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DATA CALCULATION PROGRAM FOR RELAP 5 CODE

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ABSTRACT

As the criteria and requirements for a nuclear power plant are extremely rigid, computer programs for simulation and safety analysis are required for certifying and licensing a plant. Based on this scenario, some sophisticated computational tools have been used such as the Reactor Excursion and Leak Analysis Program (RELAP5), which is the most used code for the thermo-hydraulic analysis of accidents and transients in nuclear reactors. A major difficulty in the simulation using RELAP5 code is the amount of information required for the simulation of thermal-hydraulic accidents or transients. The preparation of the input data leads to a very large number of mathematical operations for calculating the geometry of the components. Therefore, a mathematical friendly preprocessor was developed in order to perform these calculations and prepare RELAP5 input data. The Visual Basic for Application (VBA) combined with Microsoft EXCEL demonstrated to be an efficient tool to perform a number of tasks in the development of the program. Due to the absence of necessary information about some RELAP5 components, this work aims to make improvements to the Mathematic Preprocessor for RELAP5 code (PREREL5). For the new version of the preprocessor, new screens of some components that were not programmed in the original version were designed; moreover, screens of pre-existing components were redesigned to improve the program. In addition, an English version was provided for the new version of the PREREL5. The new design of PREREL5 contributes for saving time and minimizing mistakes made by users of the RELAP5 code. The final version of this preprocessor will be applied to Angra 2.

1. INTRODUCTION

After the accidents at Three Mile Island (1979) [1] and Chernobyl (1986) [2], the International Atomic Energy Agency (IAEA) together with the nuclear regulatory organizations of countries that use nuclear energy, requested numerical simulations of some possible accidents in the nuclear power facilities in order to verify their integrity when subjected to such events.

Recent accidents such as Fukushima – Japan [3] in 2011 impacted the population in the surrounding areas, causing people to feel insecure about the use of nuclear power plants. This situation contributed for the search for tests and improvement regarding the safety of nuclear reactors, especially concerning reactor simulations using computer program codes.

Nowadays, both international and national organizations that regulate and control the use of nuclear energy – the IAEA and the Brazilian National Nuclear Energy Commission (CNEN) – have made efforts to analyze and evaluate accidents and transients in nuclear facilities, ensuring the safety of the general population .

Due to the occurrence of the first nuclear accidents – Three Mile Island, Chernobyl, and Fukushima – nuclear regulatory organizations worldwide included the analysis of accidents considered design basis accidents – Loss of Primary Coolant Accident (large and small-break LOCA) – in the safety analysis reports of nuclear facilities, and currently accidents beyond the design basis accidents – meltdowns – have been studied. In Brazil, the tool that was selected by the licensing authority, CNEN, is the Reactor Excursion and Leak Analysis Program Code (RELAP5), which is the object of this study.

The RELAP5 code has been designed for best estimate transient simulation of light water reactor coolant systems during postulated accidents. The code models the coupled behavior of the reactor coolant system and the core for loss-of-coolant accidents, and operational transients, such as anticipated transient without scram, loss of offsite power, loss of feedwater, and loss of flow. The analysis of thermal hydraulic behavior during any of these accidents or transients applies to both the primary and the secondary circuits of a nuclear installation.

The program uses equation set gives a two-fluid system simulation using a nonequilibrium, nonhomogeneous, six-equation representation. The presence of boron and noncondensable gases are also simulated using separate equations for each. One-dimensional model is used to treat the fluid flow and the heat conduction in the structures; however, in some special cases such as the cross flow in the reactor core and the rewetting region in flooding model, the two-dimensional model is used [4].

One major difficulty in the simulation of a nuclear installation by using the RELAP5 code is the large amount of information required for the simulation of accidents or thermal hydraulic transient. This is due to a large number of mathematical operations for calculating the geometry of the components. There is a great difficulty to calculate the geometric data of the plant under study and to make the necessary corrections during the simulations [5].

This study presents a nodalization of a typical PWR, Angra 2, which was developed through a Technical Cooperation between the *Instituto de Pesquisas Energéticas e Nucleares* (IPEN) and the Research Institutes of CNEN: *Centro de Desenvolvimento da Energia Nuclear* (CDTN), and *Instituto de Engenharia Nuclear* (IEN), as well as the *Coordenação de Reatores* (CODRE). Furrthermore, the steady state was simulated by using the computer code RELAP5 / MOD3.2.2 as well as a number of accidents from a set of input data, so-called input basic.

