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DEVELOPMENT OF A VBA MACRO-BASED SPREADSHEET APPLICATION FOR RELAP5 DATA POST-PROCESSING

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ABSTRACT

During the use of thermal-hydraulic codes such as RELAP5, large amount of data has to be managed in order to prepare its input data and also to analyze the produced results.
This work presents a helpful tool developed to make it easier to handle the RELAP5 output data file. The XTRIP application is an electronic spreadsheet that contains some programmed macros that should be used for post-processing the RELAP5 output file. It can directly read the RELAP5 restart-plot binary output file and, through a user-friendly interface, transient results can be chosen and exported directly into an electronic worksheet. The XTRIP program can also do some data unit conversion as well as export these data to other programs such as Wingraf, Grapher and COBRA, etc.
The main features of the developed Excel Visual Basic for Application macro as well as an example of use are presented and discussed.

1. INTRODUCTION

During last decades, several tools have been developed to help the management of the large amount of data involved when using a thermal-hydraulic code such as RELAP5 [1]. A lot of calculation is needed for its input preparation and some more effort is also needed to analyze and present the calculated results. In 1994, the TRAC-PF1 code was embedded in a User Friendly Interface [2] to control its entire use: input preparation, running and output result analysis. Unfortunately, that interface was completely dependent of the code version and need to be rewritten for newer code version.

The use of a spreadsheet is fully recommended to prepare and manage the code input data. This task could be much easier if some of the needed calculation could be automatically done by macros [3]. Programmed macros can be used to supply that interface [4] for automatically do these calculation and generate the input file for the code.

There are some tools, such as XMGR5 [5] [6] and Wingraf [7], developed to analyze the data stored by RELAP5 in its binary output file. XMGR5 is a program supplied with the RELAP5 code package that has a graphical interface written to run under X-Windows system, but it can run under Microsoft Windows by using an X-Windows emulator. On the other hand,

Wingraf run directly under Microsoft Windows. Both XMGR5 and Wingraf import, manipulate, and plot the output data from the RELAP5 code. Despite XMGR5 has a graphical interface, many of its features are controlled by command lines. Wingraf can be controlled by both, graphical interface and command line.

New users are always more comfortable using graphical interface than command lines controlled programs. Although graphical interface are easy to use for fast analysis of new problems, command line are much useful when writing batch commands to automate repetitive tasks such as to plot the same set of variables for several similar problems.

Some user prefers to use a well-known spreadsheet to analyze output data, instead of learning a new application. In this case, some tools have to be developed to help importing the RELAP5 output data since none of its file formats are directly recognized by the common used spreadsheets. The easiest option to import these data was to run the RELAP5 *strip* option to extract the data from the *restart-plot file* and, after that, running some program written to reorganize these data in some format suitable to be imported.

During the last decade the XTRIP program has been developed. Since its beginning as a unpretentious helping tool for preparing the RELAP5 *strip* input file until becoming a helpful tool for importing the *restart-plot* data directly into a Microsoft Excel worksheet, several new features have been added. Now, as XTRIP is so well integrated in the spreadsheet, we think it is ready to be shared to the others RELAP5 code users. A free copy of XTRIP, as it is, can be obtained by an e-mail requesting. Suggestions, comments and bugs reports are welcome and they will be answered as soon as possible.

The XTRIP program development is presented in this paper. In the following sections, the basic required knowledge of RELAP5, the main features of XTRIP and some tips of use are presented.

2. RELAP5 CODE REQUIRED BASIC KNOWLEDGE

The RELAP5 is a “best-estimate” computer program mainly used for thermal-hydraulic calculation of nuclear power plants transients and accidents as well as many other plant thermal-hydraulic problems. It solves, through a semi-implicit numerical scheme, a one-dimensional non-homogeneous non-equilibrium set of conservation equations for mass, momentum and energy of a two-phase system.

The RELAP5 modeling of a thermal-hydraulic system is based on a set of numbered components and heat conducting structures. Among all of them, the simplest components are a single control volume (*snglvol*) and a single junction (*sngljun*). More complex components are combinations of these two components plus some component specific model plus a better organized way to enter the component data than for several single individual components. For example, the *pipe* component is an one-dimensional array of up to ninety nine single control volumes and a set of internal single junctions connecting each two adjacent control volumes; the *valve* component is a single junction plus some additional model to consider area and pressure drop changes; the *pump* is one single control volume plus two single junctions plus pump homologous curves, the *branch* is one single control volume plus up to nine single junctions; etc.

