

DESIGN SOFTWARE FOR SOLAR DISTRICT HEATING SYSTEMS

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Abstract. *The District Heating System (DHS) is used thoroughly at North European countries, as it is the case of Iceland, where a net of 29 DHS assists about 90% of houses and whose energy comes from geothermal source (Samorka - Icelandic Energy and Utilities). Still, in countries as Denmark, the penetration of the district heating systems reaches 50% of the population, with nearly 20.000 km pipe lines total length across the country (Nordvärme Association). In Germany the penetration of DHS reaches 12%, representing 46% of the energy destined to the residential sector, 36% to the commercial sector and 18% to the industrial sector (AG Fernwärme, 2002). However, in development countries, this technology is still innovative, especially to assist the demand of hot water for low-income houses. The scope of this work is motivated by the significant increase of the number of solar water heaters installed through public policies over the last years in low income houses in Brazil, and by the inherent technical challenges of the implantation of these systems such as the development of new sustainable models for this technology. Those models seek to reduce the selling of equipments, after installation, by the residents and to guarantee better operation and maintenance conditions of the systems along its useful life. Initially, information was raised about typical housing characteristics for low-income family residents at Minas Gerais State of Brazil. This research included houses with approximate area of 40m², 4 residents and family income of 3 “minimum” wages (US\$500,00) and will help the team to choose the better place to install DHS, considering architectonic and sociological aspects. At the same time, computational routines are being developed to establish the minimum criteria to be adopted in the selection of the improved model, which seek to minimize the system’s requested recirculation, the pumping energy consumption, the pipe’s diameters in the secondary system and the thermal losses in the distribution net. These routines will allow the generation of a matrix’s results with the consolidation of the gains and the identification of the disadvantages of each studied configuration. The beta version, already finished, was developed in the software Engineering Equation Solver (EES) and is based on the energy equations of momentum and mass conservation. The program presents a friendly and iterative platform that allows the user to obtain fast and reliable results. Their main objectives are to calculate, in an optimized way, the diameters of the feeding and returning pipes (sub-extensions, extensions and feeding extensions) guaranteeing, therefore, the smallest possible cost of installation and to determine the pressure losses at each interval of the net, foreseeing the need of installation of hydraulic recirculation pumps. For the final version of the program heat transfer equations will be implemented to the previous algorithm to determine the inherent pipes and connections thermal losses. Another tool to be used will be the software ANSYS CFX that will supply the bases with a more elaborated numeric simulation and validate the developed mathematical model.*

Keywords: *Solar District Heating System, solar thermal, low-income households.*

1. INTRODUCTION

A District Heating System can be defined as a system that generates and distributes thermal energy, with water as the transport fluid, which provides water and space heating for the residential and commercial sectors.

Currently, DHS is highly used in the North European countries such as Iceland, Denmark and Germany, where its penetration is of 90%, 50% and 12%, respectively, for space and water heating. At these countries, this energy

generation is used in residential, commercial and industrial sectors, with production coming from geothermal, solar and others energy sources. However, the usage of this technology in developing countries still is innovative, since their energy is basically generated by sources like hydraulic and thermoelectric centrals, coal and oil.

In Brazil, solar thermal energy is used for water heating at residential, service and industrial sectors. With a nearly 4,200,000m² solar collector area (IEA, 2008), Brazil is one of the 10th countries with greater installed solar collector area in the world and, through public policies and programs, has been installing solar heating systems in low-income communities. This trend could be confirmed by the installation of solar heating in more than 15,000 low-income households in the country. These programs aim, mainly, to reduce the family energy consumption and energy demand on peak periods – the usage of electric heating at 78% (Procel/Eletróbrás, 2005) of the Brazilian households, where 99.7% (Procel/Eletróbrás, 2005) are represented by electric showers, generates a bigger energy demand on the morning and late afternoon periods.