In all studies performed by using the RELAP5, it is observed that there are many mathematical calaculations, which cause the users of the code to spend a lot of time. The mathematic preprocessor for PREREL5 was developed to enhance the use of this code, and to reduce the input data preparation time. PREREL5 version was developed by Paladino[6].

In Paladino[6], the mathematic preprocessor considered some components that are part of RELAP5; however, users of this code identified the need for readjustments. Therefore, this work aims to improve the hydrodynamic components to meet the needs of users, to provide an English version of the mathematic preprocessor, and to provide a link with the program SF Pressure Drop 6.2 [7], that allow users to calculate pressure drop of flowing liquids in the primary circuit. A user friendly interface has also been designed.

2. METHODS

The programs that will be part of this work are: Microsoft Excel [8 to12], the SF Pressure Drop 6.2 [7], and the original version of PREREL5 [6]. In order to contribute for a better understanding of the methodology, some relevant characteristics of each of those programs will be described.

2.1. Microsoft Excel

Currently, Microsoft is considered one of the companies that has the largest spreadsheet market, MS Excel. The Excel programming language (and all Office applications such as Word, Excel, Access, Outlook, Power Point, Front Page) is the Visual Basic for Application (VBA) [8 to 12].

The use of both Macros and VBA offers greater possibilities in the search for solutions to complex problems in order to overcome the limitations due to the use of formulas, functions, and even the actions of macros.

2.1.1. Visual Basic for Application (VBA)

VBA is an implementation of Microsoft. VBA supports methods of object-oriented programming, in which an object is an independent unit, set with program instructions, and contains functions and data that describe the features.

VBA, which is the programming language used in this study, supersedes and expands on the abilities of earlier application-specific macro programming languages, and can be used to control many aspects of the host application, including manipulating user interface features, such as menus and toolbars, and working with custom user forms or dialog boxes.

Forms are windows or dialog boxes that contain controls, objects that can be of different types, according to specificity imposed by the graphical project design under development. Forms and controls are key pieces for a useful, dynamic and functional project, from the user's point of view [8 to 12].

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2.2. PREREL

The basis for developing the calculation program for the RELAP5 code was the preprocessor PREREL [6]. In this work, the programming of some components and their respective input data were carried out, and geometric calculations related to them were performed. In addition, Calculation and RELAP5 Code worksheets were created. They refer to the calculation memory, with the registration of key data from the form of each component and the availability of data to the users in the format that corresponds to the input of RELAP5 code, respectively.

2.3. SF Pressure Drop 6.2

SF Pressure Drop 6.2 [7] is a tool that calculates pressure drop of flowing liquids and gases in pipes (laminar and turbulent flows). Additionally, it calculates the pressure changes caused by vertical difference of pipe and by changes of kinetic energy. SF Pressure Drop 6.2 also calculates pressure drop in pipe elements such as changes of direction and diverse fittings – valves, bellows etc. It is possible to combine various elements, and thus calculate the total head loss, requiring data such as roughness, density and viscosity to carry out these calculations. When compared to RELAP5, SF Pressure Drop 6.2 offers easier access and lower cost.

3. RESULTS AND DISCUSSION

The calculation program consists of seven screens. All of them have gone through modifications in design and functionality. The first screen – Start – represents the starting of the program with the name and language selection option: Portuguese or English. The user may select the language by clicking on the corresponding flag icon, as shown in Figure 1.

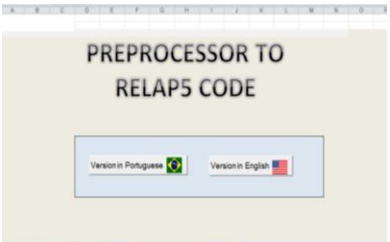

Figure 1: Start screen of the Calculation Program

The screen *Sumary* features hyperlinks to direct the user to the *PREREL5 User´s Manual* , to the screen *Geometry*, to the screen *Transfer* and to the screen *Nodalization*. Information and recommendations on the program configuration are clarified in the Report so that the user may easily use all the resources offered by the program (Fig 2).

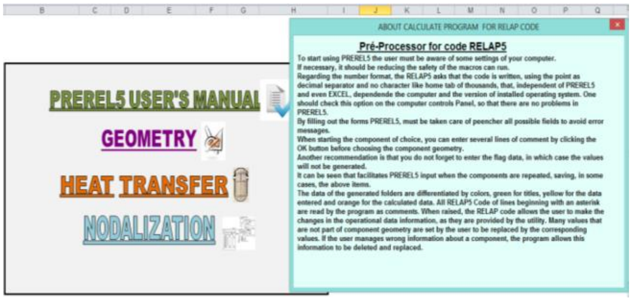

Figure 2: Link to PREREL5 user´s manual.