A typical RELAP5 running uses four files and is started by the following command line: "relap5 **–i** *input file* **–o** *output file* **–r** *restart-plot file* **–s** *strip file* **–w** *tpfh2o"* All the components, heat structures and control data are organized in a text file, the *input file*; the calculated results are stored as a formatted text in the *output file* and as a binary data in the *restart-plot file.* The *restart-plot file* also contain needed information to allow restart the problem from some previous problem simulation time. The *strip file* is used to store the chosen plot information extracted from the *restart-plot file* by running the RELAP5 *strip* option. The *tpfh2o* is an input file containing the water property data table.

2.1. Input file

The RELAP5 input file is a user-created text file that contains a set of numbered cards that supply the needed information for code running. The card number is the first data of each card which is used to identify the function of the card remained data. Table 1 show the card number range for each data card type.

Table 1. RELAP5 Card Number Ranges

Card Number	Description
1 - 199	Miscellaneous control cards
200 - 299	Time step control cards
300 - 399	Minor edit requests
400 – 599 or 20600000 - 20620000	Trip input data
801 - 999	Interactive input data
1001 - 1999	Strip request data
CCCXXNN	Hydrodynamic components
1CCCGXNN	Heat structure input
201MMMNN	Heat structure thermal property data
202TTTNN	General table data
205CCCNN or 205CCCCN	Control variable input data
2080XXXX	Expanded plot request data
30000000 - 39999999	Reactor kinetic data

The time step control cards are used to specify not only the calculation time step size but also the frequency output data should be written. The amount of minor and major edit data to be put in the output file and also the plot and restart data to be put in the restart-plot file are controlled by these cards.

The minor edit request cards specify a set of quantities to be presented in the output file. Each quantity is identified by a name composed by two part one alphanumeric and other numeric. The alphanumeric part specifies the quantity type and the numeric part, the component it belongs. The same kind of representation is used for the strip and expanded plot request data.

The strip request data are used to specify the quantities to be put in the strip file and the expanded plot request data are used to add new quantities to the restart-plot file that are not written by default.

Each hydrodynamic component, heat structure and control variable data card number contain a user chosen three digit number used to identify it and for future reference for each used component. The data to be supplied depend on the component type.

2.2. Output file

The output file is a formatted file created during the RELAP5 running where the main output data are recorded. It starts with a copy of the input file followed by the input processing results and also the errors messages if there are some.

If no errors have been detected, the calculated results are presented. They are organized in two blocks: the major and the minor edit. The major edit are sets of calculated quantities presented for each hydrodynamic component, junction, heat structure and control variable. There are some predefined quantities sets that can be specified by flags supplied in the time step control card of the input file.

The minor edit are tables containing the simulation time plus the minor edit requested quantities data. Despite these data are organized in blocks with up to 10 columns, they are not suitable for use in an spreadsheet since they are written mixed together major edits and other minor edit blocks.

2.3. Restart-Plot File

The restart-plot file is a binary file used to store RELAP5 output data that could be both used as an input as well as an output file. For new problems it is a file created by RELAP5 to only store the produced data. For restart problems, a restart-plot file from a previous running must be supplied. In this case, the restart data for the desired time-step of calculation is read and all the data stored after that time-step are replaced by the new calculated data.

This file contains, mixed together the restart data blocks and the plot data blocks. The restart data block contains a dump of all the geometric and thermal-hydraulic conditions for the chosen time-steps in order to allow the problem to be restarted. In the restart case, the simulation can simply continue the previous calculation or some nodalization changing can be done.

All information that is recorded in the restart-plot file is organized in blocks identified by a header which contain the block name, the number of variables in the block and the size of the block in bytes. The plot data are identified by the following block names: *plotinf*, *plotalf*, *plotnum* and *plotrec*. The first three blocks are used to store the variable description while the last one to store one time-step calculated data. The *plotinf* block store the dimension of the data array recorded in the *plotrec* block while the *plotalf* and *plotnum* store arrays containing respectively the alphanumeric and the numeric part of the name of each variable stored in the *plotrec* block.

There is one *plotrec* block for each time-step plot data must be stored. On the other hand, new *plotinf*, *plotalf* and *plotnum* block recordings will be needed only if the nodalization has changed during a restart of the running.

