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APPLICATION OF NEW TECHNOLOGIES FOR IMPROVEMENT OF THE SYSTEM OF INDUSTRIAL MAINTENANCE

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Summary. *We live in a time that the social, politics and financial changes happen in a frightening speed, demanding from the professionals, an accelerated search of larger knowledge to overcome constant obstacles, guaranteeing the companies survival. Not scaping from this tendency, they are the professionals of the industrial maintenance. In the last 30 years, the maintenance area suffered a big number of managerial information, it modified the vision of another companies sections. Formerly, it was considered as black art, because, historically, the maintenance was always associated the cleaning of the "existent dirt". Today, the professionals are aware, that this activity acts directly in the quality of the final product. Before its importance to industries, this work developed in way to present new technologies to improve the system of industrial maintenance. For so much, it was used, techniques as: managerial indexes, criticals equipments, Total Productive Maintenance, Reliability Centered in Maintenance, Failure Modes and Effects of Analysis, cycle PDCA of problems solutions, taking place a x-ray of the critical productive area, of a chemical industry in the Campinas region, proposing, solutions for the problems found with larger goal of evidencing the dynamics of those techniques for the system of industrial maintenance.*

Keywords: *Maintenance, Improvement, Reliability, Weibull*

1. INTRODUCTION

In any other time of the century XX, according to KRONER apud TAVARES (1996), the competition among national and international markets arrived at levels as extreme as at the present time. The world industrialization is living a new phase, the phase of the competitiveness and productivity, where new philosophies, concepts and tools are differentiating the companies and assuring its permanence in the market. Being made a brief one historical of this century, there aren’t more doubts about the necessity of continuous changes in search of a portion of the world market due to the industrial competitiveness.

TAVARES (1996) affirms that, from the postwar, the characteristics of the economic activities tried alterations that imposed different development rhythms, until the current period in that, with determination, the industrial competitiveness left of being defined by the scale gain and of the seriate production, typify for the model “Ford”, becoming decided in the fields of the quality and of the productivity.

Being like this, the professional modernization became a prerogative for everybody in all the areas of the modern organizations. NAGAO (1998) affirms that those that are attentive for the great technologicals evolutions will make the difference between the mediocre professional and the ahead professional.

Not fleeing to that tendency, it is the function maintenance. In the last 15 years it developed a lot and stopped being an activity any to become more and more an authentic science face the sophistication of machines, equipments and facilities involved by systems with complexity degree and demands of growing qualities, in agreement with MARTINA (1998) & KRONER apud TAVARES (1997).

According to VERRI (1995) the maintenance left of a black art to be considered and started to have an important mission: “to guarantee the maximum operational continuity of the equipments and systems at the smallest cost, with safety, respecting the environment, inside of a harmony climate among the involved people”, (CAMARGO, 1998). Even so, the diversification of equipments and the maintenance problems, its causes and effects take to maintain, in a lot of companies, several categories of professionals involved in the maintenance function, a lot of times of way uncordinate, without planning and without a satisfactory use of the available resources. Being like this, it is necessary that the people involved with the maintenance of equipments, try to reach excellence patterns and quality of its products and services, as well as to obtain a high level of readiness of the equipments, a maximum useful life of the components and systems and a larger operational reliability and carry out of its facilities, (AMORIM; 1996).

This comes from encounter to the that TAVARES says (1996): “The reliability demands and readiness of the modern world, face the globalization, is of such order that demand from the maintenance managers and operation responsibilities that can only be accomplished with appropriate processes of administration”. As consequence, the companies look for systems and methods to aid those managers in its functions, because should be prepared to assimilate the innovative incentives of a new culture of spread maintenance in the companies of world class of the industrialized countries, in that the terms reliability and readiness are mentioned and demanded with larger frequency, generally in relation to the results of modern maintenance programs (STULGYS; 1996).