By accessing the link *Heat Transfer*, the user is directed to the screen *Transfer*, where he will find a form to insert data concerning heat transfer (Fig. 3).

The link *Nodalization* displays the outline of the nodalization of Angra2 (Fig. 4)

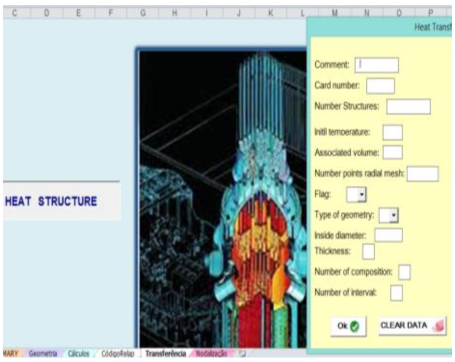

Figure 3: Calculation of the Heat Transfer

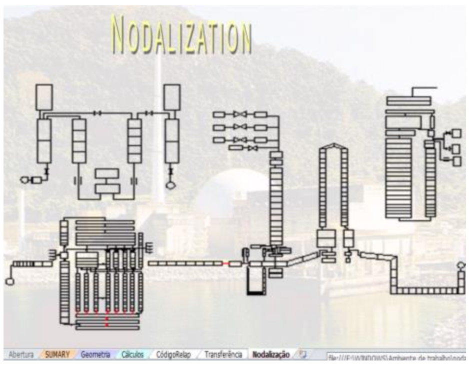

Figure 4: Nodalization of the Nuclear Power Plant

The screen *Geometry* was designed to perform the geometric calculations of all components of RELAP5 and also to provide geometric figures that can help the user to perform some complex geometry calculations as shown in Figure 5 The RELAP5 user's guidelines manual, the Calculation program manual, the website of the International Atomic Energy Agency as well as the SF Pressure Drop program can be accessed by clicking the buttons on the right at the top of the screen

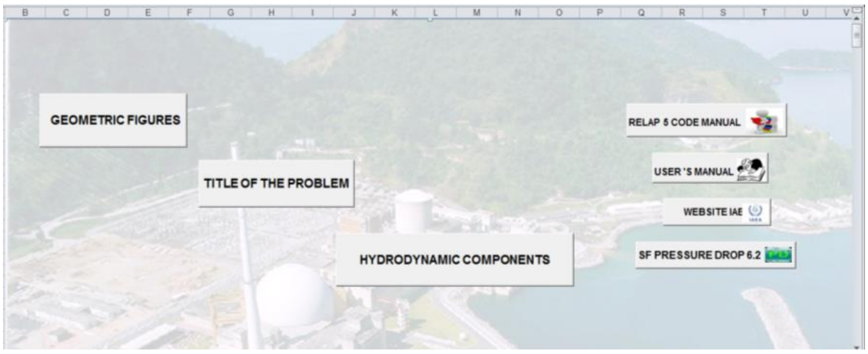

Figure 5: Geometry Screen

The button *Geometric Figures* provide different types of figures and a form as shown in Figure 6. At this stage, mathematic calculations may be performed on the screen without generating Excel files.

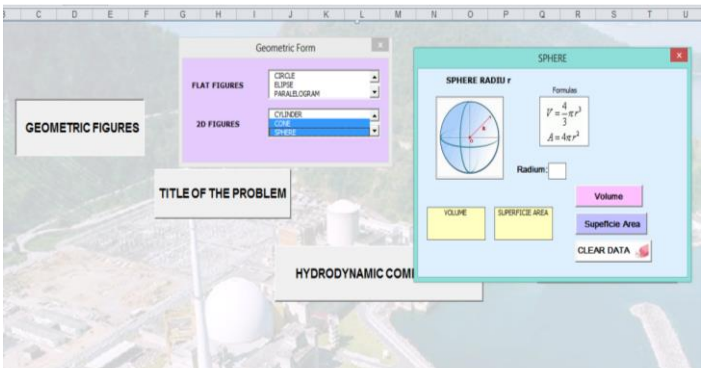

Figure 6: **Geometric Figures Screen**

When inserting a new input, the space with the title of the problem must be filled in, and then the hydrodynamic component, displayed in alphabetical order may be selected (Fig.7).

