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DEVELOPMENT AND APPLICATION OF THE PCRELAP5 – Data Calculation Program for RELAP 5 Code

Larissa J. B. Silvestre and Gaianê Sabundjian

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
larissajbs@usp.br
gdjian@ipen.br

ABSTRACT

Nuclear accidents in the world led to the establishment of rigorous criteria and requirements for nuclear power plant operations by the international regulatory bodies. By using specific computer programs, simulations of various accidents and transients likely to occur at any nuclear power plant are required for certifying and licensing a nuclear power plant. Some sophisticated computational tools have been used such as the Reactor Excursion and Leak Analysis Program (RELAP5), which is the most widely used code for the thermo-hydraulic analysis of accidents and transients in nuclear reactors in Brazil and worldwide. A major difficulty in the simulation by using RELAP5 code is the amount of information required for the simulation of thermal-hydraulic accidents or transients. Thus, for those calculations performance and preparation of RELAP5 input data, a friendly mathematical preprocessor was designed. The Visual Basic for Application (VBA) for Microsoft Excel demonstrated to be an effective tool to perform a number of tasks in the development of the program. In order to meet the needs of RELAP5 users, the RELAP5 Calculation Program (Programa de Cálculo do RELAP5 – PCRELAP5) was designed. The components of the code were codified; all entry cards including the optional cards of each one have been programmed. An English version for PCRELAP5 was provided. Furthermore, a friendly design was developed in order to minimize the time of preparation of input data and errors committed by users. The final version of this preprocessor was successfully applied for Safety Injection System (SIS) of 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 affected 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].

Due to the large number of geometric calculations of the nodalisation of a typical nuclear plant as well as input data for the thermohydraulic accident analysis programs, it is proposed to develop the PCRELAP5 in order to contemplate the needs of the users of the RELAP5 code, So that the time spent by them in preparing the calculation memorial of the analyzed plant and its input data is minimized.

Thus, the objectives of this work are: to program the hydrodynamic components in their entirety according to the RELAP5 Manual, with a more interactive and feasible interface for the end user, to automate the calculation of the loss of loads using the program SF Pressure Drop 6.2 2010) that will have a link in PCRELAP5, as this information is part of the input data of the RELAP5 components and generate an English version of PCRELAP5

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.

2. METHODS

The programs that will be part of this work are: Microsoft Excel [7 to11], the SF Pressure Drop 6.2 [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, and Front Page) is the Visual Basic for Application (VBA) [7 to 11].

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 [7 to 11].
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2.3. SF Pressure Drop 6.2

SF Pressure Drop 6.2 [6] 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 following are the main steps involved in the use of PCRELAP5 to compute the calculation memory and the input of RELAP5 from Angra 2 SIE. A screen will be presented for each component that constitutes this system. When PCRELAP5 is opened, Screen, the user must select the language that he / she wants to use when writing the RELAP5 input (Fig. 1)

Figure 1 – Screen "Abertura" of the PCRELAP5

The next screen will be the "INDEX", where the user can choose the "Geometry" worksheet, in which the components referring to this case will be chosen specifically (Fig. 2).

Figure 2 – Sreen "Índice" of the PCRELAP5

In the next step, if the user is to start writing the RELAP5 input, he should always click on the "TITLE OF THE PROBLEM" button, inserting the most appropriate title to represent his problem (Fig. 3). This action will generate the cards that initialize the problem, such as the title, the steady state or transient option, and will indicate other initial information in the worksheet "CodeRelap" as shown in Fig. 4.

