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ORIGEN-ARP: A New Windows PC Package for ORIGEN Users

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SUMMARY
The SCALE staff at ORNL has created the ORIGEN-ARP isotope generation and depletion code system to satisfy a need for an easy-to-use standardized method of isotope depletion/decay analysis for spent nuclear fuel (SNF), fissile material, and other radioactive material. It can be used to solve for isotopic inventory, radiation source terms, and decay heat. ORIGEN-ARP features the Origen Express form that enables a user to set up and run a calculation (including plots) in less than one minute. It was released from the Radiation Safety Information Computational Center (RSICC) in July 2001 as code package CCC-702.

ORIGEN-ARP runs on Pentium PCs under Windows 95/NT or later. The ORIGEN-ARP package has its own web site and user notebook at http://www.ornl.gov/origen-arp.

I. HISTORICAL BACKGROUND
Starting with the original ORIGEN code[1] as a common predecessor, the ORIGEN-S (Ref. 2) and ORIGEN2 (Ref. 3) codes were developed in the late 1970's for isotopic depletion/decay and source term analyses. ORIGEN-S was distributed as part of the SCALE (Standardized Computer Analyses for Licensing Evaluations) code system.[4] ORIGEN2 was released as a standalone code package. Both have been widely used for radiation source term analyses. Although ORIGEN-S and ORIGEN2 both solve the same point depletion and decay equations in the same manner,[5] they were independently developed with different primary objectives.

The primary objective of ORIGEN2 was to perform a broad range of fuel cycle analyses with simple input specifications and a few select cross-section data libraries (e.g., two libraries for all PWRs). The changes in cross sections caused by reactor operating history and assembly design were deemed of minimum importance based on the broad nature of the fuel cycle studies at the heart of the ORIGEN2 development. Consequently, reliance on ORIGEN2 for results that are highly sensitive to cross-section variations has become a recurring problem. Note that the ORIGEN2.1 package has not been updated since 1991.

Conversely, ORIGEN-S was developed with less attention to user input simplification but a focus on providing a flexible and efficient interface with neutronic codes that would provide burnup-dependent cross sections based on assembly design information. The capability for accurate assembly-specific cross sections was based on the use of the SCALE SAS2H (Ref. 6) /ORIGEN-S sequence. Although the SAS2H sequence provided input that was rather simple, the computing time for a depletion case using SAS2H was about two orders of magnitude greater than that for ORIGEN2 because of the time required by the neutronics codes to generate the burnup-dependent cross sections. Thus the computing speed and ease-of-use provided by ORIGEN2 together with its simple installation made it a prime choice for many users who were willing to sacrifice the rigor provided by SAS2H.

To effectively address the user community needs for computational speed and accuracy for a wide range of reactor conditions and assembly designs, the ORIGEN-ARP methodology was developed in the mid- to late-1990's (Ref. 7). ARP accurately produces ORIGEN-S libraries at any enrichment, burnup, and moderator density for a specific fuel assembly design. The ARP methodology successfully addressed the ORIGEN2 problem for results that are highly sensitive to cross-section variations. This methodology was initially released in SCALE 4.4. However, this version used an old MS-DOS interface that would not run on many

Windows PCs and was only available to SCALE users.

II. ORIGEN-ARP PACKAGE

A standalone, fast, accurate, and easy-to-use ORIGEN package was still needed. In 2001, the OrigenArp for Windows graphical user interface (GUI) was completed. This user-friendly input menu program provides ORIGEN users with tools for rapid setup, execution, and viewing of results. In addition, the new OPUS post-processing utility[8] for ORIGEN-S and PlotOPUS Windows plotting program[8] gives users the ability to easily display the results of interest in tabular and plotted formats.

These new GUIs and utilities were combined with the ORIGEN-ARP methodology to create the initial release of ORIGEN-ARP as a standalone code package in July 2001 (Ref. 9). It contains an updated version of the SCALE-4.4a ORIGEN-S and ARP codes, and a small subset of the modules, data libraries, and miscellaneous utilities from SCALE-4.4a that are used by ORIGEN-S and ARP.

This paper will focus on the new GUI and plotting programs that make the ORIGEN-ARP package a state-of-the-art tool for radiation source term generation.

