Journal of Engineering and Technology for Industrial Applications

ITEGAM-JETIA

Manaus, v.7 n.29, p. 25-35. May/Jun, 2021

DOI: https://doi.org/ 10.5935/jetia.v7i29.759

ISSN ONLINE: 2447-0228

RESEARCH ARTICLE OPEN ACCESS

APPLICATION OF STATISTICAL PROCESS CONTROL (SPC) IN THE VOLUME VARIATION OF A VOLATILE LIQUID FUEL

Everaldo de Queiroz Lima*[1], Cecília Lenzi[2], Maurício Moyses Machado[3] and Fátima Geisa Mendes Teixeira[4]

[1, 2, 4] Chemical Engineering, Lutheran University Center of Manaus – CEULM/ULBRA, Manaus, Amazonas, Brazil.
[3] University of Uberaba – UNIUBE. Uberaba, Minas Gerais, Brazil.

[1] http://orcid.org/0000-0002-6887-4594, [2] http://orcid.org/0000-0003-3123-0610, [3] http://orcid.org/0000-0002-8509-7117, [4] http://orcid.org/0000-0002-1106-980X

Email: *everaldolima.am@gmail.com, cecilia.lenzi@yahoo.com.br, mauricioepga@gmail.com, fatimageisa2015@gmail.com

ARTICLE INFO

Article History
Received: June 09th, 2021
Accepted: June 18th, 2021
Published: June 30th, 2021

Keywords:
Control chart,
Fuel,
Statistical Process Control,
Volume.

ABSTRACT

Statistical Process Control makes it possible to monitor the quality characteristics of interest, ensuring their maintenance within pre-established limits and indicating when to adopt corrective and improvement actions. The problem addressed in this work The large variation in the net mass of a volatile fuel derived from petroleum (gasoline A) stored in atmospheric tanks at a Fuel Distributor in Manaus-AM. Data on the variation in the volume of gasoline A were studied in the process of transferring between tanks. The data for the study were obtained from the Distributor's Net Cargo Tonnage Certificates (CNCT) and Quality Certificates (QC) and tabulated in an electronic spreadsheet using the Microsoft Excel software from Windows, in which the graphs of the volume variation values, specification limits (LSL and USL) and process control limits (LCL and UCL) were also plotted. All results point to an objective way of demonstrating the high degree of safety required in this process, the studied process control parameters that form the variation of the ambient volume and volume at 20 °C of gasoline A, remained within the limits of control and as for the capacity indexes it was concluded that the process produced high capacity indexes.

I. INTRODUCTION

Statistical Process Control (SPC) is a statistical technique applied to production that allows the systematic reduction of the variability in the characteristics of the quality of interest, contributing to the improvement of the intrinsic quality, productivity, reliability and cost of what is being produced [1]. The production, storage and transport of fuels in terms of volumetric quantity is a growing concern, the volume of fuels can be compromised from production at an oil refinery or biofuel plant to the final consumer tank. [2, 3]. The amount of fuel in storage and distribution tanks can undergo several changes, causing the volume to differ from the amount of fuel that initially leaves what was produced [2, 4]. The regulatory body for the activities that integrate the oil, natural gas and biofuels industries in Brazil, linked to the Ministry of Mines and Energy (MME), is the National Agency of Petroleum, Natural Gas and Biofuels (ANP), the federal agency that executes the national policy for the sector with a focus on ensuring fuel supply, product quality and protecting consumer interests [5].

II. THEORETICAL REFERENCE

II.1 STATISTICAL PROCESS CONTROL

The SPC is an inspection system by sampling, operating throughout the process, with the objective of verifying the presence of special causes, that is, causes that are not natural to the process and that can harm the quality of the manufactured product. Once the special causes are identified, we can act on them, continuously improving the production processes and, therefore, the quality of the final product. [6, 7]. The SPC makes it possible to monitor the quality characteristics of interest, ensuring their maintenance within pre-established limits and indicating when to adopt corrective and improvement actions. It allows the systematic reduction of variability in quality characteristics, in an effort to improve the intrinsic quality, productivity and reliability of what is being produced or supplied. Shewhart control charts stand out among the SPC tools for operational simplicity and effectiveness in detecting problems [8]. The SPC provides an x-ray of the process, identifying its variability and enabling the control of this variability over time through continuous data collection, analysis and blocking of possible special causes that are making the system unstable [7, 9]. The main objective of the SPC is to enable an effective quality control, carried out by the operator himself in real time. This increases the operator's commitment to the quality of what is being produced and frees management for improvement tasks [9]. The SPC makes it possible to monitor the characteristics of interest, ensuring that they will remain within pre-established limits and indicating when corrective and improvement actions should be taken. It is important to emphasize the importance of detecting defects as early as possible, to avoid adding raw material and labor to a defective product [7].

II.2 CONTROL GRAPHICS

The SPC is operationalized through control charts, which are used to monitor the performance of a process from the definition of an acceptable control range. The control chart is used to analyze trends and patterns that happen over time. Its main purpose is to monitor a process, checking if it is under statistical control indicating its range of variation [6]. There are two types of control charts: for variables and for attributes. The control graphs for attributes refer to the quality characteristics that classify items in conforming and non-conforming, while the control graphs for variables are based on the measurement of quality characteristics on a continuous scale, as shown in Figure 1 [6, 7, 9].

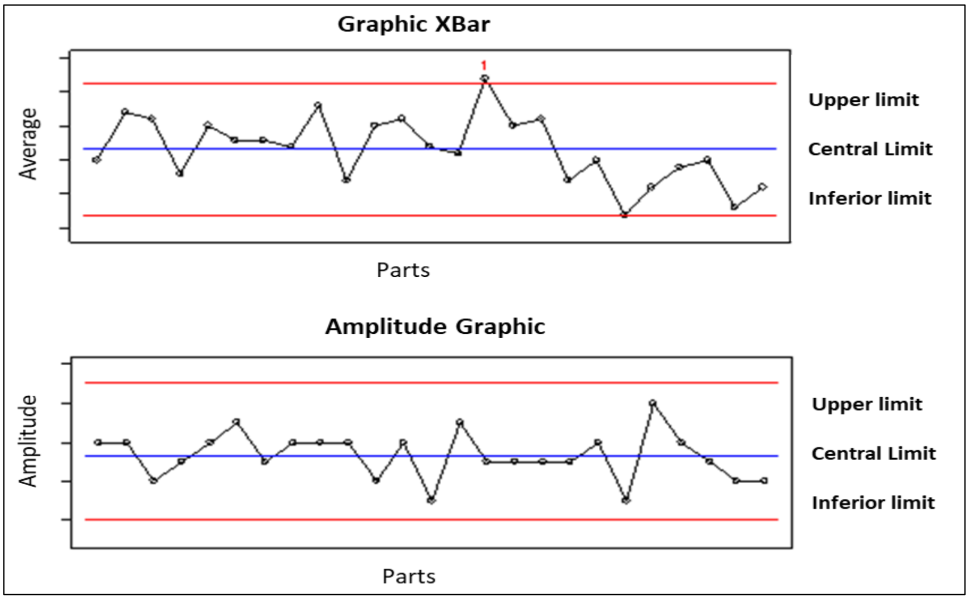

Figure 1: Control Chart Template.
Source: [17].

