

The Modern Approach to Industrial Maintenance Management

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The maintenance activity isn't a purpose in itself, it's a necessity of which "the production suffers" and the financial agent "considers too expensive". It often exists a conflict between the production units and the maintenance department, not only for a short term, but, sometimes, for a long term, imposing a rigorous definition of each person's responsibilities. Considering the mutations in the industrial equipments' technical complexity and the accidental failures' catastrophic consequences from the economic and/or social point of view, it should be assigned a new dimension to the maintenance activity. One of the imperatives imposed to this action is represented by modern means of informing through the maintenance's operational computerization.

Keywords: Maintenance's Progress, Total Productive Maintenance, Cooperation In Maintenance, The Maintenance's Costs Minimization, Maintenance's Operational Computerization

1 The maintenance's place in an industrial company's management system

The activity of maintenance isn't a purpose in itself, it's a necessity of which "the production suffers" and the financial "considers being too expensive". It often exists a conflict between the production units and the maintenance department, which is responsible with the equipments' status and conservation, not only for a short term, but also for a long term. In many cases, the industrial companies, wanting to reduce the current total costs, considering the above mentioned conception, the uncertainty about the company's future, orient towards reducing the budget allotted to the activities of preventive maintenance.

In the reality, this policy's effect isn't the wanted one, the costs with the corrective maintenance increasing as a result of an increase of the accidental failures' frequency, at which are added the greater and greater failures in case of impairment or of functioning parameters' degradation. In the same time, the maintenance works' increase in number and in value will bring about in the future a decrease in the preventive maintenance's available resources, the industrial company entering into a vicious

circle from which it will be able to come out really hard.

In order to reconcile these points of view that contradict each other just on the surface, the activity of maintenance must be put in its proper place inside the company and each person's responsibilities should be properly defined (this is an issue of policy and structure). In the same time, the maintenance activity should be organized in such a manner, that it should allow solving all the problems specific to maintenance, in the most efficient possible way (the economic criteria should become a priority, in the most of the cases). [5]

The Romanian industry, of course, even if it's mostly private, falls in a period of profound crisis and difficult times (financial blockages, a lack of markets both for the "inputs" and the "outputs", price rises, etc.), a context in which the production capacities' usage is an extremely reduced one (30-40% of the capacity, and in some cases even less), the equipments' maintenance isn't a priority in the top managers' concerns.

The present uncertainties involving many industrial companies' future, considering the current economic and financial crisis, the state of confusion that still prevails in the economy generates, in fact, the same

situation, meaning the maintenance works' limitation to the basics in order to reduce the production costs. On the other side, the current economic conjecture put the majority of the industrial commercial societies in a context of "economic war". Considering that conjecture, the issue is that of not being fatalist, passive, having in mind that we're crossing a period of economic recession and the solutions to this crisis don't depend of the company.

Out of this difficult, but stimulating situation, the societies who are going to win the day are the ones whose management will prove imagination and creativity in order to find progress solutions which are better adapted and with an increased economic efficiency, solutions of increasing the company's competitive spirit. Inside these solutions, the ones that increase the production quality should be central.

The industrial equipments' maintenance is compulsory for guaranteeing the quality in all the production process' stages, its assignment, in an attempt of warranting quality in all the production stages process being the one of identifying the equipments that have a direct effect on quality and ensuring that through the performed maintenance works is ensured the failure prevention and the prevention of some

malfunctions that may affect the production's quality [9].

What's industrial maintenance?

Trying to define the industrial maintenance, this represents a set of measures and actions that ensure an equipment's prevention, preservation or restoring in an anticipated state or capable to guarantee a certain service, altogether with the minimizing of the maintenance's costs [4] [5].

Out of this definition, the following essential conclusions can be drawn:

"**to restore**" involves the concept of "correction", as a result of losing the functioning parameters' initial values;

"**the anticipated state**" or the "certain service" involves a predetermination of the functioning parameters or the service to be attained, with the characteristic levels' quantification;

"**to minimize**" presupposes to consider the maintenance activity's economic aspect, respectively guaranteeing that all the operations will have an optimal cost;

"**the prevention**" and the "**preservation**" consists in applying some methods, procedures, measures and actions that contribute to the maintenance's progress in four major directions, as schematized in fig. 1.