Figure 7: Title and Component Input Screen

Figure 8 refer to the hydrodynamic component TURBINE. Figure 8 demonstrates how the screen of this component must be filled – compatible with the description found in the RELAP5 user's guidelines manual. The type of turbine must be selected on the user´s access screen as well as in the correspondent input data in the *RelapCode* worksheet.

In the original version, data on the flow area and volume were shown in a message box. However, when user clicked ok, data disappeared, and the operation had to be repeated. to the user that clicking "ok", it disappeared, and to click on the buttons again. Therefore, for those values to be available to the user as soon as they are calculated, text entry boxes were designed to keep data. Moreover, the moment the textboxes are filled, a green color background is added, as shown in figure 8.

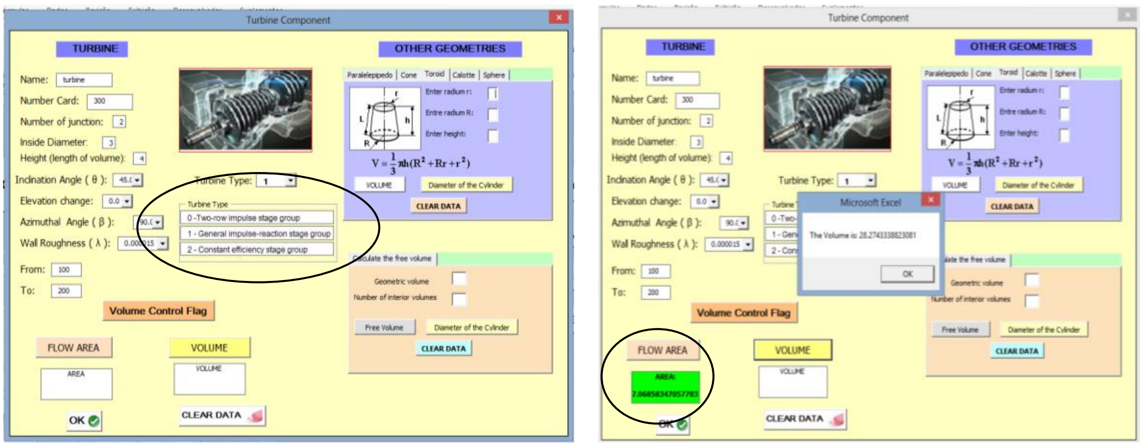

Figure 8: TURBINE Component Screen

An important feature in this Component screen is the multipage, which provides some calculation options when the volume is not a cylinder. The *multipage* provides the possibility of "cylindering" the component by calculating the volume and diameter of the equivalent cylinder. There is a page switching in the "Other Geometries", as shown in Fig. 9.

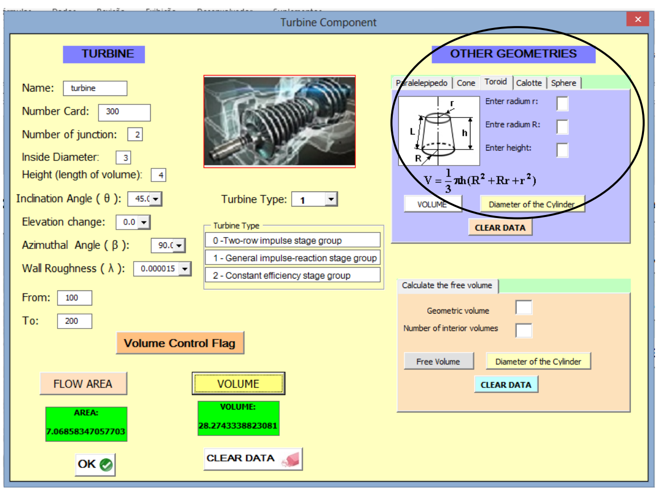

Figure 9: Link between Multipage and Turbine Component

The button *Clear data* was programmed and it is a feature added to all screens of the components, having the function of clearing up all fields at once and then leave the cursor active in the first field. In addition, the user has the option to use the keyboard, through the "TAB" key to move sequentially through all the fields of the screen. That feature help the user to be less dependent on the use of mouse to operate the program.

Concerning the filling in of the flags, in order to facilitate data insert to all components, the user has the option to fill automatically the fields with zero – a common practice adopted by RELAP 5 users – by hitting the “Load with Zero” button.

In order to avoid errors transferred to RELAP5 imput, such as filling in some fields with non-numeric data, or blank fields, or any data inserted by mistake, the *Flag* screen can only be closed if all fields are filled correctly. On the contrary, the user will be informed about the error and directed to the correspondent field, so he will be able to correct data, as shown in Figure 10.

