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DEVELOPMENT OF COMPUTATIONAL PROGRAM TO DETERMINE THE COST OF VAPOR PRODUCTION IN BOILERS: PHASE 1

Nayssa Martins Ribeiro
UEM – Universidade Estadual de Maringá
PEM – Programa de Mestrado em Engenharia Mecânica
Av. Colombo, 5790, Bloco 104, Zipo Code: 87.020-900, Maringá – PR
nayssamr@gmail.com
Alinne Geronimo
Mechanical Engineer
Barão do Rio Branco Street, 11, Baixada, Zip Code: 85.506-630, Pato Branco – PR
alinnegeronimo@gmail.com
Luiz Carlos Martinelli Júnior
UTFPR – Universidade Tecnológica Federal do Paraná
Via do Conhecimento, km 1, Zip Code: 85.503-390, Pato Branco – PR
martinelli@utfpr.edu.br
Matheus Vinicius de Oliveira Herreo
UEM – Universidade Estadual de Maringá
PEM – Programa de Mestrado em Engenharia Mecânica
Av. Colombo, 5790, Bloco 104, Zip Code: 87.020-900, Maringá – PR
herreromatheus93@gmail.com

Abstract.

To implement or analyze the project of a boiler it is necessary to consider a series of items that increase the vapor production costs such as fuel used, the area occupied, equipment maintenance, among others. This work aims to present the first part of the development of a computational program to determine the cost of vapor production in boiler. It includes the costs of various factors that have influence on boiler operation, such as the fuel used, the chemical products present in the water, equipment calibration and so on. The factors featured in the NR-13, like PPE wear and employee qualification, were also taken into consideration. This software can become an important tool to be used by companies, providing them with a good starting point for studies to improve implemented or future projects targeting economy and productivity.

Keywords: *engineering, software, production cost, vapor, boiler*

1. INTRODUCTION

The emergence of steam generating machines at the beginning of the century XVIII, was promoted by the need to find alternatives in the generation of that would replace the direct burning of fossil coal. Nowadays, the practicality and the versatility of its use have made water vapor indispensable in several industrial sectors (BAZZO, 1995).

Boilers are equipment used to produce and store vapor under high pressures, they are designed according to pertinent codes, except for reboilers and alike (Brazil, 2014). These are common in installations where there is need for thermal energy, but the use of combustion or electric systems is not possible. Therefore, the activities that require steam for its operation, in particular, water vapor due to its abundance, have as essential component for its generation, the boiler. This equipment, for operating with internal pressures well above the atmospheric pressure, being in large part of the industrial applications approximately 20 times greater and, in the applications for the production of electric energy, between 60 to 100 times greater, being able to reach values of up to 250 times is an imminent risk in its operation (Altafini, 2002).

The thermal energy generated by the equipment and transported by the vapor is used in various kinds of companies such as meat-packing industries, feed factories, pharmaceutical companies, etc. This energy is usually applied in processes like heating, cooking, heat treatment and others (Çengel and Boles, 2006; Moran *et al.*, 2005).

This equipment can use any kind of fuel as energy source, being it fossil or renewable, solid, liquid or gas. The consumption of the fuel varies mainly according to its production capacity and vapor demand, but the maintenance costs of this type of equipment is not limited only by the fuel. According to the diagram shown in Figure 1, there are many items to be looked at when selecting a boiler (Sonntag and Borgnakke, 2003; Torreira, 2002).

