EVALUATION OF THE PROJECT BY THE ENGINE OF MAINTAINABILITY FOCUS: THE CASE OF FLUSH TOILET

Sacramento, Roberto César Fernandes, robsac135@yahoo.com.br
Silva, Alexandre Cavalcanti Pereira da, xandisba@hotmail.com
Escola Politécnica da Universidade Federal da Bahia, 02, Aristides Novis

Valente, Lucas De Souza Pinto, valente999@hotmail.com
Escola Politécnica da Universidade Federal da Bahia, 02, Aristides Novis

Neves, Helaine Pereira, laneneves4@hotmail.com
Escola Politécnica da Universidade Federal da Bahia, 02, Aristides Novis

Abstract. *This paper aims to study the concept of maintainability in preparation of projects and their consequences when they are not done efficiently. The study was prepared by using the search field and references. The subject studied was the device of the kind of Close coupled cistern type flushing toilet. This case study was chosen because of being a mechanical project that exists in almost all houses in the country, besides being a very important device for the population. In this paper, were investigated two different models of flush toilet trying to find possible failures of project and maintainability, comparing them at the end in order to seek the best solutions to the problems studied. With these defects in hand, two were selected according to criteria of frequency and criticality. These two defects were assessed qualitatively and quantitatively using a series of indicators that formed the basis for measuring the maintainability. Through this system it was observed that the discharge of DECA has superior maintainability to discharges of Celite.*

Keywords: *maintainability, mechanical project, flush toilet*

1.INTRODUCTION

The proposed work aims to study the designs of two systems of domestic-type basin discharges coupled with the objective to compare them as it relates to its maintainability. This type of basin was chosen because it is currently the most widely used by Brazilian population, mainly in construction of low income. The brands were selected to Deca, a national brand, and Incepa, a Spanish brand. The criterion of choice was based on the fact that these two brands dominate much of the market and have similar prices, so given the same social group.

The study of maintainability starts with the identification of the types of defects are more common and more critical. Thereafter it is intended to qualify and quantify the resources needed for its repair and also identify possible design flaws that can be considered as a source of problems.

This work can also understand the role of the engineer in finding the well being of society. Through research like this that the machines that serve the population is improved by improving the quality of life and decreasing the costs related to repairs made. These costs, if considered individually may seem negligible, but at national level, reach huge amounts, often of the order of millions of U.S. dollars.

1.1-Description of Equipment

The toilet is one of the most important equipment in a residence, it is responsible for transporting the waste to the sewerage network. Every house has at least one of these devices and, in most cases your users do not know how your operation.

The sanitary disposal system consists basically of two components: the watershed health and water-discharge device (DECA-2005).

1.1.1-Basin Health

The pond health is developed to allow the removal of liquid and solid wastes by transporting them to the main collection system, leaving the inner surface clean after the process of unloading (DECA-2005).

There are two types of operation of sanitary basins: the traditional system or with siphon and drag system, used in some models of watershed health (INCEPA/CELITE-2004).

1.1.2-HYDRAULICS OF DISCHARGE

The function of the flushing cistern is to store water to dump it quickly into the basin health when starting the process of unloading. This consists of various pieces of machinery which can be seen in the figure below. According to the manual Incepa / CELITE the box discharge consists of two groups of mechanisms: mechanisms of exit and water entry of water.

There are currently marketing three basic types of boxes of discharge: watershed health, and added dropdown box.

Table 1: Characterization of different types of flushing cistern

Tipo de Caixa de Descarga	Características
Watershed health with wastegate or conventional basin	This type of box sets of discharge as the main feature to obtain instantaneous flow necessary for cleaning the basin health, and the time of use is determined by the time the user activates the valve (Deca).
Basin sanitary coupled with box	This model presents as main characteristic, the coupling of the discharge box in the upper back of the pond health, simplifying its installation and maintenance. Compared to the previous model, being more exposed to external environment, is more broken components.
Basin sanitary suspended with box	This model presents a box suspended above the discharge toilet. The drive is conducted by a cord.

