Accident Analysis and Prevention 41 (2009) 1172–1179

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Combining task analysis and fault tree analysis for accident and incident analysis: A case study from Bulgaria

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ARTICLE INFO

Article history:
Received 20 June 2008
Accepted 12 July 2008

Keywords:
Incident analysis
Task analysis
Human error identification
Performance shaping factors
Fault tree analysis

ABSTRACT

Understanding the reasons for incident and accident occurrence is important for an organization's safety. Different methods have been developed to achieve this goal. To better understand the human behaviour in incident occurrence we propose an analysis concept that combines Fault Tree Analysis (FTA) and Task Analysis (TA). The former method identifies the root causes of an accident/incident, while the latter analyses the way people perform the tasks in their work environment and how they interact with machines or colleagues. These methods were complemented with the use of the Human Error Identification in System Tools (HEIST) methodology and the concept of Performance Shaping Factors (PSF) to deepen the insight into the error modes of an operator's behaviour. HEIST shows the external error modes that caused the human error and the factors that prompted the human to err. To show the validity of the approach, a case study at a Bulgarian Hydro power plant was carried out. An incident – the flooding of the plant's basement – was analysed by combining the afore-mentioned methods. The case study shows that Task Analysis in combination with other methods can be applied successfully to human error analysis, revealing details about erroneous actions in a realistic situation.

1. Introduction

Accidents and incidents have occurred since the invention of the first machine and the beginning of the industrial revolution. Despite the efforts of mankind to prevent or avoid them, they continue to occur, the reasons usually being complex. An accident may be based on 10 or more events that can be counted as causes (SETON, 2006). One failure may lead to another and a chain reaction may propagate through barriers and time to produce an undesired event. The most common reasons for accident/incident occurrence are failure of people, equipment, supplies, or surroundings to behave or react as expected.

The work of Hollnagel (1999), Johnson (2003), Kirwan (1994) and Petersen (1996) are of exceptional importance to understand why accidents/incidents occur and how to prevent them. Most traditional engineering accident/incident analysis techniques focus on the technical components of the system that failed. An exception is the human related HAZOP method (Redmill et al., 1999), which is focused on human error in the context of a technical system and was developed for the process and chemical industry. Today, due to the complexity of the processes carried out and the corresponding man-machine interfaces, the share of human error in accidents/incidents occurrence has increased. As reported by the Federal Aviation Administration (Clemens, 2002) "... more than seventy percent of all crashes of scheduled commercial aircraft are caused directly by 'controlled flight' into terrain." The same percentage (human-error contribution) holds for the chemical industry.

This paper is divided in 7 sections. It presents the reasons for accidents/incidents occurrence in Bulgarian industry—an aspiring EU member country.[1] Section 3 introduces the basic concepts of accidents/incidents analysis. The next chapter sketches the concepts of the proposed analysis approach, followed by the presentation of a case study. We close by presenting the results obtained from the application of the analysis approach and give some conclusions.

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[1] Since 2007, Bulgaria is an official EU member. This paper, was first presented at the ESREL 2006 conference, before Bulgaria had joined the EU.

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doi:10.1016/j.aap.2008.07.014

2. Safety in Bulgarian industry

2.1. Health and safety conditions of work in Bulgarian industry

Bulgaria has about 30 large potentially hazardous plants on its territory, including power plants (hydro, thermal, and nuclear), refineries, production plants (chemical, metallurgical, machine, etc.) and a shipyard (SACP, 2005). The remaining power, metallurgical and chemical plants on the territory of Bulgaria, though smaller in size or capacity in comparison, should also be considered when accounting for the total number of plants with high-risk production units. According to the analysis, made by the Executive Agency "Labour inspection" (EAGLI, 2004, 2005a,b) for provision of health and safety conditions at work in Bulgarian industry, certain progress has been made, and but problems still exit. The results, which we discuss in a short overview here, are presented jointly for the metallurgical, chemical branch of industry and the plants generating thermal and electrical energy.

