RELIABILITY ANALYSIS OF AUTOMATIC METHANE CONCENTRATION MONITORING SYSTEMS IN JIUL VALLEY MINING UNITS

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Abstract: The paper presents a theoretical and practical analysis on the reliability of the automatic monitoring system used for the methane concentration supervision in all the underground mining units from the Jiu Valley.

Keywords: methane, reliability, underground mine, concentration, failure

1. INTRODUCTION

The problem of ensuring a high reliability is generally the issue of incorporating in the process of design-manufacture-operation of specific reliability activities.

Reliability is the extension of quality over time, it is achieved in all phases that a product goes through.

The need to estimate reliability generally arises in the following situations:

- when forecasting and demonstrating the reliability of a product, which is still in the design phase;
- when establishing the required reliability for a product;
- when verifying that a product in operation has operated or is operating at the required degree of reliability and whether it is capable of operating in the same manner for the remainder of the service.

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In the paper, the author aims to establish the reliability of power plants to control the decoupling of electricity to exceed the dangerous concentrations of CH4 and the ability to operate in the same way throughout the remaining service.

After defining the safety parameters against explosions in grizzly mining works, the paper presents the automatic control systems of CH4 concentration and their reliability.

A series of calculation programs were used to analyze the data and calculate the reliability parameters, the synthesis of the obtained results being presented below.

2. THEORETICAL SUBSTANTIATION OF SYSTEMS RELIABILITY

Reliability is, for the purpose of quantitative assessment, the characteristic of a product, defined by the probability that the product will fulfill its specified function, within a given time frame and under given conditions.

In order to determine the likelihood of technical equipment operating without malfunctions under certain conditions of use, in most cases even strict quality control of the parts and subassemblies that make it up is not sufficient. Thus, the analyzes performed by specialized institutions regarding the correlation between the precision, the quality of the parts and the finished product, led to the conclusion that no deviations from the technical quality requirements should be allowed, because any deviation regarding the quality of the parts is substantially amplified. at the level of the finished product.

Terms with the following meanings are used in the paper:

Reliability: the ability of a device or system to perform its specified function under given conditions for a predetermined period of time;

Failure: cessation of the ability of a device or system to perform its specified function;

Maintenance: the activity of maintaining the qualitative characteristics of a system, non-product structures.

Maintainability: the probability that a system will be put back into operation in a given period of time.

Availability: the likelihood that a product will be in good working order and can be used whenever required.

2.1. Theoretical considerations for reliability.

We consider that at a time t=0 (reference time) there are N_0 equipment in working order, after time t, in the time interval $[t,t+\Delta t]$ there are still N equipment in operation[5]. Thus in the time interval $[t, t + \Delta t]$ or faulty $\Delta N = N_0 - N$ equipment.

The share of the number of equipment N in operating condition at time t = 0 in the initial number of equipment N_0 (at t = 0) is called the reliability of the type of

[5] Obviously $N<N_0$

equipment at a time "t" and is given by the expression (1).

$$R(t) = \frac{N(t)}{N_0} \tag{1}$$

Taking into account relation (1), the function of density of faults can be defined, as follows:

$$f(t) = \frac{dF(t)}{dt} = \frac{d(1-R(t))}{dt} = -\frac{dR(t)}{dt} \tag{2}$$

A very important indicator of reliability is the failure rate λ(t).

The failure rate λ(t) is the rate of change of the probability of failure of an equipment at time t after a trouble-free operation at time t = 0.

We:

$$\lambda(t) = \frac{f(t)}{R(t)} = -\frac{dR(t)}{R(t)} \cdot \frac{1}{dt} \tag{3}$$

To define the probability function R (t) depending on the failure rate, the differential equation (3) is solved and results for the initial condition λ(0)=1:

$$R(t) = e^{-\int_0^t \lambda(\tau)d\tau} \tag{4}$$

and the reliability function for a time interval [t1, t2] is given by the relation:

$$R(t) = R(t_0)e^{-\int_{t_1}^{t_2} \lambda(\tau)d\tau} \tag{5}$$

The average operating time is the 1st order moment of the probability density, so:

$$MTF = \int_0^\infty t \cdot f(t)dt \tag{6}$$

Or

$$M = \int_0^\infty R(t)dt \tag{7}$$

The quadratic mean deviation of the operating time is given by the relation:

$$\sigma = \sqrt{\int_0^\infty (t - MTF)^2 \cdot f(t)dt} \tag{8}$$

Table 1 shows the indicators mentioned above, for the exponential law and Weibull of the reliability function, respectively;

Table 1

Parameter name	The exponential law	Weibull Law
f(t)	$\lambda \cdot \exp(-\lambda t)$	$\frac{\beta(t-\gamma)^{\beta-1}}{\eta^{\beta}} \cdot \exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right]$
R(t)	$\exp(-\lambda t)$	$\exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right]$
λ(t)	λ	$\frac{\beta(t-\lambda)^{\beta-1}}{\eta^{\beta}}$
M	$\frac{1}{\lambda}$	$\gamma+\eta\Gamma\left(\frac{1}{\beta}+1\right)$
σ	$\frac{1}{\lambda}$	$\eta\sqrt{\Gamma\left(\frac{2}{\beta}+1\right)-\Gamma^{2}\left(\frac{1}{\beta}+1\right)}$

where: λ- failure rate, η- dispersion parameter, β- shape parameter, γ- position parameter, Γ(x)-Euler[3] function of case I.

Remarks:

- The practice shows a good concordance of the exponential law with the experimental results in the case of electronic products and other complex technological equipment.
- The practice shows a good concordance of the Weibull law in case the defects are mainly due to wear and (or) aging phenomena. It is stated that the exponential law is a particular case of the Weibull law.

2.2- System reliability.

A) The notion of system in terms of reliability study is a set of simple, interconnected elements for which the parameters of reliability are known.

Thus, in order to calculate the reliability of a system, it is necessary to know the functional characteristics and the interdependence of the component elements, ie it is necessary to know the connection between the reliability of the elements and that of the system.

Given the occasion on which the reliability of the technical system is determined, the following steps can be considered:

- calculation of forecast reliability (in the design phase);
- calculation of inherent reliability (in booth laboratories);
- calculation of operational reliability (in the operation phase).

B) Calculation of the reliability of systems with series connected elements.

In the case of a system of series-linked elements, the reliability of the system is given by the value of the product of the reliability of the elements:

$$R_S(t) = \prod_{k=1}^{n} R_k(t) \tag{9}$$

where $R_j(t)$ represents the reliability of element j.

For the case of using the exponential law, the failure rate of the system is given by the value of the sum of the failure rates of the system elements:

$$\lambda_s = \sum_{i=1}^{n} \lambda_i \tag{10}$$

where λ_j represents the failure rate of element j.

