NEED FOR COMPLIANCE PROGRAM DESIGN AND MAINTENANCE OF INDUSTRIAL EQUIPMENT RELIABILITY GROWTH

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Abstract: *Reliability is a feature that creates trust and confidence in a product design and gives a determining role in the constructive solutions. Due to the particular importance of reliability in recent years manufacturers have been obliged to specify information about the parameters of reliability and maintenance program when they deliver products to customers . If the manufacturing reliability may decrease due to technological deviations or exceptions to construction documentation, operational reliability can occur at the project level only if they respect relevant maintenance program design. The reliability may decrease if the operating instructions are not followed, adapted to the conditions of use, which may differ from one point in the life of the equipment of those originally considered basic or conceptual conditions. In this paper the concept of mentanance program designed to increase the reliability of mechanical energy and petrochemical industry is highlited.*

Keywords: *reliability, program maintenance, industrial equipment*

1. GENERAL CONSIDERATIONS

According to STAS SR EN 10307/75 reliability is defined as "the ability of a device to perform the intended function - for which it was created - for a given period of time, under specified conditions". Improved performance of mobile equipment is an ongoing concern operating engineers, resulting in increased reliability - "reliability growth" - something that can be measured qualitatively by decreasing or eliminating the causes of systematic failure and a reduction in the probability occurrence of other faults, quantitrative or give a significant improvement in reliability - in English "reliability improvement".

Reliability of equipment may result in the ability to avoid damage, the ability to be restored to operation after failure or after repair, lifetime. Lifetime is the rate falls marked with z (t) (Fig. 1) in the falling rate is directly proportional to the density distribution f (t) of the time fault-free operation and inversely proportional to the reliability of the system, with the relationship [3]:

$$\lambda(t) = \frac{f(t)}{R(t)} = \frac{\Delta n}{n} \cdot \frac{1}{\Delta t} \qquad (1)$$

Step B in which the failure rate has a high value is infantile stage, but this rate decreases continuously (Fig. 1) and covers faults in commissioning of the product. These faults should not occur, but occur due to faults in material or incorrect installation, undetected quality control and have to be removed during the phase of "running" (Fig.2).

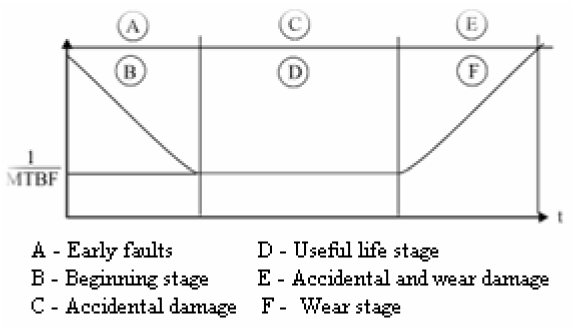

Fig. 1 The rate of failure of any product

It is recommended to be executed on *run-assemblies*, under normal operating conditions, the results are an indicator of the technical level of batch.

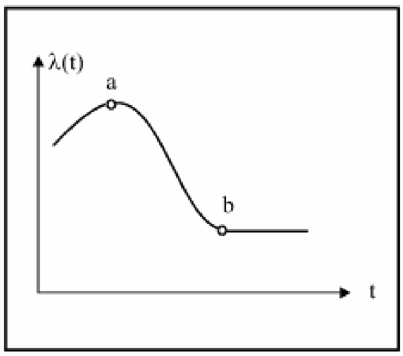

Fig.2 Stage and running-time of maturity

Step C product called *maturity period* or *useful life stage* is characterized only by accidental failures that can't be avoided and the relevant period in its operation (Fig.2 and 3). Step D or *old age stage* falling rate $\lambda(t)$ increases rapidly due Worn, consisting of two phases (Figure 3): A phase (occurring faults caused by wear combined with accidental damage) and phase B (occurring only faults caused by wear) [3].

