CHEMICAL ENGINEERING TRANSACTIONS

VOL. 31, 2013

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

Guest Editors: Eddy De Rademaeker, Bruno Fabiano, Simberto Senni Buratti

ISBN 978-88-95608-22-8; **ISSN** 1974-9791

DOI: 10.3303/CET1331070

A Critical Analysis of Techniques for the Reconstruction of Workers Accidents

Giuseppe Nano*, Marco Derudi

Politecnico di Milano, Dip. di Chimica, Materiali e Ingegneria Chimica "G. Natta"
Piazza Leonardo da Vinci 32, 20133, Milano, Italy
giuseppe.nano@polimi.it

Among the available methods for the analysis of accidents/injuries, the "Learning from Mistakes" approach and the STEP method (Sequential Timed Events Plotting) have been used to analyze a typical accident, which often occurs, in which have been involved several workers that entered in a confined space containing toxic and/or inert gases, causing the workers death. A critical analysis of the investigated methods has been performed in order to identify the best available methodology; in particular, it was evidenced a problem of events representation with the "Learning from Mistakes" method because the entire sequence of the events that led up to the accident is represented in a linear way, on a same column, by this approach making difficult to relate events that took place simultaneously. The STEP method allows, on the other hand, a good description of the events sequence making possible to organize events related to the different workers/subjects in rows and taking into account simultaneously all aspects and issues that characterize it.

1. Introduction

The problem of accidents at work has a great importance in the EU countries; in 2005, in the EU-15 community, there were about 4 million accidents with more than three days' absence from work (EU, 2009). Considering Italy, there are nearly one million of accidents per year of which about a thousand produce fatalities (INAIL, 2010). In social terms, the injury has a direct impact on workers who suffer (injury, temporary or permanent loss of vital functions, death) and the consequences in terms of costs for the society; INAIL (National Institute for Insurance against Accidents Labour) estimated a cost of about 48 billion euros for accidents at work in 2007, of which 40.4 for injuries. From this point of view is of fundamental importance the harmonization of criteria and methods for the analysis of accidents.

The accident analysis shows that in general their occurrence depend rarely from a single cause, but by many related factors. Many analytical methods have been developed in recent years (Woodcock et al., 2005), each has a specific area of application; it is sometimes useful to use multiple methods to analyze an event (Katsakiori et al., 2009). Some methods are particularly useful for collecting data, others are useful to give an overview of what has happened.

A typical accident, which often occurs, is the one which involves workers that enter in a confined environment containing toxic or inert gases, causing the workers death. One of these accidents, that occurred into an electrical arc furnace (EAF) during maintenance operation, has been analyzed in this paper through different methods for accident investigation with the aim to identify the best methodology for the accident reconstruction.

2. Methods for accidents investigation

An important aspect of the method is the ability to describe in detail all phases that characterized an accident. A good risk analysis technique must allow to recognize and describe the individual factors contributing to the occurrence of the investigated accident, to assess the role played by each factor, both

Please cite this article as: Nano G. and Derudi M., 2013, A critical analysis of techniques for the reconstruction of workers accidents, Chemical Engineering Transactions, 31, 415-420 DOI: 10.3303/CET1331070

individually and in relation with other factors, and to understand the whole accident dynamics, identifying the logical-temporal sequence that produced the event.
For the application of the method is, therefore, necessary to:
• collect information in a clear and structured way;
• reconstruct a detailed and accurate picture of the real dynamics of the accident;
• represent both the dynamics and the factors that have caused the accident;
• identify corrective measures able to affect the factors that are considered the accident causes.
Several models and theories have been proposed (Kjellen, 2009) and tested (Nano and Derudi, 2012) in the literature for the accidents analysis. Among the available methods for the analysis of accidents/injuries (Sklet, 2004), the "Learning from Mistakes" approach and the STEP method (Sequential Timed Events Plotting) have been used to analyze the case-study.

2.1 "Learning from Mistakes" approach

The first release of the "Learning from Mistakes" (originally named "Sbagliando Si Impara", SSI) model is the product of an Italian national project developed by ISPESL (Italian Institute for Prevention and Safety at Work) in 1992 in order to guarantee a homogeneous collection of information concerning accidents at work. This procedure was defined on the basis of both the international literature (Laflamme, 1990) and the Italian knowledge about safety at work (CCM, 2003).
The "Learning from Mistakes" model considers separately the concepts of accident and injury, the latter being a subset in the wider category of incidents (Campo et al., 2006). Accident is considered any event in which there is rapid and unintentional release, transformation or inappropriate application of energy that causes (or is potentially able to cause) unwanted effects such as damages to persons or property. An accident takes the status of an injury when the three following conditions are realized: it causes a damage of clinical relevance to one or more persons, the damage comes from an exchange of energy and there is a very short time interval between the time at which the energy exchange takes place and the one where the damage is established. With this technique, it is therefore possible to define the injury (Figure 1a) as an energy exchange between the environment and workers; this exchange can occur with an energy transfer (liberation, transformation) or at constant energy (improper application).
Any accident is analyzed in detail, each item is identified or listed as Determinant or Modulator.

