25th ABCM International Congress of Mechanical Engineering
October 20-25, 2019, Uberlândia, MG, Brazil

COMPARATIVE STUDY ABOUT THE RIGOR AND FALSE POSITIVES OF THE MAIN METHODS USED TO OBTAIN THE DEGREE OF TIGHTNESS FROM GAS STATIONS' TANKS

Joao Arthur da Cruz Nunes
Angelo Roncalli Oliveira Guerra
Universidade Federal do Rio Grande do Norte, R. da Tecnologia - Lagoa Nova, Natal - RN
j.ac.n@hotmail.com aroncalli@uol.com.br

Kleiber de Lima Bessa
klbessa@ct.ufrn.br

Carlos Magno de Lima
cmagno@ufrnet.br

Abstract. *Due to the great risk of contamination by leak in underground fuel storage tanks (UST) of gas stations all over the world, the establishment of effective monitoring methods in this environment is extremely necessary. Among UST monitoring methods the tightness test is one of the most effective ones in identifying leaks, it can be done in two different ways, either a wet or a dry part test. This study aims to unfold false positives and compare the rigor and the effectiveness of the parameters used for the two types of tank tightness test allowed by the current standard. The motivation comes from the necessity of supplying reliable evidence to compare both tests, coming from experimental data(laboratory and on site tests at gas stations) and theoretical concepts. But the study has a grater range, as most countries also use the USA standard as the base for theirs, with minor local adaptations. The on site tests followed this sequence: wet part test is performed, the tank is emptied, dry part test is performed. The study showed greater rigorousness coming from the dry part test and also confirmed the great influence of the fuel's evaporation rate on the results of the test for semi empty tanks. The results points to the immediate necessity of improvements of the methods and parameters for both types of test. Finally, it is noted that the coexistence of two methods with such a difference in rigor degree weakens the credibility of the standardizing, preventing, in specific situations, that the main goal of leak detection to avoid environmental accidents is achieved.*

Keywords: *tank tightness, UST, evaporation, fuel leak, pressure*

1. INTRODUCTION

The notion of engineering and development being linked to sustainability and environment is an ever-growing trend. Researches with the goal of developing technologies to monitor and reduce pollution have been growing and gaining more and more space and visibility in the engineering world, as the connection between progress and environment has already become a necessity, rather than a luxury.

The vast number of leaking cases in gas stations, coming from USTs and piping systems, have caused damage to the environment, besides also harming the security, health and life quality of the population around these sites (SANDRES et al., 2002). This contamination can affect not only the soil, but also groundwater and cause explosion and fire risk.

In Brazil, there are more than 40 thousand gas stations and soil contamination is currently one of the main concerns, once around 30% of these stations present problems that can cause contamination. Multiple companies deal daily with the unforeseen coming from leaking and incorrect storage (TERRA BRASIL, 2017).

According to a research made by CETESB, gas stations are the main responsibles for soil contamination in cities like Sao Paulo. The contamination occurs by leaking of fuel and gases due to bad installation of the USTs, which are fabricated in steel and do not possess protection against corrosion. Currently, multiple companies have invested in safer tanks, as seen that the investment in better installations it's much smaller than the costs of repairs for the problems caused by the contamination of the water and the soil (TERRA BRASIL, 2017).

Soil contamination by fuel is a big concern, seen that the fuel contains Benzene, Toluene, Ethylbenzene and Xylenes(BTEX) in its composition, that are all harmful to human health and can cause dangerous diseases. Soil contamination occurs when there isn't proper investment in quality equipment, mainly when it comes to metallic pipes and purely metallic tanks, because they are underground and it is necessary to pay attention to signs of corrosion and possible failures (TERRA

BRASIL, 2017).