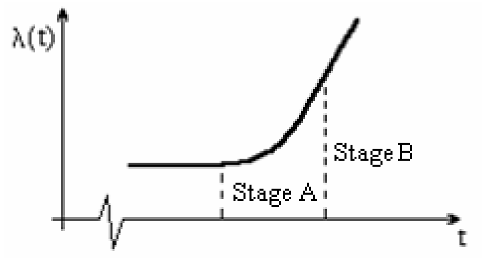

Fig. 3 Stage old age

The main objectives of the study reliability industrial equipment are:

- qualitative and quantitative definition of reliability: the causes of failures and ways in which they can be prevented or eliminated; physical analyzes of fault ;
- the behavior of the equipment under normal operating conditions and how internal and external factors affecting their operation;
- measures to increase equipment reliability through continuous improvement of technologies, methods of design, construction and operation;
- methods of calculation and simulation models with which you can make forecasts of equipment reliability; ways of processing and data selection with which equipment reliability analyzes;
- customer satisfaction on the characteristics of the purchased product. As shown in fig. 4, product quality desired by the customer must have satisfactory characteristics, in an area between the two lines :

- *characteristic line-lodging unsatisfactory*
- *identifying characteristics delightful line [6].*

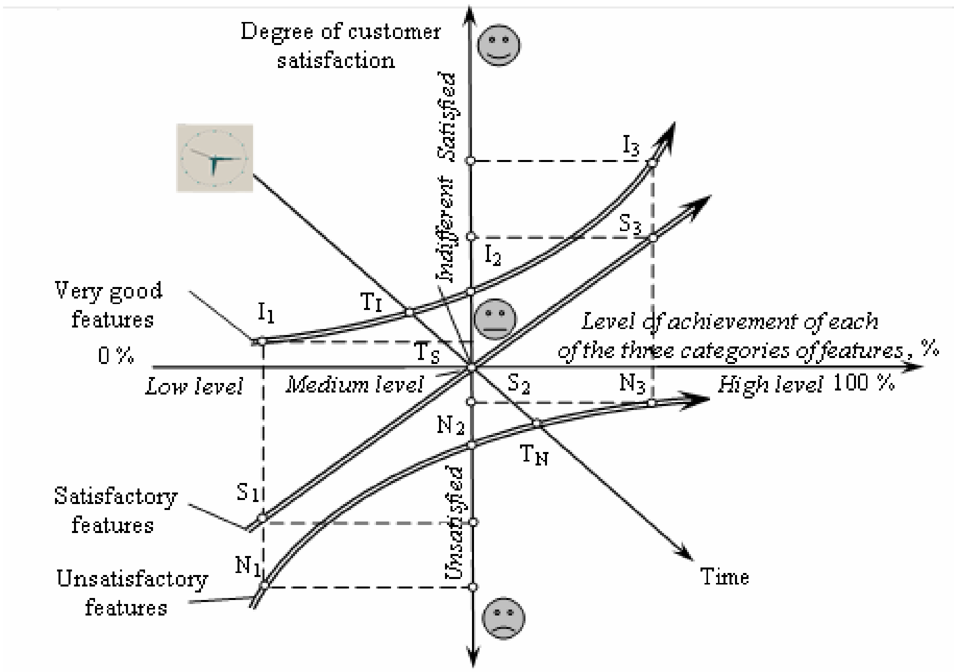

Fig. 4. Product characteristics and impact on the degree of customer satisfaction

Reliability can be defined in two ways:

a. *qualitative* - the ability to operate equipment to acceptable parameters specified operating conditions without failure within a specified time;

b. *quantitatively* - the ability of equipment to perform the functions for which it was created without damage within the time limits, and to maintain performance under operating conditions specified, quantified in the form of indicators (numbers) of reliability.

As a result of the fact that for certain manufacturing equipment the period of the manufacturing in series is large, it can be achieved a performance improvement of reliability thereof by using a feedback loop with the *loop-like automatic feedback* with the diagram shown in Fig. 5.

