FAILURE MODE AND EFFECT ANALYSIS OF WATER SUPPLY SYSTEMS

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The present paper intends to overview the problems of the failure mode and effect analysis of water supply systems. The author's efforts were channeled to systemizing, classifying and adapting the content to the hydraulics engineering field.

1. Description of the Method

Failure mode and effect analysis (F.M.E.A.) is a qualitative, inductive (from base to top) analysis method regarding safety in water supply systems operation. F.M.E.A. is adequate for studying the failures of materials, components, equipments and installations, and for studying the effects and the mechanisms that lead to their occurrence in the upper functional level of the water supply system. The F.M.E.A. method can be used for analyzing hydraulic, electrical, mechanical etc. technologies, that have relatively simple functional structures.

The F.M.E.A. method implies a comprehensive account of all failure modes for a system and, based on analysis, emphasizing their consequences on the elements (components) of the subsystems and the water supply system.

The objectives of the F.M.E.A. method consist of identifying the elements (components, modules, subsystems) that are reliability-wise vital for the water supply system and need modifications in order to reduce the probability of failure. The F.M.E.A. method can be used not only for reliability and security/risk studies for the hardware part, but also (in variants of the method) for maintainability, testability, software etc. studies.

The objectives of the F.M.E.A. method, according to (1.1), consist of:

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- Evaluating the effects and the succession of events caused by each known and analyzed failure mode of the components on the different levels of the water supply system;
- Emphasizing the potential failures and identifying the extent of the consequences they lead to;
- Determining the critical point of each failure mode taking into account its influence on the normal operation and the level of performance of the water supply system and of the installation that incorporates the system, as well as evaluating the impact on the security of the analyzed process;
- Classifying the failure modes based on ease of detection, diagnostic and replication, on the means necessary for maintaining the water supply system operating, etc.;
- Evaluating the risk level of the failures and the probability of failure.

In the initial phase, F.M.E.A. was created just for reliability analyses, but was subsequently extended to security/risk analyses for water supply systems. Since it is an inductive and systematic method of analysis, it can be used individually, as well as a complementary means to other deductive methods of system security analysis. For complex water supply systems with many functions and interconnections, the method is indispensable, but insufficient. In these cases the F.M.E.A. method needs to be completed by complementary analysis methods, such as the event-tree method, the failure-tree method, etc.

The F.M.E.A. method is a technique for post-checking the water supply system, allowing a critical examination of it. The inspection's purpose is to evaluate and demonstrate the water supply system's compatibility with the legal and technical provisions, and with the demands of the beneficiary.

Usually, the F.M.E.A. method doesn't include the analysis of human error effects and environment effects, but if the necessary modifications are made, it can be used for identifying the elements (components) of the system that are sensitive to these effects.

The information obtained by applying the F.M.E.A. method allows users to establish the priorities for an efficient control of the processes by:

- identifying singular failures that have unacceptable effects;
- analyzing the failure modes that can have serious consequences on the normal operation of the water supply system, the operators or the security of the environment ;
- providing for redundancies;
- structural modification or revision of the project;

- identifying the necessity for changing material, components or subassemblies of the water supply system;
- evaluating the occurrence probability of abnormal operating conditions of the water supply system;
- emphasizing the problems that can present risks, legal liabilities or contraventions of the legal provisions in effect;
- establishing the utilization cycles that can prevent and avoid failure due to wear and tear;
- identifying in due time design errors, which would help in avoiding expensive subsequent modifications;
- emphasizing the elements of the modules, subassemblies etc. that are critical in the operation (exploitation) of the water supply system;
- methodic, systematic and rigorous analysis of the elements of adjoining systems;
- in-depth knowledge of the water supply system analyzed by the reliability analyst.

Failure mode and effect and criticality analysis (F.M.E.C.A.) is an extension of the F.M.E.A. method, which also includes the criticality analysis by quantifying the effects of failures in terms of probability of occurrence and criticality for any failure mode. The probability of occurrence of failure modes is estimated based on known methods for evaluating reliability. Effect criticality estimation is conducted by referring to a set scale (unit of measurement).

The following can be emphasized by using the F.M.E.C.A. method:

- ✓ the elements that must become the object of an in-depth analysis, in order to eliminate or at least reduce the consequences with a high risk;
- ✓ the elements the exploitation of which should follow certain strict procedures;
- ✓ the superior parameters demanded in design, the performances, the reliability and assurance of the quality of the supplied water;
- ✓ the reception standards, PIF and parameters that must be provided during exploitation;
- ✓ the cases in which security and alarm systems or procedures must be provided, or precautionary measures must be taken;
- ✓ the situations for which emergency plans must be provided;
- ✓ utilization methods for the means provided for accident prevention.

Because of the above mentioned characteristics, we have used the F.M.E.A. method to analyze the water supply system of Oradea city.