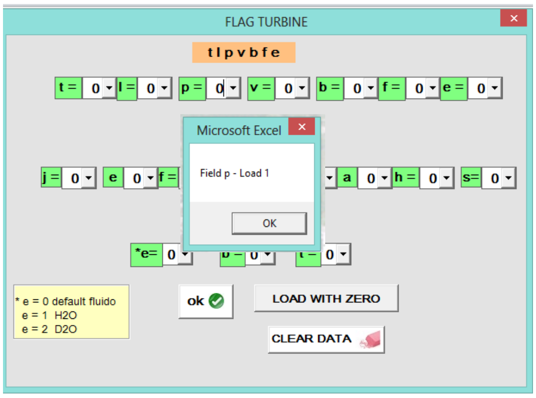

Figure 10: Example of errors from the Flag Screen

Concerning the *Flag*s, the RELAP5 preprocessor developed in this work garantees that the fields are programmed to receive a single value, which is recommended in the manual. Moreover, the *Clear Data* button provides the cleaning of all fields simultaneously.

After having all the data required inserted by the user, the program stores information in both, the *Calculation* worksheet and in *RelapCode* worksheet

The *Calculation* worksheet has the calculation memorial with important information regarding the selected component, that is, a short report about the information provided by the user in the form, as demonstrated in Figure 11.

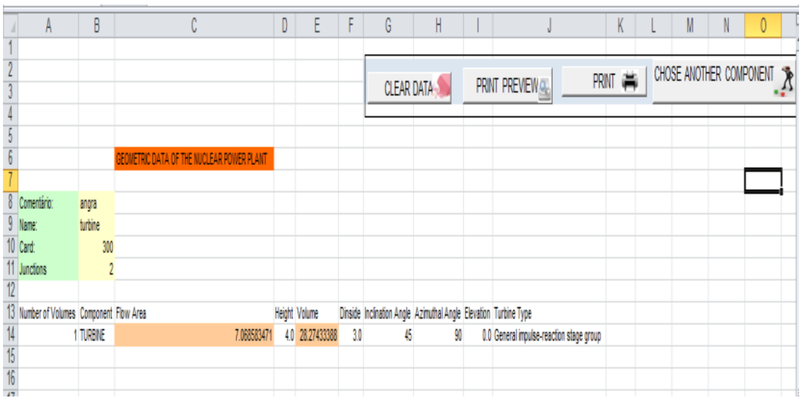

Figure 11: Worksheet of the TURBINE Calculation

In the *RelapCode* worksheet (Fig.12) the information is distributed and organized to best serve RELAP5, representing a convenience for the user as it is found in the formatting read by the program.

