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/CET1331071

Process and Plant Safety – Research & Education Strategy to Keep Long Term Competences

Schmidt Jürgen

Faculty of Chemical and Process Engineering, Engler Bunte Institut, Engler Bunte Ring 1, 76434 Karlsruhe, Germany
juergen.schmidt@onlinehome.de

Germany's chemical and petrochemical industry is the largest in Europe and one of the largest in the world. Hence, high competence in chemical engineering including safety engineering is - amongst others indispensable for keeping this position. ProcessNet, an initiative of Dechema, supported the exchange of relevant knowledge and experience in process and plant safety (PPS) since long. The Research Committee of ProcessNet published already in 1997 a curriculum on PPS. Just about that time it began to show that safety engineering shifted out of the focus of many professorships since both national and European research programs in this field expired. The Research Committee was concerned about adverse developments with respect to both teaching and research and started in 2004 a still standing competence initiative (Dechema 2004). Convincing government, universities and industry that something should be done to avoid a loss of necessary competence in PPS, it was necessary to update the "Teaching profile Safety Engineering" and to propose a research strategy for PPS.

1. Introduction

Is there a need for research and development in PPS? Certainly not, because it may give the impression that there is a necessity to overcome difficulties or weaknesses in safety concepts. Traditional safety concepts are well developed and experienced. They reflect the current state of technology. Hence, plants are safe! This strange way of argumentation stops any innovation. It drops down any initiation and funding of safety projects and at the very end it degrades the safety business. A safe way of argumentation is reversely – research is needed to ensure the latest scientifically results are evaluated and considered in the current state of technology. Plants are safe, because the safety concepts are continuously questioned and proven to be the best.

Today the funding of research projects at German universities complies with roughly 5 % of the budget in the year 1995. More than 20 institutes concerned with safety topics have been closed or moved into more challenging topics. From an industrial point of view, at the same time PPS has been strengthening to a European successor story. During the last years the number and severity of incidents continuously decreased. National and international knowledge exchange is enforced and the industrial safety competences were sustainably enlarged. Is it now time to rest?

The ongoing globalization process does not stop prior to the safety business. Regulations and management processes were extensively harmonized during the last years. In parallel, outsourcing of PPS divisions into small or midsize companies was common in the German industry. Several of them do not have enough power to initiate R&D work. As a consequence, PPS groups shrink to pure service units handling traditional safety concepts. Large effort is needed to keep the background for the application of distinct safety measures and to transfer the knowledge to the next generation of employees. With only little doubts young academics tend to apply rather complex numerical calculation methods in PPS. This lead to improvements of safety concepts accompanied by lowering over-conservatisms – traditional safety margins are questioned and stepwise reduced.

One of the trends is to use numerical models in PPS – computational fluid dynamics discovers the safety departments (Schmidt, 2012). But it is mainly overlooked that more detailed calculation methods do need even more insights of a program and a deep experience in PPS combined with a safety mindset. In detail, only sufficient training and experience in dealing with modern physical and mathematical models and their solution methods enables to responsibly answer questions in the field of safety technology. Any "black box" application mentality must be avoided in safety business. A deep technical safety mindset and expertise is needed to draw clear limits of acceptance for these trends. In industry common sense about

Please cite this article as: Schmidt J., 2013, Process and plant safety – research & education strategy to keep long term competences, Chemical Engineering Transactions, 31, 421-426 DOI: 10.3303/CET1331071

the acceptance of these applications is more important than in the past. This is especially true, because the public acceptance of incidents is continuously decreased.
Nowadays, PPS is worldwide driven by rather few fellows with a long term experience. They are often well trained by long lasting experimental research projects and with the chance given in the past to gain the most important theoretical safety methods necessary to deeply understand modern safety concepts. Is it not unfair to the next generation if they do not have the same opportunity? And how long will the PPS community in Europe keep its top level if almost no safety educated young academics fill the gap of retired experts? It is time to make a change. Now!