C) Calculation of the reliability of systems with parallel connected elements.

In the case of a system with parallel connected elements, the calculation of the reliability of the system is determined by the probability of failure:

$$R_s(t) = 1 - F_s(t) \tag{11}$$

The probability of failure of the system is given by the value of the product of the probabilities of failure of the elements:

$$F_S(t) = \prod_{k=1}^{n} F_k(t) \tag{12}$$

where $F_k(t)$ represents the probability of failure of the element k.

Serviceability

Statistical evaluation of maintenance actions is performed by a distribution function called maintainability.

The calculation of maintainability can be done with the relation (13) in case of using an exponential model and (14) for using a Weibulian model.

$$M(t) = 1 - e^{\mu \cdot t} \tag{13}$$

$$M(t) = 1 - e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \tag{14}$$

where μ represents the repair rate and is defined in the equation (16);

The average repair time represents the first order moment of the probability density (13), (14) of the repair time.

$$MTR = \int_0^{\infty} t \cdot f_{rep}(t) \cdot dt \tag{15}$$

$$\mu = \frac{1}{MTR} \tag{16}$$

Availability

Equipment availability is defined by the distribution function (17) .

$$A(t) = R(t) + [1 - R(t)] \cdot M(t) \tag{17}$$

As a statistical indicator for the expression of availability, the availability coefficient can be calculated, which for the use of the functions of distribution of operating time and repair time in exponential form is :

$$A = \frac{MTF}{MTF + MTR} = \frac{\mu}{\mu + \lambda} \tag{18}$$

The graph of the interdependence between the availability, reliability and maintainability of the equipment is shown in fig. 1.

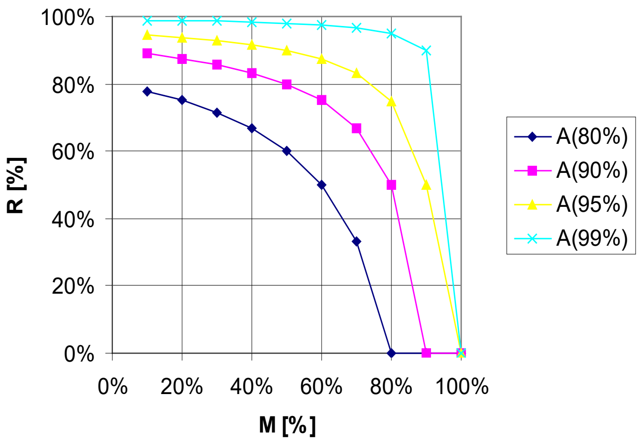


Fig.1. Graphic dependence on technical equipment reliability, maintainability, and availability in [%]

As can be seen in Fig. 1, reliability and maintainability are mutually compensated for in order to obtain a certain level of availability.

Thus, equipment with high reliability requires less maintenance operations for a certain availability for which other equipment with lower reliability requires more extensive maintenance operations.

Also from the diagram in Fig. 1 it is observed that for the high availability required for an equipment with high reliability, a small decrease in reliability (due to non-compliance with quality conditions in production), leads to a dizzying increase in maintenance operations required to maintain same availabilities.

Fig. 2 shows the availability variation depending on the reliability and maintainability of the equipment to highlight the effect of using less reliable equipment at the same level of maintenance operations on availability.

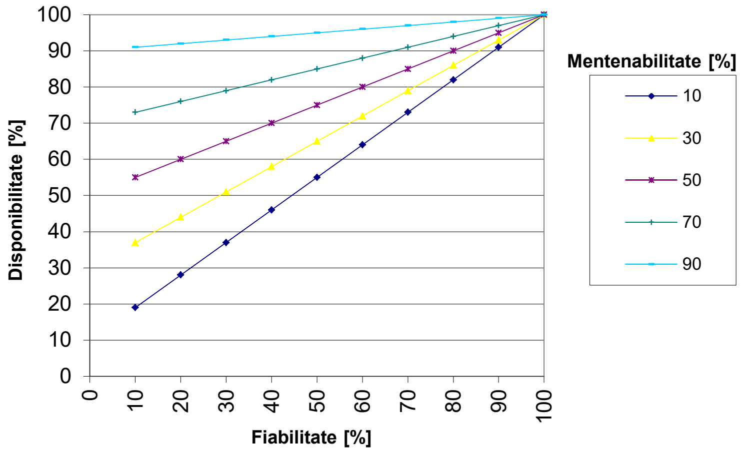


Fig.2. Availability variation depending on equipment reliability and maintainability as a parameter, in [%]

The reliability of a system depending on the reliability of the components is given by the relationship :

$$R_S(t) = 1 - \prod_{k=1}^{n} \left(1 - R_k(t)\right) \tag{19}$$

where $R_k(t)$ represents the reliability of the element k.

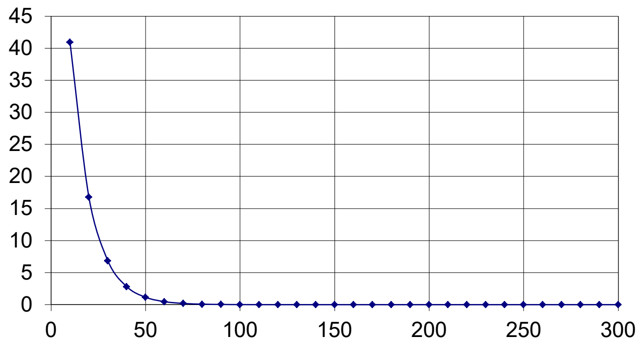


Fig.3. Dependence of the reliability of a system at time t_1 depending on the number of components[6]

The effect of the large number of series elements in a system is shown in fig.3. It is observed that in systems with a large number of series elements it is necessary to

[6] Assuming that the system consists of series elements with the same reliability

use redundant components in order to counterbalance the excessive decrease of the reliability of the assembly (system).

2.3. Determining the probability associated with the availability status of the automatic monitoring system.

We considered the probability of event S, in the case of an automatic monitoring system, given the relation:

$$P(S)=P(S_1)\cdot P(E_1)+P(\overline{S}_1)\cdot P(E_2) \tag{20}$$

with the following meanings: $P(S)=D(t+\Delta t)$ - system availability at the end of the considered interval; $P(S_1)$ - availability at time t; $P(E_1)=R(\Delta t)$ - reliability in the range (t, t+Δt); $P(E_2)=M(\Delta t)$ - maintainability in the range (t, t+Δt); $P(\overline{S}_1)=G(t)$ - unavailability at time t.