A. OrigenArp for Windows

The OrigenArp for Windows GUI provides menus, toolbars, forms, and online help that assist the user in preparing an input file to execute ARP, ORIGEN-S, and OPUS. Included in the GUI is a simplified input form referred to as Origen Express (Figure 1) that requires as few as four key input parameters (fuel type, enrichment, burnup, and average power level). In less than one minute a user can set up and run an ORIGEN-ARP case.

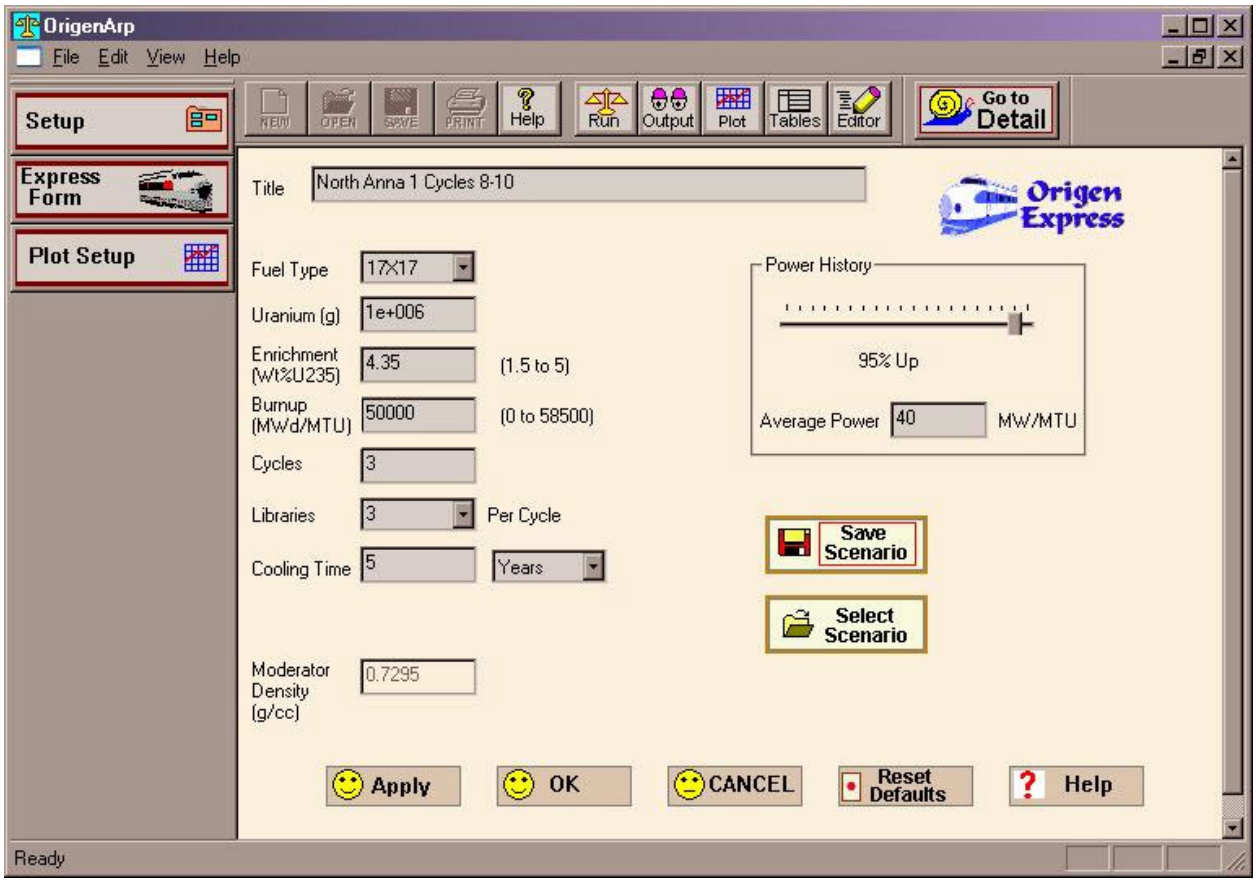

Figure 1. Origen Express form.

