Unclassified **ENV/JM/MONO(2005)6**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

18-Apr-2005

English - Or. English

ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

Cancels & replaces the same document of 30 March 2005

OECD SERIES ON CHEMICAL ACCIDENTS
Number 14

Report of the OECD Workshop on Lessons Learned from Chemical Accidents and Incidents, 21-23 September 2004, Karlskoga, Sweden

ENV/JM/MONO(2005)6
Unclassified

English - Or. English

JT00182564

OECD Environment, Health and Safety Publications

Series on Chemical Accidents

No. 14

Report of the OECD Workshop on Lessons Learned from Chemical Accidents and Incidents

21-23 September 2004, Karlskoga, Sweden

Environment Directorate
ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
Paris, 2005

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Health Aspects of Chemical Accidents: *Guidance on Chemical Accident Awareness, Preparedness and Response for Health Professionals and Emergency Responders* (1994) [prepared as a joint publication with IPCS, UNEP-IE and WHO-ECEH]

Guidance Concerning Health Aspects of Chemical Accidents. *For Use in the Establishment of Programmes and Policies Related to Prevention of, Preparedness for, and Response to Accidents Involving Hazardous Substances* (1996)

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Internet Publication, Report of CCPS/OECD Conference and Workshop on Chemical Accidents Investigations (2002)

Special Publication, International Directory of Emergency Response Centres for Chemical Accidents (2002, revision of 1st edition published in 1992)

No. 10, Guiding Principles for Chemical Accident Prevention, Preparedness and Response: *Guidance for Industry (including Management and Labour), Public Authorities, Communitites and other Stakeholders* (2003, revision of 1st edition published in 1992)

No. 11, Guidance on Safety Performance Indicators*, A Companion to the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response: Guidance for Industry, Public Authorities and Communitites for developing SPI Programmes related to Chemical Accident Prevention, Preparedness and Response* (Interim Publication scheduled to be tested in 2003-2004 and revised in 2005) (2003)

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FOREWORD

This report presents the main output of the OECD Workshop on *Lessons Learned from Chemical Accidents and Incidents*, which took place in Karlskoga, Sweden, on 21-23 September 2004. The Workshop was hosted by the Swedish Rescue Services Agency (SRSA) and in particular, the Swedish National Centre for Lessons Learned from Accidents (NCO).

73 representatives from 17 OECD member countries, two non-member countries, the European Commission, the WHO and industry participated in the workshop with the goal of sharing experiences concerning issues related to lessons learned and indeed openly discussing these issues in order to find solutions and new ways of learning from accidents. Workshop participants came from public authorities, academia, industry, professional organisations and other non-governmental organisations (see List of Participants in Annex 3).

The overall objectives of the Workshop were to: (i) improve learning from accidents; (ii) facilitate the sharing of lessons learned among countries and industry sectors; (iii) provide a basis to improve systems for collecting and disseminating lessons learned; (iv) facilitate international co-ordination among these systems; (v) make recommendations concerning good practices; and (vi) make recommendations for future actions.

The Workshop included sessions on: (1) Data sources on accidents and incidents; (2) Investigation of accidents and incidents; (3) Lessons learned from accidents and near-misses; and (4) Communication and implementation of lessons learned (see Workshop agenda in Annex 2).

The first part of the report consists of the Workshop Conclusions and Recommendations. This is followed by the Discussion Document prepared for the Workshop (see Annex 1).

The OECD Working Group on Chemical Accidents recommended that this report be forwarded to the Joint Meeting of the Chemical Committee and Working Party on Chemicals, Pesticides and Biotechnology, for consideration as an OECD publication. The Joint Meeting agreed that it should be made available to the public.

This document is published on the responsibility of the Joint Meeting of the Chemicals Group and Management Committee of the Special Programme on the Control of Chemicals of the OECD.

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

This Workshop was organized under the auspices of the OECD Working Group on Chemical Accidents and was hosted by the Swedish Rescue Services Agency (SRSA) and in particular, the Swedish National Centre for Lessons Learned from Accidents (NCO). 73 representatives from 17 OECD member countries, two non member countries, the European Commission, the WHO and industry participated in the workshop with the goal of sharing experiences concerning issues related to lessons learned and indeed, openly discussing these issues in order to find solutions and new ways of learning from accidents.