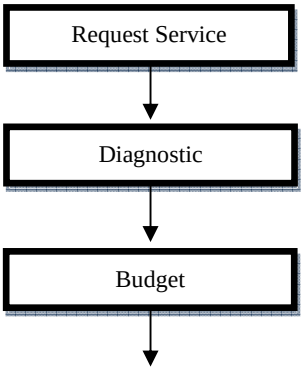
1.2.2-CHOOSE THE TYPE OF DISCHARGE HYDRAULICS

For this work was chosen to discharge the hydraulic device coupled with box, because this model is replacing the other, due to the advantages listed below:

- There is greater ease of access to their constituents, facilitating the maintenance of this model.
- There is a greater guarantee of saving water since this model the height of the water column is regulated and is independent of the pressure of the water at (Eco Producers);
- The potential for local installation are higher, it can install the toilet anywhere in the bathroom (Eco Producers);
- This system is quieter on the wastegate (Eco Producers);
- The cost of installation of this model is lower compared to the model with wastegate (Eco Producers);
- This model is more elegant when compared to the discharge suspended.

2. MAINTENANCE PROCESS

The maintenance of sanitary discharges, and the maintenance of the vast majority of machines (read corrective maintenance), the process can be modeled with a flow chart that includes: service request, diagnosis of the problem, budget, authorization of service, application of parts, disassembly, intervention, test, assembly and delivery.



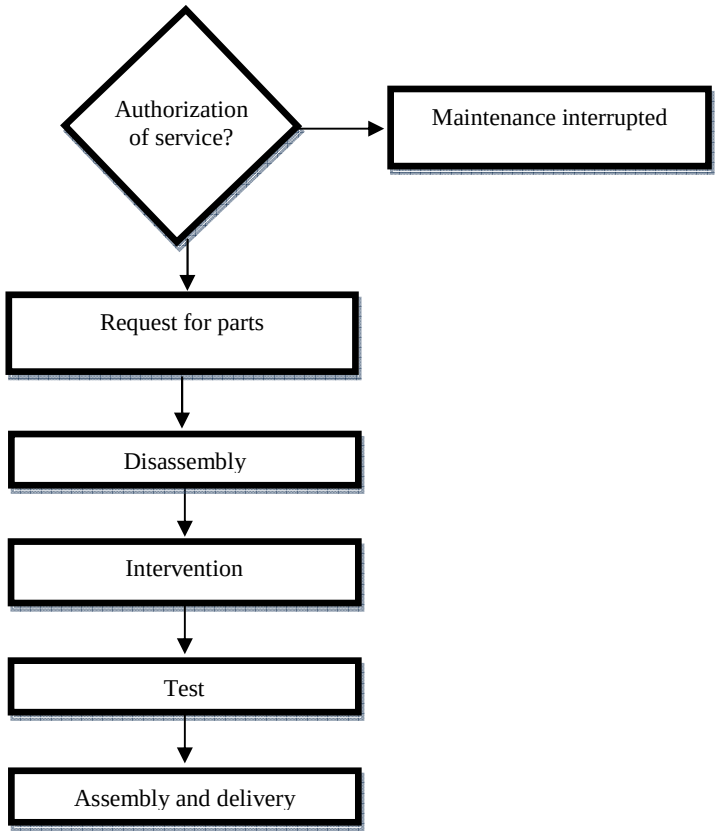


Figure 1: Flowchart of maintenance

2.1-TYPES OF DEFECTS

The maintenance of sanitary discharges in general is easy solution. The dismantling of the equipment is simple, requires few tools for the execution of work and the principle of operation is simple, so a professional without extensive training can perform the maintenance. Most problems associated with bathroom fittings coupled refers to problems of sealing the basin health. However, were analyzed in detail only the problems associated with the unloading of the box attached. The only problems related to watershed health, despite the high frequency, not part of the scope of this work.

The main failure modes of existing sanitary discharges are displayed in the table below. This table was prepared based on information from the manuals of the releases of catalogs of the manufacturers, in addition to the information collected with professionals in the area, especially plumbers and freelance professionals, technical assistance authorized.

Table 2: modes of failure

Mode of failure	Possible Cause	Possible Solution
Constant flow of water box to basin	Poor sealing of the valve	Shutter replacement
	Problem in the float (buoy)	Adjust or replace the float
	Float at the top level product extravasor	Your relationship the level of the float
	Broken latch element of the head	*Review installation and replace all of the entry tower*
	Wear rubber diaphragm	*Replacing the diaphragm*
	Current drive very stretched	Adjust the length of the current
Leaks between basin and cash	Screws for fixing poorly installed	Review installation
Insufficient amount water box	Lack of pressure	Review installation
Insufficient amount water box	Problem in the float (buoy)	Adjust or replace the float
	Tower of entry clogged	Clear entry

Slow filling of the box	Low pressure Registered partially closed	Review installation Releasing the record
Excessive noise	High pressure in the network	Review installation
Need to keep the button pressed to be operation	Current drive weak	Adjust the length of the current

Given the impossibility of analyzing in depth all existing defects, the two problems were selected for a more thorough examination. This choice was not random. The criterion for selecting the defects for analysis was the criticality, frequency and appropriateness of the proposed focus of this work. The problems chosen are directly related to the design and maintainability of the machinery, which in fact is referring to this work is proposed. According to Pareto's law "20% of the causes create 80% of the consequences," which confirms the choice of target group in their study to only two problems.