Once the user has specified the parameters on the Origen Express form, several options are available. Pressing the Plot Setup button allows the user to request one or more plots of the results. The **Run** button immediately executes the case. After the case has run, the **Output** button opens the output file for viewing in the user-specified text editor, and the **Tables** button opens all tables of results generated by OPUS. The **Plots** button displays the requested plots in PlotOPUS.

The user can modify the ORIGEN input created by Origen Express or create a specific irradiation/decay history via the **Go to Detail** button. The detailed input forms available include

- **Compositions**
- **Neutron Groups**
- **Gamma Groups**
- **Case Data**
- **Summary**
- **Plot Setup.**

The **Compositions** form (Figure 2) provides pull-down menus to specify all nuclides in the problem. OrigenArp can calculate the uranium loading automatically via the Origen Express form or the **Set Enrichment** button. The user specifies the grams of uranium and the enrichment, and the GUI fills in the values for U-234, U-235, U-236, and U-238.

The **Neutron Groups** and **Gamma Groups** are simple screens that allow the user to select the energy group structure for the neutron and gamma source terms from lists of commonly used multigroup library structures for shielding calculations. In addition, the user may explicitly specify any energy group structure. This feature makes ORIGEN-ARP a powerful tool for generating radiation source terms for any multigroup shielding analysis.