The overall objectives of the Workshop were:

- Improve learning from accidents;
- Facilitate the sharing of lessons learned among countries and industry sectors;
- Provide a basis to improve systems for collecting and disseminating lessons learned;
- Facilitate international co-ordination among these systems;
- Make recommendations concerning good practices; and
- Make recommendations for future actions.

The specific objectives of the Workshop were:

- Gain an overview and understanding of existing databases/sources and their quality;
- Share experience in how to make most effective use of lessons learned from incidents (accidents and/or near-misses);
- Facilitate information exchange and the sharing of lessons learned among countries and industry sectors;
- Identify best practices for different aspects of the process including accident reporting, investigation, dissemination of information, implementation of recommendations and feedback;
- Improve the sharing and availability of comprehensive accident statistics and analysis; and
- Provide a basis to improve systems for collecting and disseminating lessons learned, facilitate international co-ordination among these systems, and set the stage for regular sharing of information in the future.

The scope of the Workshop included any fixed installation/facility where hazardous substances are produced, processed, used, handled, stored, transported or disposed. Other sectors of industrial activity will be considered, in particular with respect to transfer of knowledge and experience (e.g. offshore, nuclear, aerospace industry).

This document does not attempt to summarize the presentations or discussions per se. It does provide conclusions based on the discussions and suggests approaches or methodologies that could be considered "best practices". It also presents some recommendations for future actions that could be undertaken to strengthen the field of learning from accidents.

The sharing of experiences in this Workshop can only really be of benefit if the presentations themselves, and this report are made widely available by the participants and their respective organizations and through the members of the OECD Working Group on Chemical Accidents. Representatives from a number of very active research institutions participated in the Workshop and hopefully, they have established new relationships with their respective colleagues to move this field of study forward.

CONCLUSIONS

Opening Session

The Workshop Chairman opened the workshop by clearly stating the objectives of the workshop:

- Improve learning from accidents
- Facilitate sharing of lessons learned
- Provide a basis to improve systems for collecting and disseminating lessons learned
- Facilitate international cooperation among these systems

The Chairman also recalled some of the conclusions from the "Joint Seminar on Systemic Risks and Lessons Learned" that was arranged by the Swedish Centre for Lessons Learned from Incidents & accidents (NCO) within the Swedish Rescue Services Agency, the Joint Research Centre of the European Union and the OECD International Futures Programme. The Seminar was held in Karlskoga on Monday 20th of September, back-to-back with the Workshop. Some of the conclusions of most relevance to consider in the chemical accident Workshop are presented below. There is a need for:

- A more integrated and holistic framework to address the various layers of risk management in society;
- Tools to better assess technological, environmental and economic trends that change our risk landscape;
- Breaking down barriers at various administrative levels (improved communication between relevant actors such as authorities, industry, citizens and NGOs);
- Leadership in addressing the changes to strengthen safety culture;
- An improved and systematic data collection, focusing on quality reporting and refinement of data for improved application/implementation, and more specifically:
  - to establish a network of national centres for lessons learned, (e.g. NCO), in order to overcome obstacles in networking and to stimulate information sharing characterised by openness;
  - to adapt the way we are learning, not only collecting, but also better validating, analysing and disseminating lessons learned; and
  - to mainstream the lessons learned process and to promote a more genuine (double- loop) learning in order to better understand the risks and manage the limited resources to influence attitudes and promote a stronger safety culture.

The necessity to extract data and to learn from the entire accident process, demonstrated by the simple "bow-tie" accident model, was stressed. While root-cause analysis is essential to improve preventive actions, analysis of the event side of the equation, e.g. emergency response operations, is necessary to improve mitigation strategies. Both should be considered natural parts of accident analysis and investigations and thus included in the concept of "lessons learned".

Session I: Setting the scene – The Discussion Document

The lead author of the Discussion Document presented the document on behalf of his colleagues at the Wharton Risk Management and Decision Processes Centre of the University of Pennsylvania. While the Discussion Document is included in its entirety later in the report, the rapporteurs believed that some of the thoughts presented in Dr. Rosenthal's powerpoint presentation as well as those in the Discussion document should be captured in the conclusions, given their relevance to the discussions that followed.

In the introductory remarks, the authors stated that the concept of learning from accidents is necessary for two fundamental reasons:

- collectively, we do not seem to learn from historical "water shed" events which should have had impacts to cause change; and
- societal concerns towards safety must drive risk managers to make changes in the way operators manage their operation even though we know that damage from natural disasters far outweighs that from technological events.

