The Management of the Industrial Maintenance at an International Level (II)

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Abstract

When defining a maintenance policy, it must be held in mind the fact that there isn't such a thing like "good maintenance policy" in itself; instead, for each industrial equipment should be adapted a particular maintenance method, coming to a technical-economic compromise through its products, through its market, its equipments, its people, the managers' psychology, the organizational culture and, as a consequence, the industrial maintenance will be different.

The present article will pursue to highlight the position of the maintenance activity having in mind the imperatives imposed to this activity, the maintenance methods applied at the international level and the methods that can be applied in our country.

Keywords: *maintenance mission, corrective maintenance, systematic preventive maintenance, conditional preventive maintenance, palliative maintenance.*

JEL classification: D24, M11, M21, O12

Maintenance methods that can be applied in Romania

Having in mind the limits of the traditional maintenance and repair systems, the changes that are recorded in the field of maintenance, the new objectives of maintenance, the fact that the companies from our country are involved into an international, extremely tough competition, we think that it's necessarily to rethink this activity, the company could choose a method or another of maintenance.

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To that effect, we suggest the following classification of the maintenance methods that can be applied in our country:

1. **The corrective maintenance;**
2. **The systematic preventive maintenance;**
3. **The conditioned preventive maintenance;**
4. **The palliative maintenance.**

The decision to adopt one method or another must be the result of a scientific analysis, based on scientific methods and models, taking into account a series of technical, economic and safety factors.

1. The corrective maintenance

The corrective maintenance is the maintenance performed after the equipment's failure. There is an ambiguity in vocabulary when we define the corrective maintenance, the notion of "correction" after the failure contains also the notion of amelioration. After discovering a failure, inside the system of maintenance and repairs, according to the necessities, there is performed a urgency repair or repair, reestablishing the lost function.

The corrective maintenance implies the following:

- an analysis of the failure's causes;
- a refit (urgency repair or repair);
- an eventual amelioration (correction), avoiding the defect's repair or minimizing its effects over the system;
- recording all the elements related to the intervention (the cause, repairs performed, replacements, the repair's cost, the standing time, etc.), allowing an ulterior exploit.

The corrective maintenance often represents the maintenance method that is especially performed before the development of the systematic or conditioned maintenance, but the last ones don't solve all the failures of the equipments and, more than this, they don't apply in all cases in economic acceptable circumstances. As a consequence, the corrective maintenance method represents a method in its own that is applied especially in the case of equipments whose damage doesn't endanger the persons' security and don't involve high costs when the equipments are unavailable.

This maintenance method can also be applied in all the categories of equipments, on all the warranty period stipulated by the equipment's designer and especially in the startup period (on trial).

What is essential in the case of adopting the corrective maintenance method is the correct estimation of the "failures"' costs. The cost of an equipment's failure is formed by the sum of the corrective maintenance's cost for its refitting (the direct cost) and also the cost of the consequences related by the unavailability of that equipment (the indirect cost). Excepting the cases with catastrophic consequences, the cost of the unavailability consequences depends on the time period of this unavailability. The unavailability time period depends on numerous parameters, the stages of the total unavailability period and the action variables being presented in table 1 (Deac, Badea, Dobrin, 2010).

Table 1 A failure's stages

Stage	ACTION VARIABLES
1. The failure' detecting	▪ means of detection
2. The information's transmission	▪ tight relationship production -maintenance
3. The announcing of the maintenance team	▪ communication methods and means
4. The circulation of the repair team	▪ organizing means allowing the maximum efficiency
5. Diagnostic	▪ the maintenance's staff qualification ▪ diagnostic means and methods ▪ equipment that facilitates the investigation
6. Deciding the changes	▪ organizing that allows taking fast decisions ▪ judicious inventory of the material stocks and replacements.
7. The troubleshooting or the repair	▪ proper qualification of the maintenance team ▪ the interventions' preparation ▪ maintenance means
8. The control	▪ -staff's qualification ▪ control means
9. The refitting	▪ staff's qualification ▪ control means

The rapidity in performing the diagnostic is an essential factor in diminishing the time and, therefore, the costs. The staff's preparation and the availability of tools, methods and investigation techniques present a crucial importance. Having the mind the new content of this maintenance methods, comparing with the maintenance system and repairs upon necessities, we consider that for the proper organization of this maintenance method there must be beforehand fulfilled some requirements, during and after the defects' apparitions.