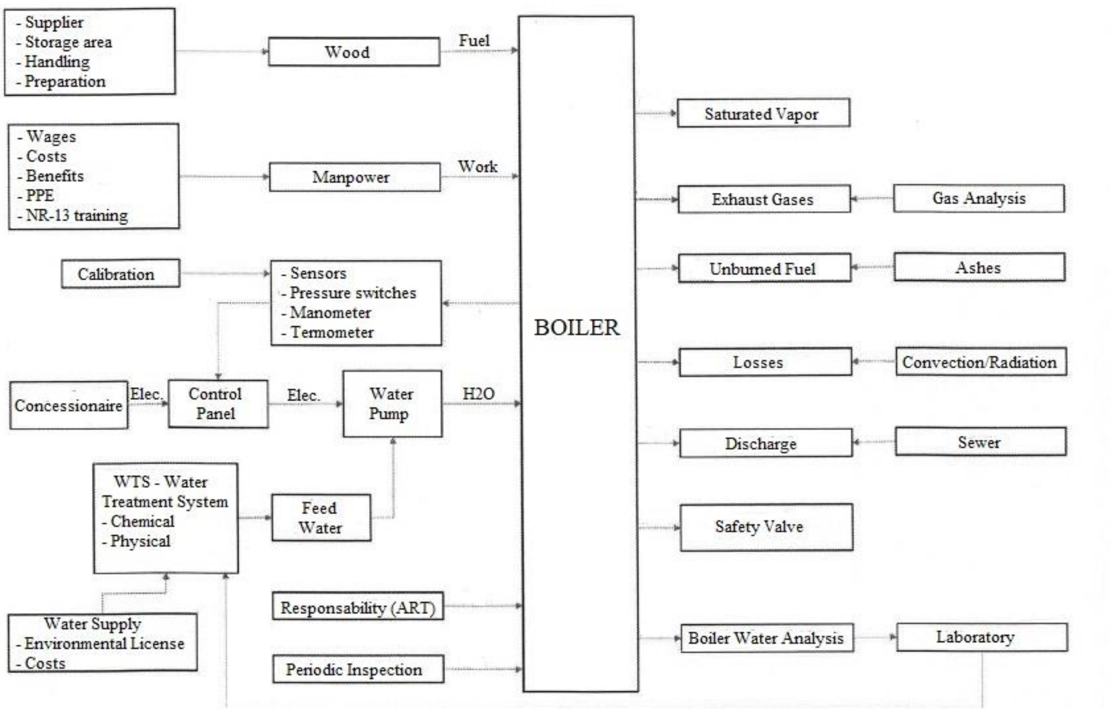

Figure 1. Cost diagram of a boiler

Boilers are widely used in industry and in the generation of electric energy, they are very important for the production process and, in some cases, they are the main equipment. On the other hand, they can be extremely lethal in the event of explosions, working in certain situations with a pressure level well above the atmospheric pressure, thus requiring extreme care throughout its from design, design, construction, installation, operation and disposal (Mello, 2010).

While predicting the acquisition of a boiler, factors such as regulatory norms, work laws and environmental requirements must be evaluated for they can create direct and indirect costs, many times disregarded by administrators. The unitary generated vapor cost must then be thoroughly measured to facilitate the calculation of the final product cost.

This work aims to present the first part of the development of a computational program to determine the cost of vapor production in boilers. It includes the costs of various factors that have influence on boiler operation, such as the fuel used, the chemical products present in the water, equipment calibration and so on. It must also facilitate the comprehension of the individual costs of each process using infographics and diagrams.

2. METHODOLOGY

Using the diagram in Figure 1 as reference, the flowchart was divided in two parts. Only the first part on the left side of Figure 1 was addressed in this article. The information obtained for each cost was:

a. Fuel: The items used to calculate the fuel costs were the fuel and delivery price per cubic meter and the quantity of fuel used weekly. The costs associated with the area and the volume used to store and handle were calculated. The cost of fuel preparation per cubic meter was also added to this category.

b. Manpower: The costs with manpower were calculated using the number of operators and their wages. Additional costs such as Christmas bonus salary, monthly insalubrity, annual NR-13 training, vacation pay, daily meal tickets, transportation allowances, monthly health plan, acquisition of PPE and other costs the company may have were also taken into consideration.

c. Engineering (NR-13): In this category were included the annual costs with inspections and ART.

d. Water: These costs were calculated from the catchment and monthly expenditure of water in cubic meters.

After obtaining all the variables involved in the vapor cost production and systematize them to obtain the value of a vapor unity produced in the final conditions of the process. All the input information must take actual data in consideration for later validation.

2.1 Equations

The equations that were used in the production of the computational program to determine the specific cost of each topic and total are described in this section.