By replacing the terms in relation (20), we obtained :

$$D(t+\Delta t)=D(t)R(\Delta t)+G(t)M(t) \tag{21}$$

Having a constant failure rate λ and also a repair rate μ, i got :

$$\begin{aligned} R(\Delta t)&=e^{-\lambda t} \\ M(t)&=1-e^{-\mu\Delta t} \end{aligned} \tag{22}$$

By developing in series:

$$e^{-\lambda t}=1-\frac{\lambda\Delta t}{1!}+\frac{(\lambda\Delta t)^2}{2!}-\frac{(\lambda\Delta t)^3}{3!}+\dots \tag{23}$$

and by neglecting higher order terms, it results:

$$e^{-\lambda t}=1\cong\lambda\Delta t \tag{24}$$

By replacing these relationships into the previous expression (21), we have:

$$D(t+\Delta t)\cong(1-\Delta t)\Delta(t)+G(t)\mu\Delta t \tag{25}$$

from where:

$$D(t+\Delta t)\cong D(t)+\left[\mu G(t)-\lambda D(t)\right]\Delta t \tag{26}$$

By grouping the terms and using limits we have:

$$\lim_{\Delta t \to 0} \frac{D(t+\Delta t) - D(t)}{\Delta t} = -\lambda D(\Delta t) + \mu G(t) \tag{27}$$

Admitting a derivative for D(t) with respect to t, we obtain the differential equation of availability:

$$\frac{dD(t)}{dt} = -\lambda D(t) + \mu G(t) \tag{28}$$

Similarly, by analogous reasoning, one can write the differential equation of the state of unavailability. Unavailability at the moment t+Δt, marked with G(t+Δt), represents the state of unavailability of the automatic monitoring system at time t of the system which is not repaired in the interval (t, t+Δt), this state being described by the equation :

$$G(t+\Delta t) = G(t)\left[1 - M(\Delta t)\right] + D(t)\left[1 - R(t)\right] \tag{29}$$

With the substitutions made in the previous case, the equation becomes:

$$G(t+\Delta t) = (1 + \mu\Delta t)G(t) + \lambda\Delta t D(t) \tag{30}$$

where from :

$$\lim_{\Delta t \to 0} \frac{G(t+\Delta t) - G(t)}{\Delta t} = -\mu G(t) + \lambda D(t) \tag{31}$$

We have thus obtained the differential equation of the state of unavailability, which is of form :

$$\frac{dG(t)}{dt} = -\mu G(t) + \lambda D(t) \tag{32}$$

Knowing D(t) + G(t) = 1, by the corresponding substitutions in the respective relations, we obtained the following differential equations :

$$\begin{aligned} \frac{dD(t)}{dt} &= -\lambda D(t) + \mu\left[1 - D(t)\right] = D(t)(\lambda + \mu) + \mu \\ \frac{dG(t)}{dt} &= -\mu G(t) + \lambda\left[1 - G(t)\right] = G(t)(\lambda + \mu) + \lambda \end{aligned} \tag{33}$$

The above equations are first order differential equations of form:

$$\frac{dy}{dx} + Py = Q \tag{34}$$

where P and Q are continuous functions. The general solution is form :

$$y = e^{-\int P dx}\left[\int Q e^{\int P dx} + c\right] \tag{35}$$

noting y = D(t) ; P = λ + μ ; Q = μ, it results:

$$D(t) = e^{-(\lambda+\mu)t}\left(\frac{\mu e^{(\lambda+\mu)t}}{\lambda+\mu} + c\right) \tag{36}$$

The constant c is determined by setting the condition at the limit t = 0, for which the automatic monitoring system is available, respectively D(0) = 1:

$$1 = \frac{\mu}{\lambda+\mu} + c \tag{37}$$

from where:

$$c = \frac{\lambda}{\lambda+\mu} \tag{38}$$

We have thus obtained the following solutions of the differential equations:

$$\begin{aligned} D(t) &= \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\mu+\lambda}e^{-(\lambda+\mu)t} \\ G(t) &= 1 - D(t) = \frac{\lambda}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu}e^{-(\lambda+\mu)t} \end{aligned} \tag{39}$$

For very long durations, we can use the following approximate relation:

$$D = \frac{\mu}{\lambda+\mu} \tag{40}$$

3. RELIABILITY OF TELEGRIZOMETRIC INSTALLATIONS

3.1. Calculation of the reliability parameters of the automatic monitoring systems with telegrisoumetry control panels

The statistical reliability parameters that were established for the analyzed monitoring system are as follows:

- Failure intensity λ (fall rate):

$$\lambda = \frac{1}{MTFB}$$

which expresses the probability that the system in good working order will fail;

- repair intensity μ (repair rate):

$$\mu = \frac{1}{MTR}$$

which expresses the probability that the faulty system will be in good working order.

The average MTBF downtime and the average MTR repair time are calculated with the formulae:

$$MTBF = \frac{\sum t'_i}{n}$$

respectively :

$$MTR = \frac{\sum t''_i}{n-1}$$

where t'_i are operating times, and t''_i you have time to repair .

Another important reliability parameter that is calculated is the availability of the automatic monitoring system A, which expresses the probability that the system will be able to operate after a time spent for repairs required by the damage of a component, after a certain period of time. The proper functioning:

$$A = \frac{MTBF}{MTBF + MTR} = \frac{\mu}{\lambda + \mu}$$

3.2. Defining the reliability indicators specific to the automatic methane concentration monitoring systems with power plants.

The functional block diagram of the automatic monitoring systems with telegrizoumetric control panels, presented in fig.4, shows the arrangement of the system elements within the structure, as well as the concrete functional characteristics of the system.

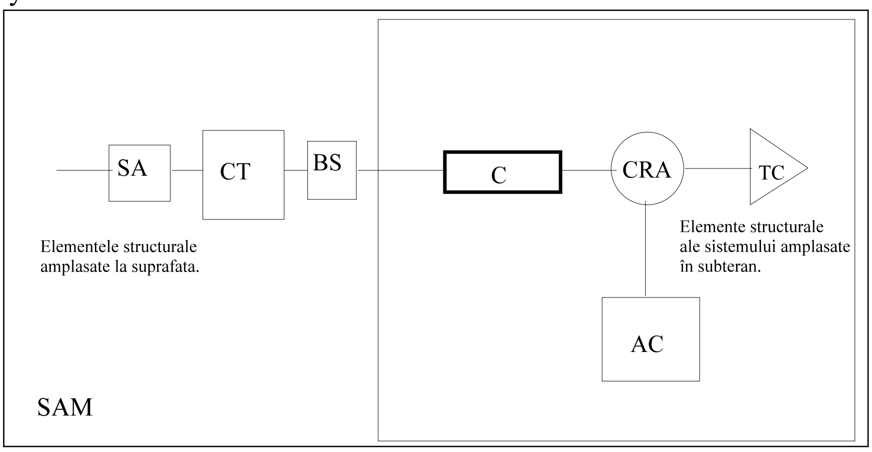


Fig.4. Block diagram of automatic monitoring systems with power plants

The determination of the reliability parameters was made statistically, as a result of the observation of several automatic monitoring systems with telegrizometric power plants, in a period of time as long as possible (one year)

The following reliability parameters have been calculated:

- MTBF, which is the average running time .
- MTR, which is the average repair time .
- $\lambda = \dfrac{1}{MTFB}$, what is the intensity of the failure or the rate of falls.
- $\mu = \dfrac{1}{MTR}$, is the repair intensity, or repair rate.
- $A = \dfrac{MTBF}{MTBF + MTR} = \dfrac{\mu}{\lambda + \mu}$, is the availability of the system.

