PROCESSNET
EINE INITIATIVE VON DECHEMA UND VDI-GVC

Recommendation for education in a Bologna Three-Cycle Degree System

Model Curriculum „Process and Plant Safety“

Released by ProcessNet Section “Plant and Process Safety”

Frankfurt am Main (January 2013)

DECHEMA

VDI

IMPRINT

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Publisher
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ISBN 978-3-89746-141-3

Published in January 2013

Original German version published in October 2012 under “Lehrprofil Prozess- und Anlagensicherheit”,
ISBN 978-3-89746-134-5, see www.processnet.org/lehrprofil

CONTENT

Safety considerations are required throughout the life cycle of technical systems for physical, chemical and biological processing of chemical substances. These are directly linked to environmental and labor protection as well as product safety. They are the basis for any process and plant safety measures. In order to sustain the corresponding skills for such exercises, it is required that universities and institutions for higher education offer an independent module „Process and Plant Safety“.

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. The Commission on Process Safety (KAS – Federal Ministry for the environment, nature conservation and nuclear safety) encouraged the review.

The new model curriculum „Process and Plant Safety“ was formulated by a working group which brought together representatives from universities and process industry: H. W Brenig, (Cologne University of Applied Sciences), U. Hauptmanns (Otto-von-Guericke-University Magdeburg), O. Klais (Sulzbach), J. Schmidt (BASF SE / Karlsruhe Institute of Technology), H.-U. Moritz (University of Hamburg), and A. Schönbucher (University of Duisburg-Essen, chairman). Helpful suggestions by Ch. Jochum (Bad Soden) and N. Pfeil (Berlin) were incorporated.

The teaching program is based on the decisions of the Bologna Process of European Ministers of Culture[1] and the recommendations of EFCE[2] for the education of chemical engineers.

Herewith the working group presents the revised model curriculum “Process and Plant Safety”. It should serve as a basis for further discussions to all persons interested in advancement of process safety.

K. Mitropetros (DECHEMA e.V.) was responsible for review and editing.

1 http://www.ond.vlaanderen.be/hogeronderwijs/bologna/conference/documents/Leuven_Louvain-la-Neuve_Communiqu%E9_April_2009.pdf
2 http://www.efce.info/Bologna_Recommendation.html

1 Introduction

Safety is a basic human need. Many inventions in the past were originated by the desire for improved safety. In many respects the chemical industry contributed with numerous products.

The safe and ecologically justifiable production of chemical products is a challenge for scientists and engineers. They ensure that manufacturing facilities are planned, built, operated and dissembled safely, and assure safe workplaces to the employees. Only if this is achieved, it is ethically responsible to operate industrial plants in modern day society.

The prevention of hazards arising from substance or from energy releases has become a main topic of social discourse. In a society of growing need and awareness for process and technical safety, a focus of safety professionals should be put on consulting the industry based on risks and chances of the industrial production.

Process and plant safety serves the prevention, the control of deviations of normal operation and to limit their consequences, respectively. It is directly related to occupational and environmental protection. In addition, it contributes to the reliability and thus the profitability of the production.

In Europe and in Germany in particular there are substantial rules and regulations on process safety, occupational health and environmental protection. Despite fulfilling the legal requirements and ongoing efforts to improve the technical safety standard and training of the operators in dealing with technology problems incidents cannot be avoided entirely. But the probability of occurrence can be reduced. These facts have to be aware to all persons involved in the production process as well as to the general public.

Process and plant safety in the material and energy converting industry is a profession in its own. It is more in need of interdisciplinary skills than other professions. Process and plant safety is a comparable corporate goal with environmental protection, product safety, quality and efficiency.

The Model Curriculum reflects the three degree levels: Bachelor, Master and doctoral. Suggestions are made for the Bachelor and Master Curriculum, which should be offered to students with focus on the process industry.

The acquisition of expertise in process and plant safety has increasingly been complemented by interdisciplinary and intersectorial competence. Future scientists and engineers should be qualified to innovative solutions of technical problems, Europe wide employment and to promote social or cultural advancement in a knowledge-based society[3].