The problems chosen are located in the tower head of entry and are related to the same mode of failure: constant flow of water to the basin of the box.

(1) Wear the rubber diaphragm

Criticality	Frequency
Low	**High**

Figure 2: Overview of the external head

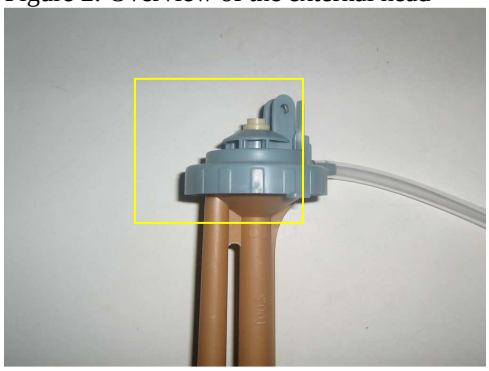


Figure 3: View inside the head: the diaphragm

The diaphragm is the element that controls the entry and exit of water in the housing coupled through the tower entrance. He is inside the head and is composed of a drive pin and a rubber. What happens is that due to the force that water rises through the tower of entry than the low purity of the water (highly chlorinated water and debris), the rubber diaphragm has a premature wear and function of control input / output of water is compromised. This is a common problem, but low criticality, since the repair is easy and cheap.

(1) Breaking of structural elements of the head lock

Criticality	Frequency
Low	**High**

Figure 4: Head open

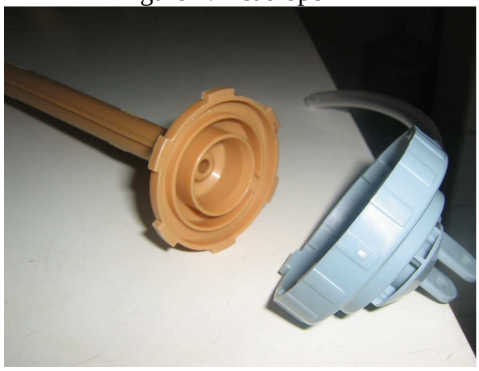
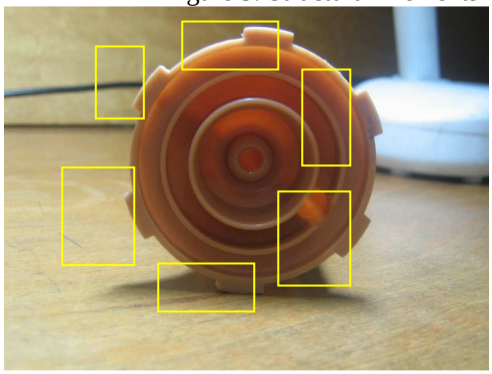


Figure 5: Structural Elements



The head is fixed to the tower of entry through the structural elements of lock. What happens is that because the force of water over years of use of the discharge, this element has broken, preventing the correct setting of the head in the entrance tower, which ends up compromising the input / output of water in the box attached. This is a problem of low frequency, but with high criticality. While the problem of wear of the rubber trade is only the diaphragm (keeping the tower of entry), this problem requires the exchange of the whole tower of entry (most expensive component of the discharge).

2.2-Time and Cost of Maintenance Steps

Although the maintenance of sanitary discharges is somewhat simplified, of course it demands time and cost for full implementation. Unlike other equipment in which the user brings his own equipment for technical assistance in the case of discharges that is completely unworkable. Indeed, the technical systems in health or the plumber does the maintenance on site, or the customer's home.

On reaching the place, the plumber makes a diagnosis and then the budget. If the customer does not give the approval for the intervention, the maintenance is discontinued, but is charged $ 20.00 for U.S. visit (cost of trip). If you give the approval for the intervention, the cost of access and payments and is to recover the cost of labor in the amount of $ 35.00. Regardless of the complexity of the problem, the value of the cost of labor is fixed. If there is a need for replacement of any component, will also be the cost of parts. Thus, the cost of maintenance is given from the following equation:

$$\mathbf{CMS = CL + COM}$$

Where:
CMS = Cost of maintenance service
CL = Cost of labor
CPM = Cost of spare parts and materials

In the table below, in addition to quantifying the cost of maintenance, there is also the time by stage of maintenance. It is emphasized that these values of time are the average values of estimated time informed by the professionals consulted during the search.

