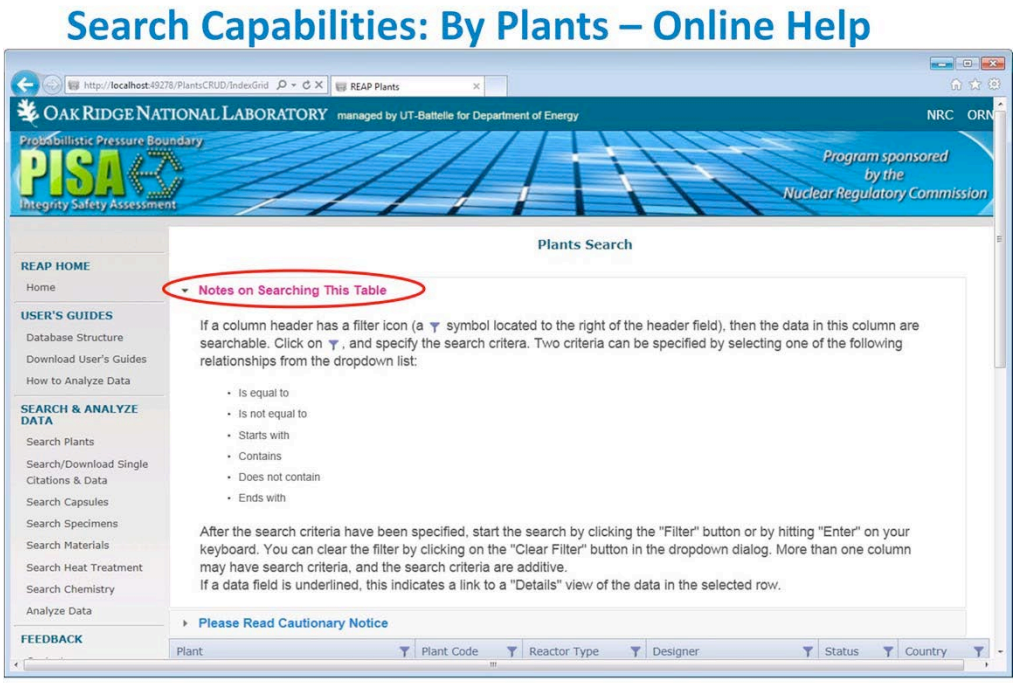


Figure 5 Online Help Features

Figure 5 is an example of some of the online help features that are provided through the REAP web application.

When licking on the “Notes on Searching This Table” bar, the bar opens up and details on how to use the individual search filters in the Plants table are provided. Users can toggle off or collapse the online help page just by clicking again on the bar.

Search Capabilities: By Plants – refining the search

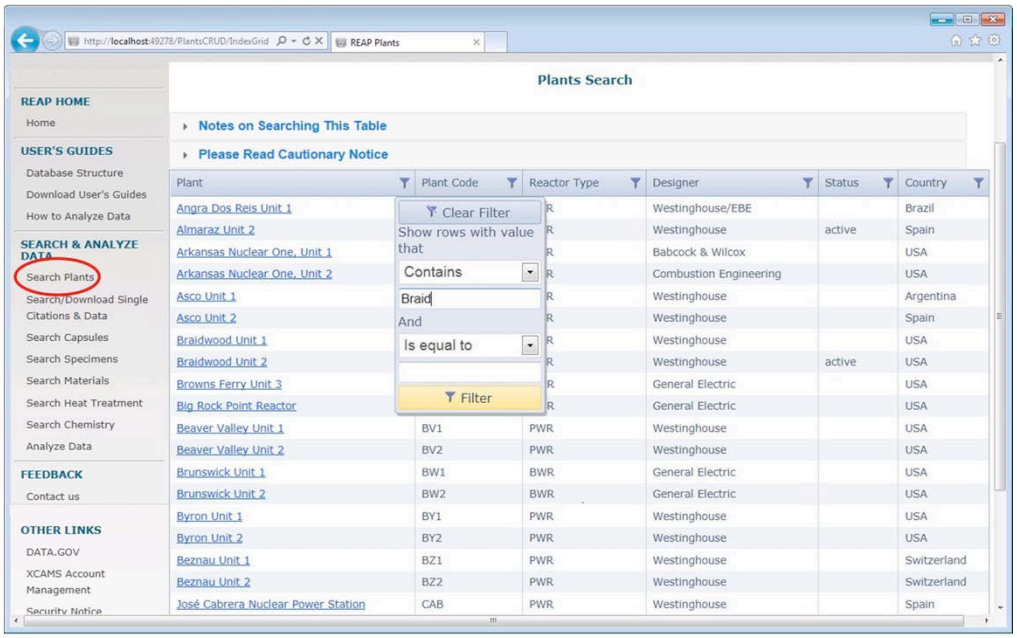


Figure 6 Refining The Search

The little filter symbol on the right side of the column headers of the Plants Table indicates that users can set up a compound search criterion for that column. Figure 6 shows information on the Braidwood plant.

If a column header has a filter icon (a symbol located to the right of the header field), then the data in this column are searchable. Click on the filter icon, and specify the search criteria. Two criteria can be specified by selecting one of the following relationships from the dropdown list:

- Is equal to
- Is not equal to
- Starts with
- Contains
- Does not contain
- Ends with

After the search criteria have been specified, start the search by clicking the "Filter" button or by hitting "Enter" on your keyboard. You can clear the filter by clicking on the "Clear Filter" button in the dropdown dialog.

These search filters are additive and more than one column may have search criteria. Thus, users can set up a filter on the Plant column and then add another search filter for designer or country. The search filters work the same for all REAP tables.

Moreover, note that if a data field is underlined, this indicates a link to a "Details" view of the data in the selected row.

2.6 Searching the Database for Cited Reports

REAP website provides access to information in two forms:

- A Document Archive, which provides access to files in PDF format of original source documents (e.g., technical reports), and
- A Data Archive, which provides access, in a relational database format, to information extracted from the document archive.

This release of REAP focuses on data collected as part of surveillance programs for light-water, moderated, nuclear power reactor vessels operated in the United States. This includes data on Charpy V-notch energy, tensile properties, composition, exposure temperature, flux, and fluence. Additionally, REAP contains some data from surveillance programs conducted in other countries. These reports can be searched by several search criteria as shown in Figure 7.

The document archive and the data archive can both be accessed via the Search/Download Single Citations & Data link under the Search & Analyze Data section to the left. Here copies of individual documents can be downloaded from the document archive, and the data from each document can be downloaded into a separate Excel workbook.

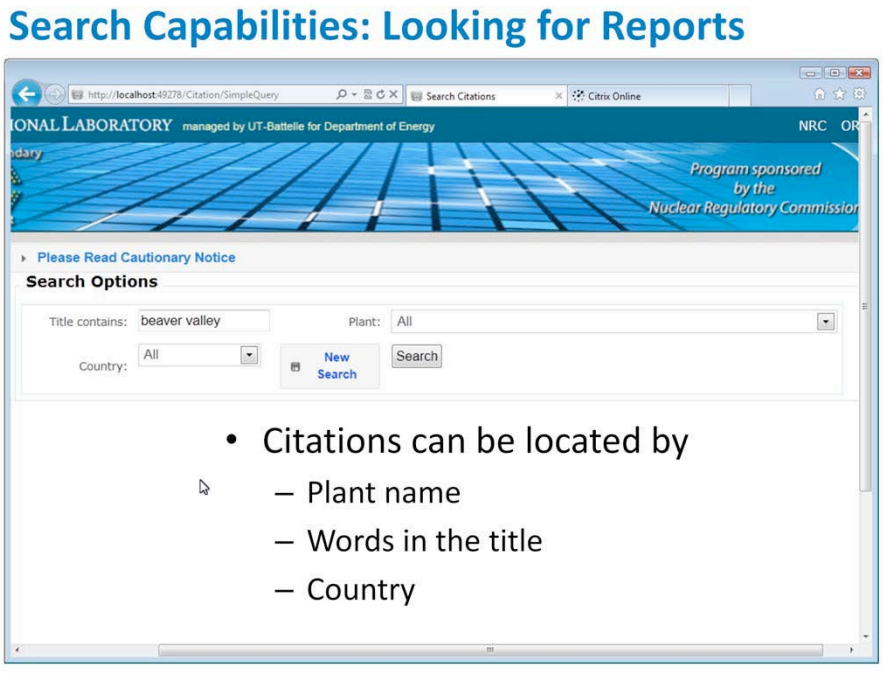


Figure 7 Searching for Reports

Users will be provided with some search options such as words contained in the title or a particular plant or country of interest.

In Figure 8, we are looking for all reports (which are usually referred to as citations in REAP) that have the word beaver valley in the title. So we are looking for reports for the Beaver Valley plant.

Users who would like to work with the data from this report in a spreadsheet form, you can click on the Excel icon in the left-most column to download a Microsoft Excel workbook. To download the data in spreadsheet format, click on the link “Search/Download Single Citations & Data”. See Figure 8 below.

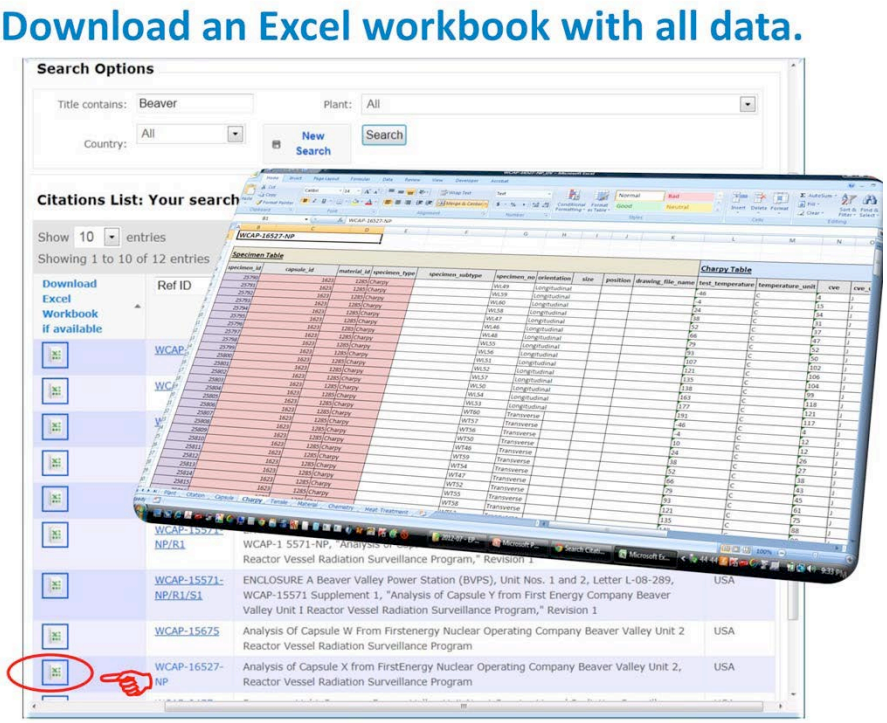


Figure 8 Download Report's Data In Spreadsheet format

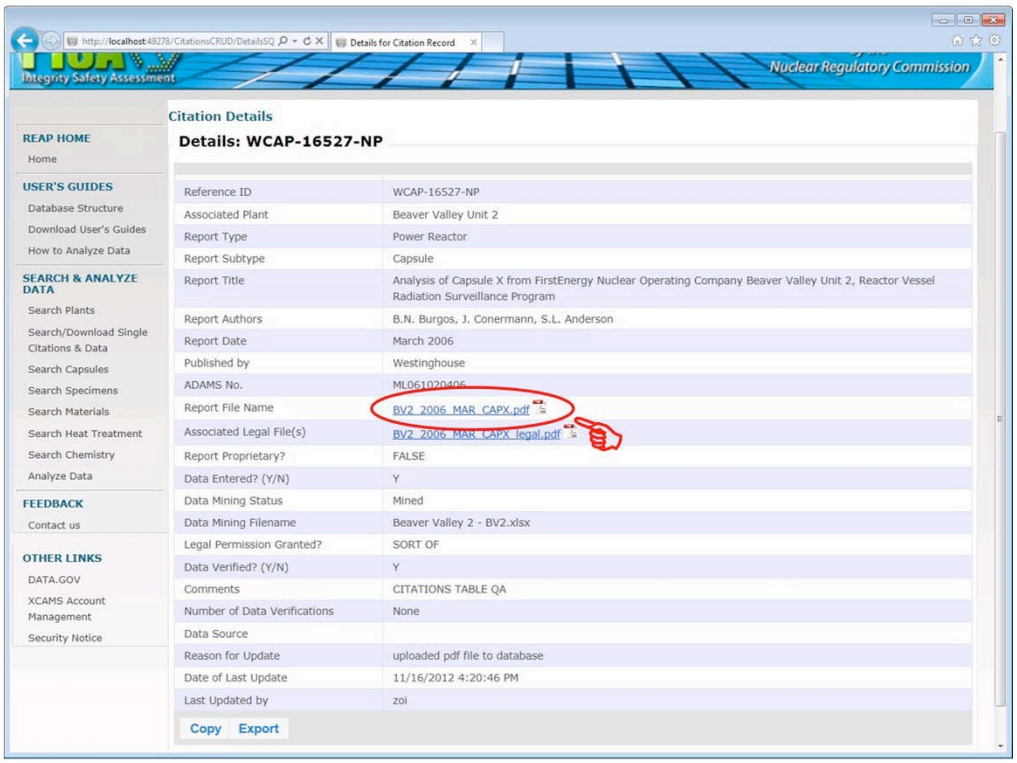


Figure 9 Citation Details

After clicking on Search, we find that there are 12 reports in the REAP database that meet this criterion. As an example, see **Figure 9**. Let's look at the WCAP-16527-NP report. We click on the link WCAP-16527- NP. Clicking on that link takes us to the Details page for this citation. We can see the title of the report, the list of authors, publication date, and who published the report.

Note that in the Citation Details page, Figure 10, there is a link to the stored PDF file that can be conveniently opened in your browser.

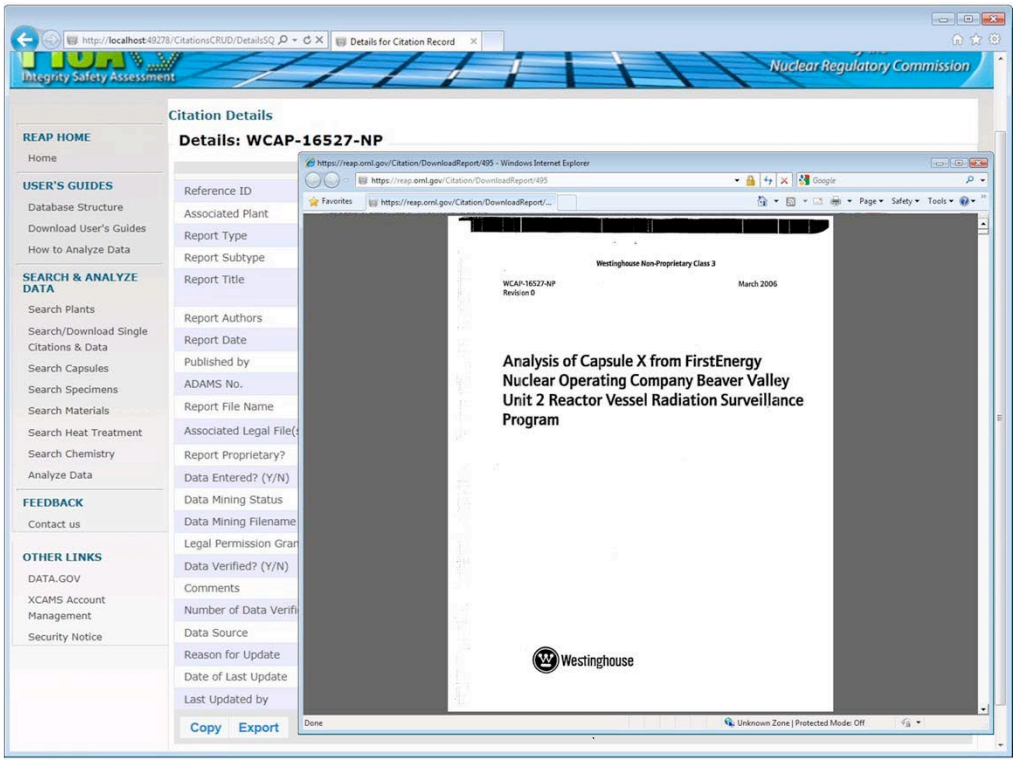


Figure 10 Link To The Report In PDF Format.

Clicking on the link to the PDF file, the system opens a new window containing the report itself where you can either read the report online, or download it to your computer.

2.6.1 Reference ID Formatting

In REAP, a citation's reference id must be a unique character string, typically the internal report number. For example, a report issued by Battelle Columbus Laboratories would have a reference ID starting with the prefix "BMI" (Battelle Memorial Institute) and ending with the unique report number, BMI-0584. A report prepared by Westinghouse Corporation would have a report number starting with "WCAP" and ending with its unique report number; therefore, the corresponding citation's reference id should be, for example, WCAP-10086.

2.6.2 ADMAS Accession Number Formatting:

At the NRC's ADAMS web site http://adams.nrc.gov/wba/ , there are two libraries that can be searched.

1. Public Library: the accession numbers are formatted with an ML prefix, e.g.,ML061020406
2. Public Legacy Library: the accession numbers are formatted without an ML prefix, e.g. 9510230407 or 018480

For the Public Legacy Library, any leading zeroes must be included in the accession number.

2.6.2.1 Notes on Searching for Documents in the NRC ADAMS Database

When searching for documents using the ADAMS accession numbers, under the Content Search or Advanced Search tabs, choose Property: Accession Number, and the Operator field can be set to "is equal to", "is not equal to", "starts with", or "not starts with", The Accession Number prefix conventions cited above must be adhered to.

For example, if you try to search for 061020406 in the Public Library, the search will not return a document; however, if you use ML061020406 in the Public Library, the search will be successful. Also, if you use a number with an ML prefix in the Public Legacy Library, you will not have a successful search. The system does not come back with an error message, just no document. For documents in the Public Legacy Library, accession numbers such as 018480 require the leading zero to be a part of the search to have a successful result.

In REAP, if the report is also in the NRC’s public ADAMS database, then the ADAMS accession number will be given.

2.7 Searching for Surveillance Capsules

Users can also search for individual capsules and you can refine your search using the individual search filters for each column. Select the Search Capsules link in the left navigation panel as shown in Figure 11 Search for Surveillance Capsules

The CAPSULE table records the exposure information for each capsule described in a particular citation. Each citation will contain this information for (a) the current capsule for which the citation is reporting Charpy and tensile data, and (b) for all previous capsules. The data in the capsule table should be recorded for both the current capsule and for all previous capsules. Thus, if the citation being entered is for the 3rd capsule in the series there will be 3 rows in the CAPSULE table for this citation. The reason for entering the information for previous capsules is that sometimes the data (e.g., fluence) is updated in subsequent reports. The exposure parameters entered in the CAPSULE table characterize the capsule. As such, the rows in which the CAPSULE table data appear should not contain any information available in the CHARPY and TENSILE tables. In some reports, specimen-specific fluence values have been reported. There is a column to record this information in both the CHARPY and TENSILE tables. Such specimen-specific data should not be recorded in the CAPSULE table.

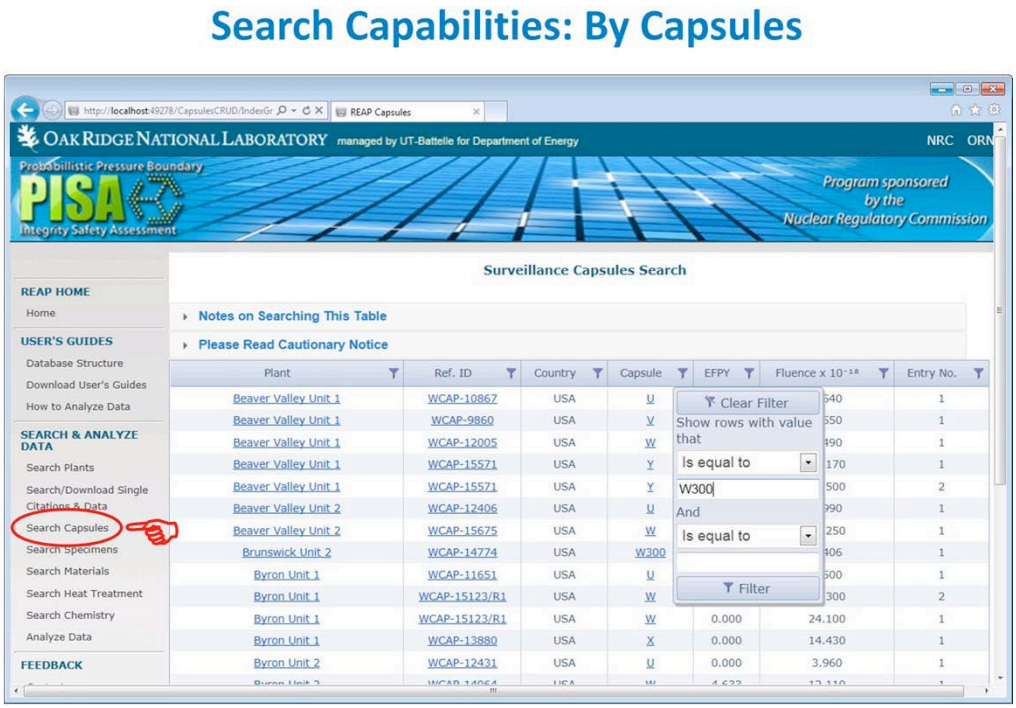


Figure 11 Search for Surveillance Capsules

The sub-sections below elaborate on some fields of the Capsules table that REAP users may find confusing.

2.7.1 Entry No. Field

The REAP team added this column to allow us to store multiple records for the same capsule and citation. That is, to allow us to store two or more records for the same plant + capsule name + citation. In this case, capsule records will have the same values for plant_id, citation_id, and capsule_name, but they will have different values for entry_no. The new entry_no column just numbers these entries sequentially. So, if there are three capsule records for the same plant + capsule name + citation, the first will have an entry_no of 1, the second will have an entry_no of 2, and the third will have an entry_no of 3. In Figure 12 the Entry No. field can be seen at the right side of the screen.

