Journal of Loss Prevention in the Process Industries xxx (2016) 1–6

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Job hazard dynamic assessment for non-routine tasks in gas transmission station

Weijun Li, Laibin Zhang, Wei Liang*

Research Center of Oil & Gas Safety Engineering Technology, Department of Safety Engineering, College of Mechanical and Transportation Engineering, China University of Petroleum, Beijing, 102249, China

A R T I C L E I N F O

Article history:
Received 15 February 2016
Received in revised form
11 July 2016
Accepted 29 October 2016
Available online xxx

Keywords:
Job hazard assessment (JHA)
Risk analysis
Cumulative risk
Gas transmission station
Non-routine tasks

A B S T R A C T

Gas transmission station is essential for long-distance natural gas transportation and its stable and safe operation matters. Non-routine tasks in gas transmission station have a significant hazard due to its high dependency on coordination between workers and strict operation procedures. Job hazard assessment (JHA) has been an effective method to decompose a non-routine process into steps and predict hazards of each step. However, people tend to ignore cumulative characteristics of risks with conventional JHA. To address this problem, the concept of cumulative risk is introduced to improve conventional JHA method. For illustration, the gas transmission startup process is chosen to apply the proposed method. First, the process is broken down into six steps in sequence and hazard preliminary analysis is conducted. Then the numeric risk matrix is used to determine risk value of each step by considering severity and possibility. Both independent risk and cumulative risk are evaluated and then compared. The results show that cumulative risk is more reasonable and practical and improves reliability of job hazard analysis.

1. Introduction

Natural gas is transported over a long distance from producing regions to consumption regions. Therefore, gas transmission system is essential for natural gas industry and pipeline is the most popular form for natural gas transmission (Kostowski et al., 2015). As an important part of pipeline transportation system, gas transmission station is the hub connecting gas sources and users by providing motive power and controlling gas flow. Once accidents occur in gas transmission station, the stability of gas supply will be directly affected. In addition, complex hazard including flammable and explosive materials and complicated processes makes accident consequences more serious. Therefore, risk analysis and management of gas transmission station is required to prevent accidents and ensure the safety and stability of gas transmission.

To reduce accidents and injuries on site, unsafe practices must be identified, assessed and prevented (Teo et al., 2005). There are many types of activities or job processes in gas transmission station, which can be divided into routine tasks and non-routine tasks. Routine tasks refer to daily activities such as facility inspection, patrol, pressure regulating, etc., while non-routine tasks include gas transmission startup and shutdown, blow down process, venting process, pigging process, etc. Non-routine jobs are performed irregularly and usually take less time to be completed (Roughton and Crutchfield, 2008). Because of this, people take chances and perform non-routine jobs without an in-depth analysis of hazards. However, due to the uncertainty, dynamic variability and complexity of non-routine tasks, it usually requires a close coordination between workers and a strong dependency on strict work process, where potential hazards hide in each step. On March 23, 2005, an industrial disaster destroyed the isomerization (ISOM) unit of BP Texas City Refinery and caused 15 deaths, 180 injuries and more than 1.5 billion dollars financial losses. It was during the startup of an ISOM unit that the disaster happened (Saleh et al., 2014). Although the Chemical Safety and Hazard Investigation Board (CSB, 2007) have concluded many causes including both technical causes and organizational causes, it is undoubted that the reason “managers did not effectively implement pre-startup safety review” remains one of triggers in workplace. Recent studies have emphasized the importance of loss prevention during the startup or shutdown stages of a process (Shin, 2014; Malmén et al., 2010). It is concluded that risk analysis of non-routine tasks is of significant importance and any minor failure could lead to job failure or a major disaster. Therefore, non-

* Corresponding author.
E-mail addresses: tongxunzuozhe1@163.com, lw@cup.edu.cn (W. Liang).

http://dx.doi.org/10.1016/j.jlp.2016.10.018
0950-4230/

routine jobs in gas transmission station require an effective risk assessment method.

Job Hazard Analysis (JHA) is a technique used to identify risks in operation process and prevent accidents (Geronsin, 2001). Occupational Safety & Health Administration (OSHA) defines job hazard analysis as "a technique that focuses on job tasks as a way to identify hazards before they occur" (Chao and Henshaw, 2002). Unlike most other risk analysis methods like fault tree (Yuhua and Datao, 2005), which focus on analyzing equipment damage or process hazard, JHA aims to reduce risks originating from performing tasks. It divides a job process into several basic steps and identifies hazards and possible causes associated with each step. JHA can help managers and operators to be aware of potential injury risks, develop standard working procedures, and even support safety training (Swartz, 2002; Chan, 1998). Conventionally, JHA statically evaluates risks in each separated step without considering the connection between different steps. However, activities on site are dynamic and all steps sequentially connect to each other. In other words, hazard generated from previous steps will increase risks to subsequent steps. For example, if not all of the valves are checked in valve checking step, the risk of gas leakage from valves will continue in the remaining steps. Another example, if an operator forgets to wear hard hat before entering site, personal injuries could possibly happen in subsequent steps. But people tend to neglect the cumulativeness features of risks in previous job hazard analysis report. Therefore, an improved JSA methodology is proposed to dynamically evaluate non-routine job risks in gas transmission station.

