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PCRELAP5 - A VISUAL GRAPHIC PREPROCESSOR FOR RELAP5

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ABSTRACT

The aim of this work is to develop PCRELAP5, a visual preprocessor for RELAP5, reducing time, effort and maintenance costs spent in new projects for RELAP5. This preprocessor allows user to draw new nuclear power plant nodalization in a completely interactive way, and input parameters for each node in a more user-friendly experience. Once parameters are changed on screen, the input cards of RELAP5 code are changed in real time. RELAP5 users will have a tool to reduce time and effort for new studies and existing projects. Therefore, this project proposes to significantly leverage studies related to nuclear accident analysis, making the RELAP5 code more user-friendly. In order to demonstrate this preprocessor capability, the CANON experiment will be used as an example. The PCRELAP5 preprocessor is being developed using Microsoft® Visual Studio® as a Microsoft® Excel® add-in, due to the low cost of distribution and maintenance, and also allowing new RELAP5 projects be leveraged by the MS Excel® flexibility.

1. INTRODUCTION

One of the most used applications the accident analysis is RELAP5 [1], developed by Idaho National Engineering Lab (INEL) to the Nuclear Regulatory Commission (NRC). In Brazil, RELAP5 is being used in the last years to safety analysis in nuclear reactors, once the Brazilian regulatory commission demands this type of study to license nuclear power plants.

Despite the power of RELAP5, the commands are inputted to the software using an old-fashion style, inherited from mainframe applications, such as input files or input cards. The input cards are coded with several information related to the plant or system being modeled, making them hard to read and maintain, even to an experienced engineer.

Furthermore, the existing tools to support RELAP5 users are not practical, either demanding complex commands and calculation to be used or limited to support users on visual organization of the code already developed.

This paper introduces PCRELAP5 [2], a powerful visual tool being created by IPEN/CNEN in order to simplify the life of RELAP5 users. With PCRELAP5, RELAP5 users will be able to visually creates their RELAP5 inputs, just dragging hydrodynamic components to diagrams, connecting them onto each other, defining heat structures, setting initial conditions, everything from a mouse click distance. The diagrams also can be connected to each other allowing users to maintain complex RELAP5 input projects with several different views, each one related to a part of the problem being modeled. As user performs any changes on diagram, these changes are reflected in real time to the RELAP5 input file maintained by PCRELAP5.

PCRELAP5 is being developed as a Microsoft Excel® add-in, using Microsoft Visual Studio® and Microsoft Visual Studio Tools for Office® (VSTO). Using Excel as development platform for this tool allows user to be leveraged by the Excel capability of performing several complex calculations in parallel, almost instantly. Also, as an add-in, the code being developed will not be part of the worksheet model, allowing users to share these models as single Excel macro-free files, avoiding safety issues; furthermore, after upgrades on add-in, users will not have to update all the projects already developed. Microsoft Excel® also offers great capability to draw diagrams, just like other Microsoft Office® tools. Considering this, RELAP5 users that already use Excel will have a reduced learning curve in order to start using PCRELAP5.

In order to demonstrate how to model a RELAP5 problem using PCRELAP5, this paper will show reader a step-by-step guide to model the "Super CANON Experiment" [3], which consists in an instantaneous rupture of one side of a horizontal pipe containing high temperature pressurized water, and retrieving measures of pressure, temperature and void fraction during transient phase. This experiment was already realized by IPEN/CNEN in previous publishing and it will be briefly summarized in section 3.

2. PCRELAP5

PCRELAP5 is a powerful visual tool being developed by IPEN/CNEN in order to simplify the life of RELAP5 users. With PCRELAP5, RELAP5 users will be able to visually creates their RELAP5 inputs, just dragging hydrodynamic components to diagrams, connecting them onto each other, defining heat structures, setting initial conditions, everything from a mouse click distance.

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A previous version of PCRELAP5 was first developed by IPEN/CNEN, but its predecessor was first presented as a tool to help RELAP5 users on geometry calculation of RELAP5 input parameters. With this version, users will be able to start planning new projects directly on PCRELAP5, once the nodalization diagrams - essential to any RELAP5 project - will be drawn directly into PCRELAP5 interface.

3. THE SUPER CANON EXPERIMENT

The Super CANON experiment intends to study depressurization phase of a LBLOCA (Large Break Loss of Coolant) accident, which consists in accidents of loss of primary coolant in PWR nuclear reactors, usually due a complete and instantaneous rupture of the cold leg of the primary circuit of a nuclear reactor cooled by pressurized light water. This type of accident is extremely dangerous, once it can let reactor core completely dry in instants due to the loss of coolant fluid and being followed by a possible melt of nuclear fuel inside the core. Furthermore, the load introduced by rupture forces may deform the core and the fuel set, leading to an inefficient cooling of parts of the reactor core, also ending into a partial reactor core melt [4].