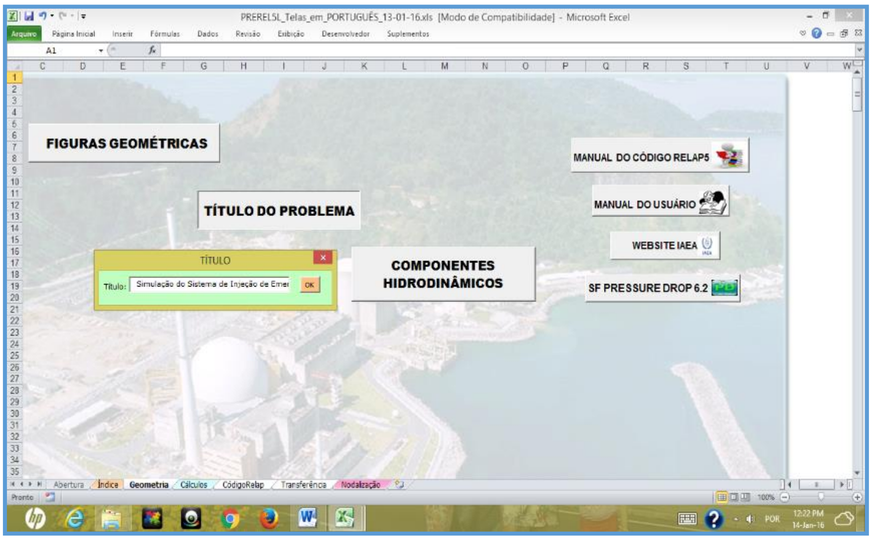

Figure 3 – Screen "Geometria" and button "TÍTULO DO PROBLEMA" of the PCRELAP5 – Angra 2

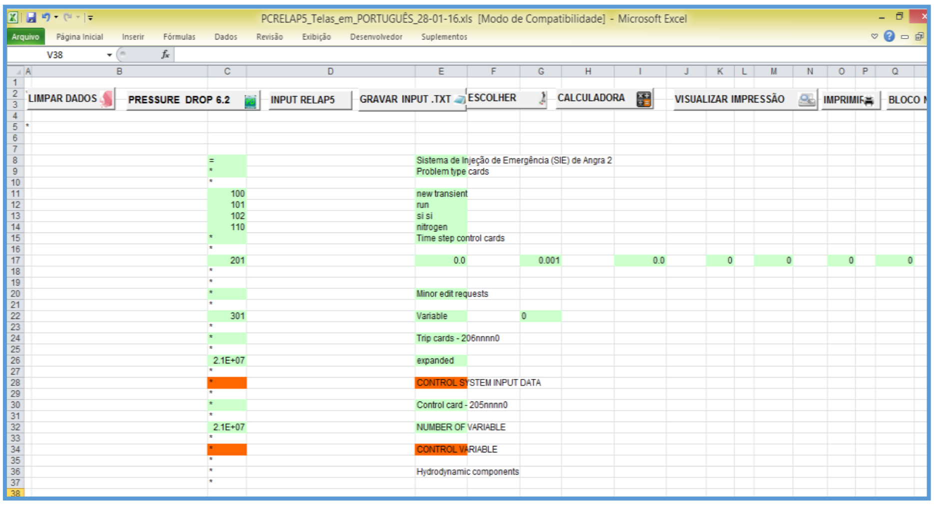

Figure 4 – Sheet "CódigoRelap" of the PCRELAP5 – Angra 2

Then, the user must click the "HYDRODYNAMIC COMPONENTS" button to choose the component that you want to create. According to Fig. 5, the option chosen is the accumulator (ACCUM), one of the components that are part of the Angra 2 SIE. When you complete the "Component" screen, the user will be directed to the screen of the selected component (ACCUM).

