UNIVERSITY – INDUSTRY COLLABORATION: SAFETY ENGINEERING EDUCATION AT KU LEUVEN

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Abstract

In collaboration with Essenscia, a multi-sector umbrella organization that represents the numerous sectors in the field of chemicals and the life sciences, KU Leuven (Katholieke Universiteit Leuven, Belgium) adapted and expanded its safety study program to train safety experts at the university level. It consists of two options, *Prevention* and *Process Safety*, which have a number of courses in common. The common courses introduce safety as a science. They cover subjects such as safety of industrial installations, building safety and fire and explosion safety, safety aspects of chemical and biological products and processes, qualitative risk analysis and safety management. The option *Prevention* of the program trains students to become general safety experts to be active in industry, government or general safety services (including consulting…). The option *Process Safety* aims at the training of technical safety experts in the field of industrial processes. The majority of the courses are taught by professionals active in the field of safety. Visits to e.g. industrial plants or laboratories are part of the program.

Keywords: safety, education, engineering, industry, collaboration

1 INTRODUCTION

With respect to safety of the workforce, in Belgium, industrial companies, organizations and institutions are categorized on the basis of their main activity and the number of their employees. Depending on their category companies may be required to dispose of an *Internal Service for Prevention and Protection at Work.* A so-called *prevention advisor* must be part of this service. This person advises all relevant stake holders (employees, management…) about all matter related to the wellbeing of the workforce and the application of the legal requirements with respect to wellbeing.
For more than 30 years the Catholic University of Leuven (KU Leuven) has offered a study program in the field of engineering safety. The purpose was to train specialists that are able to fulfill the function of prevention advisor. Such an expert must have received in depth training in the various aspects of industrial safety. The requirements which this training must satisfy are laid down in law. The KU Leuven study program not only satisfies these requirements but goes further by providing the scientific basis of the various processes and techniques.
Recently the authorities felt that the training of the prevention advisors should reflect better the evolution of labor conditions during the last decades. This led to considerable changes in the required training of prevention advisors. On the other hand industry expressed the need for training for technical safety specialists: engineers able to design and operate complex industrial processes and equipment satisfying the safety requirements. In addition it was felt that there was a lack of training for experts in the field of external safety, in particular the assessment of the impact of industrial accidents on the general public and the environment. All these considerations led to the restructuring of the safety program.
A task force was assembled consisting of professionals active in industry as safety experts, prevention advisors, safety consultants and academics involved in teaching engineering safety and related subjects. Collaboration with industry was made possible through Essenscia, the multi-sector umbrella organization that represents the numerous sectors (companies) in the field of chemicals and the life sciences in Belgium. The task force developed a new study program, identified the course contents and was instrumental in assembling the teaching staff.

2 GOALS

As was the case in the past, the modified study program is directed towards students already having a master degree in engineering or in safety related fields (nautical sciences…). A student is expected to have the skills necessary to acquire knowledge about areas of science which are of a diverse nature and which do not have a link to his previous training (law, medical science…).
Ensuring safety at work is a very complex task requiring insight into topics of a widely differing nature. Aspects of human behavior also come into play and therefore the safety expert must be familiar with the basic principles of psychology and ergonomics (stress, heat, noise…). There are the technical aspects of the job to be performed (safe process conditions and procedures). The development of safe operating procedures requires familiarity with techniques to identify and evaluate safety risks (fire, explosion…). To learn from past incidents and accidents there is the need for specific analytical and statistical skills in order to detect causes and develop remediating measures. Safety at work is a team effort requiring an efficient management system. The body of legislation regarding industrial safety is considerable. It changes and expands constantly. Safety experts must know and understand the legislation and must be able to closely follow the changes.
The safety of an industrial process depends upon a large number of factors. The choice of the necessary material and process conditions (pressure, temperature, concentrations…) are essential parameters to be identified during the initial design phase of the process. The choice of the appropriate measurement and control equipment is also made during the design phase. A risk analysis is necessary to determine the necessary safety equipment and to determine the reliability of the installation developed. Constant follow up of the equipment is required in order to assess its performance and to take the necessary measures to guarantee its safe operation. All this requires specific skills.
Because of this large diversity of knowledge and skills, the program task force considered it necessary to split up the study program in two options. One option aims at the training of safety experts that will perform the function of prevention advisor. It is called the option **PREVENTION**. The other option prepares students to function as technical experts in the field of process safety. It is called the **PROCESS SAFETY** option. Both programs options start from a common core which consists of the basic elements of industrial safety as a science. A student has to choose between one of the two options.
A goal of the program is also to provide the scientific basis for the various techniques and methodologies which are used in the field of safety. In addition care is taken to avoid a purely academic approach. For this reason the program relies heavily on safety professionals that have in depth knowledge of their field of expertise. To illustrate this, the courses that are partly or fully taught by non-university persons are listed in the figures below preceded by **X**.