This experiment is inspired in other base experiment known as “Edward’s Pipe Problem” [5], and consists in instantly rupture of a membrane in of one of the edges of a horizontal pipe, using diaphragms with different flow areas. The pipe is filled with high temperature pressurized water. Once the membrane is opened, an instantly vaporization of the water inside the tube occurs. During this transient phase, several measurements are taken, such as pressure, temperature and void fraction on different sections of the pipe.

The Figure 1 bellow shows how the Super CANON experiment were set. It consists in a section test in stainless steel with 4.389m length, and 100mm diameter, where water is pressurized in 32 and 150bar, with temperature variating from 200 to 300º C.

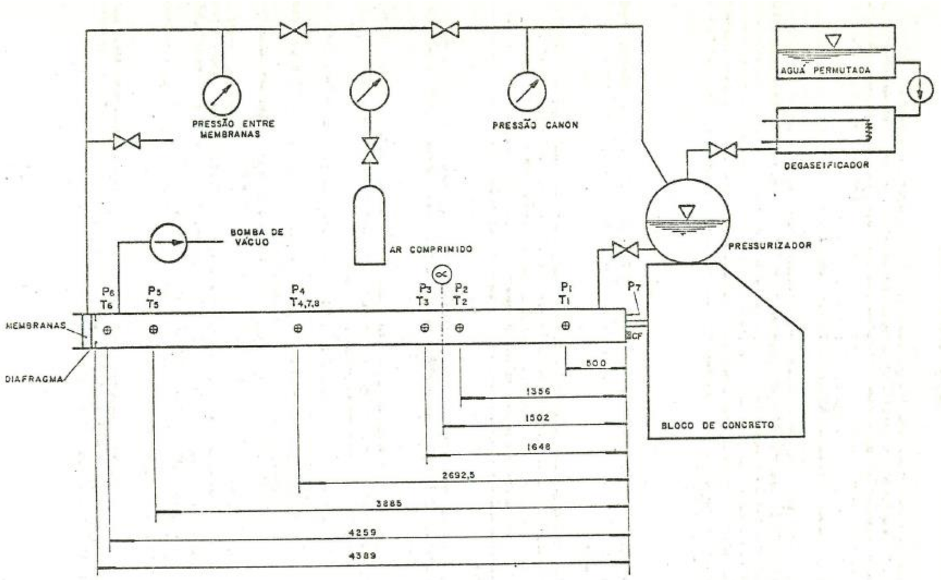

Figure 1: Super CANON experiment diagram, including measurement points

During transient phase, several measurements are taken in different points of the pipe. Besides, several void fraction measurements were taken at 1.5m from closed edge, using neutronic diffusion method.

4. USING PCRELAP5

Once RELAP5 works solving five conservation equations for biphasic outflow using finite difference method, is very common to RELAP5 users to input its problems using more nodes than the ones primarily identified at the first sight of blueprint of the problem; after all, once RELAP5 uses finite difference method to solve the conservation equations on each node, if the node is larger, the calculation may not converge to a solution.

Due to this, RELAP5 users usually start a new problem creating a nodalization schema of the targeted problem, prior on creating RELAP5 input data. To achieve the desired result, they may use several different tools, from diagram drawing tools, such as Microsoft Visio®, spreadsheet software, such as Microsoft Excel®, engineering drawing tools, such as Autodesk® AutoCAD®, or even pen and paper itself.

PCRELAP5 users, however, will start their work using PCRELAP5, once this add-in offers tools to draw the nodalization diagrams directly on a new PCRELAP5 problem. The next subsections will show how this is achieved.

4.1. Starting a New Problem on PCRELAP5

Once PCRELAP5 is installed on a computer, when user opens Excel it will see a new Microsoft Office® Ribbon® Tab with PCRELAP5 Tools, similar to what is shown in Figure 2. When selecting this Tab, users will see several groups of commands, such as Settings, Diagram, Hydrodynamic components, Heat structures, and other actions to be used on a new PCRELAP5 problem.