3 VDI: „Ingenieurausbildung im Umbruch“ (Mai 1995)

2 Curriculum Process and Plant Safety

2.1 Bachelor and Master

The Bologna Declaration of 1999 created the basis for a three-cycle higher education system with the completion of Doctoral Thesis in Europe. For the first two cycles, Bachelor and Master, 5 years of study are provided in total (standard period). This is associated with,

- the introduction of a new structure of the curriculum (modular)
- the evaluation of academic performance by a recognized European Credit Transfer System (ECTS), and
- the increased focus of studies on the acquisition of competence to respond to the changing demands of the fast evolving technology and society.

2.1.1 Modularization

A module is formed by a thematic unit of study, which usually takes 1-2 semesters. A module can consist of several courses of different types, e.g. lectures, tutorial, practical training or seminar and concludes with an examination.

2.1.2 ECTS-Concept

The ECTS evaluates the study performance based on student workload. In general, for 30 hours a credit point is given; a semester comprises 30 ECTS, the entire study (Bachelor and Master) 300 ECTS (of which 180 – 240 ECTS for the Bachelor and 60 – 120 ECTS for the master).

2.1.3 Competencies

As part of the academic studies students acquire besides the technical competence professional skill to realize the acquired knowledge (instrumental skills), profound knowledge based skills in decision making (systemic competence), responsible behavior in their profession and in society (communicative skills)

2.1.4 Bachelor[4]

- First scientific qualification relevant for employment after 3 – 4 years (180 – 240 ECTS)
- Requirements: matriculation standard (for university or college) or equivalent graduation
- Target: employability, acquisition of basic professional education in the subject
- Opportunities for Bachelor graduates:
  - enter the labor market
  - continuation of education for Master degree with the acquisition of profound knowledge and specialization on selected topics at the same or another university in the country or abroad

2.1.5 Master

- Second scientific qualification after another 1 – 2 years (60 – 120 ECTS)
- Requirements: Bachelor or comparable degree of an university or equivalent institution
- Research or application oriented study
- Subsequent options:
  - Employment in research or professional fields, which require a profound scientific education
  - Eligible for third cycle doctorate

4 Die Umsetzung der Bologna-Reform an den Hochschulen; HRK 25.5.2011

For more information on the Bologna Process and the content and structure of Bachelor and Master cycle reference is given to the website of the Standing Conference of the Ministers of Education and Cultural Affairs[5] and the German Rector Conference[6]:

2.2 Target groups and requirements

The following Model Curriculum addresses to lecturers and students (Bachelor and Master) in the area closely connected with the process industry, in particularly:

- Chemical Engineering and Chemical Technology,
- Process Engineering,
- Chemistry,
- Mechanical Engineering with focus on process industries,
- Biotechnology / Bioengineering and
- Industrial Engineering

The education presumes competent knowledge in mathematics / natural science and engineering as for a Curriculum in chemistry, chemical engineering or mechanical engineering are typically required.

The education of the required knowledge and the acquisition of the associated competencies take place in the stand-alone module “Process and Plant Safety” in the Bachelor and Master degree cycle. It can be structured depending on the scope of the curriculum into several courses. The workload for each module should be about 150 hours, including preparation and follow-up periods.

For the Bachelor degree cycles, “Chemical Engineering” and “Technical Chemistry” and “Process Engineering”, the module should be mandatory. In the Bachelor degree cycles “Chemistry”, “Mechanical Engineering”, “Bioprocess Engineering” and “Industrial Engineering” such a module should be offered as an optional module.

A particularly intense orientation on the subject Process and Plant Safety can be done through a supplementary module “Master Curriculum”. Further consolidation and concentration are required through compulsory courses and the Master thesis. Additional internships and field trips, especially to the process industry, are recommended.

For lecturers this Curriculum is considered as a guideline regarding content and volume of the courses.

2.3 Objective

The Curriculum “Process and Plant Safety” is based on the current state of science and technology. Recommendations are given regarding content and volume of the curriculum for lecturers and students. It forms the basis for the promotion of young talents and for the further development of process and plant safety. It also defines the required knowledge from the scientific respectively practical point of view.

The here given requirements should enable the students for their future tasks at the interface between environment and society and to acquire the ability to work in an evolving environment in an adequate and responsible manner.

5 http://www.kmk.org
6 http://www.hrk.de

The aim of the Curriculum program is to ensure the quality of the related courses of study, to provide expertise in process safety in research and industrial practice in future and to develop the field in accordance with the progress in the process industry.

2.4 Organization and structure of the Curriculum

The Model Curriculum "Process and Plant Safety" has to be converted into specific modules for Bachelor and Master programs by the universities in accordance with the given conditions and constrains.