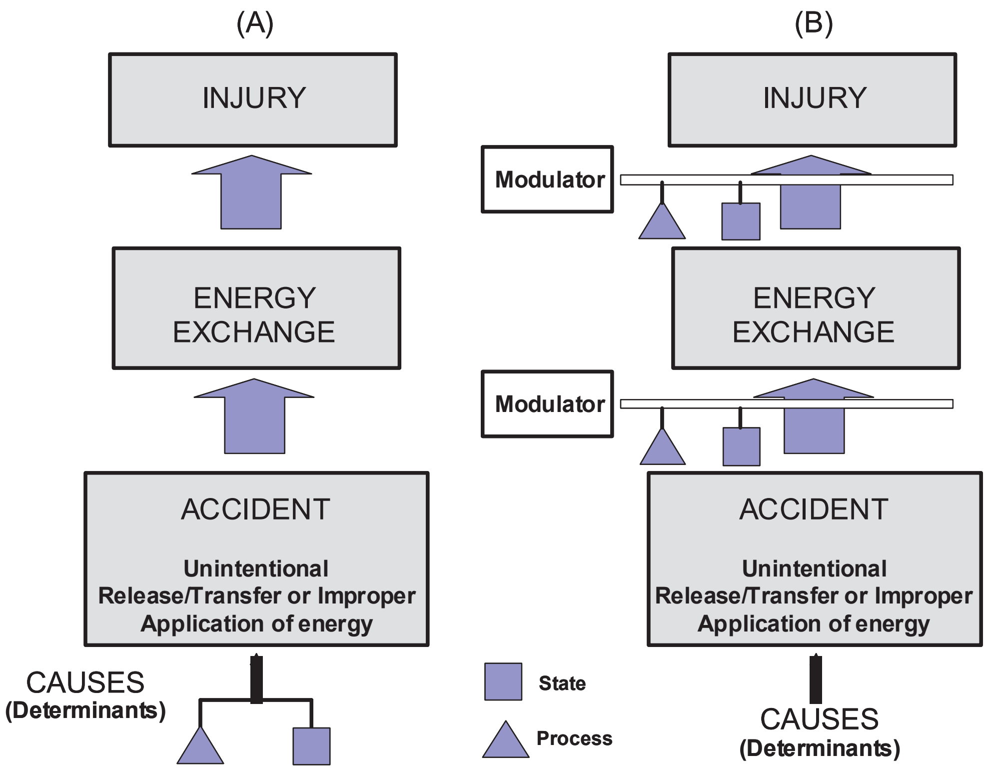

Figure 1: sketch of the "Learning from mistakes" analysis.

Each item that contributes to determine the accident is classified as a determinant; all that is irrelevant to modify the probability of occurrence of the accident, but it is able to affect the damage is considered to be a modulator. A modulator (Figure 1b) acts on the energy transfer and/or on the magnitude of the damage; a modulator may avoid, decrease or increase a possible damage.
The model traces the accident occurred starting from the exchange of energy that caused the damage, going backward through the chain of past events that where involved in the accident.

2.2 STEP technique

The STEP technique (Hendrick and Benner, 1986) provides a reconstruction of the process by plotting the sequence of events/actions that contributed to the accident. The main concepts in STEP are the initiation of the accident through an event or change that disrupted the technical system, the agents which intervene to control the system (e.g. equipment, monitoring systems, workers, automatic controllers), and the elementary “event building blocks”. The accident is commonly developed on different planes (multi-linear events) that refer to different agents and simultaneous situations; all the events are logically connected during the process (Herrera and Woltjer, 2010).
A STEP chart (Figure 2) can be prepared to represent the evolution of events, actions and system interventions (on the horizontal axis, from left to right) performed by the agents (on the vertical axis). Agents are human or inanimate objects that change their states or interact to create events leading up to the accident outcome. The STEP diagram may also include mitigation events after the accident. The first stage in STEP involves the definition of the beginning and end states of the accident. This bounds the scope of the investigation from the first event that deviated from the planned technical process to the last harmful event in the accident. Then, the main events/actions that contributed to the accident must be identified and their “event building blocks” must be constructed; typical content of these blocks can be the time at which the event/action started, its duration, the agent which caused the event/action, the description of the event/action. In the second stage, the events/actions blocks are inter-connected with arrows the recreate, with a systematic approach, a sequence of events which produces a comprehensive description of the accident dynamics. All the events should have incoming and outgoing arrows which show “precede” and “follow” relationships between events/actions. Converging arrows show dependencies between events while divergent arrows show the impact on following events. Measures for preventing an accident can be identified in terms of causal links that could be blocked and “missing” links to events with a prevention capability. STEP provides an overview of the timing and sequence of actions that contributed to the accident.