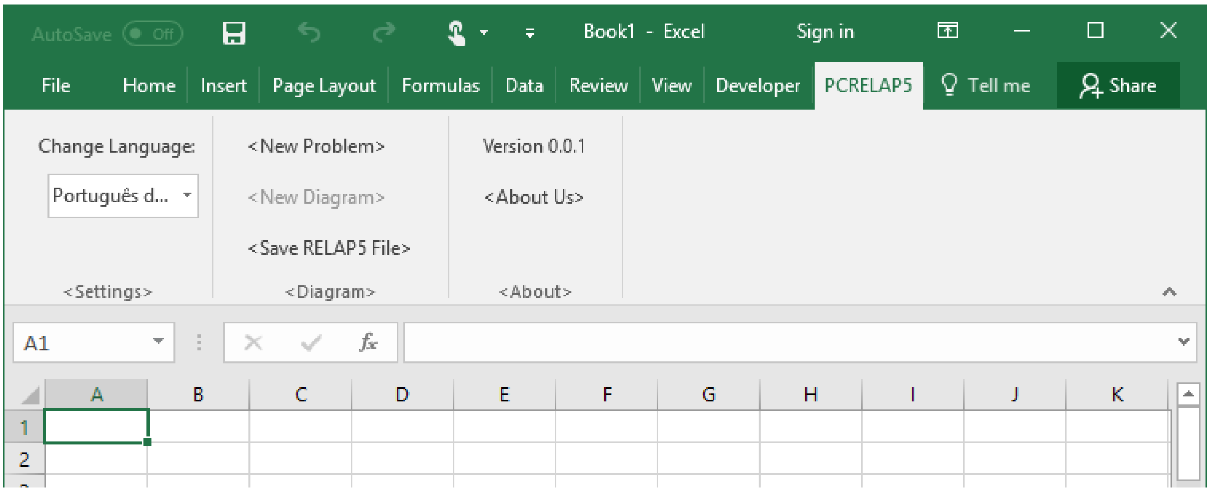

Figure 2: PCRELAP5 Ribbon Tab

After selecting PCRELAP5 tab, user must click on “New Problem” button, in order to create a new PCRELAP5 problem. A PCRELAP5 problem is nothing more than an ordinary Excel workbook file, but with specific sheets inside it already prepared to work integrated. In a problem file, there is one diagram sheet, that will be used to draw the nodalization diagram of the problem, there is also a problem cover sheet, as presented at Figure 3, where user inputs information regarding the problem to be solved, such its title, a brief description, creation date, problem type, measurement units to be used, type of gases and fluids, and so on. Also, there is a RELAP5 input sheet, where users can check the RELAP5 code being generated in real time as they draw the diagrams.