The DHS installation in low-income communities intends to improve the system's operation and maintenance conditions guarantying the quality of water supply. The work described in this paper consist on part of the research realized for the implementation of a DHS in a housing community at Minas Gerais, through the *P&D 183 - District Heating* research project signed by the Pontifical Catholic University of Minas Gerais (PUC-MG), through the laboratory Group of Energy Studies (GREEN Solar), and the Energy Company of Minas Gerais (CEMIG). Basically a DHS will be installed in a maximum 60-house community at Minas Gerais State. Four teams of research are working in this project and are responsible for studies related to the system's insertion, design, execution, operation and control. In this paper, will be presented the architectonic insertion indicators research and the development of a computer program created to improve the secondary system of hot water distribution.

2. INSERTION STUDY: ARCHITECTONIC INDICATORS

The Solar District Heating System is distinguished from a common solar heating system because of its singularities, specially if the scale factor is considered, since the primary and secondary systems present greater dimensions and complexity if compared to a conventional system. Therefore it is essential to study the insertion location as well as its legal and physical characteristics beyond population behavioral routines. Housing communities built by Minas Gerais Housing Company (COHAB-MG) on 2008-year, within a special housing program called Lares Geraes, were studied to develop this research.

The Brazilian housing deficit had achieved in 2006 the number of 7,935 million households, according to João Pinheiro Foundation (FJP, 2008), representing one of the biggest social problems of the country. This fact lead to the creation of construction and design procedures those are similar and usual all over the country. To build housing units the most used criteria is the fast and large-scale production that promotes the maximum economy savings. Thus it is common to affirm that design and execution of Brazilian housing units follow the same concepts, configurations and characteristics. However, exceptions might be found in diverse locations because of different policies and legislations, housing demand size and financial availability.

In order to characterize a typical housing set and develop DHS insertion studies, aspects such as number of houses per community, size and geometry of blocks and building sites, configuration and insertion of street ways, blocks and building sites' occupancy, characteristics of the housing units, bathroom position related to the street and post-occupancy changes. Figure 1 shows 10 images that represent some of the evaluated topics of the cataloged Housing Sets.

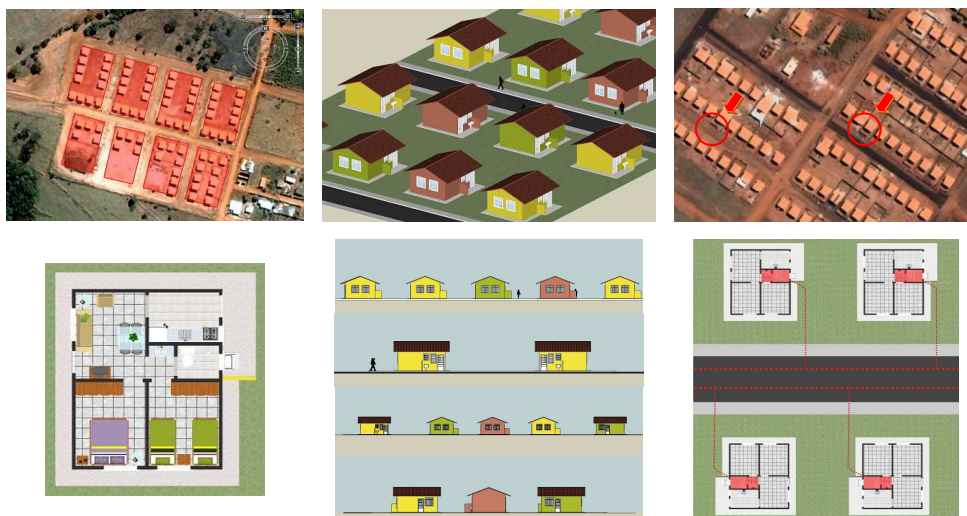


Figure 1. Some evaluated aspects of the cataloged Housing Sets

Firstly all housing sets built by COHAB-MG were cataloged for the beginning of this study. The Google Earth tool was used to visualize those housing sets, which were digitalized, when it was possible, for further analysis. This procedure can be observed in Fig. 2 below.







