

**INCORPORATING
SAFETY, HEALTH AND
ENVIRONMENTAL RISK ISSUES
IN
UNDERGRADUATE
ENGINEERING COURSES**

A document by the

Inter-Institutional Group

on

Health and Safety

of the

Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Electrical Engineers
Institution of Mechanical Engineers
The Hazards Forum

INCORPORATING SAFETY, HEALTH AND ENVIRONMENTAL RISK ISSUES IN UNDERGRADUATE ENGINEERING COURSES

Summary

The teaching of Safety, Health and Environmental (SHE) risk issues to undergraduates studying engineering courses is an important part of the education of future engineers at all levels. It is the generally expressed view amongst UK practitioners in industry, business and other organisations that the management of SHE risks in the workplace is not adequately covered in the current taught-course syllabus and content of many engineering courses.

As an integral part of their competencies all engineers need to be equipped to appreciate, understand and implement the requirements of SHE management and practice to meet the working needs of industry and of their company (or other organisation). Whilst the level of risk and degree of control is dependant on the industry sector concerned the basic principles do not change.

This paper from the “Inter Institutional Group on Health and Safety” provides fundamental information for teaching of Safety, Health and Environmental Risk Issues. It is principally a template for use by all those involved in the process of course design and accreditation of engineering courses.

The purpose of this initiative is to ensure that all students who complete their engineering course have a basic understanding of safety, health and environmental risk issues relevant to their specific course of professional study.

The Inter Institutional Group on Health and Safety commends this approach to all of those bodies and individuals involved in the process of educating engineering students to become competent in their chosen subject and career.

The Template may be downloaded from <http://www.iee.org/Policy/Areas/Health/SHE.doc>.

About the Inter-Institutional Group on Health and Safety

The mission of the Group is to enhance awareness and knowledge of health, safety and environmental risk issues in the interests of the engineering profession. The aims of the Group are:

- to raise awareness of health, safety and environmental risk issues by joint action,
- to act as a forum for the exchange of information of the member organisations,
- to promote and co-ordinate initiatives, activities and other developments originating in member organisations which may be of interest and benefit to the engineering community,
- to work jointly on an agreed basis on health, safety and environmental risk related issues where there is benefit to the engineering community

The Group seeks to involve all Institutions represented by the Engineering Council. It is currently comprises members representing the Institutions of Chemical, Civil, Electrical, and Mechanical Engineers and the Hazards Forum. The Health and Safety Executive is also represented at meetings and has supported this work on teaching of HSE risk issues at undergraduate level.

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TEMPLATE FOR INCORPORATING SAFETY, HEALTH AND ENVIRONMENTAL RISK ISSUES IN UNDERGRADUATE ENGINEERING COURSES

Introduction

This paper provides a template for use by all those involved in the process of course design and accreditation. If used it should enable engineers to graduate with a basic understanding of safety, health and environmental risk issues relevant to their specific course of study.

The template is principally intended for accredited undergraduate courses leading to chartered or incorporated engineer status in those engineering disciplines that come under the umbrella of the Engineering Council. However, the principles should apply equally well to related courses. For example, in the construction industry to potential CIOB, RICS and RIBA membership.

Use

The use of the template should enable safety, health and environmental risk issues to be incorporated into an undergraduate engineering course without the addition of further modules to the current syllabus, (although basic introductory material could be taught to avoid repetition across the syllabus).

It is designed to be used within a system, which has the following requirements and features: -

- a) the Engineering Council and professional institutions should include the requirement for courses to address SHE issues, using this template in their accreditation process ultimately leading to the award of a professional qualification
- b) accreditation bodies should concern themselves with the achieving of SHE learning outcomes rather than rigid adherence to a standardised syllabus
- c) the HSE and the Environment Agency should be encouraged to maintain contact with institutions' accreditation bodies to promote adoption of this template
- d) teaching institutions should indicate target levels of attainment selected for a particular course using the following descriptions as exemplars
- e) as far as possible, teaching on safety, health and environmental risk issues should not be confined to a single module but be an integral part of all other teaching material
- f) the teaching methods used, whilst conveying the principles of safety, health and environment listed above, may also provide opportunities to develop other essential attributes such as presentation and writing skills
- g) teaching methods should take account of the fact that safety and risk issues involve deep and fundamental ideas concerning knowledge and behaviour. To be placed in a meaningful context they need to be related to the student's own experience.