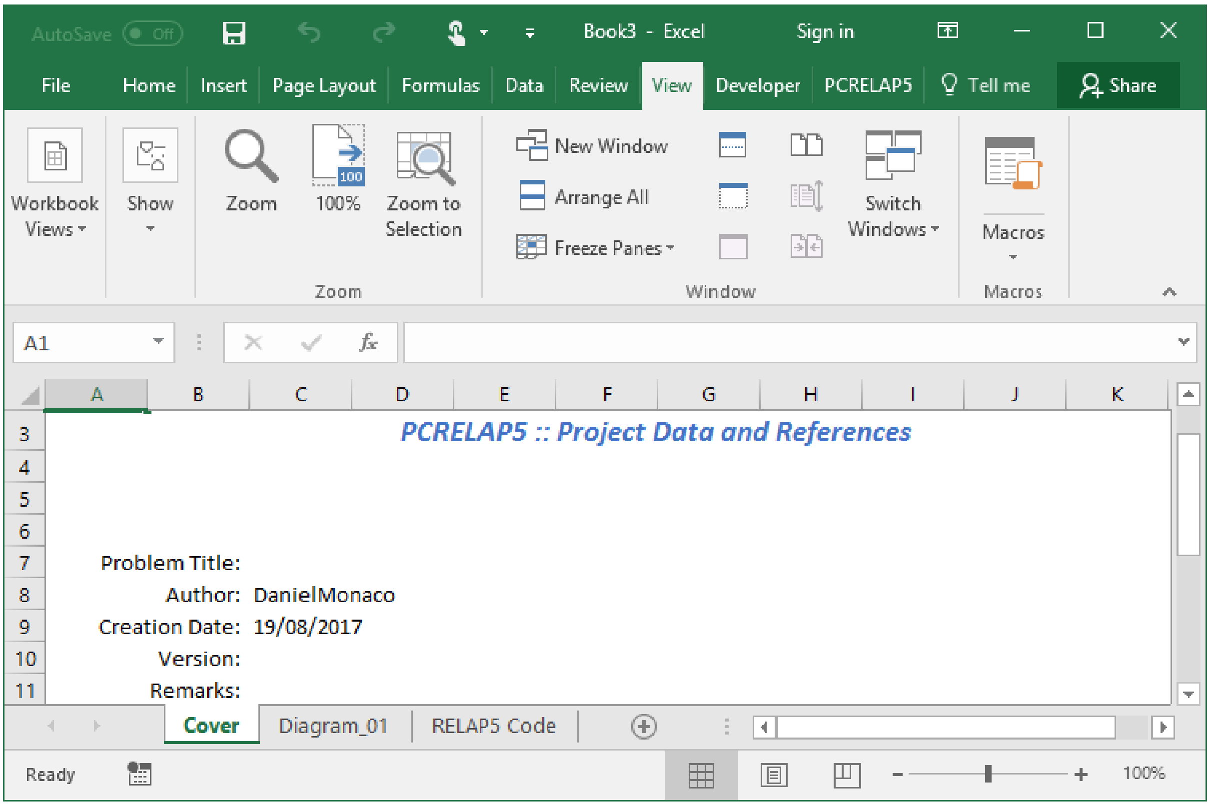

Figure 3: New PCRELAP5 Problem File

After creating a new problem file, and filling the cover information, it is time to start working on the problem itself: drawing the nodalization diagram.

4.2. The Diagram Worksheet on PCRELAP5

A new PCRELAP5 problem file always create one diagram sheet, but users may create how many diagrams they believe is necessary to better model the problem.

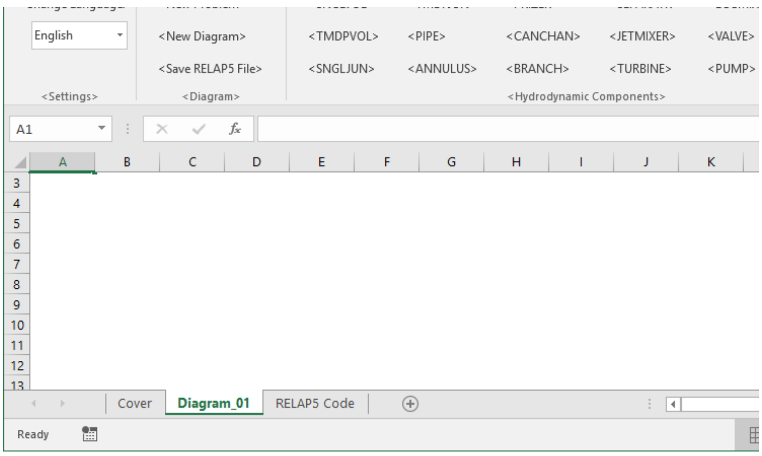

Figure 4: PCRELAP5 diagram worksheet

When users select “Diagram_01” worksheet, they will see a blank worksheet, with no lines in it (see Figure 4). This sheet will be used as a canvas for drawing the nodalization diagram. Also, when selecting a diagram sheet, new commands are revealed at the Ribbon Tab, related to hydrodynamic components, heat structures, and so on, that RELAP5 users are all familiar with.

4.3. Drawing Nodalization Diagram on PCRELAP5

After selecting the diagram sheet, with a blank canvas in it, it is time to think on the problem to be modeled.

Looking at the problem diagram highlighted in Figure 1 at Section 3, RELAP5 users will identify major components as a single pipe split onto at least seven volumes (one for each pair of temperature/pressure measurement, and an additional volume for void fraction measurement), one valve to represent the membrane that will be blown, and one Time-Dependent Volume component (TMDPVOL) to represent the external environment where the steam will flow into. Once the heat exchange between the pipe and the air in the environment may be ignored in this simulation, once the phenomenon starts and finishes on a small fraction of seconds, there will be no need to represent heat structures on this specific scenario.

Clicking on “Pipe” button inside “Hydrodynamic Components” group, brings the window as shown in Figure 5, where user can configure initial parameters of a PIPE component, including name and number, and also initial volumes parameters. Typing “7” inside the box “number of volumes” define one single PIPE component, with 7 volumes and 6 junctions in it.