In order to determine the reliability parameters of the automatic methane concentration monitoring systems with telegrizoumetric power plants, CTT-2 type, with microprocessor drawer, respectively CMM-20, not modernized, the analysis of these systems was made based on the records from the mining units, for each separate system, taking into account the data entered in the register of operation and operation of the telegrizoumetric installations and in the register regarding the maintenance, verification and repair works carried out in the telegrizoumetric installations.

These documents shall be completed in accordance with the technical requirements for the design, installation, operation, maintenance, inspection and repair of telegrizoumetric installations, PT-C-13, annex to the specific labor protection rules for coal mines. The analyzes were made for the period 1992-1996, so a period of 5 years, for the following power plants from the mining units within RAH:

- CTT-2 and CTT 63/40 Up, from E.M. Lupeni;
- CTT-2 and CMM-20, from E.M. Vulcan;
- CTT-2 from E.M. Aninoasa;
- CTT-2 and CMM-20, from E.M. Petrila;
- CTT-2 from E.M. Lonea.

3.3. Application for the calculation of reliability parameters and for the management of related information for equipment

Description

In order to determine the specific reliability parameters, the possibility of VBA programming and procedure code storage in Excel documents was used.

In the first stage, the databases (tables) for the "Equipment register" (fig.9) and the "Event register" were structured (fig.8).

The "Equipment Register" contains the following fields :

- Equipment - the name of the equipment ;
- Uniqueness - test for uniqueness in the name of the equipment ;

- Reference [dd.myyyyy mm: mm] - the date and time from which the equipment is considered ;
- MTBF [days] - the calculated program value of the average operating time;
- MTR [minutes] - the calculated program value of the average repair time ;
- Lambda [1 / day] - the calculated program value of the scale parameter ;
- Miu [1 / minute] - the value calculated by the program for the specific coefficient of the average repair time μ;
- A [%] - the value calculated by the program for the availability of the equipment.

The "Event Log" contains the following fields :

- Defect [zz.ll.aaaa oo: mm] - the date and time at which the defect was registered;;
- Commissioning [dd.mm.yyyy mm: mm] - the date and time the equipment was put into service after repair ;
- Equipment - the name of the equipment;
- DeltaT [min] - the calculated program value of the repair time in minutes ;

In addition, the "General" register contains the value of the date and time until which the calculation of the reliability parameters is taken into account.

Way of usage

To use the application, open the "reliability.xls" document or a copy of it.

Then pressing the "Start interface" button accesses the main panel (fig.5) from which you can select the interfaces for inspecting the equipment reliability parameters or entering other equipment in the database (fig.6) respectively for entering event-specific data - failure , commissioning (fig.7).

If you want to inspect the equipment reliability parameters or enter other equipment in the database, click on the "Equipment register" button.

If you want to enter event-specific data - fault, switch on the "Event log".

If you want to exit the program, press the "Exit" button.

The program only verifies the uniqueness of the equipment name, and the verification of the chronological aspects of the events remains the responsibility of the operator.

The source code of the application has also been inserted to highlight the programming details.

Fig.5. The main interface of the application

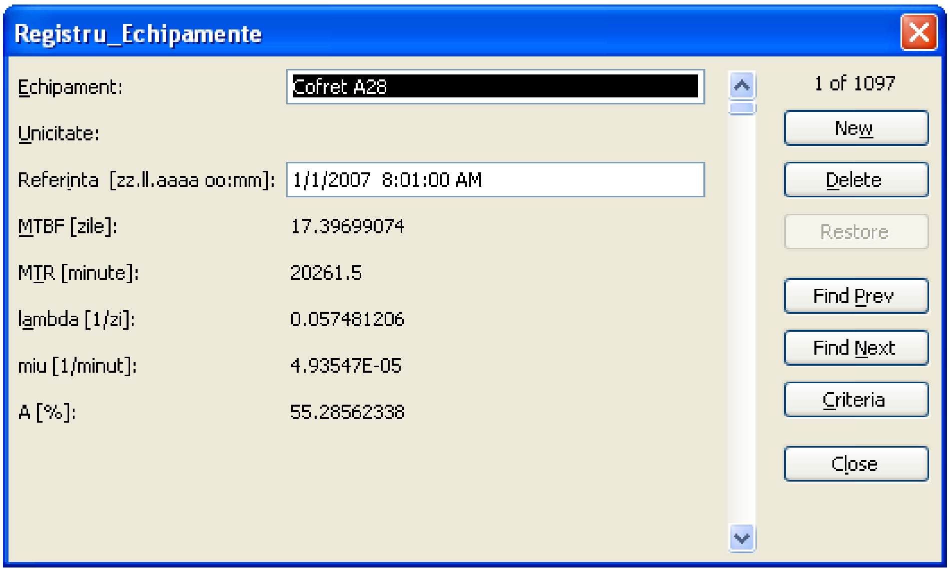


Fig.6. Interface for inspecting equipment reliability parameters or inserting other equipment into the database

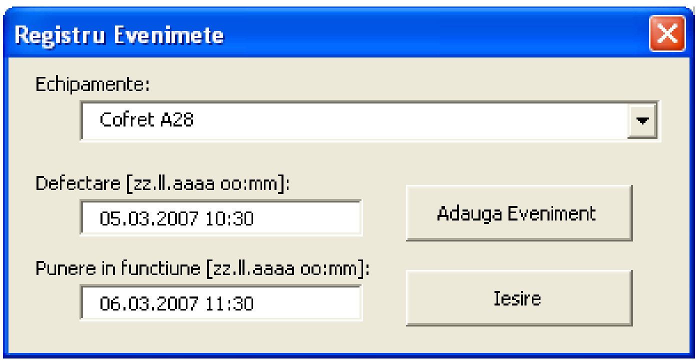


Fig.7. Interface for entering event-specific data (failure, commissioning)

