VI CONGRESSO NACIONAL DE ENGENHARIA MECÂNICA
VI NATIONAL CONGRESS OF MECHANICAL ENGINEERING
18 a 21 de agosto de 2010 – Campina Grande – Paraíba - Brasil
August 18 – 21, 2010 – Campina Grande – Paraíba – Brazil

FAILURE COSTS IN THE DEVELOPMENT OF ELASTOMERIC COUPLINGS

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Abstract. *This paper's objective is to demonstrate that any activity not carried through in a correct way causes non conforming products. And these cause costs to the company that are called failure costs. It is directed to businessmen and professionals involved with the design and development of new products and purports to show the importance of adopting procedures that accordingly will make use of Quality tools for the development of products, aiming at a larger probability of success and consequently the reduction of Quality Costs and especially the increase of clients' satisfaction. The Operational Costs are the addition of failure costs and conformity costs. These costs end up being incorporated to the products' costs, otherwise companies would not be able to absorb such costs. It is required good management and good classification of such Quality Costs, followed by a reliable collection of data and procedures that use quality tools adjusted to the organization profile and acting in the failure causes, in order to obtain the desired costs' reduction. This paper reports the launching of a product without an adjusted planning, and consequently a considerable increase in the internal costs and mainly external costs. In spite of setbacks, however, the Company proceeded fast and efficiently, reducing such flaws and solving problems in a satisfactory way to the clients.*

Key words: coupling, elastomeric, failure costs, conformity costs, quality costs.

1. INTRODUCTION

Quality costs are those costs related to non-quality or costs related to the prevention of non-quality products. According to Caminada Netto (2004), the costs of quality are generally classified as shown in Figure 1.

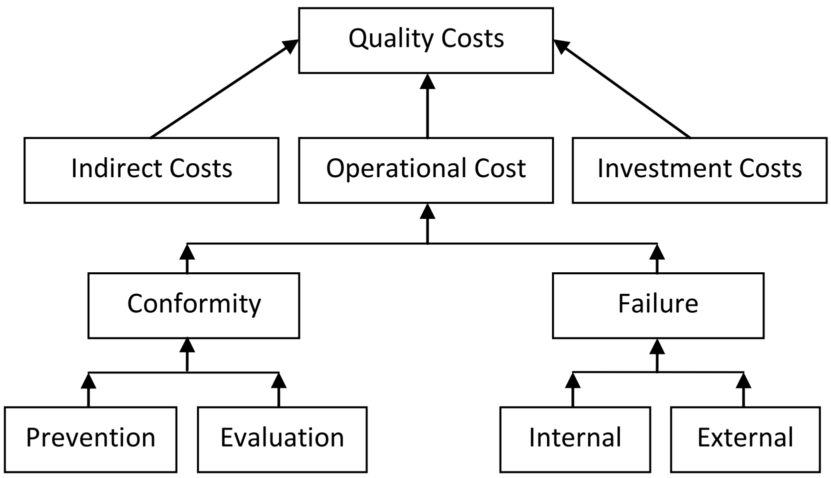

Figure 1. Classification of Quality Costs

It can be said that the costs of quality are of utmost importance for the survival of organizations. Therefore, their evaluation should be carried out because:

• They are high and in some organizations may reach a considerable percentage of sales. In addition, their analysis can confirm some of the areas that have problems and reveal other areas with problems that are not yet known.

• It helps to identify key opportunities for reducing quality costs throughout all activities in an organization.

• It helps to identify opportunities to reduce customer dissatisfaction and threats associated with sales revenues. Some costs of non-quality are the result of customer dissatisfaction with the products. This discontent leads to a loss of current customers and an inability to attract new customers. Awareness of discontent within the organization helps improving the retention of current customers and the capture of new customers.

• It provides a means of measuring the outcome of quality improvement activities.

According to Juran (1991), until the 50's organizations did not use to specifically monitor quality costs because they were usually included as overheads. During the 50's, with the emergence of new quality professionals, these began to study and use the subject to sell their professional services. In some organizations these costs could range from 10 to 30% of sales.

Still on the costs of quality, it can be said that they can help troubleshooting failures that result in immeasurable costs represented by a dissatisfied customer. To reduce customer dissatisfaction, we must accept complaints, provide feedback on all of them, and whenever possible resolve them without delay.