2. The Process and Plant Safety Life Cycle

The present PPS competences are mainly dependent on a long term human resource cycle – the PPS lifecycle, see figure 1. PPS awareness and competences are strengthened and often increased by incentives. It is seldom a continuous process. Due to the high level of PPS competences incentives are often initiated by changes in public risk acceptance, which relies mainly on the current state of technology, the communication between public and industry and the course and severity of incidents. The overall public sensitivity on PPS is nowadays to a high extent a matter of media presentation. Depending on the frequency, location and the severity of incidents it may motivate the demand towards larger investigation projects to learn from incidents. It easies the willingness to fund safety projects by the government and the industry, which is the motor for R&D activities at universities and other public institutes. In the following it attracts young academics to investigate safety topics, i.e. survey the literature, extent current methodologies and physical models or to develop new concepts. Thus, the fairly theoretical knowledge in process engineering of students, e.g. in mathematics, thermodynamics, fluid mechanics, process control etc., is exemplarily applied and transferred to safety projects and, hence, much deepened. Any co-operation with students from other study courses gives the chance to further extend the view on a certain topic. This process is the most important step for knowledge transfer and forms the special safety skills, necessary to work as a safety engineer in industry. After a final Master project or a PhD study the young academics are highly motivated to start their carrier in a safety department in industry. Here, their skills and knowledge gained from process units is practiced to the safety of real plants. Senior safety engineers should train them to fulfil the step into the safety philosophy of a certain company. The philosophy will be questioned and proved. In addition the company benefits from a more or less large part of new and fresh knowledge. This guaranties a continuous and high level of safety competences in a company even so safety engineers move to other departments or will retire.

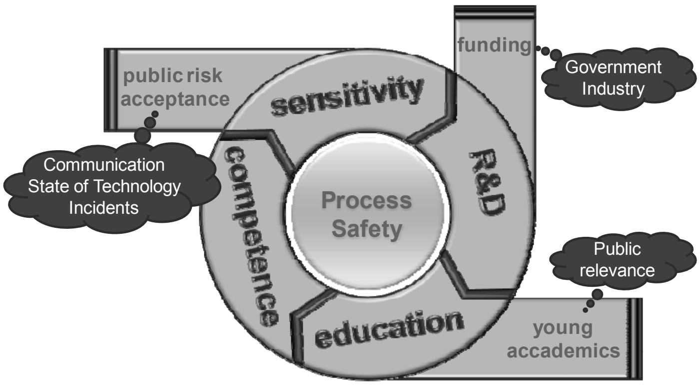

Figure 1: Process and Plant Safety Life Cycle

As long as the motivation to fund R&D projects in PPS is sufficiently high, the discipline will be attractive to students, which lead to a continuous stream of young safety engineers into industry. In Germany, the PPS lifecycle is largely unbalanced. The stream of young academics with safety skills has been dropped to a serious level. In addition the number of student in technical studies decreased at all during the last years. Hence, there has recently be some concern that process safety competence is declining, and this was a topic of discussion in the European Congress on Chemical Engineering (ECCE-8, 2011) in Berlin. Several speaker presented similar concerns from other European Countries, e.g. Netherlands (Pasman, 2011) and United Kingdom (Pitt, 2012, Jensen 2011).
The perspective is dark: there is already a large deficit in education of PPS and qualified trainees in Germany and possibly in Europe. Innovations are only hardly being possible if almost no research is done at universities. On a longer term the risk is taken to lose the high expertise in process safety and, in addition, the safety awareness may decrease. The consequences are known in industry

3. The future in process safety

Concerning the last years it has been tried in the chemical and petrochemical industry to take over main parts of the education in PPS. The idea was to educate engineers in practice - learning by doing. For that, smaller R&D projects have been performed. In larger companies there had been some success mainly with developments of safety tools. Software programs have been improved and concepts were completed. But this is not what is meant by innovations.
In the last years companies have increasingly focused on key competences resulting in a lean production in the chemical and petrochemical industry. As a result, the numbers of projects in PPS groups have drastically increased. R&D activities are more and more reduced. It takes even larger resources of safety experts to train young engineers from different engineering studies on safety topics. Innovations in PPS are not feasible on the basis of this structure. Any initiatives to change the current system failed in lack of time and priority – near term projects of existing plants have higher priorities than long term research projects.
Sustainable and united financial and research activities of the Process Industries and the Government are needed in Germany to bring the PPS Lifecycle into balance. An extended PPS study program at universities is needed to ensure necessary safety skills and a technical safety mindset. At least one PPS competence center per country is necessary to bridge the gap between safety services and safety research. The PPS competence center should be located at a university or a public institution and focused on PPS education and innovations, whereas short term R&D projects and safety services should still be performed in industry. A deep cooperation between industry and universities is needed for the knowledge transfer into the Industry.