In a gasoline spill, one of the main concerns is the contamination of aquifers that are used as source of water for human consumption (TEIXEIRA, 2008). Due to the fact that it is very little soluble in water, spilled gasoline, containing more than 400 components, initially will be underground as a liquid of non-watery phase. In contact with underground water, gasoline will partially dissolve. The mono-aromatic hydrocarbons: benzene, toluene and xylenes, called BTEX are the components present in the gasoline that have the highest water solubility, thus, they are the first contaminants to reach the groundwater. These compounds are considered dangerous substances because they are depressor of the central nervous system. The benzene is proven carcinogenic, being able to cause leukemia (TEIXEIRA, 2008).

The gasoline commercialized in Brazil is mixed with alcohol in proportions that can go from 20% to 30%, according to the current legislation. That makes it different from the gasoline sold in other countries, where it isn't mixed with oxygenated compounds. The interaction between ethanol and BTEX can cause a rise in mobility and solubility, while also difficulting the natural biodegradation of these compounds (TEIXEIRA, 2008).

The monitoring ends up being one of the main weapons to avoid contamination. The monitoring equipments e leak detection help avoiding possible contaminations to the environment and accidents at work. Amongst USTs monitoring methods, the tightness test is one of the most effectives in the identification of possible leaks, being able to be executed in two different ways: the wet part test(i.e. part filled with fuel) and the dry part test.

This study envisions to compare the results obtained from the application of both types of test.The motivation for this paper came from the necessity of supplying scientific evidence, conjugated with experimental data and theoretical concepts, some laboratory tests and real tank testing practice on site (gas stations) to better compare the rigor of the methods of leak detection regulated in Brazil by the standard ABNT 13784 in force.However, the study has a greater range, once that multiple other countries also follow the same basic rules for tank testing (that come from the USA) with their own local adjustments. This way, on site comparisons were made where, initially a wet part test was performed, and following that, the same tank was emptied and a dry part test was performed on the same tank. The research allowed us to identify a better performance in terms of rigor from the dry part test and confirmed the initial suspicion of the great influence of the evaporation rate of the fuel on the testing of partially full tanks (i.e. hybrid situation where there is a coexistence of a dry and a wet part in the tank).

2. PETROBRAS COMMON GASOLINE

On this article, common gasoline was used as the study object, due to it having the highest evaporation rate among the liquid fuels commercialized by ANP, thus, the parcel of pressure increase allowed by a possible hole in the tank is lower, so the test executed with this fuel is essentially the most critic case.

Gasoline belongs in the group of the LNAPL (Light Non Aqueous Phase Liquids) e PMOS (Partially Miscible Organics Solubility) Mindrisz, et al., (2006). Derivative from petroleum, gasoline is composed by innumerable chemical compounds (olefins, aromatichydrocarbons etc.) among which stand out as the most water-soluble contaminants, the BTEX compounds, present in 18% of the gasoline weight. A particularity differentiates Brazilian gasoline from the ones in other nations, the considerable presence of ethanol, which currently corresponds to 27% of the volume (Portal G1, March 2016). This factor makes it possible for similar studies involving other countries' gasoline to be able to present different results when compared to the ones made in Brazil.

Table 1. Main Properties of this fuel at 1 atm.

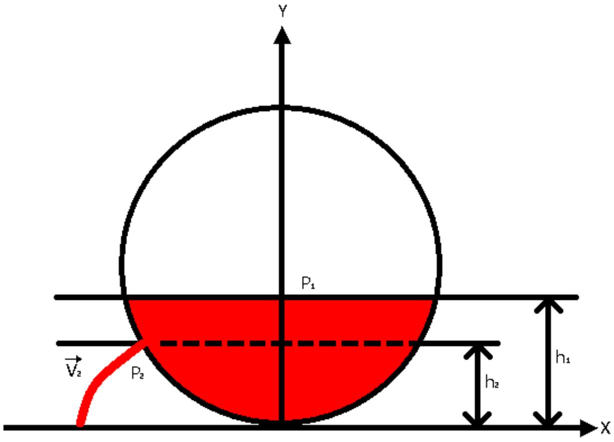
Properties	Value
Starting boiling point	>308 K
Flash Point	<230 K
Partition Coefficient - noctanol/water	Insoluble in water. Soluble in organic solvents
Auto-Ignition Temperature	Log kow 2-7
Density	0.73-0.77
Viscosity	0.6×10^{-6} m^2/s
Volumetric thermal dilation coefficient	1.2×10^{-3} $^oC^{-1}$