Note: This latter point was stressed in the OECD report on "Emerging Risks in the 21st Century: An Agenda for Action" (2003).

While the author highlighted a number of areas for discussion for each session, his powerpoint presentation concluded by noting the following issues which are an expansion of those noted in the Discussion Document:

- Use of data mining techniques to extract information on the etiology of accidents and the key prevention elements in a 'good' management system is hindered by data and resource limitations.
- Process accidents do not appear to be decreasing at the rate expected at the time that present regulatory, professional and trade association initiatives were put in place (the basis for this statement was subsequently clarified to indicate that this is the conclusion one would derive from an examination of either the EC MARS database or the US EPA RMP*Info database.
- While important new lessons are constantly being learned, and need to be learned, it is clear that implementation of lessons already learned could have prevented a large majority of process accidents.
- Inadequately designed and/or executed Process Management Systems are the "root cause" of the failure to effectively use lessons learned.
- Many countries apparently feel that a further reduction in the likelihood of firms having serious process accidents should not be a condition of a firm's continued license to operate, since they have not strengthened their regulatory measures and enforcement activities in a manner that leads to significant decreases in accident frequencies, nor have they levied penalties on firms having accidents that are large enough to either motivate firms to put in their own prevention programs for purely economic reasons or put them out of business.
- Improved industry use of lessons learned to prevent process accidents requires development of approaches that:
  - reduce the firm's and practitioner's 'cost' of learning and staying aware of pertinent lessons;
  - capture management attention by transforming lessons into emotional reminders of major process accident consequences.

Note: These two ideas are particularly important to retain as they lead directly into the subsequent discussions.

Session II: Data sources on accidents and incidents − Relevance of data sources for measuring the output of the safety work in the field of chemical accidents?

Throughout the Workshop, numerous presenters discussed the various highlights of the databases that they work with on a regular basis. The databases generally are created to meet the specific needs of the host organization. As examples:

- governments are often required by legislation to receive reports of accidents,
- industry maintain their own accident databases as a matter of sound management practice,
- industry associations often gather statistics for their entire industry sector,
- professional organizations receive reports on accidents that are then distributed to their members,
- academic organizations use databases to compare accident trends and for other research purposes, and
- commercial entities maintain databases on accidents for their particular business objectives.

Some participants seemed to express a desire to have a common wide-scale database for collecting accident information. However that is probably impossible due to the fact that many diverse organisations as noted above have specific needs to gather data to support their respective activities. Such diversity that actually gives evidence of the complementarity among the various data bases, could even be a good thing as one can learn from different accident databases that cover diverse perspectives, cultures and purposes. The real difficulty then becomes one of finding techniques for data mining that can be used across a number of these diverse databases and for facilitating data sharing.

Accident rates (at least for major accidents according to the European MARS and US RMP*Info databases) do not appear to have decreased in spite of the major legislative efforts in many countries over the past 10-15 years, while no specific reason for this has been identified, this perception may be a result of industry already taking actions in their own best interest. It may also be attributed to the fact that we are dealing with low probability – high consequence events, which while not rare, are relatively infrequent. There is a clear desire to develop and follow trends and tendencies for chemical accidents both at national and global level. However, this will be challenging due to the lack of reliable data series, and of data regarding number of facilities, processes etc, which are necessary as “denominators” to form incidence rates.

It was generally agreed that databases should be improved to make them more user-friendly, for example, in accessibility for making entries and conducting searches.

The issue of common terminology is a barrier to the sharing of information between/amongst organisations and more work is necessary to ensure complementarity, for example, obtaining consensus on critical factors such as what fields should be included and definitions, such as what is meant by "human factor".

Some experts pointed out that there is a significant lack of data on environmental effects in accidents records; data sources are in this respect generally poor and should be improved.

There was also a requirement for making information accessible to the public as much as possible. The exchange of data among all stakeholders must be promoted.

Session III: Investigation of accidents and incidents - How do we gain optimal output from the investigation of accidents /incidents with respect to both lessons learned and the dissemination of such lessons?

There is a wealth of experience in conducting accident investigation based on well-established methodologies both in public sector and private sector organisations. Many of these techniques such as ECFA+ and MORT are being updated and are freely available for users through the Internet.