2. MANAGEMENT OF MAINTENANCE SYSTEM

During the last years, the high administration centralized its attention mainly in quality of products and services, assuming that way the costs were under control. The intransigent search of competitive advantages took to the conclusion that the cost of the maintenance is not under control, and it is an important factor in the increment of the global acting of the equipments. Now, it is observed that the companies that look for the success have been adopting a modern vision of management of opportunities, usually supported for: systematized routines, electronic processing of maintenace datas, tools and mensuration devices and competent consultants.

In agreement with SIQUEIRA (1996) in the scenery of the brazilian industry the importance of the maintenance section for the companies is evident, because it affects its objectives in productivity, quality and competitiveness. Being like this, the continuous improvement of the maintenance practices and the reduction of its costs are resulted of the incessant search of the application of the cycle of the total quality in all the levels of the organizations. In a lot of companies, national and multinational, significant improvements in the maintenance costs and readiness of the equipments, they were reached through: Failure Modes and Effects of Analysis, Reliability Centered in Maintenance, Cycle PDCA of problems solutions, Total Productive Maintenance (TPM), continuous improvement of the equipment, education and training of the involved in the maintenance activity, planning of the maintenance, with focus in the strategy of specific maintenance for equipment type.

The management concept inside of the maintenance engineering it involves the study, the analysis and the diagnosis of the causes of failures, besides an attitude proative, in that looks for to ally preventive attitudes with the efforts to improve of the correction costs. Inside of the current and future context of the management area of the maintenance the information systems are essential agents in the process of changes of the paradigms of the maintenance area, because they should be capable to collect, to process and to analyze great volume of data and to provide the rationalized use of the existent resources.

3. STUDY OF CASE

The results here presented are fruits of the efforts accomplished to implant mangement technologies to establish a process of continuous improvement in the activities accomplished by the maintenance department of a chemical industry of the Campinas region. The initial stage of the project consisted of the diagnosis of the present equipments of the interest area, classification of the same ones, calculation and evaluation of the maintenance indexes, election, by means of group techniques, the most critical equipment and applying statistical models for determination of the reliability, maintenability and useful life of this, turning possible the taking of managerial decisions for solution of lifted up problems.

3.1. Determination of the critical equipments using approaches of Total Productive Maintenance

For a distribution of the efforts and available resources in the department of maintenance of a company in the sense of bringing managerial improvements to the system, it is indispensable to classify the installed equipments of a productive area in function of its degree of importance, work regime and danger index in three different categories, according to MONCHY (1987):

Equipment A: critical equipments of high responsibility, with high dependence in the productive process (not existing stand-by alternatives), with considerable losses of raw and packing materials when it happens paralyze a production area totally.

Equipment B: equipments that don't possess absolute dependence in the productive process (alternative stand-by exists), eventual it is broken it doesn't translate in considerable losses of production paralyzing the productive area partially.

Equipment C: equipments that don't possess dependence in the production, there are not risks to the quality of the product, the risk of accidents is minimum in all the levels and the costs to recuperate the normality condition they are not very representative.

With this classification is possible to dose in an appropriate way in function of the technical and economic characteristics the several maintenance types, and to adopt a maintenance system that light in bill the critical equipments in agreement with Fig. 1 and with the use of the flowchart of Fig. 2.

DEGREES	ELEMENTOS	EVALUATION RULES		
		DEGREE A	*DEGREE B*	*DEGREE C*
S	SECURITY	Influence to the site in terms of safety and owed polution the failure	Problems to the site in terms of safety and owed poluiton the failure	No problems
Q	QUALITY	Appearance of defective products due to the failure or great influences to the revenue of the material	Quality alterations due to the failure or influences to the revenue of the material	Without influence on the quality and revenue of the materiall
W	C. OPERATIONAL	Operation to 24 hours	Operation to 7-14 hours	Operation occasional
D	LOSSES	Shutdown of the whole factory due to the failure	Shut down in the corresponding line due to the failure	Existence of stand-by equipment
P	FAILURES	Many stopped by failure (1 case/before of half year)	Occasional stop for failure (1 case/half year - 1 year)	Stopped practically null for failure (1 case / + of 1 year)
M	TIME OF REPAIR	Time of repair (+ of 4 hours), cost of repair + of US$2000	Time of repair (1-4 hours), cost of repair US$500 - US$2000	Time of repair (less than 1 hour) cost of repair less than US$500