(1) measured at 25^{o}C

3. TIGHTNESS TEST: METHODOLOGY, THEORETICAL FOUNDATION AND EQUATIONS

3.1 Equations for wet part tightness test

According to the international standards and the standard ABNT 13784 in force in Brazil, the wet part test requires that, considering the tank out of operations (i.e. sales over) and the liquid at rest. The behavior of the volume of liquid inside the tank shall be observed for one uninterrupted hour and verified to see if the volumetric variation has not exceeded the permitted limit in that time. Thus, for academic purposes and to make comparisons between laboratorial and on site tests, a computational program was developed, capable of calculating the diameter of an hypothetical hole necessary for the limit situation to occur, which is 378 ml(0.1 gallon) "leaked" in one hour. Any loss of liquid volume that surpasses this limit is enough to deem the tank unfit. Thus the flow rate limit of 378 ml/h is used as input data on the implemented algorithm. Methodology illustration(figure1) and equations subsequently described.



Part Schematics.jpeg

Figure 1. Schematic representation of the methodology used to detect leaks in the wet part of a tank.

Adopting a conservative approach, simplifying and considering, hypothetically, the fluid to be incompressible, non-viscous and a stationary flow(i.e. permanent flow can be considered due to the negligible variations of the water levels to obtain the admissible flow rate), the Bernoulli equation can be used to reach the following equations:

$$\frac{V_1^2}{2} + g * h_1 + \frac{P_1}{\rho} = V_2^2 2 + g * h_2 + \frac{P_2}{\rho} \tag{1}$$

Where V_1 e V_2 are the velocities, P_1 e P_2 are the pressures, ρ is the specific mass of the fluid, h_1 is the height of the fuel at the start of the test and h_2 is the height of the theoretical hole.

It's observed on fig.1 that the pressures P_1 e P_2 are equal and manometric for the calculations, because they're in contact with the air and that the velocity V_1 is negligible, because the volume of liquid inside the tank is much bigger than what is leaking. Executing the algebric manipulations necessary to isolate V_2:

$$V_2 = \sqrt{2 * g * (h_1 - h_2)} \tag{2}$$

To find out the diameter of the hole, the volumetric flow rate formula was used ($\dot{\forall}$):

$$\dot{\forall} = V * A \tag{3}$$

Where V is the flow velocity and A is the area of the hole described by:

$$A = \pi * \frac{d^2}{4} \tag{4}$$

Inserting Eq. (3) and Eq. (4) into Eq. (2):

$$\dot{\forall} = \sqrt{2 * g * (h_1 - h_2)} * \pi * \frac{d^2}{4} \tag{5}$$

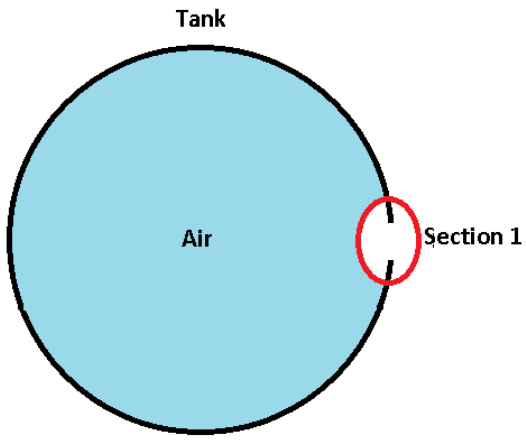
Isolating d, the equation of the necessary hole diameter is reached. Given the heights of the hole and the fuel for a volumetric flow rate of 378 ml/h, the limit value for the permitted hole diameter is found:

$$d = \sqrt{\frac{4 * \dot{\forall}}{\sqrt{2 * g * (h_1 - h_2)} * \pi}} \tag{6}$$