2. Methodology

Job Hazard Analysis (JHA), also known as Job Safety Analysis (JSA) or Task Hazard Analysis (THA), can originate from Heinrich's job analysis (JA) term (Heinrich, 1931). It is a risk analysis method for job process aiming at identifying hazard sources and reducing or eliminating risks by monitoring or improving operation procedures. It has been one of the most widely used safety management methods in operation risks elimination and unfavorable events diminution in industry site (Zangoui et al., 2014; Mattila and Hyödynmaa, 1988; Wang et al., 2013). Due to its simplicity and practicability in safety engineering, there have been many studies and applications (Chao and Henshaw, 2002; Rozenfeld et al., 2010). According to statistical data from Glenn (2011), about one in seven technical sessions at American Society of Safety Engineers (ASSE) conferences from 2001 to 2009 involved JSA related terminology. Although many researches have studied or applied this method, it lacks a systematic and dynamic description. To address these problems, a structured and dynamic job hazard assessment methodology is provided as follows.

2.1. Step 1: job decomposition

To accomplish a task, it usually takes several steps. Usually, the task is broken down into sequential steps according to operation procedures or experienced workers and supervisors. Each step is a sub-goal for the accomplishment of the job. It should be noted that if the number of steps is over fifteen, it will need more than one JSA (US. Mine Safety and Health Administration, 1990). Take the startup operation as an example, operators must wear essential personal protective equipment (PPE) before entering the site. Although the step of wearing PPE seems to be irrelevant to the startup operation, it is essential and should not be omitted.

2.2. Step 2: hazard preliminary analysis

Job decomposition not only makes it easy for operators to follow the procedures but also distinctly displays potential hazards in each individual step. Conventional JSA identifies potential hazards associated with each step. However, propagations and cumulative effects of risks will be emphasized in our work. Therefore, potential hazards will be analyzed throughout the job process. For example, in gas transmission station, risks related to field staff, equipment or instrument, and natural gas will be considered. The three types of main potential hazards are personal injuries, gas leakage, and fire or explosion. In fact, these three types of hazards have been major concerns on site. Therefore, factors leading to these major hazards should be considered during risk analysis in gas transmission station, as shown below.

- Personal injuries: exposure to noise, dust, heights, tools, object striking, etc.
- Gas leakage: leakage from flanges, pipelines, or valves due to pressure, erosion, corrosion, vibration, etc.
- Fire and explosion: ignition source from field staff, electrical equipment, static electricity, etc.

2.3. Step 3: cumulative risk analysis

The conventional JHA considers each step of a specific job process as an independent analysis object. Therefore, conventionally, risks of different steps are evaluated separately, without considering previous steps. Risk identified by this means is named Independent Risk (IR). However, although the process is broken down into separated steps, risks of the entire process cannot be decomposed. Risks in previous steps can cumulate to the subsequent steps if not eliminated, called Cumulative Risks (CR). Hence, when conducting job hazard assessment, cumulative risks should be addressed. Cumulative risk analysis is to list all possible factors leading to hazards or failures in a check list. Two sources of risks should be considered. One is from the step itself and the other is from previous steps. For example, if a worker did not wear PPE before opening a valve, the risk of personal injuries would be added into the check list.

2.4. Step 4: risk assessment

Generally, risk is regarded as a combination of probability and severity of possible accidents. In order to describe risks quantitatively and for comparison's purpose, a numeric risk symmetric matrix is designed, as shown in Table 1. Like most risk matrices, probability and severity are divided into some levels (Ni et al., 2010; Markowski and Mannan, 2008). Specifically, probability is divided into four levels, which are very likely, probable, possible, and unlikely. And severity is also categorized into four levels, which respectively are minor, marginal, critical, and fatality. Moreover, risk value ranged from 1 to 16 is assigned to each factor of the

Table 1
Risk assessment matrix.

Risk (R)		Severity (S)			
		Minor	Marginal	Critical	Fatality
Probability (P)	Very likely	10	13	15	16
	Probable	6	9	12	14
	Possible	3	5	8	11
	Unlikely	1	2	4	7