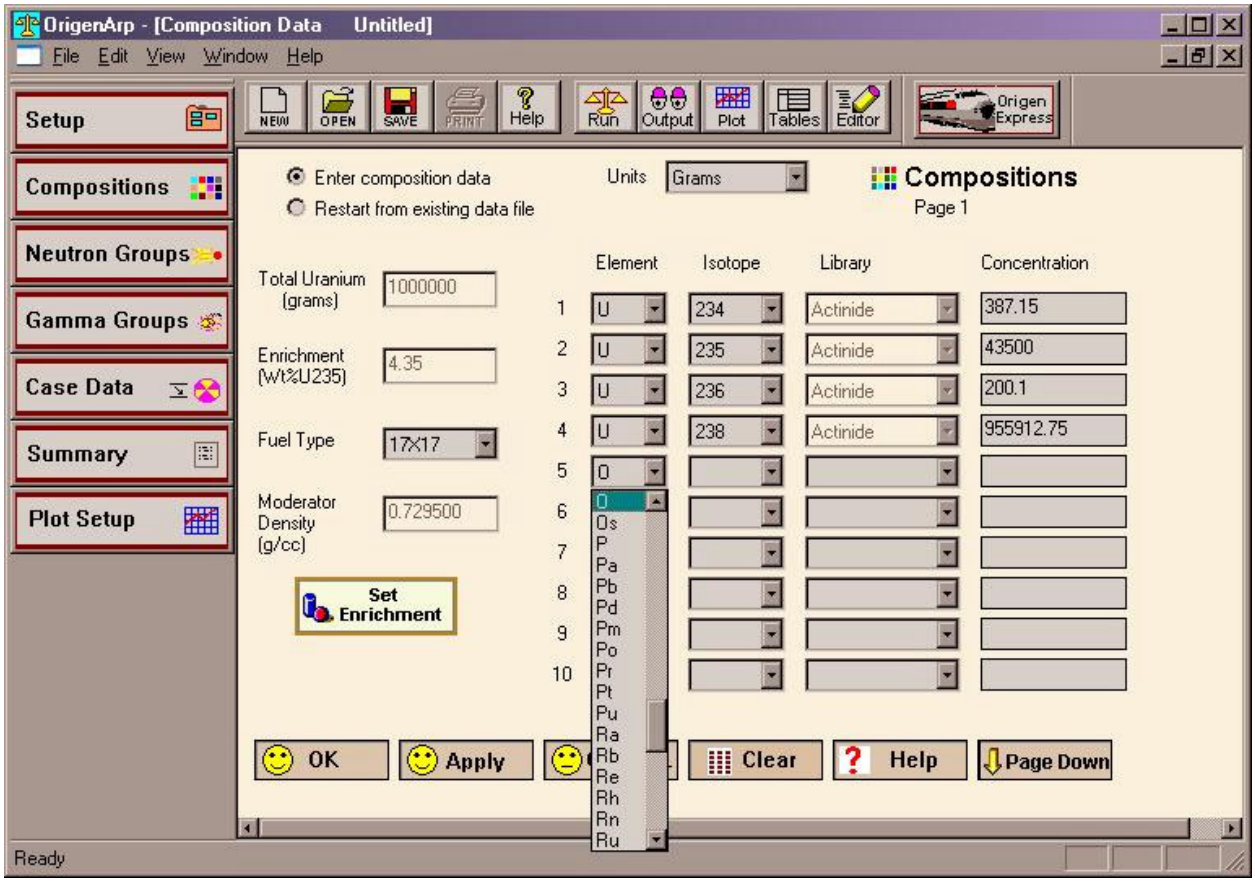

Figure 2. OrigenArp Composition Data form.

Case Data contains two forms: **Irradiation Case** and **Decay Case**. The **Irradiation Case** form (Figure 3) contains the power level and time data for each step in a case. The **Fill Form** button allows the user to specify the average power level and the total time, and it will automatically divide the time into ten equal increments. The **Save Results** checkbox must be marked if the data from that step is to be plotted. Other options include time units, insert or delete case, and output options.

Similarly, the **Decay Case** form (Figure 4) specifies the time for each step in a decay case. Once again, the Fill Form button will fill all ten timesteps for the user based on the final time. The decay case timesteps are calculated based on the "Rule-of-Three's" which says that each time step in a decay case should be approximately three times as large as the previous step. This rule is used to follow the exponential behavior versus time of radioactive decay.

The **Plot Setup** form (Figure 5) provides a wide selection of plot types and options for displaying results using OPUS and PlotOPUS. Six plot types are available:

- Nuclides
- Elements
- Gamma spectra
- Total Neutron spectra
- (Alpha, n) spectra
- Spontaneous fission spectra.