Porneste Interfata	Nr inregistrari:	4	
Defectare [zz.ll.aaaa oo:mm]	**Punere in functiune [zz.ll.aaaa oo:mm]**	**Echipament**	**DeltaT [min]**
01.02.2007 08:00	01.03.2007 10:23	Cofret A28	40463
03.02.2007 10:03	05.02.2007 15:03	Contactor R89	3180
03.03.2007 10:03	03.03.2007 11:03	Cofret A28	60
21.03.2007 11:15	22.03.2007 11:15	Contactor R89	1440

Fig.8. Event database structure

Porneste Interfata							
Echipament	**Unicitate**	**Referinta [zz.ll.aaaa oo:mm]**	**MTBF [zile]**	**MTR [minute]**	**lambda [1/zi]**	**miu [1/minut]**	**A [%]**
Cofret A28		01.01.2007 08:01	17,39699074	20261,5	0,057481206	4,93547E-05	55,28562338
Contactor R89		02.03.2007 08:00	5,708333333	2310	0,175182482	0,0004329	78,06267806

Fig.9. Database structure with equipment

Table 2. **Formulas used in the spreadsheet**

Field	*Formula used to calculate*
MTBF [zile]	=IF(A3<>"";((Generalitati!$B$2-Registru_Echipamente!C3)+1/24*HOUR(Generalitati!$B$2-Registru_Echipamente!C3)+1/(24*60)*MINUTE(Generalitati!$B$2-Registru_Echipamente!C3)-1/(60*24)*E3*COUNTIF(Registru_Evenimete!$C$3:$C$6001;A3))/(COUNTIF(Registru_Evenimete!$C$3:$C$6001;A3)+1);"")
MTR [minute]	=IF(COUNTIF(Registru_Evenimete!$C$3:$C$6001;A3)<>0;SUMIF(Registru_Evenimete!$C$3:$C$6001;A3;Registru_Evenimete!$D$3:$D$6001)/COUNTIF(Registru_Evenimete!$C$3:$C$6001;A3);"")
lambda [1/zi]	=IF(AND((D3<>0);(D3<>""));1/D3;"")
miu [1/minut]	=IF(AND((E3<>0);(E3<>""));1/E3;"")
A [%]	=IF(D3<>"";100*(D3/(D3+E3/(24*60)));"")
DeltaT [min]	=IF(C3<>"";DAY(B3-A3)*24*60+HOUR(B3-A3)*60+MINUTE(B3-A3);"")

Source of the program

```
Attribute VB_Name = "Module1"
Sub porneste()
   UserForm1.Show
End Sub
VERSION 5.00
Begin {C62A69F0-16DC-11CE-9E98-00AA00574A4F} UserForm1
   Caption         =   "Fiabilitate echipamente"
   ClientHeight    =   2475
   ClientLeft      =   45
   ClientTop       =   435
   ClientWidth     =   3300
   OleObjectBlob   =   "UserForm1.frx":0000
   StartUpPosition =   1  'CenterOwner
End
```

```
Attribute VB_Name = "UserForm1"
Attribute VB_GlobalNameSpace = False
Attribute VB_Creatable = False
Attribute VB_PredeclaredId = True
Attribute VB_Exposed = False
Private Sub ButEchip_Click()
    Worksheets("Registru_Echipamente").ShowDataForm
End Sub
Private Sub ButIesire_Click()
    If Not ActiveWorkbook.Saved Then If vbYes = MsgBox("Documentul
nu este salvat, doriti sa-l salvati?", vbQuestion + vbYesNo,
ActiveWorkbook.Name) Then ActiveWorkbook.Save
    End
End Sub
Private Sub ButRegistru_Click()
    UserForm2.Show
End Sub
VERSION 5.00
Begin {C62A69F0-16DC-11CE-9E98-00AA00574A4F} UserForm2
   Caption         =   "Registru Evenimete"
   ClientHeight    =   2505
   ClientLeft      =   45
   ClientTop       =   435
   ClientWidth     =   5760
   OleObjectBlob   =   "UserForm2.frx":0000
   StartUpPosition =   1  'CenterOwner
End
Attribute VB_Name = "UserForm2"
Attribute VB_GlobalNameSpace = False
Attribute VB_Creatable = False
Attribute VB_PredeclaredId = True
Attribute VB_Exposed = False
Private Sub ButAddEv_Click()
   linie = Worksheets("Registru_Evenimete").Range("c1").Value+3
   Worksheets("Registru_Evenimete").Cells(linie, 1).Formula =
TBDefectare.Text
   Worksheets("Registru_Evenimete").Cells(linie, 2).Formula =
TBPunere.Text
   Worksheets("Registru_Evenimete").Cells(linie, 3).Formula =
CmbEchipamente.Text
End Sub
Private Sub ButIesire_Click()
    Unload Me
End Sub
Private Sub UserForm_Activate()
    CmbEchipamente.RowSource = "Registru_Echipamente!A3:A31"
End Sub
```

3.4. Analysis of the reliability of the automatic methane concentration monitoring systems with telegrizoumetric power plants from the mining units in the Jiu Valley.

The failures (defects) of the systems were systematized in the chronological order of their production, taking into account the structural elements resulting from the block diagram presented in fig.4, ie. defects at: the power supply sources of the system; the cabinet of the telegrizoumetric power plant; safety barrier cabinet; defects on the circuits (lines) of the telegrizoumetric installations; faults in the underground alarm reception devices and the transmission of disconnection commands to the switching devices which disconnect the electrical installations in the areas affected by accumulations; faults in the switching devices on which the disconnection pulse is given; defects in the detector-encoder assembly.

They were analyzed :

- *Obvious defects* : such as deliberate misalignment of the transducers in the electric zero or potentiometer to adjust the sensitivity, incorrect determination of the position of the detectors in the mining work, in length or profile, moving the detectors from the established positions, creating a false atmosphere by coating or diluting the real atmosphere with compressed air, shorting the contacts in the underground alarm receiving devices or in the control adapters, soldering the contacts of the intermediate control relays of the control adapters.

- *Obvious defects :* such as disconnection of alarm devices or control adapters from the ground, interruption of circuits (lines) from the cables to the ground, faults in the boiler cabinet or in the safety barrier cabinet, interruption of the boiler power supply, interruption of transducer filaments and all other defects that cause alarms and disconnection of electrical installations in areas where monitoring is no longer performed automatically, blocking the possibility of reconnecting those installations until the monitoring system is put back into operation .

For the automatic computer analysis of the statistical data obtained from the records from the mining units and for the calculation of the statistical parameters of reliability, the spreadsheet programs were also used to make EXCEL and WORD PERFECT graphs.