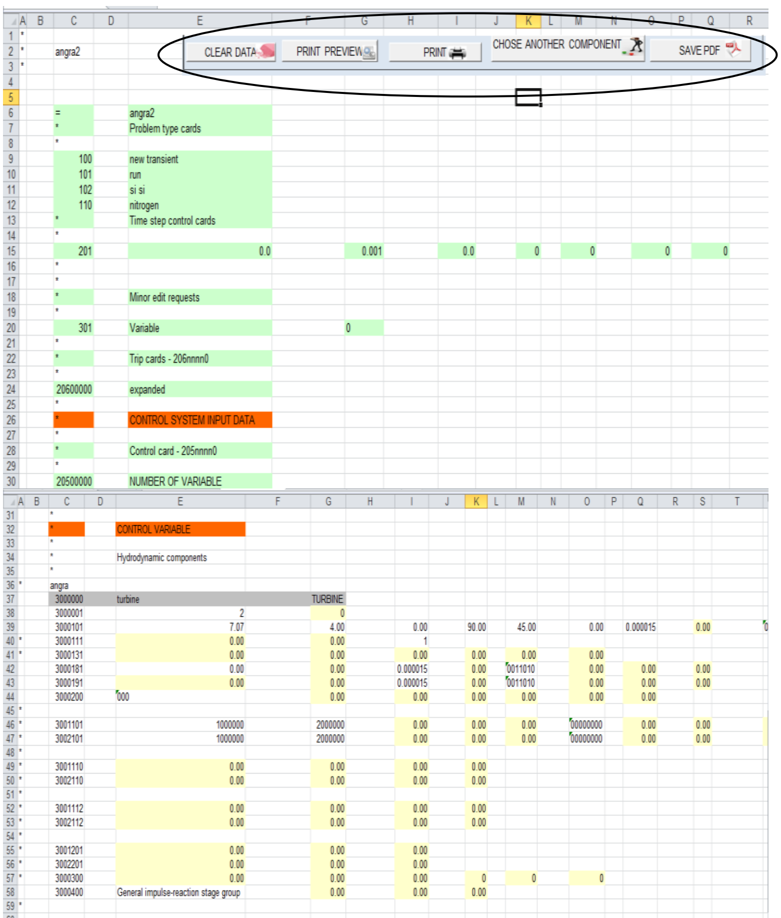

Figure 12: Worksheet of the TURBINE Input to RELAP5

The component name is also highlighted in gray color, and all data the RELAP5 user is required to insert are highlighted in beige color in order to contribute for an easy and a fast data identification. The data that were not highlighted are those inserted by the user in the screen of the chosen component.

The buttons *Clear data*, *Print View*, *Print*, C*hoose Another Component*, and *Save as pdf* were also programmed and take part of the *Calculation a*nd *Relap Code* worksheets.
Clear data button provides the cleaning of all data – in lines and colums – simultaneously. If the user wishes to clear data partially, he must not hit this button; but select manually data to be clerared.

Print View allows the user to visualize data from the worksheet for print, *and Print* allows data to be sent to a printer connected directly to the user´s computer for print. C*hoose Another Component* provides the user with the option to be directed to a form for choosing the component.*Save pdf* allows saving the file in PDF format. TURBINE and its input data are examples of a Hydrodynamic component that was programmed in this work successfully.

4. CONCLUSIONS

The VBA combined with Microsoft EXCEL demonstrated to be an efficient tool to perform a number of tasks used in the development of the program.

The forms are very useful for the preparation of the screens presented to the user in order to provide a friendly interaction through a simple and objective language. By using the forms, the user performs data entry in their respective fields, which enables the performing of geometric calculations and completing the data that compose the Calculation memory and the input for RELAP5 worksheets.

All hydrodynamic components and their respective input data, including the optional were successfully programmed. All modifications were incorporated to both versions of the program – English and Portuguese – resulting in visual and program improvement.

This preprocessor provides the users of the RELAP5 code with more agility to calculate the geometric data as well as the input data of this code.

ACKNOWLEDGMENTS

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REFERENCES

1. G.R. Corey. “A Brief Review of the Accident at Three Mile Island”**,** *IAEA BULLETIN***, V.21. NO.5**, http://www.iaea.org/publication/magazines/bulletin/bull215/21502795459.pdf (2015).

2. "Chernobyl's Legal CY: Health Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus", the Russian Federation and Ukraine IAEA. Vienna (2003-2005).
3. R. Gauntt et al, "Fukushima Daiichi Accident Study" SANDIA REPORT SAND2012-6173 (2012).
4. "The RELAP5 Development Team, RELAP5/MOD3 Code Manual NUREG/CR-5535", Idaho National Engineering Laboratory, USA (1995).
5. A.A. MADEIRA and R. C. BORGES, "Relatório de Acompanhamento da Cooperação Técnica na CNEN para a Aplicação do Código Relap5 à Usina Angra 2" *(CODRE, IPEN, CDTN E IEN)*, Comissão Nacional de Energia Nuclear, Relatório de Atividades RA-SUASE-04/2001 (2001).
6. P. A. PALADINO and G. SABUNDJIAN; "Pré-Processador Matemático para o Código RELAP5 Utilizando o MICROSOFT EXCEL". Dissertação de Mestrado do IPEN, USP, Brasil (2006).
7. Software-Factory Norbert Schmitz; "SF Pressure Dorp 6.2, Gemany", info@software-factory.de (2015).
8. A. F CINTO and W. M. GOES "EXCEL Avançado", Editora NOVATEC, Rio de Janeiro, RJ (2006).
9. J. A. N. G. MANZANO, "Estudo Dirigido de Excel 2013 Avançado", São Paulo: Érica (2013).
10. B. JELEN and T. SYRSTAD, "VBA e Macros - MICROSOFT EXCEL 2010" Rio de Janeiro, R.J., Alta Books, Elsevier (2012).
11. J. BATTISTI, "Macros e Programação VBA no Excel 2007", Instituto Alpha Editora (2013).
12. H. LOUREIRO, "Excel 2013 Macros & VBA", Lisboa: FCA Editora.Software-Factory Norbert Schmitz (2013).