Figure 2. Housing Sets examples visualized through Google Earth software and digitalized using AutoCAD software

The obtained examples were united and characterized according to quality and quantity evaluation aspects. The samples' data were tabulated to promote a better identification of the most expressive and prevailing characteristics of the sets. Through the examination and analysis of those results it was possible to elaborate architectonic insertion indicators of the DHS.

In this research were evaluated 34 housing sets, which had been built by COHAB-MG in 2008-year and are located in 9 different regions of the State.

In the project's scope it was predicted an installation of a Solar DHS in a low-income housing set that should contain the maximum number of 60 households. That definition had become the first insertion pointer: size of the community. Other important project aspects are the need of pipe cost reduction as well as the whole installation, besides system's optimization. In order to achieve these aspects it was defined that the better housing set choice would be of those that present blocks and building sites with regular geometry, maximum slope of 15% (to reduce pumping costs) and front occupancy of the building site, leading to a smaller distance between the bathroom and the street (where the main hot water distribution pipes will be located). For a better visualization of the defined insertion indicators observe the Tab. 1 below:

Table 1. Architectonic pointers for the Solar DHS insertion in a housing set

Pointers for the Solar DHS Insertion in Housing Sets built by COHAB-MG		
Topics	Pointers	Example
Number of Households	> 60 units	
Blocks' geometry	Regular blocks	
Building sites occupancy	Front occupancy	
Bathroom location related to the street way	Minimum distance related to the street way	

The forward research consists on the elaboration of sociological pointers, through the study of related references and cases, which will guide the insertion of the Solar DHS. For this research the families will be characterized according to their average financial income, number of residents per house, consumption habits and possession of equipments (television, fridge, radio, computer and others), habits of bath and the technology acceptance and use. This research will be divided into two parts – pre and post-insertion of the Solar DHS – and aims to generate a quality evaluation of the installed system, which will become a reference for future works and implementations.

3. PROGRAM DEVELOPMENT

A typical district heating system consists on 4 main components: the *generation* of hot water, that can be achieved through processes of cogeneration, geothermal, biomass and solar energy; the *storage* of water, that is characterized in most applications for seasonal reservoirs and is implemented through different constructive techniques and with volumes around 10,000 m³; *distribution*, that is characterized by hot water pipe networks; and final *consumption* by the user.

The proposal to create a computer program aims to design the entire fluid dynamic parts, taking into account heat transfer, of a secondary system of district heating. The secondary system is known as all pipes and fittings used after the hot water leaves the tank, in case of a system operating with solar energy, however, we can extend this analysis to any type of central water heating.

3.1. Main objectives

The first objective of the developed program is to design in a non-optimized way, which consider the maximum possible consumption, the diameters, pressures and flows throughout the pipe network.

The recommended processes to be adopted are the same applied to cold-water distribution net, that is the *possible maximum consumption*. Already for the equipment consumption it can be adopted the same applied for cold-water over the sub-branches sizing.

In order to avoid the delivery of insufficient water temperature at some net stretches is necessary to verify whether the hot water effectively circulates over the referred net. To perform this evaluation a closed circuit is considered, which contains the ascendant and descendant branches. It is admitted that all flow circulates into those branches when all the equipment present closed taps. To establish the circulation chain is necessary to have sufficient temperature difference between the ascendant and descendant branches, or the supply of sufficient energy for the water by a pump, which would be used to pass the pressure losses in the tubes. The flow (litres/hour) that circulates into the pipes coming from the reservoir will be called Q , and:

- t_1 : water temperature into the reservoir;
- t_2 : water temperature into the superior main branch;
- t_0 : atmospheric air temperature exterior to the pipes;
- S : surface of the pipe's ascendant branch;
- K : heat transfer coefficient through pipe's thermal insulator;
- t_3 : temperature of the water that returns to the storage tank;
- S' : surface of the pipe's descendant branch;