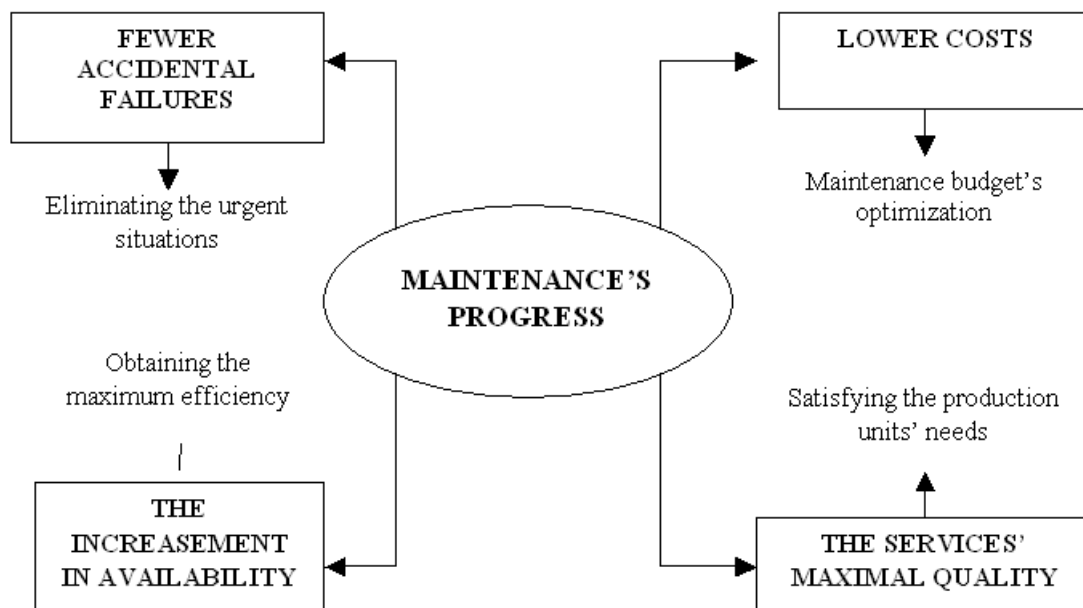


Fig. 1. Maintenance's progress [4]

Internationally, the activity of maintenance evolved in the industrial companies considering the compromise that should be done between the needs and exigencies, from the technical, economic and human point of view.

Until the 60's, the activity of maintenance was synonym with the one of repairing, the equipments being improved each time it was possible. It could be noticed the fact that improving the equipments, the human security is guaranteed, they being stopped just to examine the wearing level, it being completely abandoned when the persons' security wasn't in stake.

The period 1960-1970 generated three fundamental mutations in the industrial's maintenance's approach:

- creating the diagnostic maintenance, that led lately to the conditioned maintenance. It's about applying the techniques of nondestructive control, the vibrations' control, fluids' analysis, etc.
- taking into consideration the economic aspects in defining the maintenance's attempt. Any equipment at which an accidental failure or a decline of the functioning parameters determines in a significant manner a decrease in the production's quantity or quality is considered a "critical" one. The concept of "failure cost" appears and the indirect financial incidence of the activity of maintenance is considered. But it isn't enough just to consider the economical aspects when the maintenance actions are decided (the cost of the equipments' non-efficiency, the non-maintenance' cost). It's also necessary to evaluate the risk and the probabilities of equipments' malfunctions.
- The appeal to the reliability theory. The reliability models of study, which were initially hard to apply in the industrial units, were, subsequently, used more and more. After the 1970, two philosophies related to the industrial maintenance were developed.

In USA, it was applied the concept of Life Cycle Cost (LCC), which covers the

totality of the costs of the research, design, construction, exploit and maintenance processes for an equipment's entire life. The objective aimed is its minimization.

The second philosophy is the Japanese one, "Total productive maintenance" (TPM). If the LCC approaches the maintenance from the economic point of view, TPM approaches it from a human point of view. Its objective is the maximization of the production equipment's global efficiency and it presupposes the participation of all the "actors" that contribute to its efficiency: the designers, the users (the production staff), the maintenance stuff, from all the management's hierarchical levels, starting with the worker to the general manager [7]. Concluding, we can prove that the function of industrial equipments' maintenance is a partner in the system of ensuring the quality, and, if the company's top management wants to guarantee the production stage's quality, the product of the maintenance activity is a must to warrant this quality.

