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Title: Temperature Profile of the Solution Vessel of an Accelerator-Driven Subcritical Fissile Solution System

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Temperature Profile of the Solution Vessel of an Accelerator-Driven Subcritical Fissile Solution System

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Introduction

Dynamic System Simulation (DSS) models of fissile solution systems have been developed and verified against a variety of historical configurations[1]. DSS techniques have been applied specifically to subcritical accelerator-driven systems using fissile solution fuels of uranium[2]. Initial DSS models were developed in DESIRE, a specialized simulation scripting language[3]. In order to tailor the DSS models to specifically meet needs of system designers they were converted to a Visual Studio implementation[4] and one of these subsequently to National Instrument's LabVIEW for human factors engineering and operator training[5].

Specific operational characteristics of subcritical accelerator-driven systems have been examined using a DSS model tailored to this particular class using fissile fuel[6]. A parameter of particular interest to the operation of these systems is the temperature profile in the fuel at power. This is due to the fact that fissile solution fueled systems of any variety exhibit strong negative reactivity feedback due to fuel temperature and radiolytic gas generated void. To assist in understanding temperature profile in fuel DSS models all incorporate features to graphically present a view of this profile. Figure 1 is a capture from the Visual Studio simulation showing the temperature profile over time of ten regions, sliced vertically, of the start-up and transition to steady-state. Region 1 is the base of the core while Region 10 is the top of the core. In this view it is seen that the rate of heating in the upper half of the core is generally more rapid than in the lower half. This is primarily due to upward transport of heat from the center of the core, which is the region of greatest neutron flux from the accelerator. Once a steady-state condition is reached the variation in core temperature markedly narrows due to core mixing.

As noted, the view presented in Figure 1 is one-dimensional in the vertical direction where the temperature in a single vertical region has been averaged. DSS models developed also provide a 2-D analysis providing a view of variation in the radial direction. Figure 2 is a graphical presentation of information extracted from the DSS database of the radial variation of temperature in each of ten vertical slabs; radial information is also sliced into ten regions; in this case each region is a torus about the central core of the vessel. Figure 3 is a two dimensional view of this same information.

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[1] "Dynamic System Simulation of Fissile Solution Systems"; LA-UR-14-22490; Robert Kimpland, Steven Klein, & Marsha Roybal; April, 2014
[2] Operating Characteristics of a Subcritical Accelerator-Driven Fissile Solution System"; LA-UR-15-25067; John Determan, Robert Kimpland, Steven Klein, & Marsha Roybal; July, 2015
[3] "Interactive Dynamic-System Simulation, Second Edition"; CRC Press, Boca Raton, FL, USA; Granino Korn; 2011.
[4] "Executable Models of Fissile Reactor Systems for Hardware Simulation and Design"; LA-UR-15-20648; John Determan, Christy Day, Steven Klein & Marsha Roybal; May, 2015
[5] "Dynamic System Simulation of Fissile Solution Systems"; LA-UR-15-22074; Christy Day & Steven Klein; 2015 Annual Meeting of the American Nuclear Society; June, 2015
[6] Operating Characteristics of a Subcritical Accelerator-Driven Fissile Solution System; LA-UR-15-25067; John Determan, Steven Klein, Robert Kimpland, & Marsha Roybal; July, 2015