For the ascendant branch it could be written that its heat losses, considering time units, are those suffered by the water that circulates into the pipes. That can be represented by the Equ. (1) bellow:

$$K \cdot S \cdot \left(\frac{t_1 + t_2}{2} - t_0 \right) = Q \cdot (t_1 - t_2) \quad (1)$$

where the flow value can be defined by the Equ. (2):

$$Q = \frac{K \cdot S}{2} \cdot \left(\frac{t_1 + t_2 - t_0}{t_1 - t_2} \right) \quad (2)$$

In order to guarantee the flow occurrence into the ascendant pipe network the existence of a certain “hydraulic charge” or “hydraulic potential”, H_d , is important. This hydraulic potential is generated by the weight difference between cold and hot water, respectively into the descendant and ascendant branches. The level difference of the superior branch and the storage tank's center is called h . The H_d charge, that represents the pressure losses into the whole pipe network, is given by the Equ. (3):

$$H_d = h \cdot (d_a - d'_a) \quad (3)$$

where d'_a is the water density into the storage tank and d_a is the water density into the main branch.

If the H_d value will be insufficient to establish the Q discharge with a velocity value of about 1,5 m/s, it'll might be necessary to intercalate a centrifugal pump in the ascendant branch. The pump's manometric height added to the H_d charge should be equal to the total pressure loss value, for Q discharge and velocity V .

Another objective of the program is to improve, in tree steps, the applied diameters and flow rates in order to reduce them (Probable Maximum Consumption) after set the average point for each consumer, obeying the technical standards.

For the estimation of the flows that are considered for the pipe net's sizing, the Equ. (4) should be used:

$$Q = C \cdot \sqrt{\sum P} \quad (4)$$

where:

Q : Is the same of Flow (m^3/s);

C : Is the Discharge Coefficient, and is equal 0,30 l/s;

$\sum P$: Is the sum of the correspondent weight of all the other pieces able to be used simultaneously and are linked to the pipe network.

In a public water supply system the amount of water consumed varies continuously with variables as time, weather conditions, population habits among others. Therefore is important to establish coefficients capable to translate those consumption variations for the sizing of the different units of a public water supply system.

The major daily consumption coefficient (k_1) is the relation between the values of maximum and average annual daily consumption. Whereas the major hourly consumption (k_2) is the relation between the maximum hourly flow rate and the average daily flow consumption.

Currently the recommended design values are:

$$k_1 : 1,1 \text{ a } 1,4$$

$$k_2 : 1,5 \text{ a } 2,3$$

The previously defined coefficients are multiplied and generates the reinforcement coefficient and instantaneous variable coefficient (K). Observe Equ. (5) bellow:

$$K = k_1 \times k_2 \quad (5)$$

In addition it is known that, for the sizing of the different units of a public water supply system, is necessary to define the flows values of average flow (Q), maximum daily consumption flow (Q_1) and maximum daily consumption flow for the most required hour (Q_2). Those coefficients are defined by Equ's. (6), (7) and (8).

$$Q = \frac{P \times q}{3600 \times h} \left(\frac{l}{s} \right) \quad (6)$$

where:

Q : Annual average flow (l/s);

P : Contemplated population (inhabitants);

q : Consumption rate *per capita* (litres/inhabitants per day);

h : Number of functioning hours of the system or considered unit.

$$Q_1 = \frac{P \times q \times k_1}{3600 \times h} = k_1 \cdot Q \left(\frac{l}{s} \right) \quad (7)$$

where:

k_1 : coefficient of the major consumption day

$$Q_2 = \frac{P \times q \times K}{3600 \times h} \left(\frac{l}{s} \right) \quad (8)$$

where:

$$K = k_1 \times k_2 = \text{reinforcement coefficient}$$

For the sizing of ramified nets or meshed nets under partitioning effect, a specific flow, that is the metered canalized, is considered. Over a determined sector of the distribution system, the flow can be distributed and expressed in litres/second per meter of canalization and will obey the Equ. (9):

$$q_m = \frac{n \cdot k_1 \cdot k_2 \cdot q}{86400} \tag{9}$$

where:

q_m : is the distribution flow over the canalization, on the major consumption time, of the major required day (l/s per meter or canalization)

n : is the average number of people contemplated by the metered canalized way. In one sector this value is given by the Equ. (10):

$$n = \frac{\text{contemplated population}}{\text{sector's extension}} \tag{10}$$

and:

q : is the water quote to be distributed per person. It is expressed in litres per 24 hours.

