Fire Safety Protection Assessment of Industrial Technologies

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ABSTRACT

An accident in petrochemical industry can cause serious damages to human and animal health, property, environment and economy. That was proved by many accidents in the past. National laws, regulations, national, European or international standards or accepted protection principles define minimal requirements for safety and security protection of technologies. This restriction defines specific protections and periodical personal controls. Companies in petrochemical industry are often split in branches with specific types of technologies – pumping stations, storages, distribution lines, etc. Each of these technologies represents specific hazards for employees, environment, surrounding area or economy (national, organizational). Especially oil storages and farms represent strategical importance for national safety and continuity.

Increasing of protection is often organized individually in specific branches of the organizations. It can cause that the same organization has different protection of the same technology. That is the reason why many organizations design safety policy on higher level than is legally requested by insurance companies or by internal safety policy. The increase of policy is connected to increase of number of personal controls which can be implemented up to every hour per day, or to application technical protection. The technical protection can include leakage sensors, sprinkler systems, emergency reservoirs, process monitoring (pressure, temperature, mass flow, etc.) or CCTV systems. The uniform protection within the organization on the same technologies can increase employees working time efficiency, increase level of protection and decrease financial losses. For these purposes the evaluation of technical protection with impact on number of personal controls have been designed and described in this paper.

Presented system of assessment evaluates specific hazards and possible impact including possible damages to human health, property or environment with considered type of technology. Moreover, the building and technological protection is considered, as well as the fire protection systems, alarm systems, and monitoring cameras systems. Final number of personal controls of technology is based on type of organization, hazards and protection. A resulting recommended number is compared with required legal number of controls.

Main benefits of screening assessment are:
1) Allow planning of flat investments and development of technologies and its protection
2) Increasing efficiency of workforce
3) Defining critical areas for technical development – application of CCTV, modern detection systems, etc.
4) Increasing efficiency of working time of employees – e.g. replacement personal screening by CCTV systems
5) Decreasing costs of control and service actions

KEYWORDS:
explosion; risk assessment; detection; human behaviour
INTRODUCTION
The inherent part of oil and petroleum industry is storage and pipe transport. Manipulation with flammable liquids entails the risk of fire, explosion or leak and their consequences as injury, environmental pollution or material and financial losses. In order to prevent any incidents and ensure proper and safe operations, safety and security design and measures in petrochemical industry fulfill even higher standard level than required by laws, codes and insurance conditions in regular companies. Namely, consequences in case of accident can have big impacts on an organization, surrounding area, environment or in worst case entire nation [2][3]. A control screening assessment is a tool designed to estimate a number of personal controls based on type of technology, potential hazard and protection of technology. This tool respects all type of technologies, state of operation and their protection or law requirements.

NOMENCLATURE LISTING
\[\begin{align*}
R & \quad \text{Overall Impact} \\
C & \quad \text{Technology Type Index} \\
E & \quad \text{Environmental Impact Index} \\
F & \quad \text{Technical Failure Index} \\
I & \quad \text{Injury Index} \\
Z & \quad \text{Correction Index} \quad (\%) \\
S & \quad \text{Protection Factor} \\
M & \quad \text{Monitoring Index} \\
P & \quad \text{Technical Protection Index} \\
CCTV & \quad \text{Closed Circuit Television}
\end{align*}\]

DESCRIPTION OF ASSESSED TECHNOLOGY
As a model organisation served CEPRO,a.s., is a joint-stock company with main activities in field of transport, storage and distribution of petroleum products. One of the main tasks is to maintain and protect national material reserves. The company fulfill request of European Union to ensure 90 days of average daily consumption of fuel by governing 17 fuel storages distributed throughout the country.[1] The site of storages includes underground and ground tanks, tanks for manipulation with fuel, filling platforms for railway and automobile tanks, workshops, fire brigade stations, administrative buildings, laboratories, fire-fighting tanks, electric substations, engine rooms, pumping stations, etc. The complexity of sites presents specific requirements for fire safety and fire protection. The assessment is prepared based on internal data and current fire risk assessment required and described by the Czech national law [5] with the most important information for following assessment.