Figure 1 shows a control chart that is composed of a Central Line (CL) that represents the average value or central limit of the quality characteristic corresponding to the situation of the process under control and a pair of control limits: one of them located below the central line called Lower Control Limit (LCL) and another located above the central line, called Upper Control Limit (UCL) [10, 11].

II.3 CONTROL LIMITS

The control of the process is usually done through the control graph for individual values or gráfico graph. The variability of the process can be monitored either through the standard deviation control graph, called the S graph, or by the graph for the moving amplitude, called the R graph. To better exemplify the function of each graph, the x graph monitors the variability between samples and the S or R graph monitors the variability within the sample. The points plotted on the control graphs are joined by straight lines sequentially and are interpreted according to horizontal lines, called UCL, ML and LCL given by Equations 1, 2 and 3 for the mean graph and 5, 6, and 7 for the graph of the moving range [7, 12].

Control limits for the graph of individual measures.

$$UCL_x = \bar{x} + E_2.Rm \tag{1}$$

$$LM_x = \bar{x} \tag{2}$$

$$LCL_x = \bar{x} - E_2.Rm \tag{3}$$

Where:

$$E_2 = \frac{3}{d_2.} \tag{4}$$

Where $\bar{x}$ is the average of the graph points for each variable, $Rm = |x_i - x_{i-1}|$, that is, the difference between two subsequent values for each variable, and the parameters E_2 and d_2 are tabulated [7, 12].

II.4 VOLATILITY

Volatility is a quantity that is related to the easiness of the substance to pass from the liquid to the vapor or gaseous state. This facility depends on the referential; therefore, volatility is always relative: it takes into account two substances, one of which is the reference substance [10, 13].

The relative volatility between a substance A and a substance B is defined as follows:

$$\alpha_{AB} = \frac{y_{Ae}/x_{Ae}}{y_{Be}/x_{Be}} \quad (5)$$

Where: α_{AB} is the relative volatility between A and B. y_{Ae} and y_{Be} are molar fractions of A and B, respectively, in the vapor phase in equilibrium with the liquid phase. x_{Ae} and x_{Be} they are molar fractions of A and B, respectively, in the vapor phase in equilibrium with the liquid phase.

Relative volatility below one ($\alpha_{AB} < 1$) indicates that B is more volatile than A; otherwise, if the relative volatility is greater than one ($\alpha_{AB} > 1$), A is more volatile than B. If the liquid phase is an ideal mixture, Raoult's law can be accepted as valid:

$$p_A = P_A^{sat}.x_A \quad (6)$$

$$p_B = P_B^{sat}.x_B \quad (7)$$

Where: p_A and p_B, are partial pressures of A and B, respectively. P_A^{sat} and P_B^{sat} are vapor pressures of A and B, respectively. x_A and x_B are molar fractions of A and B, respectively, in the liquid phase.

If the vapor phase is an ideal gas, Dalton's Law applies:

$$y_A = \frac{p_A}{P} \quad (8)$$

$$y_B = \frac{p_B}{P} \quad (9)$$

Where: y_A and y_B are the molar fractions of A and B, respectively, in the vapor phase. P the total system pressure.

Replacing the eq. (6) in eq. (8) and eq. (7) in eq. (9), we will have:

$$y_A = \frac{P_A^{sat}.x_A}{P} \quad (10)$$

$$y_B = \frac{P_B^{sat}.x_B}{P} \quad (11)$$

Replacing the eq. (10) and eq. (11) in eq. (5), we will have:

$$\alpha_{AB} = \frac{P_A^{sat}}{P_B^{sat}} \quad (12)$$

That is, in cases of totally ideal liquid-vapor equilibrium, the relative volatility between two substances in a mixture is a simple relation of their vapor pressures [10, 13].

III. MATERIALS AND METHODS

III.1 COMPANY DESCRIPTION – PLACE OF STUDY

The work was carried out at a company in the oil sector in the city of Manaus, which has been operating since 2000 and has been consolidating its position as one of the largest distributors of petroleum fuels and biofuels in Brazil. As defined by the ANP, the company under study carries out the activity of distribution of liquid fuels that is of public utility and comprises the acquisition, storage, mixing, transportation, commercialization and quality control of fuels [14].

It recently underwent a process to expand its storage capacity, which went from 15.000 m^3 to 75.000 m^3, according to Regulatory Standard n° 20 (NR-20) of the Ministry of Labor is classified as a class III hazardous facility and carries out storage, transfer, handling and handling of combustible and flammable liquids [15].

III.2 STAGES OF WORK

The work was carried out on the changes in the volume of gasoline A in the process of transfers between tanks, as described in Figure 2.

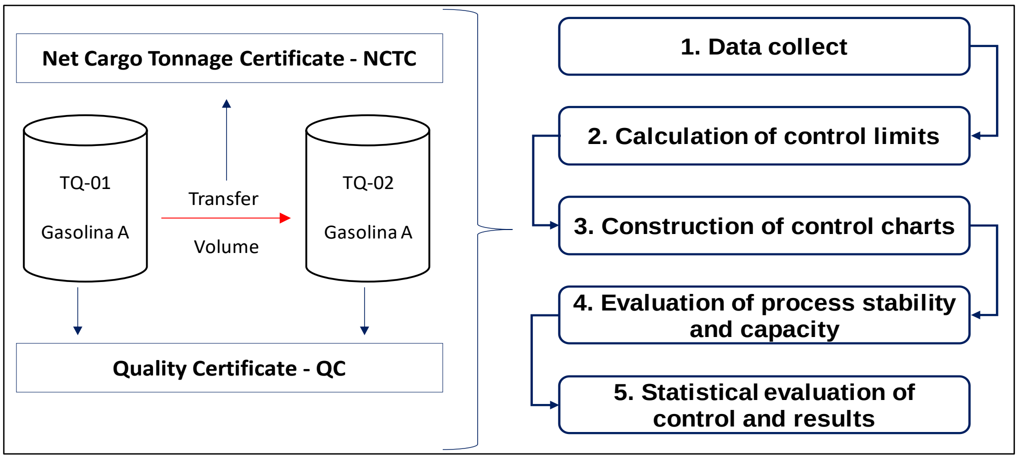

Figure 2: Fuel transfer flow and methodology flowchart.
Source: [7] and [12].

III.2.1 DATA COLLECT

Gasoline A volume data were collected in the transfer between tanks (TQ) processes. As shown in figure 2, data on volume at room temperature and volume at 20 °C from TQ-01 (shipping tank) and TQ-02 (receiving tank) were collected over a period of two months. These data were obtained from Certificates of Net Cargo Tonnage (CNCT), which is the official document for certification and quantification of the volume of fuel handled in oil terminals. The data of temperature, density and specific gravity at 20 °C were obtained from the Gasoline A Quality Certificate (QC), referring to the batch of work in the sending tank and in the receiving tank.

III.2.2 CALCULATION OF CONTROL LIMITS

The control of the process was carried out through the control chart of individual values and by control charts for mobile amplitudes. The points plotted on the control graphs were joined by straight lines sequentially that were interpreted in terms of horizontal lines, called UCL, ML and LCL that took place according to the methodology of [7] and [12].

III.2.3 CONSTRUCTION OF CONTROL GRAPHICS

The volume data at room temperature and the volume converted at 20 ° C of the transfers were organized in a spreadsheet and plotted the graphs using Microsoft Excel software from Windows. They checked how the process behaves and made an average ($\bar{x}$) and mobile range (Rm) of the data obtained to determine the UCL and the LCL to verify the expected standards of the process and define the limits according to the methodology proposed by [7], that defines the SCP for continuous and batch processes.