Table 3: Times and maintenance costs

	Wear the Rubber Diaphragm		**Broken Parts of the Head**	
Steps	*Time (min)*	*Percentage of time*	*Time (min)*	*Percentage of time*
Diagnosis	3	15,00%	3	8,11%
Budget	2	10,00%	2	5,41%
Disassembly	1	5,00%	1	2,70%
Intervention	10	50,00%	25	67,57%
Test	1	5,00%	3	8,11%
Assembly and Delivery	3	15,00%	3	8,11%
Total Time	**20**	**100%**	**37**	**100%**
Cost of labor	35		35	
Cost of spares	15		65	
Cost of maintenance (R$)	**50**		**100**	

In both problems the time of disassembly is only 5% of total time. That why, unlike other facilities where there are complex elements of sealing and fastening, discharge disassembly health boils down to close the record of water and lift the lid of the box attached.

Another aspect that can be observed is that there is a difference in the time step "test" for the two problems. The problem of wear of the rubber diaphragm, remain the tower entry and return only the diaphragm (hence why the cost of having a spare U.S. $ 15.00). Now the problem of broken parts of the head, the whole tower of entry should be replaced (hence why the cost of spare U.S. $ 65.00). The replacement of the entire tower, to be the most critical one, requires the making testing more time to evaluate, for example, if the flow and pressure of water at the entrance of the box are suitable for full operation of the discharge. The criticality of the intervention in the problem of broken pieces of head justifies the defendant more time to intervene in this problem than the problem of wear of the rubber.

3. ASSESSMENT MAINTAINABILITY

Two brands of sanitary discharges were compared: Deca X Celite. In fact the comparison of this work goes beyond the comparison of pure and exclusive brands. It is a comparison between a structure with attached float (Deca) and a structure to float (Celite).

3.1-Evaluation Criteria

In assessing the maintainability prioritize some of the secondary indicators applicable to the situation studied, since they all have some relationship to cost and time (primary indicators). For each indicator a weight was used, which represents the degree of importance of this indicator in relation to maintainability.

Table 4: Weighting of indicators

Indicator	Weighting
Accessibility	4
Knowledge of maintainer	1
Diagnostic Facility	1
Mean time between failure of parts	2

3.2-Search Field

The field research was conducted with the purpose to analyze in a comparative way the maintainability of the two brands studied. To achieve success in this analysis, was a qualitative survey followed by a quantitative survey.

Qualitative survey

Initially a survey was made of qualitative indicators, through research with two plumbers and a freelance technical assistance authorized representative of each brand. We administered a questionnaire in which the professionals should evaluate the marks for each indicator, as very good, good, fair or poor. Each of these concepts had a match in color.

Table 5: Representation of qualitative indicators

Concept	Representation
Very good	
Good	
Regular	
Low	

According to this approach, the final assessment of the problems was:

Table 6: Qualitative assessment of wear of the rubber diaphragm

Problem 1: Wear the rubber diaphragm		
Indicator	*Deca*	*Celite*
Accessibility		
Knowledge of maintainer		
Diagnostic Facility		
Mean time between failure of parts		

Table 7: Qualitative assessment of the loss of structural elements of the head

Problem 2: Shortage of structural components of the latch head		
Indicator	*Deca*	*Celite*
Accessibility		
Knowledge of maintainer		
Diagnostic Facility		

Mean time between failure of parts		

Quantitative evaluation

Although the qualitative representation have great importance in this analysis, we need a more tangible parameters to compare the two brands. For that, there was a correlation table for each numerical concept qualitatively. At this time, it emphasized that the notes are assigned on character. The fact that the note 10 is linked to the concept very well, does not show the perfection of a particular brand in that indicator. Note 10 shows that in the spectrum of existing brands, the brand has received notice that 10 has comparatively superior quality.