<i>Level</i>	<i>Description</i>
A	Appreciation and awareness, be able to refer to something
K	K nowledge and understanding, be able to explain something
E	E xperience, be able to do something with help and/or closely supervised
B	A Bility - be able to do something without supervision

Principles

The overriding requirement of this template is that engineers are able to identify and control the hazards associated with their activities. To achieve this, the graduating engineer will need to demonstrate a basic understanding of the principles and issues involved:

- a) hazard identification and risk assessment
- b) hierarchy of risk control
- c) approaches to achieve risk reduction and the substantial direct and indirect business benefits this brings through better quality and loss control
- d) the role risk management plays in the decision making process and how it can be used under conditions of uncertainty
- e) recognition of the importance of human and organisational factors in the development of an acceptable management system
- f) the professional obligations placed on engineers by the UK and European approach to health, safety and environmental regulation; and
- g) the different legislation and different cultures that may affect the approach to managing safety, health and environmental risk issues

Relevant teaching material

The following examples of information and support material are included to show how course providers can fulfill the requirements envisaged in the template. It should provide teachers with an essential guide when preparing lectures.

- Annex 1 Required learning outcomes
- Annex 2 Studies of successes and failures - published documents and reports
- Annex 3 Principal legislation
- Annex 4 Useful publications and sources

ANNEX 1 – Learning Outcomes

Required learning outcomes

This Annex gives a list of possible learning outcomes. The overriding requirement of this template is that engineers are able to identify and control the hazards associated with their activities. The most appropriate outcomes for a particular course should be selected from the list, together with levels of attainment¹. These should be adjusted in line with the academic aims and objectives of each course. They will be subject to variation for all courses, not just between MEng and BEng courses and between accredited courses for prospective corporate and incorporated engineers. For many learning outcomes the required level will be an appreciation and awareness only. This could be obtained while focusing on a detailed case study or looking at reasons behind a selection of engineering failures or successes.

Learning Outcomes

Listed below are some examples of possible learning outcomes, and in italics, the way that the student might achieve each of them.

- a) Demonstrate that at least one case study appropriate to the discipline has been studied in detail *by describing the hazards and risk concepts contained in one of the cases listed in 2.*
- b) Describe the basic human error issues in a number (say 5) of famous failures *by selecting cases from Annex 2 which can show that people are often the most unpredictable hazard and that poor communication may be the greatest hazard*
- c) Design simple engineering systems for safety *by being aware of the limitations and uncertainties in methods used, such as limit state design.*
- d) Define and discuss, the critical importance of communicating clearly safety, risk and hazard issues *by appreciating that responsibility for safety rests with everyone - not just with management. For effective safety the role of each person needs to be communicated clearly to them, being careful to avoid jargon*
- e) Identify and control safety, health and environmental hazards *by addressing these issues when carrying out their project*
- f) Describe how risk is assessed even as part of everyday life and how this can influence the engineer *by comparing everyday risk decisions taken by the individual, such as crossing the road or smoking, to risk decisions taken for the individual, for example, rail transport or GM foods*
- g) Define and discuss critically, natural and technological hazards *by comparing the various demands on the capacity of systems introduced to reduce risks*
- h) Explain the difference between ‘hard’ and ‘soft’ hazards *by using examples such as corporate safety, health and environmental programmes, incentive schemes and training*

¹ Item d) under the heading ‘USE’ suggests descriptions for four levels of attainment (A, K, E or B).