III.2.4 EVALUATION OF PROCESS STABILITY AND CAPACITY

The relationship between the levels of variability or the stability of the process in relation to the specification requirements, were made through the analysis of the capacity of the process. The verification of the ability of the process to safely meet the specifications was demonstrated by calculating the parameter C_{pk}, defined by Equations 13, 14 and 15. This parameter represents the ratio between the specification tolerance and the total dispersion of the process, according to the methodology of [7] and [12].

$$C_{pk} = \min[C_{pi}, C_{ps}] \quad (13)$$

$$C_{pi} = \frac{\bar{x} - LIE}{3.s} \quad (14)$$

$$C_{ps} = \frac{LSE - \bar{x}}{3.s} \quad (15)$$

Where LSL is the Lower Specification Limit and USL is the Upper Specification Limit, the *s* Where LSL is the Lower Specification Limit and USL is the Upper Specification Limit, the $\bar{\square}$ is the average of the samples.

The index C_{pk} evaluates the distance from the process average to the specification limits, taking the one that is less, that is, it is defined as being the lowest value between C_{pi} and C_{ps}, therefore, more critical in terms of the chances of producing out-of-specification items. If $C_{pk} \leq 1$ (unable process), $1 \leq C_{pk} \leq 1{,}33$ (acceptable process) e $C_{pk} \geq 1{,}33$ (capable process).

III.2.5 STATISTICAL EVALUATION OF CONTROL AND RESULTS

Data that exceeded the limit lines were verified and other Quality/Process engineering tools were used, such as Brainstorm and Ishikawa Diagram, which are discussions of ideas and a graphical form used as an analysis to represent influencing factors (causes) on a given problem. (effect) to find the root cause and define the process capacity indices [16].

IV. RESULTS AND DISCUSSIONS

The data of 33 transfers (samples) of Gasoline A from tank 01 to tank 02 in the months of August and September 2020 were studied. Observations of process control related to the parameters of volume at room temperature and volume at 20 °C were used. The information collected from the NCTC and product QC are described in Table 1.

Table 1: Data collected from CACL and QC for transfers of Gasoline A (33 samples - August and September 2020).

Nº.	Dispatcher Tank (TQ 01)						Receiving Tank (TQ 02)					
	Tank temp. (ºC)	Dens. read (g/cm³)	Sample temp. (ºC)	Esp. Mass at 20 ºC (kg/m³)	Ambient volume (L)	Volume at 20 ºC (L)	Tank temp. (ºC)	Dens. read (g/cm³)	Sample temp. (ºC)	Esp. Mass at 20 ºC (kg/m³)	Ambient volume (L)	Volume at 20 ºC (L)
1	31,5	0,712	29,5	719,9	1.241.029	1.224.236	30,5	0,717	30,0	725,2	1.243.243,0	1.228.130
2	31,0	0,718	30,0	726,2	1.250.090	1.234.216	30,0	0,717	29,0	724,4	1.254.595,0	1.240.037
3	29,0	0,721	28,5	728,0	1.070.774	1.059.712	28,0	0,718	27,5	724,2	1.073.099,0	1.063.134
4	30,0	0,715	28,0	721,6	1.935.762	1.013.110	29,0	0,720	28,0	726,6	1.931.089	1.911.055
5	30,0	0,710	28,5	717,1	997.157	985.329	29,0	0,708	27,5	714,3	995.546	984.831
6	29,0	0,706	28,5	713,1	964.288	953.874	28,0	0,704	26,5	709,5	964.287	954.930
7	29,5	0,707	28,0	713,7	1.026.635	1.014.950	28,5	0,712	28,0	718,7	1.028.494	1.018.176
8	28,0	0,705	27,5	711,3	330.876	327.683	27,0	0,702	26,0	707,1	330.652	327.825
9	28,0	0,714	26,0	719,0	912.786	904.177	27,0	0,710	26,5	715,4	914.522	906.896
10	28,5	0,712	27,5	720,2	776.243	768.446	27,5	0,717	26,5	724,4	776.845	770.046
11	29,0	0,717	28,5	724,0	1.406.613	1.391.908	28,0	0,720	26,5	725,3	1.409.735	1.396.690
12	29,0	0,717	27,0	722,8	1.032.362	1.021.530	28,0	0,722	27,0	727,7	1.033.674	1.024.177
13	28,0	0,716	26,5	721,4	219.162	217.110	27,0	0,715	26,5	720,4	218.192	216.399
14	28,5	0,709	28,0	715,7	908.299	899.106	27,5	0,706	26,5	711,5	908.623	900.407
15	27,5	0,711	26,0	716,0	832.622	825.195	26,5	0,716	25,0	720,1	833.066	826.706
16	29,5	0,703	29,0	710,6	1.575.481	1.557.381	28,5	0,701	27,5	707,4	1.579.472	1.563.082
17	31,5	0,705	29,5	713,0	512.228	505.152	30,5	0,703	29,5	711,0	513.398	506.886
18	31,0	0,710	30,0	718,3	1.153.299	1.138.303	30,0	0,715	28,5	722,0	1.155.210	1.141.709
19	29,0	0,713	28,5	720,0	1.200.225	1.187.528	28,0	0,710	27,0	715,8	1.203.303	1.191.847
20	30,0	0,719	28,0	725,6	1.098.599	1.085.895	29,0	0,715	28,0	721,6	1.098.678	1.087.110
21	30,0	0,720	28,5	727,0	414.281	409.510	29,0	0,725	27,5	731,1	412.711	408.487
22	29,0	0,721	28,5	728,0	913.011	902.528	28,0	0,724	27,0	729,7	914.090	905.741
23	29,5	0,720	28,0	726,6	1.218.226	1.206.291	28,5	0,725	27,5	731,1	1.220.256	1.208.463
24	28,0	0,717	27,5	723,2	1.017.680	1.008.202	27,0	0,716	25,5	720,6	1.017.412	1.009.057
25	28,0	0,710	26,0	715,0	1.059.505	1.049.393	27,0	0,707	28,5	714,1	1.062.680	1.053.784
26	28,5	0,707	27,5	713,3	476.090	471.237	27,5	0,712	27,0	717,8	476.378	472.152
27	29,0	0,706	28,5	713,1	454.002	449.099	28,0	0,704	27,0	709,9	455.905	451.487
28	29,0	0,707	27,0	712,9	928.658	918.621	28,0	0,705	27,5	711,3	927.966	919.011
29	28,0	0,705	26,5	710,5	561.877	556.441	27,0	0,710	26,0	715,0	562.394	557.698
30	28,5	0,714	28,0	720,6	1.769.183	1.751.539	27,5	0,711	26,5	716,4	1.773.054	1.757.258
31	27,5	0,712	26,0	717,0	1.112.712	1.102.816	26,5	0,708	25,5	712,6	1.112.855	1.104.166
32	29,5	0,711	29,0	718,5	1.039.391	1.027.729	28,5	0,716	27,5	722,2	1.042.358	1.032.011
33	28,0	0,717	26,0	722,0	1.028.154	1.018.543	27,0	0,720	26,0	724,9	1.026.245	1.017.927

Source: Authors, (2020).

