

EFCE Event No. 290

4th International Symposium on
**Loss Prevention and
Safety Promotion in the
Process Industries**

**Volume One — Safety in Operations
and Processes**

Organised by the Institution of Chemical Engineers in association with the Working Party on Loss Prevention of the European Federation of Chemical Engineering, held at Harrogate, England 12-16 September 1983.

**THE INSTITUTION OF CHEMICAL ENGINEERS
SYMPOSIUM SERIES NO. 80**

ISBN 0 85295 159 0

COMMITTEES

Symposium Chairman

Dr. W.L. Wilkinson

Executive Committee

Prof. C. Hanson (*Chairman*)

Mr. J. Borland

Mr. R.C. Gray

Mr. B.R. Harris

Dr. P.J. Heggs

Mr. T.A. Kantyka

Mr. M. Kneale

Dr. D.A. Lihou

Mr. V.C. Marshall

Mr. A.J. Moyes

Dr. P.E. Preece

Scientific Programme Committee

*Dr. H.I. Joschek (*Chairman*)

*Prof. A. Lefebvre (*Belgium*)

*Dr. Ing. J. Skarka (*Czechoslovakia*)

*Mr. N. Hjorth (*Denmark*)

*Mr. P. Hypponen (*Finland*)

*Mr. T. Lainto (*Finland*)

*Mr. R. Grollier-Baron (*France*)

*Mr. Y. Verot (*France*)

*Dr. F.W. Schierwater (*Germany*)

*Prof. Dr. H.G. Schecker (*Germany*)

*Prof. Dr. A. Barbieri (*Italy*)

*Prof. Ing. G. Ferraiolo (*Italy*)

*Mr. P.L. Klaassen (*Netherlands*)

*Dr. Ir. H.J. Pasma (*Netherlands*)

*Mr. E.N. Bjordal (*Norway*)

*Dr. H. Frostling (*Sweden*)

*Mr. A. Jacobsson (*Sweden*)

*Prof. Dr. G. Gut (*Switzerland*)

*Dr. P. Grimm (*Switzerland*)

*Mr. T.A. Kantyka (*UK*)

*Dr. J. Bond (*UK*)

*Mr. R.C. Mill (*USA*)

*Mr. Parker Peterson (*USA*)

Dr. J.H. Burgoyne (*N.W. Branch IChemE*)

Mr. J.A. Hancock (*N.W. Branch IChemE*)

Mr. M. Kneale (*N.W. Branch IChemE*)

Mr. T.R. Farrell (*The Royal Institution of Naval Architects*)

Mr. R.C. Gray (*The Royal Institution of Naval Architects*)

*Member of the EFCE Working Party on Loss Prevention

085 of 1003 2013

STEEL

PUBLISHED BY THE INSTITUTION OF CHEMICAL ENGINEERS

Copyright © 1983 The Institution of Chemical Engineers

All Rights Reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic tape, mechanical, photocopying, recording or otherwise, without permission in writing from the copyright owner.

First edition 1983 — ISBN 0 85295 159 0

MEMBERS OF THE INSTITUTION OF CHEMICAL ENGINEERS (Worldwide)
SHOULD ORDER DIRECT FROM THE INSTITUTION

Geo. E. Davis Building, 165-171 Railway Terrace, Rugby, Warks CV21 3HQ

Australian orders to:

R.M. Wood, School of Chemical Engineering and Industrial Chemistry,
University of New South Wales, PO Box 1, Kensington, NSW, Australia
2033.

Distributed throughout the world (excluding Australia) by Pergamon Press Ltd., except to I.Chem.E. members.

U.K.	Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, England
U.S.A.	Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, U.S.A.
CANADA	Pergamon Press Canada Ltd., Suite 104, 150 Consumers Rd., Willowdale, Ontario M2J 1P9, Canada
FRANCE	Pergamon Press SARL, 24 rue des Ecoles, 75240 Paris, Cedex 05, France
FEDERAL REPUBLIC OF GERMANY	Pergamon Press GmbH, 6242 Kronberg-Taunus Hammerweg 6, Federal Republic of Germany

THE INSTITUTION OF CHEMICAL ENGINEERS
SYNOPSIS OF PAPER NO. 10
ISBN 0 85295 159 0

CONTENTS

Page

Plenary Session: SAFETY IN OPERATIONS AND PROCESSES

Now or Later? A Numerical Comparison of Short and Long-Term Hazards A1-A10

T.A. Kletz

Efficient Time Use To Achieve Safety of Processes, or "How Many Angels Can Stand on the Head of a Pin?" A11-A19

W.B. Howard

Plenary Session: RISK ASSESSMENT

The CONCAWE Report on Methodologies for Hazard Analysis and Risk Assessment B1-B8