However, even with different approaches and philosophies incorporated into Root-Cause Analysis, there are dangers of over-simplification during investigations, for example, by using generalisations such as human error or, as was mentioned in a reference to *Rasmussen*, "keep investigating until you find a cause for which you know the cure". (Note: Rasmussen was characterising an error rather than endorsing this approach).

In this regard, there may be too much focus on 'what' happened (even if the root-cause analysis is highly sophisticated) and not enough focus on 'why' it happened; it is essential to understand what happened and then tackle the ‘why’ to learn the real lessons. That is the inherent danger of stopping short as indicated above.

Several barriers or hurdles were identified that may diminish the opportunity to learn lessons. There may be organisational resource constraints, which limit how many investigations will be undertaken and how deep they will be.

The corporate culture, including the internal legal system and a variety of other factors may limit the depth of investigation. The company may want to avoid identifying individuals or indeed the management system in order to ensure that a ‘blame’ mentality does not result from the accident.

The concept of 'drift' as defined by Rasmussen as "the systematic organisational performance deteriorating under competitive pressure, resulting in operation outside the design envelop where preconditions for safe operation are being systematically violated" was generally agreed as being a far too common occurrence in the current business environment.

There is also the issue of identifying criteria for selecting those accidents, which provide High Value (HV) learning opportunities and therefore what are the right messages to learn. Again the issue of definition arose as terms such as 'High Value Learning Incident', 'Leaning Value', 'Prevention Value' and 'Significant Learning Potential' were all utilised in the discussion.

Furthermore, sometimes accidents are actually re-occurrences of previous events, which means, at minimum, that we are possibly not finding the most useful learnings from our investigations. Other factors in this regard are discussed in later sessions.

In summary, the idea of moving from "learning to look" towards "looking to learn" is most appropriate.

Note: The reader might want to review Chapter 15 on Incident Investigations of the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response (2003).

Session IV: Lessons learned from accidents and near-misses – How can we make the most effective use of lessons learned or dissemination of lessons learned from incidents (accidents and/or near-misses)?

While it is accepted, that we must be able to learn lessons from an actual event failure (and in some cases, investigating to learn lessons and to report them is mandatory), generally organisations do not take advantage of the learnings that arise from near-misses. There is an obvious relationship between those triggers which result in numerous minor incidents to those which can result in serious injuries, property or environmental damage. Reference is made to the concept of the 'safety triangle' where there will be many incidents or near-misses at the base with relatively few more serious events at the top of the triangle.

As it is well recognised that the safety culture of an organisation starts with top management, they have the leadership responsibility to ensure that lessons learned are shared throughout the organisation and indeed outside the organisation. Some excellent examples in place in leading companies were introduced at various sessions during the Workshop. The names given to two of these are the Learning Experience Reports (LER) and the DMAI2C process, which stands for define, measure, analyse, innovative improvement and control. Both systems demonstrate how to make effective use of lesson learned within the company. However, the systems are especially efficient with data from the internal workflow. The use of external information from other sources by means of a horizontal transfer is to be improved.

In this regard a key principle for effective learning is a process for disseminating information on accidents/incidents causation and suitable interventions/modifications to all relevant parties (internal and external) as quickly as possible.

The need to share information across organisations was stressed, possibly by the creation of networks. There are positive examples of individuals having the opportunity to participate in exchanges between organisations and this approach should be expanded.

The importance of quality of information in safety reports was also stressed.

Session V: Communication and implementation of lessons learned – How do we ensure that the collected data are transformed to effective learning?

The issue of a multiplicity of data collection systems across organizations was again a central theme of this session. In fact, several speakers painted a rather pessimistic view that we really do not seem to be making the best use of the lessons learned from previous events. The highly competitive pressure on companies, and a tendency to a short-sighted attitude in company managements was raised as a serious concern.

In the discussion of these conclusions, several positive communications tools were noted. Among these were the SACHE[1] learning program being used in universities across North America in the teaching

[1] SACHE is the Safety and Chemical Engineering Education program, initiated in 1992, as a cooperative effort between the Centre for Chemical Process Safety, which operates under the American Institute of Chemical

of 'lessons learned' to undergraduate engineering students. Another was the 'Process Safety Beacon', a monthly bulletin issued by the Centre for Chemical Process Safety and available on the Internet. In Europe, the Loss Prevention Bulletin of the Institute for Chemical Engineers provides a widely-used learning tool.