1) Before the failure' apparition, the requirements that must be fulfilled are the following:

- accurate instructions concerning the equipments' exploit, in order to prevent an accidental failure due to the improper use of these equipments;
- instructions, methods, techniques and fast means of diagnostic of the failures;
- defining the means of intervention upon the equipment, in full safety;
- the good qualification of the intervention staff.

2) During the failure's apparition is very important to associate rapidly and correctly of the intervention. In order to do that:

- the diagnostic performed over the equipment must be prescribed;
- the maintenance teams must have the necessary competence to ameliorate the failure, certifying this.

3) After the failure's solving and the equipment is refit, the requirements that must be respected are:

- writing down the "Card of failure analysis". An accidental failure represents an anomaly, its cause having to be known in order to take actions of remove the reason and to increase the equipment's reliability;
- filling in the "The equipment's historic card", which cover all the corrective interventions bore by the equipment from the moment it was put into operation;
- performing the necessary corrective actions: filling in replacements inventories, improving the troubleshooting instructions, modifications into the existent documentations, etc.;
- equipment's perfecting measures, aiming at avoiding the failure's repair or minimizing its effects.

2. Preventive systematic maintenance

It represents the predicted maintenance, prepared and scheduled before the expected date of a failure's apparition. Its objectives, at which it aims through its preventive character, are:

- ✓ increasing the equipment's reliability, diminishing the failures and the unpredictable circumstances and, as a consequence, the reducing of the maintenance costs;
- ✓ increasing the equipment's life span;
- ✓ improving the activity of planning and programming; a better programming of the labour force determines a reducing of the costs with the manual labour, and a better planning of the supplying with materials and replacements determine the reducing of the storage expenses;
- ✓ improving the work safety: a periodic control of certain equipments guarantees a better safety for the staff and for the equipment;
- ✓ improving the relationship between the production and maintenance (because the preventive maintenance reduces the "unpredictability", which is often the dissentions' source), a better climate and better living conditions inside the maintenance compartment, a better instruction of the maintenance staff, etc.

We consider that putting into effect the method of the systematic maintenance involves the developing of an effective behaviour "methods-maintenance". Indeed, the "prevention" without a compartment of methods, which will increase on the short term the direct maintenance costs, but will allow:

- the administration of the technical documentation, of the equipments' files, and their history;
- technical analyses related to the exploit equipment's behaviour;
- preparing the preventive interventions.

In order to apply the systematic maintenance method, it's absolutely mandatory to exist inside the industrial units the equipments' nomenclature, established according to the usage conditions and their usage, and a history of the

equipments. If there isn't a historic, it will be performed an analysis of the equipments and of their usage conditions. This analysis is recommended to be performed by a collective formed from the maintenance and production staff, allowing their sensitizing for a preventive maintenance.

Each manager of the production subunits will be asked to classify the equipments in four categories:

- category A: equipments whose stopping provokes the total stoppage of production;
- category B: equipments whose stopping determine a slow-down of the production rhythm or a degrading in the production's quality;
- category C: equipments for which the production has replacement solutions and, therefore, their stopping doesn't play such an important role over the manufactured quantity, but it affects the maintenance costs;
- category D: equipments that don't have to be supervised through preventive maintenance.

The same classification is performed by the maintenance department, then the "maintenance" and the "production" confront the two hierarchies and agree on the different opinions, finally establishing the list of the equipments to be supervised through a preventive system maintenance, establishing priority order, finally writing down the plan of establishing and applying the systematic preventive maintenance. For each equipment of surveillance there is define through the preventive maintenance the "utilization parameter" (hours- for an equipment, tons, etc.), then according to the plan established below it's proceeded, for each type of intervention, this way:

1) Decomposing the equipment into parts and subassemblies (ex: control devices, engines, gear assemblies, measure and control devices).