According to Scriabrina and Fomichov (2006) it is very important to treat customer complaints since:

• Only 4% of dissatisfied customers complain;
• 96% move over to competitors;
• 90% of customers who move to competitors never return;
• A dissatisfied customer usually divides his negative experience with ten people;
• The costs to develop a new customer are typically 5 times higher than to keep an old customer;

Only operational costs, i.e. Prevention, Evaluation and Failure (Internal and External), will be considered in the discussion that ensues, since Indirect and Investment quality costs were not relevant as far as the new product was concerned.

2. PRODUCT

At present, the need to preserve the environment is forcing organizations to develop more advanced technologies that lead to "greener" products. The new product developed by the organization which is considered in this case study is a model of coupling that uses so-called elastic elements, also known as elastomers. This means a plastic component responsible for the transmission of power that does not require lubricants, and therefore no verification, conferring a greater ecological appeal to the product.

Since some competitors already had products with this feature, it was necessary to accelerate product development for the organization to maintain its position in the market. In addition, the developed product should have performance characteristics and a superior quality when compared to those of competitors.

Couplings are devices that transmit power from a prime mover to a driven machine, absorbing some misalignments which may occur during assembly, as shown in Figure 2. Thus, their insertion means that the life span of the equipment will be affected as little as possible. Besides, their use also makes it easier to install and maintain such equipments.

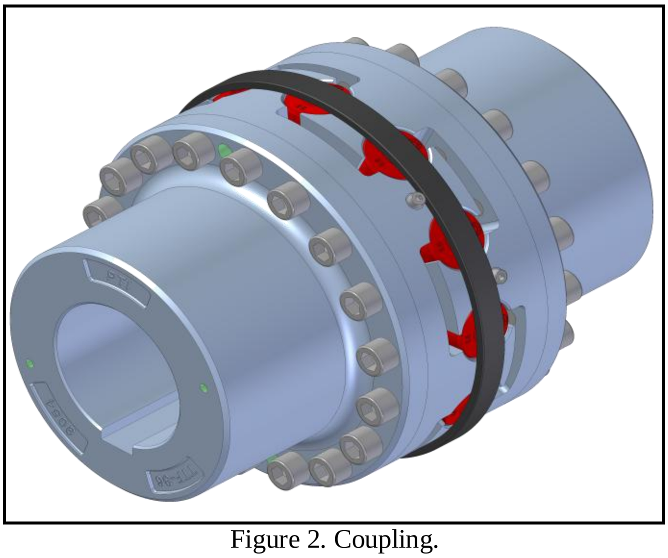

Figure 2. Coupling.

Couplings are extensively used whenever power is transmitted through electric motors, as shown in Figure 3, and are divided into two groups:

• Type 1 - lubricated couplings that use oil or grease.

• Type 2 - non-lubricated couplings that do not use any lubricants.

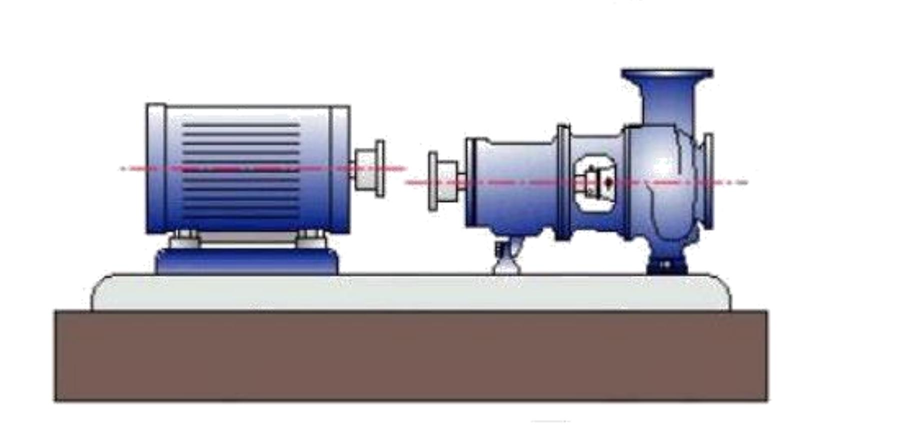

Figure 3. Power transmission through electric motor and coupling.

As can be seen in Figure 2, the couplings discussed in this case study are type 2 (non-lubricated) couplings from the "Ecological Movement" line, which are characterized by the transfer of torque and motion through elastomeric elements distributed throughout their circumference, and are described in Table 1.