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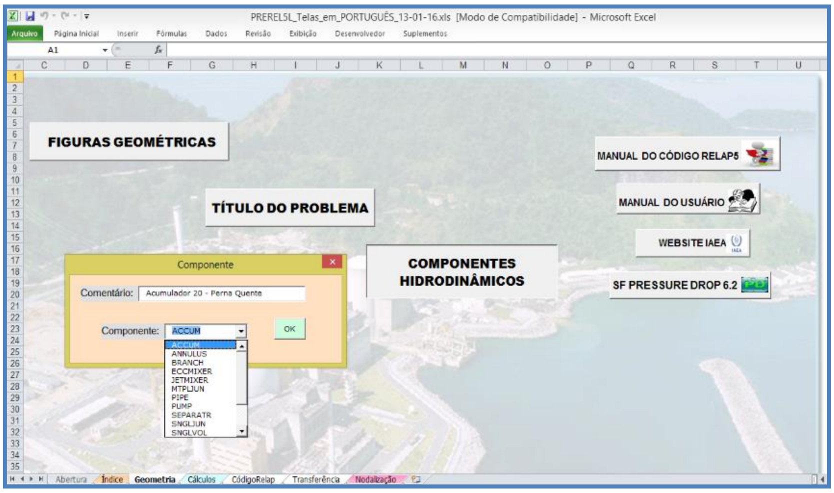

Figure 5 – Button "COMPONENTES HIDRODINÂMICOS" of the PCRELAP5 – Angra 2

The Fig. 6 shows all the screens associated with the accumulator (ACCUM), duly completed, including the screen of the flags

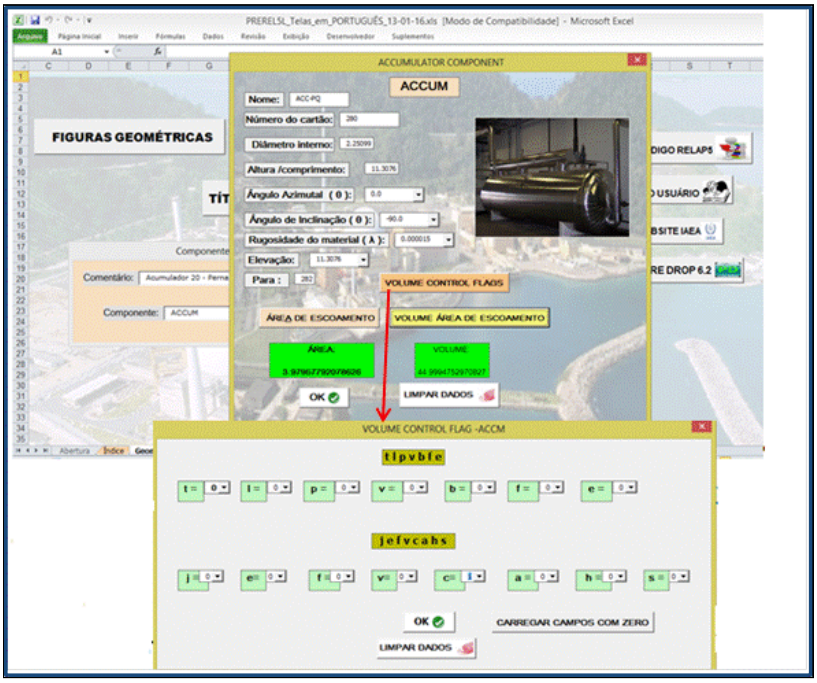

Figure 6 – Components screens "ACCUM" of the PCRELAP5 – Angra 2

In relation to the other control volumes constituting the Angra 2 SIS and which are represented by components of RELAP5 for the elaboration of their input data, PCRELAP5 was used by filling in their respective screens.

In the case of the PIPE component, only the screen of one of them will be displayed (Fig. 7). However, the other PIPE's were also filled in with their respective data, which will be presented in the txt format at the end of this chapter.

The "number of reps" field in the PIPE component form indicates the number of times that the same data is repeated for the volumes specified by the user. In some situations, it may occur that the number of repetitions coincides with the number of volumes; Then the user will be informed and once the OK button is clicked, the form will be closed (Fig.8).
Another circumstance is when the number of repetitions is smaller than the number of volumes, thus missing data from the remaining volumes. In this case, a new form (screen) will be opened so that the data is completed until the number of volumes is the same as the one provided by the user (Fig. 7).