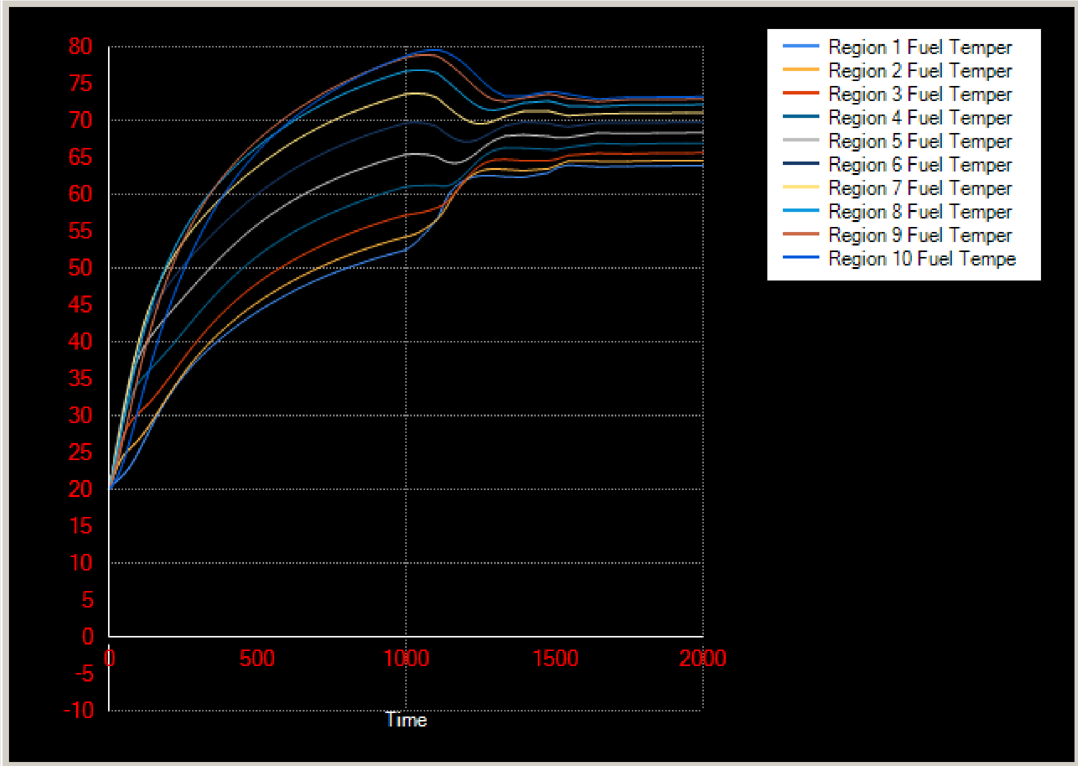


Figure 1: Vertical Temperature Profile of Start-up of an Accelerator-Driven System

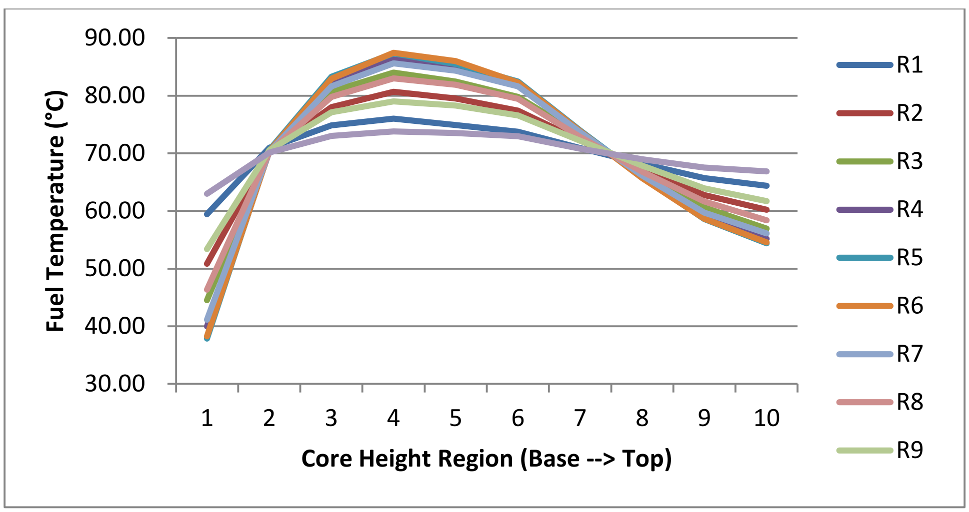


Figure 2: Radial Variation in Temperature at Steady-State

In Figures 2 and 3 the radial regions of the core are labeled R1 through R10; R1 is innermost in the annular core, while R10 is the outermost.