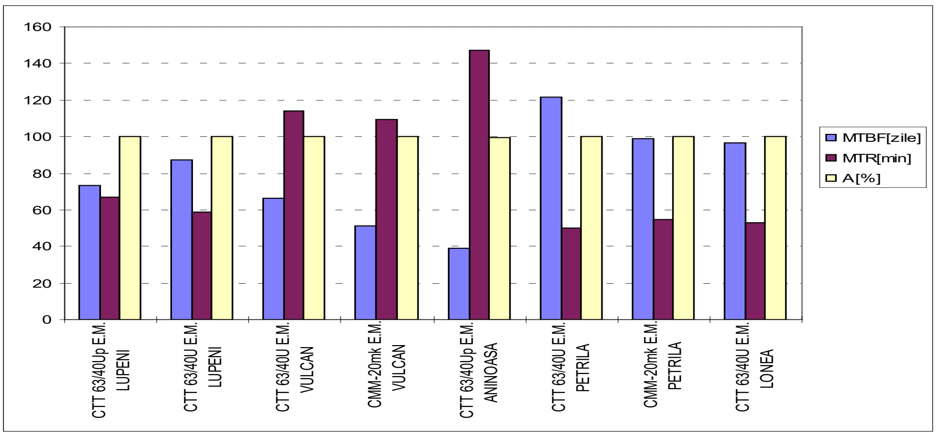
The result of this analysis is presented in tables (table 3) and in the form of graphs (Figure 10 a-h).

Table 3 **Analysis of the results in table form**

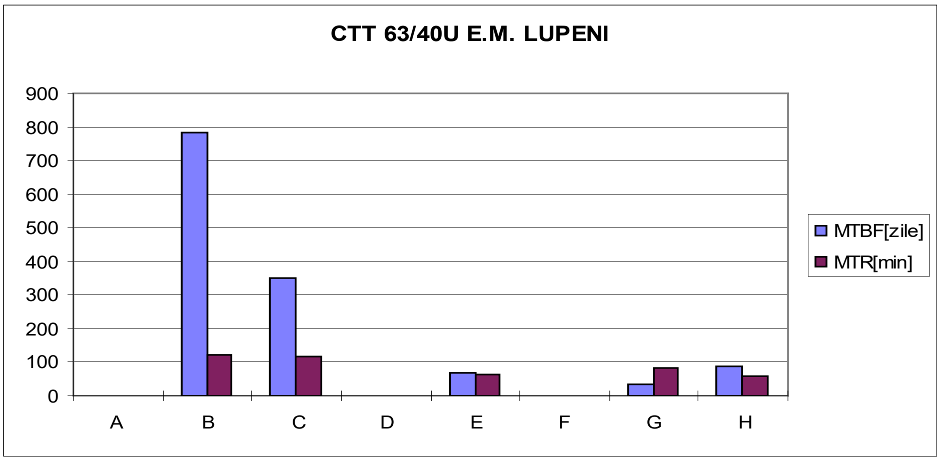
		CTT 63/40Up E.M. LUPENI	CTT 63/40U E.M. LUPENI	CTT 63/40U E.M. VULCAN	CMM-20mk E.M. VULCAN	CTT 63/40Up E.M. ANINOASA	CTT 63/40U E.M. PETRILA	CMM-20mk E.M. PETRILA	CTT 63/40U E.M. LONEA
A	MTBF[zile]	-	-	-	-	-	191	-	-
A	MTR[min]	-	-	-	-	-	45	-	-
A	λ[zile^{-1}]	-	-	-	-	-	0,00524	-	-
A	μ[min^{-1}]	-	-	-	-	-	0,02222	-	-
B	MTBF[zile]	97,5	781	959	140	-	100,667	51,3333	55
B	MTR[min]	57,5	120	290	101,667	-	42,5	59	42
B	λ[zile^{-1}]	0,01026	0,00128	0,00104	0,00714	-	0,00993	0,01948	0,01818
B	μ[min^{-1}]	0,01739	0,00833	0,00345	0,00984	-	0,02353	0,01695	0,02381
C	MTBF[zile]	351,5	351,5	-	-	-	187,75	187,75	181,1
C	MTR[min]	115	115	-	-	-	45	45	44,35
C	λ[zile^{-1}]	0,00284	0,00285	-	-	-	0,00533	0,00533	0,00552
C	μ[min^{-1}]	0,0087	0,0087	-	-	-	0,02222	0,02222	0,02255
D	MTBF[zile]	-	-	32,5455	32,5455	20,8947	128,2	128,2	131,8
D	MTR[min]	-	-	116,818	116,818	139,825	42	42	51,6
D	λ[zile^{-1}]	-	-	0,03073	0,03073	0,0486	0,0078	0,0078	0,00759
D	μ[min^{-1}]	-	-	0,00856	0,00856	0,00715	0,0238	0,02381	0,01938
E	MTBF[zile]	69,5714	69,5714	-	-	495	156,857	156,857	155,8
E	MTR[min]	62,8571	62,8571	-	-	700	55,7143	55,7143	56,4
E	λ[zile^{-1}]	0,01437	0,01437	-	-	0,00202	0,00638	0,00638	0,00642
E	μ[min^{-1}]	0,01591	0,01591	-	-	0,00143	0,01795	0,01795	0,01773
F	MTBF[zile]	-	-	-	-	-	147	147	149,5
F	MTR[min]	-	-	-	-	-	53,75	53,75	52,95
F	λ[zile^{-1}]	-	-	-	-	-	0,068	0,0068	0,00669

		CTT 63/40Up E.M. LUPENI	CTT 63/40U E.M. LUPENI	CTT 63/40U E.M. VULCAN	CMM-20mk E.M. VULCAN	CTT 63/40Up E.M. ANINOASA	CTT 63/40U E.M. PETRILA	CMM-20mk E.M. PETRILA	CTT 63/40U E.M. LONEA
F	μ[min^{-1}]	-	-	-	-	-	0,0186	0,0186	0,01889
G	MTBF[zile]	32,1	32,1	99,5714	99,5714	625	66,5833	66,5833	68,5
G	MTR[min]	81,125	81,125	107,143	107,143	310	79,1667	79,1667	81,4
G	λ[$zile^{-1}$]	0,03115	0,03115	0,01004	0,01004	0,0016	0,01502	0,01502	0,0146
G	μ[min^{-1}]	0,01233	0,01233	0,00933	0,00933	0,00323	0,01263	0,01263	0,01229
H	MTBF[zile]	73,2195	87,1	66,5854	50,9535	39,1695	121,575	98,8723	96,7
H	MTR[min]	66,686	58,9103	113,837	109,111	147,213	49,7826	54,4231	53,2
H	λ[$zile^{-1}$]	0,01366	0,01148	0,01502	0,01963	0,02553	0,00823	0,01011	0,01034
H	μ[min^{-1}]	0,015	0,01698	0,00878	0,00917	0,00679	0,02009	0,01837	0,0188
	A[%]	99,9368	99,9531	99,8814	99,8515	99,7397	99,9716	99,9618	99,9618