Figure 1: Evaluation rules

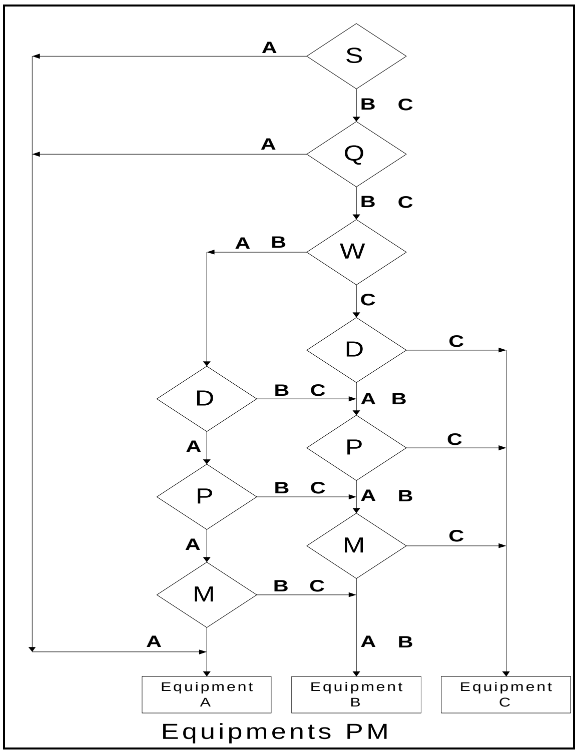

Figure 2: Classification Flowchart

Through that technique it was possible to classify the 40 equipments in the following way: 12 equipments class A, 20 equipments class B and 8 equipments class C, besides, was possible to identify a critical line where there is 4 equipments class A in line and being one of these (ME-11102 – Automatic Rotary Liquid machine) the only to present degree A in 4 of the 6 appraised requirement. In that way, it is clear the advantage of the use of that tool for rational and logical use of resources and available human efforts for the maintenance activity in this productive area, as well as in the planning and programming of the service orders.

3.2. Analysis of the critical equipment through the cycle of PDCA of solution of problems

With the use of the previous technique it was possible to establish a previous one of which would be the most critical equipment to the process, even so with the analysis of the historical of the same and aid of the cycle PDCA of improvements the importance of the same was evidenced for productivity of the company.

Being like this, the cycle PDCA of solution of problems is, according to WERKEMA (1997) constituted of the following stages: identification of the problem, observation of the phenomenons that cause the problem, analysis of the problem identifying possible causes, planning of the action to block the fundamental causes, execution of this action, verification of the results obtained by means of the executed action, standardization of the process preventing the apearing of the problem again.

Those stages should be followed by systematic way and organized to guide the activity of problems solution blocking the fundamental causes of the same ones. To identify the problem makes necessary the study of facts and such data as: production losses, expenses with repairs, historical of failures, expenses with corrections, among others. Through this study it is possible to trace the trajectory of the problem and to evaluate through techniques like

PARETO the main involved variables so much intrinsic as extrinsic to the process that is being analyzed. With the observation of the process it can be evaluated, under several point of view, the problem and study it in factors as: time, local, symptom type and individuals. Starting from this observation it is easy to trace a plan of goals minimizing, in that way, the problem and verifying its main causes.

In the case study, it was verified, through the analysis of PARETO, that with relationship to the items: absolute frequency of interventions and cost of work hand the equipment of tag ME-11102 (Automatic Rotary Liquid machine) came as more critical, being in second plan in critical in the items: aimed hours of maintenance and costs of external services. And, in a next moment of the work it was attempted that the largest number of failures happened to the Tuesday-fairs, generally with the team F (shift of the dawn) and with a specific product.

