Using software tanks for emission calculation in storage tanks

Utilização do software tanks para cálculo de emissões em tanques

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ABSTRACT
With increased activities and investments in the Brazilian petrochemical sector from the 1980s of the twentieth century, there was a concern and general interest in reducing emissions in storage tanks, both from an environmental point of view and from an economic point of view. Due to increasing demand and need for increasing reserves to supply the cities, both refiners and dealers had to increase the storage volume, creating new emission foci of volatile organic compounds. From an environmental point of view, the reduction of emissions of volatile organic compounds reflected in an improvement in energy efficiency by reducing the evaporation of the product ensures the best use of its use. It also provides a reduction of pollution and thus improve the quality of life in the neighborhood. Already from the economic and financial point of view, it is advantageous and interesting for companies that store volatile products invest in an emission reduction system, ensuring return on investment by reducing losses. Among a number of devices and emission control techniques for atmospheric tanks, one of the alternatives widely used in the industry are the internal floating roofs and this publication aims to clarify and guide the reader in a practical way of using Tanks 4.09d software, using practical examples of simulation.

Keywords: atmospheric emissions, internal floating roof, AP- 42 standard.

RESUMO
Com o aumento de atividades e investimentos no setor petroquímico brasileiro a partir da década de 1980 do século XX, houve uma preocupação e interesse geral na redução das emissões em tanques de armazenamento, tanto do ponto de vista ambiental quanto do ponto de vista econômico. Devido à crescente demanda e necessidade de reservas cada vez maiores para abastecimento das cidades, tanto
as refinarias quanto as distribuidoras precisaram aumentar o volume de armazenamento, criando novos focos de emissão de compostos orgânicos voláteis. Do ponto de vista ambiental, a redução das emissões de compostos orgânicos voláteis reflete em uma melhoria na eficiência energética, pois a redução da evaporação do produto garante o melhor aproveitamento em seu uso. Proporciona também uma redução da poluição e consequentemente melhoria na qualidade de vida na vizinhança. A partir do ponto de vista econômico e financeiro, é vantajoso e interessante para empresas que armazenam produtos voláteis investir em um sistema de redução de emissão, garantindo o retorno de seu investimento com a redução nas perdas. Dentre uma série de dispositivos e técnicas de controle de emissão para tanques atmosféricos, uma das alternativas largamente utilizada na indústria são os tetos flutuantes internos e esta publicação tem por objetivo esclarecer e orientar o leitor de uma forma prática de uso do software Tanks 4.09d, utilizando exemplos práticos de simulação.

**Palavras-chave:** Emissões atmosféricas, teto flutuante interno, norma AP-42.

1 INTRODUÇÃO

With the increase in fuel demand since 1980 and the consequent growth in the petrochemical sector, a new environmental problem has been identified, caused by emissions of volatile organic compounds in fixed sources: atmospheric storage tanks.

According to Heinsohn and Kabel (1999) the environment affects our health and our activities interfere with the environment. As the population grows, so does the need for consumption and production, which has consequences for the environment, which in turn has consequences for the health of the population.

Gaseous emissions are major contributors to this impact. Emission sources can be defined as punctual or diffuse. Point sources are characterized by being points of continuous emission of a given process, such as, for example, chimneys, pipes, equipment degassing. Diffuse sources are occasional points of emission, whose characteristics are usually variable and influenced by local environmental conditions, such as storage tanks, evaporative process emissions and fugitive emissions (QUINTANILHA, 2009).

The storage tanks allow a reserve of supply and guarantee the continuous functioning of petrochemical plants or even the supply of fuel to cities (BARROS, 2003) and fit as sources of diffuse emission. The vaporization of stored fuels causes the emission of volatile organic compounds (VOCs).

These tanks are also subject to leaks, mechanical failures, sealing wear or typical equipment characteristics that provide fugitive emissions inherent to the process (COSTA, 2010).

To reduce product emission, it is common to inject nitrogen (inert) or apply floating roofs (internal), as will be discussed below.

This work aims to clarify and guide on a practical way of applying the theoretical emission calculations presented in the *Tanks 4.09d* software, made available by the U.S. EPA and which is based
on the calculation methodology of the document AP-42 chapter 7.1, also presenting practical simulation examples and results analysis.

