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A New Model of Oil Pipeline (Oleduct) Risk Assessment

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ABSTRACT

Oil product transport pipelines are subject to failure processes, their technical accidents leading to environmental pollution, affecting human activities and especially high financial losses. That is precisely why conducting an audit regarding the condition of the pipeline is recommended by the legislation in force. The purpose of the article is to present the defects that may appear during the operation period of the pipelines transporting petroleum products and to establish a way of determining the risk in operation based on the use of numerical models created for this purpose. Also presented are the maintenance models of the main oil product transport pipelines and the history of the application of the risk assessment models in the operation of these transport systems. The model proposed in this article is based on the use of all the elements that can intervene in affecting the transportation systems of petroleum products, being the only evaluation system that uses neural networks, both in the definition of risk and especially in the establishment of pipeline rehabilitation methods.

1. INTRODUCTION

The transportation of petroleum products through pipelines is an industrial activity that, even if it meets all the conditions for ensuring safety in operation, there is still the risk of an industrial accident, which could affect the petroleum installations, the environment, the population and the employees of the company that operates the transportation system.

That is precisely why the existence of a procedure for determining the risk in operation and especially for determining the weak points of the system is useful and absolutely necessary. International legislation recommends the creation of procedures for determining the financial and environmental risk, and less the risk in the operation of oil installations.

The technical accidents of the pipeline systems, which also led to the loss of human lives, created the premise for the realization of a complex analysis of the transportation systems of petroleum products through pipelines, as well as for the realization of a system of risk analysis in operation.

If the existing systems dealt with certain effects of system damage, the present work starts from understanding the system as a unitary whole and dividing it into activity groups.

Following the analysis of the crude oil and petroleum products transportation system in Romania, the authors of this article created a risk determination model starting from the definition of the causes that could lead to an accident and determining their effect on the integrity of the pipelines.

It is also defined the needs of the rehabilitation of the system, as a result of the application of this model.

Analyzing specialized literature, we can say that accidents at petroleum installations and transportation of petroleum fluids (crude oil, natural gas, gasoline, liquefied gas, petroleum products) can occur:

- when putting the facilities into use (during the commissioning period),
- in the first 3-5 years of operation,
- after some scheduled repairs and overhauls,
- in case of non-compliance with the technological discipline,
- during pipeline abandonment operations.

2. THE FACTORS THAT INFLUENCE THE DESTRUCTIVE ACTION OF OLEDUCTS

The analysis of accidents at pressure vessels, pipelines, petrochemical reactors, facilities for the treatment and conditioning of crude oil and associated gases, as well as storage and conditioning tanks for chemical and petrochemical products, created the premises for the possibility of classifying the damage that can occur during the operation of the facilities oil tankers [1-3]:

a. Catastrophic breakdowns, which require, following their occurrence, the performance of major corrective maintenance works on oil installations and the replacement of some containers or components and sometimes even the entire installation.

b. Potentially dangerous damage. This type of damage requires the implementation of rapid preventive maintenance actions and thus combating a dangerous state of failure.

The breakdowns of oil fluid transport systems appeared both in the pre-operation phase (execution phase, pressure test, transport) and in the actual exploitation phase.

The accidents that occurred (analysis carried out on international pipeline systems), at pressure vessels (pipes, reactors and tanks), before commissioning, resulted [4, 5]:

a. Cracking of pipe material and welds. Damages were detected during the execution of pressure tests (40% of cases),

b. Catastrophic destruction (explosion) due to manufacturing conditions and detected during pressure tests (30% of cases),

c. Cracking of welds, observed during technological tests (10% of cases),

d. Corrosion of the pipe material, process noticed during pressure tests (10% of cases), or in operation (10% of cases).

Accidents during the exploitation phase were observed in 57% of cases through visual analysis, 29% were detected following hydraulic pressure tests (performed during overhauls), 8% following non-destructive examination and 6% following the explosive manifestation of technological processes [6, 7].

Most of the damages that occurred during the operation period were located near the welds (near them 70% of the cases) and in the components (connections) attached to the body of the containers.

Only 6% of cases were due to improper exploitation of oil installations (mostly due to the mismatch between actual operating conditions and design parameters).