3.3. Maintenance inedexes

Once accomplished the previous, classified study the equipments and found the possible causes for the failures, was made the analysis of the historical of the equipment to know its operational behavior better. With this enough base was had for the calculation of the maintenance indexes that allowed a first diagnosis of the equipment. The chosen indexes were some established by IBP - Brazilian Institute of Petroleum - in 1973, gathering in the professional of industries of petroleum occasion, chemistry, mining, metallurgy, electric, mechanics and another. The chosen ones for calculation in this work were:

- MTBF (Mean Time Between in Failure): medium time among failure, supplying the time of operation where the equipment carries out the functions for which it was projected with reliability varying of lathe from 95% to 99%.
- MTTR (Mean Time Technical In Repair): time medium repair technician, indicates the medium time for the maintenance activity to come back the equipment to the operation condition from the detected failure.
- CMOE (Cost of External Hand Work): relationship among the total expenses in external hand work and the total hand work.
- DISP (Readiness): relationship among the time calendar in that the equipment this available one for operation and the time of maintenance, informing how long the equipment is the disposition of the maintenance or of the production.
- CMFT (Maintenance Cost in Relation to Profits): it demonstrates the as the cost of maintenance of this equipment represents for the revenue of the area.
- CMRP (Maintenance Cost in Relation to Production): relationship between maintenance cost and total production of maintenance revealing how many dollars is worn-out in maintenance for liter formulated by the equipment.
- CMVP (Maintenance Cost for Replacement Value): relationship between total cost of maintenance and the value of purchase of a new equipment.

The obtained results are in the Table 1:

Table 1: Resultus of Maintenance indexes

MTBF = 63,06h = 2,6 days	CMVP = 17,00%
MTTR = 5,5 h	CMRP = US$ 0,003/l
CMOE = 81%	P. Dismissed = US$ 9 mi
DISP = 91,00%	CMFT = 0,05%

For these indexes it was easy to trace the behavior of the equipment: there is break of the equipment every 3 days of operation, causing a very low operational readiness, with time of maintenance of 5,5 hours (almost a whole shift), with a cost of external hand work very loud 81% once the equipment is already had gone of to warranty, and, that whole picture causes an annual dismissed profit around US$ 9 million contemplating in 0,05% of the gross revenue of the company.

3.4. Calculation of the monthly efficiency

The maintenance indexes allow to the maintenance department to verify where they are its deficiencies during the action to plan improvements. However, to supply those deficiencies it is necessary to analyze the actions of the production department contribute to the same ones increasing the dismissed profit of the area. To analyses of these actions it is facilitated by the calculation of the monthly efficiency of the equipment that relates the impact of the actions of the two departments. For the calculation the following variables and equations were considered: time of operation of a shift (8h), hours of maintenance, hours of set up, time of load of the equipment, time of effective production of the equipment, medium amount of product produced a month, index of approval of the products (H), theoretical cycle of production supplied by the maker in l/h, real cycle of production in l/h, real time of production, index of operational time (T), index of operational speed, index of effective operation, index of operational acting (L). With those you varied and the equation (1) was possible to calculate the monthly productive efficiency of the machine.

$$Monthly\ Ef. = T.L.H.100 \qquad (1)$$

The obtained results are represented in the Fig. 3 demonstrating the flotation of the efficiency of the equipment in the considered period.