At least one proposal was put forward to make the communication and implementation processes more attractive in other words to convert "lessons learned into lessons implemented". For example, by targeting investments in Process Safety Management, one might be able to obtain a certain 'return on investment' similar to successful anti-smoking and seatbelt campaigns. Again this goes to earlier points about leadership from the top in any given organisation.

In order for 'lessons learned' to be implemented they have to be communicated to someone. That means different techniques and strategies have to be used to reach different audiences throughout the organisation.

Lessons learned are sources of enrichment of knowledge and correspond to a duty of corporate memory. Process/Safety Management systems are that memory, and 'lessons learned' should be documented in these systems. Some would suggest that new engineers should be required to review that documentation and discuss it with mentors.

Finally, the concept of the 'bow-tie' model introduced earlier was expanded to better explain how accident mapping can really identify the barriers in place that may have had an impact either causally or in terms of mitigation following the onset of a critical event. The concept of accident mapping was also used to explain the socio-technical interface that comes into place in the management of hazards. This work, led by *Rasmussen* and *Svedung*, has been published by the Swedish Rescue Services Agency and is referenced below. A similar analysis method – SOL (Safety through Organizational Learning) has been developed by *Miller* and *Wilpert* of the Research Center Systems Safety in University of Technology, Berlin, Germany.

RECOMMENDATIONS FOR 'GOOD PRACTICES'

The recommendations concerning good practices are:

1. The UK Health and Safety Executive (HSE) has developed key principles for effective learning from accidents and implementation of lessons learned that may include the following:

    - an incident/accident reporting system;
    - a process for incident investigation that ensures understanding of underlying as well as immediate causes, taking account of human and organisational factors;
    - a process for analysing cumulative information on accidents and incidents (internal and external events);
    - a process for ensuring the findings of incident investigation and analysis of accident data are acted upon in a timely fashion and suitable interventions put in place or modifications made;
    - a process for evaluating the success (or otherwise) of interventions and modifications;

Engineers, and engineering schools to provide teaching materials and programs that bring elements of process safety into the teaching of undergraduate engineers. SACHE has over 125 member schools.

- a process for disseminating information on accident and incident causation and suitable interventions (i.e. on lessons learned) to all relevant parties as quickly as possible (in an appropriate communication framework); and
- a system to capture the information in a format that is readily searchable and retrievable to allow ease of access so that any lessons learned stay learned (corporate memory) ("memories" exists on different levels).

2. Leadership, particularly at the highest levels in an organisation, be it private or public, is essential in order to ensure that lessons are not only derived from actual events and near-misses but are also acted upon appropriately. The idea that rare events will not occur during a manager’s tenure must be addressed moving towards the concept of 'eternal vigilance'.

3. Accident investigation practices should be reviewed and updated as appropriate taking into account the latest developments and protocols in investigation methodologies; such information is becoming more generally available through the Internet. Accident investigations should be carried out by independent experts in close cooperation with the *ad hoc* responsible body.

4. Successful organisations in the field of learning from accidents:

   - do not focus on blame but actually strive to identify the 'root cause';
   - share lessons both internally and externally; and
   - attempt to learn from others.

5. Utilising multi-disciplinary teams having experiences in a variety of sectors, eg sociology, health, etc., is often a most successful approach to identifying lessons learned bringing to bear a broader set of perspectives.

RECOMMENDATIONS FOR FUTURE ACTIONS

The recommendations for future actions are:

1. The OECD Working Group on Chemical Accidents could be a useful global platform and forum for facilitating a dialogue/<u>exchange of investigations methodologies</u> including identification of appropriate criteria to identify those events with the potential for High Value learning.

2. Further efforts are required to <u>harmonise terminology</u> across sectors and countries so that information including data sharing, data mining techniques, investigation methodologies and communication of lessons learned is compatible and can be made available as widely as possible.

3. An effort to <u>establish a network among existing major databases</u> and competence centres for lessons learned from chemical accidents should be mounted. A suggested vision is the creation of a global "data mart", which will make comprehensive, open, user-friendly lessons learned databases widely available. This "data mart" will help to overcome to some extent the problems with today’s scattered situation and should facilitate the identification of lessons in terms of unit operation and/or class of chemicals involved. A first step towards this could be to create and keep updated an overview of relevant major databases and references to them e.g. via web-links. Moreover, accident data bases should contain more information on environmental impacts of accidents.