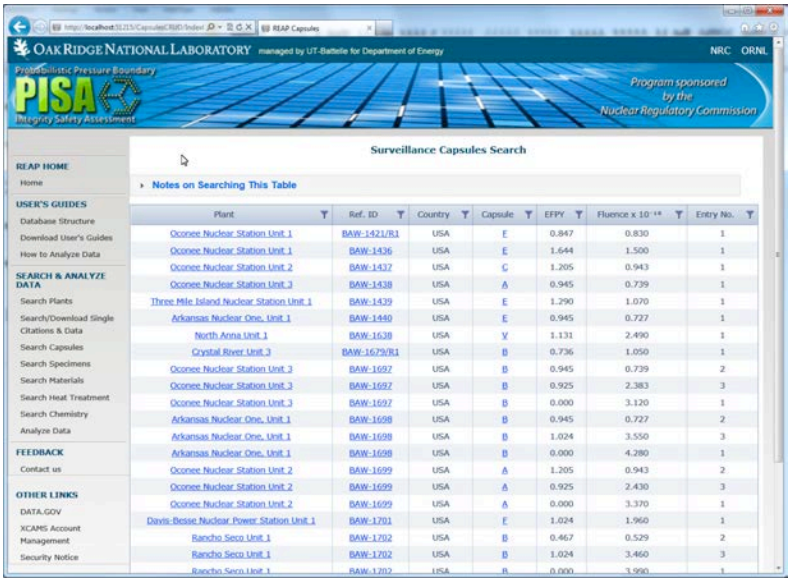


Figure 12 Capsule Table Search Results

2.7.2 Instructions for WCAP Reports (Westinghouse Reports):

In WCAP reports:

- Table 7-1 typically contains much of the information needed for both the current and the previous capsules.

- Flux and dpa information are usually included in the detailed tables that appear in Chapter 6.

If the specific EFPY and azimuthal location are missing from these tables, use linear interpolation to determine the flux and dpa information appropriate to each capsule.

2.7.3 Change in Irradiation Environment Field

The Change in Irradiation Environment Field in the Capsules Table is an indicator for change in irradiation environment, i.e., if a capsule was irradiated in one reactor for a period of time and then moved to another reactor for further irradiation. These records represent cases where a capsule was irradiated multiple times, perhaps in different environments.

2.8 Searching the Database for Specimen Data

In REAP, users can search for details on the specimen data that are in individual capsules. Click in the Search Specimens link as shown in Figure 13.

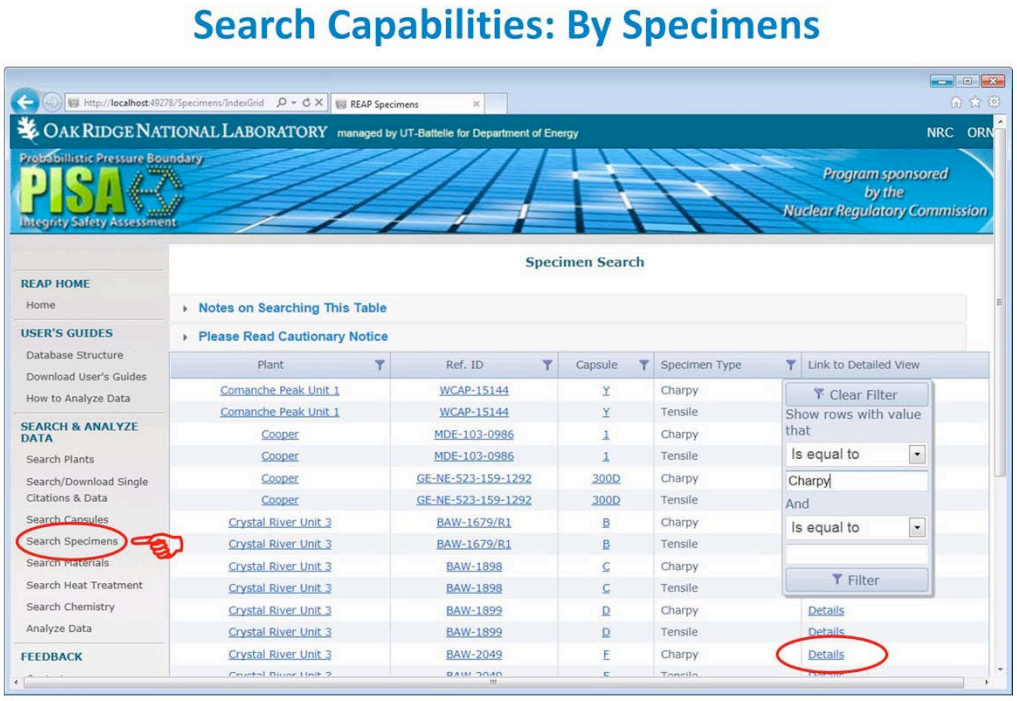


Figure 13 Search By Specimens

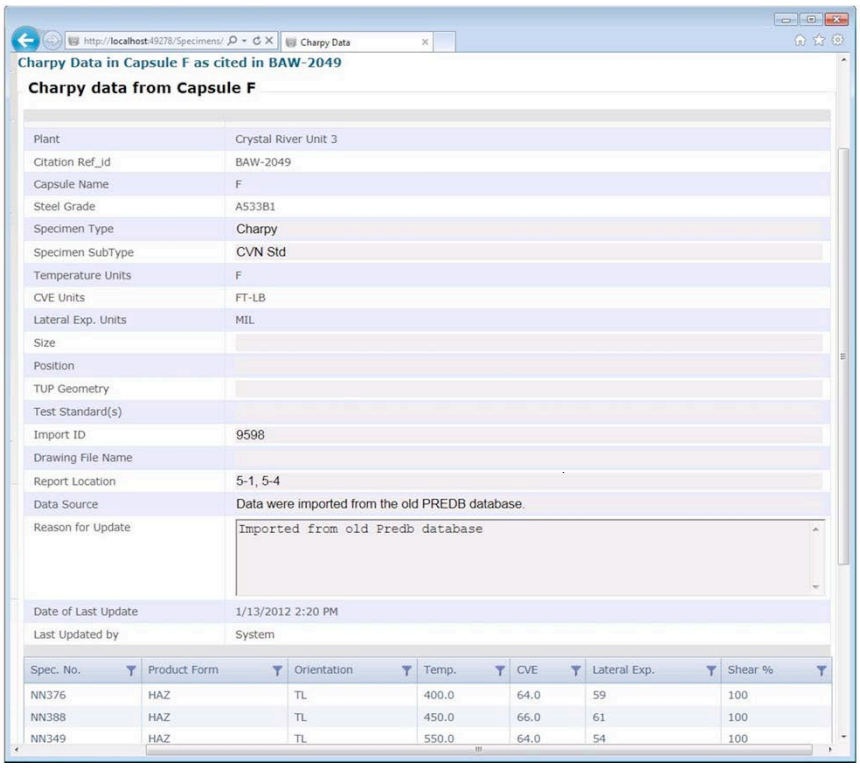


Figure 14 Sample Charpy Specimen Data

As an example, in Figure 14 users can see the Details page for the Charpy data that was collected from surveillance Capsule F taken from Crystal River Unit 3 as given in the Babcock and Wilcox report, with report number BAW-2049.

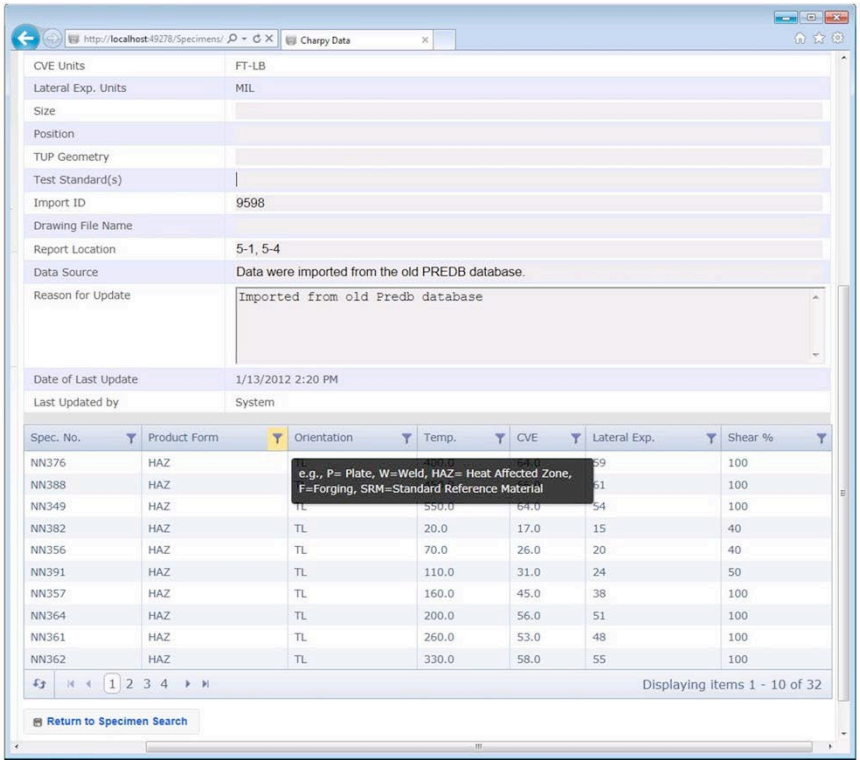


Figure 15 Sample Context Sensitive Help By Using Tooltip

REAP's tables have integrated a very useful help feature. REAP has context-sensitive help that is displayed when users place their cursor on top of the table columns' names. Figure 15 is an example of the approach we are using in REAP for providing context-sensitive help by using a tooltip.

Users can bring up the tooltip by hovering the mouse over the column header, in this case the Product Form column, and a tooltip will appear giving more details on the kinds of information available in this column.

2.9 Searching the Database for Material Data

Users can also search the database for particular materials of interest by selecting the Materials link at the left navigation panel (see **Figure 16**). Again the ability to refine your search by using compound search criteria is available to users.

The MATERIAL table records data that describe the material, such as product form, flux type, etc.

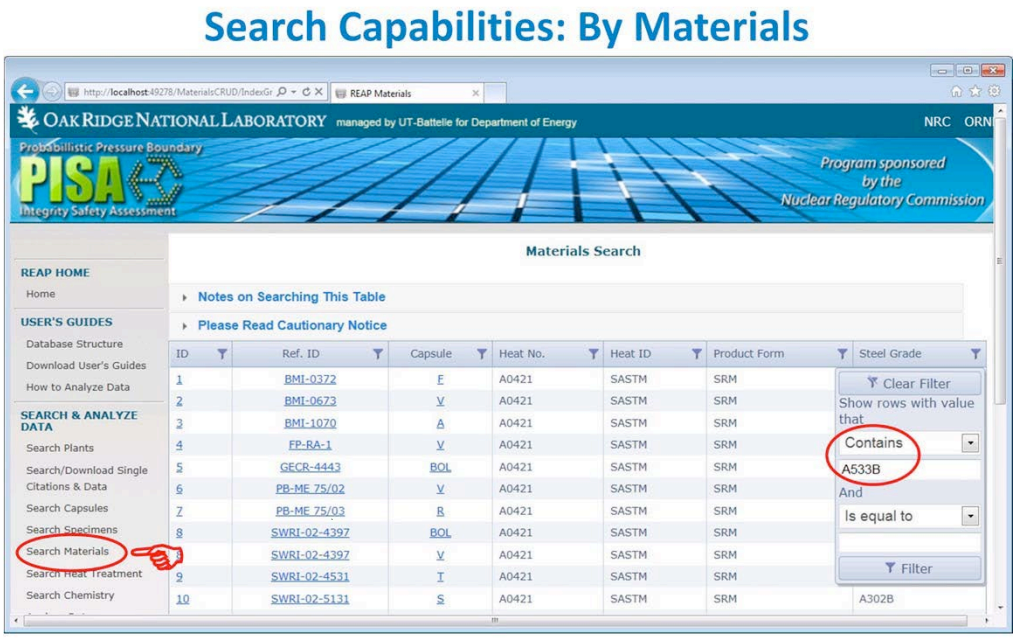


Figure 16 Search By Materials

Figure 17 shows details on a weld material, including steel grade, heat ID, Heat No., and supplier. Information on the weld flux and weld wire was also provided in the report.

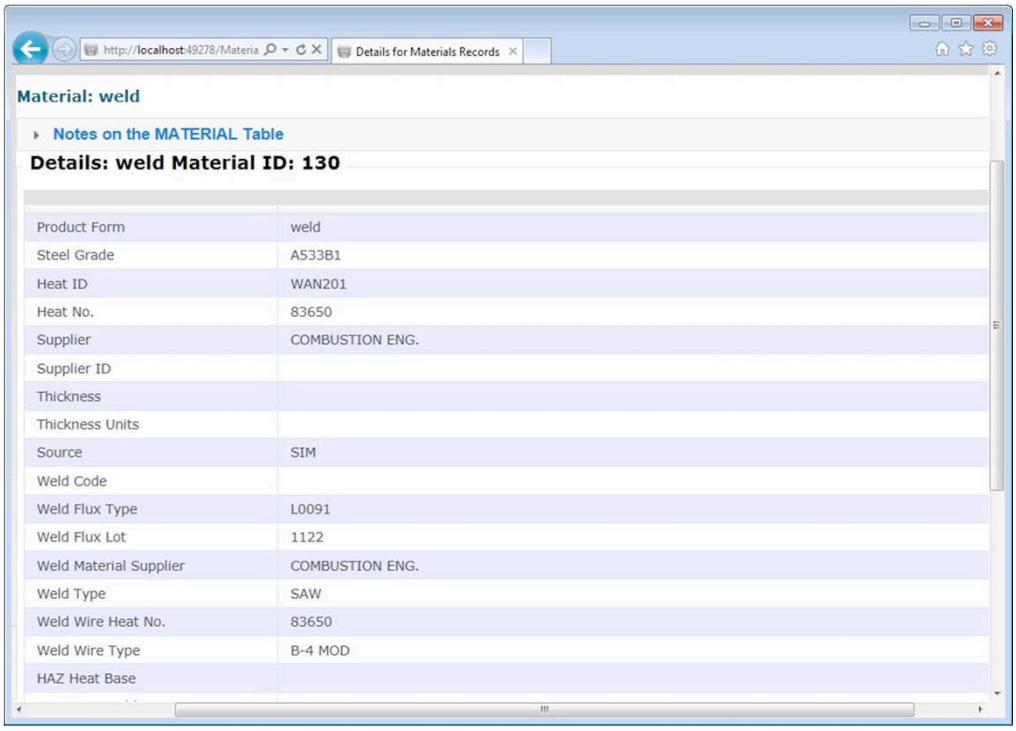


Figure 17 Details Of Sample Weld

The order of the entries in the *Report Locations* field reflects the order of the input fields in the MATERIAL form.

2.10 Searching the Database for Chemistry Content Records

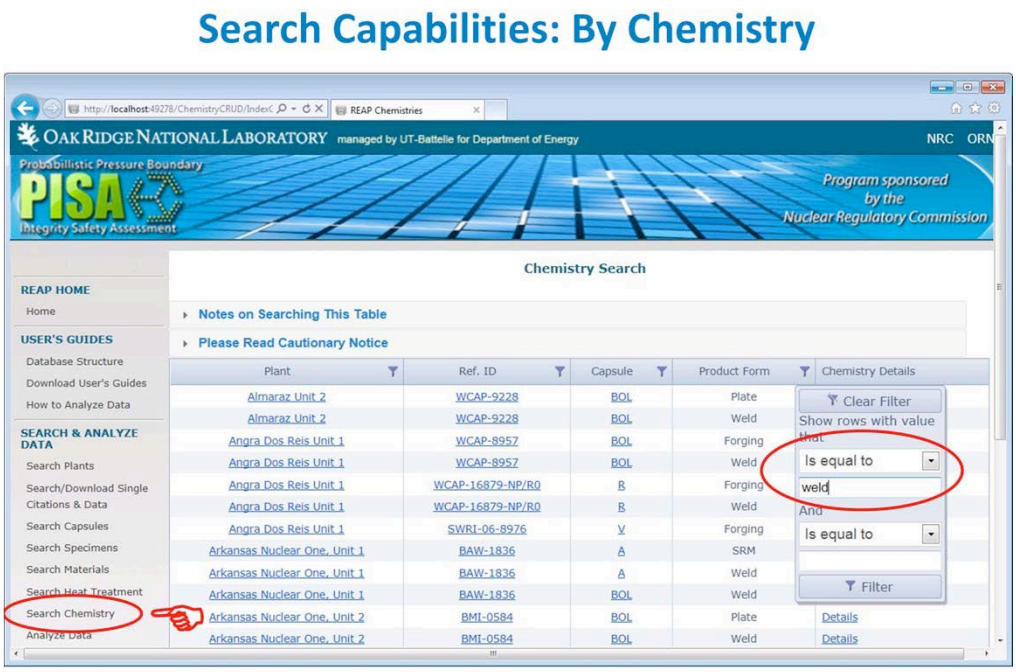


Figure 18 Search By Chemistry

A search capability that will allow you to search for details of chemical composition for specific materials and product forms is available to you through the Search Chemistry link, see Figure 18.

The chemistry table stores data related to the chemistry content of materials. There can be more than one laboratory providing chemistry data for the same materials in one citation. If the origin of this set of chemistry values is from another report then this should be noted in the comments. As the chemistry information is often heavily footnoted to describe the origin of the various values, the page number in the report on which the chemistry table appears should be placed in the comments as well.

2.10.1 WCAP Specific Instructions (Westinghouse Reports)

For Westinghouse (WCAP) reports chemistry data can usually be found in Section 4.

2.11 Searching the Database for Heat Treatment Records

Users can get details on the heat treatments applied to individual materials by using the Search Heat Treatment link, see Figure 19.

The heat treatment table records information, such as temperature, duration, etc. specific to the heat treatment applied to a material. Heat treatment data are associated with a specific material. Heat treatment data should be associated with a specific material and should not contain any information already in the Charpy or tensile tables. Not all citations will have heat treatment data.

2.11.1 WCAP Specific Instructions (Westinghouse Reports)

If present, section 4 may contain heat treatment data.

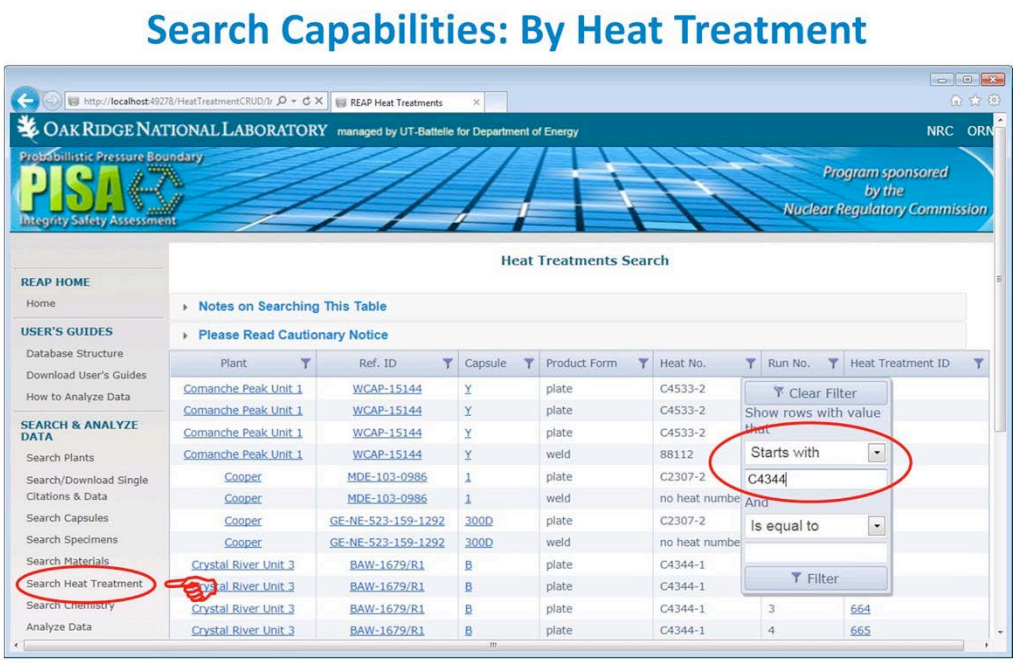


Figure 19 Search By Heat Treatment

3 REAP Analysis Service

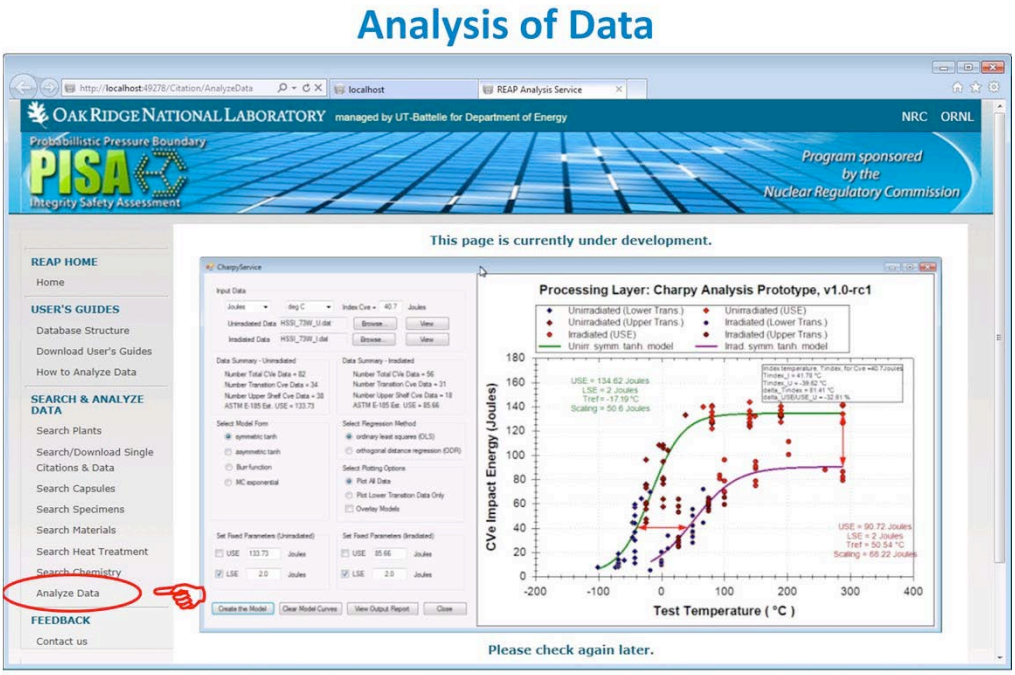


Figure 20 REAP Data Analysis

In this section, we present an overview of some of the tools that we are currently working on and hope to have available for you to use in the very near future, see **Figure 20**. We are developing a REAP Analysis Service which will allow users to search for data, collect that data into datasets, and then carry out relevant analyses on those datasets.

We are currently working to provide REAP users with the ability to carry out useful analysis while users are logged onto REAP. Currently, when users click on the Analyze Data link, they will see a place-holder that says this page is currently under development, see Figure 21. These analysis capabilities will be available to users during the REAP session.