- i) Describe a systematic risk management process, including who owns a risk, as a learning process *by studying documents such as “5 Steps to Risk Assessment” by HSE or equivalent industry-specific publications*
- j) Discuss critically the balance between risk and benefit *by reference to financial, business, environmental and ethical issues*
- k) Explain the interdisciplinary nature of the management of safety, health and environmental issues *by showing an understanding of the roles played by other professionals*
- l) Explain the importance of learning from failure *by, for example, appreciating that the hypothesis that all swans are white is true - until you find a black one!*
- m) Explain that there are limits to what we know and what that may imply for safety *by appreciating that, in engineering, uncertainties always exist and solutions must account for those uncertainties if design of the system is to minimise risk. There is no such thing as perfect safety*
- n) Behave responsibly *by knowing how to conduct oneself when exposed to hazards, such as on site or in the laboratory*
- o) Describe relevant basic legal and professional responsibilities for safety, health and environment and their history of development *by reference to principle relevant legislation. Annex 3 lists some examples of legislation from which appropriate examples may be chosen*
- p) Define safety culture and be aware of its influence on a project *by being aware of cultural issues, for example, the ‘macho image’, the ‘way we do things round here’. Also by being aware of the accident history of the relevant industry sector*
- q) Carry out a risk assessment *by putting the theory into practice during their project and when in the laboratory*
- r) Carry out typical risk and reliability calculations *by reducing a risk as low as reasonably practicable (ALARP) through the use of event trees, fault trees, first order and second order reliability methods (FORM, SORM)*

ANNEX 2 – Case Studies

Studies of failures

This annex gives a list of documents and reports that describe successes and failures. The cost, where known, is also shown to allow libraries to choose which they wish to stock for the particular courses being run by the university.

Documents and Reports

1.	Dangerous Maintenance	£7.50	ISBN 0-11-883957-8	HMSO 1987
2.	Deadly Maintenance - A Study of Fatal Accidents at Work - Plant and Machinery	£4.00	ISBN 0-11-883805-9	HMSO 1985
3.	Deadly Maintenance - A Study of Fatal Accidents at Work - Roofs	£4.00	ISBN 0-11-883804-0	HMSO 1985
4.	Deadly Maintenance - A Study of Fatal Accidents at Work	£5.00	ISBN 0-11-883806-7	HMSO 1985
5.	The Fire at Hickson and Welch Ltd	£11.00	ISBN 0-7176-0702-X	HSE 1994
6.	The Fire at Allied Colloids Ltd -	£9.00	ISBN 0-7176-0707-0	HSE 1993
7.	The Peterborough Explosion	£7.75	ISBN 0-11-885572-7	HMSO 1990
8.	The Putney Explosion	£3.75	ISBN 0-11-883818-0	HMSO 1985
9.	The Brightside Lane Warehouse Fire	£6.00	ISBN 0-11-883846-6	HMSO 1985
10.	The Abbeystead Explosion -	£3.75	ISBN 0-11-883795-8	HMSO 1985
11.	Fire & Explosion at Manro Products Ltd, Stalybridge	£3.20	ISBN 0-11-883715-X	HMSO 1983
12.	Fire & Explosion at Cory's Warehouse	£2.80	ISBN 0-11-883785-0	HMSO 1984
13.	The Rutherglen Explosion	£4.50	ISBN 0-11-883870-9	HMSO 1986
14.	The Fire Explosions at B & R Hauliers, Salford	£3.20	ISBN 0-11-883702-8	HMSO 1983
15.	The Explosion at Cardowan Colliery	£2.50	ISBN 0-11-88364-4	HMSO 1982