2.1.1 Fuel

The annual cost of supply ACS was calculated by using equation 1, where FC is the fuel cost, DC is the delivery cost FW and the amount of fuel used weekly.

$$ACS = (FC+DC) \times FW \times 50 \quad (1)$$

The monthly storage cost MSC was determined by equation 2, where SA is the storage area, FA is the free area, CL is the cost of the square meter of land, HC is the handling cost and the PC is preparation cost.

$$MSC = ((SA + FA) \times CL) + ((HC + PC) \times (50/12) \times FW) \quad (2)$$

So the total annual fuel cost TAFC was given by equation 3, where DC is the delivery cost.

$$TAFC = DC + 12 \times MSC \quad (3)$$

2.1.2 Manpower

With these information it was possible to calculate the annual cost per operator ACO by applying the values for the salary per operator SO, the thirteen first salary TS, the insalubrity IS, the additional vacation AV, the meal tickets MT, the transport allowances TA, the health insurance HI, the training costs TC and others costs OC to equation 4.

$$ACO = (12 \times SO + TS + 12 \times IS + AV + (252 \times MT) + (252 \times TA) + (12 \times HI) + (12 \times OC) + TC \quad (4)$$

The annual FGTS per operator AFGTS could be determined by

$$AFGTS = ((SO + IS) \times 12 + TS) \times 0{,}08 \quad (5)$$

And the annual INSS per operator AINSS could be found by

$$AINSS = ((SO + IS) \times 12 + TS) \times 0{,}20 \quad (6)$$

So the total annual cost with operator TACO was given by equation 7, where NO is the number of operators.

$$TACO = (ACO + AFGTS + AINSS) \times NO \quad (7)$$

2.1.3 Total personal protective equipment cost (TPPEC)

Therefore, with these information it was possible to calculate the total annual cost with PPE TPPEC with equation 8, where PPEU is the PPE unit cost and PPEY is the amount of PPE used per year.

$$TPPEC = PPEU \times PPEY \quad (8)$$

2.1.4 Engineering (NR-13) (ENC)

The annual cost related to engineering ENC could be determined with equation 9, where ACI is the annual cost with inspection and ACA is the annual cost with ART.

$$ENC = ACI + ACA \quad (9)$$

2.1.5 Water

The annual cost with water abstraction ACWA could be calculated applying the cost of the cubic meter of water WC and the monthly expenditure of water ME in equation 10. This equation could be used when using feed water from a public system.

$$ACWA = WC \times ME \quad (10)$$

And for an artesian well the ACWA could be defined with equation 11, where PW is the power consumed by the pump, RE is the potential of the reservoir, ET is the environmental tax and PC is the pump cost.

$$ACWA = (PW + RE + ET) + ((PC/100) \times time \times 160\ days \times KWh\ value) \quad (11)$$

For the annual costs with water treatment ACWT it was possible to use the equation 12, where FC is the filtering cost and DC is the demineralization cost.

$$ACWT = 12 \times (FC + DC) \quad (12)$$

The annual cost with chemical analysis ACCA could be calculated applying the values for analysis cost AC, product cost PC and the monthly consumption MC in equation 13.

$$ACCA = AC + (PC \times MC \times 12) \quad (13)$$

Therefore the total annual water cost TAWC was calculated according to equation 14.

$$TAWC = ACWA + ACWT + ACCA \quad (14)$$

2.1.6 Hydraulic pump

The annual cost of good hydraulics ACGH could be determined by equation 15, where MN is the cost with maintenance and PW is the power consumed.
x operating time

$$ACGH = MN + ((PW/1000) \times KWh\ value \times time \times 252 \quad (15)$$

And the annual cost with control panel calibration ACPC was defined using equation 16, where APA is the amount of pressure switches, VPS is the pressure switch setting value, ATM is the amount of thermometers, VTM is the thermometer setting value, APG is the amount of pressure gauges and VPG is the setting value pressure gauge.

$$ACPC = (APS \times VPS) + (ATM \times VTM) + (APG + VPG) \quad (16)$$

2.2 Program code

The software was developed using Visual Studio Community 2015 by Microsoft Corporation. Visual Studio is a program for software development compatible with various programming languages such as Visual Basic (VB), C, C++ and others. In this project the language chosen was C. The software has an interactive platform where the user can insert the data, so the program can calculate all the costs involved. For an easier interaction with the program, the questionnaires where organized in topics according to the Figure 2.