A detailed analysis of the accidents that occurred in the crude oil transport pipelines was carried out by Chiș [8-10], the assessment of the defects that appeared in the operation of the oil fluid transport systems in Romania, highlighting the following causes of technical accidents:

a. Failure of measurement and control equipment, 16% of cases,

b. The appearance of defects as a result of failure to correctly perform the manufacturing process of the pipes, 4% of cases,

c. Failure due to internal and external corrosion of pipes, 50% of cases,

d. Defect due to non-compliant execution of welds, 5% of cases,

e. Defects arising as a result of external forces acting on the pipelines (criminal attacks), 15% of cases,

f. Defects resulting from non-compliance with technological discipline (errors in the coordination and operation of employed or subcontractor personnel for some investment or repair works), 5% of cases,

g. The appearance of some destructive actions of the environment (erosion of water banks, landslides)-5% of cases.

In the analysis carried out by Amirat et al. [11] and Baek et al. [12], the authors found the possibility of accidents at natural gas transport pipelines, due to:

a. damage to the pipe material (29% of the analyzed cases),

b. operating errors (27% of the analyzed cases),

c. the interference of unauthorized works in the protection zone of oil fluid transport systems, of other operators or builders (27% of the studied cases),

d. non-compliance with the conditions imposed by the environment where the oil installations are located (11% of the analyzed cases),

e. failure of the mechanical equipment of the pipelines (6% of the studied cases).

The residual mechanical resistance is what maintains the safe operation of metal pipeline systems, necessary for the transport of oil, gasoline, liquid ethane and petroleum products.

It is recommended that the activities of transporting petroleum products through pipelines be carried out when the stresses created in the pipeline material are a maximum of 80% of the safe operating stresses of the system (the transport system should behave in the elastic domain of the stress-stress diagram).

It can be reduced mainly due to the following categories of factors [13]:

a. Natural exploitation factors:

- factors due to the environment in which the pipes are installed (erosive action of soil and water, corrosive action of water, microbiological action of soil organisms, etc.),
- factors due to the meteorological parameters of the location area (wind and precipitation action),
- factors due to the tectonic movement of the location area.

b. Factors due to improper use of materials and their faulty assembly (quality of steel, quality of welds, etc.),

c. Factors resulting from inadequate design of piping systems (choosing outdated design standards or omitting environmental factors present in the piping installation area),

d. Factors due to faulty installation of pipelines (faulty welding at the ends, faulty installation of insulation, inadequate installation of protection and control equipment, faulty installation of the cathodic protection system, etc.),

e. Factors arising from non-compliance with exploitation technology (high pumping pressures, frequent stoppages of the finished product delivery process, etc.),

f. Factors due to the use of transported substances, which are not in accordance with the design requirements (crude oil with a high content of reservoir water, salt water, corrosive waste, etc.),

g. Factors due to the frequent modification of the work regime and maintenance technologies (frequent modification of the organizational structure, reduction of maintenance expenses, inadequacy of the pipeline system for judicious exploitation, etc.).

The factors mentioned above are those that can ensure improper behavior of pipeline systems and create the conditions for their damage.

3. THE OLEDUCT DEGRADATION PROCESS

Pipelines for transporting crude oil and petroleum products are subject to the chemical and mechanical actions of the transported fluid and the surrounding environment.

These actions can result in a process of damage (degradation) of them, which usually leads to the appearance of some failures (damages) of the pipeline.

Damage to underground (buried) pipelines, in general, occurs as a result of physical, chemical or combined (physico-chemical) actions.

The fluid circulated in the pipes and the external environment (soil and air) in which they are located, are the main determining factors of the failure of the pipes.

The result of chemical actions is given by the phenomenon of corrosion of the pipe, the corrosion speed can be determined by measuring the wall thickness at determined time intervals.

The effect of corrosion is accentuated with the increase in the flow speed and the temperature of the fluid transported through the pipeline.

The main factors that cause the corrosion of petroleum fluid transport pipelines are:

- The type of hydrocarbons transported through the pipeline (the presence of free water in the interstices of the pipeline wall),

- The action of the location environment on the pipeline (installation of the pipeline in areas with standing water at the level of the pipeline),
- Their installation in the areas where cables and electricity transmission systems are located (underground or overhead installations),
- The interference of cathodic protection systems, related to oil fluid transport pipelines, mounted in parallel or in the case of their intersection,
- Defective installation of the mechanical and technological protection of the pipeline (destroyed insulation, etc.),
- Defective installation of cathodic protection installations,
- The activity of some bacterial populations on pipe insulation, which can be found in soil or waste water.