IV.1 ASSESSMENT OF AMBIENT VOLUME VARIATION

Figure 3 shows the graph of the values collected from the variation in the ambient volume of Gasoline A for 33 transfers, it is observed that the process remains within the specification limits, which are established NBR 13787 and ANP Resolution N° 23/2004 [18, 19], which are -0,6 and +0,6% of volume variation for LSL and USL, respectively.

Figure 4 shows the control chart of the individual values for the Ambient Volume parameter for the 33 lots. It is observed that the process remains within the control limits, which were calculated for the process, which are -0,34 and +0,52% for the LCL and UCL, respectively, with a mean (ML) around +0,09% for the control chart of individual values (*x*).

The values of specification limit and control limit for individual values, evaluating the parameter of ambient volume were organized in a spreadsheet and are shown in Table 2.

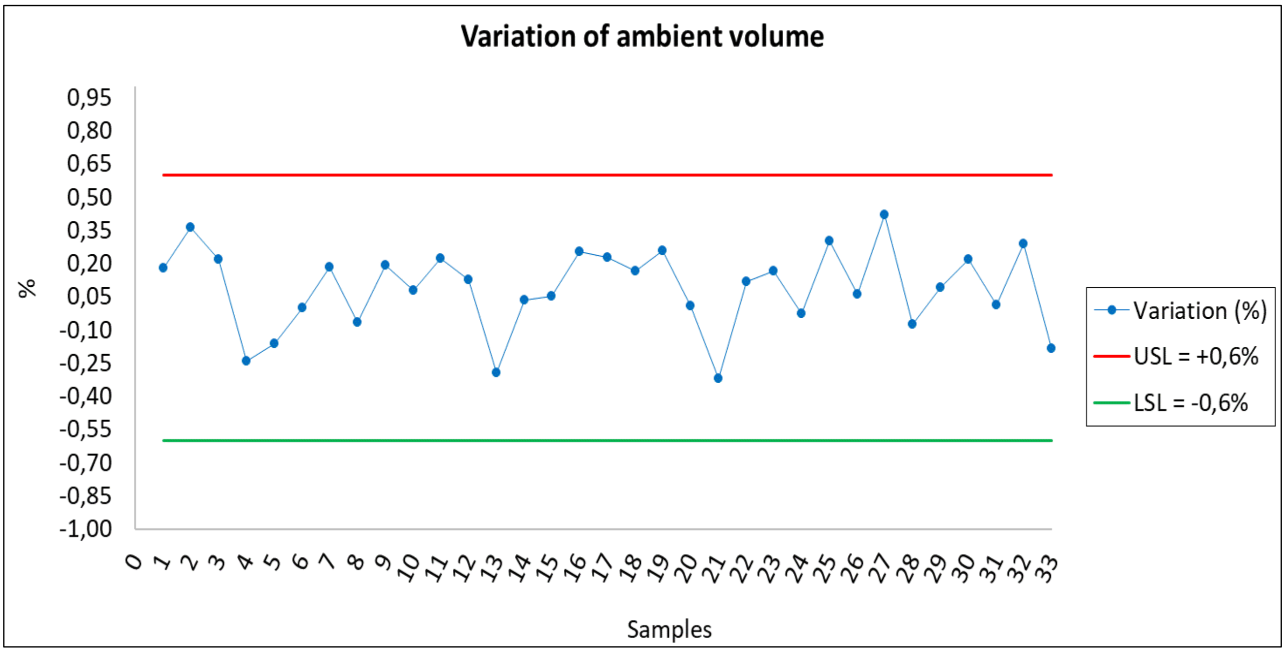

Figure 3: Graph of values and specification limits for Ambient Volume.
Source: Authors, (2020).

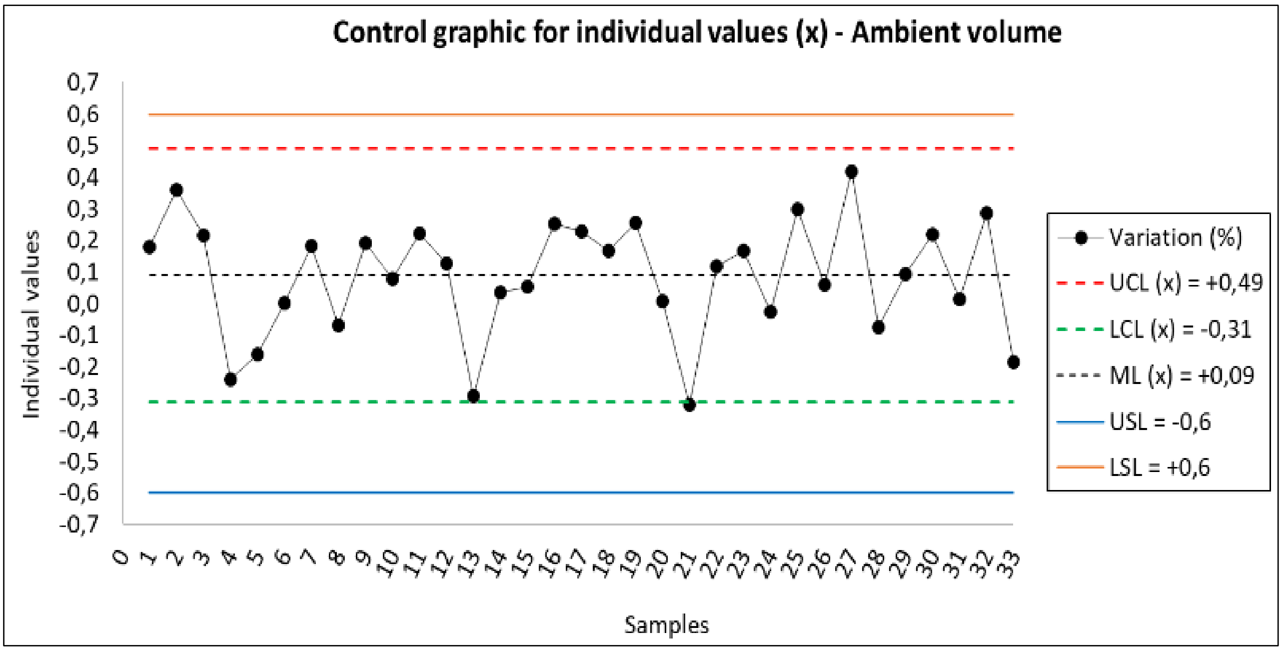

Figure 4: Control chart of individual values (*x*) - Ambient volume.
Source: Authors, (2020).

Table 2: Volume variation (%) in transfers between tanks (33 samples - August and September 2020).