In order to be a competitive partner inside this system of quality warranty it's imposed an important change inside the maintenance function, which is characterized through three major transitions:

a. The transition from the oral communication to the written communication

The transition from the oral communication to the written communication, considering the fact that the process of oral instructions' transmitting is frequently met in the maintenance activity, constitutes an especially delicate mutation. The existence of some written procedures related to the industrial equipments' exploit and maintenance constitutes a fundamental requirement in warranting the production's quality. These procedures related to the equipments' maintenance must allow: knowing the coverage of the activity of maintenance; the tasks and responsibilities of each employee covered in the activity of maintenance; the detailing of all maintenance works that are about to be performed.

b. The transition from the improvisation to the scientific rigor

No matter which is the chosen maintenance policy, respectively:

- the policy of increasing the equipments' reliability (their modifications for eliminating the "blind spots");
- the preventive policy (the anticipating of the equipments' malfunctions through a rigorous surveillance);
- the anti-malfunctioning policy, that aims to all the malfunctions' elimination through the detailed analysis of each malfunction or abnormal functionality).
- the competence and the technical value of the people that execute the maintenance works is crucial, and quality warranty presupposes the execution of all the corrective or preventive interventions with the greatest scientific rigor.

c. The transition from intuition to professionalism

With a properly trained maintenance staff, with a great technical competence, talented, the maintenance compartment can execute efficient interventions.

2 The activity of maintenance's evolution and objectives

In the current stage, the evolutions that are necessary in approaching the activity of maintenance inside the industrial companies are determined by three groups of factors, which are [2]:

a. Technological factors

Worldwide, electronic and informatics spread in the workshops and the production departments: the machines are endowed with numerical command, the industrial robots extended, the flexible fabrication workshops are in full development, everything is being automatic.

The electronic circuits are reliable because of the progresses in the components' technology; the power organs, the mechanical and hydraulic tools, the electromechanical subassemblies are more and more reliable and less and less maintenance consuming. Instead, the activity

of maintenance can appeal to new techniques of detecting the flaws (the vibration analysis, the sonic analysis etc.) which prove to be extremely efficient pointing to the blind spots and preventing the failures.

Nowadays, there is a new entry in the equipments' surveillance trend (and, in the same time, the tele-surveillance trend): the conditioned maintenance, in which:

- the inspection of the equipments which are more and more complex must be rigorous and, as a consequence, must be organized in a formal and detailed manner;
- the permanent diagnostic of the equipment's technical status must be rigorous and precise.

b. The economic factors

In order to be competitive, the company must reduce to the minimum its production expenses, both the direct and the indirect production ones and implicitly the ones related to the maintenance. Worldwide, the general trend of late years is to diminish the maintenance costs.

Another worldwide aspect, with major implication to maintenance, is the fact that, in the euphoria of the strategies of development through expansion and diversification that was specific to the 70's, we assist at a maintenance companies' development, companies that are capable to execute numerous maintenance activities instead of the traditional compartments inside the industrial companies.

This trend can be noticed in our country's economy, assisting to an increase of the small and average sized companies in the maintenance domain. It's true that they are specialized, for the moment, in some domains (maintenance in informatics, conditioned air, the buildings' maintenance, etc.), but, quite inevitable, they will regard some traditional maintenance activities, as a result of the restructuring measures from the great industrial companies.

Executing the maintenance works by specialized companies represents one of the fundamental mutations in the industrial maintenance's activity. More flexible,

capable to adapt to the new exigencies, the maintenance companies have the vocation of specialists and they will offer more often their specialized, periodic services, which proves the fact that developing (or maintaining) the traditional maintenance departments inside the companies or creating new maintenance capacities [11] isn't justified from the economic point of view.

c. Human factors

The efficiency of the maintenance activities is conditioned by the involved staff, and not only the maintenance staff but the exploit staff, too. What might prevent a progress are the difficulties related to the persons involved and the relations between these persons. The fact that, even if the employed operates a machine eight hours a day, he doesn't feel more responsible about its maintenance it's regrettable, even if his activity is, on one side, related to achieving its own objectives and, on the other side, it ensures the proper functioning of its work tool.