Model	Diameter	Power max. (Nm)	Rotation max. (Rpm)	Weight
1	220	8.800	3.500	35
2	250	12.800	3.000	50
3	280	17.800	2.700	70
4	320	25.900	2.400	100
5	360	37.200	2.100	140
6	400	55.700	1.900	200
7	450	77.700	1.700	255
8	500	110.800	1.500	335
9	560	151.900	1.350	480
10	630	197.300	1.200	665
11	710	304.700	1.000	980
12	800	42.400	950	1.350
13	900	589.500	850	1.950

Table 1. Product Line

3. RECORDS OF THE NATURE OF NONCONFORMITIES

The Company has developed an ad hoc software for recording nonconformities by production batch, and containing nonconformity description, causes identification and disposition measures. Through this corporate system it is also possible to compute the costs of raw materials and of machine time employed for the production of nonconforming parts. At the end of each month, with the closing of the accounting report, the figures for the cost of each nonconformity are registered and divided into labor and raw materials costs.

The costs reported by the accounting sector and recorded in the NCR system refer accurately to parts that were scrapped, and present an estimate based on the number of hours employed for parts that were reworked. The values are removed from the system whenever external rework is required.

The manipulation of such recorded data allows the generation of graphs for analysis, taking into consideration the costs caused by failures, and therefore the determination of priorities for actions to be taken and investments to be made in order to reduce those costs.

4. CASE STUDY / IDENTIFYING THE CAUSES / ACTIONS TAKEN

4.1 Nonconformities

After the release of the new product numerous nonconformities were detected. Their variety, however, wasn't not very wide, basically restricted to pores and broken elastic elements restraining rings.

Confronted with such an adverse situation, the organization took immediately two steps: acted in the foundry of the raw material supplier for the cubes, and introduced changes in the ring containment design. Thus, a new solution was developed in a joint effort with the vendor: the steel core ring, that is discussed in more detail in this work.

4.2 Porosity

This type of failure, which consists of pores in the inner region of the raw material, and which not always becomes apparent in machining, was the first to be detected after the release of the product. Figure 4 clearly illustrates porosity detected when drilling a hole.

Figure 4. Internal porosity

4.3 Broken rings

This failure occurs with the rupture of the retaining ring. As a consequence, the elastic elements are released from their housings and prevent the equipment from continuing to operate.

Since his type of failure can only occur in service conditions, it was invariably detected by clients while operating their machines and equipment. This fact caused serious damage to the company's image, and therefore demanded an immediate action of contention. Besides, it generated additional costs, such as those involved with the displacement of technical personnel and transmission components for replacement. Figure 5 shows a device that had a failure on the containment, resulting in the release of elastic elements.

Figure 5. Release of an elastomeric element in service.

4.4 Investigation of causes

In order to determine the causes an investigation was carried out using the "5Ws and 1H" tool, and an Ishikawa or fishbone diagram. These quality tools were applied as follows:

1. The probable causing factors were investigated by the 5Ws (What, Who, When, Where, and Why) and 1H (How) until the definition of the root cause was attained. Responses were recorded in individual NCRs basically containing, in addition to flawed product data, nonconformity definitions, responsible persons, causes and disposition measures.

2. For best viewing and control of decisions an Ishikawa diagram was used, such as the one shown in Figure 6, which allows greater accuracy when defining actions to be taken.

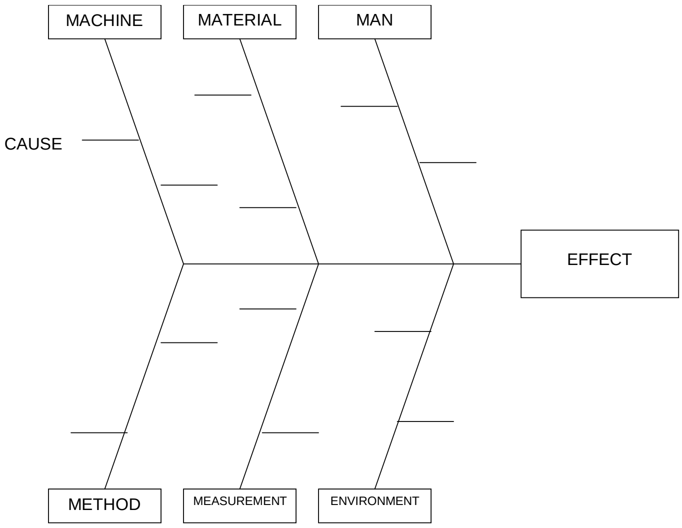

Figure 6. Ishikawa or fishbone diagram.