3.2 Equations For Dry Part Tightness Test

For the execution of this type of test, a pump is coupled to the tank's breather, sealing all possible air inlets and cracks. With sales already over, as required per the ABNT 13784 standard, considering the tank completely sealed, the pump starts sucking air out of the tank untill a preassure drop between 90 to 100 mmHg is reached and then the pump is turned off. This procedure is repeated until the pressure drop value maintains itself stable inside the aforementioned range after the pump's turning off. After that, the tank is put under observation for 30 minutes. During this time, the pressure raise cannot surpass 10mmHg(current standard) or 15mmHg(in study standard). In any case that the used limit value for the test is exceeded, the tank is deemed unfit. Thus, equally to the previous case of the wet part, for academic purposes, a computational program was developed, capable of calculating the diameter of the hypothetical hole necessary for the limit of pressure raise to be achieved. The procedures of the implemented algorithm, illustration of the methodology (fig.2) and equations are described next.

3.3 Dry Part Test On A Completely Empty Tank (i.e. only air)



Dry Part Schematics.jpeg

Figure 2. Schematic representation of the methodology to detect leaks on the dry part of a completely empty tank.

Initial considerations adopted:
(1)The air behaves as an ideal gas at pressures below 30 atm.
(2)The properties of air in the tank are uniform, but time dependent.
(3)Incompressible flow.
The continuity equation was used to approach the problem:

$$\frac{\partial}{\partial t}\int\limits_{CV}\rho d\forall + \int\limits_{CS}\rho\vec{V}d\vec{A} = 0 \tag{7}$$

Where: The first term represents the mass variation rate inside the control volume and the second term represents the net rate of mass flow to the outside trough the control surface.
Once the properties in the tank are considered uniform, the specific mass (ρ) can be taken out of the integral:

$$\frac{\partial}{\partial t}[\rho_{CV}\int\limits_{CV}d\forall] + \int\limits_{CS}\rho\vec{V}d\vec{A} = 0, where, \int\limits_{CV}d\forall = \forall \tag{8}$$

so,

$$\frac{\partial}{\partial t}(\rho V)_{CV} + \int\limits_{CS}\rho\vec{V}d\vec{A} = 0 \tag{9}$$

The only place where mass crosses the control volume's boundary is at section 1, this way:

$$\int\limits_{CS}\rho\vec{V}d\vec{A} = \int\limits_{A_1}\rho\vec{V}d\vec{A} \quad and \quad \frac{\partial}{\partial t}(\rho\forall)_{CV} + \int\limits_{A_1}\rho\vec{V}d\vec{A} = 0 \tag{10}$$

On the surface of section 1, the sign of $\rho\vec{V}d\vec{A}$ is negative,

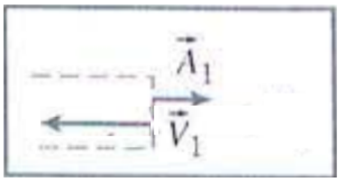
1.jpeg


Figure 3. Surface 1

Thus,

$$\frac{\partial}{\partial t}(\rho\forall)_{CV} - \int_{A_1} \rho V dA = 0 \tag{11}$$

As the flow is considered uniform on surface 1,

$$\frac{\partial}{\partial t}(\rho\forall)_{CV} - \rho_1 V_1 A_1 = 0 \quad or \quad \frac{\partial}{\partial t}(\rho\forall)_{CV} = \rho_1 V_1 A_1 \tag{12}$$

Once $\forall$ (tank's volume) isn't a function of time,

$$\forall\frac{\partial \rho}{\partial t} = \rho_1 V_1 A_1 \tag{13}$$

isolating $\frac{\partial \rho}{\partial t}$,

$$\frac{\partial \rho}{\partial t} = \frac{\rho_1 V_1 A_1}{\forall}, where, A_1 = \pi * \frac{d^2}{4} \tag{14}$$

Where,

$$\begin{cases} \frac{\partial \rho}{\partial t} = specific\ masss\ variation\ rate\ in\ time \\ \rho_1 = specific\ mass \\ \forall = tank's\ volume \\ V_1 = Air\ inlet\ velocity\ into\ the\ tank \\ A_1 = Section\ 1\ area \\ d_1 = Hole's\ diameter \end{cases}$$