2 STORAGE TANKS

In general, the standard atmospheric tanks API-650 (2010) (Figure 1) or the equivalent national standard, NBR 7821 (ABNT, 1983) are divided into constructive groups, with their variants approached from the constructive point of view.

Figure 1 - Atmospheric storage tanks and their components

The design of atmospheric storage tanks can be divided, basically, into: bottom, side, roof, metallic structures and openings (GUIZZE, 1989).

In addition to the different design variables, ranging from dimensional, stored product, temperature and pressure conditions, construction material and others, there are also conditions for each component of the tank.

The bottom can be classified by “ring plate” or rectangular plate patterns, depending on the welding characteristics between the bottom and side, as this is the most fragile region of the tank (MAIA and AURELIO, 2012; CONTEC 2010).

The side has different plate thickness calculation methods provided for in the API-650 norm (2010), as the most traditional 1-foot method; the variable point method, the appendix A method and the appendix S method (LIMA et al., 2014; COSTA, 2011).
The metallic structures, which are normally selected according to the customer's standard, must comply with the minimum loads of norms such as NBR 8800 (ABNT, 2007), as well as safety norms NR 18 (BRASIL, 1978).

For the nozzles, which are usually directly linked to the operating standard of the location where the tank is installed, they can have manholes and cleaning doors meeting the minimum quantities required or according to the customer's standard, being generally 180° out of phase around the tank, to ensure air flow (BARROS, 2003).

Roofs vary according to design definitions, stored product and local characteristics. The influence of the choice in the type of roof in the composition of the tank generates consequences in the efficiency of the storage during the useful life of the equipment (API-650, 2010). The main types of roofs foreseen in the TANKS 4.09d software (self-supporting cone, supported cone, self-supporting dome, external floating, internal floating and aluminum geodesic dome) and their characteristics are shown in Table 1.

2.1 INTERNAL FLOATING ROOFS

There are several options for methods to control fugitive emissions in tanks, the use of floating roofs being the most common and economical. The characteristics of floating roofs that most interfere with emissions are: constructive model (welded or riveted), peripheral seals and number of internal seals, such as nozzles, masts, support feet, among others (MACHADO, 2009).

Pressurized tanks are also an alternative for controlling emissions, but the factors that cause the emission have not yet been studied and their cost is usually higher in relation to the use of floating roofs (TELLES, 2007).

Likewise, injecting inert gases can also provide a dry atmosphere over the liquid and prevent emissions. With gas injection the vapors remain inside the tank until the pressure reaches a predetermined value and then a pressure sensor activates blowers that collect and transport the vapors to a ventilation system that treats and releases the vapors (MCDONALD, 1992).

Complementary techniques such as incinerators or condensers are also alternative methods for controlling emissions. In this case, the condensation of vapors used for the storage of chlorinated solvents, which cause corrosion problems in internal aluminum floating roofs, can be mentioned (MCDONALD, 1992).
Table 1 - Types of roofs for atmospheric storage tanks (continued)