S. Hope

The Question of Quality of Risk Analysis for Chemical Plants: Discussing the Results for a Sulphuric Acid Plant B9-B19

P. Jäger

Plenary Session: DISPERSION OF FLAMMABLE CLOUDS AND THE CONSEQUENCES

A Study of Vapour Cloud Incidents — An Update C1-C19

J.A. Davenport

Unconfined Vapour Cloud Dispersion and Combustion — An Overview of Theory and Experiments C20-C34

M.J. Pikaar

FIRE AND EXPLOSION

Probabilistic and Deterministic Safety Study of the Sea-Borne Traffic of Liquefied Gases in the Vicinity of a Nuclear Site D1-D9

S. Hendrickx, A. Lannoy

Experimental Analysis of Unconfined Explosions of Air-Hydrocarbon Mixtures — Characterisation of the Pressure Field D10-D19

J. Brossard, J.C. Leyer, D. Desbordes, J.L. Garnier, S. Hendrickx, A. Lannoy, J. Perrot, J.P. Saint-Cloud

Experimental Investigation Into the Blast Effect Produced by Unconfined Vapour Cloud Explosions D20-D29

J.P. Zeeuwen, C.J.M. van Wingerden, R.M. Dauwe

Explosion Development in Unconfined and Partially Confined Ethylene-Air Mixtures Due to Jet Initiation D30-D40

M. Schildknecht, W. Geiger

RELEASE

Two Phase Discharge of Liquefied Gases Through Pipes. Field Experiments with Ammonia and Theoretical Model E1-E11

K. Nyrén, S. Winter

Mitigation of the Evaporation of Liquids by Fire Fighting Foams E12-E22

J. Jeulink

Discharges of Pressurised Liquefied Gases Through Apertures and Pipes E23-E35

H.E.A. van den Akker, H. Snoey, H. Spoelstra

DISPERSION

- Steam Curtains — Effectiveness and Electrostatic Hazards** F1-F14
H. Seifert, B. Maurer, H. Giesbrecht
- The Application of Gas Curtains for Diluting Flammable Gas Clouds to Prevent Their Ignition** F15-F25
P.F.M. Rulkens, A.J.P. Bongers, G.P. ten Brink, C.P. Guldemond
- Simulation of Propane Dispersion from Spills in a Petrochemical Plant Using A Water Tunnel Technique** F26-F34
R. Wighus
- The Physical Modelling of Heavy Gas Plumes in A Water Channel** F35-F44
S.C. Cheah, J.W. Cleaver, A. Millward
- Experimental and Computational Assessment of Full-Scale Water Spray Barriers for Dispersing Dense Gases** F45-F55
D.M. Deaves
- The Simulation of Dense Vapour Cloud Dispersion Using Wind Tunnels and Water Flumes** F56-F65
C.I. Bradley, R.J. Carpenter
- Dense Gas Dispersion Behaviour: Experimental Observations and Model Developments** F66-F75
G.W. Colenbrander, J.S. Puttock

RISK ASSESSMENT — INTERNATIONAL STUDY GROUP ON RISK ANALYSIS

- Introduction** G1
A.P. Cox
- Risk Analysis in the Process Industries** G2-G7
A.P. Cox, H.J. Pasma
- Hazard Identification Procedures** G8-G24
D.R.T. Lowe, C.H. Solomon
- Consequence Analysis** G25-G32
G. Opschoor, H.G. Schecker
- Quantification of Risk** G33-G45
J.T. Daniels, P.L. Holden
- Application of Risk Analysis Techniques** G46-G55
H.J.D. Lans, E.N. Bjordal

RISK ASSESSMENT — Swedish Model

- Introduction — Safety on Gas Cloud Explosions — A Swedish Approach** H1-H2
O. Fredholm
- Unconfined Gas Clouds** H3-H9
O. Hertzberg, S. Lamnevik
- The Siting and Construction of Buildings** H10-H18
S.E. Beigler
- Authorities Aspects** H19-H25
E. Nilsson

ASSESSMENT OF EFFECTS — APPLICATIONS

- Validity and Accuracy of a Commonly Used Toxicity-Assessment Model in Risk Analysis** I1-I12
W.F. ten Berge, M. V. van Heemst
- A Method for Assessing the Offsite Risks from Bulk Liquid Oxygen Storage** I13-I22
D.A. Jones
- A Hazard Assessment of the Morecambe Bay Gas Pipeline and Coastal Reception Terminal** I23-I35
M. Considine
- The Use of Acute Toxicity Data in the Risk Assessment of the Effect of Accidental Releases of Toxic Gases** I36-I45
N.C. Harris, A.M. Moses
- A New Approach to Automation of Process Loss Prevention and Safety Actions in Refining Operations** I46-I55
A. Auffret, L. Boulvert, E. Thibault