We think that all these factors of influence are found or will be found (in the case of the technological factors) in the industrial companies from our country, too, and, in consequence, the maintenance activity should develop a new dimension characterized through:

- **A transfer of tasks towards the production and the companies specialized in maintenance.** This will lead to the progressive disappearance of the execution staff specific to the maintenance compartments. The current maintenance activities (visits, greasing, cleaning, small repairs, etc) should be gradually transferred to the production staff, through task diversification and the proper stimulations and the complex maintenance activities will be ordered to some specialized companies selected because of their competence and seriousness.

- **Ascribing new tasks to the maintenance compartment.** The tasks transfer towards the production and the resort to cooperation mustn't lead to the liquidation of the maintenance compartment inside the industrial units.

The maintenance's tasks will focus in three main directions:

- the maintenance activity's execution by the production staff (or for the start, mixed teams of production-maintenance), according to the established programs and with the help of the defined measures. This involves not only a role of prediction, but also that of counseling and assistance in difficult situations.
- contracting other companies' interventions and activities;
- exploiting all the information referring to the functioning equipments' behavior for improving the maintenance programs, for consumptions' optimization and the optimization of the replacements, for improving the equipments' reliability, for optimizing the maintenance methods, for renewing the equipments in due time.

For carrying out these tasks, the maintenance department should contain a staff, a not too numerous one, but one of a great professional competence, made of:

“experts”: engineers and technicians with a polyvalent technical training, capable to supervise the activities made by the external partners and to provide special technical assistance to the production teams;

“method agents”, charged with establishing and surveillance of the maintenance programs, making out the maintenance's specifications, information analysis from the equipments' history, etc.

Considering the things that were previously presented, the industrial maintenance's evolution is systematically presented in fig. 2.