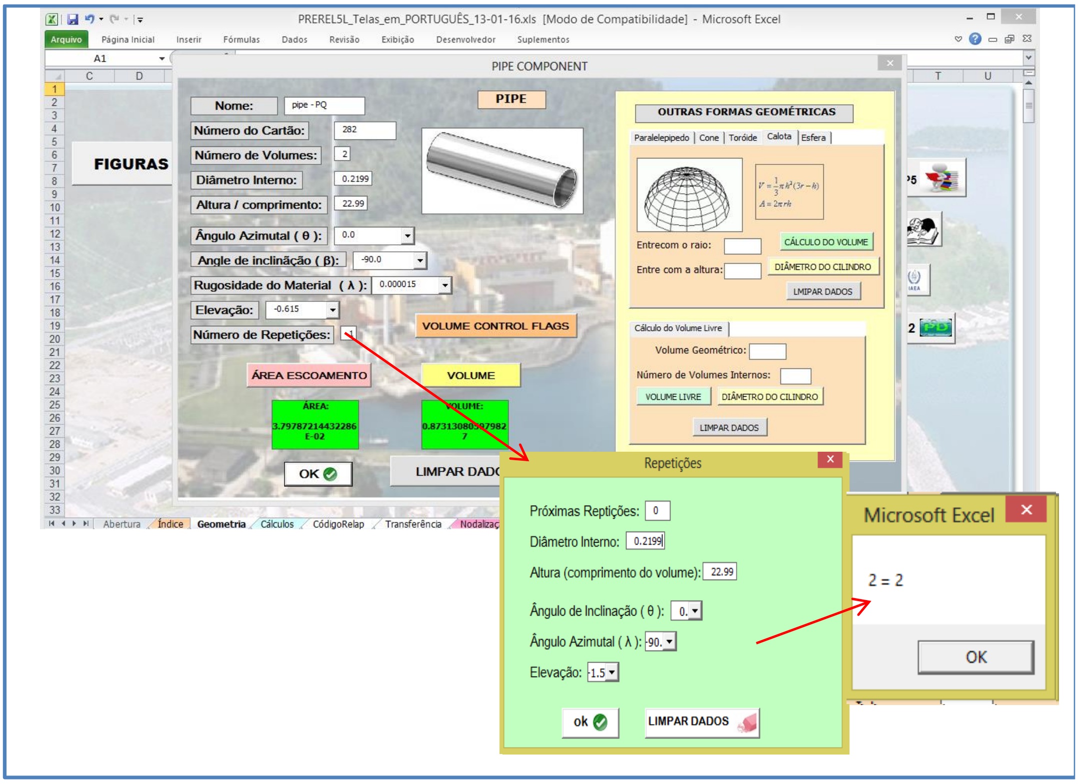

Figure 7– Components screens "PIPE" of the PCRELAP5 – Angra 2

This procedure was also adopted for the other components that constitute the EIS, being BRANCH, TMDPVOL, VALVE and SNGJUN (Figs 8 to 11).