| Type of roof          | Main characteristics                                                                                           | Application advantages                                                                                                                                                                                                 | Application disadvantages                                                                                                                                 |
|-----------------------|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| a                     | - Material according to the tank, according to the product stored (carbon steel or stainless steel).           | - The slope ensures optimum flow of rain                                                                                                           | - Higher weight in relation to the self-supporting dome roof.                                                                                             |
|                       | - Usually used in tanks up to 15 m in diameter.                                                                | - It has lower weight in relation to structured tanks.                                                                                                  | - Hardly applied to tanks over 15 m in diameter.                                                                                                         |
|                       | - Supports its own weight and applied loads                                                                    | - For tanks with this type of roof, you can easily apply internal floating roofs, to reduce the loss of product by fugitive emission.                           | - The bigger the tank, the more difficult it is to manufacture this type of roof.                                                                                 |
|                       | - They have a slope between 9.5° to 37° (the higher the slope, the more self-supporting the roof is. Consequently, the smaller the necessary thickness, |                                                                                                                                                | - It is not recommended to perform weak welding on its periphery.                                                                                         |
|                       | - Maximum thickness of 12.7 mm.                                                                                 |                                                                                                                                                | - An emergency valve is always needed in case of fire.                                                                                                      |
| b                     | - Material according to the tank, according to the product stored (carbon steel or stainless steel).           | - Applicable to any type of tank.                                                                                                                     | - Usually heavier than self-supporting tanks (when both types can be applied, for the same diameter).                                                     |
|                       | - Used regardless of the tank diameter.                                                                         | - Thin roof plate thickness (4.75 mm).                                                                                                               | - Weak welding can be used on its periphery.                                                                                                              |
|                       | - As it is supported, it needs a support structure, normally composed of a central column (with or without auxiliary columns) and radial beams. | - The entire roof load is supported by the structure. So, this type of roof can be applied to any tank size.                                           | - Requires a more complex engineering study, in its design when compared to self-supporting roofs.                                                          |
|                       | - They have a slope between 3.5° to 9.5°.                                                                       | - Minimum plate thickness of 4.75 mm.                                                                                                               | - Requires a longer and more detailed assembly when compared to self-supporting roofs.                                                                   |
|                       | - The entire roof load is supported by the structure. So, this type of roof can be applied to any tank size.    |                                                                                                                                                |                                                                                                                                                          |
|                       | - Minimum plate thickness of 4.75 mm.                                                                          |                                                                                                                                                |                                                                                                                                                          |
| c                     | - Material according to the tank, according to the product stored (carbon steel or stainless steel).           | - The slope guarantees the flow of rain.                                                                                                           | - Hardly used in tanks over 20 m in diameter.                                                                                                             |
|                       | - Usually used in tanks up to 30 m in diameter.                                                                | - It usually has the best weight-to-diameter ratio when compared to other carbon steel or stainless steel roofs.                                   | - As it is a more robust roof, it is not advisable to perform weak welding on its periphery.                                                             |
|                       | - Supports its own weight and loads applied to it.                                                            | - For tanks with this type of roof, internal floating roofs can be easily used to reduce product loss.                                               | - An emergency valve is always needed in case of fire.                                                                                                      |
|                       | - Radius between 0.8 to 1.2 times the tank diameter                                                          | - Easy fabrication and assembly regardless of its size.                                                                                               |                                                                                                                                                          |
|                       | - Maximum thickness of 12.7 mm.                                                                                 |                                                                                                                                                |                                                                                                                                                          |
|   |   |
|---|---|
|**d** | **External Floating Roof** |
|   | - Material, usually in carbon steel. |
|   | - Usually applied in tanks with large diameters (30 to 90 m in diameter). |
|   | - Used in tanks with very volatile product, with the intention of reducing losses due to fugitive emission. |
|   | - Type of roof that requires the greatest analysis in terms of design engineering. |
|   | - Runoff of rain through internal drain. |
|   | - Peripheral sealing using the PW type seal (aluminum sheets that act as springs, pressing the side of the tank), reducing losses by fugitive emission. |
|   | - Applicable to any diameter. |
|   | - The PW seal also works as an anti-emergency device, opening in cases of over pressure. |
|   | Runoff of rain is done by an internal drainage system, by a hose or an articulated drain (which usually requires maintenance). |
|   | - Requires articulated stairs for access. |
|   | - High complexity in the design, manufacture, assembly and even commissioning. |
|**e** | **Internal Floating Roof** |
|   | - Usually aluminum roof, |
|   | - It was initially created as an accessory (appendix H of API-650) and today it is a type of roof that is increasingly applied, always in conjunction with fixed ceilings (cone or dome). |
|   | - Used in any tank diameter. |
|   | - Easy fabrication and installation on any type of fixed roof. |
|   | - Significant reduction in emissions (up to 95%). |
|   | - Reduction in environmental impact. |
|   | - Usually, its implantation presents the best cost-benefit relation in relation to the tanks without its application, when taking into account the reduction of losses due to fugitive emission. |
|   | - Cannot be applied without a fixed roof. |
|   | - Needs specialized team for assembly. |
|**f** | **Aluminum Geodesic Dome** |
|   | - Aluminum roof |
|   | - It was initially created as an accessory (appendix G of API-650) and today it is the preferred type of roof for diameters above 30 meters, but also applicable to smaller diameter tanks. |
|   | - In conjunction with the internal floating roof, it has gradually replaced the external floating roofs, with a higher cost benefit. |
|   | - Easy fabrication and assembly |
|   | - Less maintenance when compared to an external floating roof. |
|   | - As it is normally applied to large diameter ceilings, it is much easier to install in relation to the supported or external floating ceilings. |
|   | - No painting required |
|   | - Aluminum works as a reflective, decreasing the internal temperature of the tank during the day. |
|   | Initial cost very close to that of a fixed roof in carbon steel. |
|   | - Needs specialized team for assembly. |

Source: Oliveira, 2011; Vetor-Mathias, 2014
3 METHOD OF CALCULATING EMISSIONS BY SOFTWARE TANKS 4.09d

For atmospheric storage tanks, there is a direct relationship between the evaporation of stored products and their emissions, according to the methodology of the U.S. EPA presented in document AP-42 section 7.1. This methodology is the basis of the TANKS 4.09d Software used in this study (U.S. EPA, 2006).