PROBLEMS WITH METHODS OF HAZARD IDENTIFICATION

- Hazard Warning Structure: Some Implications and Applications** J1-J14
F.P. Lees
- Design Error in the Chemical Industry — Case Studies** J15-J27
P. Haastrup
- A Comparison of Automatic Fault Tree Construction with Manual Methods of Hazard Analysis** J28-J41
J.R. Taylor, J.V. Olsen

EVENT DATA COLLECTION AND USE

- Computerised Data Base for the Storage and Retrieval of Abnormal Occurrence Reports** K1-K10
K.R. Davies
- Collection and Application of Incident Data** K11-K21
P. Bockholts
- *Accident Casuistry and External Safety** K22
F. Bruning, A. Ohm

CASE HISTORIES I

- Circumstances Surrounding Emissions of Ammonia — A Case History** L1-L8
C. Trotter
- Propylene Discharge — A Case Study** L9-L14
L.E. Jørgensen, J.H. Christiansen
- Explosion in Cone-Roof Gas Oil Tank** L15-L22
A.H. Searson
- The Propane Explosion in Gothenburg 8th May 1981** L23-L33
E. Nilsson

*This paper was received too late to be included in the preprints.

CASE HISTORIES II

- Low-Level Ethylene Decompositions — An Inconvenience or a Warning?** M1-M9
D.G. Bowen
- Safety Aspects of Urea-Ammonium Nitrate Solutions** M10-M19
G. Perbal
- Effects of Power Frequency Discharges on Flammable Mixtures** M20-M27
A. Fiumara, F. Avella
- Emergency Actions — Two Case Histories** M28-M33
V.J. Clancey

CASE HISTORIES III

- Fire Caused by Vinyl Chloride Release from a Rail Tank Car** N1-N3
W. Ernst
- Hazard Assessment from Industrial Explosion Investigation** N4-N13
W.O. Ursenbach
- Investigations into the Circumstances Surrounding an Accident in Nijmegen Involving a Tanker** N14-N23
J.B.R. van der Schaaf, C.F. Steunenberg

COMMITTEES

Symposium Chairman

Dr. W.L. Wilkinson

Executive Committee

Prof. C. Hanson (*Chairman*)

Mr. J. Borland

Mr. R.C. Gray

Mr. B.R. Harris

Dr. P.J. Heggs

Mr. T.A. Kantyka

Mr. M. Kneale

Dr. D.A. Lihou

Mr. V.C. Marshall

Mr. A.J. Moyes

Dr. P.E. Preece

Scientific Programme Committee

*Dr. H.I. Joschek (*Chairman*)

*Prof. A. Lefebvre (*Belgium*)

*Dr. Ing. J. Skarka (*Czechoslovakia*)

*Mr. N. Hjorth (*Denmark*)

*Mr. P. Hypponen (*Finland*)

*Mr. T. Lainto (*Finland*)

*Mr. R. Grollier-Baron (*France*)

*Mr. Y. Verot (*France*)

*Dr. F.W. Schierwater (*Germany*)

*Prof. Dr. H.G. Schecker (*Germany*)

*Prof. Dr. A. Barbieri (*Italy*)

*Prof. Ing. G. Ferraiolo (*Italy*)

*Mr. P.L. Klaassen (*Netherlands*)

*Dr. Ir. H.J. Pasman (*Netherlands*)

*Mr. E.N. Bjordal (*Norway*)

*Dr. H. Frostling (*Sweden*)

*Mr. A. Jacobsson (*Sweden*)

*Prof. Dr. G. Gut (*Switzerland*)

*Dr. P. Grimm (*Switzerland*)

*Mr. T.A. Kantyka (*UK*)

*Dr. J. Bond (*UK*)

*Mr. R.C. Mill (*USA*)

*Mr. Parker Peterson (*USA*)

Dr. J.H. Burgoyne (*N.W. Branch IChemE*)

Mr. J.A. Hancock (*N.W. Branch IChemE*)

Mr. M. Kneale (*N.W. Branch IChemE*)

Mr. T.R. Farrell (*The Royal Institution of Naval Architects*)

Mr. R.C. Gray (*The Royal Institution of Naval Architects*)

*Member of the EFCE Working Party on Loss Prevention

EFCE Event No. 290

4th International Symposium on **Loss Prevention and Safety Promotion in the Process Industries**

Volume Three — Chemical Process Hazards

This volume forms the proceedings of the 8th Symposium on Chemical Process Hazards. Organised by the Institution of Chemical Engineers, held at Harrogate, England 12-16 September 1983

**THE INSTITUTION OF CHEMICAL ENGINEERS
SYMPOSIUM SERIES NO. 82**

ISBN 0 85295 161 2

PUBLISHED BY THE INSTITUTION OF CHEMICAL ENGINEERS

Copyright © 1983 The Institution of Chemical Engineers

All Rights Reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic tape, mechanical, photocopying, recording or otherwise, without permission in writing from the copyright owner.