Finally the last objective of the presented program is to create a friendly interface where the user can input the project data and view the output data (flow, pressure and diameter optimized and not optimized) afterwards. This interface will also generate graphics of all information.

4. ANALYSIS

The initial version, developed at the Software Engineering Equation Solver (EES), uses the equations of mass, momentum and energy conservation to determine pressure, flow and diameter at each point of the pipe network at the secondary circuit (Sub-Branches, Branches, Supply and Return Branches). The program works in an iterative way through equations, functions and procedures of analysis and optimization, taking into account the guidelines set by existing laws and standards.

The system is divided into primary and secondary circuit. The primary circuit is the source generating and storage of energy, in this case hot water. The secondary circuit is the network distribution of hot water to consumers and it is divided into: Sub-Branches, Branches, Supply and Return Branches.

Figure 3, presented below, represents the configuration used for the secondary circuit, where the first house, in 1st and 2nd block, is considered the farthest house on the input power. Thus the fourth and last house is regarded as the closest of the input power of the Supply Branches. From this configuration all the modeling was performed and characterized in the analysis item.

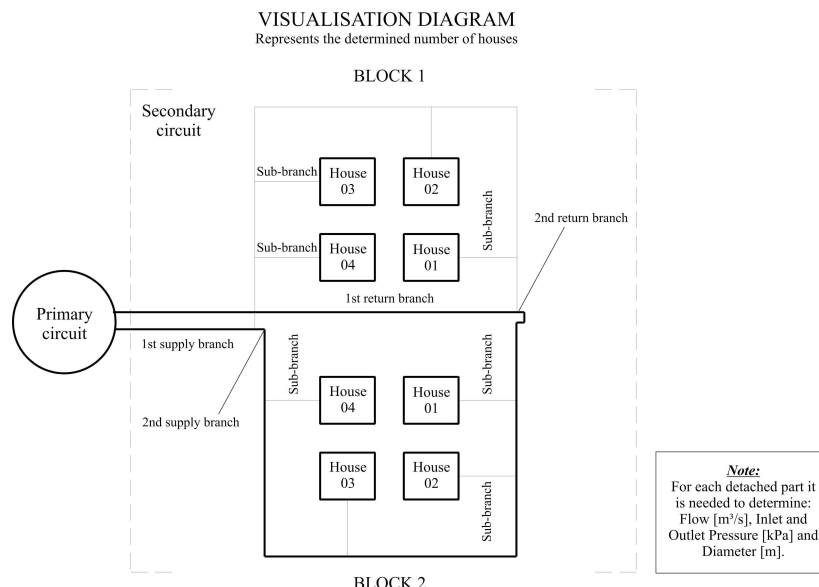


Figure 3. Diagram sketch of the secondary circuit

To perform an analysis is necessary to input specific data into the program interface. Figure 4 represents the main screen of the program. Each number represents one input data that is needed to realize the analysis. The sequence bellow shows the meaning of those numbers along with the procedures that the user must adopt.