The topics represented in Figure 2 are windows where the user informs the data for the calculation of each specific and total cost. In each window was created a button to clear the form, another to advance to the next form and an option to return to the previous page. In software programming, each specific cost was calculated at the end of the form itself, and in the last program window the sum of each was calculated and shown on the screen.

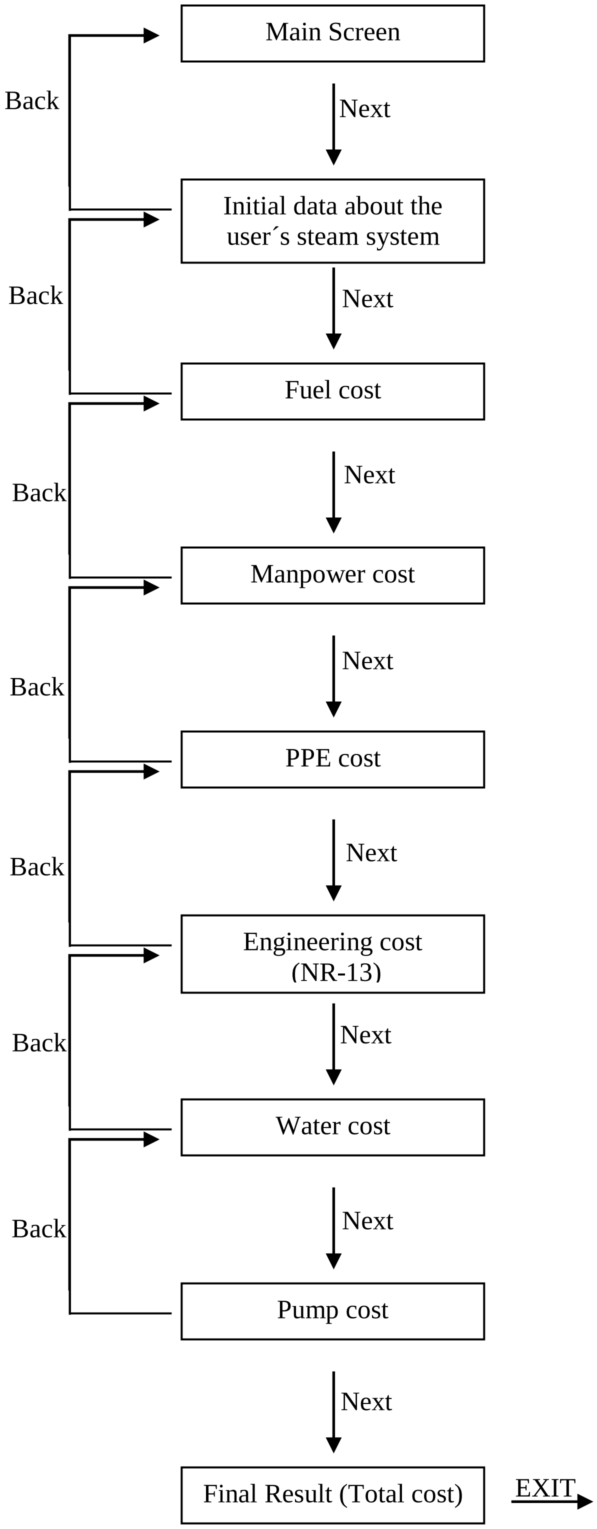

Figure 2. Program windows flowchart

3. RESULTS

The developed program offers an interactive platform where the user must input all the required data so the software can automatically calculate the costs involved in the process. The following picture illustrates the program home page.