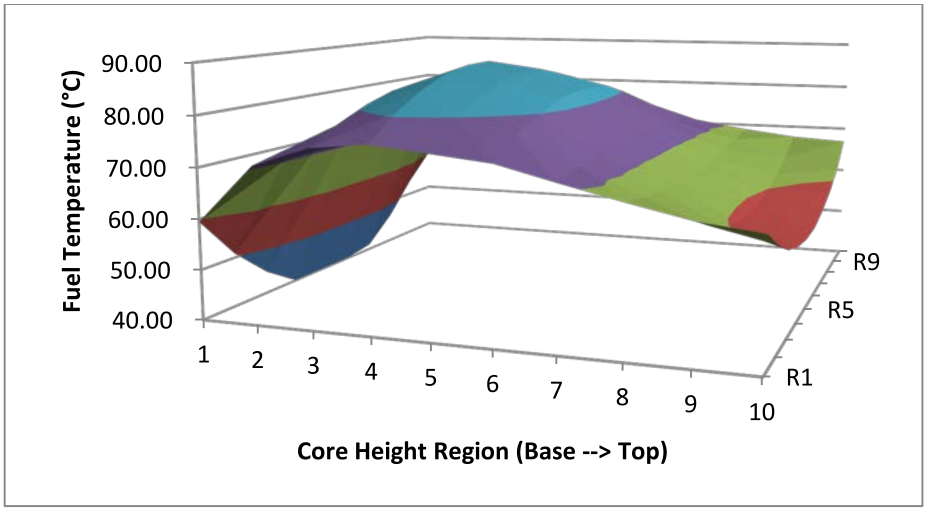


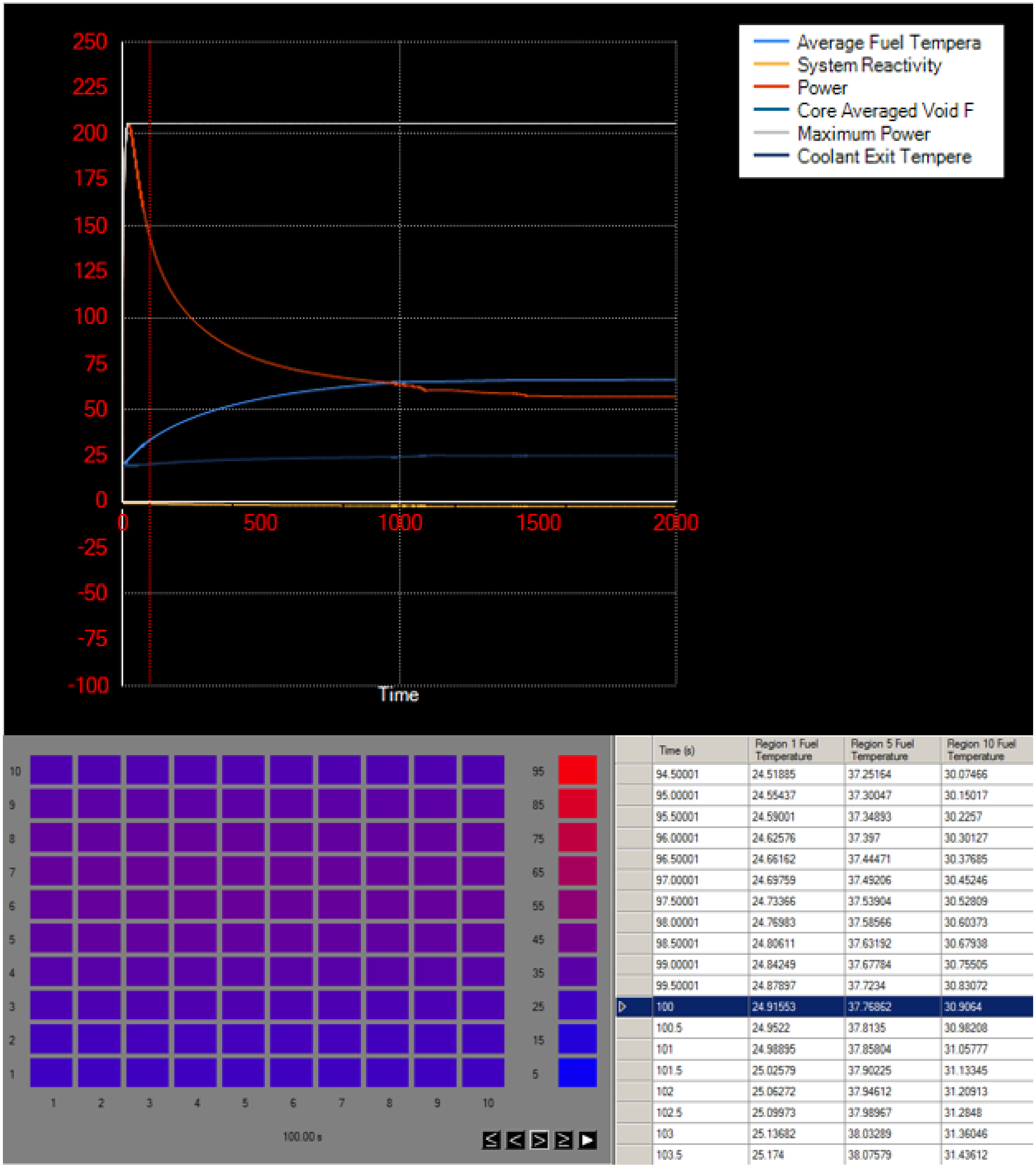
Figure 3: 2-D Temperature Profile

Dynamic Color Display

In order to provide a meaningful visual display of the evolution of the thermal profile in these systems the information displayed in the 1-D and 2-D graphs can be displayed as an aurora in color bars as an option in the Visual Studio implementation. Figures 4 and 5 are screen captures at selected times from the simulation of startup of a system, and show an amalgamation of the data plot, data table and temperature profile displays, all synchronized to the same time. Figure 4 is from 100 s. when the core temperature gradient is just beginning to be established: the table shows the temperature varying from 25 C to 38 C and back to 31 C across the height, while the profile file display indicates the temperature peak is radially central and in the upper half of the vessel. Figure 5 is from 1050 s when the core temperature gradient is near its peak: both the data table and the profile displays indicate a larger temperature gradient showing smooth increase with height. Figure 6 presents the time evolution of the core temperature profile (100 s, 250 s, and 1050 s).