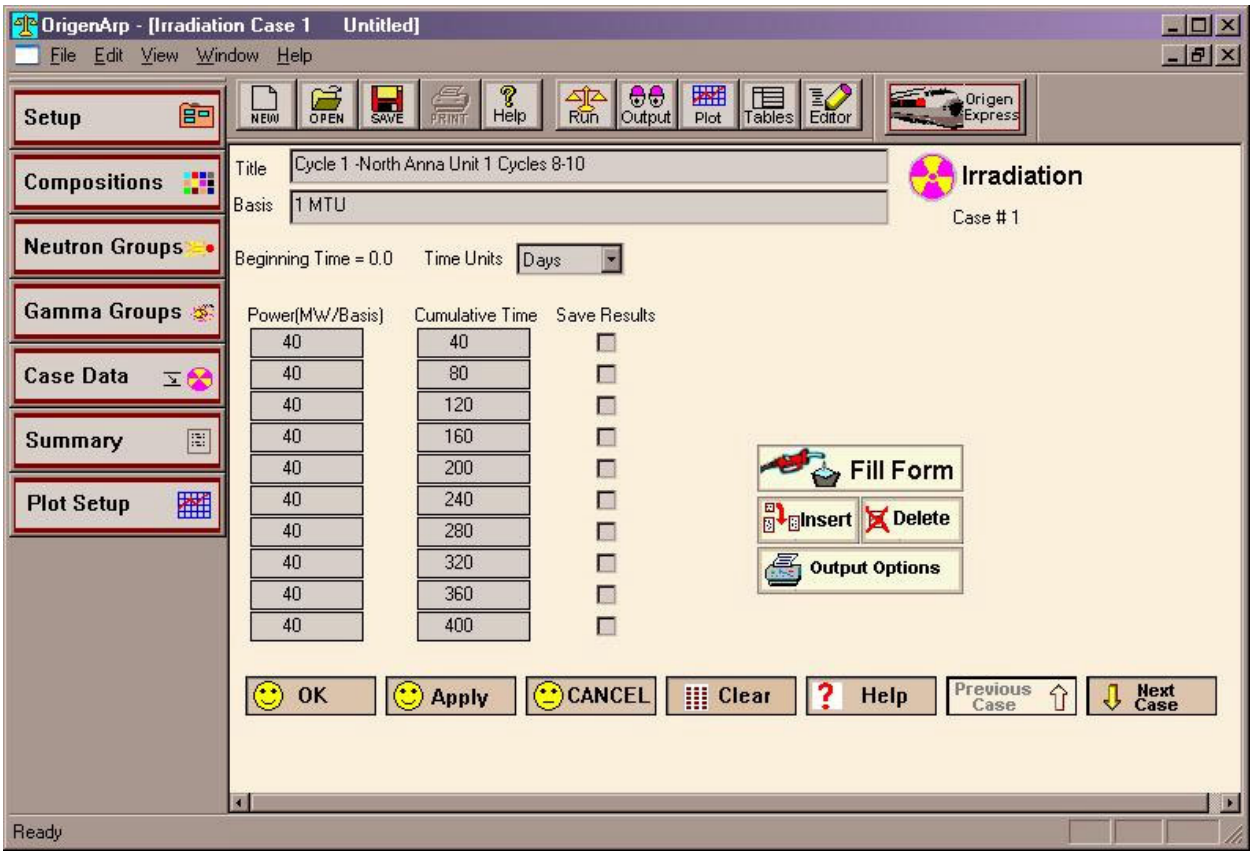

Figure 3. OrigenArp Irradiation Case form.

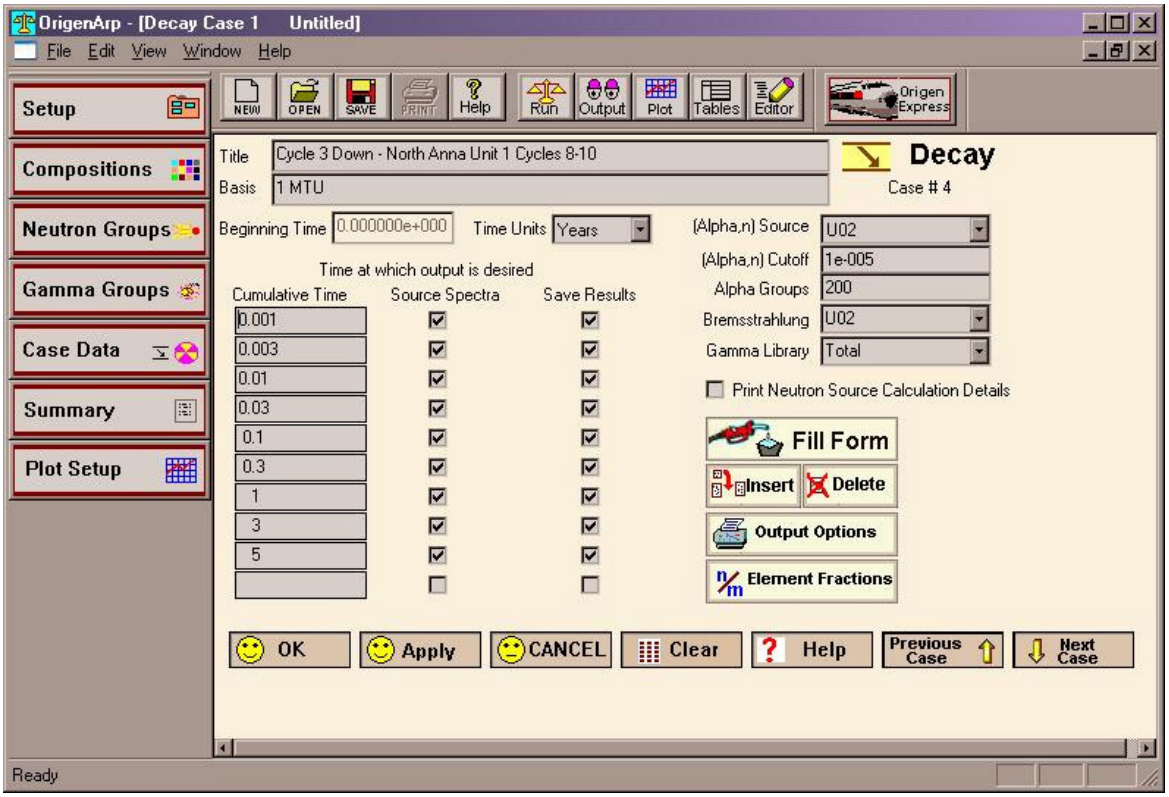

Figure 4. OrigenArp Decay Case form.