But there are also mechanical factors that can lead to the destruction of oil fluid transport pipelines, namely [13]:

- erosion of the pipeline inside, due to the mechanical action of some impurities in the transported fluid (sand, salt water, sulfur-containing impurities, etc.),
- the erosion of the pipe on the outside, due to its installation in an unstable area of the site and especially the displacement of some blunt elements located in the area of the pipes,
- the appearance of some vibrations of the pipes, due to the faulty installation of the pumps,
- the appearance of vibrations in the pipes, due to its installation on improperly designed supports (at a long distance or welded to the pipe),
- the occurrence of higher pressures than the designed one, as a result of the existence of areas with free gases in the pipeline, which are exposed to solar radiation.

Regarding the causes of oil pipeline damage, detected by the subsequent examination of breaks (tough or brittle), they are divided into two large groups:

- causes of damage in the pressurization conditions during the hydraulic test,
- causes of damage during the normal operation of the pipelines.

Hydraulic testing of pipelines is the simplest means of determining the state of integrity of pipelines, both at commissioning and during operation. In Romania, it is recommended that after the pipeline has been stationary for more than 2 years, the hydraulic test should be repeated, and once every 5 years, a hydraulic test should be performed.

Although these hydraulic tests are useful especially when putting pipes into use (when they achieve a maximum pressure of 1.5 above the operating pressure), it is found that not all defects are detected instantly (with long pipes there is the danger that small cracks or pores in the material of the pipe not to be detected - the drop in the temperature of the water in the pipe and therefore the drop in pressure being interpreted as the cause of these pores).

This is precisely why we recommend performing non-destructive
ILI (In-line) inspections (ultrasound or magnetic flux indentation) both when commissioning and when retesting the pipeline. From practice we recommend the inspection once every 2.5 years.

The failure states, corresponding to the causes in the first group, are mainly due to the following defects, pre-existing in the fluid transport pipeline system:

1) defects in the wall of the piping components (mechanical damage, cracks, lamination overlaps);

2) defects in welds and especially in longitudinal welds (superficial cracks, insufficient melting, pores, slag inclusions, inclusions at the boundary between the base material and the thermal influence zone, non-penetration, non-compliant repairs);

3) welding defects (welding without preheating, excess deposited material, arc ignition burns, hardened areas);

4) defects specific to welding carried out in the field (on site).

The failure states, generated by the causes from the second group, are due to:

1) defects and damage detected in the wall of the tubular elements (mechanical deterioration, corrosion, cracking or fracturing due to hydrogen appearing in the pipe material, blistering);

2) defects and damage in welds, especially longitudinal ones (welding defects, selective corrosion, cracking or fracturing by hydrogen in hardened areas);

3) construction-execution and operation-supervision anomalies, respectively the occurrence of special situations (additional requests not considered in the design calculation, wrinkles of the pipelines or the protection system, inflammation of the transported product and its internal combustion, explosions, diversionary actions and sabotage).

4. DANGERS OF OLEDUCT DEGRADATION

The dangers of pipeline degradation have been divided into several categories depending on their destructive action.

a. Hazards that are dependent on the operating time (time dependent):

- A.1. External corrosion of the pipe,
- A.2. Internal corrosion of the pipe,
- A.3. Cracked corrosion (due to the internal stresses of the pipe material).

b. Dangers due to improper construction of equipment, measuring and control devices, tubular material and pumping systems (stable):

b.1. Defects due to improper manufacturing of pipes (manufacturing related defects),

- B.1. Pipe seam defects,
- B.2. Manufacturing defects of pipe material (defective pipes),

b.2. Defects due to the location and improper installation of the pipes

-B.3. Defects of the welded joints (between the pipeline pipes) (defective pipe girth weld),
-B.4. Defects due to welding (defective fabrication weld),
-B.5. Wrinkles or folds due to the improper curvature of the pipes (wrinkle bend or buckle),
-B.6. Damaged threads/inappropriate pipe/ damaged plugs or sleeves (stripped threads/broken pipe/ coupling failure).

b.3. Defects of pipeline equipment (equipment failure)

- B.7. Gasket O-ring failure,
-B.8. Improper operation of control and safety equipment (control/relief equipment malfunction),
-B.9. Cracking of pump housings/failure of sealing systems (seal/pump packing failure),
- B.10. Various causes (miscellaneous).