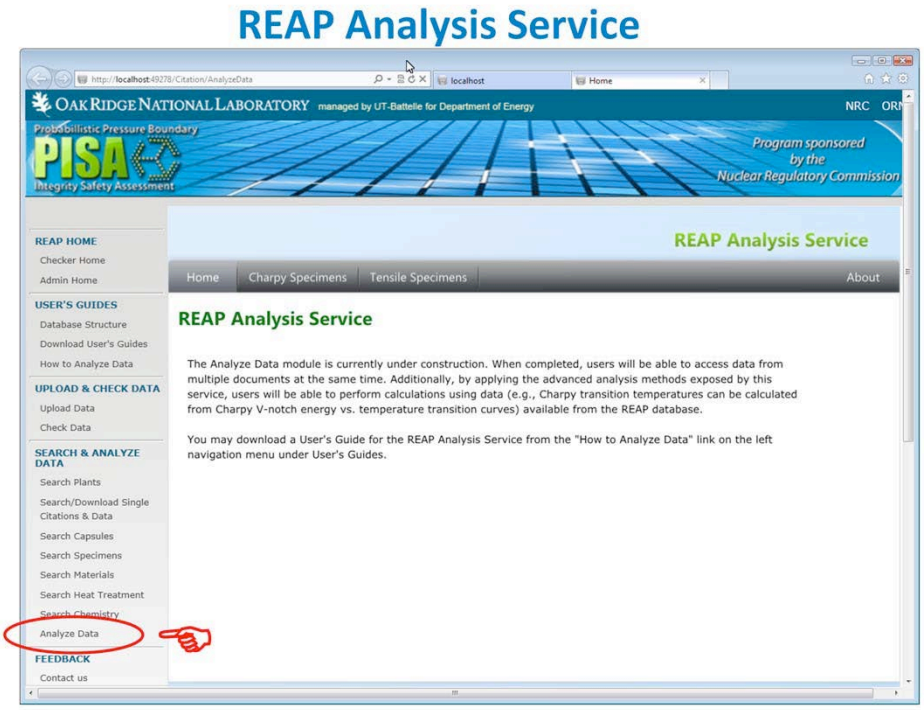


Figure 21 Analysis Service Place-Holder Page

For this prototype, the tab control organizes the analysis process into a logical sequence of steps, see Figure 22; for example

(1) Create Charpy Datasets

(2) Charpy Analysis – setup the models and carry out selected numerical analysis procedures

(3) Data Visualization – visualize the results through online plots of the data overlaid by the results of the modeling analysis

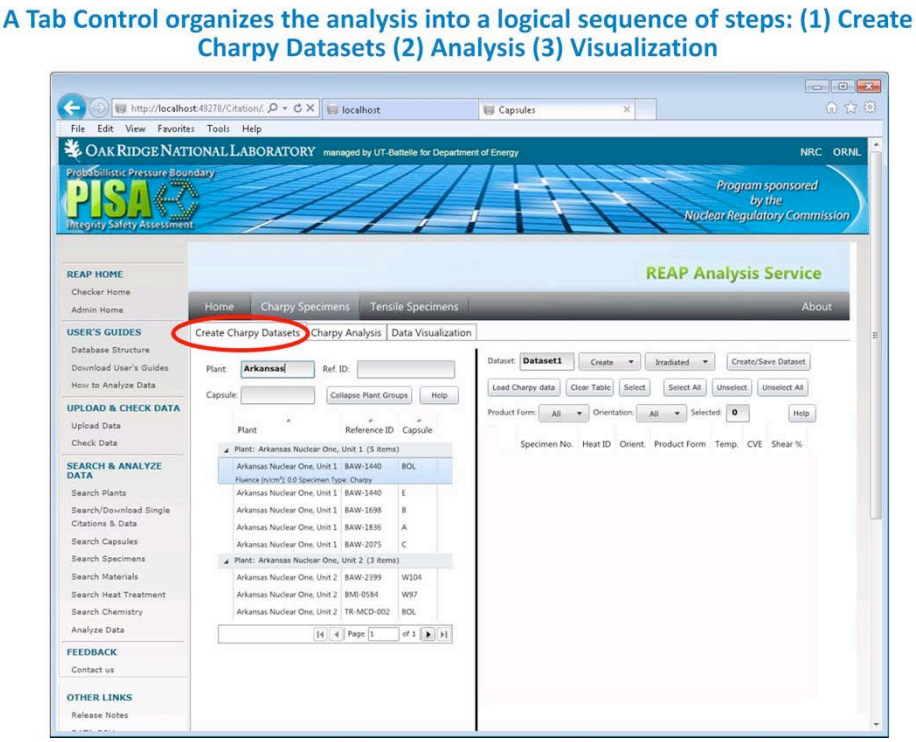


Figure 22 Tab Control Organization

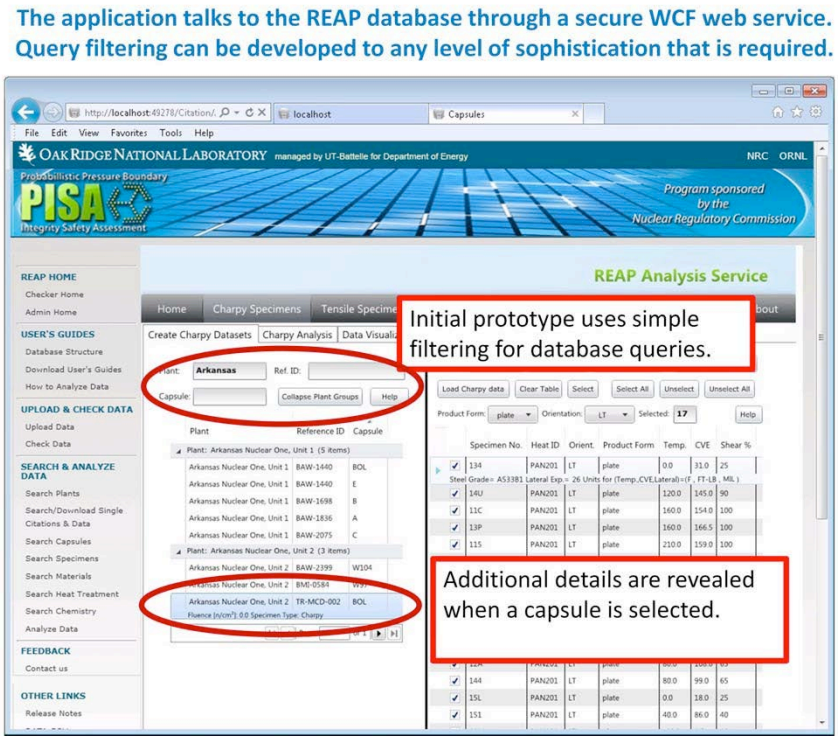


Figure 23 Sample Filtering of Data

The REAP Analysis Service communicates directly to the REAP database. We are working on developing search capabilities that cover a wide range of possibilities.

This initial prototype uses fairly simple search criteria, see Figure 23; however, the intent is to extend that search capability significantly beyond what is shown here in the prototype.

We are working on ways of allowing the user to see as much detail as possible of the data returned by the search.

Once a specific capsule has been selected, additional filtering is available. For the prototype, product form and orientation filters are implemented. Further filters can be easily developed.

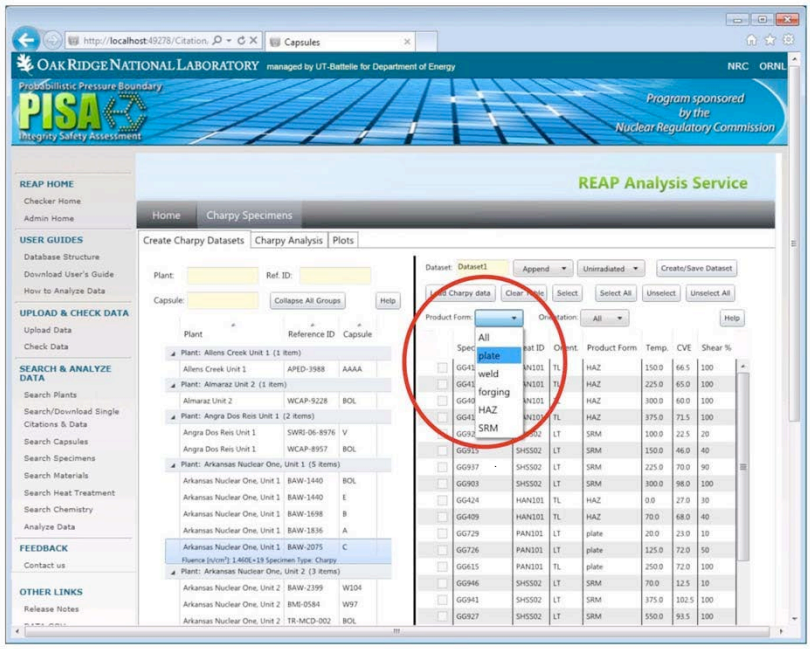


Figure 24 Easy Data Access Through Filters

Figure 24 shows data of a specific capsule. Once that capsule has been found, then additional refinement for selecting data can be performed if desired.

We are allowing the user great latitude in creating datasets.

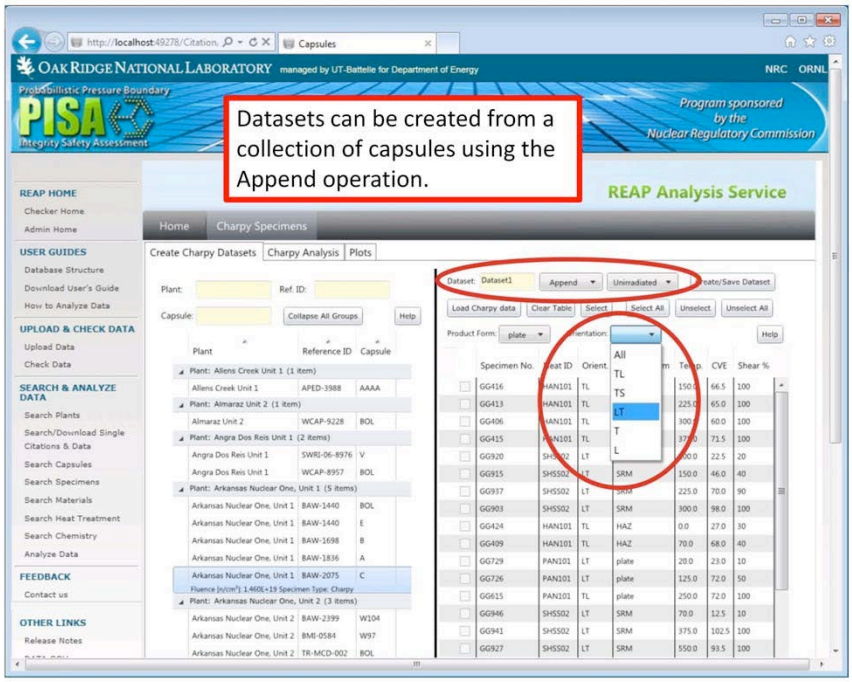


Figure 25 Datasets Creation

On Figure 25, we are looking for all the data available from the plate product form specimens in Capsule C that was taken from Arkansas Nuclear One, Unit 1. Now we can further refine the dataset by choosing a specific orientation. In the prototype, we allow the user to develop datasets from across plants, capsules, and materials by using the Create/Append operations.

We intend to extend these capabilities significantly in future development of the REAP Analysis Service.

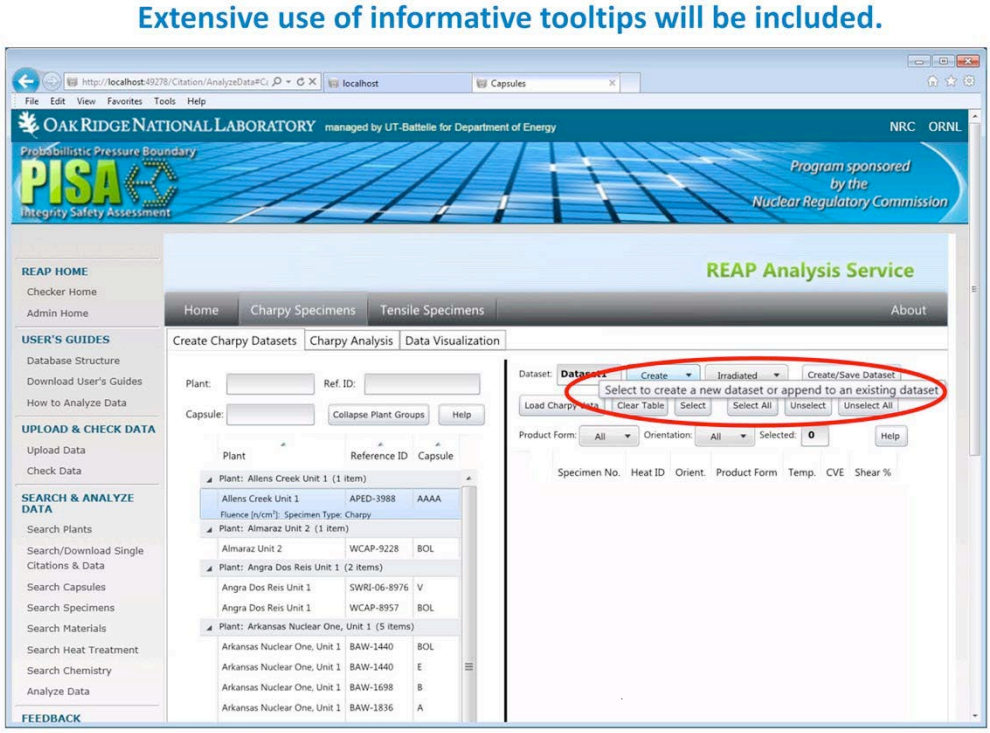


Figure 26 Context Sensitive Help Tooltips

As with the overall web application, we will continue to provide context-sensitive and online help throughout the REAP Analysis Service.

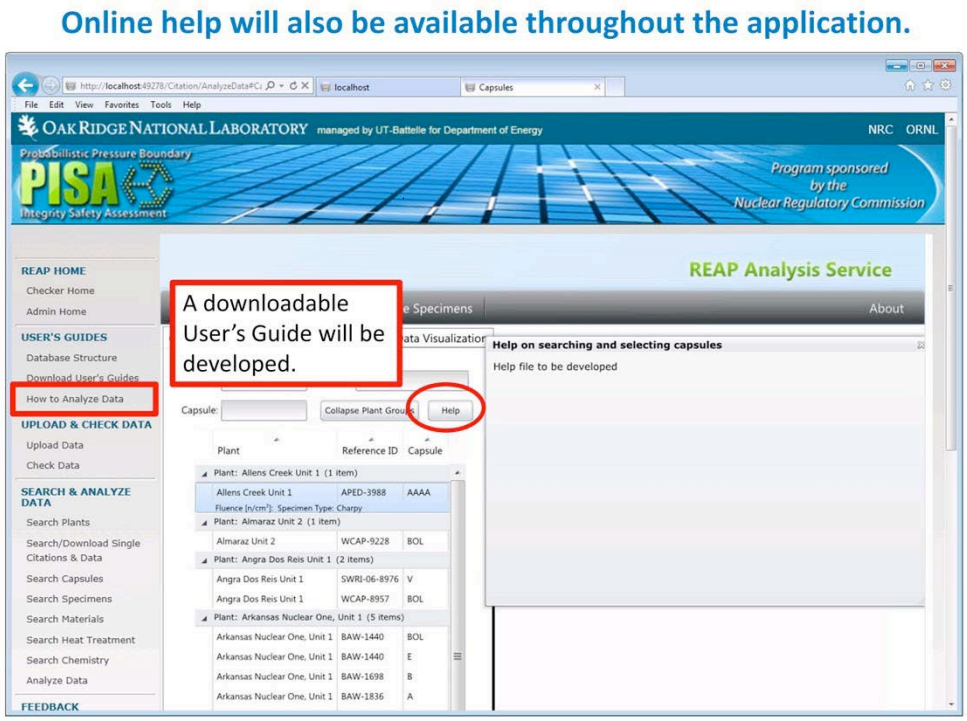


Figure 27 Online Help

As shown in Figure 27, we'll also have a downloadable User's Guide specifically developed for the Analysis Service.

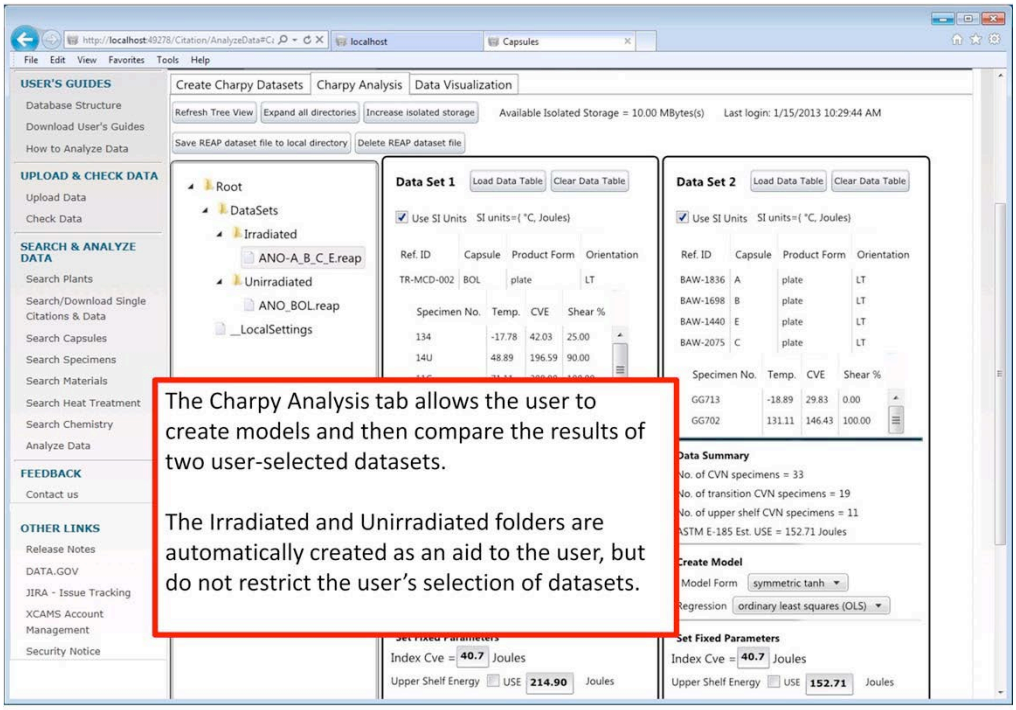


Figure 28 Charpy Analysis Tab

The Charpy Analysis tab, see Figure 28, allows the user to create models which can be applied to previously developed datasets. Currently, the prototype focuses on comparing only two datasets.

The created datasets are stored in a secure area on the user's computer and are available for future sessions.

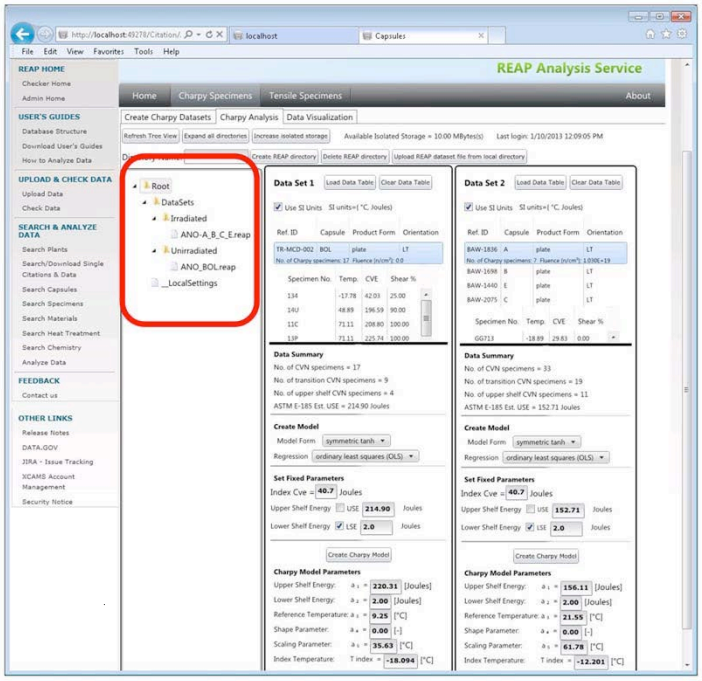


Figure 29 Session Persistence Capabilities

We recognize that session persistence is an important part of any analysis service. We provide the user with the capability of carrying out work during one session, see Figure 29. Users can log out of the session and then return at some later date to pick up right where they left off.

The previously developed datasets, models, and analysis results should be available to users upon their return during a new session.

These next few slides show some the features currently available with the prototype. On Figure 30, we are selecting a model form among several options made available to the user.

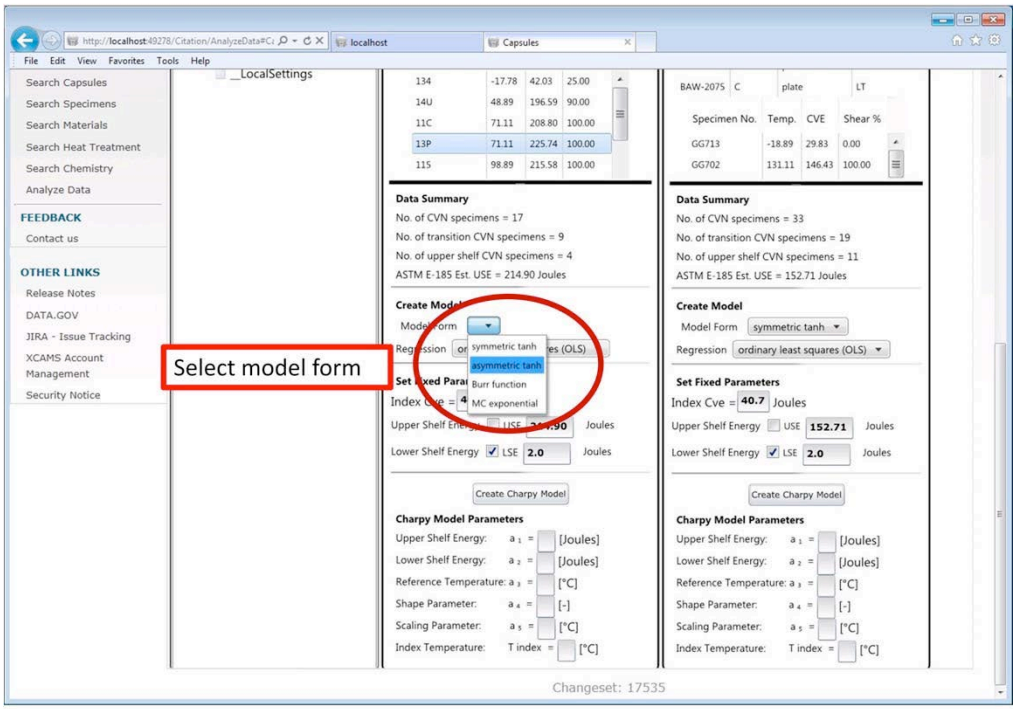


Figure 30 Selection of Model Form

We can then select a curve fitting method, see **Error! Reference source not found.**.