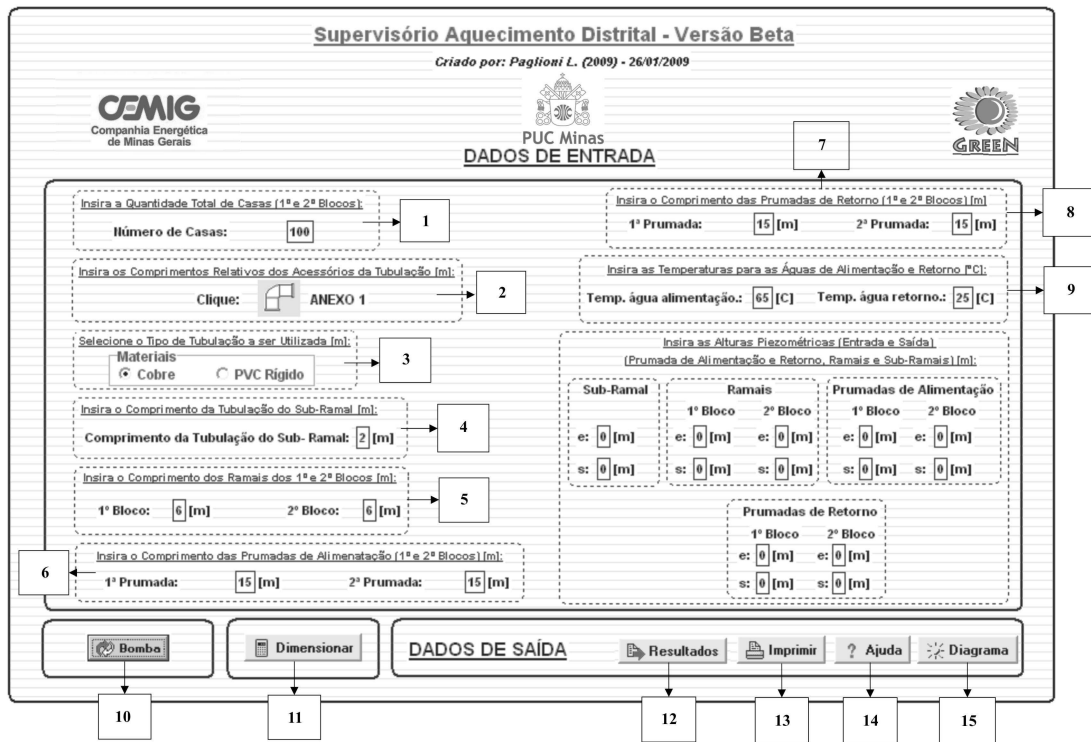


Figure 4. Main Program Screen

In Gap **Number 1** is necessary to input the amount of houses (1 and 2 blocks), thus the number of houses of the project.

In Gap **Number 2** is necessary to input the relative length (using meter units) of the Pipe Accessories. This field leads the user to "Annex 1" in another window. Each accessory and its amount used in each sub network (Sub-branches, branches, Supply and Return branches) must be selected, as showed in Fig. 5.

ANEXO 1							
	Sub-Ramal	Ramais		Prumadas de Alimentação		Prumadas de Retorno	
		1º Bloco	2º Bloco	1º Bloco	2º Bloco	1º Bloco	2º Bloco
Joelho de 90° Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Joelho de 45° Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Curva de 90° Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Curva de 45° Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Tê 90° Pass. Direta Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Tê 90° Saída de Lado Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Tê 90° Saída Bilateral Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Entrada Normal Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Entrada de Borda Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Saída de Canalização Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Válv. de Pé e Crivo Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Válv. Ret. Tipo Leve Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Válv. Ret. Tipo Pesado Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Registro Globo Aberto Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Reg. Gaveta Aberto Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Reg. Ângulo Aberto Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Acess. Diversos Quantidade:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>
Comprimento Relativo:	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>

Figure 5. Annex 1 Screen Accessories

In the “Annex 1”, where the accessories are inserted, is necessary to complete the gaps **number 2.1 and 2.2**. In the field **number 2.1** the user must enter the amount of each type of accessories in every part of the network (Sub-branches, branches Supply and Return Branches). Already in gap **number 2.2**, which is related to "Other Accessories in the Annex 1", the user can input any other type of accessory that is not listed before. To do this, the user should insert the amount (as in the project) and its relative length in meters (from technical literature). To return to the main screen of the program the button **number 2.3** can be used.

The material used in pipes can be selected in the field **number 3** where two kinds of materials are available (copper or CPVC). It is only possible to select one type of material for each simulation.