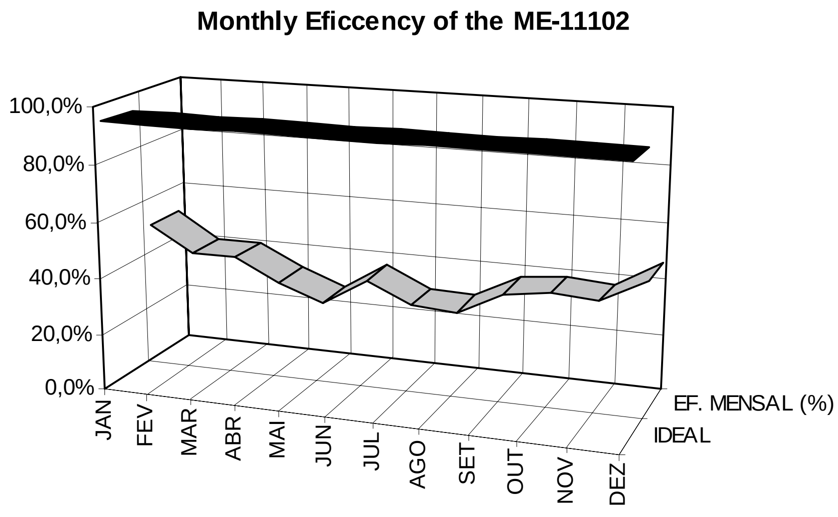

Figure 3: Monthly Eficciency of the ME-11102 (1997)

The calculations of that stage of the work revealed that the monthly productive efficiency of the machine ME-11102 rotated, the year of 1997, around 37%, considered, in a first moment, very preoccupying. This, because that value not reflects the annual production of

25.000 m³, in a value of dismissed revenue of US$ 175 million. However, of course would be necessary an analysis of the demand of the products of the company in the consuming market, once the same can justify the non use of all the capacity of the machine.

3.5. Weibull model

With the objective of to turn the more precise previous diagnosis and to have means with which it is possible to elaborate a plan of preventive intervention, the model of propability of Weibull allows to analyze and to identify the way and effect of failure of the way equipments to identify the form parameter b, indicative of the period of the life in that is the machine (youth, maturity and aging), once the studied equipment was a " black " box.

The obtained results are in the Table 2, as well as the characteristic equations, Equations (1), (2) and (3), of the behavior of the machine, and the graphs, Figures 4 and 5, of the functions distribution and reliability meet below:

Table 2: Results of Weibull model

β = 2,60	R = 0,93
η = 3807,97 hours	**MTBF = 3382,24 hours = 4 months**
-β. lnη = -21,04	σ = 1397,52 hours = 2 months
Cmp = US$ 12,03	VC = 0,41
Cmc = US$ 411,80	**T = 816,63 hours = 1 month**

The values in boldface reveal the great times of intervention considering the number of failure happened during the period in study and the costs related to these failure. The value of MTBF only takes in consideration the number of failure happened in the period, already the following value (T) it takes in consideration the costs of failure involved in the period, being them: Cmc - cost of correct maintenance/failure and Cmp - cost of preventive maintenance. That is to say, being just considered the number of failure the preventive intervention should happen of 4 in 4 months, however if that one wants it is the improvement of the cost this intervention it should be done once a month.

$$\lambda(t) = \frac{2,60}{3807,97} \cdot \left[\frac{t}{3807,97} \right]^{2,60-1} \quad \text{(Density of probability)} \qquad (2)$$

$$R(t) = e^{-\left[\left(\frac{t}{3807,97}\right)^{2,60}\right]} \quad \text{(Function partition)} \qquad (3)$$

$$L_{10} = 3807,97 \cdot (0,105)^{\frac{1}{2,60}} \text{ (Life duration associated to the reliability)} \qquad (4)$$