The use of the TANKS 4.09d Software as a calculation reference for emissions in atmospheric tanks began to be used in Brazil due to the requirement of some environmental agencies, such as, for example, CETESB (2015). The use of the software is aimed at creating a database, inventory and monitoring fugitive emissions in atmospheric tanks.

The TANKS 4.09d Software can also be used in order to establish emission reduction comparisons for future projects or even adaptations of existing projects, bringing elements not only for environmental assessment, but also for assessing return on investment from a constructive alteration in the tank.

Martins (2004) used the TANKS 4.09d Software to determine the emission losses due to work and the decision to install or not an internal floating roof in an already built tank. The use of the software allowed sizing decisions (stock volume), changing the dimensional characteristics of a tank for future application, taking into account the movements expected in its volume.

Oliveira (2015) used the same software to establish a simplified mathematical model for financial evaluation to decide on the application of internal floating roofs, enabling the technical evaluation in environmental terms of emission reduction and the investment return time.

4 USE OF SOFTWARE TANKS 4.09d

Filling in the TANKS 4.09d Software is self-explanatory and allows the creation of new input data, such as meteorological data, technical product characteristics and constructive characteristics of the equipment not registered in the software library, presented on the initial screen (Figure 2).
The environmental data for a location can be entered in the software database, as shown in Figure 2, represented by the letters c to f. Figure 2-c shows the selection of a city from the software database or a city previously entered. The data presented in Figure 2-d are the average daily ambient temperature over a period of one year and atmospheric pressure at a given location. The table shown in Figure 2-e shows the daily maximum and minimum ambient temperature, in the monthly period, as well as the solar radiation factor and wind speed, with their units broken down.

If the location where the tank will be simulated is not part of the program's database, it is possible to add a location (Figure 2-f) by adding the variables mentioned above. Similarly, it is possible to add variables for products, constructive characteristics of the equipment (Figure 2-a).

In this work, the software tools were used to analyze vertical tanks with fixed roof (with conic and dome type roofs) and tanks with fixed roof and internal floating roof.

The necessary input data for fixed roof tanks (Figure 3-a) are: side height, diameter, maximum product height, average product height. The workload is automatically calculated by the software. The number of work cycles per year (each cycle a filling and emptying). In addition to these, the program requests the color and condition of the side and roof, as well as the type of roof (cone or dome). With this information the height and slope (for cone roofs) and the radius of curvature for dome roofs are calculated automatically. The units of each parameter are listed in their field.

For fixed roof tanks with internal floating roof, the input data (Figure 3-b) are: diameter, tank volume, number of work cycles per year (each cycle a filling and emptying), the volume moved per year being calculated automatically.

The software requests if the tank in question has a fixed roof supported or self-supporting...
and, for a supported roof, the characteristics of support columns, and the condition and coloring of the roof and side painting must be informed.

In internal floating roofs it is necessary to inform if the internal sealing is single or double and the type of sealing of the aluminum films (riveted, screwed or welded).

Figure 3 - Input data for tanks  
a) Fixed Roof; b) Fixed Roof with internal floating roof

In addition to the specific characteristics of each type of tank, shown in Figures 3-a and 3-b, it is also necessary to complement the information with the environmental conditions. Therefore, the selection of a specific city (Figure 4-a), the conditions of the stored product (Figure 4-b) and the presentation of the calculation of emissions losses, which can be annual or monthly (Figure 4) must be carried out.

Figure 4 - Selection of location and stored product  
a) City; b) Stored product

Source: U.S. EPA (2006)
The results obtained with Tanks 4.09d Software (U.S. EPA, 2006) are issued in the form of standard reports (Tables 2 and 3) always showing the losses in mass (lb). The losses of tanks with fixed self-supporting roof dome and cone separated into work losses ($L_W$) and losses due to temperature variations or tank respiration ($L_S$). Losses from tanks with an internal floating roof are divided into: seal ($L_R$), withdrawal ($L_{WD}$), internal nozzles ($L_{RF}$) and internal joints ($L_D$). These, presented throughout the twelve months of the year.