2.1.1. Achievements

In all enterprises and power plants inspected by the Executive Agency, the main requirements of the Health and Safety (H&S) regulations are fulfilled: a risk assessment of the places of work and the production process is carried out, employees are provided with services by the Office of "Labour medicine" (referred to as the "Office"),[2] committees or groups responsible for conditions of safety work are established, as well as health and safety departments, or gas rescue departments. Most of the companies have implemented the ISO 9001:2000 standard. Some have even implemented an integrated environmental, quality and safety management system according to the requirements of ISO 90001:2000, 14001:20002 and OHSAS 18001. The rest are following suit. Training and educational systems for health and safety conditions of work have been established in all companies. Every newly appointed employee must undertake and pass a course dealing with H&S conditions of work, according to the specifics of his working place and profession. In general, the main process equipment is well maintained. Measurements of the parameters of the working environment are carried out annually by companies externally authorized by the Ministry of Health or by the "Office". The production output from these three sectors has increased visibly in comparison with 2003.

2.1.2. Problems

Although risk assessment is performed in all companies of these three branches, and safety departments are established, the assessments carried out are incomplete, according to the requirements of article 3 of Ordinance N 5/11.V.1999 of the Ministry of Labour and Social Policy and Ministry of Health. In most cases during the risk assessment implementation, the specific hazards and harms, resulting from operation with hazardous chemical substances and products, are not identified. The level of safeguarding the production process and the safety of machines in manufacturing sectors of companies from the metallurgical industry in particular is neglected. In some of the enterprises, the risk assessment is based on out-of-date measurements of the working environment parameters. In most of the high-risk chemical companies, the main process equipment is more than 30 year old. Therefore, the relative share of employees working in bad conditions (combined negative influence of different parameters of the working environment like noise, dust, harmful substances, especially carcinogenic chemical substances, exceeding the threshold limits of the Ministry of Health) is still high. A general wrongdoing in metallurgical companies is that repaired equipment is set back in operation, without proving sufficiently its safe performance or guarantee the safety of its employees. Controlling compliance with health and safety at work regulations by top management is not performed strictly enough, including the implementation of duties in this area by operators and employees. Overall, there is a lack of control and demand for the development of an organization of work which ensures accident free and health secure working conditions.

The data for the metallurgical industry from the observed breaches of health and safety and labour regulation by the EA shows that 40% of them are due to lapses in organization and management of health and safety activity, 36% are due to lapses in provision of safety at work, 21% are due to problems with provision of hygiene labour conditions and 3% due to legislative issues. The percentages for the power plants, regarding the same problems, are similar.

3. Accident and incidents analysis

3.1. Purpose and definition

The purpose of accident and incident analysis is to determine their causes and the specific factors that contribute to them. The analysis gives insight into what went wrong in order to take counter-measures to avoid recurrence. During the analysis, information is collected about the workplace, the work itself, the work process, and the process technology involved.

In the literature (Blacket, 2005; Johnson, 2003) different definitions of accidents and incidents exist. There is general agreement, however, that an accident can be defined as "an undesired event or sequence of events causing injury, ill-health or property damage" (NRMC, 2006), while an incident is "an unplanned, undesired event that hinders completion of a task and may cause injury or other damage" (NRMC, 2006). Incidents can include human operator injury that results in a short absence from work, minor damage to a smaller part of the system, or failure of a component—but these events do not lead to a disruption of the system as a whole (Blacket, 2005). There are five primary accident analyses types, as defined by Stellman (1998):

- Analyses and identification of where and which types of accidents occur.
- Analyses with respect to monitoring developments in the incidence of accidents.[3]
- Analyses to prioritize initiatives that call for high degrees of risk measurement, which in turn involve calculating the frequency and seriousness of accidents.
- Analyses to determine how accidents occurred and, especially, to establish both direct and underlying causes, and
- Analyses for elucidation of special areas which have otherwise attracted attention (a sort of rediscovery or control analyses).

In the following we take a closer look on existing accident analysis techniques.

3.2. Accident analysis techniques

There are many ways to analyse an accident or an incident. Traditional analytical techniques deal mainly with the identification

[2] The Office is an external centre that provides medical and health services and examination of company's employees.

[3] This type of analysis looks at factors that affect the process operation and could lead to accident and urges for monitoring the effectiveness of preventive activities (Stellman, 1998).