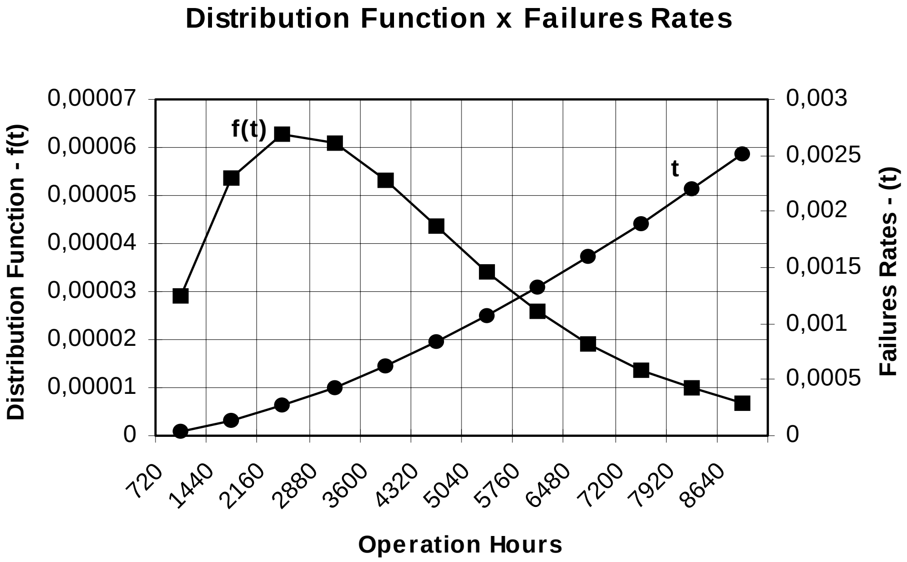

Figure 4: Graphic representation of the function distribution and it rates of failure

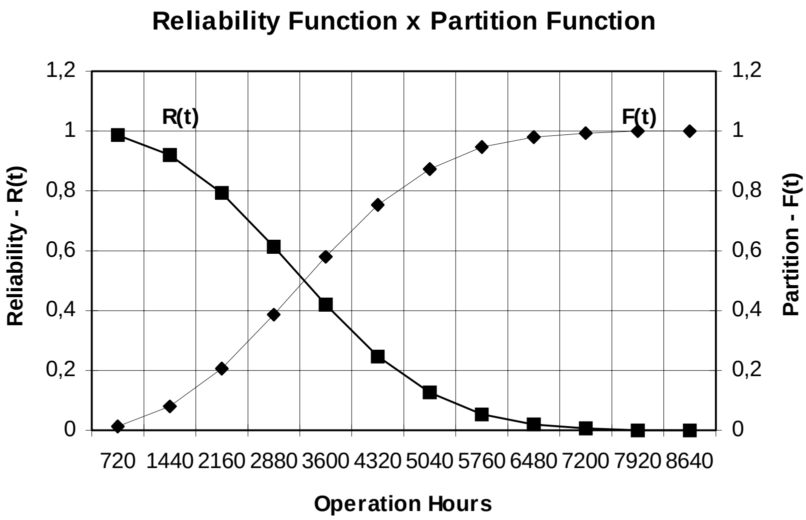

Figure 5: Graphic representation of the function reliability and partition

The graph of the Figure 5 demonstrates the level of reliability of the equipment during its operation in the time executing the functions for which it was projected. Therefore it is verified that in the fourth month the probability of happening a faliure is around 50% and that its reliability will rotate around 90% if the preventive interventions happen once a month a cost of 1/3 of the worn-out total in correctives maintenances in agreement with studies already accomplished for theoretical.

3.6. Diagram causes and effects

Once a process is a combination of the elements: equipments, input, methods or procedures, environmental conditions, people and information of the process or measures, tends as objective the production of a good or the supply of a service; it is possible to evaluate the influence or effect of those elements in the result wanted by the diagram of the wellknown Figure 6 as: diagram causes and effect, diagram fish spine or Ishikawa diagram. Like this being, with the analysis procedure described previously can be arrived the following decisive causes in the breaks of the Automatic Rotary Liquid machine:

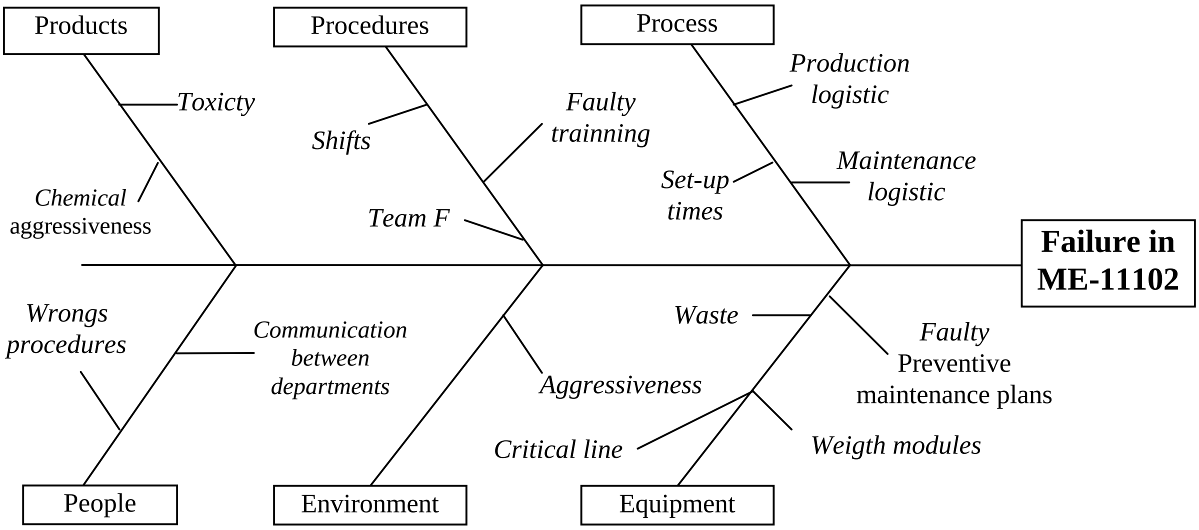

Figure 6: Flowchart of causes and effects of the ME-11102

3.7. Intervention points

In the elaboration of the maintenance plan the number of extracted information of the historical, the accomplished calculations and the field analyses made beside the machine allowed the identification of the intervention points and elaboration of a preventive plan that for own of the production department reasons had its periodicity determined in one month. In the Fig. 7 are possible to verify the main intervention points: product reservoir (1), injection beaks (2), scale modules (3), dealer of covers (4), electric panel (5), label machine (6), electronic panel (7), motor-reducer (8), wake carrier (9).

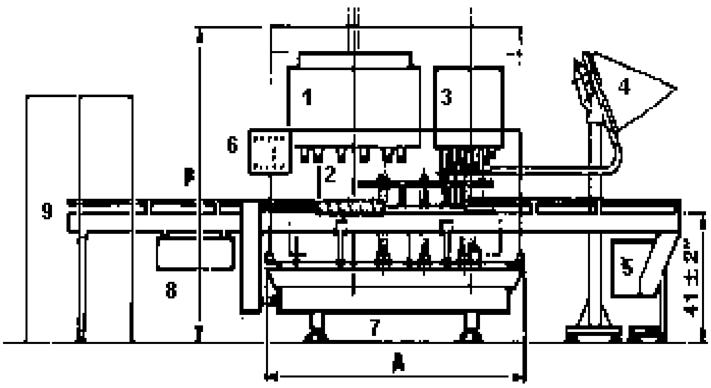

Figure 7: Intervetion points of the ME-11102

4. CONCLUSION

With this work, it is verified that the company that has the objective always to be the front, needs to enrich its processes with new technologies in the maintenance area, and, for so much, studies as this should be accomplished, in the factory ground, demonstrating the significant results the one that can arrive using such tools supplying the base for answer of some subjects as: is the repair of the equipment enough, or is the engineering personnel's precise involvement?, which does the great time to plan a preventive intervention and which components of the machine need to be being verified during that action?, which the reliability of the equipment for certain time of operation so that the same carries out its functions in the process?

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