Table 2 illustrates an example of a report issued by the TANKS 4.09d software of typical monthly losses from tanks with fixed roofs: losses related to temperature variations ($L_S - breathing loss$) and work losses ($L_W - working loss$).

| $L_S$ | $L_W$ | $L_R$ | $L_{WD}$ | $L_{RF}$ | $L_D$ |
|-------|-------|-------|----------|----------|-------|
| 1476  | 14861 | 0     | 0        | 0        | 0     |
| 1597  | 16027 | 0     | 0        | 0        | 0     |
| 2101  | 17404 | 0     | 0        | 0        | 0     |
| 2655  | 19863 | 0     | 0        | 0        | 0     |
| 3293  | 22786 | 0     | 0        | 0        | 0     |
| 3738  | 26079 | 0     | 0        | 0        | 0     |
| 3445  | 27741 | 0     | 0        | 0        | 0     |
| 3203  | 26800 | 0     | 0        | 0        | 0     |
| 2763  | 24400 | 0     | 0        | 0        | 0     |
| 2393  | 20560 | 0     | 0        | 0        | 0     |
| 1718  | 16880 | 0     | 0        | 0        | 0     |
| 1436  | 14901 | 0     | 0        | 0        | 0     |

Source: The Author (2006)

Table 3 illustrates an example of a report issued by the TANKS 4.09d Software for typical monthly losses for tanks with fixed roofs and internal floating roof: losses in the seal seal ($L_R - rim seal loss$), losses by withdrawal of product ($L_{WD} - withdraw loss$), losses in the internal nozzles of the film ($L_{RF} - deck fitting loss$) and internal joints of the film ($L_D - deck seamloss$). The data presented in Tables 2 and 3 are figurative and were not used in this work.
5 METHODOLOGY ADOPTED FOR SIMULATIONS USING SOFTWARE TANKS 4.09d

The simulations were carried out to determine the losses due to fugitive emissions and to evaluate, in percentage, the advantages or disadvantages (in terms of product loss) of the application of internal floating roof in storage tanks.

The following premises were adopted in the simulations:

Environmental conditions: the choice of location was kept constant. As the intention was to make a comparison between the application or not of an internal floating roof, the choice of location (and its characteristics) was indifferent. However, the location was kept the same in all simulations and was chosen arbitrarily in the city of Miami, Florida, United States.

Working conditions: 365 filling and emptying operations per year.

Construction conditions of the roof: welded aluminum films and self-supporting external roof (without supporting structure columns).

Dimensional characteristics: the characteristics of diameter and height adopted in the simulations, as well as the operational height of the internal product column are shown in Table 4.

| Diameter D [m] | Height H [m] | Total volume V [m³,1000] | Operational height h [m] | Operational volume [m³] |
|--------------|-------------|----------------------------|--------------------------|-------------------------|
| 29.5         | 25.0        | 17.1                       | 7.3                      | 5.000                   |
| 28.6         | 35.0        | 22.5                       | 14.6                     | 10.000                  |
| 45.0         | 28.8        | 45.8                       | 12.6                     | 20.000                  |
| 65.0         | 25.0        | 82.9                       | 12.1                     | 40.000                  |

Source: The Author (2006)
Stored product: the following products were adopted: alcohol, gasoline, crude oil and aviation kerosene. The physical-chemical properties used follow the standards used in the software and obtained in the literature. Table 5 presents the data used.

Table 5 - Specific mass and flash point

| Product          | Specific mass (lb/gal) | Specific mass (kg/m³) | Flash Point (°C) |
|------------------|------------------------|-----------------------|-----------------|
| Gasoline         | 5,60                   | 671                   | -43             |
| Crude Oil        | 7,10                   | 851                   | -3 a 32         |
| Alcohol          | 6,61                   | 759                   | 13              |
| Aviation Kerosene| 7,00                   | 839                   | 40              |

Source: softwareTanks 4.09 (U.S.EPA, 2006)

From the definition of the premises, it was possible to obtain the losses by emission in mass (lb).