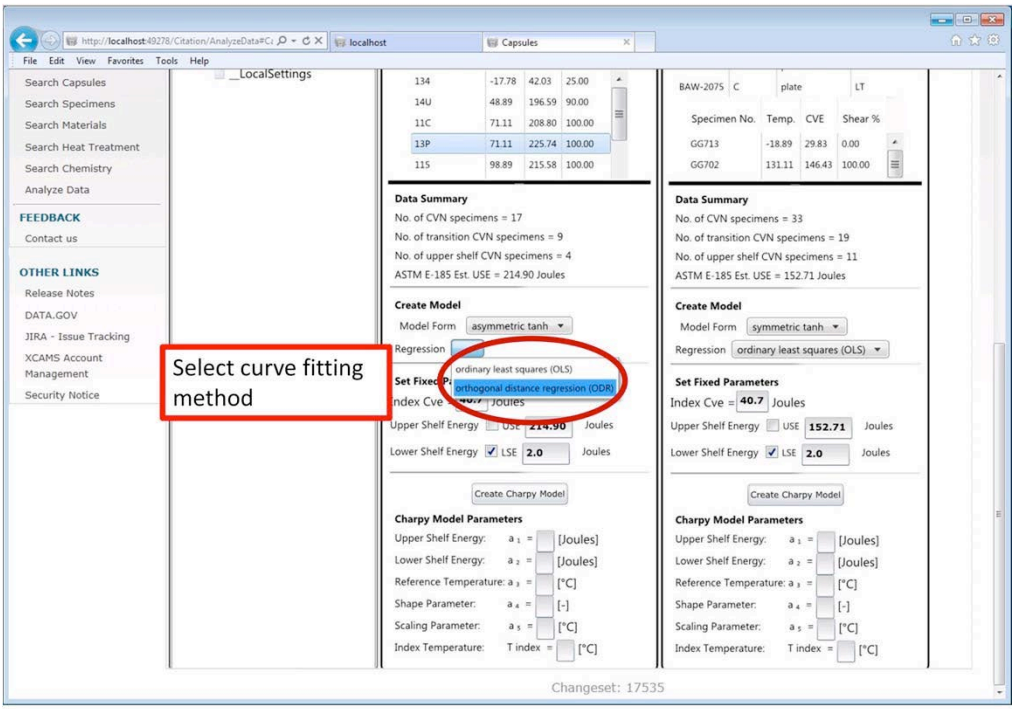


Figure 31 Selection of Curve Fitting Method

On Figure 32, we can choose which parameters of the selected model can be set to constants and which need to be fitted by the analysis using the provided dataset.

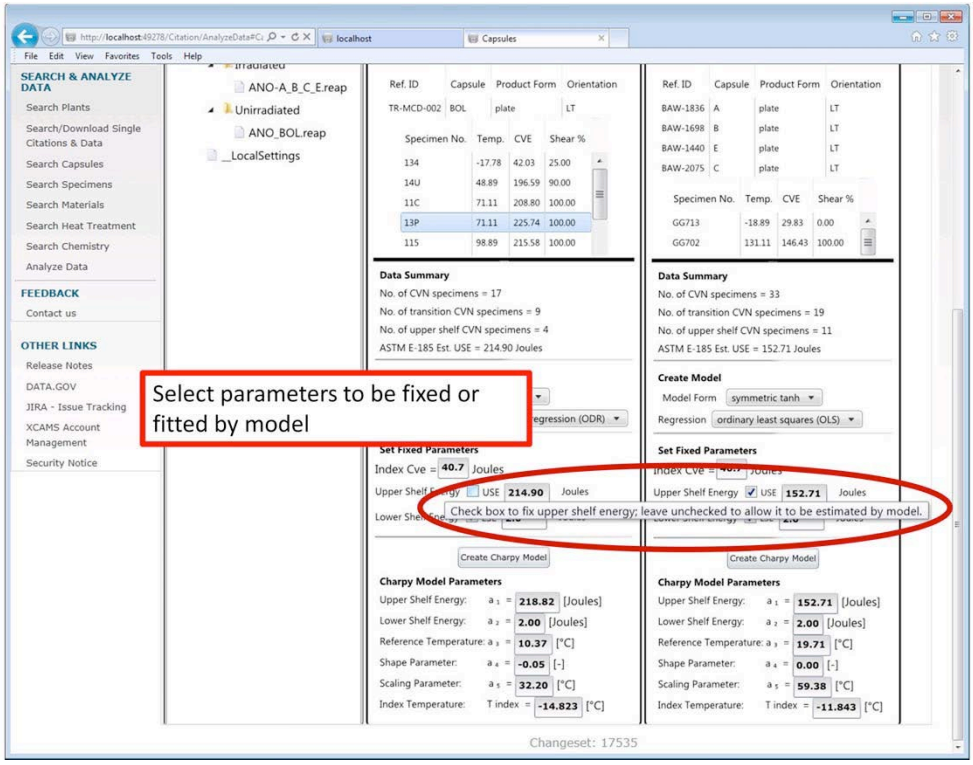


Figure 32 Selection of Parameters

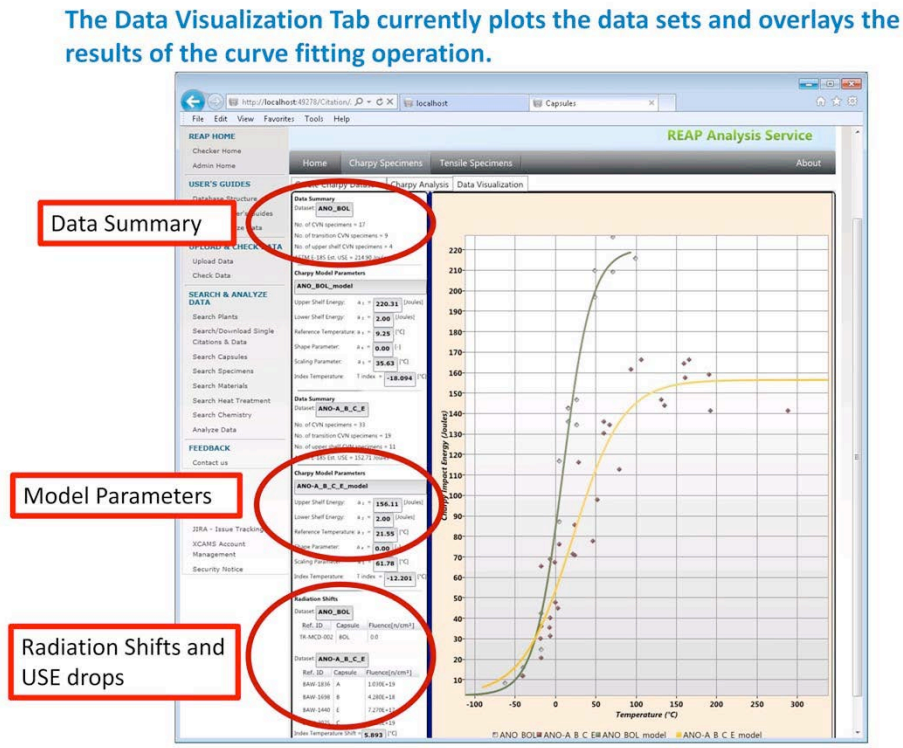


Figure 33 Data Visualization Tab

After clicking on the Create Model buttons, we can then move over to the Data Visualization tab, see Figure 33. On this tab, you will see plots of the datasets overlaid by the results of the model analyses on the two datasets. You can also see summaries of the datasets, the model parameters determined by the analysis.

Zooming in a little bit closer, we can see comparisons of the two datasets, which will show you the resulting radiation shifts and USE drops, see Figure 34.

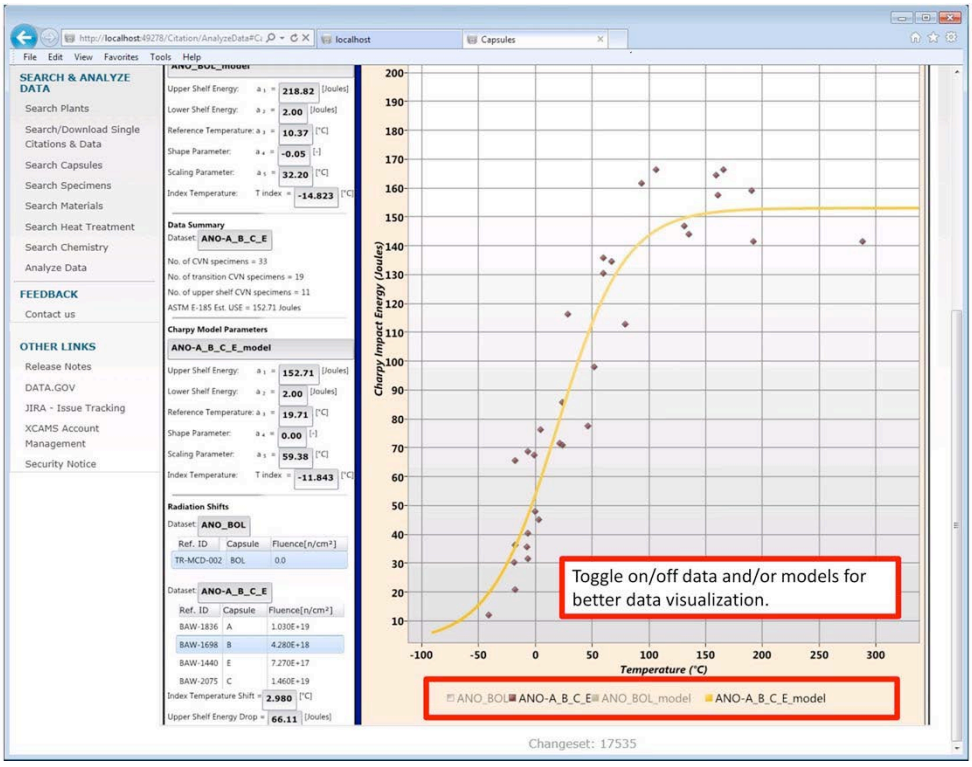


Figure 34 Image Zooming Capability

We are also working on making the plotting of data and results as dynamic as possible to allow users to able to manipulate the presentation to reveal the kind of information that they are looking for.

As an example of this dynamic capability, along the legend at the bottom of the plot you can toggle off or on models and/or data to isolate certain aspects of the analysis.

4. References

1. Klasky, H. B., et al "*Radiation Embrittlement Archive Project"*, Transactions, SMiRT-22, Division II, San Francisco, CA, USA, August 18-23, 2013.
2. Wang, John Jy-An (2010), "Lessons Learned From Developing Reactor Pressure Vessel Steel Embrittlement Database" ORNL/TM-2010/20, Oak Ridge National Laboratory, Oak Ridge, TN
3. International Atomic Energy Agency (IAEA), Nuclear Power Reactors in the World, Reference data Series No. 2, Vienna April 2006
4. US Nuclear Regulatory Commission (NRC) 2010-2011 Information Digest, NUREG-1350, Volume 22.

5. Appendix A – Mining of surveillance data of irradiated capsules into REAP web application

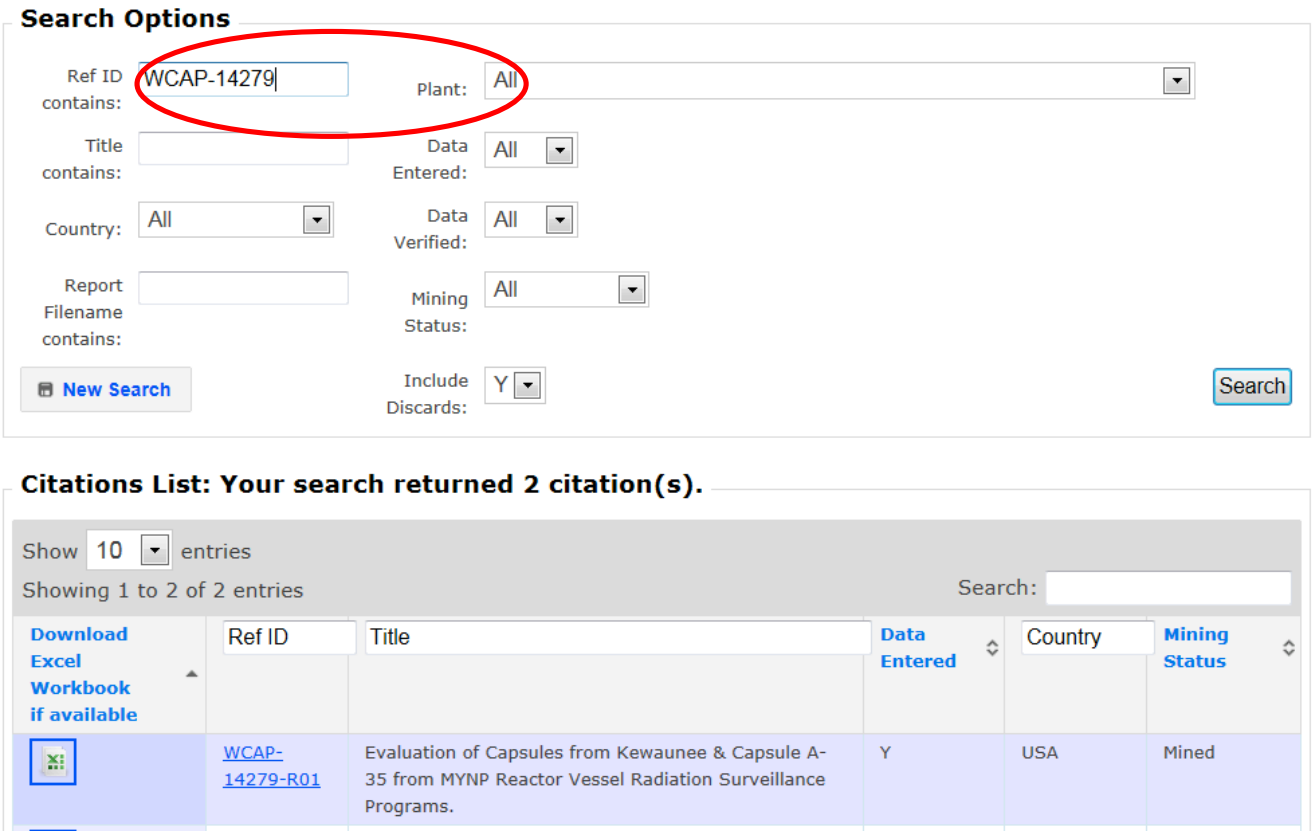
Notes from Sashi Tadinada, PhD

The steps in mining data from a citation are:
Step 1. Begin search of citations using filters shown below.
Step 2. Get the pdf report and download.
Step 3: After selecting and downloading the citation to be mined, begin the process by adding a new Capsule.
Step 4. Add Material data.
Step 5. Add Heat Treatment.
Step 6. Add Charpy Data
Step 7. Add Tensile Data
Step 8. Add Chemistry Data
The following pages detail each of these steps with screenshots.

5.1 Step 1. Begin search of citations using filters shown below.

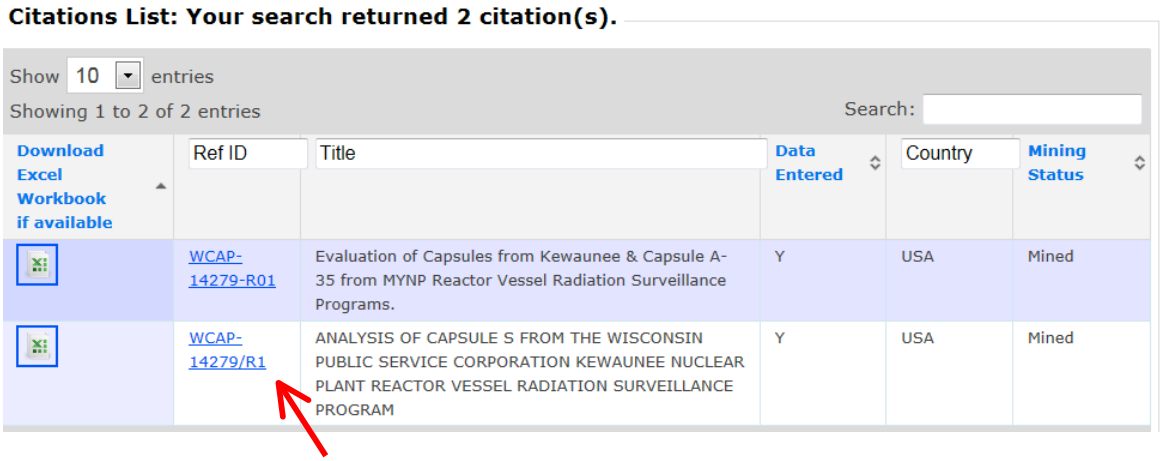
- Go to REAP main page: https://reap.ornl.gov/
- In the left pane menu, click on "Search/Download Single Citations & Data" under the section "SEARCH & ANALYZE DATA".

- The link navigates to https://reap.ornl.gov/Citation/SimpleQuery. Search for the citation to be mined by entering the search criteria



5.2 Step 2. Get the pdf report and download.

- Click on the citation of interest for details



- The link displays the details of the citation. Download the PDF containing the surveillance data

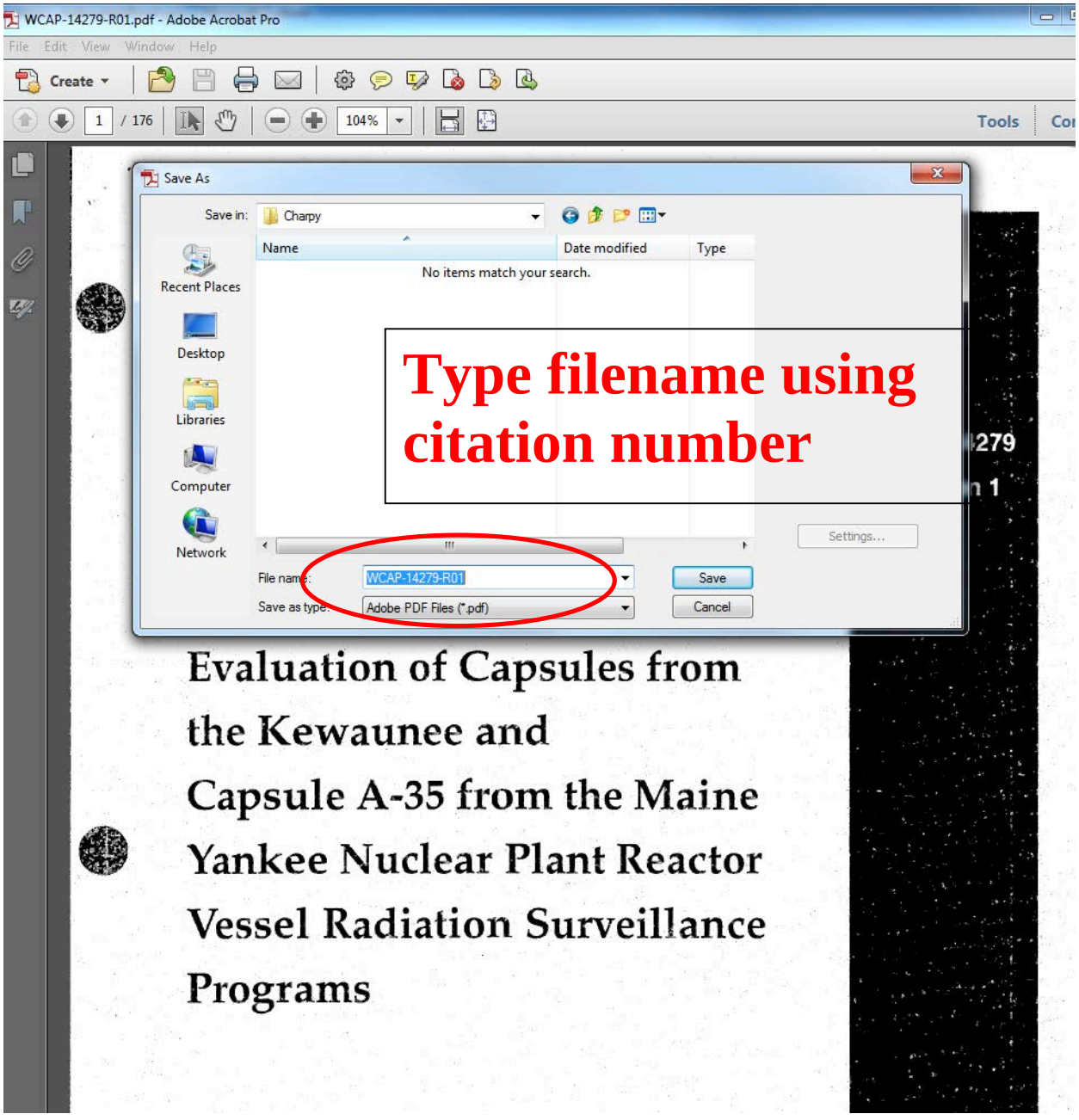
Citation Details

Details: WCAP-14279-R01

Reference ID	WCAP-14279-R01
Associated Plant	Kewaunee Nuclear Power Plant
Report Type	Power Reactor
Report Subtype	Capsule
Report Title	Evaluation of Capsules from Kewaunee & Capsule A-35 from MYNP Reactor Vessel Radiation Surveillance Programs.
Report Authors	Boyd C.H., Terek, E., Anderson S.L.
Report Date	September 1998
Published by	Westinghouse Electric Company
ADAMS No.	ML111861764
Report File Name	KWE_1998_SEP_CAPS.pdf
Associated Legal File(s)	No legal documents have been uploaded for this citation.
Report Proprietary?	FALSE
Data Entered? (Y/N)	Y
Data Mining Status	Mined
Data Mining Filename	
Data Mining File Location	
Legal Permission Granted?	FALSE
Data Verified? (Y/N)	Y
Comments	
Number of Data Verifications	None
Data Source	
Reason for Update	citation updated using web app

Click on link to open the report

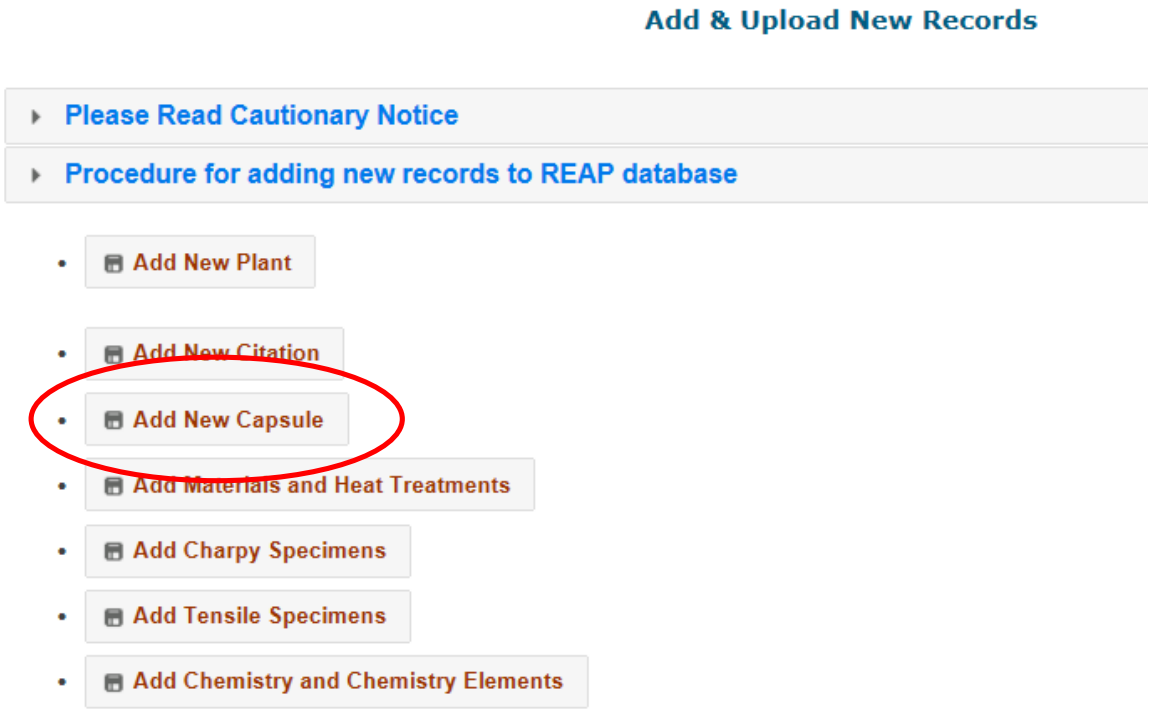
- Save the file on the hard disk. It's useful to use the name of the citation as the filename of for the PDF rather than the default.