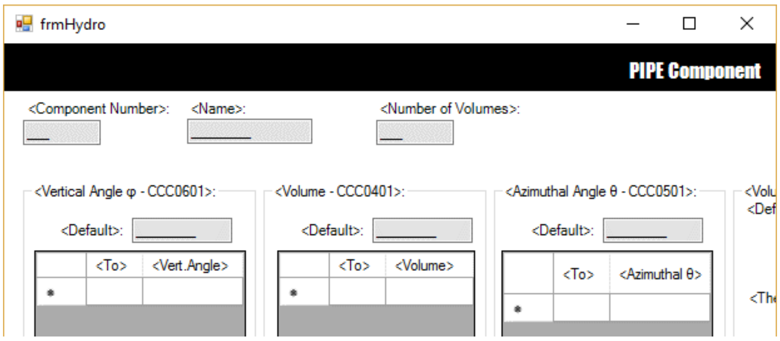

Figure 5: Pipe Component Properties

After clicking in “create” button on the Pipe properties window, user will see the component being drawn in canvas as requested, as reader can check at Figure 6. Even the vertical angle is reflected in canvas, although users may change the inclination of the pipe without affecting RELAP5 “vertical angle” parameter.

After better analyzing the pipe, authors decided to design it with 23 volumes – instead of the initial 7 volumes wonderer at first sight, allowing volumes with similar lengths, and avoiding too long volumes on which RELAP5 might not converge into results. This can be done just by selecting the already created pipe, and clicking on “Properties” button on Ribbon Tab. Users will see the same window as shown at Figure 5, but already filled with the previous input information. Therefore, by changing the number of volumes from 7 to 23, and clicking on “change” button, the results will be reflected at real time in canvas, as it can be seen in Figure 7.

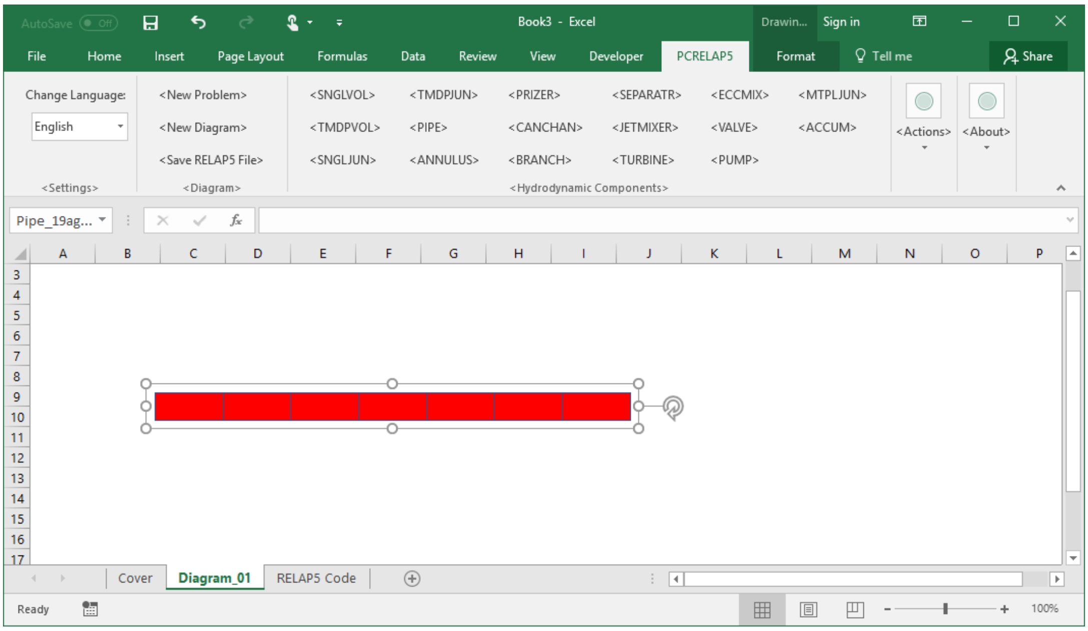

Figure 6: Pipe with 7 volumes drawn in canvas

In time: the fill and border colors that are created by default can be changed anytime by users using the format option of Excel. Users may also use shadows, texture or any other effect they desire, once this will not affect the RELAP5 properties already assigned to the object itself. Furthermore, Excel features as adding text labels on shapes can be used to assign custom information to any object. And also, spreadsheet cells can be formatted with text, colors, borders or any other Excel feature as desired by user. Despite the fact this information will not be considered to generate the input file for RELAP5, it may be helpful when fixing problems on the model.