Hazards that are dependent on the operating time (40% of the calculation value)

Categ.	Element analysis name	Scores	%
A1	***Corrosion of pipes and installations located above ground***		***40***
	A.1.1. Corrosion of external installations		30
	- wall thickness over 80%	5	
	-wall thickness 80-60%	4	
	-wall thickness 60-40%	3	
	-wall thickness 40-20%	2	
	-wall thickness 20-0%	1	
	A.1.2. Cathodic protection installations		20
	- existence of cathodic protection	1	
	- lack of cathodic protection	2	
	A.1.3. Analysis of stray currents		10
	- existence of grounding facilities	1	
	- lack of grounding facilities	2	
	A.1.4. Active conduit grounding analysis		10
	- existence of electrically insulating flanges in working condition	1	
	- existence of faulty electro-insulating flanges	2	
	- absence of faulty electro-insulating flanges	3	
	A.1.5. Inspection program analysis		10
	- existence of inspection program	1	
	- lack of inspection program	2	
	A.1.6. Maintenance schedule analysis		20
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program.	3	
A2	***Corrosion of pipes and installations located in the basement***		***50***
	A.2.1. Corrosion inside pipes		20
	- wall thickness over 80%	5	
	-wall thickness 80-60%	4	
	-wall thickness 60-40%	3	
	-wall thickness 40-20%	2	
	-wall thickness 20-0%	1	
	A.2.2. External corrosion of pipes		20
	- wall thickness over 80%	5	
	-wall thickness 80-60%	4	
	-wall thickness 60-40%	3	
	-wall thickness 40-20%	2	
	-wall thickness 20-0%	1	
	A.2.3. Cathodic protection installations		10
	- existence of cathodic protection	1	
	- lack of cathodic protection	2	
	A.2.4. Analysis of stray currents		10
	- existence of additional anodes and leakage current drainage facilities	1	
	- absence of additional anodes for picking up dispersion currents	2	
	- lack of facilities for draining stray currents	3	
	- lack of additional anodes and leakage current drainage facilities	4	
	A.2.5. Potential pipeline analysis		10
	- potential of 850-1150 mV	1	
	- potential 850-650 mV	2	
	- potential above 1150 mV	3	
	- potential below 650-mV	4	
	A.2.6. Inspection program analysis		10
	- existence of inspection program	1	
	- lack of inspection program	2	
	A.2.7. Maintenance schedule analysis		20
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program.	3	
A3	***Corrosion due to stress cracks in the pipeline***		10
	A.3.1. Inspection program analysis		50
	- existence of inspection program	1	
	- lack of inspection program	2	
	A.3.2. Maintenance schedule analysis		50
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program.	3	

HAZARDS THAT ARE DEPENDENT ON THE OPERATING TIME (40% OF THE CALCULATED VALUE)
B.1. DEFECTS THAT MAY OCCUR DURING THE MANUFACTURE OF THE PIPE– 40%

Categ.	Element analysis name	Scores	%
B1	***Defects of welded pipes (welding technology analysis)***		***50***
	B.1.1. Optimum welding temperature assurance		30
	-welding temperature assurance	2	
	-welding directly without insurance welding conditions	1	
	B.1.2. Automatic flow welding		20
	-realization of welding in automatic flow	2	
	- manual welding	1	
	B.1.3. Constant weld bead insurance		20
	- 3 layers of welding	1	
	- 2 layers of welding	2	
	- 1 layer of welding	3	
	B.1.4. Conduct welding inspection		20
	- NDT control	1	
	- control with magnetic powders	2	
	- control 50% of the welds	3	
	B.1.5. Analysis of welding repair procedure		10
	- existence of welding repair procedure and welding repair under special conditions	1	
	- welding repair without insurance special conditions	2	
B2	***Pipe manufacturing defects***		***50***
	B.2.1. Constant internal diameter assurance		30
	- diameter with an error of more than 10%	3	
	- diameter between 5 and 10%	2	
	-diameter below 5%	1	
	B.2.2. Constant outer diameter assurance		20
	- diameter with an error of more than 10%	3	
	- diameter between 5 and 10%	2	
	-diameter below 5%	1	
	B.2.3. Welding type pipe pipe		20
	- drawn pipe	1	
	- longitudinally welded pipe	2	
	- helical welded pipe	3	
	B.2.4. Inspection program analysis		10
	- existence of inspection program	1	
	- lack of inspection program	2	
	B.2.5. Maintenance schedule analysis		10
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program	3	
	B.2.6. Pipe type		10
	- construction pipe under X50	4	
	- construction pipe X50-X60	3	
	- construction pipe X60-X70	2	
	-construction pipe over X70	1	