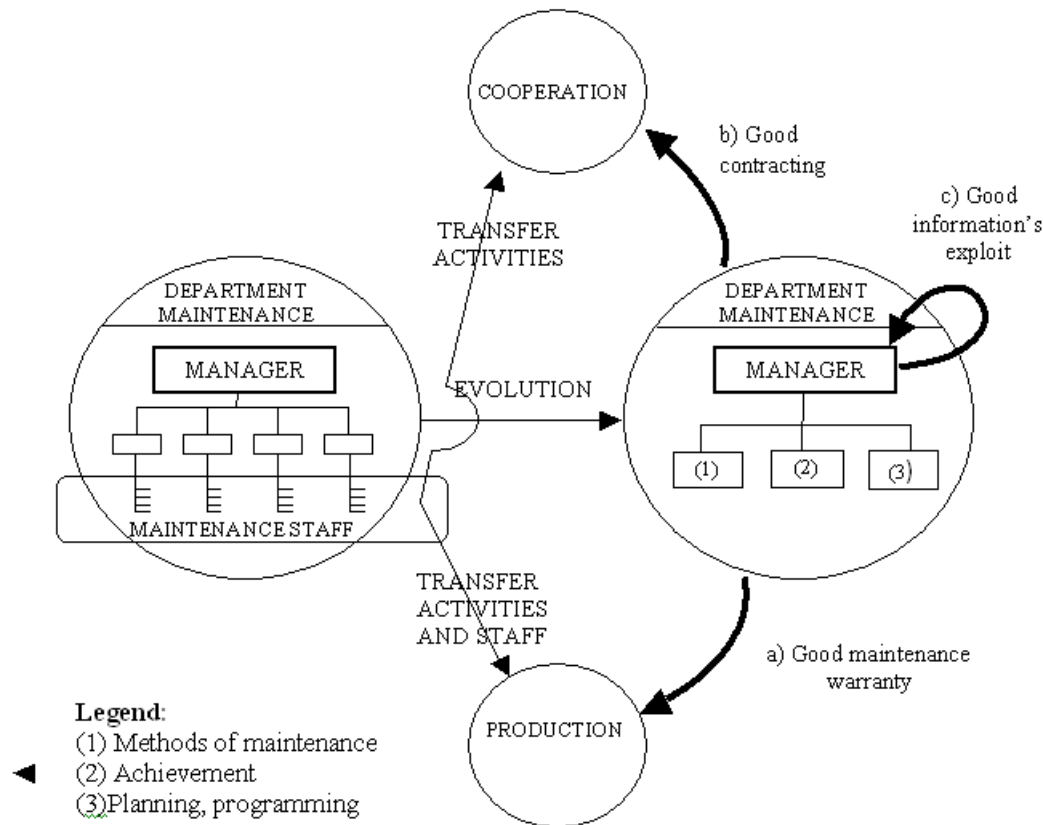


Fig. 2. The maintenance activities' evolution [1]

The maintenance's objectives result out of the general objectives, which, in an industrial company's case, focus on profitability, growth, security, etc. However, the profitability appears as a priority for the great majority of the industrial companies (in the current stage of recession, the surviving is the most important), being in the same way an imperative condition, allowing, for a long term, achieving some other objectives. The maintenance activity must, like the other activities, contribute to achieving an essential objective.

The maintenance activity's management, which figures through the other decisional centers inside an industrial unit can be defined through (figure 3):

- a. the general objectives it aims at;
- b. the respect restrictions and, in particular, regulations related to security;
- c. action variables that are available for achieving the objectives: methods and means of maintenance;
- d. estimation and control variables.

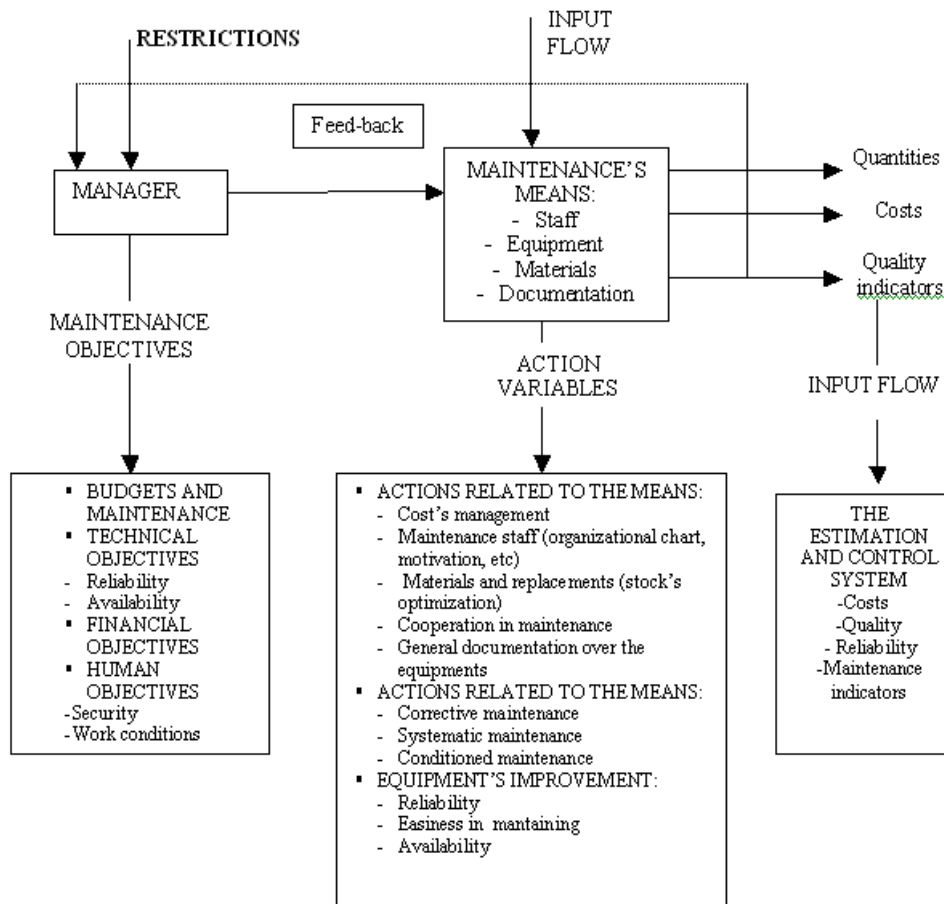


Fig. 3. The systematic analysis of the maintenance management [4]

The maintenance's general objectives are:

- The objectives related to security, which can be expressed through an increased reliability coefficient of the equipments that are prone to "critical" failures;
- The availability objectives for the whole company or for its key equipments;
- Objectives that are related to a certain maintenance budget, respectively those objectives that involve a diminishing to the minimum of the maintenance or objective costs, that aim at long term management's optimization of the equipments, substituting, if necessary, the equipment, aiming at optimizing the global cost in its life span.