The Bachelor module "Process and Plant Safety" will extend over 1 – 2 semesters and should conclude with an examination. The Consecutive Master module can be offered in the form of a seminar extended by exercises and project work.

The assignment of the Model Curriculum to offered courses should consider the changes in the academic education triggered by the Bologna Process. These changes touch the learning concepts in particular with regard to subject-specific and cross-disciplinary skills as a "learning outcomes" as they are currently being discussed in Europe[7]. It is also suggested to structure the Curriculum corresponding to a fictitious or existing process plant in order to emphasize the practical relevance.

2.5 Curriculum

The described contents of the Curriculum are related to a basic Bachelor module with a subsequent Master module. The detailed description of the education subjects and the content structure of each module are subject to the responsible lecturers.

2.5.1 Bachelor Module

(1) Introduction

- Normal operation, maloperation and accidents - causes and technical as well as financial consequences
- Basic opportunities for plant protection
- Process and plant safety as an interdisciplinary working field
- Correlation of process safety in regard to occupational health
- Plant Safety and plant Security
- The legal framework (national and Europe)

Time units: 1

(2) Safety and Risk Management

- Concepts / definitions: hazard, risk, limiting risk, acceptable risk
- Concepts for plant safety (primary and secondary protection measures)

7 Wildt J.; Vom Lehren zum Lernen – Zum Wandel der Lernkultur in modularisierten Studienstrukturen; Neues Handbuch Hochschullehre (NHHL); Raabe Fachverlag;

- Methods of hazard identification, assessment and mitigation e.g. HAZOP, Failure Modes and Effects Analysis, Fault Tree Analysis, Layers of Protection Analysis (LOPA)
- Risk analysis and assessment
- Possibilities of hazard prevention / risk minimization
- HSE Integrated Management Systems

Time Units: 4

(3) Safety assessment of hazardous substances

- Hazardous substances, preparations and products
- Classification, packaging, labelling of dangerous substances
  - Physical and chemical hazards
  - Health Hazards
  - Environmental Hazards
- Risks related to chemical agents at work (indicative occupational exposure limit values)
- Material Safety Data Sheets and their use
- Transport, storage and handling of materials including corrosion
- Product safety

Time Units: 3

(4) Safety assessment of chemical reactions

- Runaway of a chemical process / theory of thermal explosion / TRAS 410
- Self-ignition of solids
- Identification of safety risks and assessment of corresponding hazards
- Safety-related parameters (such as adiabatic temperature rise, adiabatic induction time)

Time Units: 4

(5) Plant Safety Concept

- Optimization of production processes
- Safety Concepts (inherently safe)
- Failure of technical components
- Personnel actions (Human Factors)
- Particular safety concepts (e.g. biosafety, working with nanoparticles)

Time Units: 2

2 CURRICULUM PROCESS AND PLANT SAFETY

(6) Protection of apparatus (End-of-Pipe-Technology)

- Mode of function of safety devices (e.g. protecting system against explosion, safety valves, bursting discs)
- Ebullition of fluids, mass flow / vapors to discharge in case of reactor relief
- Protection mode in case of larger hold-up masses
- Specific requirements for process equipment such as distillation columns, heat transfer oil systems
- Protective measures for storage of hazardous liquids and solids (e.g., inerting, temperature control)

Time Units: 3

(7) Recovering Systems for hazardous Materials

- Typical applications in process industry
- Recovery of hazardous liquids / vapors
  – Collecting tray and disposal systems
  – Pressure relief into disposal system: e.g. separator, direct condensation (quenching / immersion), flare

Time Units: 2

(8) Safety Instrument System (SIS)

- Design of safety instrument systems including signal processing
- Classification of instruments including sensors, logic solvers and actuators
- Requirements for Safety Instrument Function / Safety Integrity Level (SIL)
- Software-based protection systems (modeling, validation, IT security)

Time Units: 3

(9) Atmospheric releases of hazardous substances as result of maloperation

- Source terms (type of release, mass and energy flows)
- Releases to form a free jet (high pressure systems)
- Atmospheric dispersion (inversion, atmospheric temperature stratification, turbulence)
- Evaluation of the spread of toxic substances and comparison with accepted level of exposure (e.g., ERPG, AEGL, Probits)
- Review of fire and explosion hazards (limiting risk)