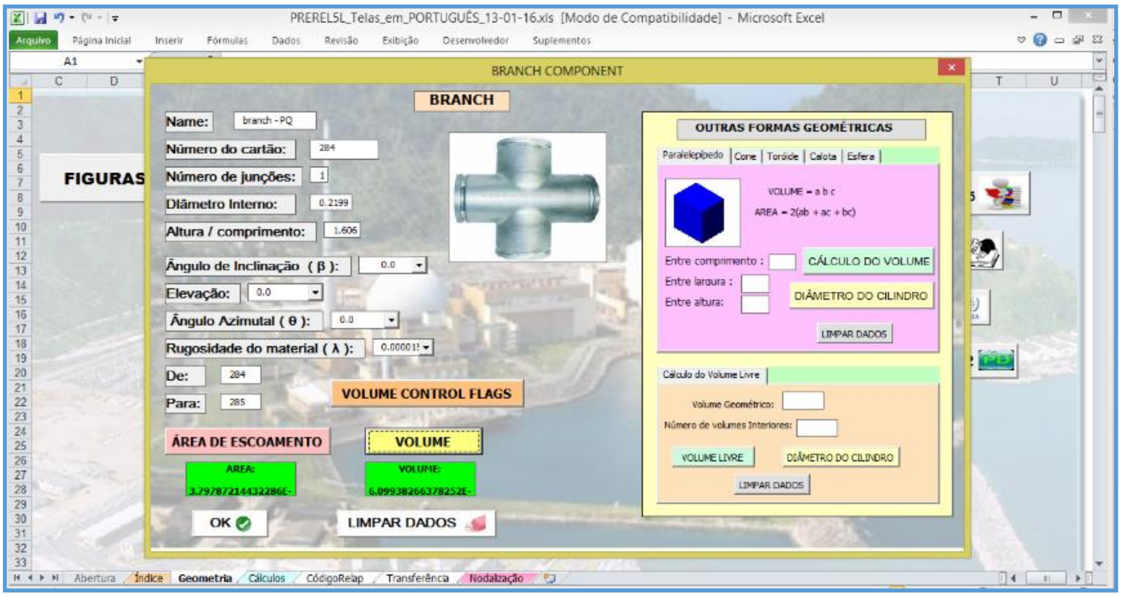

Figure 8 – Components screens "BRANCH" of the PCRELAP5 – Angra 2

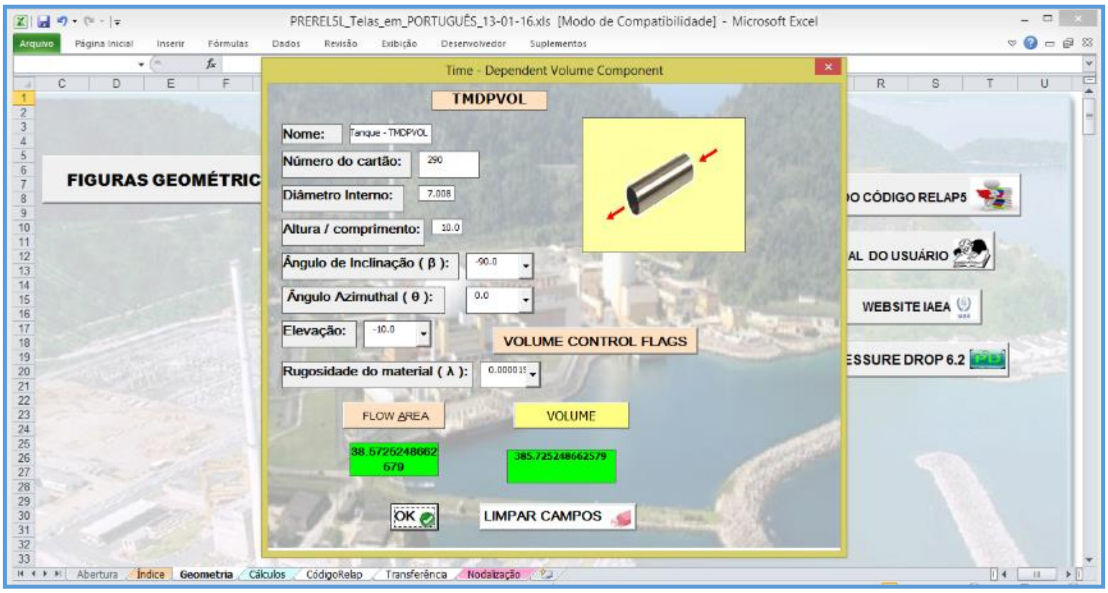

Figure 9 – Components screens "TMDPVOL" of the PCRELAP5 – Angra 2

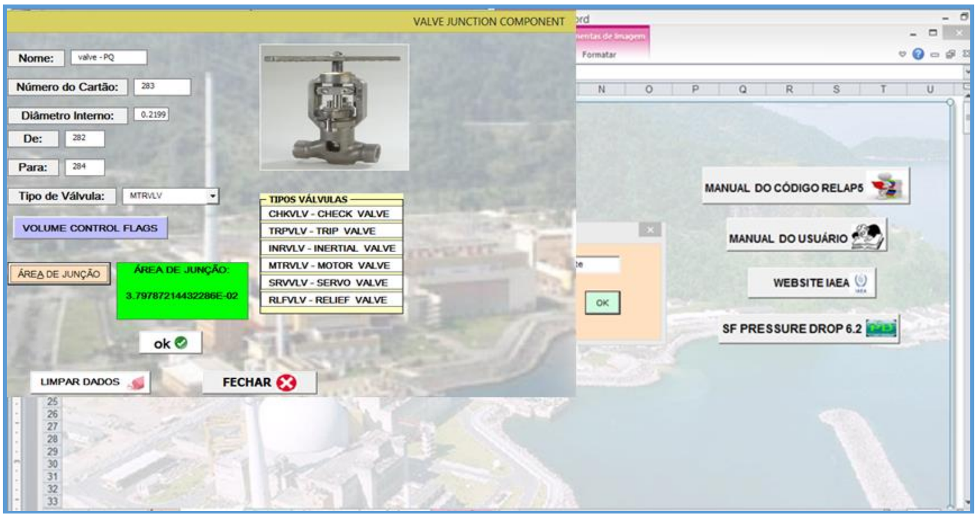

Figure 10 – Components screens “VALVE” of the PCRELAP5– Angra 2

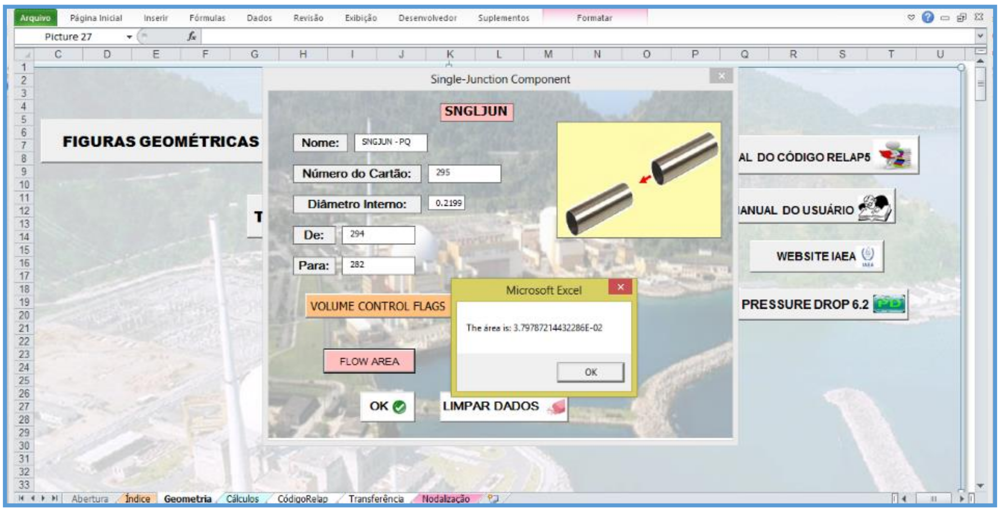

Figure 11– Components screens “SNGJUN” of the PCRELAP5– Angra 2

After completing all the screens of the PCRELAP5 components that make up the Angra 2 SIE, the "Cálculos" and "CodigoRelap" worksheets are generated automatically (Figs 12 and 13). However, only the first screens of the "Calculations" and "CodigoRelap" folders are displayed in this chapter. Finally, by clicking the "INPUT RELAP5" and "SAVE INPUT.TXT" buttons, the RELAP5 input for this system is then obtained (Fig. 13).