GOALS OF ASSESSMENT
The main goal of this assessment is to get unified approach to assessment of the technology and defining number of personal controls for all branches within a company and therefore decrease man-hours, give a company tool how to improve fire safety and generally increase efficiency. Importantly also communication between specific branches and planning of horizontal development. Guidelines of Confederation of Fire Protection Associations - Europe (CFPA-E) and standards of NFPA [6] were used as source methodologies for assessment [3][4]. These guidelines are improved and implemented considering conditions of petrochemical industry. Source data are valuable for personal visits and fire safety documentation required by national laws [5].

Primary target of the assessment:
- Fire Risk Assessment and assessment of facility protection.
- United assessment approach of all branches in fire risk assessment and assessment of facility protection.
- Number of controls between branches for the same facilities unification.

Secondary impact of the assessment:
- Areas of technical development definition.
- Horizontal planning of organizational development.
- Estimating simple basic overview of technological protection.
- Efficiency increase of employees’ working time.

STRUCTURE OF SCREENING ASSESSMENT
For efficient approach of the screening assessment, it is important to follow next specific steps for each technology during the process of assessment:
1) Basic description of technology
2) Risk Assessment
3) Protection Assessment
4) Correction
5) Result Evaluation
6) Comparing results with Law Requirements
7) Final recommended number of controls
Main Layout of Control Assessment Index

Procedure to conclude final number of controls depends on many factors and has to follow process as presented in Fig. 1. Overall Impact (R) includes influence of Technology type (C), possibility to harm Environment (E), Technical Failure (F), Injury (I), and Correction Factor (Z). Following, the Overall Impact is corrected by Safety correction (Z) and resulting value is adjusted by considering Actual level of protection (S) for both, Monitoring (M) and Technical Protection (P). For any requirements of national orders, laws or technical codes, resulting number of controls needs to be compared and then, final recommended number can be determined.

Overall Impact Index R

As any safety measures primarily targets at people protection, it is necessary to perform initially assessment of impact of possible accident. Moreover, assessment includes operation of technology, its type, impact on the environment (E), employees and process continuity. Numbers in right columns in Table 1 are designed and evaluated in accordance with real company.

\[ R = C + E + F + I \]  

The final correction of Overall Impact is revised by responsible specialist who considers other conditions (e.g. accidents). This correction is adapted by Correction Index (Z) as given by Eq. (2).

\[ R = R \cdot (1 + Z) \]  

**Technology Index C**

This index considers type of technology, its operational stated (e.g. non-stop operation or out of service), or presence of chemical substances. Values for specific sub-indexes can be found in Table 1.

\[ C = C_1 + C_2 + C_3 + C_4 + C_5 \]  

**Index of Environmental Impact – E**

In terms of environmental pollution, distinguishing whereas there is a risk of liquid leakage from evaluating technology needs to be done firstly. Next step is to consider possible amount of liquid leaked. Finally, index of environmental impact is calculated as with values given from Table 1 as stated by Eq. (4):

\[ E = E_1 \cdot E_2 \]  

**Failure Index - F**

This index specifies impact on continuity of organizational processes and connections of technology to other technologies or processes for a case of failure or accident as given by Eq. (3):

\[ F = F_1 \]  

**Injury Index - I**

There is a various presence of persons on different workplaces and technologies. Some technologies require permanent service and some are out of service and presence of persons is excluded, which is described by Eq. (6):

\[ I = I_1 \cdot I_2 \cdot I_3 \]  