3 PROGRAM

The overall structure of the program is shown in Fig 1.
A study program leading to an additional master diploma (i.e. for those already having a master diploma) requires 60 student credits. A credit is a measure for the quantity of material covered in a course, the number of teaching hours and the effort required to complete the course. A course load of 60 credits corresponds to one year of full-time study.
About one third of the total credits is devoted to subjects which are common to the two options. This corresponds to about half of the course credits of the program. The common courses are all compulsory.
Seminars and exercise sessions are part of every course. The course credits take into account the number of hours assigned to the seminars and exercise sessions.
Figure 1 gives an indication about the language in which the subjects are taught. All the common courses and the specialty courses of Process Safety are taught in English (E). The specialty courses of Prevention, as they are intended to cover Belgian (legal) aspects of safety, are taught in Dutch (D). The elective courses of the Prevention program have to be chosen from the list of specialty courses of the Process Safety program and therefore are taught in English. The elective courses of the Process Safety program have to be chosen from the list of English language courses of the faculty of engineering of KU Leuven.

Master of Science in Safety Engineering (60 credits)	
Common courses (23) E	
Prevention	**Process Safety**
Compulsory courses (16) D	Compulsory courses (16) E
Elective courses (6) E	Elective courses (6) E
Master thesis (15)	

Figure 1 Study program general outlook

3.1 SAFETY FUNDAMENTALS

The core of the program consists of a number of courses which are compulsory for both options (see Fig. 2). The contents of these courses can be described as follows.

Introduction to Safety Engineering
This course is the starting point of the study program. The basic concepts (accident, risk...) of safety as a science are introduced and illustrated. An analysis of major industrial accidents is made to illustrate the large diversity of causes of accidents and the extent of their effects. The complexity of the task of safety experts is illustrated. The basics of risk analysis, prevention and protection are described. At the end of the course, the student is able to assess the importance of occupational safety and health within a company context and in society. He can make a choice out of the range of existing risk assessment methodologies to analyze a given situation and apply the chosen method in an elementary industrial environment. He can explain the essential features of a safety management system and outline the responsibility of the various stakeholders. He can identify the basic notions with respect to well-being at the workplace and he can analyze and investigate occupational accidents and develop appropriate preventative measures.

Prevention Policy and Safety Management Systems
At the end of this course, the student is able to demonstrate why and how specific management systems and managerial tools will lead to a balanced control of occupational safety issues. He will be able to select an appropriate management system out of the available international standards, within the constraints imposed by legal and mandatory requirements. He can analyze and optimize an existing safety management system and can implement the management systems studied in a real environment.

Safety of Chemical and Biological Products and of Chemical Processes
The aims of the course are to achieve that the student can identify and assess the hazards of chemical and biological products. He can retrieve information on these hazards. He understands this information and can interpret it. The student is familiar with the classification and labelling of chemical and biological products (CLP regulation).The student knows the differences between chemical and biological product safety.

Safety Aspects of Industrial Installations
The aim is to provide insight in the diverse technical safety problems in industry in order to allow the safety engineer to recognize the risks and to take the necessary measures to control them. The technical measures to guarantee the safe operation of systems such as thermal (heating and cooling) and

electrical power plants are described and analyzed. National and international safety codes and directives concerning mechanical and electrical systems are described.