B.2. DEFECTS THAT MAY OCCUR DURING PIPE CONSTRUCTION (ON SITE) 30%

Categ.	Element analysis name	Scores	%
B3	***Defects of joints to be welded (between pipeline pipes)***		***20***
	B.3.1. Realization of pipe welding thresholds		
	- automatic production from the factory	1	
	-manual realization in the construction site	2	
	- without welding thresholds	3	
B4	***Defects of welded joints***		***40***
	B.4.1. Optimum welding temperature assurance		30
	- realization of welding temperature	2	
	-welding directly without insurance welding conditions	1	
	B.4.2. Automatic flow welding		20
	-realization of welding in automatic flow	2	
	- manual welding	1	
	B.4.3. Constant weld bead insurance		20
	- 3 layers of welding	1	
	- 2 layers of welding	2	
	- 1 layer of welding	3	
	B.4.4. Conduct welding inspection		20
	- NDT control	1	
	- control with magnetic powders	2	
	- control 50% of the welds	3	

	B.4.5. Analysis of welding repair procedure		10
	- existence of welding repair procedure and welding repair under special conditions	1	
	- welding repair without insurance special conditions	2	
B5	***Gouged and wrinkled curves***		***20***
	- curves with undulations (wrinkles)	4	
	- curves with thinner wall by more than 50%	3	
	- thin-wall curves with a wall between 20 and 50%	2	
	-curves with thin wall with wall below 20%	1	
B6	***Damaged threads/damaged plugs or sleeves***		***20***
	B.6.1. Thread wall thickness		30
	- Damaged threads with 80% wall thickness damaged	6	
	- Damaged threads with 60-80% wall thickness damaged	5	
	- Damaged threads with 40-60% wall thickness damaged	4	
	- Damaged threads with 20-40% wall thickness damaged	3	
	- Damaged threads with 20-10% wall thickness damaged	2	
	- Damaged threads under 10% wall thickness damaged	1	
	B.6.2. Thread chamfers		30
	- threads with more than 50% chamfers	4	
	- fillets with chamfers between 30 and 50% chamfers	3	
	- fillets with chamfers between 10 and 30% chamfers	2	
	- threads under 10% chamfers	1	
	B.6.3. Inspection program analysis		20
	- existence of inspection program	1	
	- lack of inspection program	2	
	B.6.4. Maintenance schedule analysis		20
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program	3	

B.3. EQUIPMENT DEFECTS-30%

Categ.	Element analysis name	Scores	%
B7	***Defects of sealing rings (gaskets).***		***20***
	B.7.1. O-ring type		60
	- soft metal sealing rings	1	
	- plastic or non-metallic sealing rings	2	
	- without welding thresholds	3	
	B.7.2. Flange clamping method		40
	- machines with torque wrenches	1	
	- manuals with torque wrenches	2	
	- manual without torque wrenches	3	
B8	***Malfunction of control and safety equipment***		***40***
	B.8.1. Inspection program analysis		30
	- existence of inspection program	1	
	- lack of inspection program	2	
	B.8.2. Analysis of maintenance program and metrological control		30
	- existence of a maintenance program and metrological control	1	
	- carrying out scheduled repairs without the existence of metrological control	2	
	- no maintenance program	3	
	B.8.3. Additional control mode analysis		20
	- existence of additional control system	1	
	- lack of additional control system	2	
	B.8.4. SCADA (System of Controlling and Acquisition Data) system analysis		20
	- existence of SCADA system and automatic control	1	
	- existence of SCADA system and manual control	2	
	- non-existence of SCADA system and manual control	3	
B9	***Failure of pump housings/failure of sealing systems***		***20***
	B.9.1. Inspection program analysis		20
	- existence of inspection program	1	
	- lack of inspection program	2	
	B.9.2. Analysis of maintenance program and metrological control		20
	- existence of a maintenance program and metrological control	1	
	- carrying out scheduled repairs without the existence of metrological control	2	
	- no maintenance program	3	
	B.9.3. Pump wall thickness analysis		20
	- wall thickness over 80%	5	
	-wall thickness 80-60%	4	
	-wall thickness 60-40%	3	
	-wall thickness 40-20%	2	
	-wall thickness 20-0%	1	
	B.9.4. Coupling state analysis		20

	- couplings with more than 50% missing wall thickness	4	
	- couplings with wall thickness between 30% and 50% missing wall thickness	3	
	- couplings with wall thickness between 10% and 30% missing wall thickness	2	
	- couplings below 10% lack of wall thickness	1	
	B.9.5. Type of pumps used		20
	- piston pumps	3	
	- helical pumps	2	
	- centrifugal pumps	1	
B10	***Analyzes defects various causes***		***20***
	B.10.1. Investment program analysis		30
	- existence of investment program	1	
	- no investment program	2	
	B.10.2. Maintenance schedule analysis		30
	- maintenance program existence	1	
	- no maintenance program	2	
	B.10.3. Analysis project execution		20
	- choice of maximum safety factors	1	
	- choice of average safety factors	2	
	- choice of minimum safety factors	3	
	B.10.4. Site management analysis		20
	- existence of legal documents for tracking works	3	
	- existence of site managers	2	
	- execution of works without specialized site supervisors	1	