Time Units: 2

(10) Fire and Explosion Protection

- Explosion with air as oxidizer (gas and dust explosion)
- Chemical explosion (deflagration / detonation)
- Explosion limits in dual / ternary systems
- Area Classification regarding explosion risk (zoning)
- Primary, secondary and constructive protective measures for explosion
- Fire protection (preventive, plant design, protective and organizational)
- Fire protection concepts for process plants

Time Units: 3

(11) Electrostatics

- Basics of electrostatics / physical effects (electrostatic induction, contact charging)
- Discharge mechanisms / discharge modes (sparks / brush discharges / propagating brush discharges / cone discharges)
- Protective measures against dangerous discharges of static electricity

Time Units: 1

ITotal: 28 Time Units (14 weeks at 2 x 45 minutes / week)

Recommended:

I. **exercises / practical training (scope: about 28 time units)**
II. Excursions
III. Visit to a process plant
IV. Evaluation the safety concept of a real plant

2.5.2 Master Module

Non Consecutive

The above course content (Bachelor) can be offered in a None-consecutive Master program. The course contents should be presented in an extended volume and in more details in reference to the extensive knowledge of the students in mathematics, physics, chemistry, thermodynamics and fluid dynamics.

Consecutive

The Bachelor degree including the above described module “Process and Plant Safety” is assumed. Core of the consecutive Master program is the following Master Module. To acquire the expertise, additional subjects must be studied, for example, numerical mathematics, stochastic, occupational health, guidance of and communication with staff, risk management, regulatory directives and economics.

a) Familiarization with process control tools / acquisition of knowledge on function of equipment on the basis of:

- R & I flowcharts
- Systems and process descriptions
- Assessment of material properties, chemical reactions and the process (safety parameters)
- Formulation of the focal parameters to control the desired chemical reaction / process
- Safety assessment of the intended operation
- Alternative process steps to enhance safety
- Determination of the permissible range of deviations from normal (alarms)

2 CURRICULUM PROCESS AND PLANT SAFETY

b) Risk analysis (application of methods), hazard identification for a fictitious / real plant

- Assessment of possible deviations in technology and maloperation of operators
- Environmental hazard
- Quantification of event and fault trees
- Assessment of results – discussion on design alternatives

c) Implementation of divers safety concepts

- Development and evaluation of alternative plant safety concepts through independent Layers of Protection
- Specification for Process Control System
- Design of mechanical protective measures including recovering systems (safety valve, rupture disc, cyclone, quench, immersion)

d) Failure Impact Assessment

- Identification of potential maloperations with release of substances
- Development of scenarios and assessment of their probability
- Calculation of the corresponding source terms for a release of substance
- Numerical simulations of the spread of dangerous substances
- Simulations for explosion / Fire: blast, thermal radiation, debris litter
- Reduction by secondary protection measures

e) Determination of location-specific risk, individual and collective risk and comparison with risk limits and curves for a selected case study

f) In-depth analysis of safety-related topics

- SIL-protection concepts, analysis and determination of reliability parameters
- Safety requirements in the field of biotechnology
- New process equipment such as micro-structured reactors
- Explosion-protection concepts for complex exhaust systems, dust extraction plants, etc.
- Calculation of two-phase pressure relief
- Limitations of simulation and modeling in their predictions (uncertainty in models and data)
- Contribution of process safety to sustainability in the process industry (Eco-efficiency and Sustainability Assessment)

g) Risk Assessment and Risk Communication

h) Training in the field of process safety, preferably experimental, e.g.:

- Reaction calorimeter for the characterization of substances and mixtures
- Determination of flammability data
- Measurement of multiphase flows characteristic data
- Numerical modeling of pressure relief into disposal systems including reference to substance relation, explosion and / or fire scenarios

i) Experimental lecture and / or excursion to technical institutes / test laboratories

Master thesis in the field “Process and Plant Safety”

The Master program should be supplemented by elective courses in accordance to the individual educational focus of the university / college.

3 Recommendations for the practical implementation

It is assumed that the entire teaching spectrum usually cannot be covered by a single lecturer. In the light of the diversity of the Curriculum it may be useful to split the course to several lecturers specialized on the specific subjects, the cooperation with lecturers of other educational institutions respectively the commitment of lecturers with practical experience.

Because of the importance of the topic, the establishment of more commensurate training and research facilities at universities and colleges is needed. The focus of research at the various institutions should be complementary.