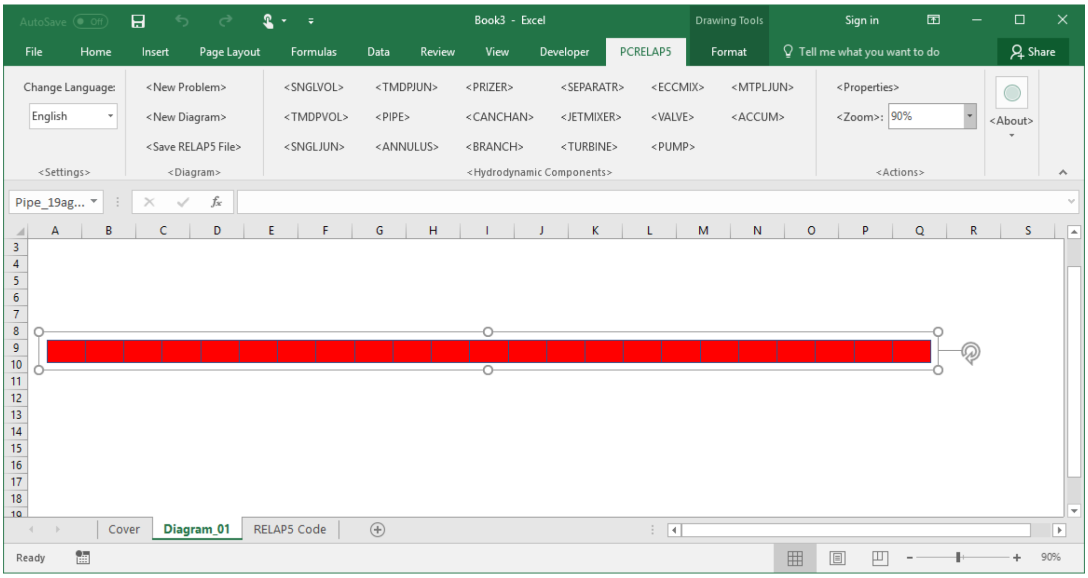

Figure 7: Pipe changed to 23 volumes

4.4. Changing PIPE Volumes Properties on PCRELAP5

After creating the pipe with its volumes and junctions as desired, it is time to change properties of each one of the volumes, in order to get a better simulation of the experiment being modeled. As user may notice in Figure 5, either default properties may be assigned to all of the volumes at once, or specific volume properties can be defined for every volume when creating the pipe itself. This last option is done selecting a single volume at canvas, and this is performed doing this: first, user must click at the pipe whose volume user want to change; second, user clicks again over the volume he/she wants to change, and finally, user may click at the “properties” button on Ribbon Tab. This will open a properties window only where can be changed the parameters of the selected volume and its related junctions.

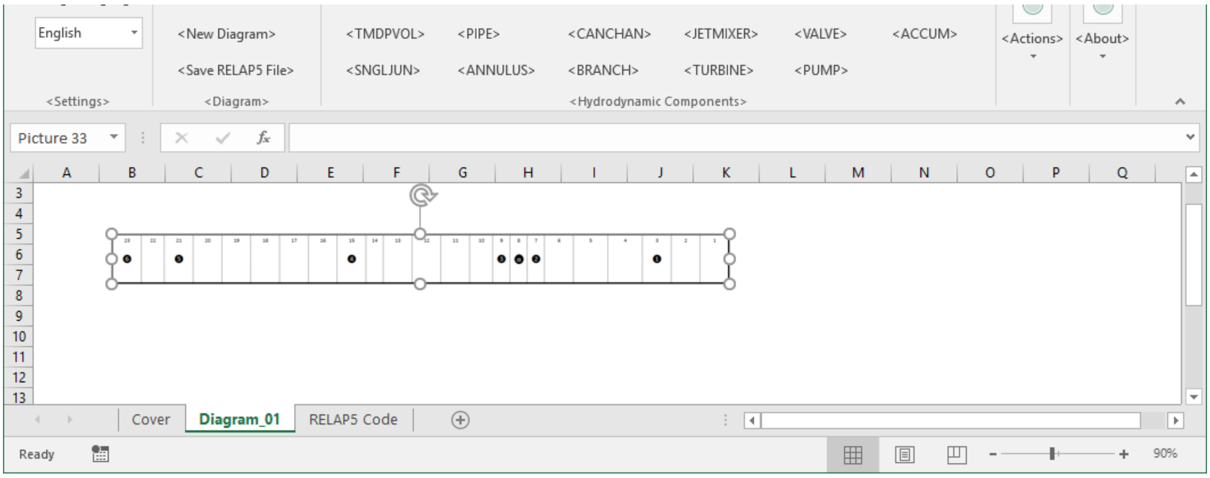

Figure 8: Pipe and Volumes Configured

Once it was already defined junction properties as default values when the pipe was created, authors used this feature to change the length property of every volume created so far. After changing the colors of the pipe to a black-and-white approach, what user sees at its canvas will look like the Figure 8

4.5. Checking RELAP5 Code Generated by PCRELAP5

At any time, users can switch to “RELAP5 Code” worksheet in order to check which code was generated so far. After following the present article until this point, the user that switch to that sheet will see the generated code, as shown in Figure 9:

As readers may notice, the code is generated with some comment cards and other comments in it in order to ease the depuration process. Also, PCRELAP5 avoids generating redundant cards: readers may notice that any of the optional cards that were not set in the config window were not created; they may also notice that it was not created one card for all of the 23 volumes created; also, only one junction card was created, once all junctions have the same flow area. Avoiding generate unnecessary cards reduces the load time of this input file for RELAP5, and also gives users a cleaner and more readable RELAP5 input file.