Nº.	Ambient Volume (L)				Volume at 20 ºC (L)			
	Dispatched (V_{TQ1})	Received (V_{TQ2})	Difference (V_{TQ2} - V_{TQ1})	Variation ambiente volume (%)	Dispatched (V_{TQ1})	Received (V_{TQ2})	Difference (V_{TQ2} - V_{TQ1})	Variation volume at 20 ºC (%)
1	1.241.029	1.243.243	2.214	0,18	1.224.236	1.228.130	3.894	0,32
2	1.250.090	1.254.595	4.505	0,36	1.234.216	1.240.037	5.821	0,47
3	1.070.774	1.073.099	2.325	0,22	1.059.712	1.063.134	3.422	0,32
4	1.935.762	1.931.089	-4.673	-0,24	1.913.110	1.911.055	-2.055	-0,11
5	997.157	995.546	-1.611	-0,16	985.329	984.831	-498	-0,05
6	964.288	964.287	-1	0,00	953.874	954.930	1.056	0,11
7	1.026.635	1.028.494	1.859	0,18	1.014.950	1.018.176	3.226	0,32
8	330.876	330.652	-224	-0,07	327.683	327.825	142	0,04
9	912.786	914.522	1.736	0,19	904.177	906.896	2.719	0,30
10	776.243	776.845	602	0,08	768.446	770.046	1.600	0,21
11	1.406.613	1.409.735	3.122	0,22	1.391.908	1.396.690	4.782	0,34
12	1.032.362	1.033.674	1.312	0,13	1.021.530	1.024.177	2.647	0,26
13	219.162	218.192	-970	-0,29	217.110	216.399	-711	-0,17
14	908.299	908.623	324	0,04	899.106	900.407	1.301	0,14
15	832.622	833.066	444	0,05	825.195	826.706	1.511	0,18
16	1.575.481	1.579.472	3.991	0,25	1.557.381	1.563.082	5.701	0,37
17	512.228	513.398	1.170	0,23	505.152	506.886	1.734	0,34
18	1.153.299	1.155.210	1.911	0,17	1.138.303	1.141.709	3.406	0,30
19	1.200.225	1.203.303	3.078	0,26	1.187.528	1.191.847	4.319	0,36
20	1.098.599	1.098.678	79	0,01	1.085.895	1.087.110	1.215	0,11
21	414.281	412.711	-1.570	-0,32	409.510	408.487	-1.023	-0,19
22	913.011	914.090	1.079	0,12	902.528	905.741	3.213	0,36
23	1.218.226	1.220.256	2.030	0,17	1.206.291	1.208.463	2.172	0,18
24	1.017.680	1.017.412	-268	-0,03	1.008.202	1.009.057	855	0,08
25	1.059.505	1.062.680	3.175	0,30	1.049.393	1.053.784	4.391	0,42
26	476.090	476.378	288	0,06	471.237	472.152	915	0,19
27	454.002	455.905	1.903	0,42	449.099	451.487	2.388	0,53
28	928.658	927.966	-692	-0,07	918.621	919.011	390	0,04
29	561.877	562.394	517	0,09	556.441	557.698	1.257	0,23
30	1.769.183	1.773.054	3.871	0,22	1.751.539	1.757.258	5.719	0,33
31	1.112.712	1.112.855	143	0,01	1.102.816	1.104.166	1.350	0,12
32	1.039.391	1.042.358	2.967	0,29	1.027.729	1.032.011	4.282	0,42
33	1.028.154	1.026.245	-1.909	-0,19	1.018.543	1.017.927	-616	-0,06

Source: Authors, (2020).

IV.2 ASSESSMENT OF VOLUME VARIATION AT 20 °C

Figure 5 shows the graph of the values collected from the volume variation at 20 °C of Gasoline A for 33 transfers, it is observed that the process remains within the specification limits, which are established by NBR 13787 and resolution ANP n° 23/2004 [18, 19], which are -0,6 and +0,6% of volume variation for LSL and USL, respectively.

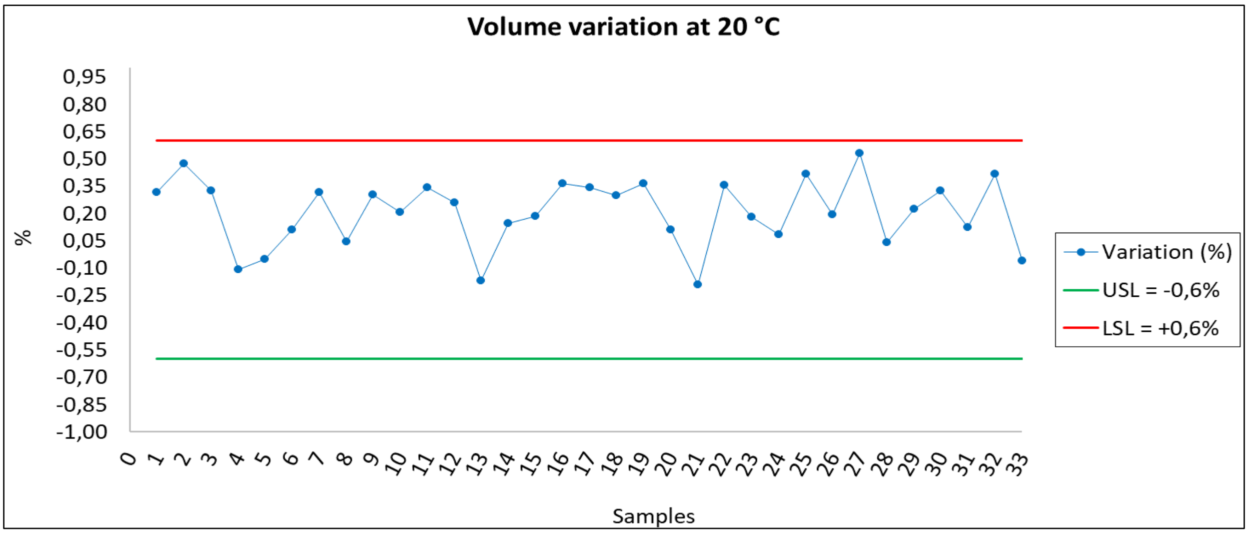

Figure 5: Graph of values and specification limits for Volume at 20 °C.
Source: Author (2020).

Figure 6 shows the control chart of the individual values for the Volume parameter at 20 °C for the 33 lots. It is observed that the process remains within the control limits, which were calculated for the process, which are -0,19 and +0,61% for LCL and UCL, respectively, with an average (LM) around +0,21% for the control chart of individual values (*x*).

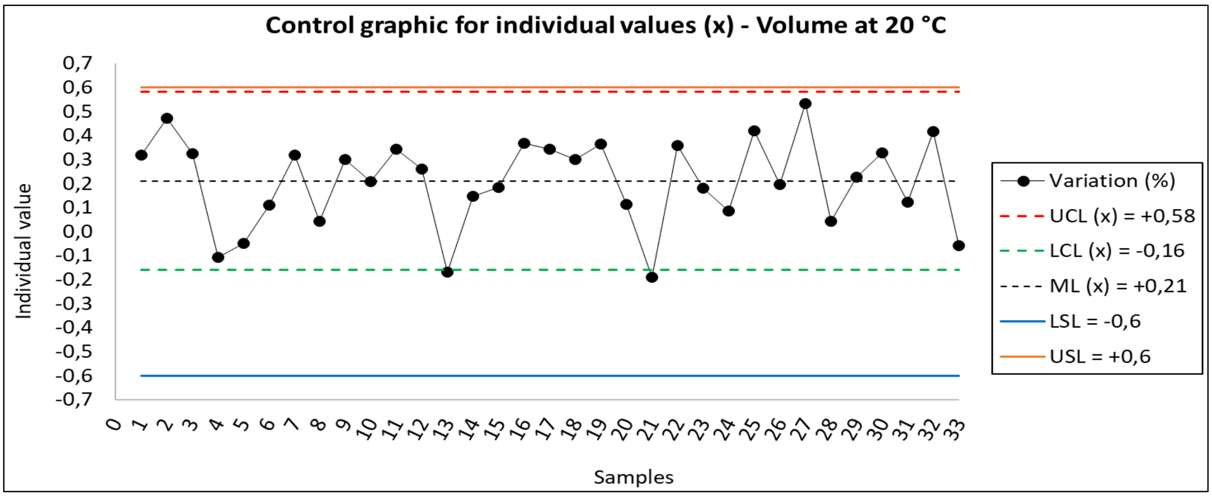

Figura 6: Control chart of individual values (*x*) -Volume at 20 °C.
Source: Authors, (2020).