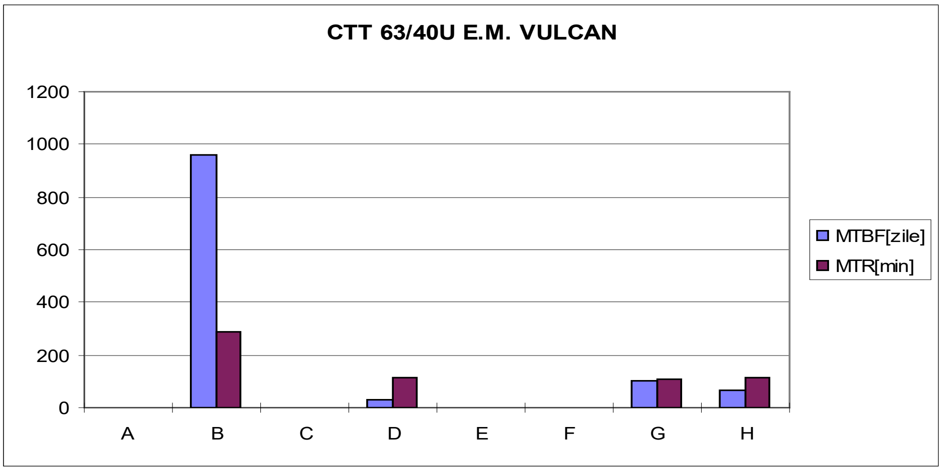
A - power supplies
B - the cabinet of the telegrizometric power plant
C - safety barrier cabinet
D - power cords (including branch boxes)
E – alarm reception devices
F – switching devices on which the disconnection pulse is given
G - encoders
H – automatic control and protection system



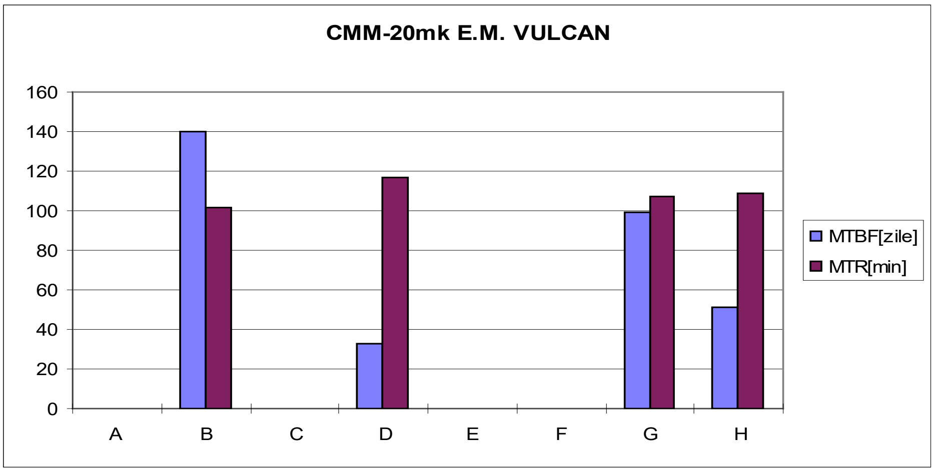
a)


CTT 63/40U E.M. LUPENI
900
800
700
600
500
400
300
200
100
0
A
B
C
D
E
F
G
H
MTBF[zile]
MTR[min]

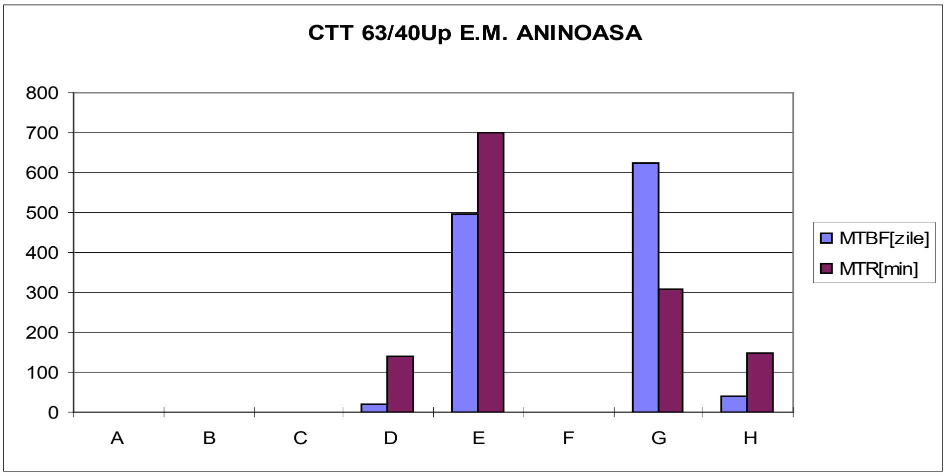
b)


CTT 63/40U E.M. VULCAN
1200
1000
800
600
400
200
0
A
B
C
D
E
F
G
H
MTBF[zile]
MTR[min]

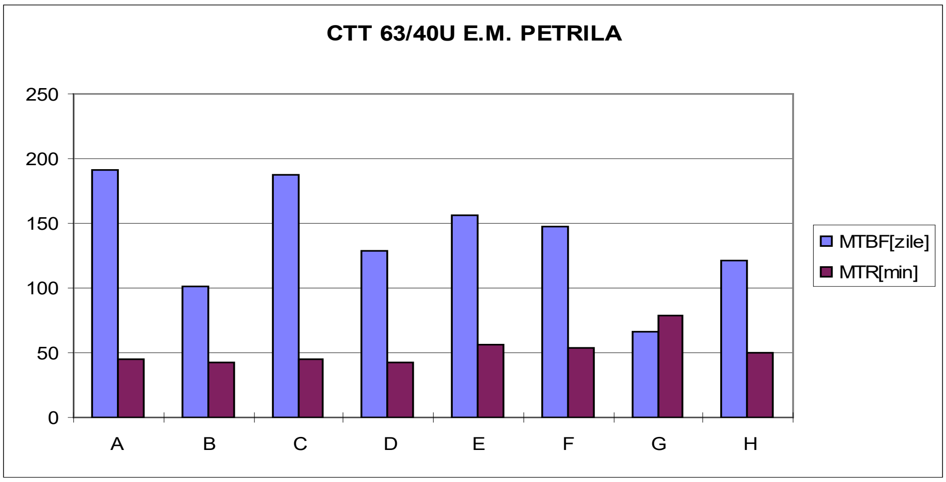
c)