At this point the concept of stagnation pressure was used to find the velocity V_1 with which the air flows into the tank. Thus for an arbitrary point inside the tank, with the subscript "0" representing the stagnation conditions:

$$P_0 = P + \frac{\rho v^2}{2} \tag{15}$$

Isolating the velocity:

$$V = \sqrt{\frac{2 * (P - P_0)}{\rho}}, where, \rho = \frac{P[Pa]}{R_{air}[J * Kg^{-1} * K^{-1}] * T[K]} \tag{16}$$

Starting here, the subscript t_0 will be used to indicate the start of the test and $t_0 + \Delta t$ to indicate the end of it.

The velocities were obtained through the developed equations. Thus, for a vacuum (induced pressure drop) of 100 mmHg and a temperature of 27 °C (300 K):

$$\rho_{t_0} = \frac{87992.76}{287 * 300} = 1.022 \tag{17}$$

$$V_{t_0} = \sqrt{\frac{2 * (89325.99 - 101325)}{1.022}} = 161.257 m/s \tag{18}$$

And for an increase of 10 mmHg of pressure according to the in-force standard:

$$\rho_{t_0 + \Delta t} = \frac{89325.99}{287 * 300} = 1.037 \tag{19}$$

$$V_{t_0+\Delta t} = \sqrt{\frac{2*(89325.99-101325)}{1.037}} = 152.09m/s \tag{20}$$

For a velocity of the sound on air at 27 °C, $c = \sqrt{kRT}$,Where: K is the Volumetric Elasticity Module of the air:

$$c = \sqrt{1.4*287*300} = 347.189m/s \tag{21}$$

And the mach numbers:

$$M_{t_0} = \frac{161.257}{347.189} = 0.46524 \tag{22}$$

$$M_{t_0+\Delta t} = \frac{152.09}{347.189} = 0.438 \tag{23}$$

The Mach numbers obtained (M>0.3) suggested that the flow is actually compressible, different from what was initially assumed.

Correcting the approach to a compressible flow the stagnation conditions for a compressible flow are:

$$P_0 = P*(1+\frac{k-1}{2}+M^2)^{\frac{k}{k-1}} \tag{24}$$

and

$$\frac{T_0}{T} = 1+\frac{k-1}{2}+M^2 \tag{25}$$

Isolating the Mach number in the stagnation pressure formula:

$$M = \frac{\sqrt{2}*\sqrt{P_0*(\frac{P_0}{P})^{-\frac{1}{k}}-P}}{\sqrt{k*P-P}} \tag{26}$$

The new mach numbers will be:

$$M_{t_0} = \frac{\sqrt{2}*\sqrt{101325*(\frac{101325}{87992.76})^{-\frac{1}{k}}-87992.76}}{\sqrt{1.4*87992.76-87992.76}} = 0.4535 \tag{27}$$

$$M_{t_0} = \frac{\sqrt{2}*\sqrt{101325*(\frac{101325}{89325.99})^{-\frac{1}{k}}-89325.99}}{\sqrt{1.4*89325.99-89325.99}} = 0.4282 \tag{28}$$

To find the flow velocities it is necessary to obtain the sound velocity and the temperature inside the tank.

Thus, using the stagnation condition of the temperature:

$$T = \frac{T_0}{1+\frac{k-1}{2}+M^2} \tag{29}$$

For the start and the end of the test:

$$T_{to} = \frac{300}{1+\frac{1.4-1}{2}+0.4535^2} = 288.15K \tag{30}$$

$$c_{to} = \sqrt{1.4*287*288.15} = 340.26m/s \tag{31}$$

$$T_{to+\Delta t} = \frac{300}{1+\frac{1.4-1}{2}+0.4282^2} = 289.39K \tag{32}$$

$$c_{to+\Delta t} = \sqrt{1.4*287*289.39} = 340.99m/s \tag{33}$$

In possession of the Mach numbers and the respective sound velocities it is possible to calculate the inlet velocities of air into the tank:

$$V_{t_0} = c_{t_0}*M_{t_0} = 154.31m/s \tag{34}$$

$$V_{t_0+\Delta t} = c_{t_0+\Delta t}*M_{t_0+\Delta t} = 146.01m/s \tag{35}$$

Back to the continuity equation:

$$\frac{\partial \rho}{\partial t} = \frac{\rho_1 V_1 \pi D_1^2}{4\forall} \tag{36}$$

the time of the test can be represented by:

$$t = \frac{\Delta\rho}{\frac{\partial \rho}{\partial t}} \tag{37}$$

Where,

$$\Delta\rho = \rho_{t_0+\Delta t} - \rho_{t_0} \tag{38}$$

With,

$$\rho_{t_0} = \frac{P_{t0}}{R * T_{t0}} = 1.064 \tag{39}$$

$$\rho_{t_0+\Delta t} = \frac{P_{t0+\Delta t}}{R * T_{t0+\Delta t}} = 1.076 \tag{40}$$

Having $\Delta\rho$, obtained trough the analysis of the stagnation conditions and the velocity of the sound, it is possible to find the diameter of the hole in an iterative way, varying it until the time of the test reaches the desired 1800 seconds (30 minutes).

3.4 Dry Part Test On A Semi Empty Tank

This is a very common situation, which corresponds to a hybrid case with simultaneous coexistence of both wet part and dry part. The standardizing and procedures adopted to test tightness of the dry part of partially filled tanks is similar to the one described in the previous section (i.e. completely empty tank).However, a fundamental detail has to be considered in this case. As there is fuel present in the tank, part of the pressure increase will happen simply due to the evaporation rate of the fuel during the test, with this, not necessarily indicating a leaking through a hole or something similar. By neglecting this fact, the testing companies risk mistakenly deeming a tank unfit without knowing the real cause of the vacuum drop (pressure increase).

This way, the challenge question that comes with applying this method to semi empty tanks is the following: A result that deems a tank non-tight and unfit has that result because of a real hole or simply due to fuel evaporation at low pressures generating a false positive of untightness? To help solve this problem, it is necessary to determine the parcel of the pressure raise in the tank caused only by atmospheric air inlet trough possible holes in the tank and, this way, distinguish with reliability the two possible sources of pressure increase. Throughout the research process, multiple laboratory tests were made simulating diverse situations, including on site tests contemplating real empty tanks from gas stations, which were certified tight. As a result of these experiments an empiric constant was obtained. It represents the median pressure increase in a tank on critical temperature conditions due to natural reasons (i.e. a perfect vacuum doesn't exist) and leftover gas after the emptying process of the tank. The value found was between 9 and 10 mmHg. This empirical constant was used on this paper as the way to correct possible distortions in the application of the method and due to theoretical approximations, besides other ideal laboratory considerations applied to the equations of the study. Ratifying the fact that a perfect vacuum does not exist. Thus, the empirical constant above served to attenuate the main differences between theoretical conditions and the real situations on the gas stations.

To validate the computational simulation and the laboratory tests trough practical dry part tests of semi empty tanks, the following considerations were taken:

(1)At the start of the test, the control volume is completely occupied by gasoline vapor, as it is denser than air, thus, it tends to expel it.

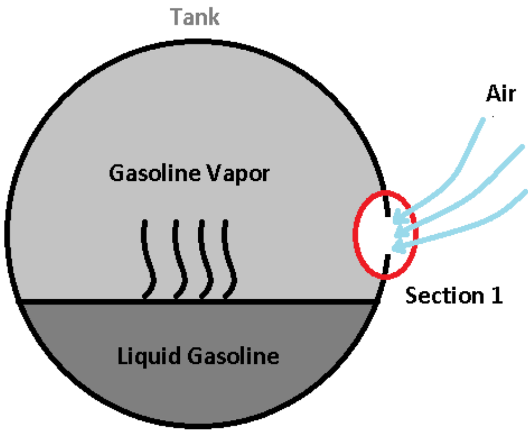
(2)The control volume is the dry part of the tank not filled with fuel, and the variations on its dimensions are negligible.