TIME-INDEPENDENT HAZARDS (20% OF THE CALCULATION VALUE)

C.1. EQUIPMENT DEFECTS-30%

Categ.	Element analysis name	Scores	%
C1	***Damage caused by the first second of operation (pressure tests) or due to a third party***		***20***
	C.1.1. Damage occurred following the hydraulic test		60
	- existence of test program and test procedure	1	
	- performing a pressure test without a test procedure	2	
	- performing an air pressure test	3	
	C.1.2. Damage caused by accidental interventions		40
	- existence of topographic elevations of the pipelines	1	
	- notification to the authorities regarding the existence of the pipelines	2	
	- installation of warning tape and warning plates	3	
	- installation of warning tape	4	
	- the absence of warning tape and warning plates	5	
	Pre-damaged pipes		***40***
C2	C.2.1. Inspection program analysis		
	- existence of inspection program	1	
	- lack of inspection program	2	
C3	***Vandalism/unlawful interventions***		***40***
	C.3.1. Pipeline surveillance and inspection program analysis		40
	- existence of pipeline surveillance and inspection program	1	
	- lack of pipeline surveillance and inspection program	2	
	C.3.2. Pipeline leak detection system analysis		60
	- existence of pipe leak detection system	1	
	- pipe leak detection system operation with 10% error	2	
	- pipe leak detection system operation with 20% error	3	
	- lack of pipeline leak detection systems	4	

C.2. INCORRECT OPERATION-30%

Categ.	Element analysis name	Scores	%
C4	***C.4.1. Pipeline operation manual analysis***		***100***
	- existence of pipeline operation manual	1	
	-absence of pipeline operation manual	2	

C.3. EXTERNAL FORCES OR WEATHER CONDITIONS-40%

Categ.	Element analysis name	Scores	%
C5	***Cold weather with low temperatures***		***30***
	C.5.1. Use pipe protection systems		
	-use of pipes with high resilience at low temperatures and thermal protection	1	
	- use pipes with high resilience at low temperatures	2	
	- use pipes with thermal protection	3	
	-use of pipes without high resilience at low temperatures and thermal protection	4	

C6	***Thunderbolt***		***30***
	C.6.1. Use pipe protection systems		40
	-use of earthing systems and pipe shielding	1	
	- use earthing systems	2	
	- use of pipes without lightning protection	3	
	C.6.3. Inspection program analysis		30
	- existence of inspection program	1	
	- lack of inspection program	2	
	C.6.4. Maintenance schedule analysis		30
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program	3	
C7	***Heavy rain or flooding***		***30***
	C.7.1. Inspection program analysis		30
	- existence of inspection program	1	
	- lack of inspection program	2	
	C.7.2. Maintenance schedule analysis		40
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program	3	
	C.7.3. Pipeline installation project analysis		30
	- existence of additional protection	1	
	- existence of additional protection	2	
C8	Earthquakes/landslides		***10***
	C.8.1. Inspection program analysis		50
	- existence of inspection program	1	
	- lack of inspection program	2	
	C.8.2. Maintenance schedule analysis		40
	- existence of a maintenance program and scheduled repairs	1	
	- carrying out scheduled repairs without the existence of a maintenance program	2	
	- no maintenance program	3	
	C.8.3. Installation of pipe witnesses in delicate areas		10
	- existence of pipe movement detection systems	1	
	- non-existence of pipeline movement detection systems	2	

c. Hazards independent of operating time:

c.1. Mechanical damage caused by a third party,

-C.1. Damage caused by the first second of operation (production and resistance-hydraulic tests) or due to a third party (damage inflicted by first, second or third parties),

- C.2. Pipes damaged during transport and storage (previously damaged pipe -delayed failure mode),
- C.3. Damages due to acts of vandalism or illegal interventions (vandalism).

-C.4. Damages due to incorrect operation (incorrect operational procedure)

c.2. Weather-related and outside forces

- C.5. Cold weather with low temperatures (cold weather),
- C.6. Thunder (Lightning),
- C.7. heavy rains or floods,
- C.8. Earthquakes/landslides (earth movements).