With the application of the above mentioned tools, it was possible to determine the following "root" causes for the observed nonconformities:

• Failure in the supplier's casting process, and inadequate location of the liquid metal supply, which does not guarantee the required quality;

• Failure in the engineering selection of the right material for use in the manufacture of the retaining rings, since the plastic ring was not strong enough to withstand the centrifugal force in the cylindrical elastomeric elements.

As a result of the preceding verification, the following emergency actions were taken:

• Submit 100% of the stocked cast iron raw materials to ultrasonic testing;

• Provide customers with an immediate solution for the flaws encountered in the field involving the rupture of the containment ring. Accordingly a new steel containing ring was designed as a split ring, see Figure 7. This unique solution was adopted exclusively to address these shortcomings, since it was produced at very high costs. The split ring format made it easier to immediately solve the clients' problems in place, without the need for axle removal. Therefore, it caused minor inconvenience to customers, and being made of steel resulted in a more robust equipment.

Figure 7. Split steel ring.

4.5 Corrective actions

The following corrective measures were taken afterwards:

• The supplier of the cast iron raw material was requested to improve the process and to submit 100% of parts to ultrasound tests, in order to prevent defects detected during machining or by customers. Process improvement was surveyed by staff members of our Process Engineering sector who required some changes and corrected models developed for casting.

• To perform research studies in collaboration with the supplier, in order to find a cheaper solution for the flaws detected in the containing rings, as regards the raw material used to manufacture them.

5. COSTS AND RESULTS OBTAINED

Guarantee costs referring to failures in couplings are shown in Figures 8 to 10, according to the year when costs were incurred. Sales (*Vendas*), Guarantees in Brazilian currency, Reais (*Garantias-R$*), and % Sales (*%Vendas*) are shown for each month from January to December. Aggregate values (*Acumulado*) are also shown.

GUARANTEES 2006

	Janeiro	Fevereiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Outubro	Novembro	Dezembro	Acumulado
Vendas	0	0	321.124	112.878	149.733	43.986	90.321	89.349	11.568	78.143	68.852	97.728	1.063.683
Garantias - R$	0	0	0	0	0	0	0	739	0	2.275	0	1.866	4.880
% Vendas	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,83%	0,00%	2,91%	0,00%	1,91%	0,46%

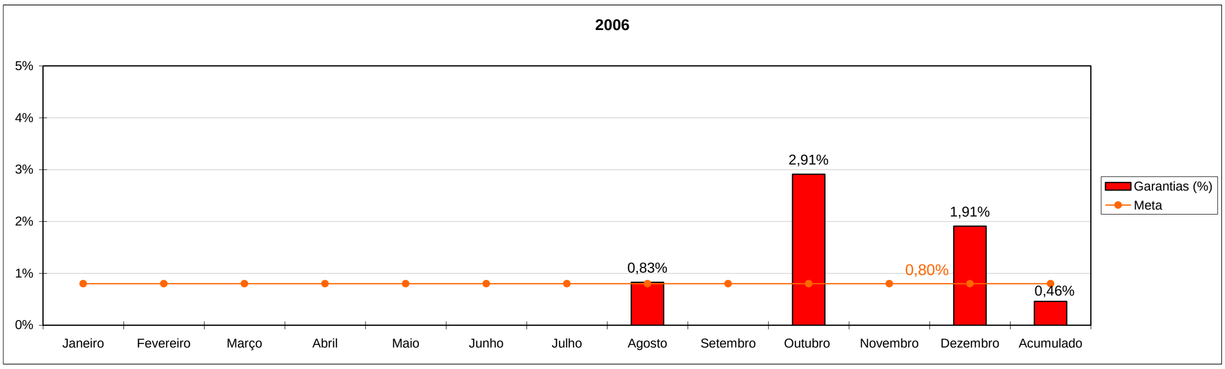

Figure 8. Guarantee costs for 2006

With respect to internally detected faults such as porosity, it is estimated that if the company had not invested and required investments from the supplier under evaluation, monthly losses could have amounted to something in the region of R$15,000. This estimate includes costs with machining of parts up to the detection of porosity, issuance of documents for the return of defective raw materials, and delays with respect to terms agreed with our customers.