2) Defining for each part of: the visiting points and the operations to be performed; the visit's objective; the parameters to be measured; the stage or the tolerance of the permissible usage; the equipments or measure equipments; the periods of the visits;

3) The classification of the visiting points and of the operations to be performed, into operation groups, for defining the number of interventions of systematic preventive maintenance.

The systematic preventive intervention can be of "surveillance" or "absolute":

- "absolute" means that no inspection can be performed between two scheduled interventions;
- "surveillance" – "periodic inspections" can be scheduled aiming at controlling the gap between the constant condition and the condition estimated in the moment of calculation the average time of good functioning.

The methods of the systematic preventive maintenance are the following:

a. **Telesurveillance**

It consists in putting into permanent or occasional control of the key points of the equipments through measuring and knowing the functioning condition, being

achieved with automatic means and allowing: either the alerting, or the actions' launching; either the launching of the well-defined actions in the case of a certain type of behaviour or in case in which there is a auto-diagnostic coupled system. Telesurveillance uses the non-destructive means of control and means of transmitting the information, which must be scheduled in the equipment's design.

b. Systematic visits

This is, in general, a less costing solution and the easiest to apply, being of various types, opting in favour of a certain solution according to the objectives and to the economical criteria:

b.1. Systematic visits without stopping the equipment

They represent, in fact "the maintenance on patrol", which is characterized through a regular surveillance of the equipments, "patrolling" in short intervals, well-established, training small interventions when it's necessary. Performed by a careful staff, it ensures an equipment's surveillance on the whole, avoiding, this way, the apparition of a great number of minor failures that might, in time, have some major consequences.

Traditionally, "the maintenance on patrol" was always applied, being the preventive part of the maintenance. The patrolling upon the equipments covered:

- lubricating them;
- controlling the pressure, the temperature, the quotes, the vibrations etc.;
- sensorial exams: visual detections, hearing abnormal sounds etc.;
- tests;
- minor interventions, tunings, standard replacements (for example, the lamp's replacement).

But, on the international level, two trends change the nature of this maintenance towards the "patrolling maintenance", namely tele-maintenance" and "integration in production".

Tele-maintenance consists in relating the data receivers to a surveillance center, which records all the alerts and measuring. The synoptic tables give an image of the data localization. This technique, which necessitates great investments, ensures a good functioning security on the whole, saving the money allocated for the movements related by the activity of "patrolling", but it can't substitute the "flair" of a good companion. The surveillance agent, confronted with the apparition of a failure, has the responsibility of organizing a saving procedure, either through putting the equipment out of order, remedying the defect appeared or alerting the required intervention agents.

Related to the integration in production, in the Japanese model of TPM, the responsibility of level I surveillance and maintenance can be assumed by the directly productive worker.

b.2. Systematic visits stopping the equipment

Taking into account the type of the visit and the available time, they can be performed without dissembling the equipment, with a partial disassembling and with a total disassembling.

c. Systematic relocations. It's known beforehand, when a maintenance operation is launched, that a certain part will be replaced, at an organ or subassembly, whichever could be its state.

According to their complexity, the systematic preventive maintenance can be grouped on several levels, their classification on five maintenance levels being the following (Boucly, 2007):

1) Level 1 systematic preventive maintenance covers actions performed on a functioning equipment, and available for being stopped, like:

- actions of surveillance and maintenance of the equipment: maintaining the general aspect and solving some insignificant oil leaks; the various parameters control (pressure, temperature, noise, vibrations, various quotas etc.), lubricating the various organs etc.;

2) Level II systematic preventive maintenance covers actions performed upon stopped or functioning equipment, like:

- standard replacements and changes of consumables, replacements which wear out very fast and small subassemblies (filters, cartridges, disks, sealing parts etc.);
- adjustment operations and trials;
- the cleaning of the equipment;
- controlling the functioning parameters.

3) Level III preventive systematic maintenance, covers actions performed only upon a stopped equipment, after a certain number of functioning hours (or usage units) and consists in the checking up, repairing or replacing of all the components of the equipment, through its complete disassemble;

4) Level IV preventive systematic maintenance, covers actions performed only upon a stopped equipment, after a certain number of functioning hours (or usage units) and consists in the checking up, repairing or replacing of all the components of the equipment, through its complete disassemble; but without modifying the initial condition of the equipments;

5) Level IV preventive systematic maintenance, covers complex maintenance actions which aim at the respective equipment's modernization.