3.1 Research Strategy

Good safety concepts and solutions are always based on common sense within the safety community. Consequently, a number of companies applying these concepts and representing the community should support research topics, especially those to create long lasting innovations in PPS. It is only seldom a topic for a single company. As a second consequence, the research should be investigated at universities and public institutes rather than in Industry. But the objectives, initiatives and a substantial part of the project funding are expected from the industry.
Typically, industrial research projects are judged by the return of investment. It is a reasonable indicator for product developments. But in case of PPS projects this indicator is most often a large barrier. Instead, the height of risk reduction or the decrease of the severity of an incident may be used, although these indicators are not usual in industry. Hence, the value of safety projects is often not feasible to the management. Safety is recognized as a cost factor, whereas product development can be estimated in earnings. As an alternative, a survey on incidents regarding a research project and an estimation of the potential harm in case a worst case scenario occur may at least help to initiate safety related research projects. The success of a safety research project accompanied by the industry is often dependent on the monitoring or steering process. A periodical review of the current activities is key important for these projects.
Main PPS topics for the next century are among others e.g. economic safety and green safety (Schmidt 2012). Economic safety measures guaranty the safety necessities of a plant, while product quality or output of the plant is increased. As an example, intelligent PLC systems may dynamically change the demands on safety measures as an alternative to a static worst case consideration of the whole process. Secondly, green safety comprises of projects to suppress any emission of a plant even under abnormal conditions. It should not be accepted, e.g., that leakages in a technical plant or pipeline may lead to large gas clouds and further potential gas explosions, leading to damages of surrounded plants and buildings. Large investment costs are needed to rebuild the buildings to withstand a higher pressure or to reroute a pipeline. Smart measurement grids may be able to detect leakages in a very early stage or even before a leakage take place. Another topic may be the development of mechanical safety devices with dynamic set pressures that do not depend on inlet pressure losses or back pressures, but still consisting of the highest safety integrity.
There are many ideas to push PPS innovations and to adapt current safety concepts on the latest developments of process plants. Recently, several chemical and petrochemical companies, safety service supplier and gas network operators have expressed their interest to found and finance a safety competence center at a German university, e.g. the Karlsruhe Institute of Technology. Research and education in PPS will be supported. It is expected to form a new generation of safety engineers with special safety skills and the typical safety mindset.

4. The new generation of Safety Engineers

What are the demands on safety engineers today? What are the expected competences? From an industrial point of view, the young academic safety engineer should be well trained in latest safety methodologies practiced on real industrial projects. Experience is expected in safety typical networking and communication. A good safety engineer relies on conservative best practices and standards well discussed and accepted in the safety community. It is her or his respond to assure not only a correct calculation based on an empirical or a physical model but also to validate the application range of the model for her or his certain project. A safety engineer must be able to develop new approaches or safety concepts from a safety point of view and to apply self evident safety methodologies and practices. In addition to any improvement of the safety level the reliability of a plant need always be considered. A deep interdisciplinary education is needed to understand the physical processes and the appropriate safety measures. This is the basis for new innovative safety concepts. Intercultural team work is desirable and a good preparation for typical for HAZOP teams in industry. The safety engineer must also be trained in physical essentials, e.g. short cut methods, to safe and fast double-check any key important result and to estimate the consequences of a proposed safety measure or recommendation (application of risk management principles). She or he should have a fundamental knowledge and experience in numerical modeling and must be well train experimentally to judge and validate models needed to reliably transfer methods to abnormal plant conditions.

A technical safety mindset of a safety engineer is formed based on a profound safety education and an intensive training to

- think lateral to get the bottom of a problem and to find its backgrounds,
- double-check and examine any result carefully to stay with conservative boundaries instead of averaging results. A safety engineers always questions interpolations and assumptions and he uses quick short cuts to validate the results of complex calculations. Furthermore, she or he is trained to
- communicate actively any new type of safety measure and to consolidate safety approaches in expert networks,
- evaluate results discipline overlapped,
- act socially responsible and convinced and
- seek for economical safety solutions.

The personal motivation of young academics and a top level safety engineering education should form the safety mindset necessary to evaluate new ideas to improve the safety of technical plants, to work out the ideas in research projects and to transfer the knowledge into a technical plant or to create a new methodology for a certain type of plants, see figure 2.