All estimated values for specific indexes which are used for calculations and assessing the impact index (R) given by Eqs. (1) – (4) are presented in table 1.
Table 1. – Estimated values for indexes used for assessment of Impact Index - R

| Index - C | State | Value |
|-----------|-------|-------|
| C1 - Category of Facility | 1 - Technological | 10 |
| | 2 - Continuous | 10 |
| | 3 - Other | 1 |
| C2 - Stored Liquid | Flammable Liquid (I. – III. class) | 10 |
| | Flammable Liquid (IV. class) | 5 |
| | No Flammable Liquid | 0 |
| C3 - Technology | Open | 2 |
| | Closed | 4 |
| | Not relevant | 0 |
| C4 - Type of Technology | Storage | 3 |
| | Continual | 5 |
| | Not relevant | 0 |
| C5 - Operation | Active operation | 20 |
| | Passive operation | 10 |
| | Out of Service | 0 |

\[ \Sigma \text{ Max. 50} \]

| Index - E | State | Value |
|-----------|-------|-------|
| E1 - Hazard of liquid leakage out of technology | Yes | 1 |
| | No | 0 |
| E2 - Quantity of possible leakage | Tens of litres | 3 |
| | Leakage in technology and its accidental protection | 10 |
| | Out of accidental protection | 20 |

\[ \Sigma \text{ Max. 20} \]

| Index - F | State | Value |
|-----------|-------|-------|
| F1 - Impact on process continuity | Without impact or with minimal limitation of processes | 0 |
| | Limitation of processes for hours. Short-term affection | 10 |
| | Large impact - Affection of operation all company / areal / etc. | 20 |

\[ \Sigma \text{ Max. 20} \]

| Index - I | State | Value |
|-----------|-------|-------|
| I1 - Facility service | Permanent service | 1 |
| | Without permanent service | 0 |
| I2 - Possibility of persons injury in case of accident | No persons | 0 |
| | One person | 1 |
| | Two or more persons | 2 |
| I3 - Which injury imminent | Minor injuries | 1 |
| | Short-term hospitalization or convalescence | 3 |
| | Death, long-term hospitalization, invalidity | 5 |

\[ \Sigma \text{ Max. 10} \]

**Correction Index - Z**

The Correction Index (Z) is important for specific conditions which can be observed during practice e.g. maintaining of a technology or occurrence of specific hazards known by an attendant responsible for technology evaluation. The index allows increase in hazard index in range from 0% to 30%.

- **30 %** - Accidental or different unaccepted state, working on technology by extraneous persons
- **20 %** - Very frequent manipulation over the frame of unusual service in organization
- **10 %** - Other risks
- **0 %** - No correction.

**Protection Assessment – S**

The estimation of protection is based on assessment of monitoring by CCTV, sensors, detection which could substitute personal controls. This includes index \( M \) described by Eq. (7). The technical protection assesses possibility of protection technology in cased of non-standard situation. These factors are included in Index \( P \) (Eq. (8)).

**Monitoring Index - M**

\[ M = (M_1 \cdot (M_2 + M_3 + M_4)) + M_5 + M_6 \]  

(7)
Technical Protection Index - P

\[ P = P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 \]  \hspace{1cm} (8)

All values for calculated indexes are summarized in Table 2., with description of specific values.

| Index – M | State | Value |
| --- | --- | --- |
| M_1 – CCTV | Rotate | 2 |
| M_1 – CCTV | Fixed | 1 |
| M_1 – CCTV | None | 0 |
| M_2 – Does CCTV cover all areas? | Yes | 3 |
| M_2 – Does CCTV cover all areas? | Partially | 2 |
| M_2 – Does CCTV cover all areas? | No | 1 |
| M_3 – Is CCTV with permanent service? | Yes | 5 |
| M_3 – Is CCTV with permanent service? | No | 0 |
| M_4 – Is CCTV equipped with night-vision / thermal vision? | Yes | 5 |
| M_4 – Is CCTV equipped with night-vision / thermal vision? | No | 0 |
| M_5 – Permanent service of operational values | Yes | 8 |
| M_5 – Permanent service of operational values | Partially | 5 |
| M_5 – Permanent service of operational values | No | 0 |
| M_6 – Indication of danger substances presence? | Yes | 5 |
| M_6 – Indication of danger substances presence? | No | 0 |
| \( \Sigma \) | | Max. 29 |