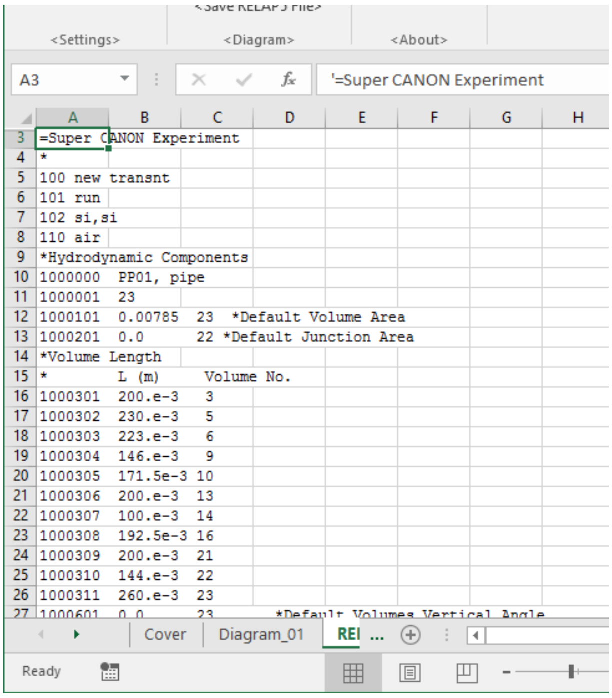

Figure 9: RELAP5 Code Generated by PCRELAP5 Diagrams

4.6. Adding Other Hydrodynamic Components

Once the pipe is satisfactorily designed, user can add other components into his/her diagram. According to the problem being analyzed, there are two other components that the problem being modeled needs: a TMDPVOL component and a valve component.

Users may add those components and configure them the same way they did to draw the initial pipe, using the corresponding buttons at the PCRELAP5 Ribbon Tab.

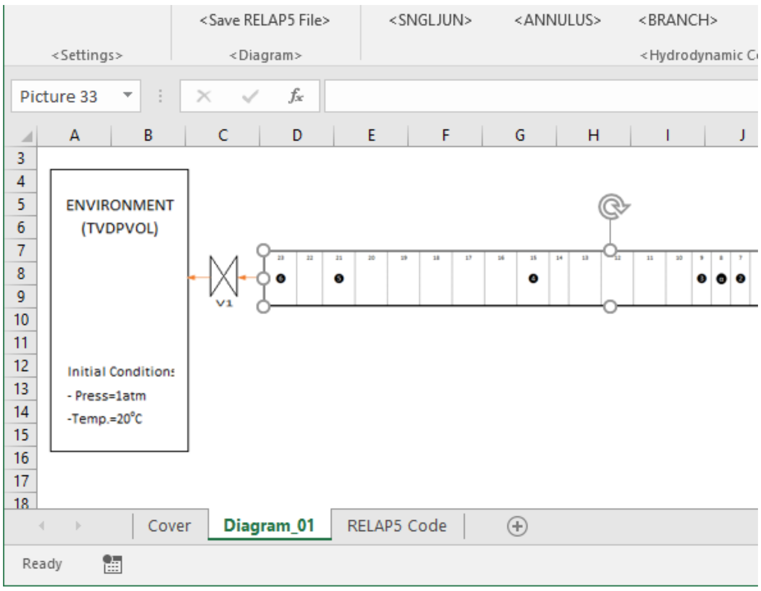

Figure 10: Final diagram for Super CANON Experiment using PCRELAP5

Once users drag a VALVE component, user will notice that these component comes with two arrows attached to it: those arrows indicate the “from” and “to” parameters of the valve junction geometry card, and they must be attached to other components in order to work. Attaching the arrows from valve onto pipe and onto TMDPVOL will generate the proper geometry cards at RELAP5 input worksheet. Note that this operation may also be performed selecting the “from” and “to” components from “Valve properties” window. The diagram therefore may look like Figure 10.