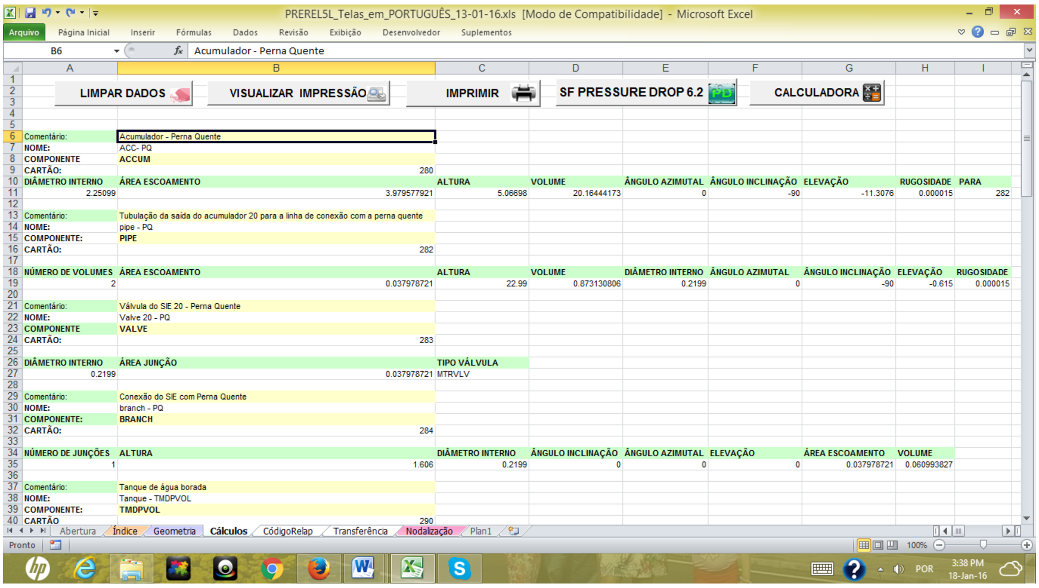

Figure 12 – Sheet "Cálculos" of the PCRELAP5 – Angra 2

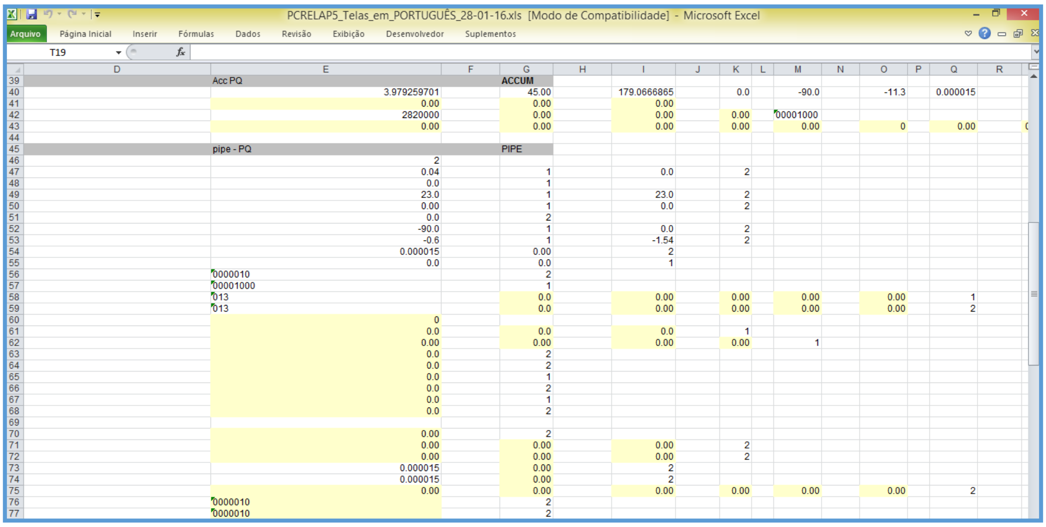

Figure 13 – Sheet "CódigoRelap" of the PCRELAP5

In the following, one of the screen is shown, Fig. 14, generated by PCRELAP5 regarding the input to RELAP5 in relation to Safety Injection System (SIS) of Angra 2.The input is presented in text file (txt), as this is the format acceptable by the RELAP5 code for your input data.