(3)A maximum natural increase of 10mmHg(empirical constant) is expected on the simulation and happens, even if there are no detectable holes to allow air inlet or increase due to evaporation rate of the fuel troughout the duration of the test.

For this analysis, the Dalton law of partial pressures was used.

$$P_{Total} = P_{Air} + P_{GV} \tag{41}$$

$$P_{Air} = \eta_{Air} + \frac{RT}{V}, air's\ partial\ pressure \tag{42}$$



Dry Part Schematics.jpeg

Figure 4. Schematic representation of the semi empty tank at the start of the test.

$$P_{GV} = \eta_{GV} + \frac{RT}{V}, gasoline\ vapour's\ partial\ pressure \tag{43}$$

As the objective is to know the parcel of the pressure increase for which the air inlet is solely responsible for, the equation to be used is:

$$P_{Air} = \eta_{Air} + \frac{RT}{V} \tag{44}$$

Which can be expanded as:

$$P_{Air} = \frac{m_{Air}}{M_{Air}} + \frac{RT}{V} \tag{45}$$

As the control volume does not contain any air at the start of the test, it is needed to find the final mass of air in the tank, which means, how much air entered the tank during the test.

To exemplify and validate the methodology and make the due approximations, it will be considered a tank with volumetric dimensions equal to the volume of the parcel of the tank not occupied by liquid gasoline (Ex.: for a tank with 30 thousand liters with 76 cm of column of liquid fuel, this theoretical volume will be of 22947 cubic meters) full of air. As the volume doesn't change, the variation of the mass of air will be given by:

$$\Delta M = \rho_{t_0+\Delta T} * \forall - \rho_{t_0} * \forall = FinalMass \tag{46}$$

The volume $\forall$ is the parcel of tank's volume that is not occupied by liquid gasoline.

In possession of the value corresponding to the mass of air that entered the tank the Eq. (45) can be used to calculate the increase of pressure by air inlet into the tank. This was always the procedure adopted on this research for multiple simulations e practical validation.

The temperature is the one at the end of the 30 minutes of the test. In this specific practical example the temperature was measured with the aid of well calibrated equipment of Veeder Root brand installed on the 30 de setembro gas station in Natal,RN, Brazil. The utilized tank in the simulation was of 30,000 liters with 76 cm of liquid column (common gasoline). The control volume (the volume not occupied by liquid fuel) corresponds to 22,497 liters.

Figure 5. Veeder-Root equipment.

Having the value of pressure increase for which is responsible solely the inlet of air in the control volume, which is exactly what is necessary to certify tightness, a test situation of dry part test on an empty tank(only air) with a volume of 22,947 liters and a limit pressure raise corresponding to the pressure increase only by air inlet is simulated.

4. GENERAL RESULTS OF THE SIMULATION

The following tables present the data regarding the results obtained for the smallest hole diameter than can be identified by a specific test situation and the variables used in the simulation.

Table 2. Results for the simulation of a wet part test with a completely full tank

Variable	Value
Volume of the tank	30.607 m^3
Liquid Column Height(h)	254 cm
Volume of fuel	30.607 m^3
Flow rate($\dot{\forall}$)	0.378 l/h
Gravity(g)	9.81 m/s^2
Diameter of the hole(d)	0.1375 mm

Table 3. Results for the theoretical simulation of a dry part test with a completely empty tank considering the empirical constant

Variable	Value
Allowed pressure increase	15 mmHg
Empirical Constant	10 mmHg
Variation of specific mass$\Delta\rho$	0.017217 Kg/m^3
Volume of the tank($\forall$)	30.607 m^3
Initial air inlet velocity($\vec{V_0}$)	154.3069 m/s
Initial specific mass(ρ_0)	0.1375 Kg/m^3
Specif mass variation rate, calculated from the equation in the integral form($\frac{\partial\rho}{\partial t}$)	$9.53 * 10^{-6}$
Time(t)	1800 s
Diameter of the hole(d)	0.753 mm