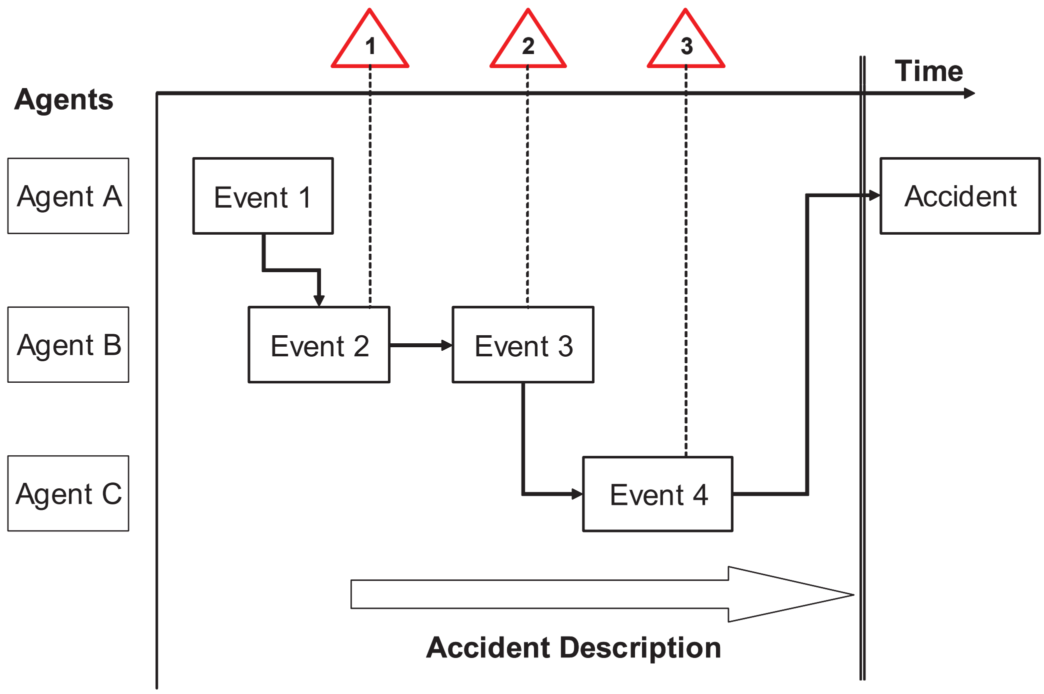

Figure 2: sketch of the STEP representation.

3. Results and discussion

The two above mentioned methods have been used to analyze a complex accident that involved four people, two of which died.

3.1 Case-study

The accident occurred in the melting area of an electric steelmaking company where there was an electric arc furnace (EAF); the EAF was equipped with three porous plugs, located on the bottom part of the furnace, for blowing Argon into the molten bath so as to homogenize the steel.
The furnace was turned off and put in safe conditions to allow maintenance operations; among the operations required to secure the furnace there was also the shut off of the Argon supply to the furnace. These safety operations were in charge to the maintenance manager, worker (A), who did all the required activities. To allow the maintenance work, both the charge and the slag doors of the furnace were opened.
Thirteen days after the safety operations, three workers (A, B, and C) did an inspection into the furnace for planning properly the maintenance work. Before going into the oven, worker (B) checked that the Argon valve was closed; during this inspection, worker (C) squatted twice to collect some materials from the bottom of the furnace, without having any inconvenience.
The day later, the maintenance manager, worker (A), and worker (D) were seen outside the furnace ready to perform the maintenance intervention; after about 20 minutes, they were found dead inside the furnace. Once they have entered in the furnace, they began to make repairs on the upper part of the oven (time estimated for the activity: 10-15 min); at a certain point, one of the workers, probably (D), squatted to change the disk of the grinding wheel. Because the Argon valve has been opened (it was not possible to know who carried out this operation), the bottom of the furnace (between the floor and the slag door, located at about 1.3 m from the sole) was saturated by the gas, given that it is heavier than air. Under these conditions, in a low oxygen environment, worker (D) lost consciousness and his death occurred within a few moments. Worker (A) saw probably his colleague on the ground, he knelt to help him but he lost consciousness and then died.