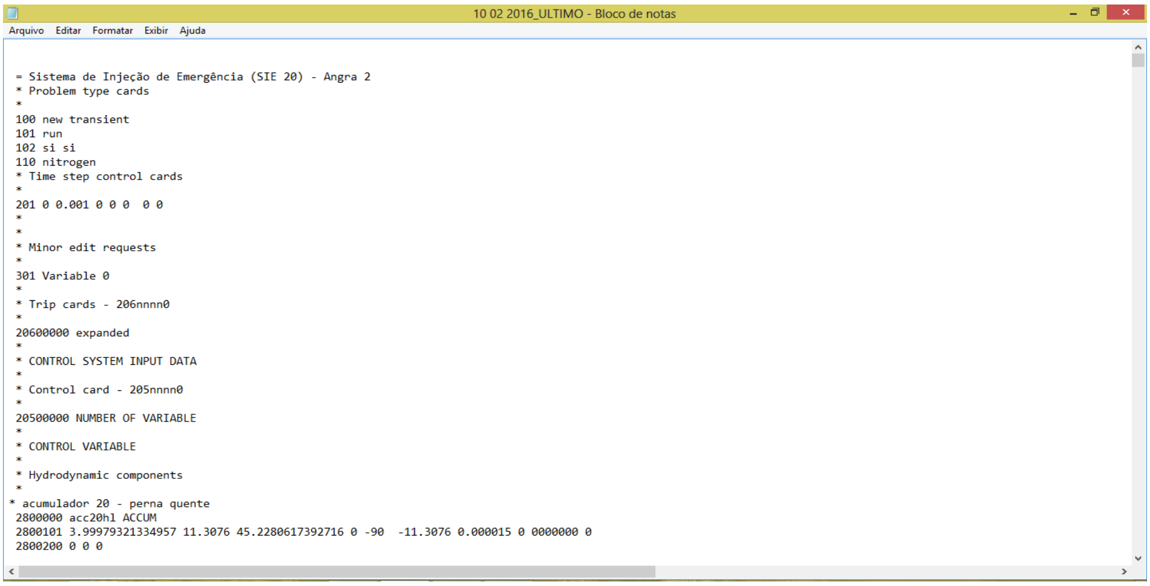

Figure 14 - Input for RELAP5 of Angra 2 SIE in txt format generated by PCRELAP5

In this work all the input of the Angra 2´s SIE was generated, demonstrating so, the efficiency of the PCRELAP5 computer tool;

4. CONCLUSIONS

The choice of VBA for Excel as programming language in the preparation of PCRELAP5 proved to be efficient in the course of the work.The forms resource was of great value for the elaboration of the screens created for the user, so that the interaction became more intuitive.
An objective language, easy to understand was used, besides the possibility of insertion of images.

It should be noted that the use of macros in MS Excel is a feature susceptible to failures, especially in macros that are recorded by the user, compared to those that have been programmed. It is often necessary to exit MS Excel and return to this software for a new run of the macros, so that they work correctly. This is a difficulty pointed out by some authors, such as Walkenbach (2013).

The objectives established in this work were achieved, and the results show compliance objectives. Successfully programmed and tested all screens for each of the components, in a total of fifteen, according to the description of the RELAP5 Code Manual.
To facilitate user actions, some access links were added to the "Geometry" worksheet, such as: queries to the RELAP5 manuals, the PCRELAP5 user manual, the IAEA website and the SF Pressure Drop 6.2 program.

The complete cleaning of the information, the possibility to save them in pdf, txt format, to view them, to print them, to choose another component without needing to return to the initial screen of the program, were some features incorporated in the spreadsheets "Calculations" CodeRelap ".

As an example of the efficiency of PCRELAP5, it can be said that it has been used successfully to generate the input data of Angra 2 SIE, For RELAP5.

It is concluded, therefore, that PCRELAP5 is a facilitating tool in the preparation of the input data of the RELAP5 code, reducing the time spent by the user in the execution of the work. The next steps suggested from this work are: automatically transfer the pressure drop data generated by SF Pressure Drop 6.2 to the "CodeRap" worksheet and build the nodulation through VBA programming and insert into the PCRELAP5.

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