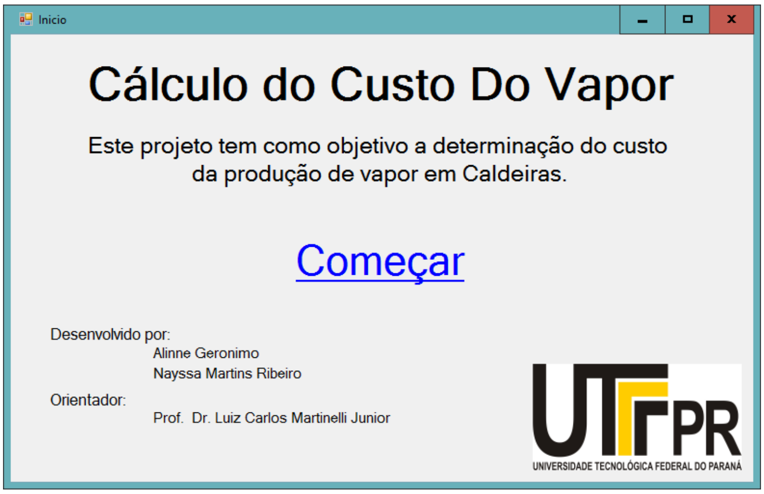

Figure 3. Main screen

For an easier interaction with the program, the questionnaires where organized in topics according to the role of the user. Each questionnaire is displayed in different screens as shown in figures 4 and 5.

Figure 4. Initial questionnaire

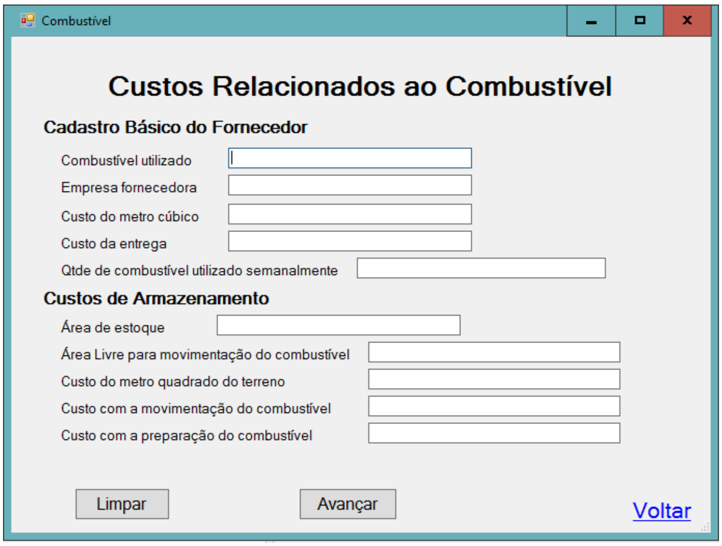

Figure 5. Fuel questionnaire

The cost of each item that make up the final vapor cost is displayed on the last screen after the registration of all the information required for the calculation. The partial cost of each item along with the total cost is then shown. Figure 6 represents the screen with the partial and final results.

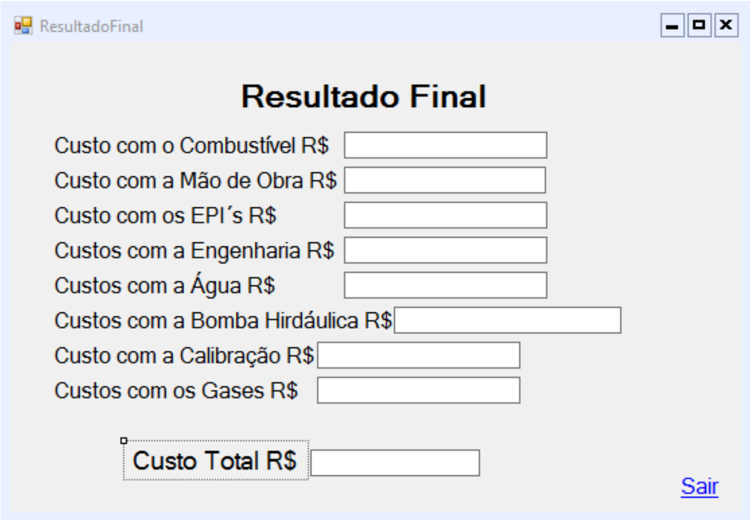

Figure 6. Cost screen

4. CONCLUSIONS

From the results shown, it is clear that the program can be used as an important tool for enterprises that use boilers, providing an estimation of the costs involved in vapor generation and helping with the economic viability analysis of new projects.

In future studies a deeper investigation using the energy losses suffered by the boiler is suggested. This approach can lead to more accurate results. A database with the input and output history can also be implemented allowing the user to detect weak points in the boiler operation and apply corrections to improve productivity.

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6. RESPONSIBILITY NOTICE

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