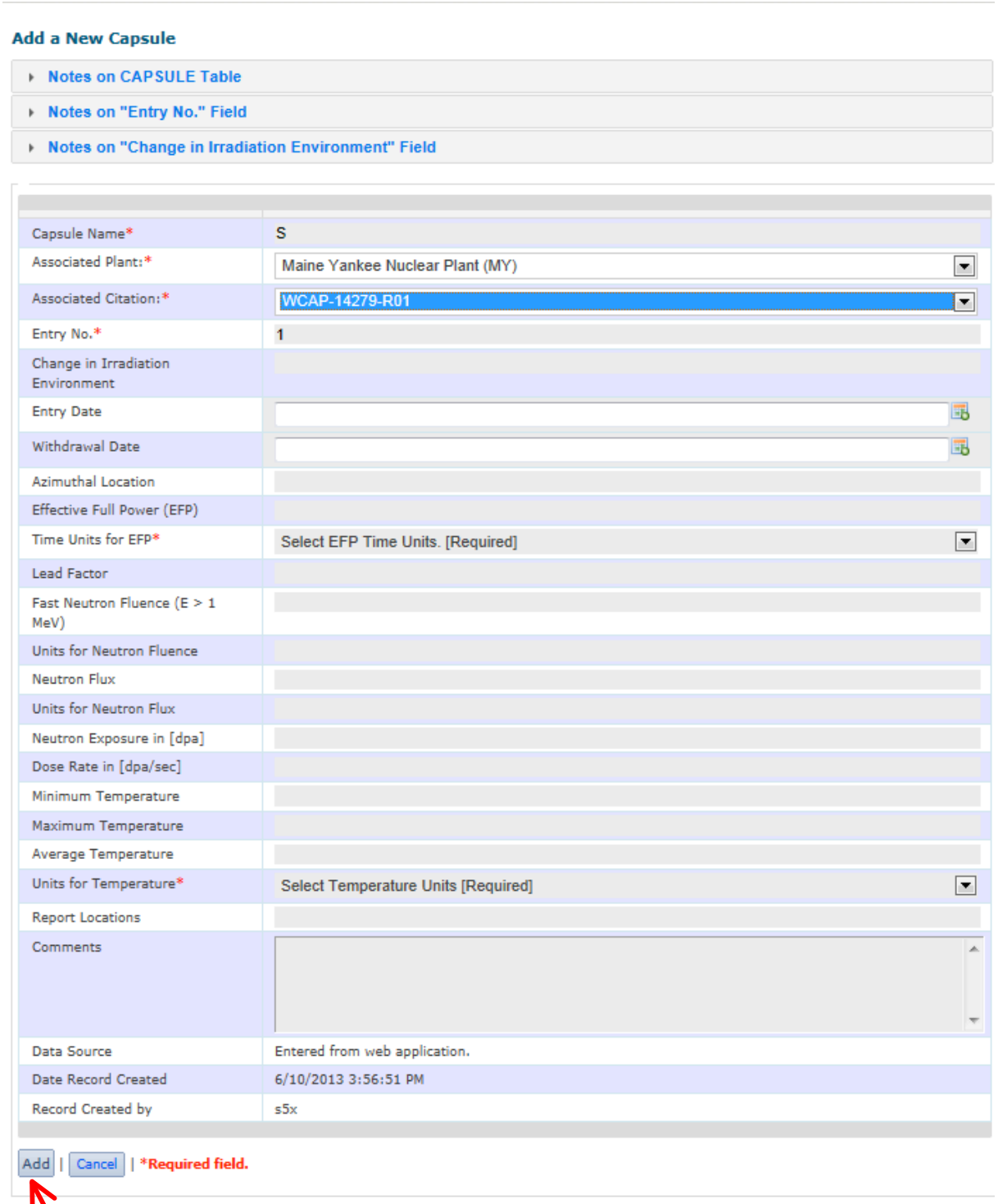
5.3 Step 3: After selecting and downloading the citation to be mined, begin the process by adding a new capsule.

- In the left pane menu, click on “upload data” under the section “UPLOAD & CHECK DATA”.

- The link navigates to display various options for adding and uploading new records. Click on “Add New Capsule”.



- The ***"Add a Capsule"*** page comes up to begin the process of entering the initial overview capsule data. Finish entering the capsule data and click "Add".



- This is an example of capsule data for an irradiated capsule.

Capsule: S from Kewaunee Nuclear Power Plant as cited in report WCAP-14279-R01

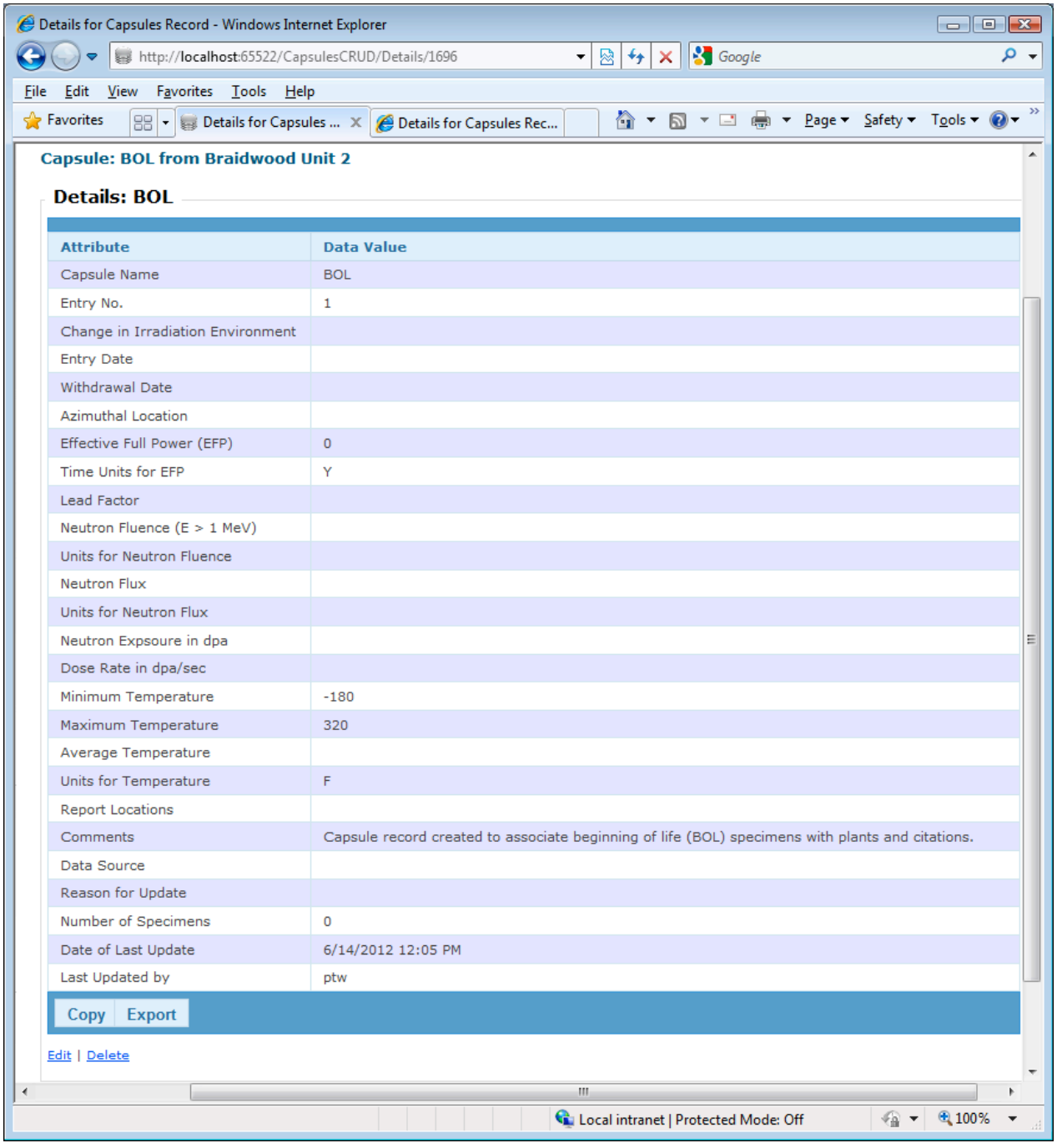
Capsule Details

Attribute	Data Value
Capsule Name	S
Entry No.	1
Change in Irradiation Environment	
Entry Date	
Withdrawal Date	
Azimuthal Location	
Effective Full Power (EFP)	16.2
Time Units for EFP	Y
Lead Factor	
Neutron Fluence (E > 1 MeV)	3.36E+19
Units for Neutron Fluence	n/cm2
Neutron Flux	6.57e+10
Units for Neutron Flux	n/cm2-s
Neutron Exposure in dpa	5.69e+-02
Dose Rate in dpa/sec	1.1e-10
Minimum Temperature	
Maximum Temperature	
Average Temperature	
Units for Temperature	F
Report Locations	6-34
Comments	
Data Source	
Reason for Update	capsule updated using web app
Number of Specimens	59
Date of Last Update	6/10/2013 4:00 PM
Last Updated by	s5x

Copy Export

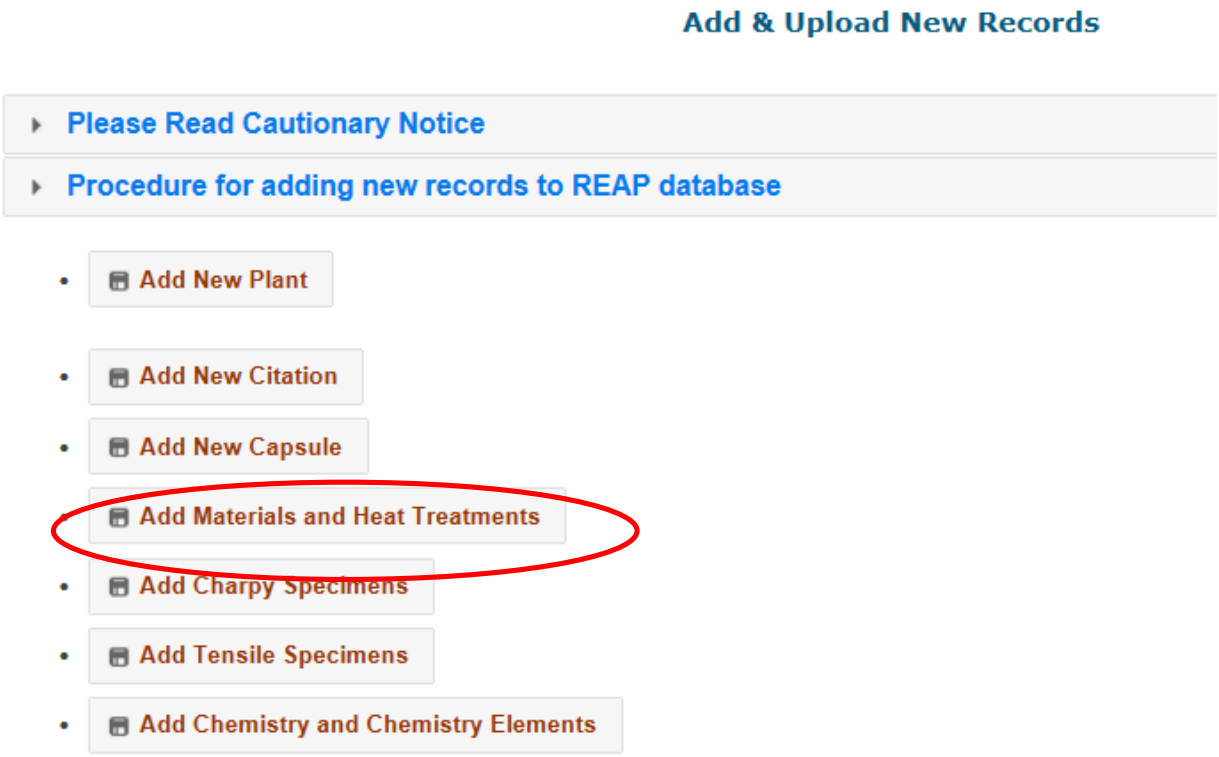
Edit | Delete

- Sometimes, the capsule may be irradiated or is a BOL (Beginning of Life, i.e., no irradiation damage) entry. Example of a BOL capsule record:

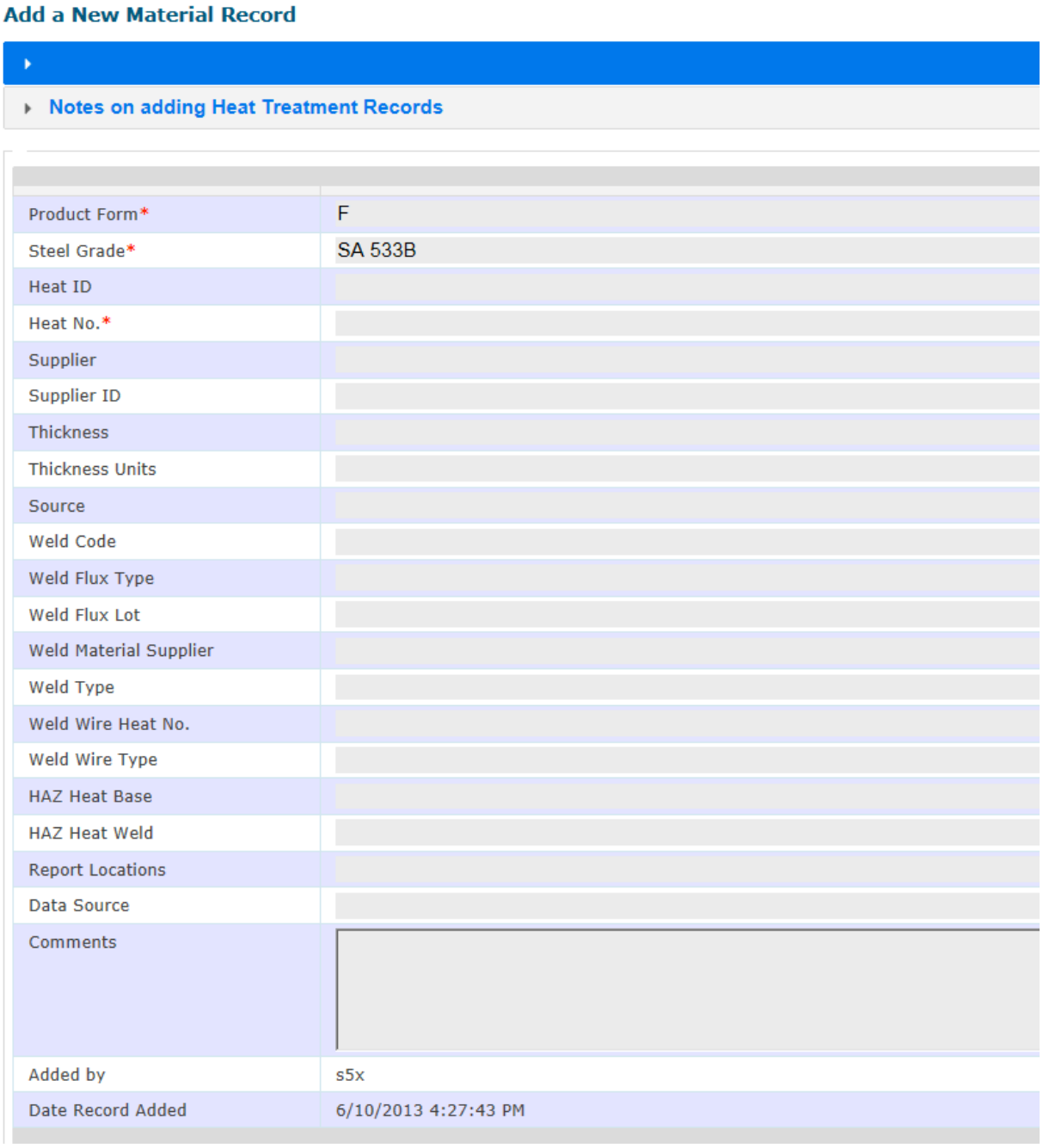


5.4 Step 4. Add material data.

- Navigate to Upload Data -> “Add Materials and Heat Treatment”



- Enter information on Product Form (Plate, Forging, Weld or HAZ), Steel Grade, Heat No. etc.



- Often, many capsules contain specimens of multiple materials. A separate record must be created for each material.
- **IMPORTANT: NOTE DOWN THE MATERIAL ID.** It is needed for entering heat treatment data in Step 5.

Example: Record for a Forging Material

Material: forging

Note the material ID

▸ Notes on the MATERIAL Table

Details: forging Material ID: 1628

Product Form	forging
Steel Grade	A533 Grade B, Class 1
Heat ID	
Heat No.	122X208VA1
Supplier	
Supplier ID	
Thickness	
Thickness Units	
Source	
Weld Code	
Weld Flux Type	
Weld Flux Lot	
Weld Material Supplier	
Weld Type	
Weld Wire Heat No.	
Weld Wire Type	
HAZ Heat Base	
HAZ Heat Weld	
Report Locations	5-8
Comments	entered from web application
Data Source	
Reason for Update	

Example: Record for a Weld Material

Material: weld

▸ Notes on the MATERIAL Table

Details: weld Material ID: 1629

Product Form	weld
Steel Grade	A533 Grade B, Class 1
Heat ID	
Heat No.	1P3571
Supplier	
Supplier ID	
Thickness	
Thickness Units	
Source	
Weld Code	
Weld Flux Type	Linde 1092
Weld Flux Lot	3958
Weld Material Supplier	
Weld Type	3/16-inch Mil B-4
Weld Wire Heat No.	1P3571
Weld Wire Type	
HAZ Heat Base	
HAZ Heat Weld	
Report Locations	4-1
Comments	entered from web application
Data Source	
Reason for Update	