The values of specification limit and control limit for individual values, evaluating the volume parameter at 20 °C, were organized in a spreadsheet and are shown in Table 2.

IV.3 PROCESS CAPABILITY ASSESSMENT

After proving the stability of the process, the process capacity index was calculated as described in Table 3.

Table 3: Control limits and capacity study.

Parameter	Ambient volume	Volume at 20 °C
Especification limits	-0,6 a + 0,6%	-0,6 a + 0,6%
Control limits (x)	-0,31 a + 0,49%	-0,16 a + 0,58%
Standard deviation	0,184	0,184
Cpi	1,245	1,463
Cps	0,931	0,712
Cpk = mín[Cpi,Cps]	**0,931**	**0,712**
Conclusion	Inability process	Inability process

Source: Authors, (2020).

For the Ambient Volume variable, the value of C_{pk} = 0,931, considering the standard deviation calculated for the 0,184. Having resulted $C_{pk} \leq 1{,}33$ the process is qualified as Incapable.

For the variable Volume at 20 °C, the value of C_{pk} = 0,712, considering the standard deviation calculated for the 0,184. Having resulted $C_{pk} \leq 1{,}33$ the process is qualified as Incapable.

IV.4 ACTION PLAN

Since, according to the result of the Process Capacity Index (C_{pk}), the process was considered Incapable, in this condition a brainstorm (sharing of ideas) was carried out in which everyone involved in the fuel transfer process (liquid bulk operator, operations supervisor and research student) exposed the ideas for surveying the causes that resulted in the undesired effect and from this survey, a Cause-Effect Diagram or Ishikawa Diagram was built, as shown in Figure 7.

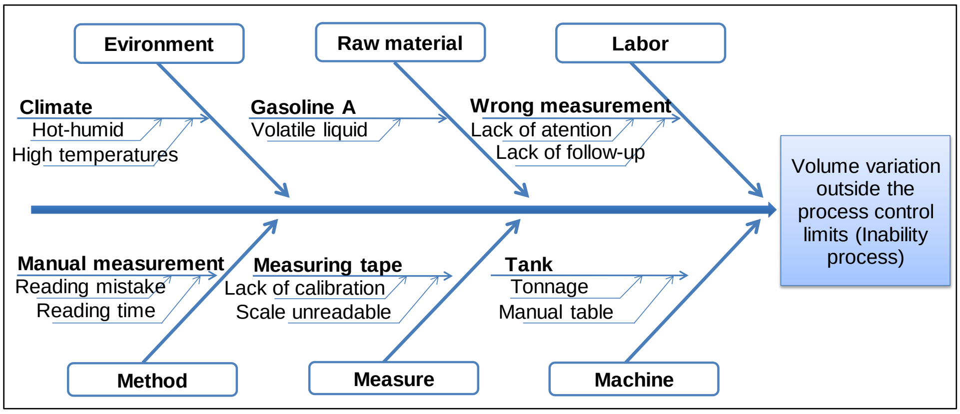

Figure 7: Ishikawa Diagram (cause-efectt) for volume variation.
Source: Authors, (2020).

From the Cause-Effect Diagram, a check-list was elaborated in which the variables and causes that led to the unwanted effect were listed. For each cause discussed for the process, it was verified whether or not the company met the requirement to inhibit the effect, and by elimination, work on the root cause.

As described in the check-list, the root cause of the unwanted effect for the process was the labor variable, which is caused by the wrong measurement that originated from the lack of attention during measurements and the lack of monitoring of a third party regarding the process carried out.

Once the root cause was verified, the data of 15 more transfers of Gasoline A from tank 01 to tank 02 were studied in October 2020 to review the fuel transfer process. The activity was monitored by an operations supervisor and the student researcher and carried out by the liquid bulk operator.

Observations of process control related to the parameters of volume at room temperature and volume at 20 °C were used. The information collected from the product quality certificates received and ANP specifications are described in Table 4 and Table 5**.**

Table 4: Data collected from CACL and QC for transfers of Gasoline A (15 samples - October 2020 - process review).

Nº.	**Dispatcher Tank (TQ 01)**						**Receiving Tank (TQ 02)**					
	Tank temp. (ºC)	**Dens. read (g/cm^3)**	**Sample temp. (ºC)**	**Esp. Mass at 20 ºC (kg/m^3)**	**Ambient volume (L)**	**Volume at 20 ºC (L)**	**Tank temp. (ºC)**	**Dens. read (g/cm^3)**	**Sample temp. (ºC)**	**Esp. Mass at 20 ºC (kg/m^3)**	**Ambient volume (L)**	**Volume at 20 ºC (L)**
1	30,0	0,719	28,0	725,6	1.098.599	1.085.895	29,0	0,715	28,0	721,6	1.098.678	1.087.110
2	30,0	0,710	28,5	717,1	997.157	985.329	29,0	0,708	27,5	714,3	995.546	984.831
3	29,0	0,721	28,5	728,0	913.011	902.528	28,0	0,724	27,0	729,7	914.090	905.741
4	27,5	0,711	26,0	716,0	832.622	825.195	26,5	0,716	25,0	720,1	833.066	826.706
5	28,0	0,717	27,5	723,2	1.017.680	1.008.202	27,0	0,716	25,5	720,6	1.017.412	1.009.057
6	28,0	0,705	26,5	710,5	561.877	556.441	27,0	0,710	26,0	715,0	562.394	557.698
7	28,5	0,709	28,0	715,7	908.299	899.106	27,5	0,706	26,5	711,5	908.623	900.407
8	28,5	0,707	27,5	713,3	476.090	471.237	27,5	0,712	27,0	717,8	476.378	472.152
9	29,0	0,717	27,0	722,8	1.032.362	1.021.530	28,0	0,722	27,0	727,7	1.033.674	1.024.177
10	29,0	0,707	27,0	712,9	928.658	918.621	28,0	0,705	27,5	711,3	927.966	919.011
11	29,0	0,706	28,5	713,1	964.288	953.874	28,0	0,704	26,5	709,5	964.287	954.930
12	28,0	0,705	27,5	711,3	330.876	327.683	27,0	0,702	26,0	707,1	330.652	327.825
13	27,5	0,712	26,0	717,0	1.112.712	1.102.816	26,5	0,708	25,5	712,6	1.112.855	1.104.166
14	28,5	0,712	27,5	720,2	776.243	768.446	27,5	0,717	26,5	724,4	776.845	770.046
15	29,5	0,720	28,0	726,6	1.218.226	1.206.291	28,5	0,725	27,5	731,1	1.220.256	1.208.463

Source: Authors, (2020).

Table 5: Volume variation (%) in transfers between tanks (15 samples - October 2020 - process review).