There are also some long term objectives related to the equipment's management and maintenance. In reality, there are more possibilities for each industrial equipment and these possibilities are: maintaining the equipment functional by executing some maintenance activities, but with increasing

maintenance costs and non-efficacy costs (having in mind that the failures' coefficient increases in time); the equipment's modernization, the equipment's replace with an improved one; the equipment's replace with one with a new technology.

A more profound analysis of the place and the role of the maintenance activities inside the industrial companies reveals the fact that this activity is directly or indirectly involved in achieving the five operational management objectives, which are called the "five Olympic zeros", objectives that present a certain improving degree that seem capable to evoke an inaccessible ideal:

- Zero breakdown;
- Zero failures;
- Zero stock;
- Zero delays
- Zero paper.

The objective "**Zero breakdown**" is essential for the maintenance. Is it a utopia or an inaccessible-ideal? It's in fact an imperative

that must be achieved when people’s life is in stake [3].

The objective „zero failures” involves the quality management, but the maintenance is rigorously related to it, because a product’s quality is highly dependent of the tool’s and the industrial equipments’ condition, especially in the case of the automatic and robotized ones.

The objective “zero stock” also involves the process of maintenance, especially in the case of “just in time” organization, where the intermediary stocks are significantly reduced. This kind of result can be obtained just with a corresponding reliability of the upstream equipments [10].

The objective “zero delays” is relevant for the maintenance activity related to the interventions’ duration, in case of some accidental blockage, in order to reduce at the maximum the immobilization period.

The objective “zero paper” is indirectly related to the maintenance, but the informatics’ applications in the maintenance activity contributes to its achievement.

The industrial maintenance’s necessity results from the equipment’s tendency of failing in time. This failure risk depends in an essential way on the equipment’s reliability, but the failure’s consequences depend on the period in which they appear, related to the possibility of their being recovered, in other words by the maintenance. The conditions in which the equipments are used represent an important aspect of these failures. The equipments’ terms of usage are important for these kinds of failures. Therefore, the means through which the maintenance’s general objectives are achieved depend on more partners that intervene in the equipments’ conception and design stage, usage and maintenance.

S. Nakajima [7] [8] highlights five categories of measures taken for preventing the equipments’ accidental failures, measures in which there are involved the factors mentioned above and of which the maintenance objectives depend, as it results from fig. 4.