First edition 1983 — ISBN 0 85295 161 2

MEMBERS OF THE INSTITUTION OF CHEMICAL ENGINEERS (Worldwide) SHOULD ORDER DIRECT FROM THE INSTITUTION

Geo. E. Davis Building, 165-171 Railway Terrace, Rugby, Warks CV21 3HQ

Australian orders to:

R.M. Wood, School of Chemical Engineering and Industrial Chemistry, University of New South Wales, PO Box 1, Kensington, NSW, Australia 2033.

Distributed throughout the world (excluding Australia) by Pergamon Press Ltd., except to I.Chem.E. members.

U.K.	Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, England
U.S.A.	Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, U.S.A.
CANADA	Pergamon Press Canada Ltd., Suite 104, 150 Consumers Rd., Willowdale, Ontario M2J 1P9, Canada
FRANCE	Pergamon Press SARL, 24 rue des Ecoles, 75240 Paris, Cedex 05, France
FEDERAL REPUBLIC OF GERMANY	Pergamon Press GmbH, 6242 Kronberg-Taunus Hammerweg 6, Federal Republic of Germany

CONTENTS

Page

Plenary Session: SAFETY IN OPERATIONS AND PROCESSES

Thermochemistry of Exothermic Decomposition Reactions A1-A11
T. Grewer, E. Duch

Thermally Stable Operating Conditions of Chemical Processes A12-A21
H. Fierz, P. Finck, G. Giger, R. Gygax

RUNAWAY REACTIONS

Controlling Thermal Instabilities in Chemical Processes B1-B9
V. Pilz, H. Schacke, N. Schulz

Runaway Reactions in a Polyacrylonitrile Wet-Spinning Plant B10-B17
G. Arabito, V. Caprio, S. Crescitelli, G. Russo, V. Tufano

Thermohydraulic Processes in Pressure Vessel and Discharge Line During Emergency Relieving B18-B33
L. Friedel, S. Purps

UNSTABLE PRODUCTS

Self-Accelerating Decomposition of Ethylene Cyanide C1-C4
W. Berthold, U. Löffler

Thermal Explosion of Liquids C5-C13
J. Verhoeff

Experimental Principles for Predicting Safe Conditions for the Storage of Bulk Chemicals C14-C23
G. Giger, R. Gygax, F. Hoch

Pressure Increase in Exothermic Decomposition Reactions — Part II C24-C34
O. Klais, T. Grewer

FIRE AND EXPLOSION

Fire Engulfment Trials with LPG Tanks with a Range of Fire Protection Methods D1-D10
A.F. Roberts, D.P. Cutler, K. Billinge

Explosions in Flammable Smokes from Smouldering Fires D11-D22
K.N. Palmer

An Experimental and Theoretical Study of Blast Effects on Simple Structures (Cantilevers) D23-D32
D.K. Pritchard

EXPLOSION HAZARDS

Purge Limits for Paraffin in Hydrocarbons in Air and Nitrogen E1-E10
P. Roberts, D.B. Smith

The Effect of Ventilation on the Accumulation and Dispersal of Hazardous Gases E11-E22
M. R. Marshall

Experimental Investigations on the Run-up Distance of Gaseous Detonations in Large Pipes E23-E33
H. Steen, K. Schampel

Pressures Generated by Blast Waves in Channels with 90° Bends	E34-E43
M. Nettleton, P. Fearnley	
Ignition/Explosion Risks in Fluidised Dryers — Avoidance and Containment (Practical Aspects — A Users Viewpoint)	E44-E52
R.W. Grafton	
Static Charging in Powder Conveying Systems	E53-E62
D.H. Napier	

EXPLOSION RELIEF

Performance of Low Inertia Explosion Reliefs Fitted to a 22 m³ Cubical Chamber	F1-F10
P.F. Thorne, Z. W. Rogowski, P. Field	
Dust Explosion Experiments in a Vented 500 m³ Silo Cell	F11-F20
R.K. Eckhoff, K. Fuhre	
Gaseous Combustion Venting — A Simplified Approach	F21-F37
I. Swift	
Venting of Gas Explosions in Large Rooms	F38-F47
C.J.M. van Wingerden, J.P. Zeeuwen	

SPECIAL DESIGN PROBLEMS

Protection of Distillation Columns Against Vacuum Caused by Loss of Heating	G1-G9
J.S. Fitt	
Deterioration of Structures Supporting Refinery Equipment	G10-G22
B.N. Pritchard	
Determine Safety Zones for Exposure to Flare Radiation	G23-G30
G. Fumarola, D.M. de Faveri, R. Pastorino, G. Ferraiolo	