16.	The Explosion and Fire at Chemstar Ltd	£3.00	ISBN 0-11-883666-8	HMSO 1982
17.	Leakage of Propane at Whitefriars Glass Ltd	£1.00	ISBN 0-71-76 0083-1	HSE 1981
18.	The Fire and Explosions at Permaflex Ltd	£1.00	ISBN 0-71-76 0073-4	HSE 1981
19.	The Fire and Explosions at River Road, Barking	£1.00	ISBN 0-71-760060-2	HSE 1980
20.	The Fire on HMSO Glasgow	£2.75	ISBN 0-11-883075-9	HMSO 1978
21.	The Explosion at the Dow Chemical Factory	£1.00	ISBN 0-11-883003-1	HMSO 1977
22.	Fire at Dudgeons Wharf	35p	ISBN 10-144700-0	HMSO 1970
23.	The Fire and Explosion at BP Oil (Grangemouth) Refinery Ltd	£7.50	ISBN 0-11-885493-3	HMSO 1989
24.	The Fire and Explosion at Braehead Container Depot, Renfrew, 4 January 1977	£1.75	ISBN 0-11-883220-4	HMSO 1979
25.	Corn starch dust explosion at General Foods Limited, Banbury, Oxfordshire, 18 November 1981	£3.00	ISBN 0-11-883673-0	HMSO 1983
26.	Explosion on 15 June 1984 on MV Pointsman at Milford Haven		Available from HSE	HSE 1987
27.	Explosion at Appleby Frodingham Steelworks, Scunthorpe - 4 November 1975	£4.00	ISBN 0-11-880331	HMSO 1976
28.	Explosion at Laporte Industries Ltd, Ilford	O/P	ISBN 0-11-880333-6	HMSO 1976
29.	Report on gas explosion 3 November 1988, Longshaw Street, Warrington	Free		HSE 1989
30.	Report on a petroleum spillage at Micheldever Oil Terminal, Hampshire, 2 February 1983	£2.80	ISBN 0-11-883768	HMSO 1984
31.	Fatal accidents in construction 1978	£1.75	ISBN 0-11-883419-3	HMSO 1981

32.	Fatal accidents in construction 1977	90p	ISBN 0-11-883238-7	HMSO 1978
33.	One hundred fatal accidents in construction	90p	ISBN 0-11-883071-6	HMSO 1978
34.	Blackspot Construction	£4.00	ISBN 0-11-883992-6	HMSO 1988
35.	Management's responsibilities in the safety operation of mobile cranes	50p	ISBN 0-11-883301-4	HMSO 1980
36.	The hoist accident at Littlebrook 'D' Power Station, 9 January 1978	£1.75	ISBN 0-11-883273-5	HMSO 1981
37.	Report on the collapse of falsework for the viaduct over the River Loddon on 24 October 1972	47p	ISBN 0-10-242573-6	HMSO 1973
38.	Summit tunnel fire	Free	IR/L/FR/85/26	HMSO 1985
39.	Extensive fall of roof at Seafield Colliery, Fife 10 May 1973	O/P	ISBN 0-10-154850-8	HMSO 1973
40.	Incident at Staveley Chemicals Ltd, Derbyshire on 27 June 1982	Free		
41.	Inrush at Lofthouse colliery, Yorkshire on 21 March 1973		ISBN 0-10-154190-2	HMSO 1973
42.	Outbreak of coal and firedamp at Cynheidre/Pentremawr colliery, Carmarthenshire on 6 April 1971		ISBN 0-10-148040-7	HMSO 1971
43.	Outbreak of fire and explosion at Coventry Mine, Keresley, Warwickshire, 10 December 1982			
44.	A report of a train accident that occurred on 22 August 1990 at Hyde North junction in the London Midland region of British Railways	£4.00	ISBN 0-11-886304-5	HMSO 1992
45.	A report of the collision that occurred on 8 January 1991 at Cannon Street Station	£8.00	ISBN 0-11-886303-7	HMSO 1992