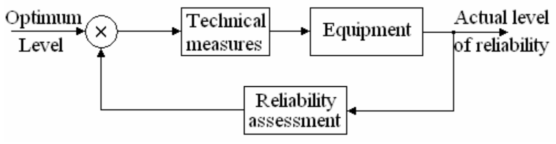

Fig.5. Scheme of reliability level control

A special role in the quantitative assessment of the reliability have the instruments to make the evaluation of the reliability of the equipment. Determining the optimal level of reliability is given by several factors, including the economic one, which is predominant. In the case of strategic equipment or very important (eg power plants - nuclear, intensive care equipment, etc.) to assess the reliability, safety and the economic determinant is a secondary target.

To determine the optimal level of reliability is a separation of manufacturing costs of equipment maintenance costs (operation), yielding a correlation between total costs and reliability of the product as shown in Figure 6. As can be seen, the optimal level of reliability in economic terms is the appropriate minimum total cost of production and maintenance.

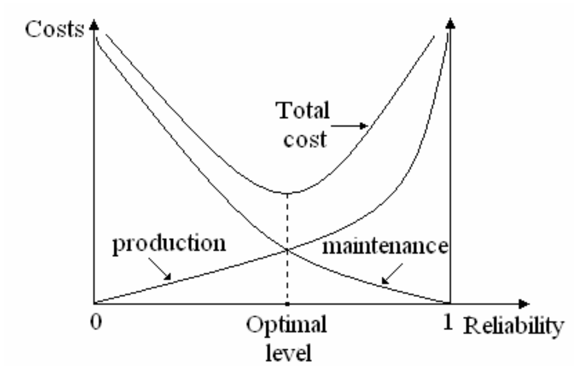

Fig. 6. Determining the optimal level of reliability

2. THE ASSESSMENT OF THE RELIABILITY OF INDUSTRIAL EQUIPMENT

The information required to determine the reliability of industrial equipment are obtained:

- forward - through the use of data tables representing the rate of failures or lifetime ;
- by creating databases that reflect the behavior of products in use ;
- by creating databases that summarizes the results of experimental tests of reliability ;
- by using software to simulate the operating conditions of the products .

2.1. Predicted reliability is determined by calculation based on the data tables containing various component parts falling rate. It takes place at the design stage, before the experimental phase, before entry into service or industrial.

Assessment of the reliability of the forecast calculations is based on the reliability of the components of the product and the development of functional connections schemes involving relatively low cost.

2.2. Experimental reliability is expensive because of the cost :

- the need for design and construction of stands and other test equipment with which to simulate the operating conditions of the products ;
- the need for planning a space that can accommodate test bench ;
- the need for highly qualified staff for organizing and supervising the tests for recording data processing and especially to draw conclusions ;
- the necessity of building a product sample to be achieved (whose number of products is default) to be tested experimentally ;
- reliability tests are destructive because the tests are carried up to failures;
- to ensure appropriate environmental conditions for operation of the test stands and associated equipment, record high energy (lighting of the premises, controlled humidity, proper temperature, etc.).

Experimental reliability can be ***estimated*** - when seeking operation of the product by testing in the laboratory or extrapolated - when making estimates on the life of the product on the basis of information obtained from laboratory tests [1].

In the laboratory tests, it is intended the product resistance (R) in response to the requests applied to (S) and it must be greater than the application (fig. 7).

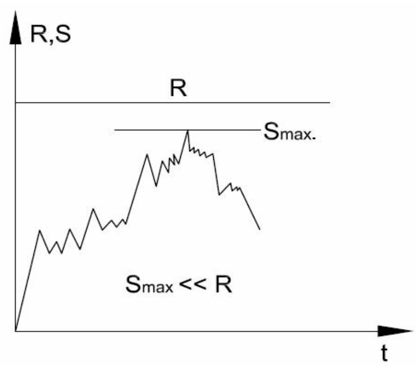

Fig. 7 Operating Conditions R >> S

In most cases, use endurance tests in which the equipment operates under particular conditions of constant $S=S_{max}<R$ (fig. 8) .