Common courses
X Introduction to Safety Engineering (3 credits)
X Prevention Policy and Safety Management Systems (3)
Safety of Chemical and Biological Products and of Chemical Processes (4)
X Safety Aspects of Industrial Installations(4)
X Qualitative Risk Analysis Techniques (3)
X Fire Protection and Building Safety (3)
X Explosion Safety (3)

Figure 2 Common courses
(**X** indicates course partly or fully taught by non-university person)

Qualitative Risk Analysis Techniques
After taking this course, the student will be familiar with and be able to use the different qualitative techniques that are available to analyze and determine the risks associated with processes, installations and their components. The different qualitative techniques that are available for the identification and assessment of risks are described. Their specific applicability is discussed and demonstrated e.g. for the design of installations, for the execution of safety studies, for the determination of SIL (Safety Integrity Level) classification, for accident investigations, for incident analysis etc.

Fire Protection and Building Safety
The course covers the following aspects of fire protection: fire risk, severity of a fire, human reaction to fire, carbon monoxide poisoning, fire resistance, fire codes, fire properties of construction materials, legislation and standards, evacuation in case of fire and other emergencies, fire alarm systems, smoke and heat evacuation systems, fire extinguishing systems, fire safety engineering and management, fire investigation. Although it is impossible to treat in detail all these aspects, the student should nevertheless be able to recognize fire risks and to have a reasonably good view of how these can be eliminated or at least he should know where to look for solutions and where to find them.

Explosion Safety
The general aim of this course is to enable the student to evaluate the explosion risk of industrial installations based on the characteristics of the combustible substance and of the installation; and to lower this risk by applying explosion prevention and protection methods. The course covers topics such as explosion characteristics of gases, vapors, liquids and dusts, ignition sources, effects of explosions, explosion prevention and protection, ATEX and hazardous area classification. Techniques with which the strength of explosions can be estimated are explained and illustrated.

3.2 Prevention

The option “Prevention” (Fig. 3) also includes non-technical aspects and refers to the local Belgian context. This option leads to the “Certificaat Preventieadviseur Niveau 1” as defined by Belgian law. Mainly for that reason, part of the teaching here is in Dutch.

Prevention
X Introduction to Safety Engineering: Belgian Context (2)
Legal Aspects of Safety (3)
Ergonomics and Psychology (6)
Medical Implications of Safety (5)
Electives
X Quantitative Risk Analysis Techniques (3)
Statistics for Safety Engineers (3)
Process Control and Safety of Digital Systems (3)
X Environmental Safety Management (3)

Figure 3 Courses Option Prevention
(**X** indicates course partly or fully taught by non-university person)

This option starts with the second part of the introductory safety course in which some specific local aspects of Belgian safety regulations are treated. The other compulsory courses of this option are as follows:

Legal Aspects of Safety
The aim is to provide insight into the legal context of plant internal and external safety with emphasis on accident and loss prevention. The skills are developed to solve safety problems taking into account the legal requirements.

Ergonomics and Psychology
The course provides scientifically based insights into the man-machine environment with special attention for the perceptual-cognitive, motor and emotional aspects of human functionality and the factors which may have an impact upon it. The fundamental aspects of labor psychology are introduced by means of a description of the basic variables and processes and by a presentation of the most important theories. A number of methods and instruments are presented which are used in the field of labor psychology.

Medical Implications of Safety
The goal of this course is to provide insight into the relationships between health effects, loss of health and unsafe work practices and conditions. In addition one demonstrates how risk factors related to occupational diseases and accidents can be present in the work environment and how these factors can be detected. The physiological criteria applied when establishing work load limiting values are explained. The student is provided with the basic knowledge and skills to allow him to establish the presence of health risks in practice. He should be able to develop the necessary preventive measures in collaboration with a medical doctor trained in occupational health.

Students of the option Prevention in addition take 6 study credits from the group of elective courses listed in Fig.3.