46.	A report of the inquiry into the accident that occurred on 16 May 1990 at Chorleywood on the Metropolitan Line of London Underground Limited	£4.75	ISBN 0-11-886381-9	HMSO 1992
47.	A report on the enquiries into the collisions between passenger trains that occurred on 20 August 1984 near Leyton station and on 11 December 1984 at Kilburn on the railways of London Regional Transport	£26.00	ISBN 0-11-886320-7	HMSO 1992
48.	Flixborough disaster 1974	£4.00	ISBN 0-11-883246-8	HMSO 1975
49.	The Cost of Accidents at Work	£8.50	ISBN 0-11-886374-6	HMSO 1976
50.	Human Factors in Industrial Safety	£4.25	ISBN 0-11-885486-0	HMSO 1989
51.	The Hillsborough stadium disaster, 15 April 1989		ISBN 0-10-109622-4	HMSO 1989
52.	Investigation into the Clapham Junction railway accident		ISBN 0-10-108202-9	HMSO 1989
53.	The public enquiry into the Piper Alpha disaster		ISBN 0-10-113102-X	HMSO 1990
54.	Investigation into the Kings Cross underground fire		ISBN 0-10-104992-7	HMSO 1987
55.	'M.V. Herald of Free Enterprise'. Report of Court No 8073. Formal Investigation		ISBN 0-10-1550828-7	HMSO 1987
56.	Inquiry into the basis of Design and Method of Erection of Steel-Box Girder Bridges (Milford Haven)		ISBN 0-15-502793	HMSO 1973
57.	Collapse of flats at Ronan Point, Canning Town, London		ISBN 1-17-501212	HMSO 1968

ANNEX 3 - References

References

This annex provides a selection of principal statutory legislation, some of which is supported by codes of practice and guidance. The publications are listed in date order.

The full listing is available from Health and Safety Executive and the Environment Agency, or on their Websites at www.open.gov.uk/hse/hsehome.htm and <http://www.environment-agency.gov.uk/> respectively.

Principal Statutory Legislation

The Factories Act 1961

The Power Presses Regulations 1965

The Fire Precautions Act 1971

The Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972

Health and Safety at Work etc. Act 1974

The Wildlife and Countryside Act 1981 & 1985 amendment

The Ionising Radiations Regulations 1985

The Electricity at Work Regulations 1989

The Noise at Work Regulations 1989

The Pressure Systems and Transportable Gas Containers Regulations 1989

The Environmental Protection Act 1990, parts 1, 2 & 3

The Simple Pressure Vessels (Safety) Regulations 1991

The Water Resources Act 1991, schedule 10

The Management of Health and Safety at Work Regulations 1992¹

The Workplace (Health, Safety and Welfare) Regulations 1992

The Manual Handling Operations Regulations 1992

The Supply of Machinery (Safety) Regulations 1992

The Personal Protective Equipment Regulations 1992

The Health and Safety (Display Screen Equipment) Regulations 1992

The Clean Air Act 1993

The Noise and Statutory Nuisance Act 1993

The Construction (Design and Management) Regulations 1994

The Control of Substances Hazardous to Health Regulations 1994

The Environment Act 1995

The Construction (Health, Safety and Welfare) Regulations 1996

The Noise Act 1996

The Work in Compressed Air Special Regulations 1996

The Air Quality Regulations 1997

The Provision and Use of Work Equipment Regulations 1998

The Lifting Operations and Lifting Equipment Regulations 1998

The Town and Country Planning Acts 1995 & 1999

The Control of Major Accident Hazards Regulations 1999

¹ This is a principle set of regulations emanating from EC legislation.

In addition Integrated Pollution and Control Legislation is imminent implementing EC Directive 96/61/EC. This will replace IPC under the Environmental Protection Act.

ANNEX 4 - Publications

This annex lists some useful publications and sources of publications.