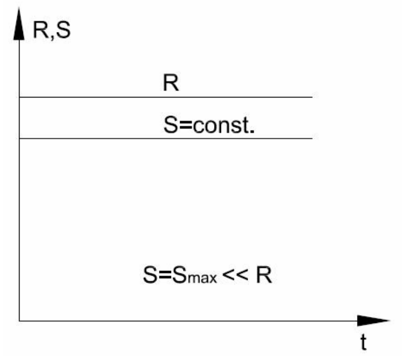

Fig.8. Endurance test $S=S_{max}<R$

2.3. Operational reliability is estimated based on operating and reliability with the lowest margin of error, reflecting best results reality. The disadvantage of this estimation is that to obtain a complete database requires a very long time.

In assessing operational reliability, part of the costs are passed on to the user of the product who at the same time uses it for the purpose for which he acquired it. Companies producing equipment malfunction take their data on the network of service stations repairing the equipment under operating at different customers, both during warranty and post warranty . Equipment manufacturer's task is to appreciate the predicted reliability and the experimental and operational reliability assessment is on both the manufacturer and the user of the product.

Indicators of reliability, according to STAS 10307-75 are sizes according to which the reliability of industrial products is characterized quantitatively, based on the law of distribution of time between fault-free operation. Given that the products are repairable, it can be considered that the undamaged elapsed time is a random size, whether we are talking about the period of time until the occurrence of the first fault is and the period between two failures.

Given that one of the indicators is known fault-free operation time, one can determine the equipment reliability :

1. *The reliability function R(t)*
2. *Non – reliability function F(t);*
3. *The density distribution f(t)* of operating time without failure;
4. *The intensity of the fault z(t);*
5. *The mean of better functioning (MTBF);*
6. *The standard deviation of operating time*

The standard deviation of operating time is a good indicator of reliability through which can be seen better time distribution function of a group of similar products.

To collect statistics on the distribution falls, it is necessary data obtained from observations made during certain periods of time, as shown in the table in Fig. 9.

Observation interval	Absolute frequency of falls	Relative frequency of falls	Absolute frequency of total falls	Relative frequency of total falls
t_0-t_1	k_1	k_1/N	k_1	k_1/N
t_1-t_2	k_2	k_2/N	k_1+k_2	$(k_1+k_2)/N$
…………...	……………..	…………….	…………..	…………….
t_{i-1}-t_c	k_i	k_i/N	$k_1+k_2++k_i$	$(k_1+k_2++k_i)/N$
…………..	…………..	……………..	…………….	……………..
t_{c-1}-t_c	k_c	k_c/N	$k_1+k_2++k_c=N$	1,00
Total	$\sum_{i=1}^{c} k_i = N$	1,00	----	----

Fig .9 Observation intervals and frequency of falls

3. EQUIPMENT FAILURE

Failure (in English "*failture*") is a physical-chemical process by which a device reaches a state of disrepair, resulting default ("*fault*"). In other words, the failure means a cessation of fitness equipment to perform the intended function or required.

To solve the problem of applied research failures put special emphasis on the development of types of equipment that are *tolerant to failures*. An equipment failure is considered tolerant when it can continue right functions for which it was designed (without external intervention), despite failures occurring during the operation.

A *failure* occurred during the use of equipment is a change in operating status or a deviation of quality characteristics occurring with sufficient severity that it does not fulfill the operational requirements, which leads to the change of output values or most often stop the gateway.

Damage may be caused by the following factors :

- *a physical imperfection* spent as part of an item of equipment leading to malfunction and may be temporary, intermittent or permanent ;
- *the inadequate* design, inappropriate choice of material, type of coupling and hence the type of bearings of the lubricant, etc ;
- *the chosen technology*, from manufacturing, assembly and coupling elements ;
- *external factors* (shock, vibration, humidity, temperature, electric field or electromagnetic disturbances) , leading to non-functioning equipment ;
- *operating conditions* manifested by deviations of working regime parameters ;
- *non-operating parameters* (strain) of equipment due to human error or overload device to achieve a higher production than normal ;
- *lack of a preventive maintenance program* on operations that must be made for equipment maintenance (lubrication , vibration measurement and temperature, checking the oil level in bearings , etc.);
- wear while equipment is an important factor influencing failure
- wear while equipment is an important factor influencing failure
- for equipments with functioning at different kinematic scheme, it is necessary to send a stream of force which implies a relative speed between components of the transmission, and the emergence of tangential forces [3];
- thermal distortion in time, although quite small, producing a uniform distribution of load on the active surface, which is passed on to other machine parts (bearings, gears, etc .) ;
- the occurrence of *shocks* during operation, depending on their intensity, can cause serious damage, being caused by several large accidental task due to a velocity discontinuities. To be protected against shocks, more and more systems are fitted with damping which take accidental shocks, thereby protecting equipment;
- *damage caused by the action of disturbing factors* in the environment. There are many disturbing factors that can produce a wide range of faults. Most a meet are: humidity, temperature, pressure, vibration, shock, dust and sand in suspension, solar radiation and nuclear , fog , microorganisms.
- *Damage caused by packing , handling, transportation and installation* of equipments and related replacement parts.