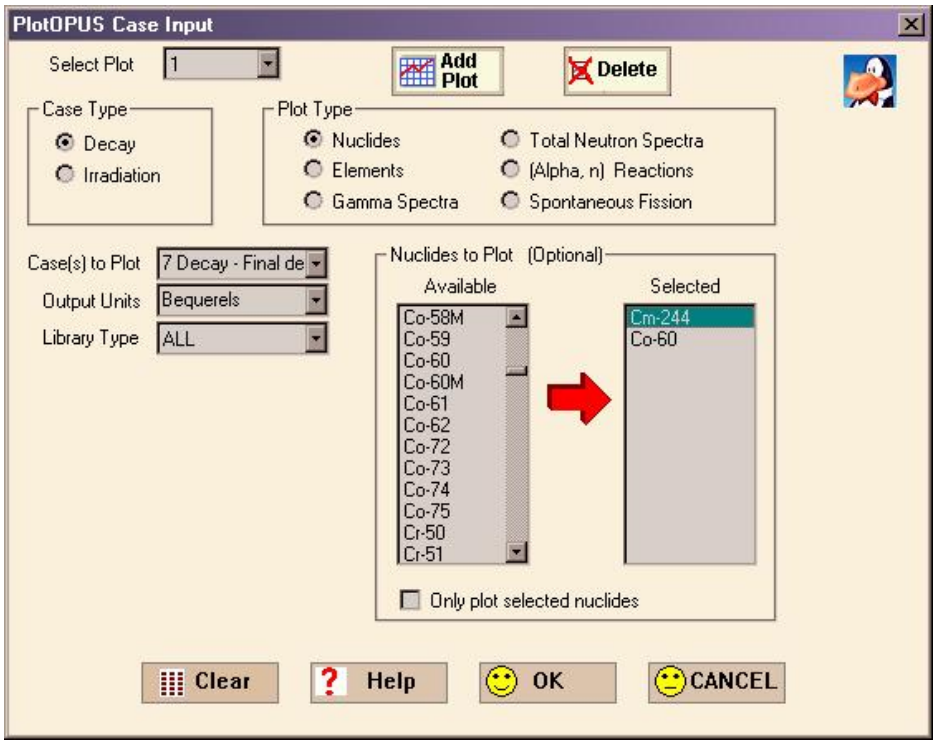

Figure 5. OrigenArp Plot Setup form.

The output units include

- Gram-atoms
- Grams
- Curies
- Bequerels
- Kilograms
- Atom %
- Weight %
- Total watts
- Gamma watts
- Atoms/bn-cm
- Grams/cm^3
- Absorptions
- Photons/sec/MeV
- Energy/sec/MeV
- Neutrons/sec/MeV.

B. OPUS/PlotOPUS

The OPUS utility program reads and processes the ORIGEN-S results that have been saved on a binary file and produces an ASCII output file that can be used for making a variety of plots. Tables containing individual and total nuclide or element concentrations may be generated as a function of time. Three classes of plot data may be produced by OPUS: (1) dominant or selected isotopes or elements, (2) photon and neutron source spectra, and (3) comparisons of output results from different ORIGEN-S cases. The input is designed for ease of use with keyword names and commonly used default values. One of the key features of OPUS is its ability to automatically extract the most dominant nuclides or elements in the problem, rank them using the output parameter and time periods of interest as specified by the user, and give the total. The selection, ranking, and totals may be generated for any group of nuclides including actinides, fission products, or activation products, or for all nuclides in the problem. The totals are printed for all nuclides in the specified group, and a subtotal is generated for all nuclides in the printed nuclide-ranking list. The user may also specify any nuclide or element to be included in the output. The results may be ranked and listed using any of 16 different units, some of which are not available in ORIGEN-S.