3.2 Analysis with the "Learning from Mistakes" method

The graphical representation of the accident with this method (Figure 3) is difficult and largely incomplete, the causes of the accident can be easily represented but this is not the case for the temporal dynamics.

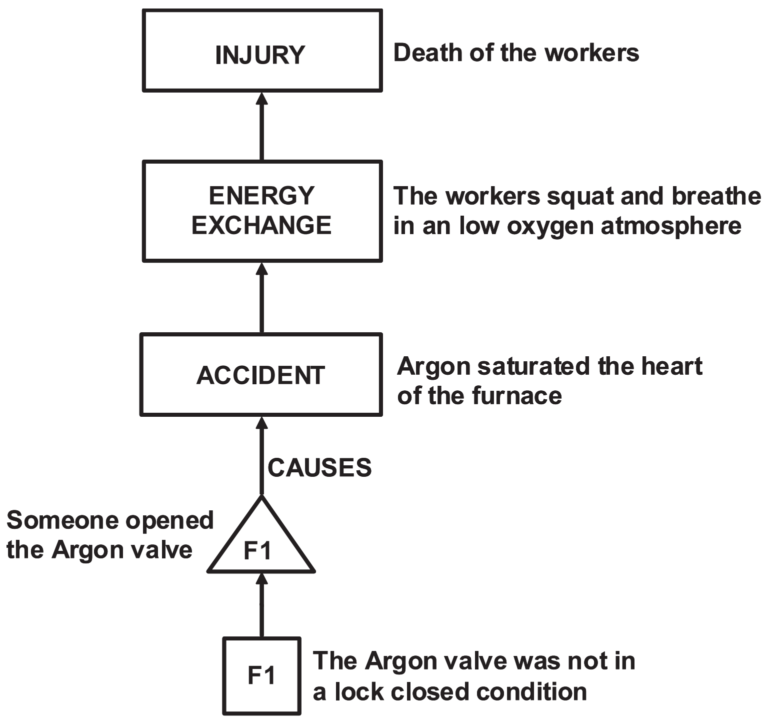

Figure 3: case-study analysis with the "Learning from mistakes" approach.

Once the bottom of the oven is saturated of Argon, there are no possible modulators apart from the use of oxygen detectors; on the other and, considering that the furnace doors were open and that the furnace was inspected the day before without problems, it was reasonable to do not consider the use of the gas detectors. This risk analysis approach seems to be more effective in representing mechanical accidents, involving only one worker and occurring with a linear dynamics.

3.3 Results with the STEP method

Using this methodology, it is possible to obtain a complete graphical representation of the accident (Figure 4) and the events dynamics is also very well described.

All the events prior to the one represented by the triangle symbol labelled 1 show that all the operations were carried out correctly; the opening of the Argon valve was ascribed to a person who has never been identified and this highlights two critical issues: the missing block of the Argon valve in a lock closed position during the operations inside the furnace and the lack of coordination among workers that have different assignments in that working area.

The events represented by the triangle symbol labelled 2 have been crucial in causing the death of the workers, who probably did not have been trained on the risk of oxygen-deficient atmospheres.