During operation, all equipment has a certain frequency of failures, calculated failure rate (in percent) is subject to maintenance activities. Overall cost of maintenance activity is 10-30% of the equipment, but can significantly increase, unless the schedule maintenance and repair are respected (Fig. 10). The occurrence of a fault involves sending an error message. Eliminating errors is usually achieved during laboratory tests that are performed for both increasing equipment reliability and for its approval.

To implement a system reliability is necessary to know the logic diagram of reliability, which includes:

- ➢ conducting analysis on the operation of the equipment and the influence of external factors on its operation;
- ➢ the modalities of failure that may occur during normal operation to every element and finding optimal solutions for equipment operation ;
- ➢ determine the influence that it has the status of each element failure in equipment operation;
- ➢ establish vital parts whose proper functioning depends on equipment operation.

On the studying of fault elements, it is assumed that the events are independent, although in practice primary failure of an item involves damage to other parts. These measures are provided for different stages:

- ✓ design stage;
- ✓ the stage in which the technology is developed;
- ✓ execution stage;
- ✓ operating and maintenance stage;

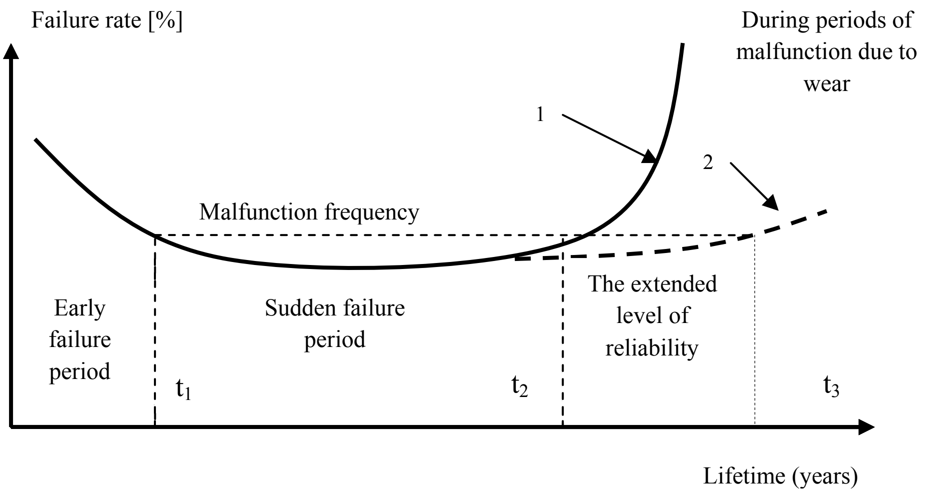

Fig. 10 Periods and frequency of failures occurred in the life cycle of equipment

4. MAINTAINABILITY OF INDUSTRIAL EQUIPMENT

Maintainability is the ability of industrial equipment that, in conditions of operating data, to be maintained or restored to fulfill the required function, when maintenance actions are carried out under conditions specified in a given time, the procedures and remedies prescribed [3]

The concept involves all maintenance operations required to maintain the operation of the equipment, which has a preventive or corrective character. Usually maintenance activities include maintenance and repair.