The output data produced by OPUS are designed to be displayed by the PlotOPUS graphics-plotting program. PlotOPUS is an interactive Windows program that reads the OPUS output data file and plots the data. It can save the plot images in JPEG (JPG), Windows metafile (WMF), or bitmap (BMP) files. A sample plot of curies versus time for a 10,000-year decay is shown in Figure 6. PlotOPUS allows the user to select which nuclides to plot from the ORIGEN-S/OPUS data. In addition, the user can customize the plot by changing many parameters such as

- Plotting method
- Numeric precision
- Grid lines
- Data labels
- Line color and thickness
- Symbols
- Fonts
- Data labels

PlotOPUS also offers a zoom feature. The user can drag the mouse to draw a rectangle over a portion of the plot. The program will then display a zoomed view of that area.

III. CONCLUSIONS

The ORIGEN-ARP package provides ORIGEN users with state-of-the-art PC tools for quick and accurate depletion/decay analyses and generation of radiation source terms. The OrigenArp for Windows GUI provides a simple and straightforward mechanism to set up and run ORIGEN calculations via the Origen Express form or the detailed input forms. OPUS offers the capability to easily produce concise output tables of parameters of interest for the most important nuclides and/or user-specified nuclides. PlotOPUS produces interactively customizable plots that can be saved and incorporated into reports or presentations. With a few mouse clicks, a user can execute a case, view the output, and display customized plots.

Version 2.0 of the ORIGEN-ARP software package is scheduled to be available from the Radiation Safety Information Computational Center (RSICC) in March 2002. This version will include the new version of ORIGEN-S with the upgraded neutron source capabilities discussed in Ref. 10 at this meeting.

The ORIGEN-ARP package has its own web site and user notebook at http://www.ornl.gov/origen-arp.