Example: Record for a HAZ Material

Material: HAZ

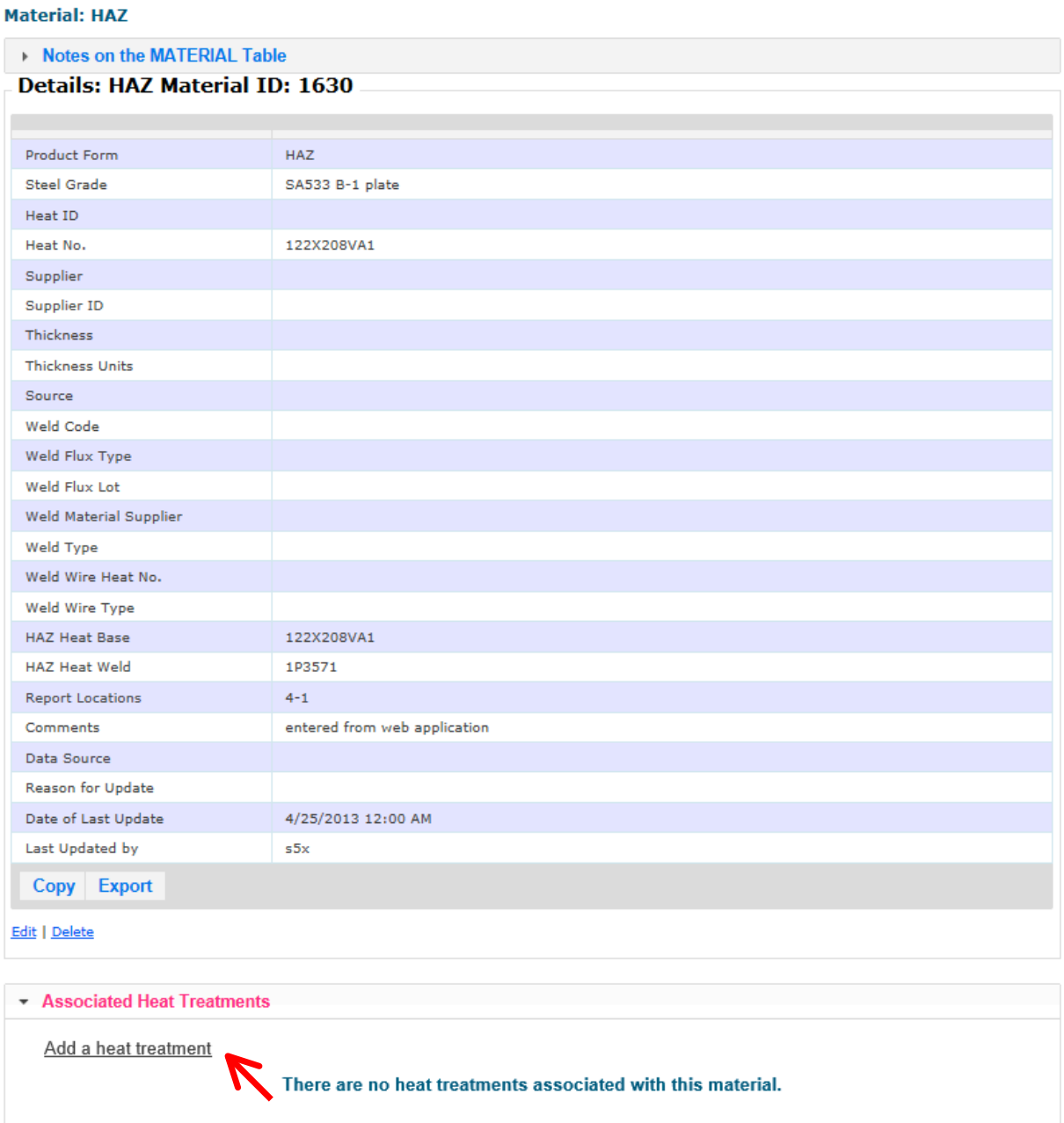
▸ Notes on the MATERIAL Table

Details: HAZ Material ID: 1630

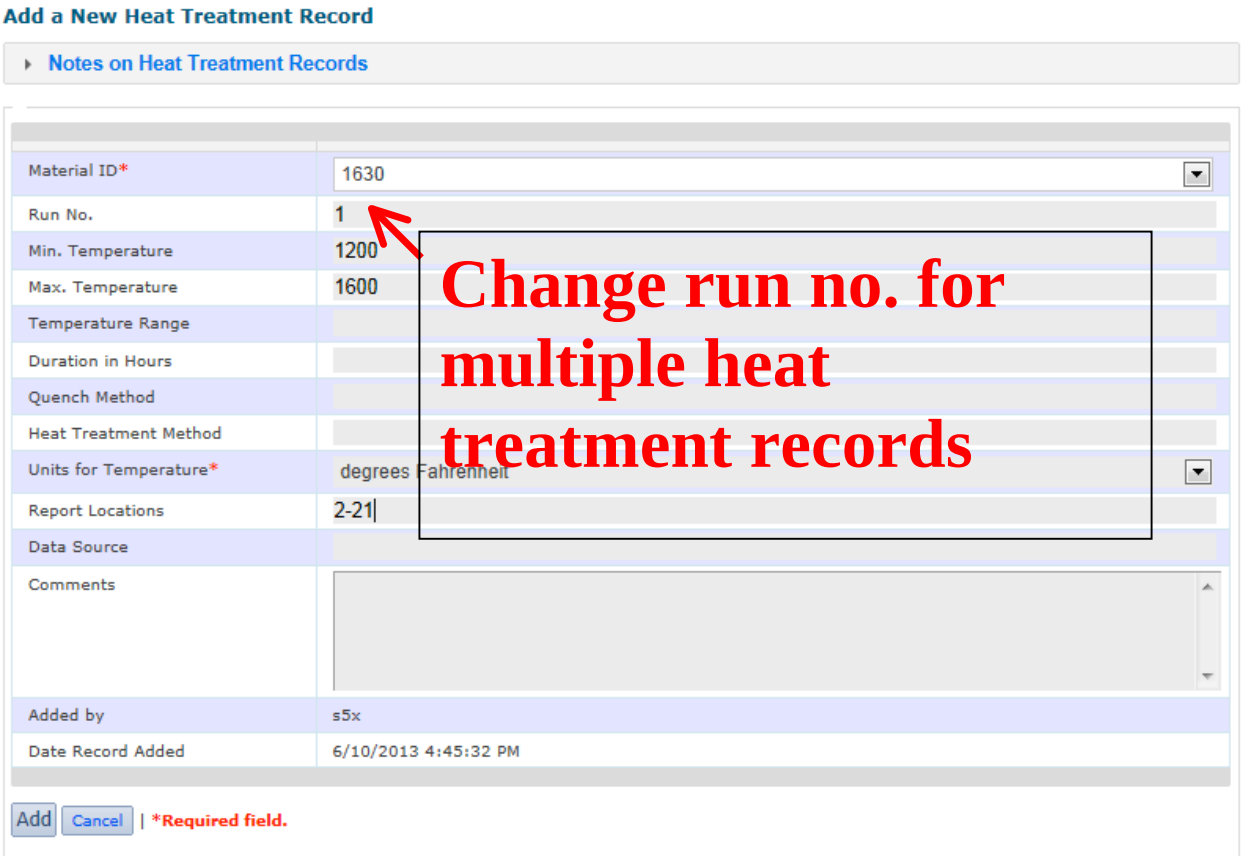
Product Form	HAZ
Steel Grade	SA533 B-1 plate
Heat ID	
Heat No.	122X208VA1
Supplier	
Supplier ID	
Thickness	
Thickness Units	
Source	
Weld Code	
Weld Flux Type	
Weld Flux Lot	
Weld Material Supplier	
Weld Type	
Weld Wire Heat No.	
Weld Wire Type	
HAZ Heat Base	122X208VA1
HAZ Heat Weld	1P3571
Report Locations	4-1
Comments	entered from web application
Data Source	
Reason for Update	

5.5 Step 5. Add Heat Treatment.

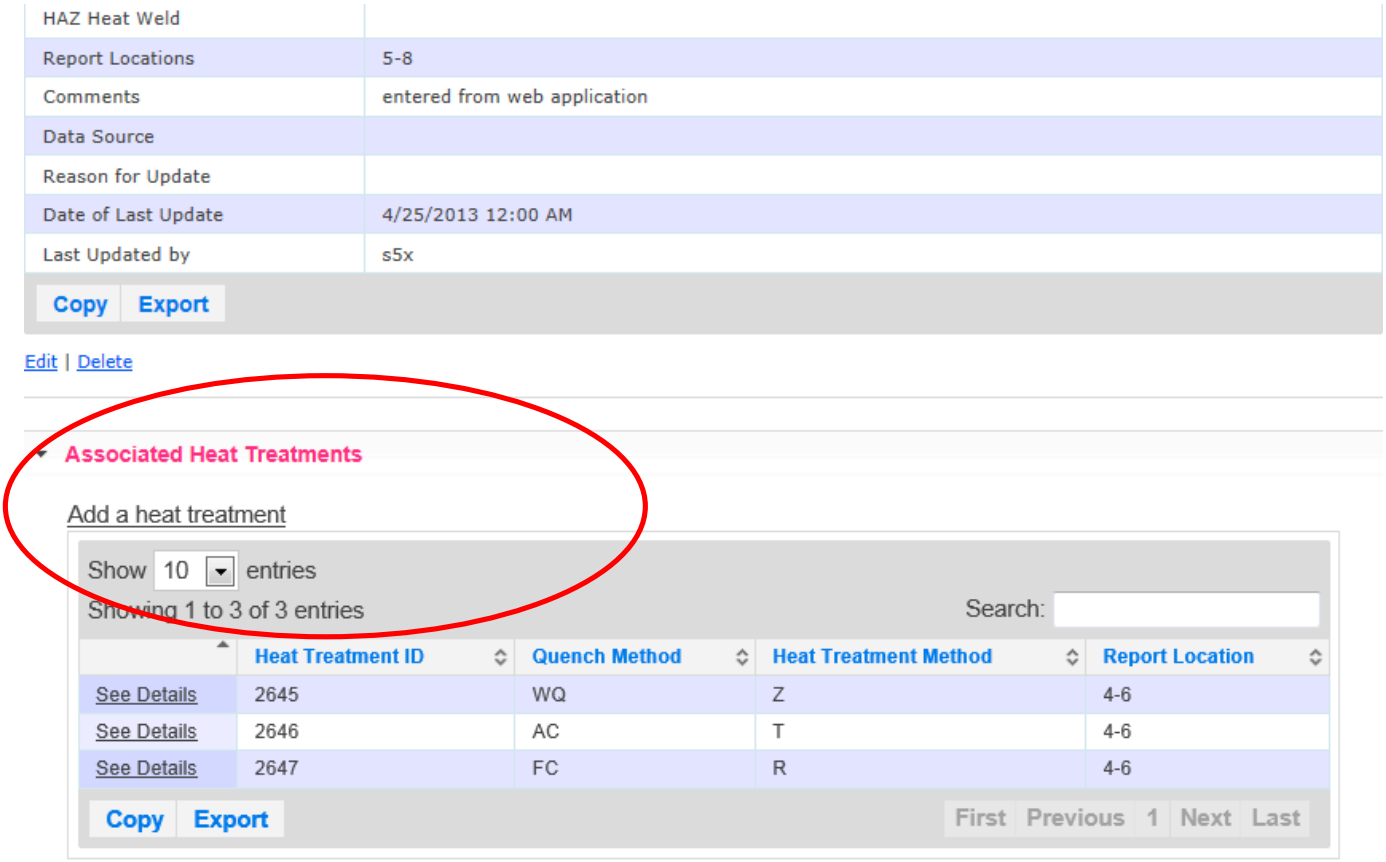
- Get the material ID for entering the heat treatment details.
- Navigate to the details page of the material and click on the “Add a Heat Treatment” under Associated Heat Treatments section on the page.



- Enter heat treatment details as per the menu


Add a New Heat Treatment Record
Notes on Heat Treatment Records
Material ID*
1630
Run No.
1
Min. Temperature
1200
Max. Temperature
1600
Temperature Range
Duration in Hours
Quench Method
Heat Treatment Method
Units for Temperature*
degrees Fahrenheit
Report Locations
2-21
Data Source
Comments
Added by
s5x
Date Record Added
6/10/2013 4:45:32 PM
Add
Cancel
*Required field.
Change run no. for multiple heat treatment records

- For multiple runs of Heat Treatments for the material, change Run no. and create multiple records. The various heat treatment records should now be displayed in the material details page:



HAZ Heat Weld	
Report Locations	5-8
Comments	entered from web application
Data Source	
Reason for Update	
Date of Last Update	4/25/2013 12:00 AM
Last Updated by	s5x

Copy Export

Edit | Delete

Associated Heat Treatments

Add a heat treatment

Show 10 entries

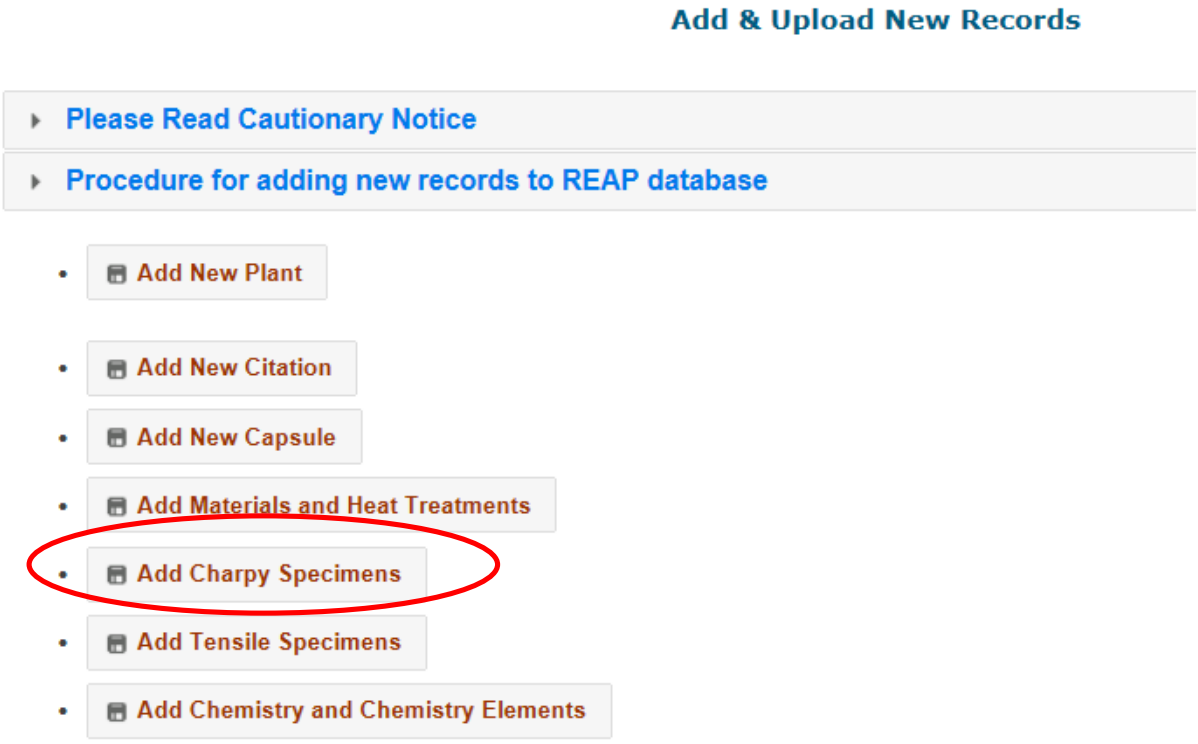
Showing 1 to 3 of 3 entries Search:

	Heat Treatment ID	Quench Method	Heat Treatment Method	Report Location
See Details	2645	WQ	Z	4-6
See Details	2646	AC	T	4-6
See Details	2647	FC	R	4-6

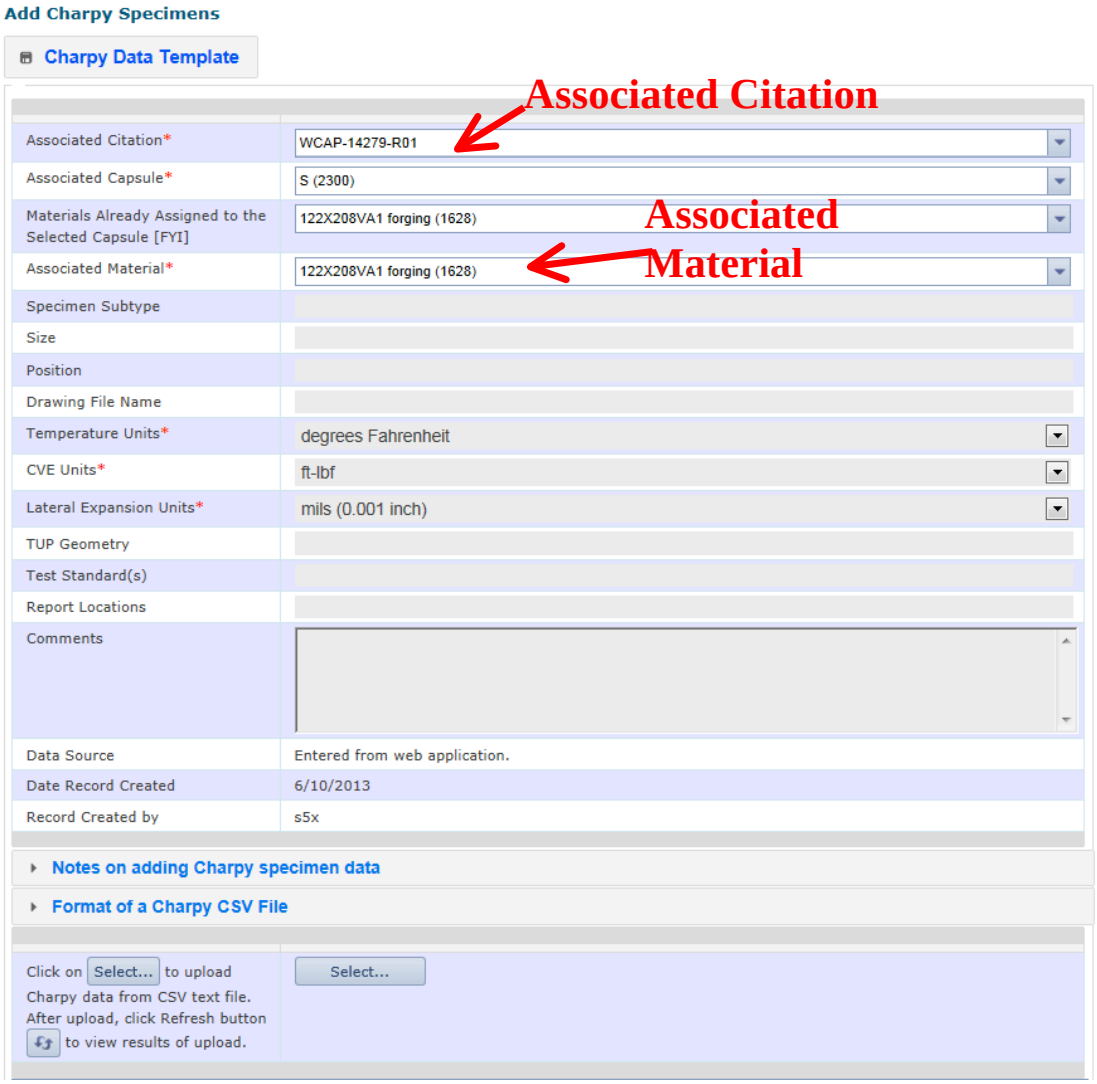
Copy Export First Previous 1 Next Last

5.6 Step 6. Add Charpy Data

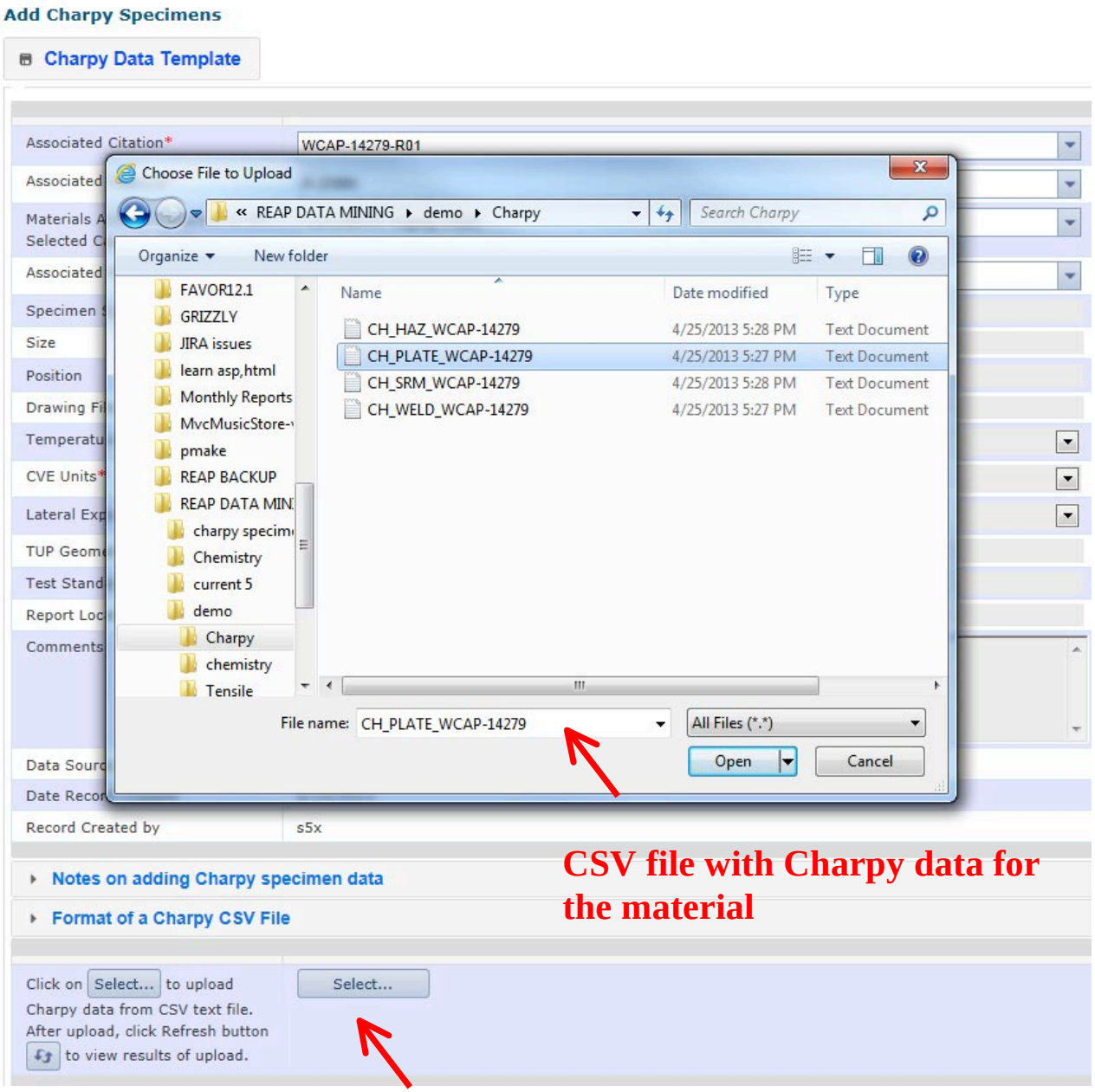
- Prepare Charpy data CSV file. See Appendix – A for details.
- Navigate to Upload Data -> “Add Charpy Specimens”



- In the form, select Associated Citation, Associated Capsule, Associated Material for which the charpy data is to be uploaded

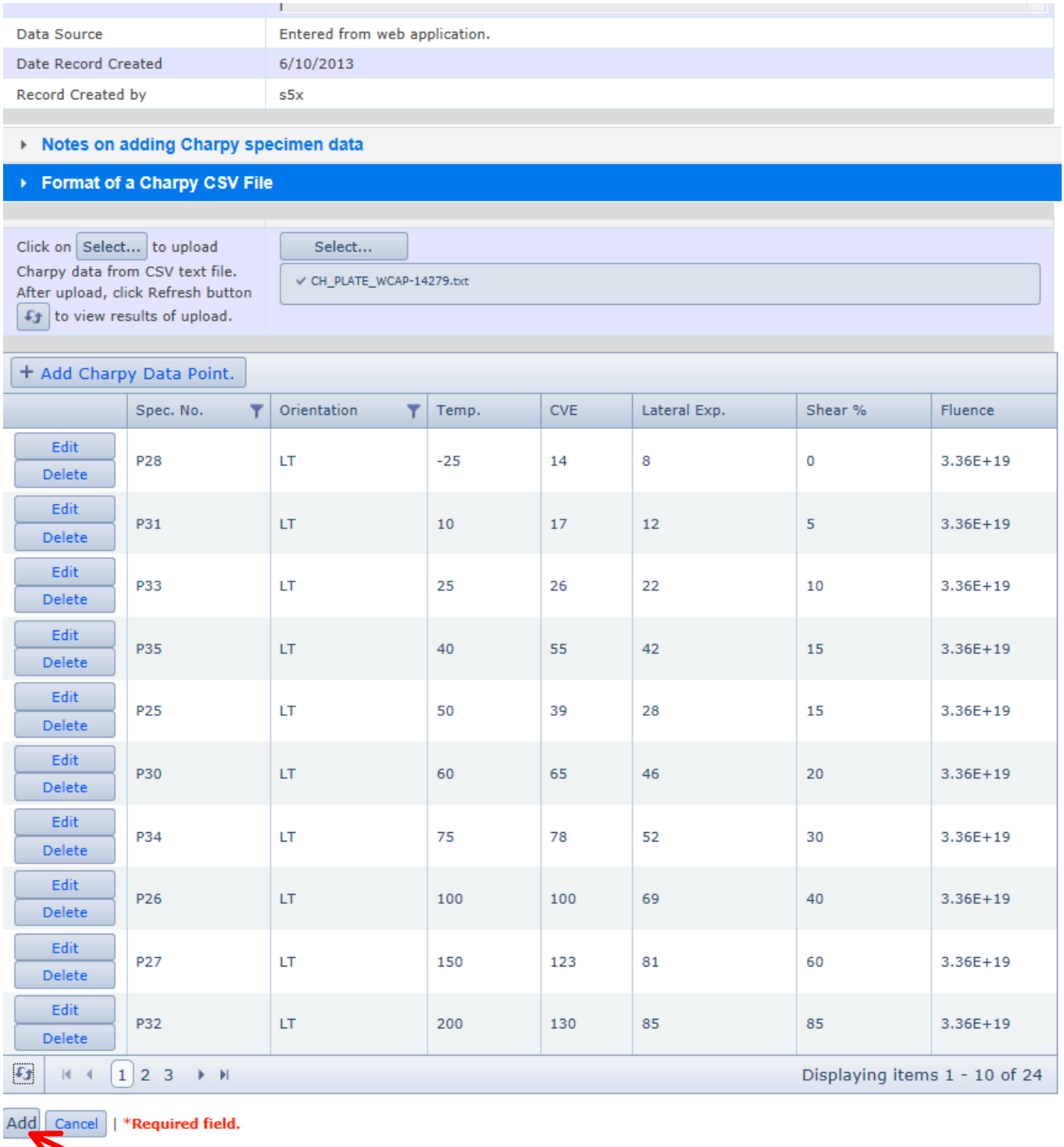


- Click on “Select …” button to upload the Charpy test data.