In order to enable the comparison of results, from the total loss \( L_T \) of each simulation, the loss by emission was determined. The percentage of loss by emission was obtained by relating the volume of product lost to the volume of product stored (operational), according to Equation 1.

\[
\xi = \frac{L_T \rho}{V} \quad (1)
\]

In which \( \xi \) is the loss by emission percentage of product by evaporation (%); \( L_T \) the total lost load (lb), which consists of the sum of all annual losses presented in the TANKS software report (Figure 5).
6 RESULTS OBTAINED WITH THE SIMULATIONS

In order to make it possible to compare the simulations whose only different characteristic was the application of the internal floating roof, these were selected and grouped and the results are shown in Figure 6.

Figure 6 - Loss ratio of tanks with and without floating roof (%)

Figure 6 shows the results for each product in a full (1) and half full (1/2) tank configuration, and each simulation was performed for tanks with and without floating roof.

It was observed that, for tanks without the internal floating roof applied, the losses of the tanks whose filled volume was half of its capacity provided a higher percentage of loss than when the tank has its total storage capacity, this is caused by its biggest “empty volume”, its exponential growth in relation to the increase of the nominal volume of the tank.

On the other hand, it was possible to assess that for tanks with an internal floating roof, this loss stabilized and became a function of the quantity handled per year.

It was also possible to observe that the loss due to fugitive emissions for crude oil and aviation kerosene is very low, being on average less than 8% for crude oil and 0.1% for kerosene. This is due to the fact that these products have a very high flash point.

Equation 1 made it possible to determine a ratio of emission losses in tanks with the same characteristics, but with and without the application of the floating roof. Using this, we can establish a percentage gain ratio, based on the relationship between the losses of a tank with a floating roof applied and the losses of a tank without the floating roof applied, keeping all other variables constant.
\[ Gn = 1 - \left( \frac{\xi_{\text{floating}}}{\xi_{\text{fixed}}} \right) \]  

(2)

In which \( Gn \) is the annual percentage gain (\%) of the product stored with the application of internal floating roofs, that is, the savings generated by reducing the loss of product by fugitive emission.

In Figure 7, it was possible to verify that with the increase in the stored volume, the reduction in emissions with the application of the floating ceiling increases, reaching 92% (maximum), with an average of 82%.

Figure 7 - Ratio of percentage gains of tanks with and without floating roof (%)

From the various simulations made it was possible to evaluate that, relating a tank without the internal floating roof applied to another in an equivalent situation but with the floating roof applied, the latter tends to show less losses, depending on all other variables applied to this study.

Another finding was to verify that the advantages of emission reduction in the application of the internal floating roof grow with the increase in the volume of the tank, in a more relevant way than with the increase of its diameter.

7 CONCLUSIONS

The use of the Software TANKS 4.09d made it possible to estimate the losses by emission in atmospheric storage tanks of four types of fuels with and without the application of internal floating

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[Image of Figure 7]

Source: The author (2015)
roofs, and also compare them and predict the efficiency of the application of the internal floating roof for each situation.

There are several difficulties in collecting real data for comparisons with the software (instead of comparisons with prototypes). They range from the fact that it is common for tank parks to always have the same constructive characteristics (due to the fact that they normally carry out the construction of the plant with a single tank contractor, and consequently they apply the most profitable construction technique in all tanks), due to the fact that the parks are usually of specific types of product (oil products, chemicals and others), but there is hardly a wide range of products in the same place. Another factor that hinders a more complete and full-scale work is the competitiveness between storage plants. Thus, the information is considered confidential and for commercial strategy is not disclosed.

When creating several possible situations in simulations with the TANKS 4.09d Software (US EPA, 2006) it was possible to realize that the use of the software and the collection of information about the minimum boundary conditions to obtain the results, require a degree of knowledge and reasonable training of the operator in the system tools, which we present in this work.

In this work, it was possible to verify that the TANKS 4.09d software covers a series of boundary conditions and enables the user to identify and compare possible situations in terms of emission and, from this data, convert into mass losses to compare emission reduction costs (loss of product) with investment decision (acquisition of internal floating roof).
REFERENCES

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 7821: Tanques Soldados para Armazenamento de Petróleo e Derivados. Corpo de norma, capítulos de 1 a 13 e anexos: D - Tetos flutuantes; H - Tetos Flutuantes Cobertos. Rio de Janeiro, 1983.
ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 8800: Projeto de estruturas de aço e de estruturas mistas de aço e concreto de edifícios. Rio de Janeiro, 2007.