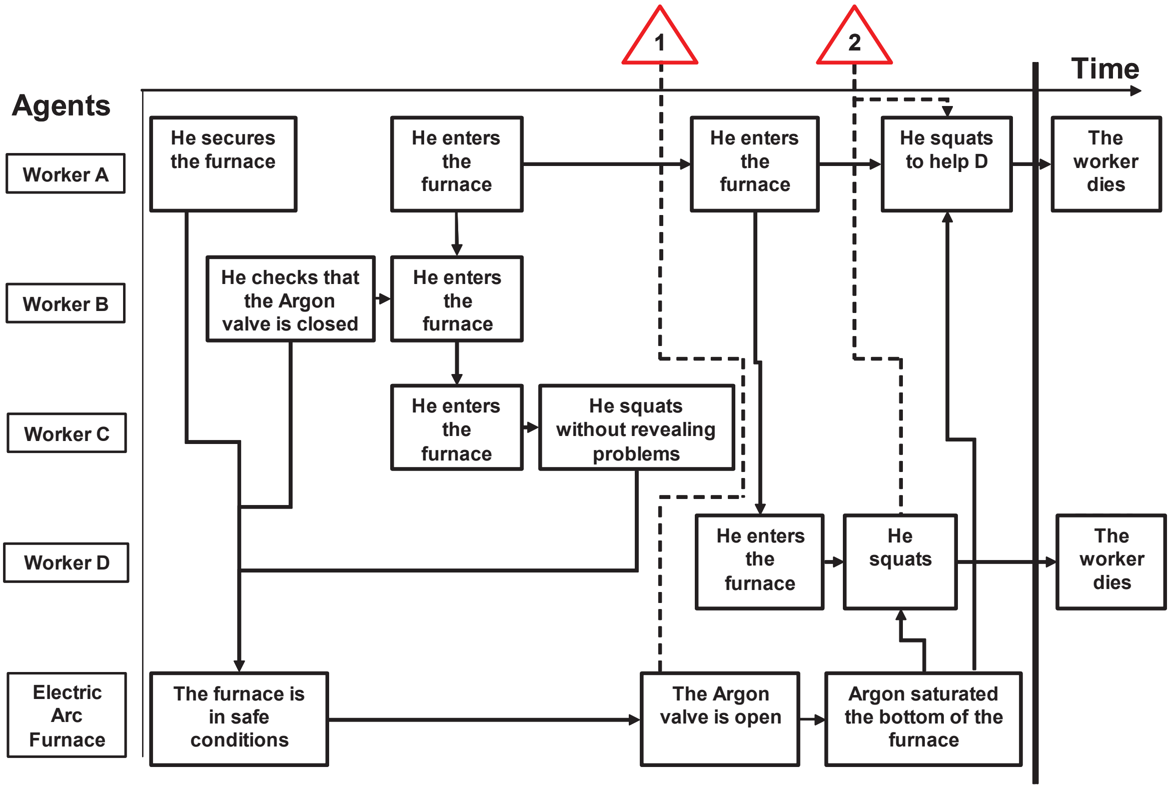

Figure 4: case-study analysis with the STEP method.

4. Conclusions

Two risk analysis methods have been tested for the investigation of a complex accident in which to 2 people were mainly involved and died; some critical issues have been evidenced. In particular, it was evidenced a problem of events representation with the “Learning from Mistakes” method because the entire sequence of the events that led up to the accident can be represented by this approach only in a linear way, thus making difficult to relate events that took place simultaneously. Moreover, this technique did not allow to describe independently the actions of few workers.

The STEP method allows, on the other hand, a good description of the events sequence making possible to organize events related to the different workers/subjects in rows and taking into account simultaneously all aspects and issues that characterize it. In the same chart, the points in which main events had effect can be highlighted.

References

Campo G., Guglielmi A., Marconi M., Pianosi G., 2006, The reconstruction of the causes and dynamics of work-related injuries using the model “we learn by our mistakes”, Prevention Today, 2, 27-39.

CCM (National Centre for the Prevention and Control of Diseases), 2003, The “Learning from Mistakes” model <http://ambienti.conform.it/webeditor/writable/389/8ModelloSbagliandoImpara.pdf> accessed 30.08.212.

European Commission, 2009. Causes and circumstances of accidents at work in the EU, Office for Official Publications of the European Communities, Luxembourg.

Hendrick K., Benner L., 1986, Investigating accidents with STEP, Ed. M. Dekker, New York/Basel.

Herrera I.A., Woltjer R., 2010, Comparing a multi-linear (STEP) and systemic (FRAM) method for accident analysis, Reliability Eng. System Safety, 95, 1269-1275.

Katsakiori P., Sakellaropoulos B., Manatakis E., 2009, Towards an evaluation of accident investigation methods in terms of their alignment with accident causation models, Safety Science, 47, 1007–1015.

Kjellen U., 2009, The safety measurement problem revisited, Safety Science, 47, 486–489.

Laflamme L., 1990, A better understanding of occupational accident genesis to improve safety in the workplace, J. Occup. Accidents, 12, 155-165.

INAIL (National Institute for Insurance against Labour Accidents), 2010, Annual report on accidents (In Italian), INAIL, Rome, Italy.

Nano G., Derudi M., 2012, Evaluation of Workers Accidents Through Risk Analysis, Chemical Engineering Transactions, 26, 603-608.

Sklet S., 2004, Comparison of some selected methods for accident investigation, J. Hazard. Mater., 111, 29–37.

Woodcock K., Drury C.G., Smiley A., Ma J., 2005, Using simulated investigations for accident investigation studies, Applied Ergonomics, 36, 1–12.