3.3 Process Safety

Students interested in the more technical aspects of safety may select the option “Process Safety” which is geared towards the study of safe and reliable plant operation. Teaching is exclusively in English, opening up the program to an international audience. The compulsory courses of this option are:

Quantitative Risk Analysis Techniques
The objective of the course is to provide participants with the basic knowledge and skills to conduct a quantitative risk assessment (QRA). The course covers the key principles and the successive steps involved in performing a QRA: hazard identification and scenario selection, consequence and effect analysis, event probability and failure frequency calculation and presentation of risk estimates. The quantitative analyses of the various physical processes are described in detail.

Statistics for Safety Engineers
The course "statistics for safety engineers" specifically focuses on those elements in safety analysis that make use of probability and/or statistics and explains the basic theory and methods behind these elements. The objective is that the students hereby gain a better understanding of how probability and statistics can be used to quantify and improve safety and what the practical implications and limitations are. Emphasis is on concepts and practical applications.

Process Control and Safety of Digital Systems
The course on process control and safety of digital systems has as objective to provide the basic knowledge of and insight into process control and into the use of safety functions provided by digital systems. Students will be able to assess safety integrity levels and to understand system architectures that provide sufficient safety for specific applications.

Selected Topics: Safety in Unit Operations
In this course the student is introduced to the technique of process hazard analysis as applied to unit specific generic operation systems. Three specific unit operations are selected: reactors (from batch to continuous), storage operations and the generic distillation process. During the course the corresponding process safety aspects and techniques are explained both in a theoretical and applied way, and are illustrated by an accompanying site visit. Discussion and analysis of specific incidents are also part of this course. An overview is given of various protective systems as applied in practice.

The students of the option Process Safety can take up to 6 study credits of elective courses from a list of courses from other KU Leuven study programs (see Fig. 4).

Process Safety
X Quantitative Risk Analysis Techniques (3)
Statistics for Safety Engineers (3)
Process Control and Safety of Digital Systems (3)
X Selected Topics: Safety in Unit Operations (4)
X Selected Topics: Competence in Operations (3)
Electives
Materials Selection (3)
Degradation and Corrosion (3)
Reliability and Safety of Nuclear Power Plants (3)
Advanced Process Control in the (Bio)Chemical Industry (3)

Figure 4 Courses Option Process Safety
(**X** indicates course partly or fully taught by non-university person)

Selected Topics: Competence in Operations
In order to operate a high risk plant in a competitive environment, management and operators need specific competences. In this course those specific competences are taught by specialists within this

specific topic. The course starts with alarm management, one of the utmost important aspects in case of for instance process deviation. To prevent the use of alarms, in this part of the course risk based inspection, detailed design of safety devices, product safety aspects in case of scaling up, contractor management and functional safety stresses the preventive part of process safety risk assessment. Specific enabling topics such as the integration in a safety management system and human factors are also part of 'Competence in Operations'.
The students of the option Process Safety can take up to 6 study credits of elective courses from a list of courses from other KU Leuven study programs (see Fig. 4).

4 CONCLUSIONS

In close collaboration with industry a master degree program in the field of safety engineering has been established at KU Leuven.

After finishing this advanced master study program, the student should:

- have a broadly based knowledge of the different scientific disciplines that are needed to study and analyze the diverse technical and non-technical issues related to safety technology, risk management or prevention.
- have acquired the capabilities and competences to perform or co-ordinate a scientifically sound analysis of safety related problems and to develop and implement solutions for these problems within the governing boundary conditions (legal, organizational, technical, environmental, etc.).

To carry out the program objectives, teaching activities consist of a combination of classroom lectures, practically oriented seminars and site visits. The instructors themselves come from the academic world both inside and outside KU Leuven, or have been recruited from reputable industrial companies because of their long-standing expertise and willingness to contribute to teaching and training.

Graduates of the Master of Science in Safety Engineering program fill vacancies in small national and large multinational industrial companies at home and abroad or are employed in private and/or governmental organizations. Such organizations need experts with the ability to conduct research, carry out analyses, and perform inspections, monitoring and certification in the broad field of safety.