API-650. American Petroleum Institute (Instituto do Petróleo Americano). Welded Tanks for Oil Storage (Tanques soldador para Armazenamento de Óleos). Corpo de norma, capítulos de 1 a 10 e anexos: C - External Floating Roofs (Tetos flutuantes externos); G – Structurally-Supported Alluminium Dome Roofs (Domos de Alumínio Estruturalmente Suportados); H – Internal Floating Roofs (Teto Flutuante Interno). 11ªEd., maio, 2010.

BARROS, S. M. Curso de Tanques de Armazenamento. Centro de Desenvolvimento de Recursos Humanos - Sudeste, Rio de Janeiro, RJ. 2003.

BRASIL. Ministério do Trabalho e Emprego. NR 18 - Condições e meio ambiente de trabalho na indústria da construção, julho de 1978. Disponível em: http://portal.mte.gov.br/images/Documentos/SST/NR/NR18/NR18.pdf Acesso em: 27 nov. 2015

CETESB. Licenciamento Ambiente Unificado. Base de Armazenamento de Combustíveis e Produtos Químicos, São Paulo, SP, 2015, disponível em: http://licenciamento.cetesb.sp.gov.br/unificado/pdf/bases_emissoes_atmosfericas.pdf, acesso em 26 mai. 2015.

CONTEC - COMISSÃO DE NORMALIZAÇÃO TÉCNICA. CONTEC N-270: Projeto de Tanque de Armazenamento Atmosférico. Revisão E, Rio de Janeiro, 2010.

COSTA, D. M. B. da; Avaliação das Emissões Fugitivas de Metano em Sistemas de Transporte de Gás Natural. O Caso do Gasoduto Bolívia-Brasil. 153f. Trabalho de Graduação (Graduação em Engenharia Ambiental) – Setor de Engenharia Ambiental, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2010.

GODISH, T. Air Quality (Qualidade do Ar). 4ª Ed. Lewis Publishers: Estados Unidos, 2004.

GUIZZE, A; Manual de Trocadores de Calor, Vasos e Tanques, Ibrasa Editora: São Paulo, 1989.

HEINSOHN, R. J; KABEL, R. L; Sources and Control of Air Pollution (Fontes e Controles de Poluição do Ar). Prentice Hall, 1999.

LIMA, A. H. T. de; SILVA Jr. L. P. da; SILVA, W. M. B; Estocagem de Petróleo, Universidade Federal de Campina Grande, Campina Grande, PB, 2014.

MACHADO, E. M; Apostila Curso Tanques de Armazenamento. Escola Técnica União, Santo André, SP, 2009.

MAIA, C; AURELIO, R; Tanques de Armazenamento, Instituto Federal Bahia, Salvador, BA, 2012.

MARTINS de, D. O; Estudo de controle de Emissões de Compostos Orgânicos Voláteis em Tanques de Armazenamento de Produtos Químicos. Trabalho de Mestrado (Mestrado Profissional em
Gerenciamento e Tecnologias Ambientais no Processo Produtivo), Universidade Federal da Bahia, Salvador, 2004.

MCDONALD, R; Air Pollution Engineering Manual – Petroleum Storage (Manual de Engenharia de Poluição do Ar – Armazenamento de Petróleo). Air & Waste Management Association (Associação de Gerenciamento de Ar e Resíduos), 1ª Ed, 1992.

OLIVEIRA, R; Acervo pessoal, cedido pelo Grupo VETOR-MATHIAS, Obra em SUAPE, PE, 2011.

OLIVEIRA, R; Modelo matemático para avaliação ambiental e financeira da aplicação de dispositivos de controle de emissão em tanques de armazenamento: tetos flutuantes internos. Trabalho de Mestrado (Mestrado Profissional em Meio Ambiente Urbano e Industrial), Universidade Federal do Paraná, 2015

QUINTANILHA L; O Universo das Emissões Atmosféricas. Revista Meio Ambiente Industrial, São Paulo, SP, 2009.

TELLES, S; Vasos de Pressão. 2ª Edição, Editora LTC, Rio de Janeiro, RJ, 2007.

U.S. EPA – Environmental Protection Agency (Agência de Proteção Ambiental). Software TANKS4.09d outubro – 2006, disponível em: http://www.epa.gov/ttnchie1/software/tanks/, acesso em 16 fev. 2015.