- Click Refresh Button to view the results of upload.
- Click “Add” to complete the upload of Charpy data.

NOTE: REPEAT THESE STEPS FOR ALL MATERIALS IN THE CAPSULE.



Data Source	Entered from web application.
Date Record Created	6/10/2013
Record Created by	s5x

Notes on adding Charpy specimen data

Format of a Charpy CSV File

Click on Select... to upload Charpy data from CSV text file. After upload, click Refresh button to view results of upload.

Select...

CH_PLATE_WCAP-14279.txt

+ Add Charpy Data Point.

	Spec. No.	Orientation	Temp.	CVE	Lateral Exp.	Shear %	Fluence
Edit Delete	P28	LT	-25	14	8	0	3.36E+19
Edit Delete	P31	LT	10	17	12	5	3.36E+19
Edit Delete	P33	LT	25	26	22	10	3.36E+19
Edit Delete	P35	LT	40	55	42	15	3.36E+19
Edit Delete	P25	LT	50	39	28	15	3.36E+19
Edit Delete	P30	LT	60	65	46	20	3.36E+19
Edit Delete	P34	LT	75	78	52	30	3.36E+19
Edit Delete	P26	LT	100	100	69	40	3.36E+19
Edit Delete	P27	LT	150	123	81	60	3.36E+19
Edit Delete	P32	LT	200	130	85	85	3.36E+19

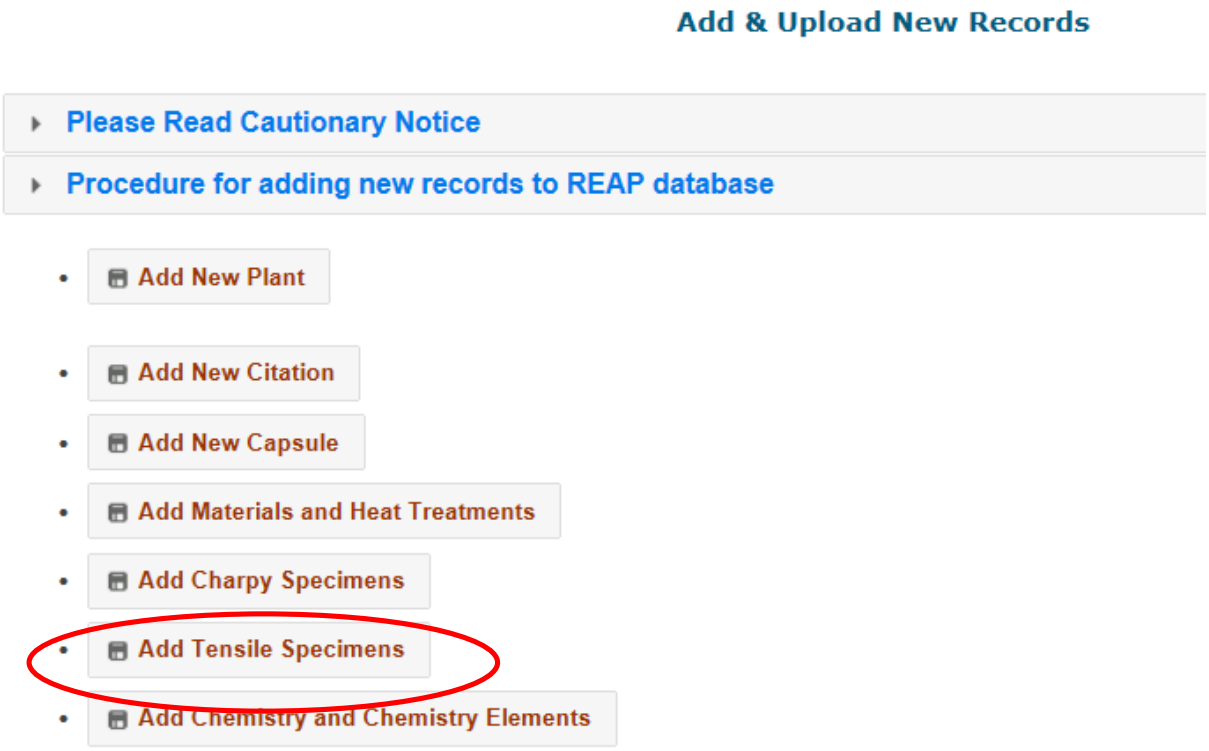
1 2 3 Displaying items 1 - 10 of 24

Add Cancel | *Required field.

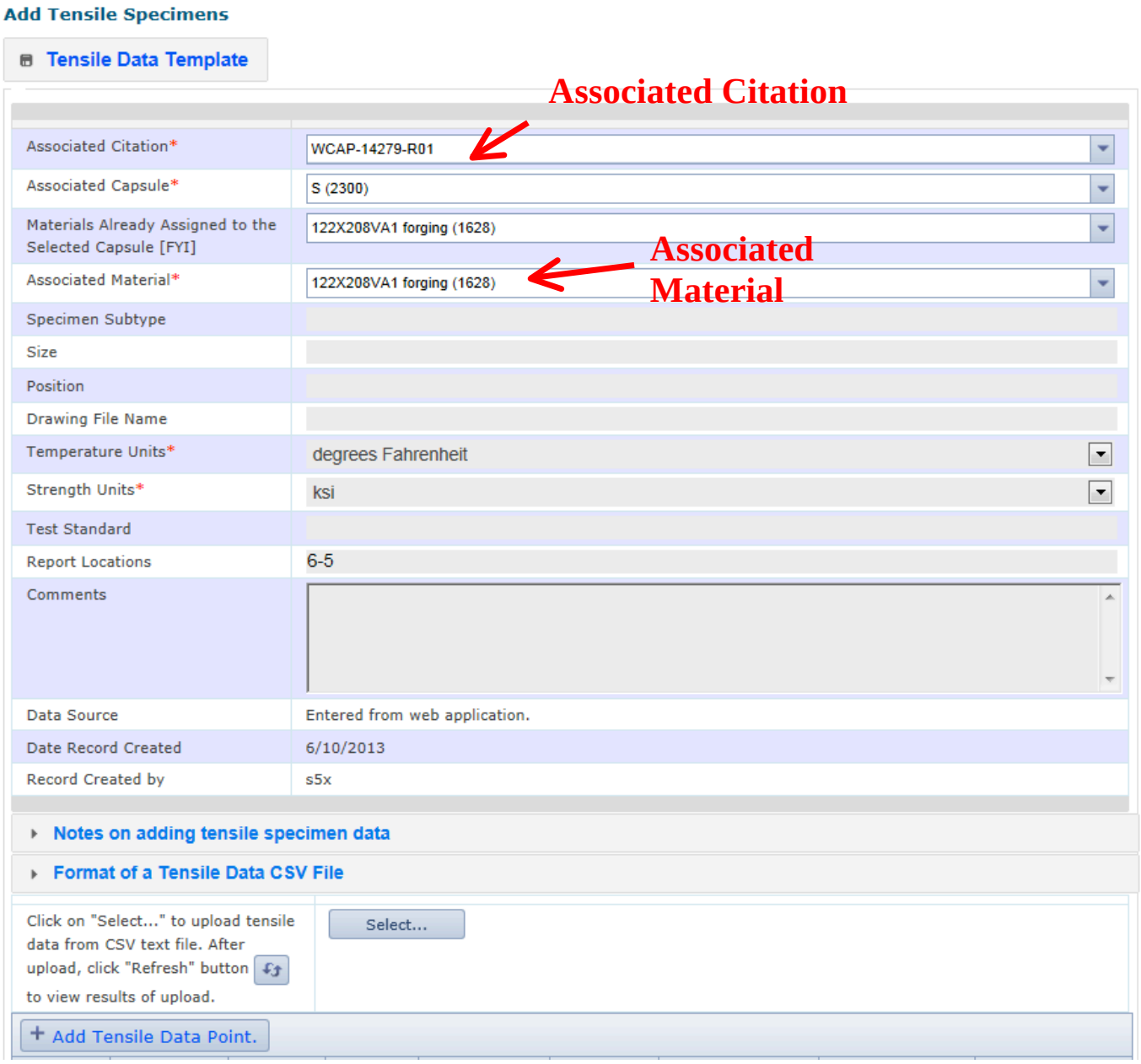
Hit add to finish upload of Charpy data

5.7 Step 7. Add Tensile Data

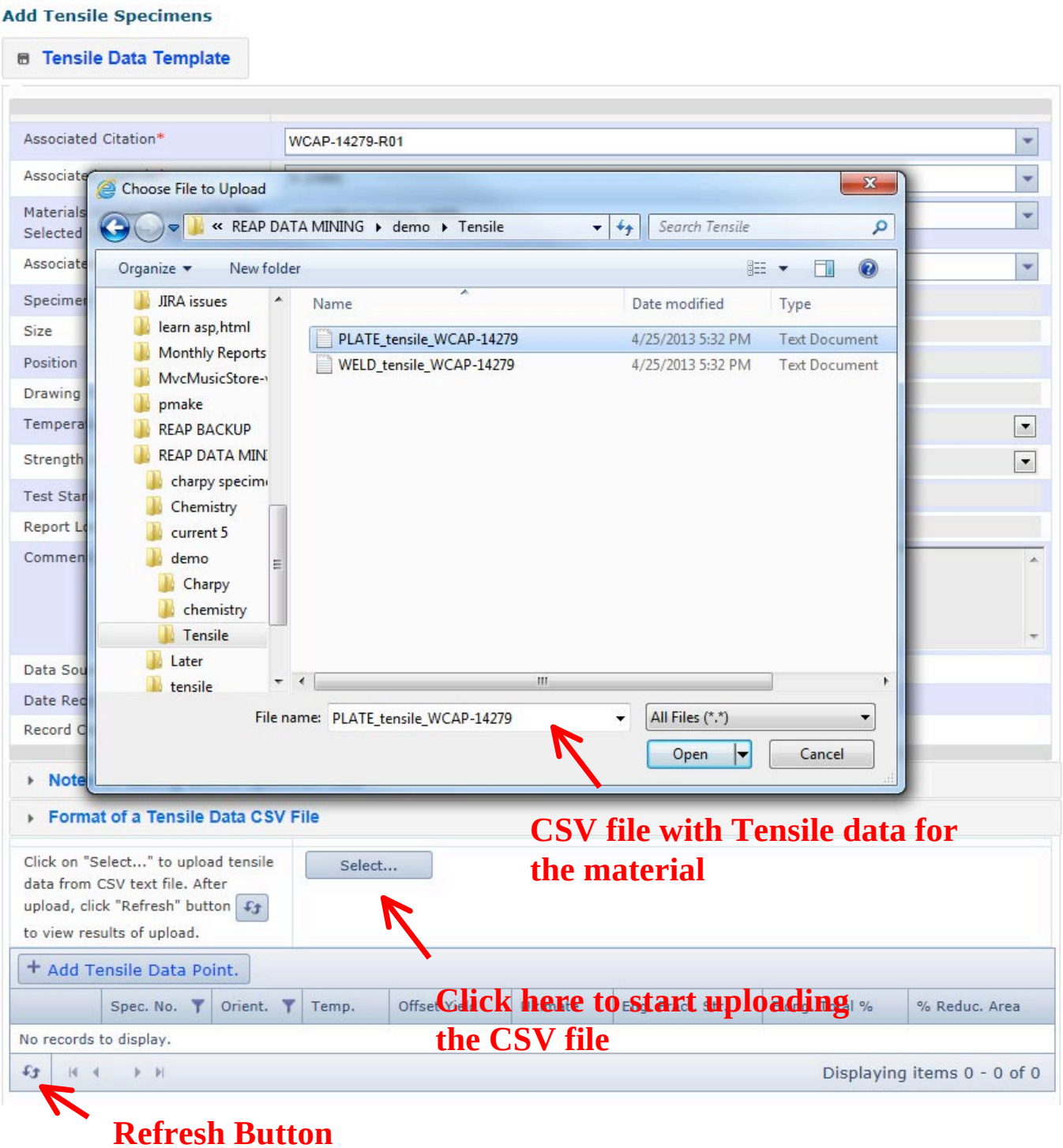
- Prepare Tensile data CSV file. See Appendix – B for details.
- Navigate to Upload Data -> “Add Tensile Specimens”



- In the form, select Associated Citation, Associated Capsule, Associated Material for which the Tensile data is to be uploaded

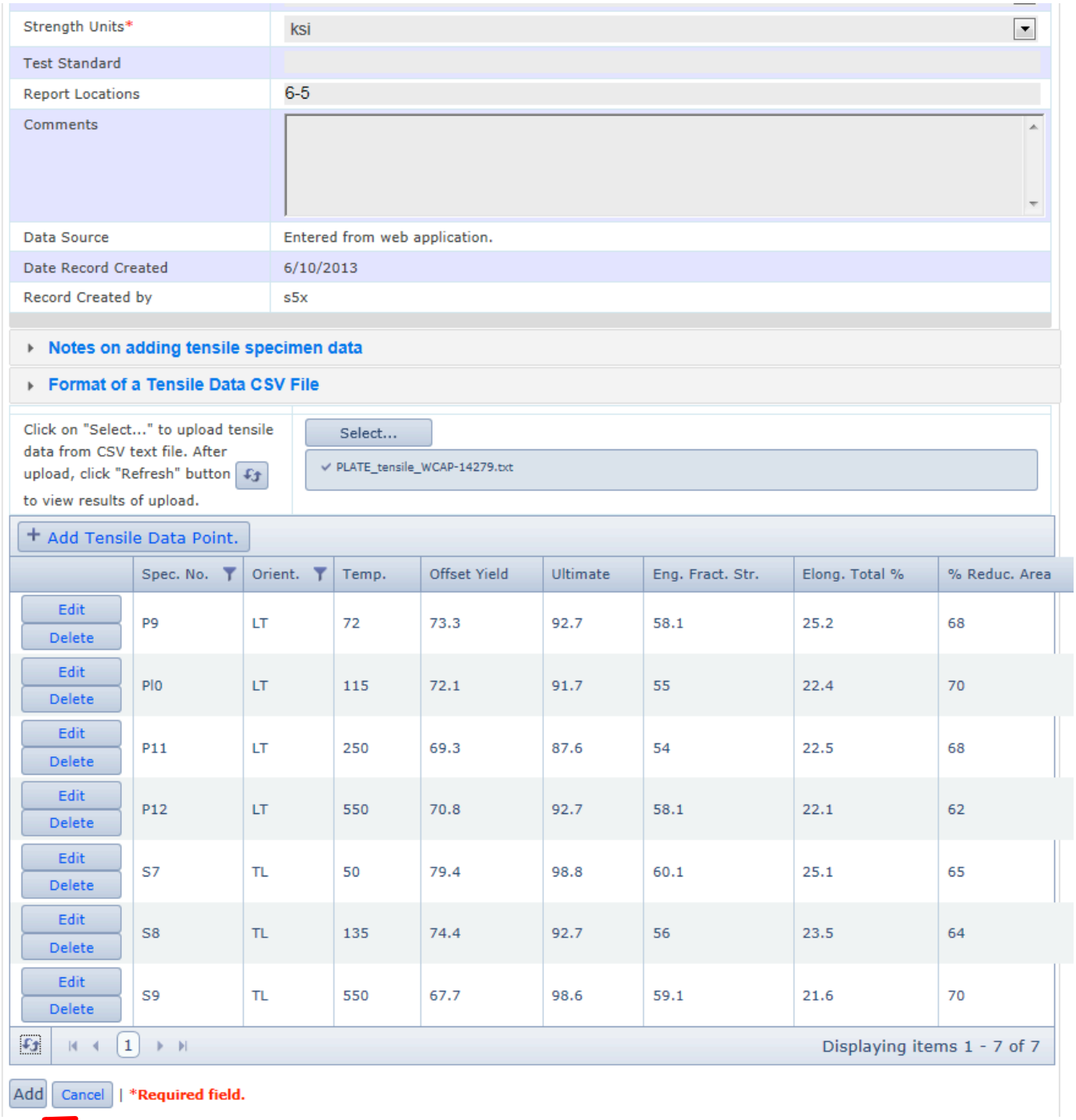


- Click on “Select …” button to upload the Tensile test data.



- Click Refresh Button to view the results of upload.
- Click “Add” to complete the upload of tensile data.

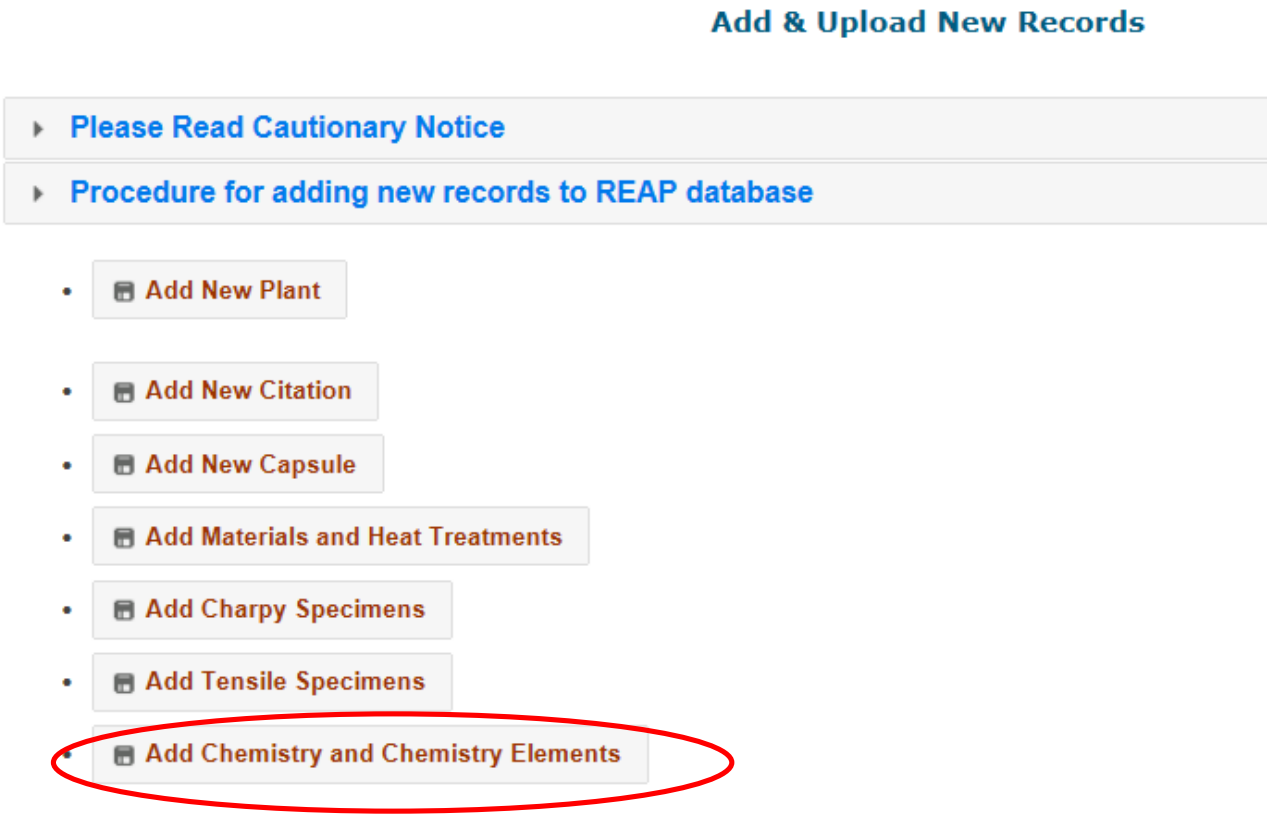
NOTE: REPEAT THESE STEPS FOR ALL MATERIALS IN THE CAPSULE.