After the scores assigned to each indicator was an average, taking into account the balance that was allocated for each indicator. (Weighted Average)

Table 8: Equity qualitative / quantitative

Concept	Grade
Very good	8,5 – 10
Good	7 – 8,5
Regular	5 – 7
Low	0 – 4

According to this approach for the evaluation was problem 1:

Table 9: Quantitative assessment of wear of the rubber diaphragm

Problem 1: Wear the rubber diaphragm			
Indicator	*Weighting*	*Deca*	*Celite*
Accessibility	4	10	6
Knowledge of maintainer	1	8	8
Diagnostic Facility	1	8	10
Mean time between failure of parts	2	10	8
Nota global		**9,50**	**7,25**

For the problem 2, the evaluation was:

Table 10: Quantitative assessment of the loss of structural elements

Problem 2: Shortage of structural components of the latch head			
Indicator	*Weighting*	*Deca*	*Celite*
Accessibility	4	8	6
Knowledge of maintainer	1	8	8
Diagnostic Facility	1	8	10
Mean time between failure of parts	2	10	8
Nota global		**8,50**	**7,25**

3.3-Analysis of Data

The result of the analysis of problems shows that in general all the two have a good maintainability. Almost all indicators of the two brands were assessed as very good or good, except the indicator accessibility, which is a priority indicator in the maintenance and where there are substantial differences in the two brands. Despite this apparent equilibrium, the model of coupled discharge of Deca reasonably obtained a superior performance in the analysis of two problems.

3.3.1-Analysis of data for the problem of wear of the rubber diaphragm

Accessibility, as already mentioned, is a priority in the maintenance of sanitary discharges. The structure of the discharge of Deca is the float attached to the tower of entry, with the float rod and lifting of the buoy, which ultimately save reasonable space in the box attached, allowing greater mobility of the maintainer in the box. The fact of having a more compact structure is a determining factor for access to components of the discharge. While you have access to the

head, the mark must be Celite Unscrew the stem of the float in the fall, as these elements are already engaged is not necessary, facilitating the maintenance and requires less time for intervention. For this reason Deca was given to a note rather than the Celite.

Figure 6: Discharge DECA

Figure 7: Discharge CELITE

The knowledge of the maintainer is not a main factor in the differentiation of the maintainability of the marks. A maintainer of discharges experienced in maintaining traditional (Celite) with little effort be able to maintain in discharges of Deca. Although there is a slight difference in that indicator of brands to avoid discrepant results with reality, notes were taken identical for the two brands.

If on the one hand, the fact of the discharge of the coupled Deca helps accessibility, the other has depreciated its ease of diagnosis. The fact of the discharge Celite have their isolated components facilitates the visual identification of where the problem is. For this reason has been given notice over Celite.

The TMEF of parts is a factor that differentiates the brand. Celite while in the water enters the inbox, free, Deca in there at the beginning of the entrance tower of a flow reducer and a filter. The flow just enough to reduce the force that promotes the water on its components, reducing wear. The filter prevents some particles of impurity are taken by the water and come into contact with the components, reducing wear. Thus, even if made of similar materials, the average time between failures (TMEF) of parts of the Deca is greater than the Celite, or the durability of the parts is greater than the Deca Celite.

Figure 8: Filter entry in the region of the tower of Deca.

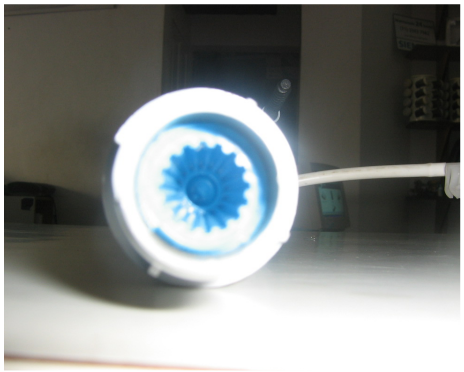


Figure 9: Region of entry into the tower of Celite.

3.3.1-Analysis of data for the problem of loss of structural components of the head

The problem 1 and problem 2 are closely linked. First because of being located at the head of the tower entrance. Second because they are problems related to the same question: Force of water and wear due to the low purity of the water (chlorine + waste). Thus, almost all indicators had the same assessment for both the problem 1 as to the problem 2, except accessibility.

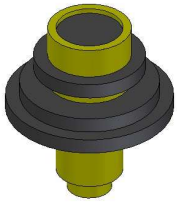
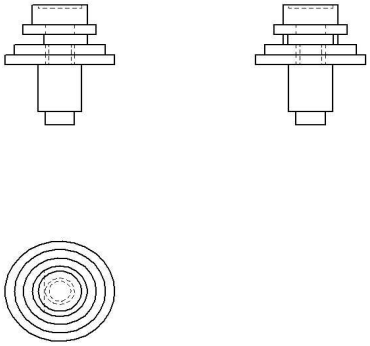
Accessibility, as already mentioned is a primary indicator in the evaluation of maintainability. What happens is that while the problem 1, only part of the tower of entry needed to be changed (head of the diaphragm), and to carry out this intervention there differences in the accessibility (one needed Unscrew the stem of the float, the other not) to problem 2, both for Deca Celite as for the whole tower of entry should be changed. Despite the accessibility of Deca be greater, as this issue, regardless of brand, the whole tower of entry should be changed, the comparative advantage of Deca front of Celite decreases, but still was given a note slightly higher than Deca.