4.7. Exporting RELAP5 Input File

Once PCRELAP5 users finish its diagrams, the final RELAP5 input file may be generated just by clicking on the “Save RELAP5” button. A dialog box will be shown asking user the desired file name and path where the RELAP5 Input File may be saved. This will create a ASCII file with the desired name. Once saved for the first time, the chosen file name and path is saved at the cover worksheet. This way, next time user clicks on “Save RELAP5” button, PCRELAP5 will ask user to overwrite current RELAP5 input file, or to save as another file.

It is important to notice that the RELAP5 input file may be changed directly onto “RELAP5 Input” worksheet, if users need to do so. Once some input cards are not being considered yet on this version of PCRELAP – such as Time Step control cards, minor edits cards or even trip cards) – these cards may be entered and saved direct to RELAP5 sheet before exporting the input file. This way, even cards that are still not supported by the current version of PCRELAP5 may be used by user when necessary, which turns PCRELAP5 into a very flexible tool to any situation.

5. ADITIONAL PCRELAP5 FEATURES

Some other PCRELAP5 features were not explored in the present paper, but must be mentioned.

One of them is the “Choose Language” feature, where user may choose which language will be used by PCRELAP5 interface and messages generated to end user. Once changed, users will see all interfaces in chosen language, without need of restarting Excel.

PCRELAP5 interface will be hardcoded in English by default; however, it will be originally distributed with additional 3 languages: Brazilian Portuguese, French and Spanish. After installing PCRELAP5, users will see a file where translations and localization messages are stored. This way, after initial distribution, any user may contribute translating all the PCRELAP5 interfaces just using any text editor, without any programming knowledge, and with no need of accessing source codes. This may contribute to allow this tool for being worldwide distributed.

PCRELAP5 users will be powered by a special calculator of area, hydraulic diameter, volume for different geometries, not only cylindrical. This feature may be particularly useful when entering initial parameters on components for the first time.

Another feature slightly mentioned in this paper is the fact that users will have the possibility of integrating several diagrams into one single RELAP5 input file. All the components created in every diagram of the present problem can be connected on each other. The inter-diagram connections will be marked with a special symbol to represent that one component is attached to another component from another diagram. For example, users may model a PWR power plant spreading the problem into several diagrams, such as one for pressurizer, another for the hot leg, cold leg, reactor core, and so on, all of these interconnected. This way, even very complex problems can be properly modeled using PCRELAP5

As mentioned, even cards not supported by the current version of PCRELAP5 can be added directly to the RELAP5 Input worksheet. This way, PCRELAP5 users will not have to worry on maintaining a problem version for drawing diagrams and another RELAP5 input file with additional cards. And once PCRELAP5 uses the RELAP5 Input worksheet to store configuration from components, PCRELAP5 will protect those cells maintained by itself, in order to avoid conflicts between cards entered directly by user versus cards generated by PCRELAP5.

And at last, once PCRELAP5 is being developed powered by Microsoft .NET® Framework, its distribution will be as easy as copying files from one computer to another. The additional step is to register the PCRELAP5 add-in into Excel, easily done by “Options” settings from Excel.

6. FINAL CONSIDERATIONS

The presented version of PCRELAP5 is still under development, therefore some features may behave differently on final version when compared to this paper.

7. CONCLUSIONS

PCRELAP5 is a powerful graphic tool being developed by IPEN/CNEN that will leverage RELAP5 users on maintaining and reducing time and effort spent in the creation and depuration of RELAP5 problems. This tool will allow RELAP5 users to concentrate their efforts on the problem approach instead of coding and syntax issues.

PCRELAP5 introduces a new approach to RELAP5 problems, not only helping users on code organization, but leveraging users on code maintenance as well, once the diagram changes are generating changes at the RELAP5 input cards in real time.

PCRELAP5 is being developed as an add-in extension for Microsoft Excel®, taking advantage of the Excel design features, such as parallel calculation, drawing tools, allowing users to have a more fluid experience with PCRELAP5 at the same time the learning curve is reduced. Furthermore, the nodalization diagram, used only as an accessory tool to create RELAP5 code, is turned into RELAP5 code itself, being boosted by rich Excel features of coloring, writing, creating formulas and documenting, offering RELAP5 users an experience of code maintenance and depuration far beyond the RELAP5 comment cards could ever offer.

As readers could notice in present paper, a problem like Super CANON Experiment were created just using mouse clicks, through a unique user-friendly experience. While PCRELAP5 users are invite to focus on the solution of the problem itself, the component cards are generated automatically by PCRELAP5 on RELAP5 Input worksheet.

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