In the gap **number 4** the designer must provide the length of one sub-branch in meters, taking into account that the blocks are symmetrically constructed. This procedure is basically the same for gap **number 5**, the difference is that in this field the length of the branches in 1st and 2nd blocks must be provided.

For the gap **number 6** the user must input the length of the 1st and 2nd “Supply branch” in meters (data project). And in gap **number 7** the user must input the length of the 1st and 2nd “Return branch” in meters (data project).

In gap **number 8** the user should input the temperatures of supply and return water in the secondary circuit in Celsius degrees. It is recommended to use the average of the temperatures founded along the pipes.

The gap **number 9** is filled by the Piezometer Heights (Input and Output) (Prum Supply and Return, Branches and Sub Branches) [m]. The designer should input the entry and exit heights of the pipes in each of the sub network of the secondary circuit (Sub-branch, branch, Supply and Return branches). The letter "e" determines the entry and the letter "s" the output of the pipe.

To dimension the hydraulic circulation pump in the secondary circuit the user must enter information about the used pump in gap **number 10**. In Fig. 6 the project’s pump circulation can be viewed.

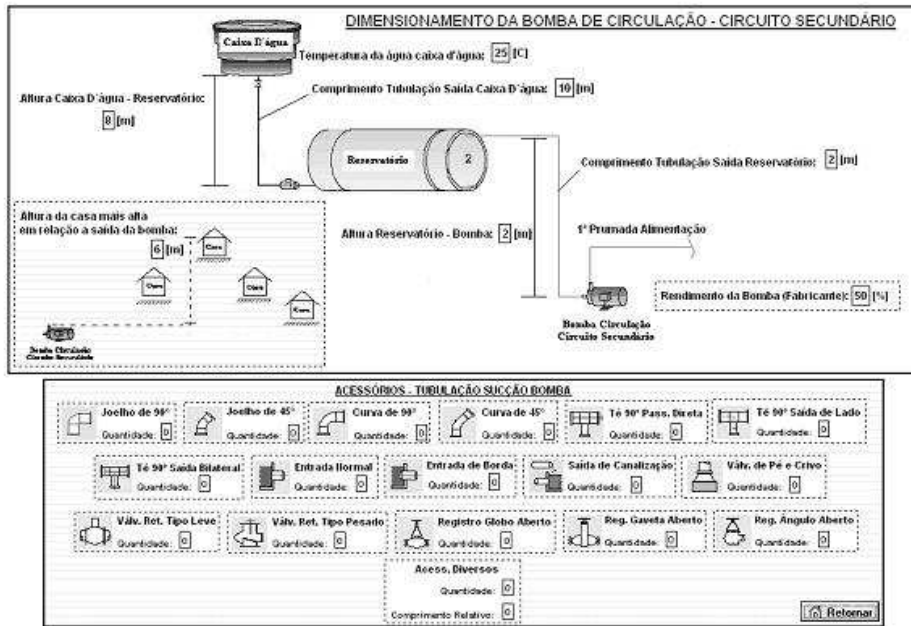


Figure 6. Screen that shows the circulation pump’s project

Finally to perform the calculations the user must select the button represented by the **number 11**.

For the output data all the results (numerical and graphical), for the Supply and Return Branches, Branches and Sub-Branched can be observed by the user in the selection of button **number 12**. If printing is interesting to the user it can be done through the **number 13** button’s selection. Here the main screen, graphs, diagrams and results can be printed.

The program also counts on a “help” section, that can be accessed pressing the **number 14** button. Also using the **number 15** button the user can view a schematic diagram of a secondary circuit of district heating as Figure 03. In this screen the user can understand what each variable represents, and where it is exactly located.

5. RESULTS AND CONCLUSIONS

The program allows the visualization of several numerical and graphical results for each part of the network in the secondary circuit, such as Diameter [m] X Flow [m³/s], Pressure [kPa] X Diameter [m], Pressure [kPa] X Flow [m³/s] and so on.

As an example, the graph of Figure 07 allows the analysis of the diameters behavior (optimized and non-optimized) in the branches of the 1st block according to the sequence of houses in each branch.