CMM-20mk E.M. VULCAN
160
140
120
100
80
60
40
20
0
A
B
C
D
E
F
G
H
MTBF[zile]
MTR[min]

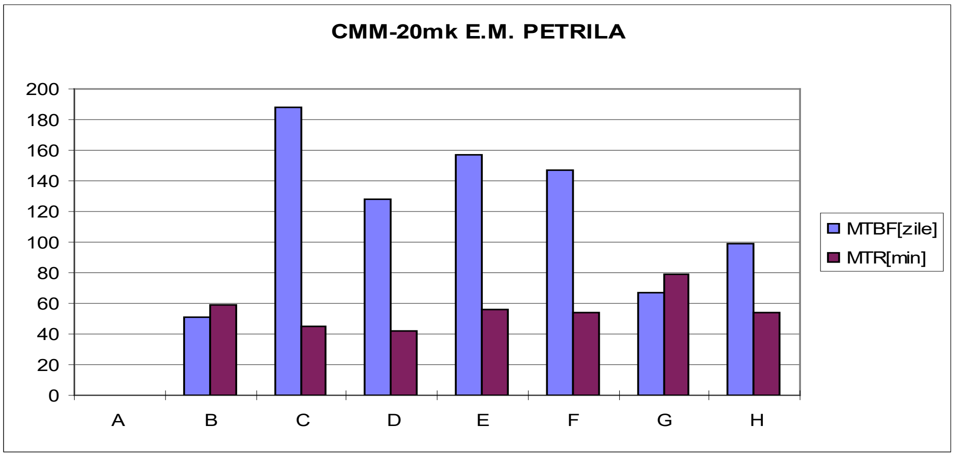
d)


CTT 63/40Up E.M. ANINOASA
800
700
600
500
400
300
200
100
0
A
B
C
D
E
F
G
H
MTBF[zile]
MTR[min]

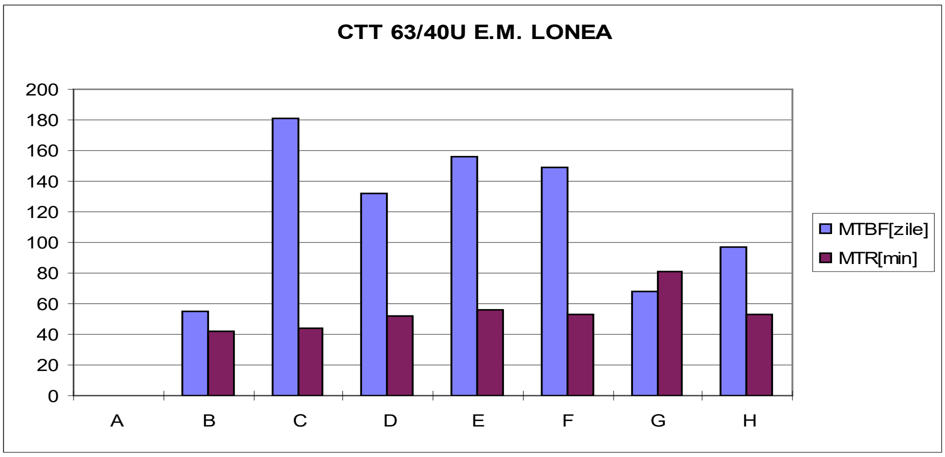
e)


CTT 63/40U E.M. PETRILA
250
200
150
100
50
0
A
B
C
D
E
F
G
H
MTBF[zile]
MTR[min]

f)


CMM-20mk E.M. PETRILA
200
180
160
140
120
100
80
60
40
20
0
A
B
C
D
E
F
G
H
MTBF[zile]
MTR[min]

g)



h)

Fig.10. Results of the analysis for each mine

5. CONCLUSIONS

- Evidence from mining companies is not uniform in interpretation and recording in terms of events (defects and their remediation), structural elements and the whole system.

- Existing records, except for the situation of the system with CTT-2 power plant, from the main enclosure from E.M. Petrila does not refer to power supplies (SA element). This is explicable given that in E.M. Petrila, during the analyzed period, there were problems with the general energy system to supply the main enclosure, disconnecting both sources provided for powering the plant.

- The availability of all underground methane concentration monitoring systems, made with telegrizoumetric power plants, is high, over 99.00%.

- The average good performance reliability parameter (MTBF) for the whole system indicates that it varies widely. For example, a maximum of 121,675 days was obtained for the CTT-2 boiler system from E.M. Petrila, but also a minimum of 39.1695 days for the system with the same type of CTT-2 power plant from E.M. Aninoasa. For systems with CMM-20mk type control panels, the MTBF parameter varies between a maximum of 98.8723 days at E.M. Petrila and the minimum of 50.9535 days from E.M. Vulcan. For the CTT 63/40 Up boiler system from E.M. Lupeni has an average operating time of 73.2195 days. It can be concluded that this parameter is not dependent on the type of power plant (functional blocks of power plants) nor on the structural elements of the complete delivery of these plants (transducers-encoders and alarm reception devices located underground).

- In the functional blocks in the cabinet of the power plant, the most frequent defect refers to the electromechanical recorders: breaking of the actuating wires of the pen support devices, breaking them, disturbing the advance devices, etc. In general, there are possibilities to repair these defects at the recorder even at the mining units, so the average repair time (MTR parameter) is relatively short.

- In the case of safety barrier cabinets, the only defects are related to the burning of ultra-fast fuses in the barriers, due to the appearance of leakage currents through the lines of monitoring systems, due to insulation defects, both in power installations and on power lines. telemechanics

- Cables containing telemechanics lines related to automatic monitoring systems have the lowest reliability. The MTBF parameter for this structural element varies between a minimum of 20.8947 days in Aninoasa and 131.8 days in E.M. Lonea. Moreover, for this structural element (element C), the average repair time (MTR) is relatively high, ranging from a maximum of 139,826 minutes to E.M. Aninoasa, about 51.6 minutes at E.M. Lonea. The causes of this situation are related to the faulty laying of the cables, to the very long lines, to the negligence of the personnel when transporting some oversized materials through the mining works in which the lines are installed.

- With regard to the transmission of alarms underground, this function is dependent on the reliability of the CRA structural elements (underground alarm reception devices, components supplied by plant manufacturers) and adapters for transmitting alarms and disconnection commands to switching equipment. Mining records are uneven in interpretation and values, for example, control adapter data exists only at E.M. Lonea and E.M. Petrila. The MTBF parameter for adapters, in value is relatively similar, 147 days or 149.5 days, but the average repair time (MTR) is high (about 53 hours). The cause is related to the lack of interchangeability of the adapter components. For CRAs, the reliability parameters are relatively similar in value to those for adapters.

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