3. The conditioned preventive maintenance

It represents the maintenance related to the evolution of a symptom characteristic to a certain type of event, which can be predetermined through the following means: diagnostic, measuring the usage, information received from a receiver, etc. This maintenance method prevents the apparition of some supplementary sources of shut-downs, resulted from the sometimes useless dismounting required by the systematic preventive maintenance, intervening in the most favourable moment. This represents the gain of the "time" dimension, which enriches the conditioned maintenance on its "preventive" plan.

The control and diagnostic operations, in the case of a preventive conditioned maintenance, accompany all the equipment's life, grounding it, and refer to:

- the quality control while the equipment is created;
- the reception control, before being put into operation;
- the regular controls, prescribed during the equipment's life span;
- controlling and supervising the equipment's condition and supervising the evolution of the beginning of a abnormality in its functioning;
- controlling the quality of the maintenance actions performed.

This maintenance method provides for the continuous surveillance of the equipments in action, towards preventing the failures. It doesn't imply knowing the degradation law, the decision of a preventive intervention being taken when there is an experimental evidence of an imminent failure or when it comes close to the degree of predetermined degradation.

The first requirement of putting into effect the conditioned preventive maintenance is that the equipment should lend itself to this maintenance method, meaning that it should be a progressive and detectable degradation and it must be found a correlation between a measurable parameter and the equipment's condition. Having in mind this aspect, a period of systematic preventive maintenance or an experimenting related to it is necessary for fixing the "toleration threshold", from which a stopping of the equipment's functioning (be it automatic or not) is necessary. Keeping track of the reaction time and the degradation speed, it will be established a "emergency threshold", before establishing the "toleration threshold" (figure 1).

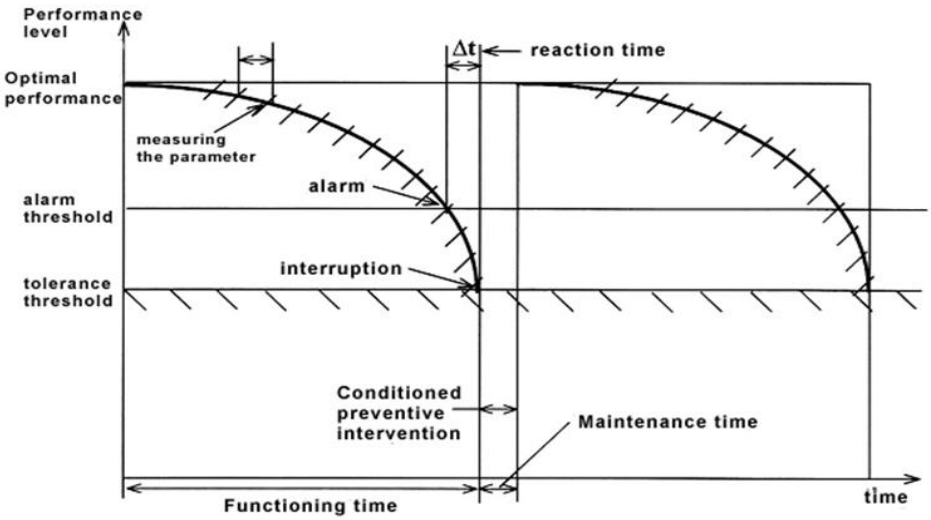

Figure 1 Preventive conditioned maintenance

The stages of the conditioned preventive maintenance are (Boucly, F., 2007):

- detecting the symptoms of deterioration of the condition of the equipment and of its functioning conditions;
- transmitting an alarm signal adequate to the detected danger;
- the processing and the memorizing of the received information;
- putting a diagnostic of the causes and the estimation of the danger's consequences;
- envisioning the immediate or the subsequent actions, having in view the danger's importance and its evolution;
- the decision about the action and the means of action;
- the putting into effect of the precedent decision;
- the control of the efficiency of the adopted measures and, if necessary, the procedures' amelioration.