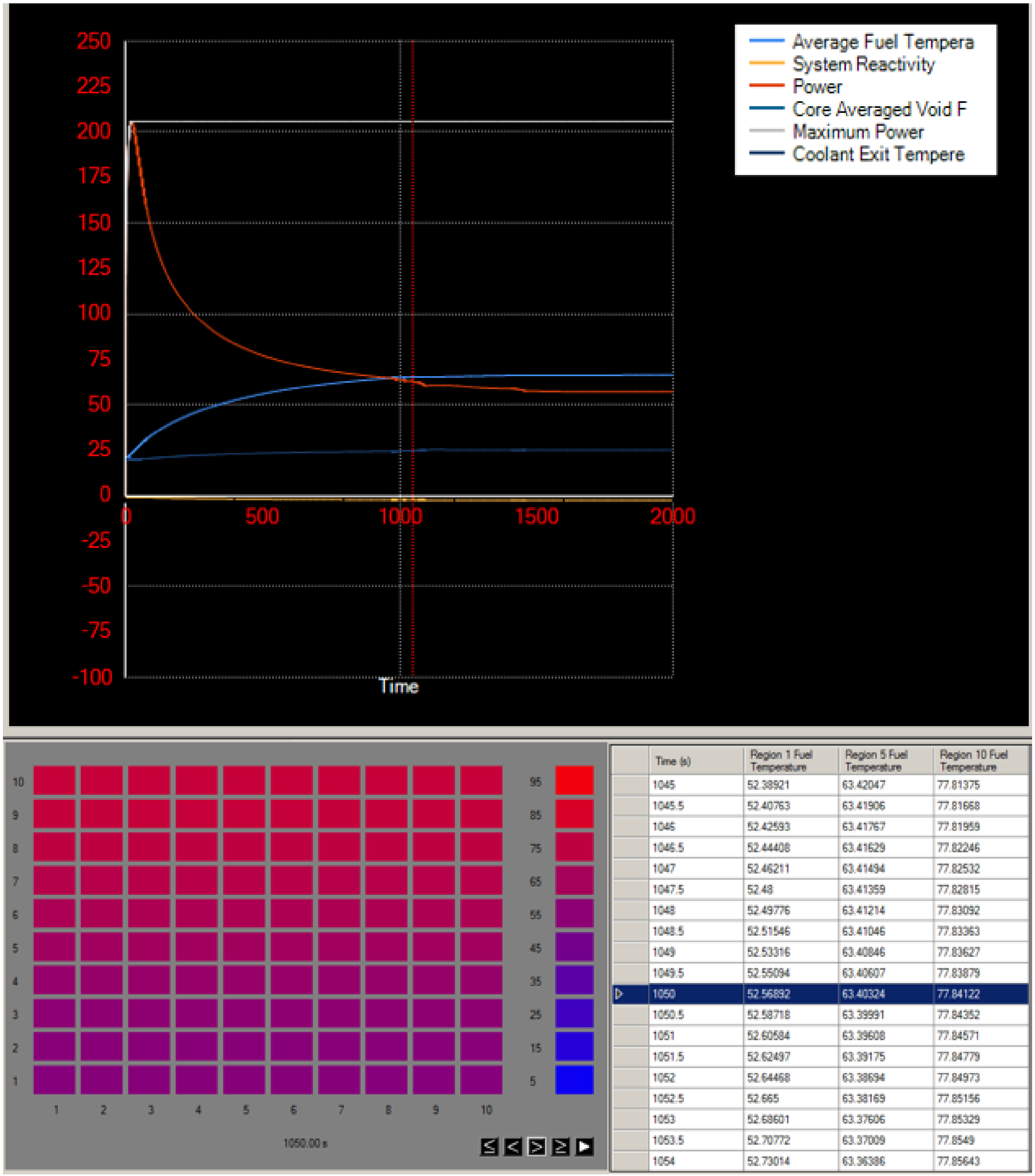
Conclusion

This work has shown that a two-dimensional array of color bars visually sums up the state of a property like temperature that can have a distribution of values across a region, and is very informative when combined with the DSS models used in this project. This technique conveys information more intuitively than any plot or combination of plots can do, and is especially helpful when viewed as an evolution over time – very much like a motion picture. Temperature is an intensive property of a system; that is, it does not depend on the size, quantity or amount of anything in the system, but instead, has a value at any arbitrarily small point (within reason) of the system. It can be reasonably expected that any other intensive properties that our equations track over a finely nodalized region can be treated in the same manner. The void fraction in the core particularly stands out as a candidate for this type of treatment. An additional action to take in representing the void fraction, however, would be to have the logarithm of the void fraction affect the opaqueness of the color bar, such that the presence of very small amounts of void could be represented.



	Time (s)	Region 1 Fuel Temperature	Region 5 Fuel Temperature	Region 10 Fuel Temperature
	94.50001	24.51885	37.25164	30.07466
	95.00001	24.55437	37.30047	30.15017
	95.50001	24.59001	37.34893	30.2257
	96.00001	24.62576	37.397	30.30127