4 Literature

The progress in process and plant safety is documented in scientific publications, monographs and books. In the following, selected reference books and standard works are listed, which can facilitate the access into the topic. The change of classification and labeling of dangerous substances in consequence of global harmonization demonstrated what changes take place in a short time. A look at the current legislation / European directives and the documents of the Commission for Plant Safety (KAS) is thus recommended.

The literature is divided according to the curriculum.

(1) Introduction and (5) Plant Safety Concepts

Overview

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Complementary

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- Methods for the calculation of Physical Effects Due to releases of hazardous materials (liquids and gases) – Third edition Second revised print 2005
- Methods for the determination of possible damage to people and objects resulting from releases of hazardous materials - First edition 1992, ISBN 90-5307-052-4
- Guidelines for quantitative risk assessment – First edition 1999/2005
- Methods for determining and processing probabilities - Second edition 1997/2005

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[8] Hauptmanns, U., Prozess- und Anlagensicherheit, in Vorbereitung, Wiley-VCH, Weinheim

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(2) Safety and Risk Management

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- Chemie Ingenieur Technik, Volume 81, Issue 1-2, Pages 3-186, February 2009, ISSN 0930-7516
- Chemical Engineering & Technology, Volume 32, Issue 2, Pages 167-327, February, 2009, ISSN 0930-7516
- Technische Überwachung, Ausgabe 1-2/2009, ISSN 2191-0073
- Forschung im Ingenieurwesen, Volume 73, Number 1, April 2009, ISSN 0015-7899
- Forschung im Ingenieurwesen, Volume 73, Number 2, June 2009, ISSN 0015-7899

(3) Safety assessment of hazardous substances

[16] Verordnung (EG) Nr. 1272/2008 des Europäischen Parlaments und des Rates vom 16. Dezember 2008 über die Einstufung, Kennzeichnung und Verpackung von Stoffen und Gemischen (CLP-Verordnung) und Anpassungsverordnungen (Harmonisiertes Einstufungs-und Kennzeichnungssystem)

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[18] Technische Regeln Gefahrstoffverordnung, z.B.: TRGS 200: Einstufung und Kennzeichnung von Stoffen, Zubereitungen und Erzeugnissen (2006/2010); TRGS 400: Gefährdungsbeurteilung für Tätigkeiten mit Gefahrstoffen (2010); TRGS 510: Lagerung von Gefahrstoffen in ortsbeweglichen Behältern (2010); TRGS 900: Arbeitsplatzgrenzwerte (2006); Bekanntmachung 220: Sicherheitsdatenblatt (2007)

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(6) Protection of Apparatus (End-of-pipe-Technology) and (7) Recovering systems for hazardous Materials

Explosions venting, Explosion suppression, Explosion proofed construction: see Explosion Protection (10)

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[30] Schmidt J.: Auslegung von Sicherheitsventilen für Mehrzweckanlagen nach ISO 4126-10, Chem. Ing. Techn. 83, No 6, 796-812 (2011)

(8) Safety Instrument System

[31] VDI/VDE 2180: Sicherung von Anlagen der Verfahrenstechnik mit Mitteln der Prozessleittechnik

[32] DIN IEC 61511 / VDE 0810: Sicherheitstechnische Systeme für die Prozessindustrie

[33] Publikationen der KAS (Kommission für Anlagensicherheit)

(9) Atmospheric releases of hazardous substances as result of maloperation

[34] Kommission für Anlagensicherheit: KAS-18: Empfehlungen für Abstände zwischen Betriebsbereichen nach der Störfall-Verordnung und schutzbedürftigen Gebieten im Rahmen der Bauleitplanung-Umsetzung § 50 BImSchG (Nov. 2010)

[35] VDI 3783 Blatt 1 “Ausbreitung von Luftverunreinigungen in der Atmosphäre; Ausbreitung von störfallbedingten Freisetzungen; Sicherheitsanalyse“ (2004-08)

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[37] VDI 3783 Blatt 4 “ Umweltmeteorologie - Akute Stofffreisetzungen in die Atmosphäre - Anforderungen an ein optimales System zur Bestimmung und Bewertung der Schadstoffbelastung in der Atmosphäre“ (2009-12)

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See also Website ProcessNet Section „Plant and Process Safety“: www.processnet.de/APS

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