The danger symptoms of the equipment's condition refer to: the position of various equipments' parts, due to their position resulting failures or progressive usages, the dimension of different parts through usage, sedimentations, corrosions, vibrations; fluidic indications (pressure, temperature, debit); mixtures of greasing oils, steam or gases; the nature and proportion of the impurities etc.

The practical means of detecting the anomalies are:

a) Detecting the anomalies with the help of the human beings. The production equipments' operators are, generally, the best located to detect the anomalies, due to their availability, instruction and, not at last, enough motivation. The detection with the help of human beings has the advantage of using in the same time of many senses and the one that they can continue immediately the interpretation and eventually the decision. Human beings can have difficulties in the quantification of his observations (when he lacks the measure instruments) and, in the same time, can be the victim of illusions related to his senses.

b) Detecting the anomalies through the control equipments. The means and the detecting and surveillance of the anomalies start from simple devices and measuring tools to the modern method of non-destructive control.

We consider that applying the conditioned maintenance method involves the previous performing of a study, its stages being the following:

1) Classifying the equipments taking into account the importance of the shutdown risks

The criteria that can be taken into consideration for making this classification are: the safety of the persons and of the goods, the unavailability costs or the degrading of the functioning, the incomprehensible incidents etc.

A historic of the noticed incidents can serve for performing the classification, but there can also be taken into consideration an analysis and an estimation of all the potential risks.

2) Grouping the equipments on homogenous groups

The diversity of the equipments inside an industrial unit requires their previous grouping into homogenous groups, taking into account the technical and functional characteristics.

3) The research of the diagnostic means for each group

The stage refers to the inventory of all the detectable symptoms and the means of noticing them. In this stage the producing firm and the ones specialized in this field must be consulted.

4) Elaborating the initial variants

They can differ from the point of view of the controlled spots' number, the control frequency, the detecting means and the information' treatment.

5) Comparing the established variants and choosing the final variant

Taking into account all the aspects required by the adopting of the conditioned preventive maintenance, and also its implications, we recommend for choosing the final variant the utilization of the method of rationalization of the decisions based on multiple criteria in certitude conditions (the global utility method, ELECTRE method etc.).

6) Implementing the conditioned maintenance

According to the results of the previous stage, it can be decided to use either a global solution, or a progressive application, starting with the solutions which are the easiest to apply, also taking into account the high costs this maintenance method involve, in the early stage.

7) Control

A control of the results obtained is important for two reasons. On one side, for correcting the eventual dysfunctions, and on the other side, for the future decisions related to the extending of this maintenance method, especially in the case of a progressive putting into effect.

In general, through implementing the conditioned preventive maintenance system it is also needed tele-maintenance. A qualified staff provides the entire equipment's surveillance, interpret the measurements and decides upon the opportunity of an immediate intervention.

Making a comparison between the two preventive maintenance methods, we notice the following:

- the main difference: the date of the preventive intervention is predetermined in the systematic maintenance case and determined when it intervenes the alarm in the conditioned maintenance's case.
- consequences: through the conditioned maintenance there are used the parts (replacements, subassemblies) at their maximal performance, but this involves a chain of measurements (instruments, receivers, telematic network, surveillance center, the eventual usage of information), which are hard to put into effect.

To draw a conclusion, it could be demonstrated the fact that the maintenance evolves towards the concept of conditioned maintenance.

4. Palliative maintenance

Having in view the fact that in many industrial companies from our country, currently, the equipments are "old", some of them being totally paid off,

but still maintained in the production process from certain reasons (especially because of the impossibility, from the financial point of view, of buying other equipments), we suggest, as an intermediary transition stage, the palliative maintenance, which consists only in the performing of the actions that are absolutely necessary for its functioning (in general, their putting into operation again through replacement or repairing the defect parts of subassemblies).

This maintenance method is also recommended to be applied in the case of the industrial equipments which are technically outdated, with a high moral wear, with a low performance, but which are still in the normal functioning period. Beginning with a general management rule, that of adapting the means to the needs, to the reality ("don't use an elephant to crush an ant!"), the implementing of the preventive maintenance isn't justified, in this particular case, from the economic point of view. Taking into account the experience in the field, we recommend that, in the palliative maintenance's case to be made an inventory and a supervise of the maintenance expenses, not to end as in some cases, when the maintenance expenses exceed the equipment's cost (especially taking into account the very high price of the replacements) (Deac, 2000).