5. THE RISK IN OIL PIPELINE TRANSPORTING

Risk is defined as "the possibility of getting into danger, of facing trouble or suffering damage" [14, 15].

In Romanian Risk Index, risk is also defined "as a possible danger" [16].

In everyday life, risk is associated with the term "uncertainty" or "accident" [17].

It is also proposed for risk synonymous words like [18]:

- the chance to lose,
- possibility of loss,
- the uncertainty that affects the final result, etc.

In absolutely any field of activity, but especially in the petroleum industry and especially in the transportation of petroleum fluids through pipelines, there are certain risk factors, which must be taken into account in the operation of facilities [19].

Prevention (which is the opposite of risk), is necessary in the context of insurance [20]:

- the protection of workers,
- security of facilities,
- environmental protection,
- the proper performance of the actual activity.

So, when we talk about risk factors, we refer to those specific elements, which more or less influence the occurrence of a possible danger, at a given time.

In the petroleum fluid transportation industry, risk is analyzed through the lens of threats, causing the process to suffer [21].

In the last period of time, a positive component was also included in the definition of risk, necessary for the creation of development opportunities and therefore the reduction to the total elimination of the risk.

This reduction can be achieved through efficient management and the development of appropriate strategies [22].

The evolution of quality assurance standards (and implicitly risk reduction) created the possibility of risk management standardization.

In 2018, the International Organization for Standardization developed the ISO 31000/2018 standard [23].

New Zealand and Australia introduced risk and threats and opportunities [24]

Dr. David Hillson appreciates that risk is an uncertain event, taking into account the Latin etymology of the word (risk=risk=to dare) [25].

This, once embodied in actions or circumstances, will impact the objectives of an activity.

This happens for various reasons:

a. or the intervention of something unplanned in the course of an activity,

b. either because an activity that was planned did not proceed as it was intended to proceed.

Robert T. Futrell, classified risks into three broad general categories (being the most beautiful classification of risk made to date) [26]:

- Known knowns.
- Known unknowns.
- Unknowns unknowns.

Both external and internal risks can occur in the activity of a company.

External risks are conditioned by various factors, the most common being [26]:

- the competition,
- political changes,
- changes in commercial legislation,
- changing the policies dedicated to increasing the security of environmental protection,
- changing the competition of players on the industrial market.

Internal risks arise as a result of internal problems of petroleum fluid transport companies or companies due to:

- the poor elaboration of the specifications necessary to be launched for the purchase of some products or the realization of some investments,
- non-compliance with the technology of using the oil fluid transport system

Other risks that may arise in the conduct of a company's activity are:

- technological risks,
- product risks,
- industrial risk.

The industrial risk is given by the ignorance of new technologies by the company and the failure to perfect the manufacturing lines or the personnel.

Product risk and industry risk occur when a manufactured product is no longer fashionable or if demand for that product declines for other reasons.

When we refer to technological risk, we can say that it is accepted from two perspectives: one qualitative and the other quantitative.

From a qualitative point of view, the technological risk is defined taking into account the entire lifetime of the system under consideration.

The technological risk [27] is due to the non-adaptation of the society or the company to the modern values imposed by the new technologies on the industrial market.

Risk is defined as the possibility (probability) of an accident (P) inducing a certain severity (G).

That event has an acceptability of the system of which A is a part [8]:

$$Risk=P*G*A \tag{1}$$

The industry of transporting petroleum fluids through pipelines is affected by the possibility of breakdowns in operation.

That is precisely why the operational risk analysis is useful for defining investment plans and especially the purchase of control and safety equipment.

Relationship 1 introduces into the risk assessment a factor of certain severity, which defines the susceptibility of the environment (human, ambient or industrial) to accept an accident at a petroleum product transport facility. The negative reaction of the population to this type of accidents and especially the environmental penalties is known, and that is precisely why this risk factor also defines the acceptance of this industrial activity.

In the operation of oil installations, the risk is divided into two areas of analysis [9]:

a. Residual risk.

In the specialized literature, this type of risk is also called acceptable risk and is defined as that part of the operation where small faults may occur, but which do not affect the quality of the process and the environment.

There are those pipeline defects that do not affect its bearing capacity, or the corrosion rate is very low and the time to move to another risk category exceeds the pipeline's operating time.

It should be noted that the residual (acceptable) risk can become unacceptable risk at a given moment.

b. Unacceptable risk.

It is the domain in which behaviors of the petroleum fluid transport system are not accepted. Damage to transport pipelines are unacceptable risks.