4.1. THE ORGANIZATION OF MAINTENANCE OF EQUIPMENT

Because the operation (use) of equipment leads to wear it is absolutely necessary a preventive maintenance strategy that will lead to a more rational and to extend the operation. The difference in the application of adequate maintenance (route DMN) shown in fig. 11 to another similar device is that it worked without a preventive maintenance (route DEFGH) [4].

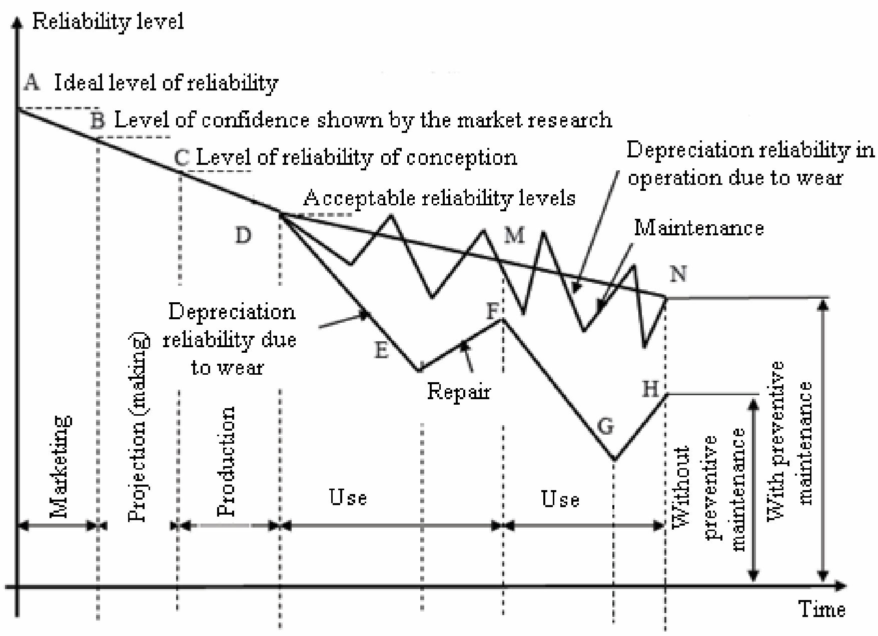

Fig. 11. Impairment of quality

Preventive works are divided into:

- *regular checks* (VP) are executed without stopping the equipment or very short stops under an hour to check and control its shortcomings , removing sudden blockages, etc.;
- *current repairs* (RC) are made for maintenance of equipment - usually called revisions - and include cleaning operations, repair, adjustment, and replacement of elements that have a high degree of wear due to the stresses to which they were exposed ;
- *medium repairs* (RM) are called intermediate repairs having to replace normal wear and tear components, troubleshooting mechanisms, performance or adjustments which require a work volume and a larger than cure current. Sometimes they are divided into two degrees of complexity (RM_1 și RM_2) ;
- *overhaul repairs* (RK) aim to complete overhaul of equipment by:
  - dismantling them completely;
  - checking subassemblies that can cause falls;
  - replacement of parts that have reached the limit of operation ;
  - replacement of drive belts , gaskets , bearings , etc.
  - upgrading works have been planned ;
  - making adjustments and a trial after repair.

Depending on the complexity and equipment failure rate, a graph can be made - in hours - the time interval between two repairs is called total operating cycle, and the time between an overhaul and a middle repair is called an average cycle (fig. 12) [4].

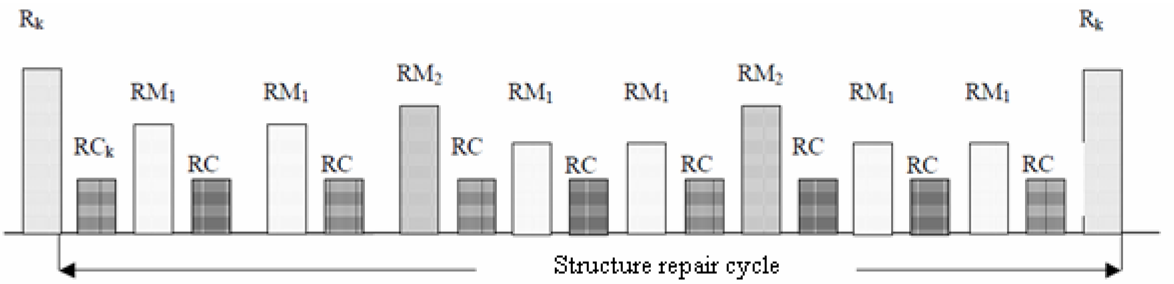

Fig.12. Total operating cycle of equipment

In time the equipment can only be in two states : running (F) and repair (R), often unnecessarily we increase the repair times due to lack of spare parts or failure to provide technical conditions for making repairs.