Once defined a certain maintenance method, the most delicate issue remains to be solved, which is the issue of putting it into effect. A certain number of conditions are needed to be met (in the mathematical acceptance) in applying some maintenance methods, but none of these conditions is sufficient.

Among the absolute necessarily conditions that must be met, we highlight the following:

1. The will and understanding of the top management in an industrial unit, respectively:

- the clear conceptualization of the maintenance function, of its possibilities and limits;
- the involvement of the top management in defining the maintenance's objectives and endowing with the necessary means;
- the acknowledge of the necessity of an initial investment, without expecting to obtain immediate profits;
- the expressing of the "will to maintain".

2. Organizing structures that are compatible with the maintenance function:

- the structural equilibrium of the three technical functions: design, production, maintenance;
- the centralization in the central department of the maintenance actions on polyvalent technical teams;
- developing the department "methods-maintenance" and "planning-programming-maintenance".

3. Assuring the employment, respectively:

- a sufficiently numerous maintenance staff, with an efficient structure and good qualification;

- the staff's agreement in implementing of a certain maintenance policy;
- instructing the staff and making it accept the novelties.

4. The financial means:

- a sufficient budget according to the aimed objectives;
- investment possibilities (example: evolving to the conditioned maintenance involves complex systems, very expensive, of tele-surveillance of the equipment, requiring great investments).

5. The material means:

- a proper equipment inside the maintenance department;
- standard and special tools, adapted to the production equipment, surveillance means, of detecting, testing, of non-destructive control etc.

6. Controlling the information flow:

- informational documents: the equipment's file, its historic etc.;
- defining the intervention procedures: damage inspection reports, intervention reports, acceptance certificate, the harmonizing of the relationships: "methods-programming-achievement";
- exploiting the operational data of: reliability, availability, costs etc.

Related to the effective put into force of the adopted maintenance method, each industrial unit is confronted with its own problems, but there can be distinguished two reorganization methods, but there can still be developed particular forms, which are:

a) Implementation "in the mass" (or "the surgery").

In this case the maintenance and repairs department must be restructured in order to proceed at the maintenance related to: defining the objectives, everybody's tasks, the modernization of the means and procedures, instructing and motivating the people to embrace the "novelties", to forget about the routine etc.

b) Progressive implementation (or the "homeopathy").

It consists in selecting a "critical" equipment and to apply on it a plan of systematic preventive maintenance and then a conditioned one (for the subassemblies, the components for which this plan can be applied).

The procedures of surveillance, of methods, of interventions, can be developed in a progressive way. Then the maintenance plan will be extended to other equipments, too, with a priority order (the date, for example, through a ABC graphic), this thing permitting a progress of the investments, too.

The main obstacle inside an industrial unit in developing the maintenance is "the human being", regarded through his relationships and from a professional point of view (his instruction drawbacks). The performed studies highlight the following aspects:

- at the level of the general management: a ignorance of the possibilities offered by maintenance, of the gains that can be achieved: the "will to change" isn't so clearly formulated as something crucial, which proves to be something irrational in most cases, the investments being postponed "waiting for a better turn

of events", which obviously impede the evolution from conservation to maintenance;

- at the level of the people who are responsible with the maintenance: on one side, there is the older staff, of a good technical competence, (in many cases, an empirical one), but insensible to the economic management of the compartment. They are excellent maintenance leaders, but they are less motivated to go further, to break the routine. On the other side, we meet young staff, which tend to discover the new, but being less inclined to reorganize the compartment on the whole, an activity which is going to develop well and which is going to go well after their leave, too;
- at the level of the technicians: a lack of education, less sensible about the economic aspect;
- at the level of the workers: a fear of change, difficulties about the team work;
- at the level of the company: an incompatibility between the promoting of the "maintenance mood" and a level of human relationships established into a far too restrictive hierarchy, based on obeying the orders and reports.

This is the major impediment! The maintenance's developing involves the active participation and the responsibility of all the company's members.

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