Quantitative risk correction method of storage tank based on safety measures

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Abstract. Aiming at the safety risk of storage tank in port area, the control measures of tank safety risk are analysed, and the quantitative risk correction method based on safety measures is studied to reduce the risk of tank accident in port area.

1. Introduction
In addition to crude oil leakage, fire and explosion accidents in the tank farm of storage and transportation enterprises, there are also associated accidents caused by pipeline accidents connected with the tank farm.

OCS (Outer continental shelf) has more than 4000 oil and gas storage and transportation facilities, and its pipeline length is 33000 miles. In the 30 years from 1981 to 2010, there were 59 times of tank leakage, and the crude oil leakage was 1495bbl, or 237705l. The number of tank leakage accidents accounts for about 4% of the total leakage accidents.

2. Analysis of common leakage causes of storage tank
The common leakage scenarios and other accidents (fire and explosion accidents in case of fire source) are mainly caused by:

(1) Due to material, corrosion, aging and other factors, flange sealing surface, gasket and other sealing failure, resulting in leakage and explosion in case of fire source;

(2) Valve packing is damaged;

(3) The main reason of pipeline corrosion perforation and leakage is as follows
   Damage of anti-corrosion paint;
   Low point drainage weld;
   The pipeline welding joint.
   Mechanical damage and fracture.

(4) Medium leakage due to failure of accessories:
   Liquid level gauge failure;
   High liquid level alarm, high and high level alarm failure;
   High-high liquid level alarm and emergency shut-off valve interlock failure.

   During the secondary dehydration, the liquid level gauge of dehydration package fails, resulting in medium leakage (oil products need to be dehydrated);

(5) The liquid level gauge on site is broken;

(6) Whether the drain valve of the storage tank is equipped with heat tracing is easy to crack in winter, and the operation is frequent and easy to be damaged;
(7) If the electrostatic grounding is loose, the lightning protection device fails, or the lightning or static electricity ignites the combustible gas cluster, the explosion will occur within the explosion limit;

(8) Tank repair, maintenance, non-standard fire and other causes of explosion.

3. Control measures of tank safety risk based on bow-tie model

According to the causes of common leakage, the safety protection technical measures of protective layer are formulated, mainly including:

| Serial number | Protective layer                           | Safety measures                                      |
|---------------|-------------------------------------------|------------------------------------------------------|
| 1             | Process design (intrinsic safety)         | Production process design                            |
|               |                                           | Process selection                                    |
|               |                                           | Selection of raw materials                           |
|               |                                           | Equipment selection                                  |
|               |                                           | Instrument sensitivity, reliability selection, etc    |
| 2             | Basic process control system              | DCS control system                                   |
|               |                                           | PLC control system                                   |
|               |                                           | Liquid level high / low alarm                        |
|               |                                           | High / low temperature alarm                         |
| 3             | Key alarms and personnel intervention     | High / low pressure alarm                            |
|               |                                           | Temperature limit alarm                              |
|               |                                           | Combustible gas detection device                     |
|               |                                           | Toxic gas detection device                           |
|               |                                           | Emergency stop system (cut off)                      |
| 4             | Safety instrumented function              | Interlock shut-off valve                             |
|               |                                           | Interlock vent valve                                 |
| 5             | Physical protection                       | Safety valve                                         |
|               |                                           | Bursting disc                                        |
|               |                                           | Same as 5 (cross)                                    |
|               |                                           | Fire dike                                            |
| 6             | Physical protection after release         | cofferdam                                            |
|               |                                           | Isolation system                                     |
|               |                                           | Fixed fire fighting system                           |
|               |                                           | Fire rescue                                          |
| 7             | Emergency response of plant area          | Evacuation                                           |
|               |                                           | Medical rescue                                       |
| 8             | Emergency response of surrounding         | Same as 7                                            |
|               | communities                                |                                                      |

Once an accident occurs in the storage tank of dangerous goods, the damage of the accident is serious and the influence range is large. Safety work is the top priority. In addition to the above-mentioned safety technical measures, such as safety distance between devices, regular maintenance and repair of equipment, reminder of safety warning signs, use of explosion-proof tools, are all part of safety management measures, but they are not listed in the above table due to difficulties in quantification.
4. Correction of safety risk by control measures

4.1. Correction of failure frequency of preventive safety measures

The influence of a certain initial event risk impact factor RIFS is closely related to its classification and weight. Set $P_r(a)$ as the failure frequency of the corrected initial event or safety technical measures. The calculation process is as follows (formula 4-1):

$$P_{rev}(A) = P_{ave}(A) \sum_{i=1}^{n} \omega_i Q_i \quad (4-1)$$

$$MF = \sum_{i=1}^{n} \omega_i Q_i \quad (4-2)$$

Where: $P_{rev}(a)$ is the frequency of modified event $a$; $P_{ave}(a)$ is the intermediate value in different failure databases; $\omega I$ is the weight of the $i$th RIF that affects the occurrence of event $a$; $Q_i$ is the grade estimation of the $i$th RIF; $n$ is the number of RIFS affecting event.

$$\sum_{i=1}^{n} \omega_i = 1 \quad (4-3)$$

At present, the biggest challenge in the revision is to determine the valuation of $Q_i$. $Q_i$ is combined with RIF grading, and $Q_i$ values corresponding to A-F are given respectively.