Analyzing the guarantee amounts for 2006 (Figure 8), it is possible to see that after five months of the new product release start appearing the first cases of failures. However, the aggregate result over the months does not compromise the goal of 0.8% since the annual aggregate was 0.46%. The organization took no action at that time because it did not consider the flaws to be critical and had no idea of what lay ahead.

The year 2007 (Figure 9) in its first two months, exceeded in value the entire year of 2006, which forced the organization to rethink guarantee values and perform stronger action involving all sectors responsible for launching the product. It may be noted in the chart that in August there was a peak that refers to a "recall" held by the organization of all products that could be flawed.

GUARANTEES 2007

	Janeiro	Fevereiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Outubro	Novembro	Dezembro	Acumulado
Vendas	121.404	419.877	295.237	66.717	251.576	476.415	146.462	320.857	41.823	229.805	192.797	44.337	2.607.307
Garantias - R$	0	1.917	4.682	4.049	18.012	20.459	3.542	224.694	0	552	0	0	277.906
% Vendas	0,00%	0,46%	1,59%	6,07%	7,16%	4,29%	2,42%	70,03%	0,00%	0,24%	0,00%	0,00%	10,66%

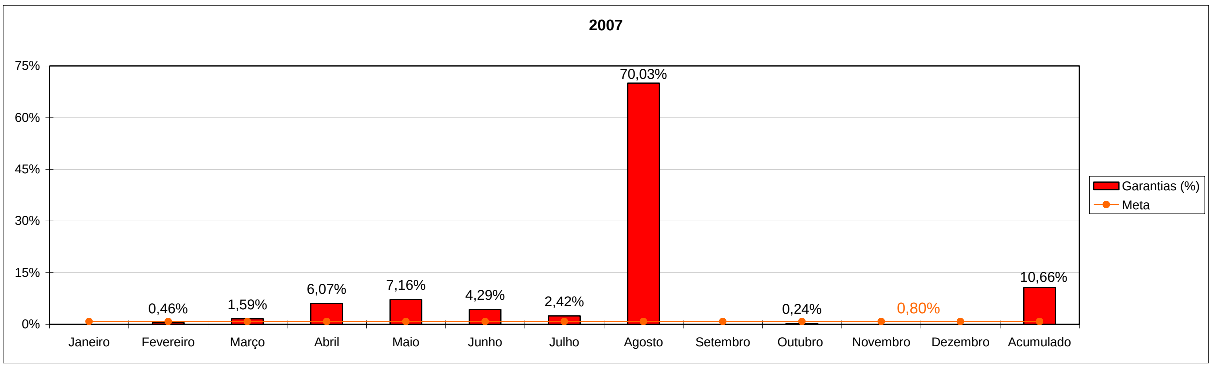

Figure 9. Guarantee costs for 2007

The year 2008 (figure 10) clearly shows what happened after the execution of corrective actions, i.e., showed that certain actions by the organization were so effective as to reduce the accumulated cost of failure from 10.66% in 2007 to 0.11 % in 2008.

GUARANTEES 2008

	Janeiro	Fevereiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Outubro	Novembro	Dezembro	Acumulado
Vendas	103.486	109.419	196.485	54.664	154.158	356.245	153.435	155.924	98.054	187.459	127.052	65.487	1.761.867
Garantias - R$	0	0	0	0	270	0	1.242	414	0	0	0	0	1.926
% Vendas	0,00%	0,00%	0,00%	0,00%	0,18%	0,00%	0,81%	0,27%	0,00%	0,00%	0,00%	0,00%	0,11%