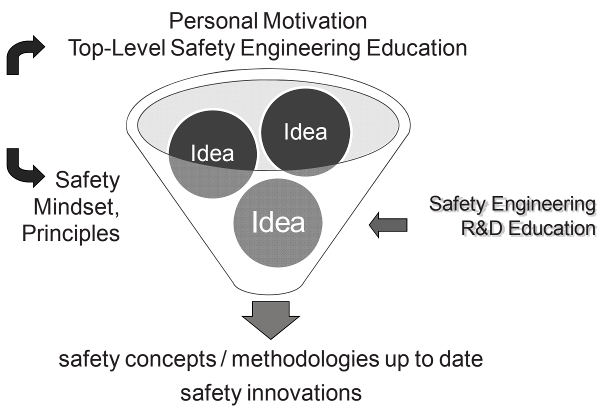

Figure 2: Innovation cone

All these aspects of training maintain the typical safety culture. But special skills need special training. It is reasonable to establish a special PPS study to form these skills. None of the current studies of process or chemical engineering in Germany are aimed to train theses skills.

A competence center in PPS is a reasonable first step towards the necessary education of engineers in PPS. Either a major concentration in process and chemical engineering or a master in PPS may be suitable. Dechema forces the integration of PPS as a mandatory part of any Bachelor engineering study. In 2012 Dechema published a curriculum for universities (Dechema 2012) to pronounce the requirements and to give hints for the topics to be lectured.

5. Educational strategy

5.1 Dechema´s curriculum

PPS competence requires specific knowledge and skills beyond what can be expected of graduates having successfully passed a standard curriculum in process or chemical engineering or chemistry. However - a sound basic knowledge in PPS has to come with every relevant bachelor or master degree.

Obviously this is only rarely the case. Furthermore, to achieve student's necessary awareness of safety needs as a first step from knowledge to competence, academic teaching must be complemented by industrial traineeships.
The ProcessNet section "Plant and Process Safety" decided to adapt the DECHEMA brochure "Safety Engineering" (1st edition 1997) to the Bologna three cycle degree system with Bachelor Master and Doctorial theses. Suggestions are made for the Bachelor and Master Curriculum, which should be offered to students with focus on the process industry. The Commission on Process Safety (KAS – Federal Ministry for the environment, nature conservation and nuclear safety) encouraged the review. The teaching program is based on the decisions of the Bologna Process of European Ministers of Culture and the recommendations of EFCE (EFCE 2010) for the education of chemical engineers.
A PPS engineering lecture of 28 hours per semester is proposed for a bachelor course. The objective is mainly to give a basic training concerning of all aspects of PPS (basic principles). The curriculum recommends the following topics and gives guidelines for the content of the lectures and courses:
(1) Safety and Risk Management
(2) Safety assessment of hazardous substances
(3) Safety assessment of chemical reactions
(4) Plant Safety Concept
(5) Protection of apparatus (End-of-Pipe-Technology)
(6) Recovering Systems for hazardous Materials
(7) Safety Instrument System (SIS)
(8) Atmospheric releases of hazardous substances as result of maloperation
(9) Fire and Explosion Protection
(10) Electrostatics

All topics are depicted in more detail in the curriculum (Dechema 2012). Beside the exercises and practical trainings recommended excursions and visits to a process plants should be offered to evaluate the safety concept of a real plant.
For the Bachelors degree cycle, process and chemical engineering and chemistry, the module is recommended to be mandatory. A particularly intense orientation on the subject PPS can be done through a supplementary module (consecutive master curriculum). Further consolidation and concentration are required through compulsory courses and the Master's thesis. Additional internships and field trips, especially to the process industry, are recommended.
PPS is particularly suitable for project oriented and discipline overlapped team work on methods and methodologies, e.g. on an industrial plant. Additionally, further subjects must be studied, for example, numerical mathematics, stochastic, occupational health, guidance of and communication with staff, risk management, regulative directives and economics to acquire the expertise and a technical safety mindset.
Main topics of a Master module are as follows:
(1) Risk analysis (application of methods), hazard identification
(2) Implementation of divers safety concepts
(3) Failure Impact Assessment
(4) Determination of site-specific risk, individual and collective risk and comparison with risk limits and curves for a selected case study

Further safety-related topics may be deepened:

- Application of numerical methods in PPS - either single or multi-dimensional fluid mechanic or
- thermodynamic calculations are feasible
- International risk assessment and risk communication including modern web-applications
- Experimental training in the field of PPS, e.g.: experimental lecture and / or excursion to technical institutes / test laboratories. Two-phase flow applications, reactor relief experiments and modern PLC techniques should be offered as mandatory exercises or part of any Master / PhD-Thesis.