Maintenance activities are divided in [4] :

a) **Preventive maintenance**- aims to reduce the probability of failure or breakdown of equipment, which is of several types:

- *Systematic Maintenance* - is a set of maintenance activities, RC and RK, contained in a technical plan of action specific to each piece of equipment;
- *Conditional maintenance* include operations of checksing the parameters or wear, with the help of some special equipment AMC (vibration analyzers, instrumentation wear, etc.) ;
- *Maintenance foreseeing* is made by checks and analysis of the evolution of the main parameters of equipment degradation and allows postponement or planning interventions.

b) **Corrective maintenance** is all measures taken after equipment failure, which consists in locating and diagnosing faults , reinstatement of the equipment with or without modifications. These activities can be classified into two categories:

- *Curative maintenance* - involves performing corrective activities in order to restore the function of the equipment even if it has a specific operating condition. The purpose of these interventions (modifications , design , repair) is elimination of damage ;
- *Palliative maintenance* - involves carrying out corrective activities that aim reinstatement equipment provisionally , even if the unit does not work fully. Because these activities are only temporary curative action must be followed as soon as possible.

c) **Other types of interventions** (other repairs) :

- *accidental repairs* - performed in order to re-equipment in operating condition, as determined by accidental drops or sudden removal of equipment operation;
- *repairs refurbishment* - performed on equipment that have a high degree of wear and can be combined with various equipment modernization works;

- *damage repairs* - performed when the equipment fails due to improper equipment, faulty maintenance or due to natural disasters (fires, floods, earthquakes, etc.).

Given the complexity of maintenance activities performed , the following levels of maintenance activity are given:

Level I - activities that have a low to medium difficulty, performed by maintenance staff

- overall cleaning of the work area of the equipment ;
- adjustment of operating parameters , lubrication ;
- checking fluid levels, voltage clamping of different components, the extent of transmission belts ;
- preparation of records containing data on technological parameters obtained and the actual operating time and archiving ;
- maintain order in the workplace;
- other preventive activities carried out by small difficulty.

Level II - activities which have a higher degree of difficulty, performed by specialists:

- corrective current activities;
- preventive interventions that have a high degree of difficulty ;
- installation / relocation of equipment .

LEVEL III - activities which have a very high degree of difficulty, performed by specialists :

- corrective current activities that have a low degree of repetition occurring in exceptional cases ;
- current activities conducted by consultancy and supervision corrective maintenance activities .

Level IV - work performed occasionally systematically having a low degree of difficulty:

- a distribution of work between departments is made (production departments);
- interventions usually have a corrective feature .

4 . CONCLUSIONS

Because of the particular importance given to maintenance activities, managerial leadership should adopt different strategies that lead to goals. There can be addressed three objectives (alternatives) of the strategic maintenance activity [4] :

- carrying out their specific maintenance activities ;
- subcontracted maintenance activities;
- Purchase of equipment and new machinery.

THE STRATEGIES adopted for each strategic altenative are:

Strategic Alternative 1 - Performance of activities specific to their maintenance:

- Total Productive Maintenance (MPT)
- Investments' orientation
- Restriction of activity
- Focus activity
- Diversification of activities
- Reliability-based maintenance (MFB)

Strategic Alternative 2 - Subcontracting maintenance activities:

- Total Productive Maintenance (MPT)
- Restriction of investments
- Reliability-based maintenance (MFB)

Strategic Alternative 3 – Purchase of equipment and new machinery.

- Total Productive Maintenance (MPT)
- Restriction of investments
- Reliability-based maintenance (MFB)

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