4. PROPOSAL FOR IMPROVEMENT

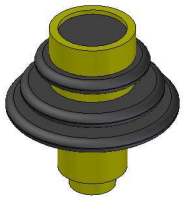
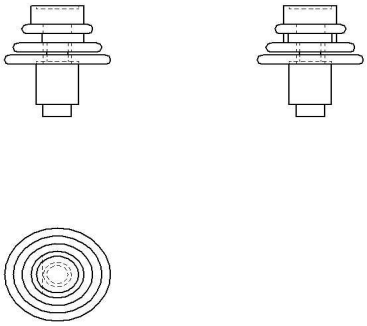
The diaphragm is located at the top of the tower of entry, especially in the head. He is the element that controls the entry and exit of water in the box attached. The wear of the rubber diaphragm, and was reviewed previously is due to the force that promotes water on the diaphragm, in addition to the low quality of water that is chlorinated and has too many debris, which eventually causing premature wear of the rubber.

The morphology of the rubber in this application has great influence on the premature wear. Cantos promote live known as the effect of stress concentration, which ultimately nuclear and cracks propagate, leading to wear / fracture (William Callisto, 2001). Therefore, this problem can be alleviated by changing the geometry of the rubber to replace the songs live for curved corners. Thus, resistance to fracture / wear would be greater, which extend the useful life of rubber.

Current: Diaphragm with straight edges

Figure 10: Perspective of diaphragm with live songs	Figure 11: orthographic view of the diaphragm with live songs
	

Suggestion for improvement: Diaphragm with curved corners

Figure 12: Perspective of the diaphragm with curved corners	Figure 13: orthographic view of the diaphragm with curved corners
	

5. BRAZIL COST

Failures of equipment when they are critical, need of immediate repair, because the products are unable to carry out their duties properly. The cost of intervention in society entails a social cost that depends directly on the frequency of occurrence and the cost specific repair.

According to the IBGE, Brazil has a population of approximately 182 million people. Each family is composed on average by 3.2 people (IBGE). Thus, in Brazil there are about 50 million households. Data show that 78% population has sanitation service for waste (IBGE), or 39 million households have this feature. According to the manufacturers of Deca and Celite discharges, discharges of sanitary type coupled representing about 40% of discharges installed, totaling 15.6 million discharges of the type attached.

The breach or failure of the elements of the head is usually once every six years and should be replaced immediately because it is a defect of high criticality, this leads to the repair of 2.6 million pieces per year. Your repair cost between forty dollars (play in a cheaper and the service performed by the owner of the discharge) and one hundred dollars (in the most expensive piece, sixty dollars, and service performed by specialized technical assistance, forty reais). Used to calculate the average of seventy dollars, can then say that the annual cost of repair in Brazil is about 182 million reais.

The defect of the diaphragm occurs on average once every two years, totaling 7.8 million annual repairs. The repair costs between fifteen real (part cheaper labor, and the actual owner of the discharge) and fifty-five dollars (most expensive piece and labor-specialized). Use the average of thirty real. The total annual cost is 234 million reais.

The two defects in Brazil cost about 400 million reais a year. This social cost is not much studied in the country, because people are concerned only in the individual values of each repair, without having an idea of the amount spent by the whole society with these problems. However, with small changes in design, they may reasonably fall, thus providing an economy in which money could be reinvested in other key issues for society such as health and education.

6. CONCLUSION

At the end of this study it is clear that both the Deca on Celite has good maintainability, with advantage for Deca. However we must strengthen the inherent limitations to this study. In this work, the project was evaluated under the focus of the machinery of maintainability. Therefore, it is considered wrong, hasty and superficial a conclusion on the functionality, operability and constructed of discharges, since these were not the focus of this work.

It is suggested as a possible approach to maintainability in industrial equipment. Thus, in addition to providing the development of work skills discussed previously, it will allow a view of maintainability in an industrial situation, which is of fundamental importance for the mechanical engineer.

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