(1) According to the recommended values of different databases of the same event, the minimum value $p_{low}(a)$ is determined as the modified lower limit of $P_{rev}(a)$.

(2) In the same way, the maximum value $p_{high}(a)$ is the modified upper limit value of $P_{rev}(a)$.

(3) According to the number of RIFS, $n = 1, 2, 3$ is the level of the $i$th RIF.

$$Q_{s(a)} = \begin{cases} \frac{P_{low}}{P_{ave}}, & s = A \\ 1, & s = C \\ \frac{P_{low}}{P_{ave}}, & s = F \end{cases} \quad (4-4)$$

According to the formula (4-4), when $s = a$, plot is $1 / 10$ of $P_{ave}$, $Q_i(a) = 0.1$; if $s = F$, $phigh$ is 10 times of $P_{ave}$, then $Q_i(s) = 10$. When all RIFs are graded C, $P_{rev} = Pave$. Set $SA = 1$, $SB = 2$, $SC = 3$, $SD = 4$, $SE = 5$, $SF = 6$.

We assume that $Q_i(a)$ and $Q_i(c)$ are linear. When $s = B$:

$$Q_i(B) = \frac{P_{low}}{P_{ave}} + \frac{(s_D - s_C)(P_{high} / P_{ave}) - 1}{s_F - s_C} \quad (4-5)$$

It is assumed that there is a linear relationship between $Q_i(c)$ and $Q_i(f)$

$$Q_i(D) = 1 + \frac{(s_D - s_C)(P_{high} / P_{ave}) - 1}{s_F - s_C} \quad (4-6)$$

4.2. Safety compensation and correction of accident consequence

4.2.1. Compensation coefficient of fire and explosion protection measures

The fire wall can prevent the spread of fire by blocking the heat flow. However, the weight of the firewall should be considered to avoid collapse due to its failure to support its own weight. In addition, for steel structure supports, fire retardant coating is often used to reduce the flammability of the structure surface and achieve the effect of retarding fire spread. The thermal damage of thermal radiation to the device and high heat conduction to the contents are fatal to the device. Therefore, the
corresponding degree of fire prevention is mainly determined by the physical properties and operating pressure of each content in the device system. The coefficient is 0.9 ~ 0.98.

4.2.2. Compensation coefficient of isolation system
If the leakage of stored materials cannot be effectively controlled or spread to other units, the accident will be expanded. Installation of remote control isolation valve, dispatch and purging system, design of surface drainage ditch, construction of fire dike and so on, play a great role in early leakage control. The coefficient is 0.9 ~ 0.97.

4.2.3. Compensation coefficient of fire protection system
Considering that the quantitative risk analysis in this paper is based on the TNO-risk curves software, only the assessment personnel need to pay attention to the impact of fire-fighting facilities on the personnel within the scope of the accident. The compensation coefficient of fire-fighting system is selected according to the fire-fighting and reserve capacity of the fire-fighting system. The coefficients are 0.9 and 0.95.

4.2.4. Compensation coefficient of self-rescue
The self-help ability of personnel is mainly reflected in the perception, judgment and reaction of risk. These abilities mainly reflect the safety awareness of personnel and the effect of daily fire drill. Compared with ordinary people, people with higher safety awareness tend to have higher ability of perception and judgment of danger. Similarly, for personnel with certain fire drill or practice experience, they can quickly make correct response and choose appropriate escape route when encountering dangerous situation. All of these personnel help to reduce the number of casualties and injuries at the scene when they occur. The coefficient is 0.95 ~ 1.

4.2.5. Compensation coefficient of emergency medical rescue
Accident medical rescue refers to a series of medical rescue activities carried out after the accident, including emergency rescue, follow-up rescue and recovery rescue. In the emergency medical rescue, the main goal should be to search and rescue the injured. The initial emergency medical rescue can rely on the social support, in order to rescue the injured in the shortest time, reduce the casualty rate caused by the accident, and minimize the loss of life and property in the disaster area. The coefficient is 0.85 ~ 1.05.

5. Conclusion
This paper analyses the existing tank safety accident statistics, summarizes and analyses the tank risk and leakage causes, summarizes the common tank accident development mode, summarizes and analyses the tank risk and leakage causes, summarizes the development mode of common tank accidents, and based on the protection layer analysis method, analyses and implements the tank safety risk control measures with the help of bow tie model, so as to reduce accidents occurrence frequency and accident consequence, thus reducing the safety risk.

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