Nº.	**Ambient Volume (L)**				**Volume at 20 ºC (L)**			
	Dispatched (V_{TQ1})	**Received (V_{TQ2})**	**Difference (V_{TQ2} - V_{TQ1})**	**Variation ambiente volume (%)**	**Dispatched (V_{TQ1})**	**Received (V_{TQ2})**	**Difference (V_{TQ2} - V_{TQ1})**	**Variation volume at 20 ºC (%)**
1	1.098.599	1.098.678	79	0,01	1.085.895	1.087.110	1.215	0,11
2	997.157	995.546	-1.611	-0,16	985.329	984.831	-498	-0,05
3	913.011	914.090	1.079	0,12,	902.528	905.741	3.213	0,36
4	832.622	833.066	444	0,05	825.195	826.706	1.511	0,18
5	1.017.680	1.017.412	-268	-0,03	1.008.202	1.009.057	855	0,08
6	561.877	562.394	517	0,09	556.441	557.698	1.257	0,23
7	908.299	908.623	324	0,04	899.106	900.407	1.301	0,14
8	476.090	476.378	288	0,06	471.237	472.152	915	0,19
9	1.032.362	1.033.974	1.312	0,13	1.021.530	1.024.177	2.647	0,26
10	928.658	927.966	-692	-0,07	918.621	919.011	390	0,04
11	964.288	964.287	-1	0,00	953.874	954.930	1.056	0,11
12	330.876	330.652	-224	-0,07	327.683	327.825	142	0,04
13	1.112.712	1.112.855	143	0,01	1.102.816	1.104.166	1.350	0,12
14	776.243	776.845	602	0,08	768.446	770.046	1.600	0,21
15	1.218.226	1.220.256	2.030	0,17	1.206.291	1.208.463	2.172	0,18

Source: Authors, (2020).

IV.4.1 Assessment of Ambient Volume Variation – Process Review

Figure 8 shows the graph of the values collected from the variation in the ambient volume of Gasoline A for 15 transfers, it is observed that the process remains within the specification limits, which are established by NBR 13787 and ANP resolution n° 23/2004 [18, 19], which are -0,6 and +0,6% of the volume variation for the USL and LSL, respectively.

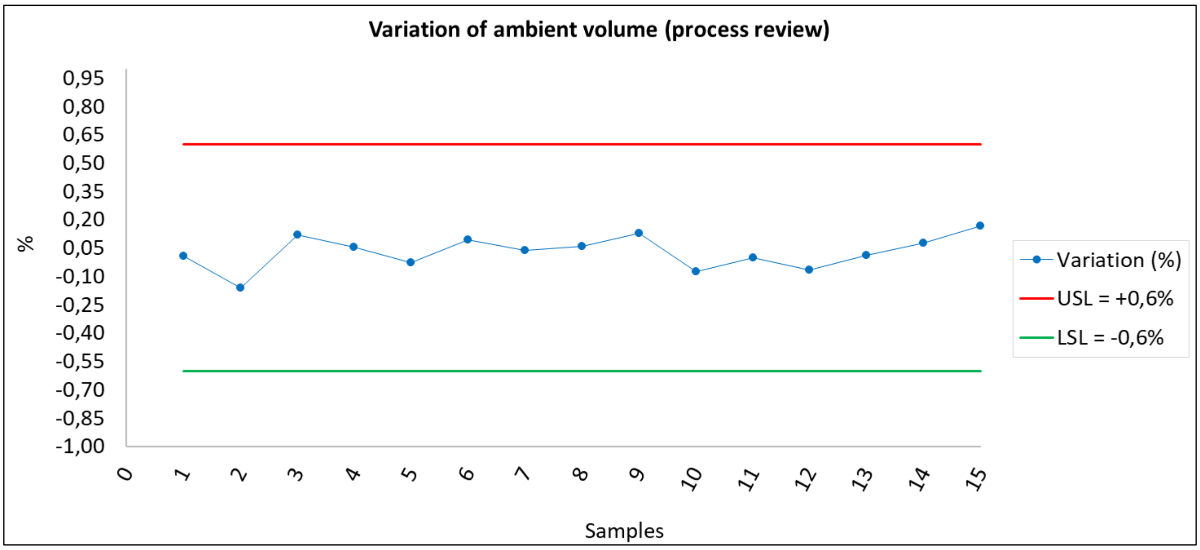

Figure 8: Graph of values and specification limits for Ambient Volume - process review.
Source: Author (2020).

Figure 9 shows the control chart of the individual values for the parameter of the Ambient Volume for the 15 samples. It is observed that the process remains within the control limits, which were calculated for the process, which are -0,26 and +0,32% for the LCL and UCL, respectively, with an average (ML) around +0,03% for the control chart of individual values (x).

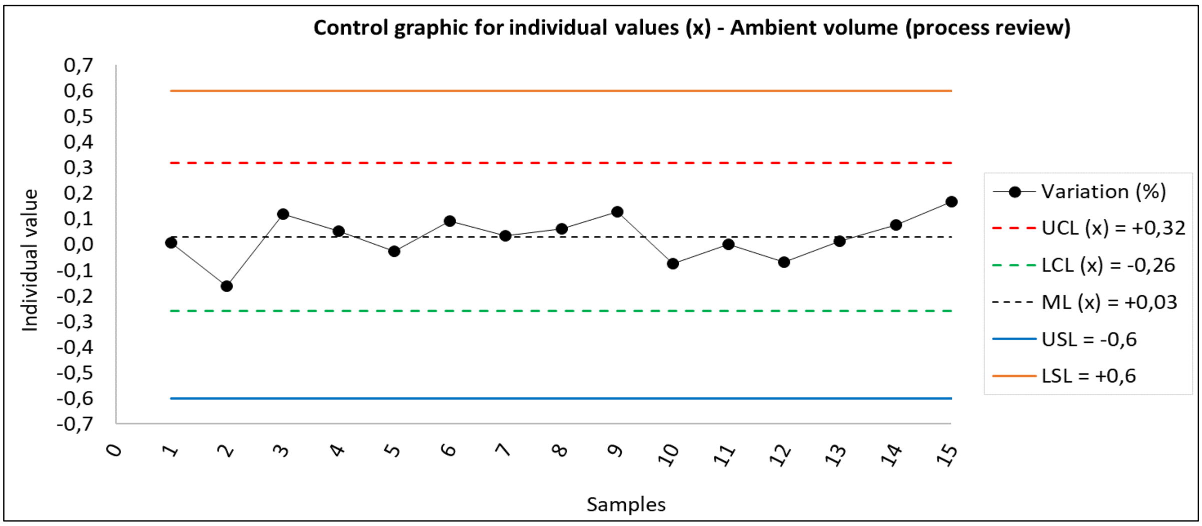

Figure 9: Control chart of individual values (x) - Ambient volume (process review).
Source: Authors, (2020).

The values of specification limit and control limit for individual values, evaluating the parameter of ambient volume for review of the process were organized in a spreadsheet and are presented in Table 5.

IV.4.2 Assessment of Volume Variation at 20 °C – Process Review

Figure 10 shows the graph of the values collected from the volume variation at 20 °C of Gasoline A for 15 transfers, it is observed that the process remains within the specification limits, which are established by NBR 13787 and resolution ANP n° 23/2004 [18, 19], which are -0,6 and +0,6% of volume variation for LSL and USL, respectively.