- | | | | |
|-----|---|--------------------|-----------------------|
| 1. | Safety by Design - An Engineer's Responsibility for Safety
(This booklet contains six sets of notes, each providing a reference for use by teachers) | ISBN 09525103 1 6 | Hazards Forum
1996 |
| 2. | Lessons From Disasters – How Organisations Have no Memory and Accidents Recur
(by Trevor Kletz) | ISBN 0 85295 307 0 | IChemE 1993 |
| 3. | An Engineer's View of Human Error
(2 nd edition by Trevor Kletz) | ISBN 085295265 1 | IChemE 1991 |
| 4. | Major Hazards and Their Management
(by Geoff Wells) | ISBN 0 85295 368 2 | IChemE 1997 |
| 5. | Don't Forget the Environment
(Prepared by the Environmental Analysis Co-operative) | ISBN 0 8592 5422 0 | IChemE 1999 |
| 6. | Management of Process Industry Waste
(edited by Richard Bahu, Barry Crittenden and John O'Hare) | ISBN 085925 324 0 | IChemE 1997 |
| 7. | Hazard Spotting
(an interactive multi-media CD-ROM-based training package) | | IChemE |
| 8. | Competency, Safety and Commitment | ISBN 0 85296 787 X | IEE 2000 |
| 9. | Nuclear Decommissioning | ISBN 0 85296 945 7 | IEE 1999 |
| 10. | Year 2000 Problems in Machinery: Managing the Risk in Smaller Companies | ISBN 0 85296 940 6 | IEE 1998 |
| 11. | Embedded Systems and the Year 2000 problem: Guidance notes | ISBN 0 85296 930 9 | IEE 1997 |
| 12. | SEMPLE Guidelines: Safety-Related Application Software for Programmable Logic Controllers | ISBN 0 85296 887 6 | IEE 1996 |

13.	Safety Related Systems: Guidance for Engineers	ISBN 0 95251 030 8	Hazards Forum 1995
14.	Education and training requirements for safety critical systems	ISBN 0 85296 533 8	IEE 1992
15.	The Possible Effects of Low-Frequency Electromagnetic Fields	ISBN 0 85296 521 4	IEE 1991
16.	Formal methods in Safety Critical Systems	ISBN 0 85296 518 4	IEE 1991
17.	The Environmental Effects of Electricity Generation	ISBN 0 85296 599 0	IEE 1993
18.	Nuclear power in the UK (2 nd Edition 1993/4)	ISBN 0 85296 581 8	IEE 1993
19.	Renewable Energy in the UK	ISBN 0 85296 527 3	IEE 1992
20.	Syllabus for Postgraduate Qualifications in Safety-Related Systems	ISBN 085296 518 4	IEE 1995
21.	Formal methods in Safety Related Systems	ISBN 0 85296 632 6	IEE 1995
22.	Engineering System Safety (by G J Terry)	ISBN 0 85298781 1	IMechE 1991
23.	Emergency Planning and Management	ISBN 0 85298 954 7	IMechE 1995
24.	Process Machinery - Safety and Reliability (Edited by William Wong)	ISBN 1 86058 046 7	IMechE 1996
25.	Pressure Systems: Operations and Risk Management	ISBN 0 85298 951 2	IMechE 1995
26.	Railway Safety	ISBN 0 85298 941 5	IMechE 1994
27.	Noise Control	ISBN 0 85298 943 1	IMechE 1994
28.	Assuring it's Safe: Integrating Structural Integrity, Inspection, and Monitoring into Safety and Risk Assessment	ISBN 1 86058 147 1	IMechE 1998

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|----|--|--|--|
| 29 | Environmental, Health and Safety Auditing Handbook: Guide to Corporate and Environmental Risk Management. Author Harrison, Lee | ISBN 007026904-1 | McGraw 1994 |
| 30 | Industrial Pollution Prevention Handbook. Freeman, Harry M | ISBN 007022148-0 | McGraw 1994 |
| 31 | Sources of Control of Air Pollution: Engineering Principles. Heinsohn, R J. Kabel, R L | ISBN 013624834-9 | Prentice Hall
1998 |
| 32 | Pollution Prevention: Methodologies Technologies and Practices | ISBN 081690782-X | American
Institute of
Chemical
Engineers. |
| 33 | IEE Health and Safety Briefings (a series of titles is available) | information available at
http://www.iee.org/Policy/Areas/Health/hsbrief.cfm or direct from the IEE | |
| 34 | Contaminated Land Legislation – Briefing Note | information available at
http://www.iee.org/Policy/Areas/EnvEnergy/ | |
| 35 | Guidance for the adoption of tools for use in safety related software development | available at
http://www.iee.org.uk/PAB/Safe_rel/tools/ | |

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<http://www.iee.org/Policy/Areas/Health/SHE.doc>