2.4. Strip File

The strip file is an output file that is used to store the strip requested data produced by running the RELAP5 strip option. It can be a formatted text file or a binary file depending on the user choice. The strip file only contain data for the strip requested variable organized in the same four plot data block that the restart-plot file although, without any restart data block. Neither the formatted text file nor the binary file is suitable to be directly imported to a spreadsheet since their data are not column organized.

3. THE XTRIP PROGRAM

The XTRIP program was developed during the past few years in order to make it easier to do the post-processing of RELAP5 output data through an electronic spreadsheet. During its development, several useful features have been identified and added, mainly by attending suggestion of its small group of users.

The first version of XTRIP was a macro embedded in a Microsoft Word document. At that time, Microsoft Word was used only to supply the Integrated Development Environment (IDE) to run the Visual Basic for Application program developed. Despite it had almost the same user interface that the current version, the earlier XTRIP versions were only used to help code users to choose, among the variables contained in the *restart-plot* file, a set to fill in the strip request data card of RELAP5 *input* file. In order to get the data to be analyzed, RELAP5 should be run to process this input file to produce a *strip* file that must still be reorganized by another program before being suitable to be imported by an electronic spreadsheet.

The XTRIP program became really useful after it had been implemented fully integrated in a Microsoft Excel spreadsheet and some new features were added. The most important of them was the capability to extract the data from the *restart-plot* file, using just one mouse click, directly into an electronic worksheet.

3.1. XTRIP Main Features

The Fig. 1 presents the main XTRIP user form. It has two List Boxes and some Command Buttons. The List Box on the left side is the “Available List” that contains the names of the variable that can be chosen and the one on the right side is the “Selected List” which contains the names of the variables that are actually chosen.