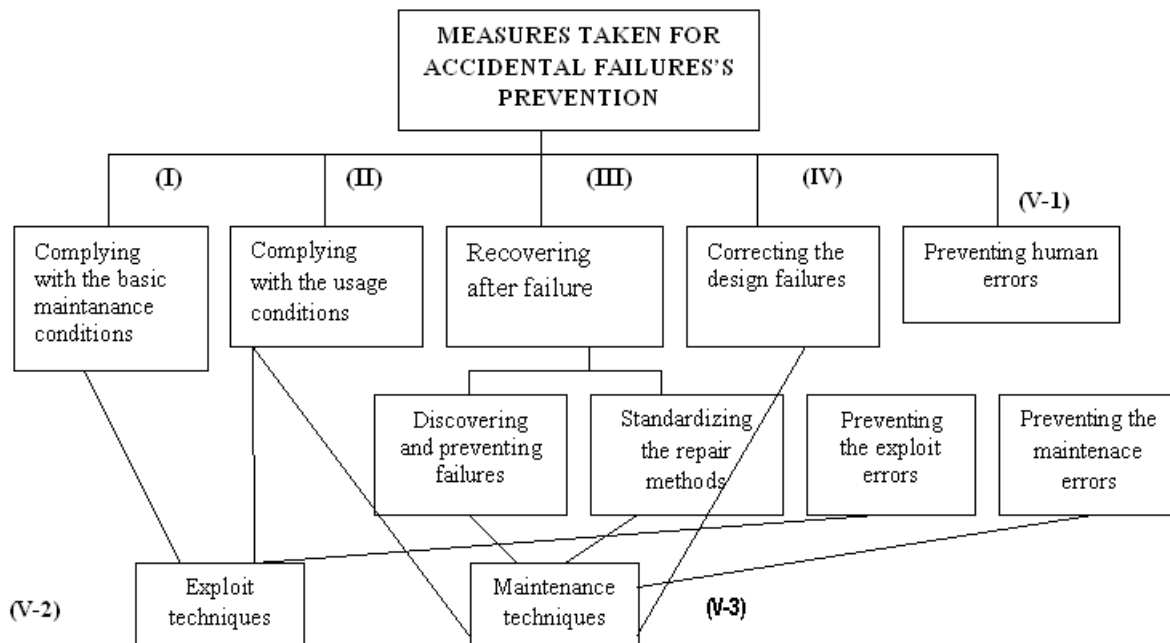


Fig. 4. Measures of preventing the accidental failures

3 The equipment’s evolution and its effect over maintenance

The industrial equipments’ technical complexity, the accidental failures’

catastrophic consequences from the economic and/or the social point of view impose the following measures for the maintenance activity:

a. The improvement of the staff's qualification, instruction and informing.

For assimilating the new technologies, the maintenance staff must be highly qualified. The staff's competence must be certified at the employment and through some qualifying actions. Therefore, the maintenance manager must dedicate a part of his time informing himself with the achievements abroad, in what concerns the technical skills and maintenance methods.

b. Associating the specialization with the polyvalence.

When confronted with new and complex techniques, the company is tempted to draw a conclusion: the maintenance staff must be specialized. But in the same time, considering the fact that there are multiple problems, the company will draw the conclusion that it needs some polyvalent people. Two apparent contradictory exigencies can be satisfied: creating teams of specialists, who must work together under a common coordination and total polyvalence, that can't be achieved by only one individual, but by a team. In general, we'll find in a maintenance department a staff with a certain technical polyvalence. The proportion between the two categories depends on the company's size and on how technical the equipment is. There is a tendency of placing in the first lines, in the production sectors, of either "generalists", or an polyvalent team, formed from various specialists and led by a generalist or the other way around, in the central maintenance departments, when they exist, teams made of technical specialists or people specialized on a certain type of equipment.

c. To predict and control.

In order to control the maintenance's costs, the prediction must be developed in all the domains:

- predicting the staff's management (career evolution, permutations, leaves, necessary instructions etc.);
- predicting the expenses for establishing predicting budgets;

- predicting and applying an operational technical documentation (the technical files categorized on types of equipments, technical files categorized on devices, logical repair schemes etc.);
- methods of predictive maintenance;
- work's planning;
- replacements' predictive management

On the other hand, we must develop the means of control in order to analyze the obtained results, to correct and improve the correspondent previsions:

- equipment's history in order to supervise and control the operation of equipment;
- the analysis of the costs and failures through the operations of selection, efforts' focusing, previsions and acting on the "blind spots or the most expensive parts" (meaning, on the equipment's weaknesses);
- the dashboard to control different aspects of maintenance etc.

d. Increasing the rapidity of the intervention.

Irrespective of the prediction's quality, there will always be unpredictable situations in the maintenance's domain. It can be said that a maintenance activity without unforeseen situations is, by definition, a highly expensive maintenance. The intervention's rapidity can be measured acting on:

- the means of communication and informing;
- the staff's quality;
- the coordination of various specialists (a structural problem);
- the technical documentation, in order to be operational;
- material stock's management, like: transport means, maintenance tools etc.

An important issue that must be held in mind is the issue of the couple "maintenance-security", from the initial stage of equipment's design, in order to facilitate the access and guarantee a greater security of the staff and of the equipment.

e. The developing and the facilitation of the relationship production-maintenance and transferring some

maintenance operations towards production.