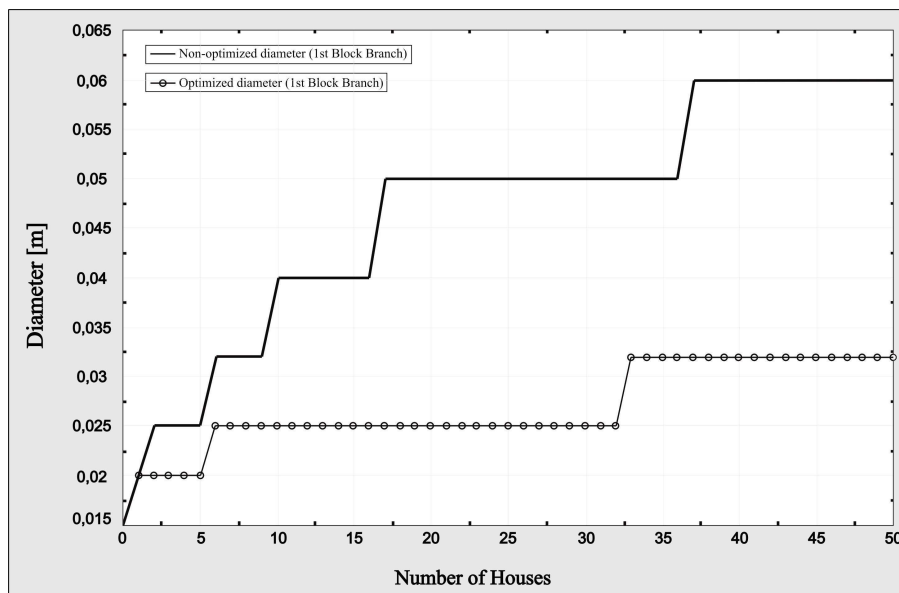


Figure 7. Diameters [m] X N^o. of Houses Branches in the 1st Block

The continuous line represents the sequence of diameters non optimized for the 1st block branches starting at house no. 0 to house no. 50. The diameters vary from 0.015 [m] at house no. 0 (which is the farthest on the Supply Branch entry that feeds the branches) by 0.060 [m] at house no. 50 (which is the closest on the Supply Branch entry that feeds the branches).

After the optimization (line with symbols), based on the concept of the probable maximum consumption (based on the low probability of all houses consume water at the same time), the diameters are reduced at the range of 0.015 [m] in the house no. 0 to 0.032 [m] in the house no. 50. Reducing the diameters in expressive way, consequently the cost of building the system is also reduced. It is important to say that all technical standards were maintained after optimization, as minimum flow and pressure of consumption beyond the limits of the flow velocities in pipes.

The analysis can also be made to the sub-branches, Supply and Return Branches. The system can be extrapolated to any number of houses wanted. The results can be viewed in graphical form, as in Figure 07 or in a numeric matrix through a data spreadsheet provided by the program.

The program developed allows a systemic analysis of the pressure, flow and diameter of each part of the secondary network of hot water distribution. Thus it serves as a basis for identification of critical points, such as excessive pressure over the network and the need of the recirculation pumps installation. In addition, the program provides a solid basis for reliable and complete system design. Several publications have been consulted and used as the basis for the hydraulic design and optimization of functions and procedures. Among them there is Gebremedhin *et al.* (2004) with their article on modeling and optimization of district heating and industrial power systems; Larsen *et al.* (2001) with their article entitled "Aggregated dynamic simulation model of district heating networks"; and Raab *et al.* (2005) with the validation of a computational model for district heating systems with seasonal storage of hot water.

Although the initial version does not deal with the thermal exchanges along the pipes with the environment, experience demonstrates that they only become relevant when these pipes are buried less than 0,30 [m] in the soil. The final version of the program seeks to deal with the changing temperature for different soils and insulation settings, thus generating a most complete and reliable results matrix.

6. REFERENCES

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7. RESPONSIBILITY NOTICE

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