The Master's program should be supplemented by elective courses according to individual educational focus primarily given by industrial representatives to bridge theory and practice of PPS. In general, PPS courses should meet the requirements of the current PPS practices in industry. Most favourable to lecture the courses are one or more supervisors with a long term experience in safety engineering.

5.2 Lifelong learning

The training at universities in Bachelor (basic education level) and consecutive master (primary education level) modules is a major step towards the lifelong learning strategy in PPS. Additional, PhD studies (secondary education level) must be offered to stimulate the research and to keep the PPS life cycle balanced.
In industry, special strategies and applications as well as deeply adapted solutions of safety methods have to be learned (primary industrial education level). This takes typically 1 to 3 years of practice. In several companies this education time of young academics is used to further develop internal application software and extend existing safety concepts. With each new industrial project and each consideration of a specific

plant experience in safety engineering is growing up. This leads to a senior level of safety education after a few years.
Education levels in PPS must be distinguished from training levels - education is about knowledge and understanding and should enable people to deal with new situations (typical for university graduates). By contrast, training is about knowing and practicing what to do in predefined circumstances. One is not superior to the others, they are just appropriate for different objectives, and it is a common error to confuse the two (Pitt 2012).

6. Conclusion

PPS has to keep up with other developments in science and engineering. Since years, research funding programs primarily support topical research areas like climate change, life sciences or security. Other areas like safety remain neglected. One consequence is that the academic research on PPS continues to decrease more than desirable. Long lasting solutions have to be found to prevent any degradation in PPS competence in Europe (ECCE-8, 2011).
There is a strong need to focus industry-wide at least on certain "PPS hot spots" at universities in any European country. Research must be initiated, funded and accompanied to balance the PPS lifecycle. Furthermore PPS must be a mandatory lecture for graduates in process and chemical engineering and chemistry. A consecutive Master intensifies the knowledge. Bachelor, Master and PhD thesis in PPS allow for focusing on specific methods and methodologies and are a major part towards a technical safety mindset. Dechema´s curriculum gives practical recommendations about industrial requirements.

References

Dechema, 2004, Maintaining and improving competence in safety engineering, Position paper of the DECHEMA/GVC Research Committee "Safety Engineering in Chemical Plants", March 2004

Dechema, 2012, Model Curriculum "Process and Plant Safety" - Recommendation for education in a Bologna Three Cycle Degree System, Dechema, Frankfurt am Main, Germany

ECCE-8, 2011: booklet on the ECCE 8's special session on process and plant safety "Process Safety Competence - European Strength degrading to Weakness?" 25th to 29th Sep. 2011 at the IC Berlin

EFCE 2010, EFCE Recommendations for Chemical Engineering Education in a Bologna Three Cycle Degree System, 2nd revised edition, http://www.efce.info/BolognaRecommendation.html

Jensen N., 2011, Universities teaching process and plant safety – the European map, presentation on the 8th European Congress of Chemical Engineering, 25th to 29th September 2011 at the IC Berlin

Pasman H., 2011, "Safety competence - Key insights from a study on the Dutch situation" presentation on the 8th European Congress of Chemical Engineering, 25th to 29th September 2011 at the IC Berlin

Pitt M.J., 2012, Teaching Safety in Chemical Engineering: what, how and who? Chemical Engineering Technology, 35, No. 8, 1341-1345

Schmidt J. (ed.), 2012, Process and Plant Safety: Applying Computational Fluid Dynamics. Wiley Verlags GmbH

Schmidt J., 2012: Wangerooge Safety Days 2012, Workshop „Catastrophic Incidents and Exceptional Hazardous events“, presentation of Schmidt. J., “Preservation of Competences in PPS as a Strategy for a Sustainable Prevention of Incidents”. Wangerooge 22 to 25 of April 2012 (in German)