In the practical use of the F.M.E.A. method, two basic techniques are employed: functional and hardware (1).

In the **functional** approach the subsystems, modules etc. are treated as black-boxes that carry out certain functions imposed in such way as to have the system accomplish its mission. The analyst engineer, when this approach is used, must analyze the effects caused to the system's mission by the lack of entrance signals as a result of internal failures of the subsystems, modules etc.

In the **hardware** approach the analyst studies each system component individually and establishes its failure rate. Based on the possible combinations of elements that lead to the same failure mode, a failure rate is established for each failure mode of the system. The preference of one technique over the other is conditioned by the available data at the time of analysis. In practice, most of the time we see combinations of the two analysis techniques described here.

Practical use of the F.M.E.A. method implied covering the following phases:

1) defining the analyzed system;
2) drawing up the reliability and functional block diagrams;
3) establishing the hypotheses and work principles;
4) identifying the failure modes;
5) analyzing the causes and effects of failures;
6) analysis of the possibilities for eliminating the undesired effects (effect compensation);
7) evaluating the risk associated with each failure mode;
8) recommendations, measures for repair and prevention.

2. Defining the System

Defining the system represents the first step in the application of the F.M.E.A or F.M.E.C.A. method. This phase allows the system analyst, reliability engineer, a well management of the component elements and the functions fulfilled by them, the working modes and the functions fulfilled or assured by the system in general.

In the first phase the characteristics, the role and the component elements functions of the water supply system, the links between the elements, the level and the type of redundancies are specified. The functioning modes in their different phases should be specified both for the system and for the components, after that, the framing characteristics for the acceptable or unacceptable functioning are specified. For this, it is necessary that the minimum performances of the water supply system should be specified, and the particular requirements, for example the availability and the security will be studied as compared to the specified performance or failure levels. For this matter the following issues must be identified:

- the duration of each intervention;
- the intervals between periodical verifications;
- the times of corrective intervention before severe consequences occur;
- assembly, installing and exploitation conditions;
- qualified staff for installing, exploitation and maintenance;
- mentenace conditions.

In this phase it will be also specified the environment conditions in which the water supply system works or to which it is accidentally exposed both from the environment and also from other subsystems linked to it.

3. Establishing the Hypothesis and Work Principles

For putting into practice the F.M.E.A. method, it should be mentioned from the beginning the explanation and assignation of work hypothesis and the approximations which will be used during the experiment.

The hypothesis will include both the definition of the system's lines and also the definition of the subsystem's lines, the modules, the sub modules, the elements and their analysis.

It is also compulsory the specification of the operating modes, the failure rates and failure modes for each analysis level, and also the characteristics for the in and out signals for each exterior element, with which it interacts and which can affect the reliability performances of the water supply system.

The analysis execution level was established even before the proper beginning of the study, for the water treatment subsystem. At the basis of this analysis level, the following criteria were taken into consideration:

- the water treatment subsystem has the highest risk degree regarding the final quality of water supply;
- the disturbance of the technological processes within any subsystem module can affect or even block the water supply for different sectors, having major implications, with important economic losses and endangering the consumer's health;
- the analyzed subsystem permitted the collection of sufficient data for each failure mode.

The information obtained by applying the F.M.E.A. method have been collected in table especially made for the water supply system from Oradea.

The table mentioned before includes columns regarding the following information:

- the treatment phase;
- failure mode;
- failure cause;
- failure effects both locally and also at the system's level;
- treatment phase which can overtake the function;
- repair measures;
- the gravity category of the failure;
- the failure probability of emergence;
- risk degree;
- observations.

4. Failure Modes Identification

The failure mode represents the effect by which a failure is noticed at the level of analyzed entity. In this phase, the list with the possible failure modes has been prepared, for all the elements of the studied subsystem, knowing that the F.M.E.C.A method has as main instrument this list.

Along the analysis, some of the failure effects identified at the lowest level, have become failure modes at the upper level, and the failure modes identified at the lowest level have become failure causes for the upper level.

The failure modes could be classified in two large categories:

1. general failure modes, inferred from defining the reliability of the water supply system;
2. specific failure modes, characteristic for the analyzed element.

In identifying and in defining the failure modes, we took into consideration:

- the destination of the subsystem;
- the element to be taken into consideration;
- the mode and the specifications regarding the functioning;
- the environment conditions and time limits.

Some of the general failure modes indicated by STAS 12689-88, are:

- ✓ premature functioning;
- ✓ it does not function at the estimated moment; it does not break up functioning at the estimated moment;
- ✓ failure during functioning.

Among specified failure modes noticed during the analysis the following are mentioned:

- clogging sand trap;
- unsuccessful chemical coagulation procedure;
- clogging the filtering level;
- proofing the filtering level;
- unsuccessful disinfestations chemical procedure.

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