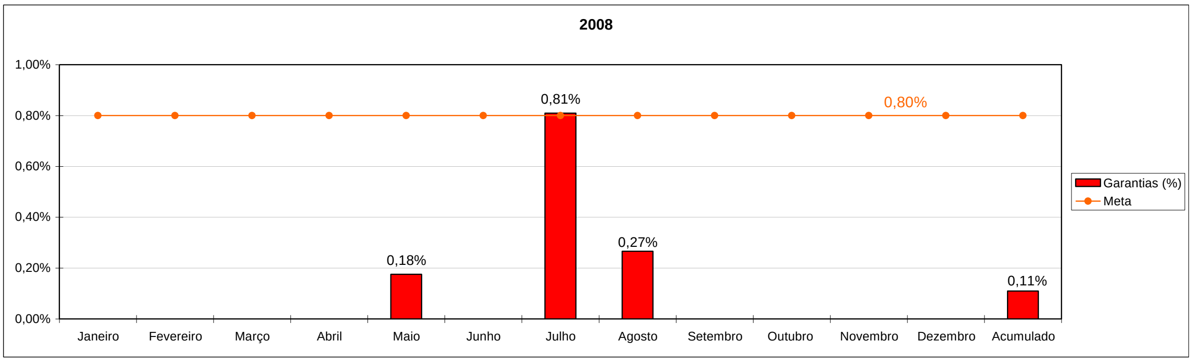

Figure 10. Guarantee costs for 2008

Considering the previously mentioned charts, one reaches the conclusion that the actions taken by the organization were very effective, because the proportion of failure costs from 2007 to 2008 was reduced around a 100 times. This fact reinforces the importance of properly using quality tools, particularly activities aimed at monitoring the costs of quality in order to determine when and how to make investments in quality.

The comparison shown in Table 2 gives a good idea of what happened in this case study. One can see that good design would cost about R$ 40,000.00 more and would need an extra month of development. It would also require a higher cost of inspection, around R$ 3,200.00. On the other hand, the values that would be saved in production and guarantee costs would be in excess of R$ 200,000.00, that is, higher than the average monthly value of product sales. Given this, it could be said that even with a slower speed-to-market the organization would have profited. In addition, it would not have run the risks involved with the launching of the product, which could have seriously damaged the company's image. As previously seen, this was only avoided by means of very costly emergency actions.

	Ill planned design	Well planned design	Balance
Engineering professionals	54,000	81,000	
Quality professionals	9,000	13,500	
Ultra-sound tests	10,000	10,000	
Cycle tests	18,000	18,000	
Visits to suppliers	9,000	17,500	
Design	100,000	140,000	40,000
Re-machining of rejected parts (machine-hour)	5,000	500	
Production	5,000	500	- 4,500
Inspection	4,000	7,200	3,200
Guarantee	277,906	78,219	199,687
		Total:	160,987

Table 2. Comparison of Quality Costs (R$).

As a result of this experience, the company decided to adopt more permanent measures to avoid similar problems in the future, and created a section called D & D (Design and Development). This new sector has immediately added significant value by participating in the intensive development of improvements applied to the supplier's casting processes. As for the containing rings, the company has developed a joint work with the vendor that resulted in a market differential, the plastic lined steel ring shown in Figure 11.

Figure 11. Plastic lined steel ring.

6. CONCLUSIONS

It can be concluded from the case study that the costs of evaluation and prevention, if well applied, generate numerous benefits for the organization. In the one hand, because as a result of actions taken the organization profited from the reduction of guarantees and production losses, an amount that represented a much higher value than the expenses incurred with professional work and resources employed to reduce failures. On the other hand, if one compares the costs that might have been incurred if the organization had carried out a better planning for the launching of the product, it can be perceived that such costs would have been much smaller, and without putting in jeopardy the reputation of a new product in the market arena.

Finally, another conclusion reached with the case study is that a product needs to go through all the necessary stages of development, preferably by making use of the adequate quality tools, instead of being unconditionally released in a misguided quest for speed-to-market. It should always be remembered that nothing costs more than a dissatisfied customer.

One suggestion for future studies is the use of quality tools for the successful launch of products, so that organizations may learn to differentiate urgency from hurry.

7. ACKNOWLEDGEMENTS

The authors wish to thank all those who helped carrying out this work through motivation and collaboration.

8. REFERENCES

CAMINADA NETTO, A., 2004 Custos da Qualidade. São Paulo: Programa de Educação Continuada em Engenharia da Escola Politécnica – PECE,. 34p. Apostila de EQ-019 Técnicas Avançadas para a Qualidade Total.

JURAN, J. M., 1991, Controle da Qualidade Handbook: Conceitos, Políticas e Filosofia da Qualidade. Ed 4. São Paulo: McGraw-Hill, 377 p. v.1. Série Manual da Qualidade.

SCRIABINA, N and FOMICHOV, S., 2006. Seis maneiras de se beneficiar com as reclamações dos clientes (Six wys to benefit from clients' complaints). Banas Qualidade, São Paulo, ISSN 1676-7845, Nº 167, Abril de 2006.

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