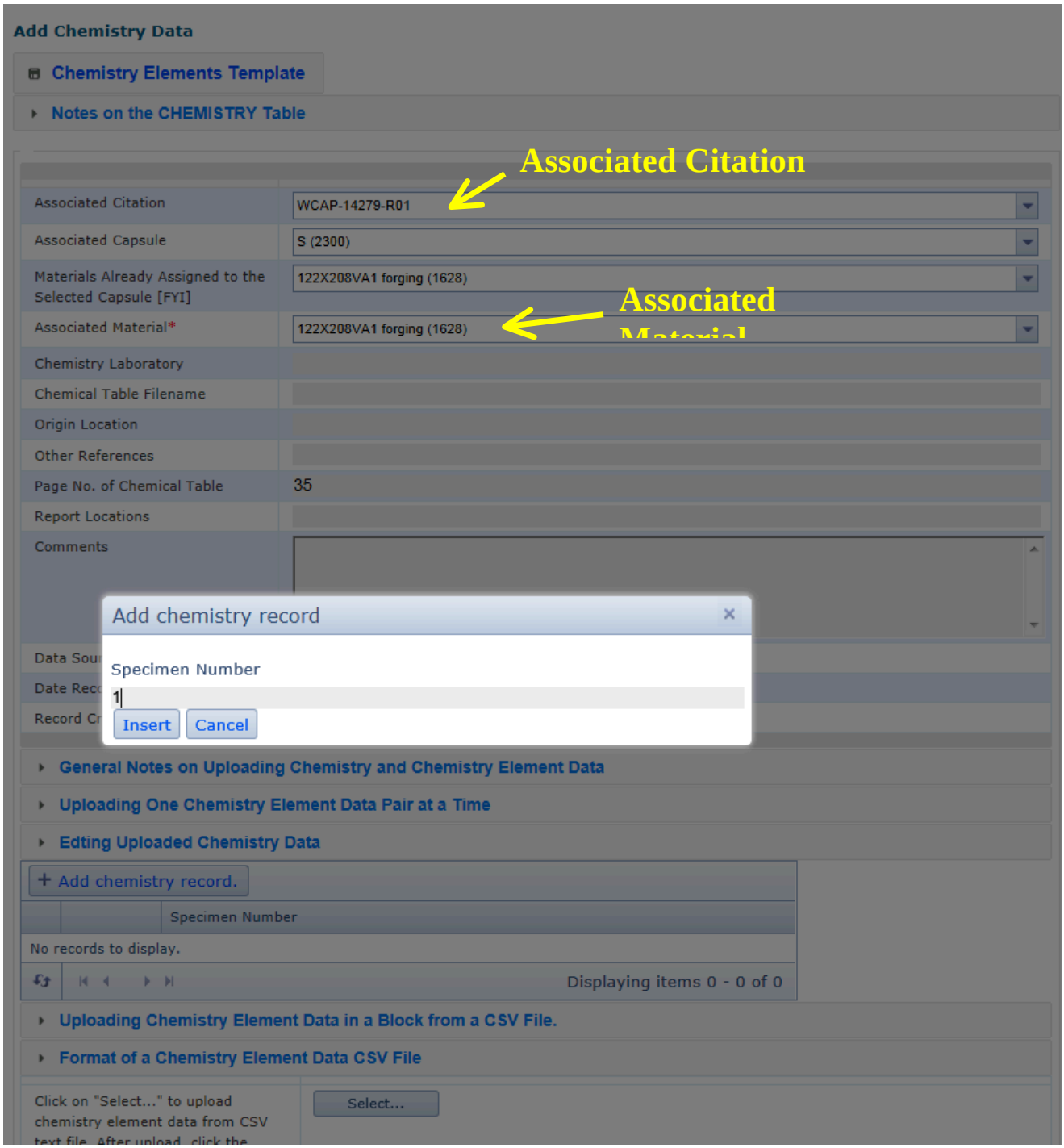
Hit add to finish upload of Tensile data

5.8 Step 8. Add Chemistry Data

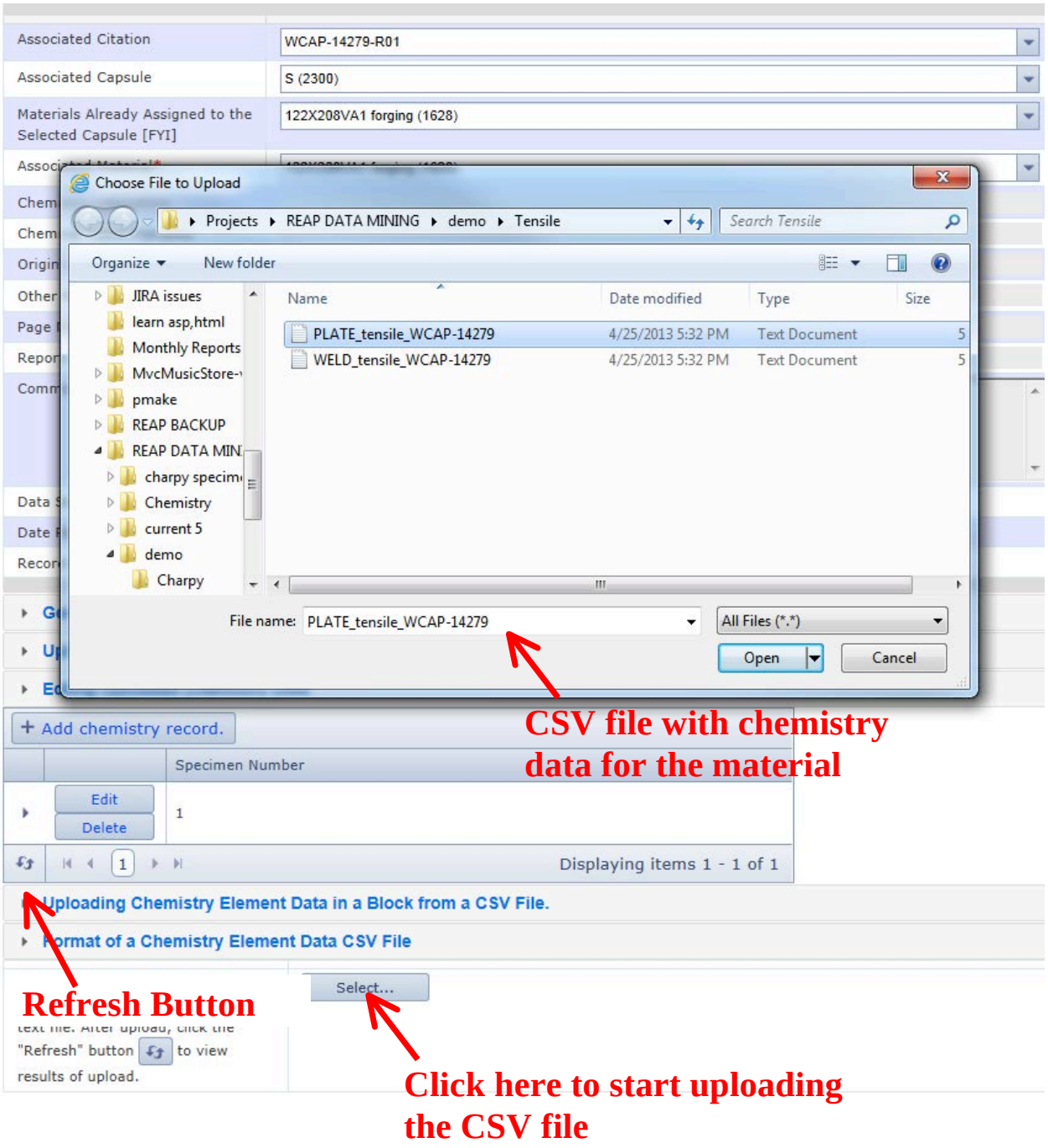
- Prepare Charpy data CSV file. See Appendix – C for details.
- Navigate to Upload Data -> “Add Chemistry and Chemistry Elements”



- In the form, select Associated Citation, Associated Capsule, Associated Material for which the Chemistry data is to be uploaded
- After that, click on the "+ Add chemistry record" to insert the specimen number



- Click on “Select …” button to upload the Chemistry data.



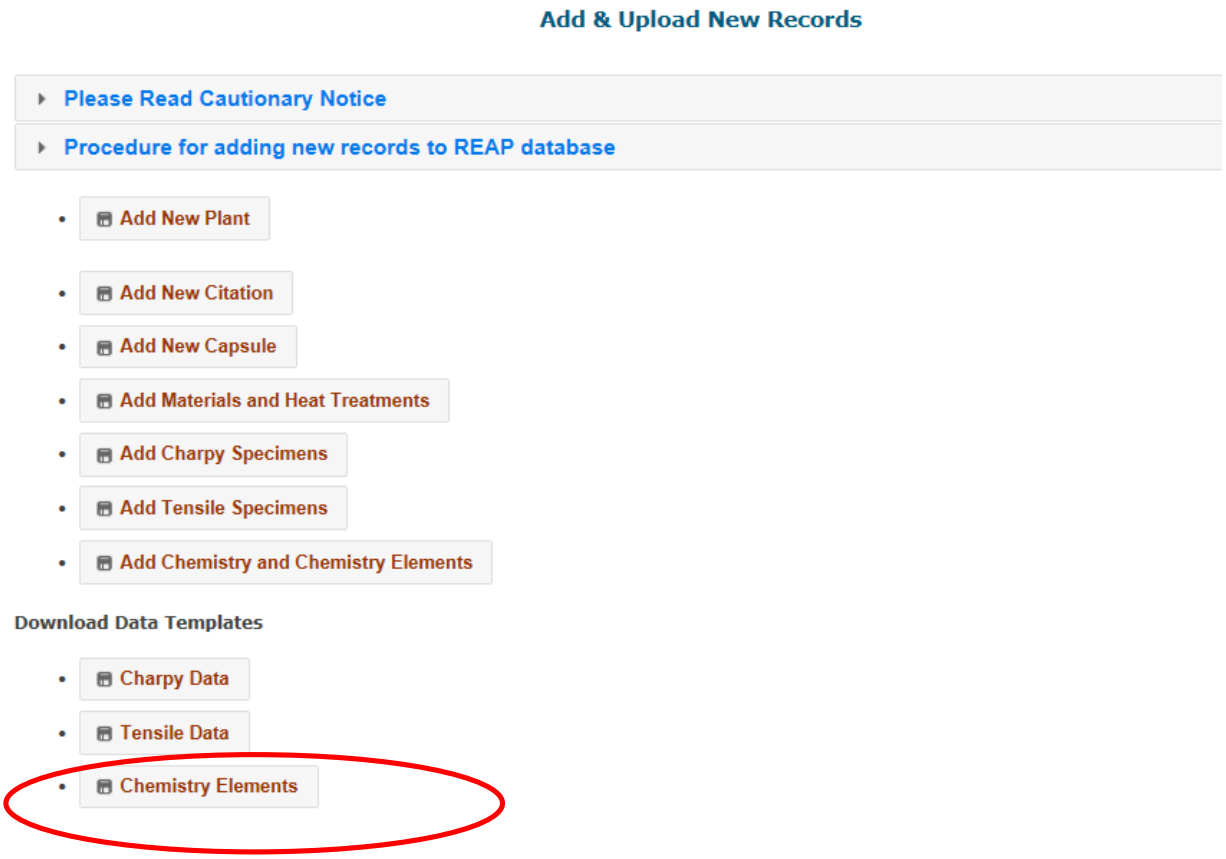
- Click Refresh Button to view the results of upload.
- Click “Add” to complete the upload of tensile data.

NOTE: REPEAT THESE STEPS FOR ALL MATERIALS IN THE CAPSULE.

5.9 Preparing CSV file for Charpy data

- Navigate to Upload Data

- Download “Charpy Data” Template



- Copy the Charpy data from the citation and arrange into the format required of CSV file.

Specimen orientation

Fluence value

Table 5-3 Charpy V-notch Data for the Kewaunee Intermediate Shell Forging 122X208VA1 Irradiated to a Fluence of 3.36 x 10^{19} n/cm^2 (E > 1.0 MeV) (Tangential Orientation)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	(°F)	(°C)	(ft-lb)	(J)	(mils)	(mm)	(%)
P28	-25	-32	14	19	8	0.20	0
P31	10	-12	17	23	12	0.30	5
P33	25	-4	26	35	22	0.56	10
P35	40	4	55	75	42	1.07	15
P25	50	10	39	53	28	0.71	15
P30	60	16	65	88	46	1.17	20
P34	75	24	78	106	52	1.32	30
P26	100	38	100	136	69	1.75	40
P27	150	66	123	167	81	2.06	60
P32	200	93	130	176	85	2.16	85
P29	200	93	142	193	81	2.06	100
P36	300	149	154	209	85	2.16	100

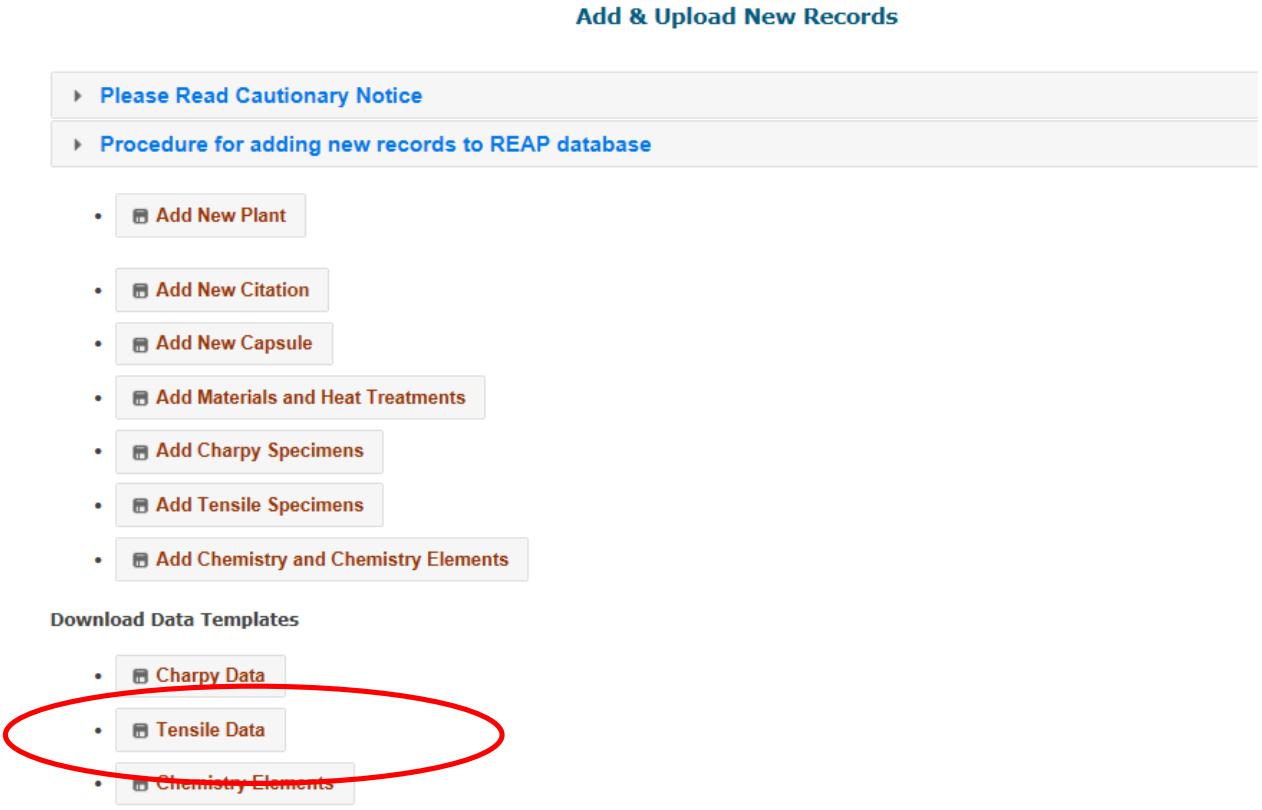
Typical Charpy test results table

```
63  ** replace examples records shown be
64  ** the data from the current citatic
65  ************************************
66  P28,LT,-25,14,8,0,3.36E+19
67  P31,LT,10,17,12,5,3.36E+19
68  P33,LT,25,26,22,10,3.36E+19
69  P35,LT,40,55,42,15,3.36E+19
70  P25,LT,50,39,28,15,3.36E+19
71  P30,LT,60,65,46,20,3.36E+19
72  P34,LT,75,78,52,30,3.36E+19
    P26,LT,100,100,69,40,3.36E+19
    P27,LT,150,123,81,60,3.36E+19
    P32,LT,200,130,85,85,3.36E+19
76  P29,LT,200,142,81,100,3.36E+19
77  P36,LT,300,154,85,100,3.36E+19
78  S31,TL,-50,13,8,0,3.36E+19
79  S33,TL,-25,36,24,10,3.36E+19
80  S27,TL,-10,5,4,0,3.36E+19
81  S35,TL,-5,69,51,20,3.36E+19
82  S30,TL,0,48,35,10,3.36E+19
83  S36,TL,10,37,26,10,3.36E+19
84  S26,TL,50,48,35,15,3.36E+19
85  S28,TL,75,87,60,25,3.36E+19
86  S29,TL,100,115,76,50,3.36E+19
87  S34,TL,150,154,91,100,3.36E+19
88  S25,TL,200,147,90,100,3.36E+19
89  S32,TL,300,156,77,100,3.36E+19
```

CSV Data File

5.10 Preparing CSV file for Tensile data

- Navigate to Upload Data
- Download “Tensile Data” Template



- Copy the tensile data from the citation and arrange into the format required of CSV file.

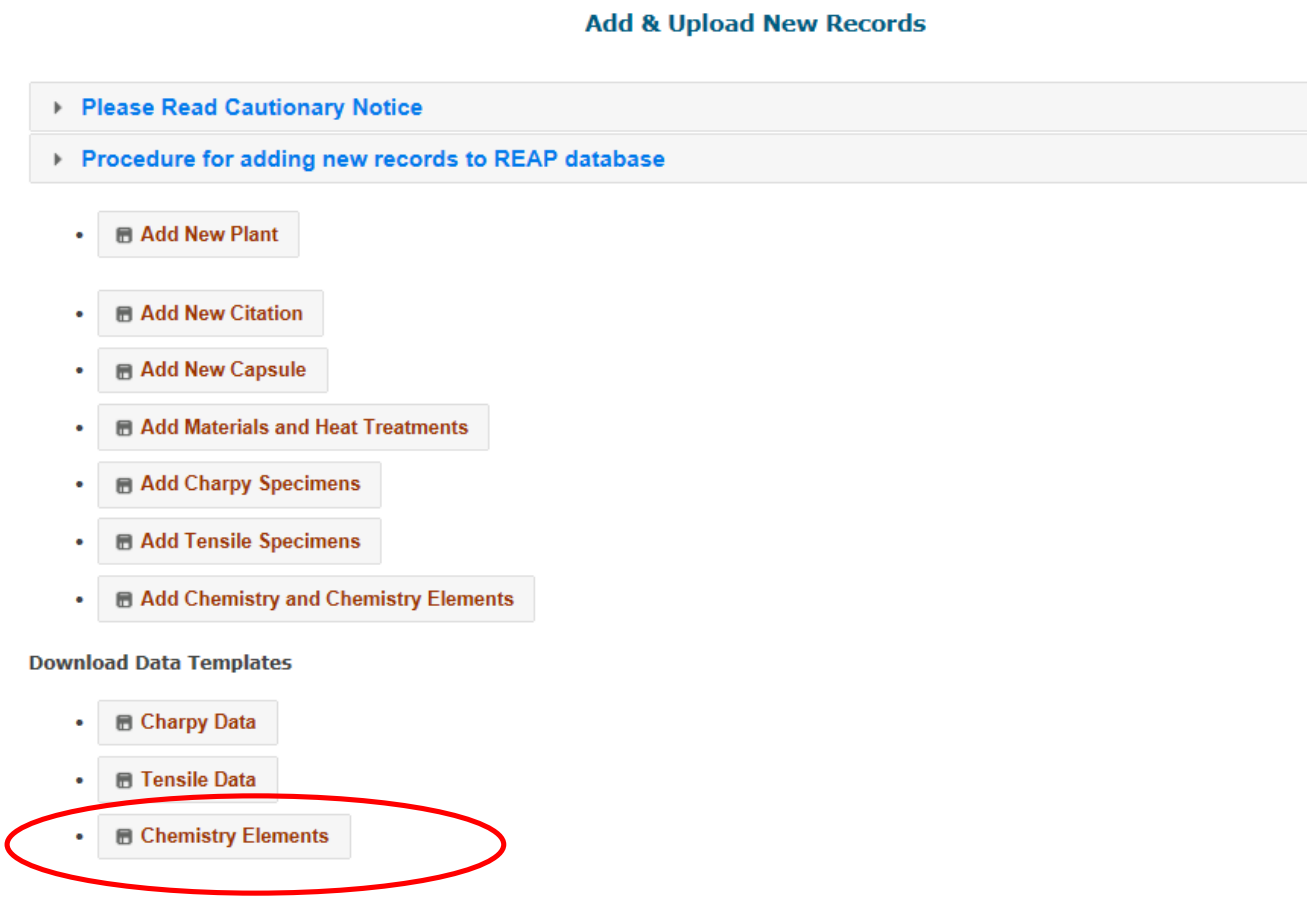
Table 5-9 Instrumented Charpy Impact Test Results for the Kewaunee Lower Shell Forging 123X167VA1 Irradiated to a Fluence of 3.36×10^{19} n/cm^2 (E > 1.0 MeV) (Tangential Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			Yield Load P_{cy} (lbs)	Time to Yield t_{cy} (µsec)	Max. Load P_M (lbs)	Time to Max. t_M (µsec)	Fast Fract. Load P_f (lbs)	Arrest Load P_A (lbs)	Yield Stress σ_y (ksi)	Flow Stress (ksi)
			Charpy E_D/A	Max. E_M/A	Prop. E_f/A								
S31	-50	13	105	61	44	3952	0.19	4234	0.22	4234	217	131	136
S33	-25	36	290	260	30	3919	0.16	4910	0.53	4909	120	130	147
S27	-10	5	40	18	22	2673	0.12	2673	0.12	2673	148	89	89
S35	-5	69	556	368	187	3651	0.18	4946	0.74	4946	209	121	143
S30	0	48	387	354	33	3878	0.18	4925	0.69	4914	76	129	146
S36	10	37	298	270	28	3670	0.18	4995	0.57	4995	179	122	144
S26	50	48	387	341	45	3524	0.18	4738	0.69	4738	148	117	137
S28	75	87	701	369	332	3551	0.18	4308	0.76	4308	323	118	138
S29	100	115	926	360	566	3372	0.18	2946	0.76	2946	736	112	134
S34	150	154	1240										
S25	200	147	1184										
S32	300	156	1256										

```
70
71  ** replace examples shown below with                **
72  ** the data from the current citation                **
73  ************************************************************
74  P9,LT,72,NOT_REPORTED,NOT_REPORTED,73.3,92.7,178.7,58.1,NOT_REPORTED,11.3,25.2,68,3.3600E+19
75  P10,LT,115,NOT_REPORTED,NOT_REPORTED,72.1,91.7,181.8,55,NOT_REPORTED,10.5,22.4,70,3.3600E+19
76  P11,LT,250,NOT_REPORTED,NOT_REPORTED,69.3,87.6,166.2,54,NOT_REPORTED,9.8,22.5,68,3.3600E+19
77  P12,LT,550,NOT_REPORTED,NOT_REPORTED,70.8,92.7,151,58.1,NOT_REPORTED,9,22.1,62,3.3600E+19
78  S7,TL,50,NOT_REPORTED,NOT_REPORTED,79.4,98.8,172.6,60.1,NOT_REPORTED,11.3,25.1,65,3.3600E+19
79  S8,TL,135,NOT_REPORTED,NOT_REPORTED,74.4,92.7,155.6,56,NOT_REPORTED,9.3,23.5,64,3.3600E+19
80  S9,TL,550,NOT_REPORTED,NOT_REPORTED,67.7,98.6,195.3,59.1,NOT_REPORTED,9,21.6,70,3.3600E+19
```

5.11 Preparing CSV file for Chemistry data

- Navigate to Upload Data
- Download “Chemistry Elements” Data Template



Material type

Table 4-1 Chemical Composition (wt%) of the Kewaunee Reactor Vessel Beltline Region Surveillance Material[3]

Element	Intermediate Shell Forging 122X208VA1	Lower Shell Forging 123X167VA1	Weld Metal
C	0.21	0.20	0.12
Si	0.25	0.28	0.20
Mo	0.58	0.58	0.48
Cu	0.06	0.06	0.219[a]
Ni	0.71	0.75	0.724[a]
Mn	0.69	0.79	1.37
Cr	0.40	0.35	0.090
V	<0.02	<0.02	0.0
Co	0.011	0.012	<0.0
Sn	0.01	0.01	0.004
Ti	<0.001	<0.001	<0.001
Zr	0.001	0.001	<0.001
As	0.001	0.004	0.004
Sb	<0.001	0.001	0.001
S	0.011	0.009	0.011
P	0.01	0.01	0.016
Al	0.004	0.006	0.010
B	<0.003	<0.003	<0.003
N_2	0.006	0.010	0.012
Zn	--	--	<0.001

Typical chemistry elements table

```
49  **       citation, use "not_reported"
50  **       as shown below.
51  **
52  ****************************************
53  ** replace examples records shown below
54  ** the data from the current citation
55  ****************************************
56  C,0.21
57  Si,0.25
58  Mo,0.58
59  Cu,0.06
60  Ni,0.71
61  Mn,0.69
62  Cr,0.4
63  V,<0.02
64  Co,0.011
65  Sn,0.01
66  Ti,<0.001
67  Zr,0.001
68  As,0.001
69  Sb,<0.001
70  S,0.011
71  P,0.01
72  Al,0.004
73  B,<0.003
74  N,,0.006
75  Zn,-
```

CSV Data File

- Copy the Chemistry data from the citation and arrange into the format required of CSV file.