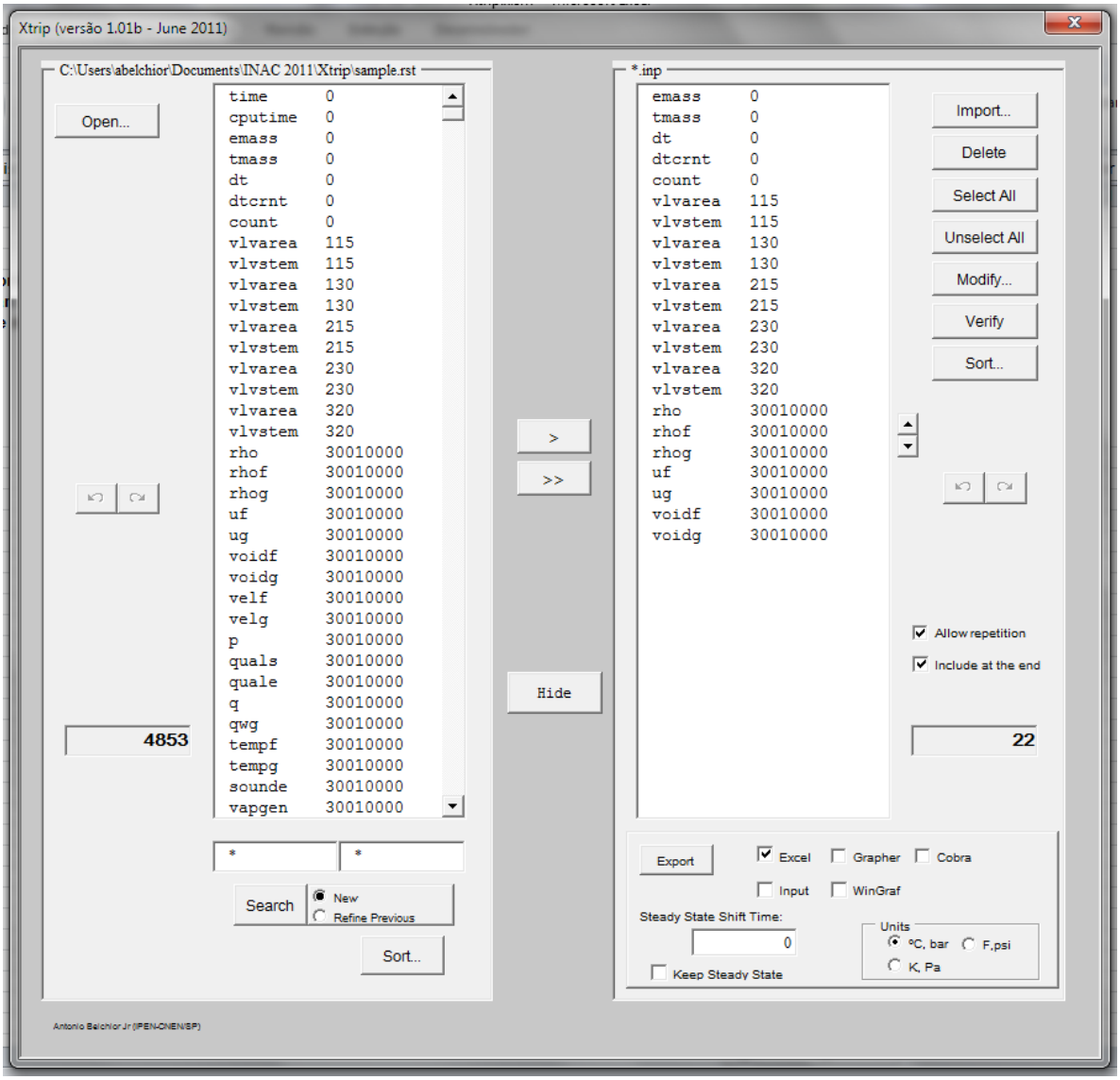

Figure 1. XTRIP program main user form.

Items of Available List can be copied to the Selected List by double-clicking on them or by selecting them and then clicking on the “>” Button or by clicking on the “>>” Button to copy all the items. User custom variables can also be added to the Selected List by clicking the “Modify” button. Through this option, the form presented in Fig. 2 is shown, and the selected variables can be renamed or cloned, and new variables can be added.

The Available List can be filled by variable names coming from an *input* file or a *restart-plot* file. In the case of an input file being used, all the data contained in cards with numbers within the range of the minor edit request, the strip request and the expanded plot data card are used to fill the this list. If a *restart-plot* file is used, in order to saving computing time, only its first *plotinf*, *plotalf* and *plotnum* blocks data are retrieved and the list is filled using that *plotalf* and *plotnum* information. Variables that would be created when restarting some previous calculation will not be caught, but they can be added as user custom variables.