Table 4. Results for the theoretical simulation of a wet part test with a semi empty tank

Variable	Value
Volume of the tank	30.607 m^3
Liquid Column Height(h)	76 cm
Volume of fuel	7.660 m^3
Flow rate($\dot{\forall}$)	0.378 l/h
Gravity(g)	9.81 m/s^2
Diameter of the hole(d)	0.186 mm

Table 5. Results for the real analysis of a dry part test with a semi empty tank

Variable	Value
Amount of air that entered the tank(m_{Air}	0.131979 Kg
Final temperature(T)	292.7 K
Molar Mass of the air(M_{Air})	0.029
Number of mols of air(η)	0.102979
Allowed pressure increase	15 mmHg
Empirical constant	10 mmHg
Pressure increase by air inlet(P_{Air})	10.92 Pa
Diameter of the hole(d)	0.097 mm

With the obtained results, it is possible to verify the clear effect of the evaporation rate on the total pressure increase during the test. When comparing the smallest identifiable hole of the dry part test with a semi empty tank versus a completely empty one, the 0.753 mm from the latter is approximately 8 times bigger, thus less rigorous, than the 0.097 mm found on the former.

It is also possible to state the superiority of the dry part test when compared to the wet part one, as seen that in the same situation (semi empty, 76 cm of liquid column of gasoline) the dry part test showed itself two times more rigorous than its rival, thus, much stricter when judging the integrity of the tank.

Substituting the diameter of the hole obtained on the dry part test of a semi empty tank into the Eq. (6), the allowed flow rate necessary for the tests to be equally rigorous can be obtained. This flow rate of ml/h would mean the amount of fuel in ml that would be fine to "leak" in an hour with a hole at the base of the tank (critical case).

The wet part test with the current parameters is only more rigorous in the very specific case where the tank is full with a hole on its base, compared to a dry test on completely empty one.

5. CONCLUSION

This study verifies the suspicions of the great difference in rigorousness between the two types of tightness test for USTs in gas stations allowed by the in force standard in Brazil.

The results of the study confirmed the superior rigorousness of the dry past test. For the wet part test to become equivalent to its rival, which means, being able to identify the same minimum hole diameter, it would be necessary for the "total allowed leak"trough the duration of the test(one hour) to be changed to 100 ml(result obtained from plugging the diameter of the hole found for the dry part test of an semi empty tank on the Eq. (6) having the flow rate as the unknown).

The obtained results allow a suggestion to the immediate improvement of the parameters required by the wet part test on the current standard, as seen that this test only has about 50% of the rigorousness of its competitor and takes much more time to be performed. The allowed flow rate needs to change from 0.378 ml/h to 100 ml/h and there already is equipment in the Market capable of meeting these demands.

The results were also capable of confirming the initial suspicion of the great influence of the evaporation rate of the fuel on the total pressure increase throughout the duration of the test.

6. REFERENCES

Andre, T.S., Fontes F.A.O., Guerra A.R.O and Barbosa, C.R.F., 2016. "Taxa De EvaporaÃğÃčo Da Gasolina Comum Em Tanques De Postos De Combustiveis: Uma Avaliacao Em Funcao Da Temperatura". In Proceedings of the 25^{th} Congresso Nacional de Engenharia MecÃćnica - CONEM 2016. Fortaleza, Brazil.

Fox, R.W., Pritchard, P.J. and Mcdonald, A.T., 2010. Introduction to fluid mechanics. Wiley, New Jersey, 7^{th} edition

Teixeira, R.M., 2008. "2008. Postos de combustiveis âĂŞ contaminacao de aquiferos e solos por vazamento em tanques subterraneos." CENED. 05 Oct. 2018 <http://www.cenedcursos.com.br/meio-ambiente/postos-de-combustiveis-contaminacao-de-aquiferos/>

Terra Brasil, 2017. "Contaminacao do solo de posto de combustivel." Terra Brasil. 05 Oct. 2018 <http://terrabrasilambiental.com.br/b do-solo-de-posto-de-combustivel/>