6. A NEW RISK ASSESMENT METHOD

A risk assessment methodology was developed in 1987 at the Dow Chemical company [28].

This risk assessment technique was based on the premise of establishing a priority scheme, regarding the preventive maintenance of the 14 locations (14 hazardous fluid transport systems), which the company operated, in that period of methodology development, in geographical areas different.

The methodology analyzes a finite number of ways in which a pipeline, transporting petroleum products, can be damaged.

These "modes" of damage have been identified and classified [29] by answering the questions, "what could go wrong" and "how likely is the damage".

In this risk model, the causes of accidents at oil product transport pipelines were grouped into four categories:

-third party damages.

-corrosion.

-design.

-incorrect operations.

This rating, proposed by Kent Muhlbauer, has been used for pipeline systems of short lengths (maximum 20 km) to assess the relative risk of oil spills, dividing the risk of an accident into (0-1), high (1-2), medium (2-3), low (3-4) and very low (4-5). The results can bring to the fore the dangerousness of a segment of actions that can degrade pipelines (corrosion being the most destructive action in the vision of this theory).

Unfortunately, this model did not identify all the possibilities of damage of petroleum fluid transport systems [30].

The model proposed in this paper wants to quantify the elements that can fail a petroleum fluid transport system [31].

Thus, starting from the identification made within the analysis of the pipeline systems in Romania, the following risk calculation scheme was created [32]:

a. collection of data from the records of the measuring and control devices or from the data sent by the operator or the control institutions, collected following the audit interview

b. analysis and quantification of hazards that are dependent on operating time,

c. analysis and quantification of stable hazards,

d. analysis and quantification of time-independent hazards,

e. the summation of quantified indices,

f. taking into account the impact factor on the environment in the event of an accident,

g. risk assessment.

The calculation is made by choosing the values from the tables, multiplying them by the weight in the relationship and adding them up.

The final amount will be multiplied by the pipe damage factor.

7. THE IMPACT FACTOR IN THE EVENT OF A DAMAGE

a. The effect caused by the fluid in the pipe in the event of a breakdown -50%;

a1. acute (70%); refers to the immediate catastrophic effect it has on the population of the area, damage to a pipeline in which a fluid with a high accident rate circulates (it is methane, ethane, propane, polypropylene, etc.), score 0-5 points.

- human accidents - 5 points,
- animal accidents - 4 points,
- water pollution - 3 points,
- soil pollution - 2 points,
- basement pollution - 1 point.

a2. chronic (30%); refers to the long-term catastrophic effect in the event of a breakdown of a pipeline, which carries fluid with a low hazard rate on the population of the area (crude oil, benzene, styrene, etc.), score 0-3 points.

- ethane transport - 3 points,
- gasoline or natural gas transport - 2 points,
- crude oil transport - 1 point.

b. Fluid dispersion in the populated area (50%)

b.1. amount of liquid or gaseous product losses, (50%)

- massive pollution (over 10% of the hourly flow) 4 points,
- low pollution (below 10% of the hourly flow) 3 points,
- detectable pollution (below 5% of the hourly flow) 2 points,
- undetectable pollution (below 1% of the hourly flow) 1 point.

b.2. population density in the area, (50%)

- urban area 8 points
- rural area 7 points
- car transport area 7 points
- transport zone CF 5 points
- shipping area 4 points
- river transport area 3 points
-hilly area 2 points
-mountain area and difficult access 1 points.

*risk assesment=hazard * impact factor in the event of a damage*

$$hazard = \sum A1 \dots C8 * risk\ factor \cdot \left(\sum_{i=1}^{n} risk\ factorpoint\ of\ influences\right)$$

$$impact\ factor = 50\% \cdot A + 50\%\ \cdot B$$

The maximum score for fluids oil pipelines is 29.26 and 30.20 for ethane transport (29.73 for gasoline).

The minimum score for a crude oil pipeline is 0.70 points.

8. CONCLUSION

Concluding and analyzing specialized literature, we can say that accidents at petroleum installations and transportation of petroleum fluids (crude oil, natural gas, gasoline, liquefied gas, petroleum products) can occur:

- when putting the facilities into use (during the commissioning period),
- in the first 3-5 years of operation.

This evaluation method ensures the detection of the risk in the operation of a pipeline system, being carried out based on the observations of the oil fluid transport pipeline system in Romania.

It includes all the data of a correct assessment and above all it can provide the perspective of the influence of a non-conformity of the system on the operational risk.

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