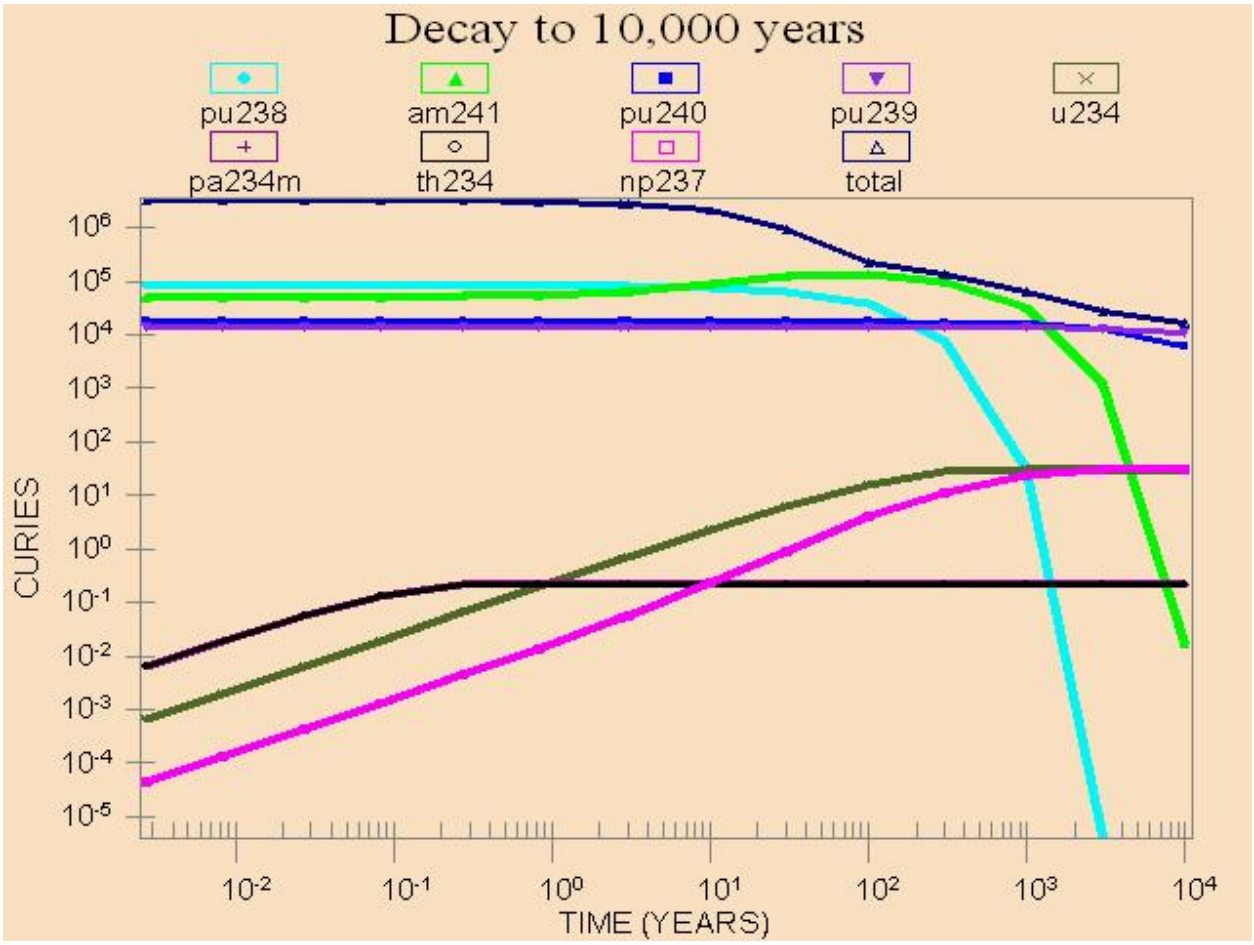

Figure 6. Sample PlotOPUS plot.

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REFERENCES

1. M.J. Bell, *ORIGEN – The ORNL Isotope Generation and Depletion Code*, ORNL-4628 (CCC-217), Union Carbide Corp., Nuclear Division, Oak Ridge National Laboratory, May 1973.

2. O.W. Hermann and R.M. Westfall, "ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms," Vol. II, Sect. F7 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 6 (ORNL/NUREG/CSD-2/R6), Vols. I, II, and III, May 2000. Available from Radiation Safety Information Computational Center at Oak Ridge National Laboratory as CCC-545.

3. A.G. Croff, *A User's Manual for the ORIGEN2 Computer Code*, ORNL/TM-7175, Union Carbide Corporation, Oak Ridge National Laboratory, July 1980. Available from Radiation Safety Information Computational Center at Oak Ridge National Laboratory as CCC-371.

4. *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 6 (ORNL/NUREG/CSD-2/R6), Vols. I, II, and III, May 2000. Available from Radiation Safety

Information Computational Center at Oak Ridge National Laboratory as CCC-545.
5. C.V. Parks, "Overview of ORIGEN2 and ORIGEN-S: Capabilities and Limitations," Vol. 1, pp. 57–64 in *Proc. of the Third International Conference on High Level Radioactive Waste Management*, April 12–16, 1992, Las Vegas, NV.
6. O.W. Hermann and C.V. Parks, "SAS2H: A Coupled One-Dimensional Depletion and Shielding Analysis Module," Vol. I, Sect. S2 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 6 (ORNL/NUREG/CSD-2/R6), Vols. I, II, and III, May 2000. Available from Radiation Safety Information Computational Center at Oak Ridge National Laboratory as CCC-545.
7. S.M. Bowman and L.C. Leal, *ORIGEN-ARP, A Fast and Easy-to-Use Source Term Generation Tool*, in *Proc. of ICRS-9 — Ninth International Conference on Radiation Shielding*, October 17–22, 1999, Tsukuba, Japan.
8. I.C. Gauld, D.L. Barnett, O.W. Herman, and S.M. Bowman, *OPUS/PlotOPUS: An ORIGEN-S Post-Processing Utility and Plotting Program for SCALE*, NUREG/CR-6718 (ORNL/TM-2001/26), U.S. Nuclear Regulatory Commission, Oak Ridge National Laboratory, April 2001.
9. *ORIGEN-ARP 1.00: Isotope Generation and Depletion Code System — Matrix Exponential Method with GUI and Graphics Capability*, RSICC code package CCC-702.
10. I.C. Gauld, E.F. Shores, and R.T. Perry, "New Neutron Source Algorithms in the ORIGEN-S Code," in *Proc. of the 12th Biennial RPSD Topic Meeting*, Santa Fe, NM, April 14–18, 2002 (2002).