The manner in which the maintenance activity is organized must allow an improvement of these connections, which are primordial. The urgent matters will be the object of direct relationships between the executors, and the issues of improvements and modifications will be the object of profitability studies and of relationship between the persons who are responsible and the management. The maintenance compartment must participate at writing the orders of equipment's introduction, supervising and liquidation, it should be informed over the production programs and consulted on these programs' modifications in order to give the okay and to take the eventual necessary measures in the maintenance's domain.

A mixed team will establish the "production-maintenance", the list of banal maintenance operations that are the exclusive task of the production or exploit operators and the ones who need the services of a maintenance person. This process of operation transfer towards the production has as objective the costs' reduction and determines the production staff to closely supervise the equipment.

In the same time, through the fact that production offers the necessary assistance, when a maintenance agent must be accompanied (out of security reasons, or out of reasons that are inherent to the intervention executed), his being accompanied by another person must be avoided. In the same time, it's noticed that for the handling and supervising of the automatic equipments, which are provided with tele-surveillance and functioning systems, it's necessary to hire in production some high trained operators. They can be properly instructed, even from the time in which they are hired, in order to be given all the "first degree" (or level one) maintenance operations, including emergency repairs and small maintenance operations. This maintenance transfer, named "level one" transfer, towards the production, is

facilitated, at modern equipments, by the presence of:

- systems of maintenance's tele-surveillance, which allow the supervising and control of an equipment's key points at a centralized location;
- diagnostic systems that allow the failures' visualization and determining the failures' causes;
- the "expert informatics" system that allows for the person who is interested an automatic technical assistance through detecting the flaw and studying the causes.

f. The developing and facilitation of the relationships between the research and design department and the maintenance department.

The best manner of reducing a cost element is the one of eliminating the elements that determine this cost. From this point of view, it must be considered, from the early stage of conception and investments' achievements, the problems raised by the equipments' maintenance. Important progresses are made, in this aspect, improving the relationships between the research and design departments and the maintenance ones.

These improvements are made through the following methods:

- in the industries in which the maintenance costs are superior to the processing operations' costs, will be assigned a person responsible with the equipment, which will have the responsibility of providing the production some equipments whose global costs (acquisition plus maintenance) are the smallest possible;
- the participation of the maintenance department at the design and achievement of the investments and at the research-design department for improving and modernizing the existent equipment;
- a common team will establish:
 - the documentation that must be given by the equipments' builders, suppliers and installers;
 - the list of necessary items of information regarding the nature,

the importance, the costs and the frequency of the failures and malfunctions, the costs of the maintenance's operation, the number of functioning hours, the necessary replacements, etc, the necessary elements for a better choice of equipments from the reliability, endurance and global cost's points of view;

- a policy of standardizing the equipment;
- general specification conditions related to the maintenance cooperation; it's desirable that some specification conditions of "maintenance" and "reliability" should be established.

g. The maintenance cooperation's development.

Nowadays, diversifying the equipments and techniques at play and the necessity of costs' minimizing doesn't allow a company to be endowed with all the maintenance means in order to face all the needs. In consequence, it must be appealed to cooperation in all the cases which are justified from the economic point of view. This cooperation's development needs [6] [11]:

- defining everything that must be executed through cooperation and the means in which this cooperation is executed, meaning defining a cooperation policy;
- establishing some specifications or specification conditions, general and specific to each activity achieved through cooperation;
- achieving a central coordination and a cooperation control, the assistance in informatics proving itself very useful in this domain;
- creating a department capable to be given the task of maintenance cooperation or to assist the persons who are responsible with the maintenance in choosing and estimating their partners, in the commercial negotiations and in controlling the cooperation operations.

h. The usage of modern means of information

A better development of a maintenance activity can't be imagined without possessing detailed information covering the knowledge, analyze and management of: the equipment that must be conserved; the materials stocks and the replacements; cooperation activity; equipment maintenance's costs. Only a "**maintenance's operational computerization**", with means that are adapted to its needs can be able to offer the necessary and sufficient information to the maintenance department and to the other departments involved in maintenance with a satisfying rapidity, accessibility and selectivity. This computerization's cost, even if it may seem high first, it may prove extremely low compared to the ulterior services it brings to the company.

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