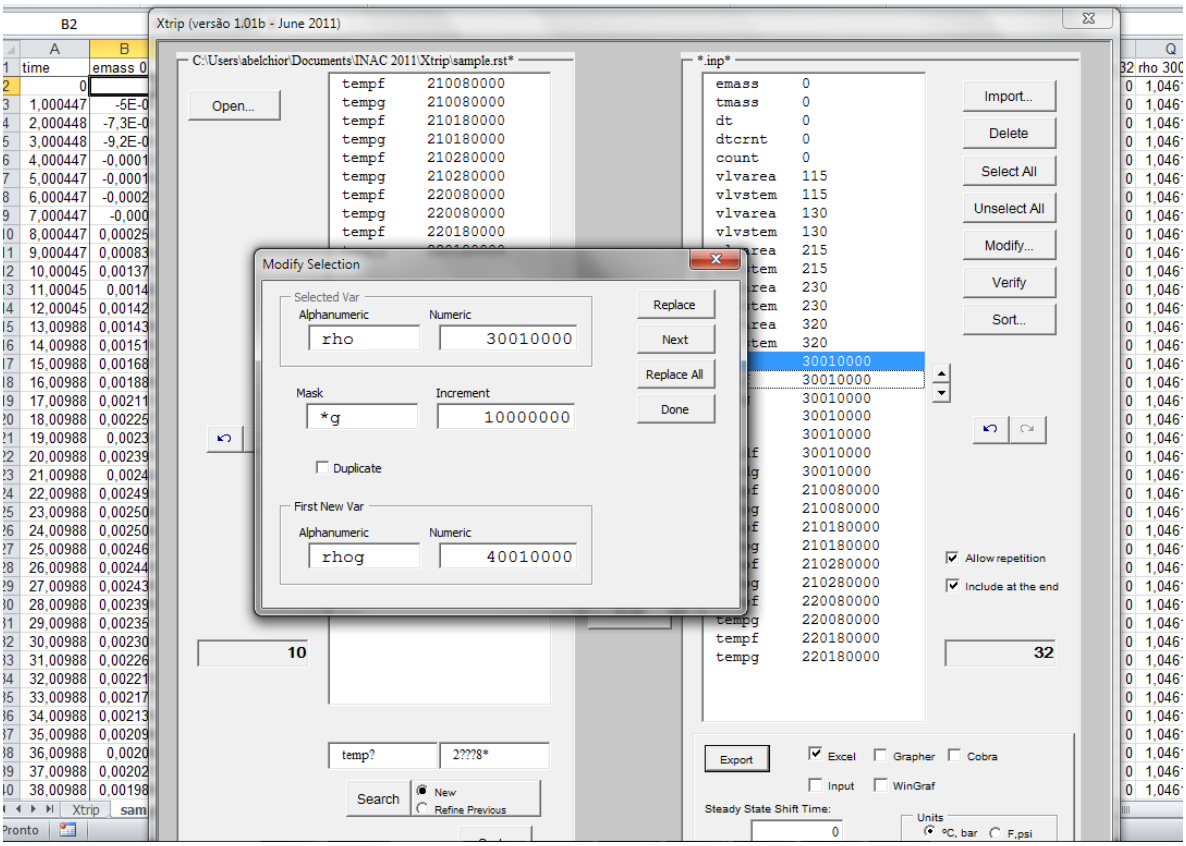

Figure 2. User form for editing and adding user custom variables.

In order to help finding variables in the Available List, this list can be reorganized by sorting and filtering. Microsoft standard wildcards "*"and "?" could be used in the filter searching string. All this changes are tracked so they could be undone if necessary.

The order of the variables in the Selected List is the same for the extracted data. There are two ways to reorganize this list. It can be reorganized manually through the "up" and "down" Buttons or automatically through the "Sort" button. The "Verify" button can be used to ensure that all the variables in the Selected List are really in the Available List. All unmatched variable are selected so they could be deleted if desired.

The Selected List can be saved by exporting it as an input file. Doing so, a RELAP5 input file for a strip running is generated. The Selected List variables are stored as strip request data. This Selected List can be retrieved by importing this generated input file.

3.2. Exporting the RELAP5 Plot Data

The plot data recorded in the *restart-plot* file can be exported by clicking the "export" button. The *restart-plot* file will be opened, the selected variables will be identified, their plot data will be read, the unit conversions will be applied and the selected data formats will be written. Some larger *restart-plot* files would not be completely processed, since a 32 bits system cannot easily address files larger than 2 GBytes and alternative methods should be much time-consuming.

The *restart-plot* file contains several data blocks. Among them, only the blocks identified by *plotinf*, *plotalf*, *plotnum* and *plotrec* headers should be processed. Opening the *restart-plot* file in random access mode showed to be faster than in sequential access mode. The use of random access allows the undesired block data to be skipped, advancing the reading point, since the size of the block is specified in its header. On the other hand, the use of sequential mode impose that all the data in the block must be read.

The *plotinf*, *plotalf* and *plotnum* blocks are used to build an order index in which the alphanumeric and numeric parts of a variable name in the Selected List match, respectively and simultaneously, one item of the *plotalf* and *plotnum*. A new index must be done whenever another set of *plotinf*, *plotalf* and *plotnum* blocks is found.

The *plotrec* block data are read and stored in an array from which only the ones specified by the order index are exported to the selected data format. XTRIP always consider *restart-plot* data are in SI units, but can export the in another unit system. Based on each variable name, a suitable pair of array for multiplying and adding constant is set for the requested conversion. If no conversion is needed, 1.0 and 0.0 are respectively used.

When exporting data to a worksheet, the cells of the first line are filled with the variables name from the Selected List. The following lines are filled with data from each *plotrec* found, considering the order index previously identified and doing the specified unit conversion. If there is no data for some variable, the corresponding cell is left blank.

After finish reading the entire *restart-plot* file, the first line and columns of the worksheet are frozen in order the time column and the variables names line would be always visible while scrolling through the worksheet data.

A similar way is used to export the data to Grapher format. In this case, a text file is generated also organized in line and columns, but comma separated. On the other hand, for Wingraf and Cobra formats, the data are also text file, but presented normalized and grouped by variable.

4. CONCLUSIONS

A new application for post-processing the RELAP5 results was developed as a VBA macro fully embedded in an Excel spreadsheet. Since XTRIP can easily export any recorded RELAP5 plot data directly to a worksheet, it showed to be a very helpful tool for speeding the output data analysis.

The developed interface can be effortless adapted to be used by other thermal-hydraulic codes. Some minimum changes shall be necessary in order to adjust XTRIP to handle other codes data format.

As XTRIP is still under development, some new features should still be added. Anyway, it is mature enough to be shared with other RELAP5 code users.

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