| Index – P | State | Value |
| --- | --- | --- |
| P_1 – Critical places – Are they defined for the facility? | Yes | 4 |
| P_1 – Critical places – Are they defined for the facility? | No | 0 |
| P_1 – Critical places – Are they defined for the facility? | Not relevant | 0 |
| P_2 – Presence of electronical fire signalization | Yes | 10 |
| P_2 – Presence of electronical fire signalization | No | 0 |
| P_3 – Equipped by Sprinkler / Dry Sprinkler System | Yes | 10 |
| P_3 – Equipped by Sprinkler / Dry Sprinkler System | No | 0 |
| P_4 – Gas Detection | Yes | 10 |
| P_4 – Gas Detection | No | 0 |
| P_5 – Drainage/ Separator/ Scumboart / Control Borehole | Yes | 1 |
| P_5 – Drainage/ Separator/ Scumboart / Control Borehole | No | 0 |
| P_6 – Bund / Collection Sump | Yes | 5 |
| P_6 – Bund / Collection Sump | No | 0 |
| P_7 – Level Detection and Accident (high) Level Detection (gradient to Control System/ Out of Control System), Operational State of Technology Monitoring | Transmitting in Control System | 3 |
| P_7 – Level Detection and Accident (high) Level Detection (gradient to Control System/ Out of Control System), Operational State of Technology Monitoring | Local Signalization | 1 |
| P_7 – Level Detection and Accident (high) Level Detection (gradient to Control System/ Out of Control System), Operational State of Technology Monitoring | None | 0 |
| P_8 – Detection of Substance Presence in Sump (Interlayer), Transmitting in Control System / Local Signalization | Transmitting in Control System | 3 |
| P_8 – Detection of Substance Presence in Sump (Interlayer), Transmitting in Control System / Local Signalization | Local Signalization | 1 |
| P_8 – Detection of Substance Presence in Sump (Interlayer), Transmitting in Control System / Local Signalization | None | 0 |
| \( \Sigma \) | | Max. 46 |

Calculation of Protection Assessment

Assessment of protection is based on evaluation of level of monitoring \((M)\) and protection \((P)\). The main reason is a possibility to substitute personal visiting of technology by employees and level of protection.

\[ S = M + P \]  \hspace{1cm} (9)

RESULT EVALUATION OF ASSESSMENT

The final calculation assesses estimated values. Number of personal controls \((H)\) of technology for resulting values need to be estimated first with Eq. (10).

\[ H = R \cdot (1 - \frac{S}{100}) \]  \hspace{1cm} (10)

For this evaluation it is important to account for the technologies in service state or out of service as well as technologies in non-stop operation with the highest level of protection. Number of controls and range of controls are estimated based on practice, safety requirements and impact assessment. Range moves from once a year
(e.g. storages out of service with no chemical substances) to 12 per 24 hours (e.g. pumping stations in operation). These values are described in Table 3.

| Number of Controls per 24 h | Result Value of Assessment | Final number of recommended number of controls |
|-----------------------------|-----------------------------|-----------------------------------------------|
| 1 - 5                       | 1 per year                  | 16 - 28                                       |
| 6 - 15                      | 1 per month                 | 29 - 36                                       |
| 37 - 44                     |                             | 53 - 59                                       |
| 45 - 52                     |                             |                                               |
| 51 - 59                     |                             |                                               |

Final Decision of Control Assessment

Specific number of personal controls in frame of fulfilling code or law requirements for specific technologies can be required. For this reason, the final decision needs to consider whereas determined number of personal controls includes required number of compulsory controls or not.

Calculated number of controls > Compulsory number of controls = Calculated number of controls
Calculated number of controls < Compulsory number of controls = Compulsory number of controls

CONCLUSIONS

While data from the assessment of the case study branch Sedlnice will be post-processed, the verification of efficiency will be evaluated. Additional work will identify possible initiating events and component failure modes with dynamic fault trees. These trees will be developed in Bayesian network. For evaluation of efficiency and development of assessment Bayesian network will be used as a technique considering investigation of possible scenarios with domino effects. A mapping of scenarios with analysis of probability and evaluation should be included [9][10]. The impact of possible accidental scenarios can be additionally investigated with numerical modelling software such as ALOHA. This software can provide data for defining impact of various scenarios e.g. jet-fire, boilover or leakage. Obtained data will be compared with case study real conditions and with designed assessment procedure described in this article.

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