	96.50001	24.66162	37.44471	30.37685
	97.00001	24.69759	37.49206	30.45246
	97.50001	24.73366	37.53904	30.52809
	98.00001	24.76983	37.58566	30.60373
	98.50001	24.80611	37.63192	30.67938
	99.00001	24.84249	37.67784	30.75505
	99.50001	24.87897	37.7234	30.83072
▷	100	24.91553	37.76862	30.9064
	100.5	24.9522	37.8135	30.98208
	101	24.98895	37.85804	31.05777
	101.5	25.02579	37.90225	31.13345
	102	25.06272	37.94612	31.20913
	102.5	25.09973	37.98967	31.2848
	103	25.13682	38.03289	31.36046
	103.5	25.174	38.07579	31.43612

Figure 4: Data Plot, Data Table and Temperature Profile Displays Synchronized at 100 s.



Time (s)	Region 1 Fuel Temperature	Region 5 Fuel Temperature	Region 10 Fuel Temperature
1045	52.38921	63.42047	77.81375
1045.5	52.40763	63.41906	77.81668
1046	52.42593	63.41767	77.81959
1046.5	52.44408	63.41629	77.82246
1047	52.46211	63.41494	77.82532
1047.5	52.48	63.41359	77.82815
1048	52.49776	63.41214	77.83092
1048.5	52.51546	63.41046	77.83363
1049	52.53316	63.40846	77.83627
1049.5	52.55094	63.40607	77.83879
1050	52.56892	63.40324	77.84122
1050.5	52.58718	63.39991	77.84352
1051	52.60584	63.39608	77.84571
1051.5	52.62497	63.39175	77.84779
1052	52.64468	63.38694	77.84973
1052.5	52.665	63.38169	77.85156
1053	52.68601	63.37606	77.85329
1053.5	52.70772	63.37009	77.8549
1054	52.73014	63.36386	77.85643

Figure 5: Data Plot, Data Table and Temperature Profile Displays Synchronized at 1050 s.

Figure 6: Temperature Profile Evolution: 100 s, 250 s and 1050 s.