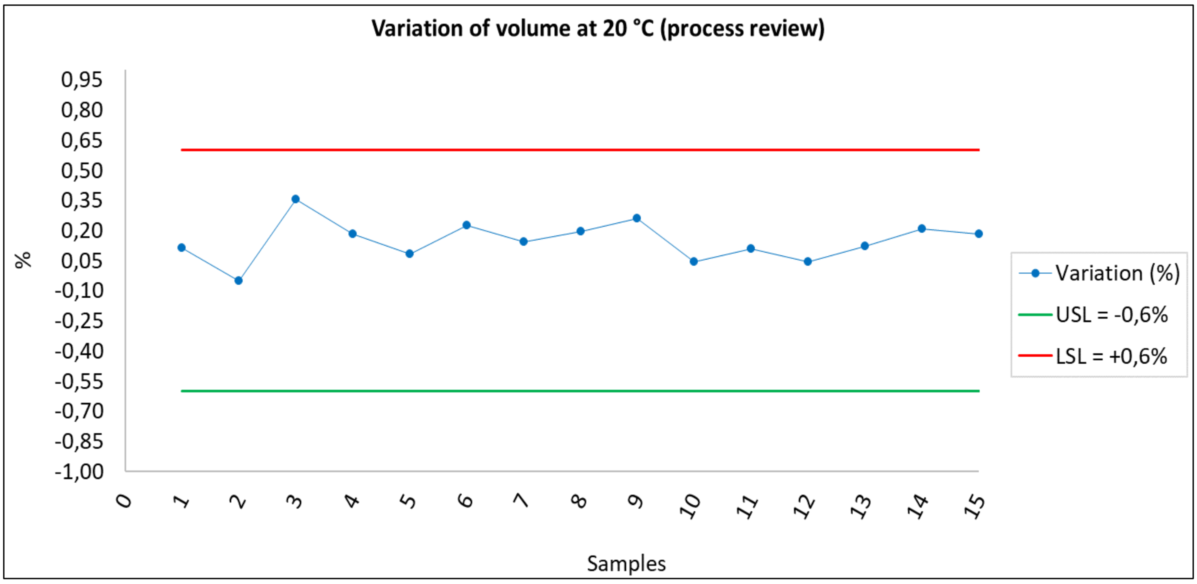

Figure 10: Graph of values and specification limits for Volume at 20 °C - process review.
Source: Authors, (2020).

Figure 11 shows the control chart of the individual values for the Volume parameter at 20 °C for the 15 lots. In both figures, it is observed that the process remains within the control limits, which were calculated for the process, which are -0,12 and +0,42% for LCL and UCL, respectively, with an average (ML) around + 0,15% for the control chart of individual values (x).

The specification limit and control limit values for the individual values, evaluating the volume parameter at 20 °C, were organized in a spreadsheet and are presented in Table 5.

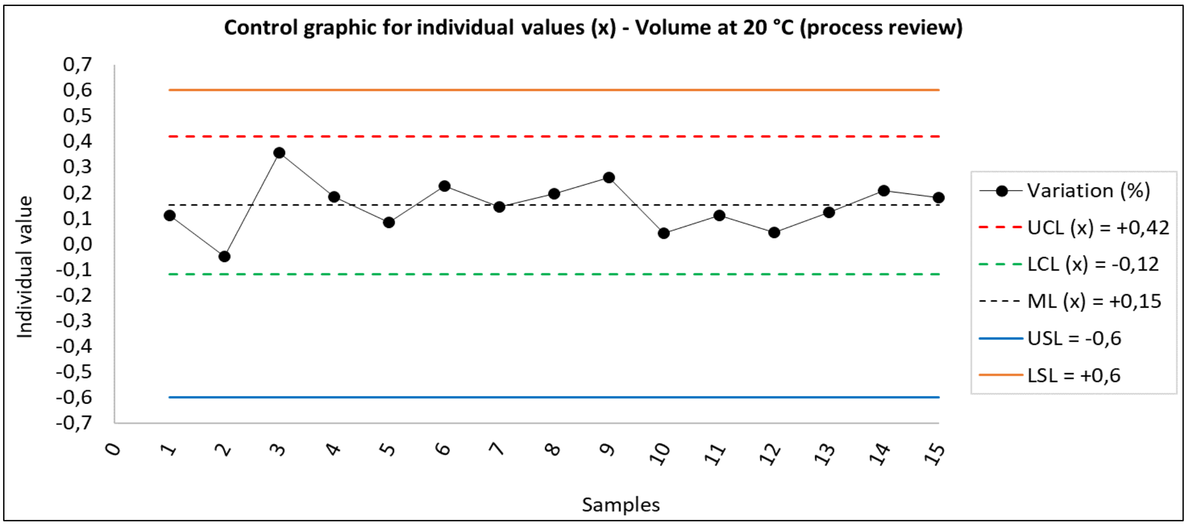

Figura 11: Control chart of individual values (x) - Volume at 20 °C - process review.
Source: Authors, (2020).

IV.4.3 Process Capability Assessment – Process Review

After proving the stability of the process, the process capacity index was calculated as described in table 6.

Table 6: Control limits and capacity study (process review).

Parameter	Ambient volume	Volume at 20 °C
Especification limits	-0,6 a + 0,6%	-0,6 a + 0,6%
Control limits (x)	-0,34 a + 0,52%	-0,2 a + 0,6%
Standard deviation	0,087	0,099
Cpi	2,412	2,505
Cps	2,196	1,515
Cpk = mín[Cpi,Cps]	**2,196**	**1,515**
Conclusion	Capable process	Capable process

Source: Authors, (2020).

For the Ambient Volume variable, the value of C_{pk} = 2,191, considering the standard deviation calculated for the 0,087. Having resulted $C_{pk} \geq 1{,}33$ the process is qualified as Capable.

For the variable Volume at 20 °C, the value of C_{pk} = 1,515, considering the standard deviation calculated for the 0,099. Having resulted $C_{pk} \geq 1{,}33$ the process is qualified as Capable.

V. CONCLUSIONS

In this work, Statistical Process Control (SPC) was used to demonstrate the performance of changes in the volume of gasoline A during the transfer process between tanks at a fuel distributor in the city of Manaus / AM and to establish a study for the use of this tool control.

An analysis of the graphs described in Figures 8, 9, 10 and 11 and Table 6, show that the process is capable of meeting all control specifications from a review of the process that was followed up in August and September of 2020. All the process control parameters studied, ambient volume and volume at 20 °C, remained within the control limits and as for the capacity indexes, it was concluded that the process produced high capacity indexes.

The SCP used here enabled the use of information accumulated in historical receipt data that had not been used for other purposes, allowing the knowledge of the levels of variation produced by the process, which can be a starting point for implementing a process of continuous improvement.

The use of SCP is also a systematic of continuous process validation, since it can be managed continuously. The use of SCP enabled the unveiling of unnoticed instabilities by simply comparing the targets to specifications and an opportunity to trigger continuous improvement actions.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Everaldo de Queiroz Lima and Fátima Geisa Mendes Teixeira.
Methodology: Everaldo de Queiroz Lima and Fátima Geisa Mendes Teixeira.
Investigation: Everaldo de Queiroz Lima.
Discussion of results: Everaldo de Queiroz Lima and Cecília Lenzi.
Writing – Original Draft: Everaldo de Queiroz Lima.
Writing – Review and Editing: Everaldo de Queiroz Lima and Cecília Lenzi.
Resources: Everaldo de Queiroz Lima.
Supervision: Cecília Lenzi and Maurício Moyses Machado.
Approval of the final text: Everaldo de Queiroz Lima and Cecília Lenzi.

VII. ACKNOWLEDGMENTS

MSc. Cecília Lenzi for guidance, to the Lutheran University Center of Manaus (CEULM-ULBRA) and Coordination of the Graduation in Chemical Engineering for the availability of the course, structure and management.

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