4. The following Recommendations have been taken directly from the Discussion Document:

   - Priority should be shifted from generating and gathering new lessons learned to emphasizing the improvement of the dissemination of such lessons and to implementation of measures responsive to lessons already learned;
   - Fashion measures that result in strengthening institutional memory by integrating lessons learned safety measures into facility process safety management systems as well as into emergency management systems in addition to relying on employee memory; and
   - Develop model "carrot and stick incentives" that private bodies (insurance, chemical and labour associations) in addition to regulatory agencies could use to motivate efficient implementation of pertinent lessons already learned.

5. The OECD should consider organising a Workshop on Human Factors in Chemical Accidents and Incidents to investigate human factors related to management and operation of a hazardous installation (definition, causes, characterisation, how to minimise the number of errors, how to limit the impact of those which do occur, etc.). The proposed workshop should explore all aspects of the relationships 'human factors – accident prevention' that have not yet been addressed or sufficiently addressed or need to be revisited.
   Note: An OECD Workshop on Human Performance in Chemical Process Safety: Operating Safety in the Context of Chemical Accident Prevention, Preparedness and Response took place in Germany in 1997.

GENERAL WRAP-UP CONCLUSIONS

The major focus of this workshop was directed towards the fault tree side of the "bow-tie" model, in other words, prevention of accidents and near-misses. Nonetheless, the EU MARS and US RMPInfo data demonstrates that there has not been a significant reduction in accident frequency over the last several years. A number of barriers to progress were identified.

At the same time, there were only two or three papers, which dealt with the event tree side of the model (preparedness and response) dealing with environmental impact and damage. We know that the preparations for the Y2K have had a positive effect in overall preparedness to deal with events when they occur. But further development of data collection and analysis in this respect, as well as better use of existing databases across civil protection and environmental agencies should help in learning lessons in this regard.

There is an obvious need to ensure organisations disseminate and implement procedures and techniques that have been learnt from accidents and near-misses. This is an ongoing and dynamic process.

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ANNEX 1

OECD Workshop

on

Lessons Learned from Chemical Accidents and Incidents
21 – 23 September 2004, Karlskoga, Sweden

DISCUSSION DOCUMENT

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Abstract

The objective of this paper is to provide some background information and stimulate discussion of the major issues pertinent to the subject of the OECD Workshop: Lessons Learned from Chemical Accidents and Incidents. It will set the scene for discussions on issues affecting the effective use of lessons learned to prevent and mitigate chemical process accidents.

The Workshop is organized around the following six themes:

Session I: Setting the scene – Description of the themes addressed in the following sessions and presentation of the main issues to discuss. Session I will also address terminology

Session II: Data sources on accidents and incidents – Relevance of data sources for measuring the output of the safety work within the field of chemical accidents

Session III: Investigation of accidents and incidents – How do we gain optimal output from investigation of accidents/incidents with respect to both lessons learned and the dissemination of such lessons?

Session IV: Lessons Learned – How can we make the most effective use of lessons learned from incidents (accidents and/or near-misses)?

Session V: Communication and Implementation of lessons learned – How do we ensure that all the data being gathered are transformed to effective learning?

Session VI: General discussion – Conclusions and Recommendations

The Discussion Document, to be presented in Session I, will first propose and then discuss definitions for some of the key terms and concepts that are likely to be used during the Workshop. It will then attempt to stimulate Workshop discussion on Sessions II through V by providing some background information on each session's theme. The discussion document will also try to put forward ideas and viewpoints aimed at provoking vigorous discussion on the key issues that need to be addressed in each session in order to make further progress towards the Workshop's objective: Reduction of chemical process accidents thru improved use of Lessons Learned.

Session I – Setting the Scene

Session I will address: Description of the themes addressed in the following sessions and presentation of the main issues to discuss. Session I will also address definitions and terminology to be used at the Workshop.

Introduction and Overview

The title of this workshop, "Lessons Learned from Chemical Accidents and Incidents", might lead some to believe that the Workshop will be primarily occupied with descriptive issues. Examination of the issues to be discussed at the Workshop's Sessions shows that this is not true.

While all of the Workshop sessions are related to lessons learned from accidents and incidents, the themes of the sessions make it clear that the Workshop Planning Committee hoped to stimulate papers and discussions that explore all aspects of the subject of lessons learned from chemical accidents and incidents, and go far beyond merely describing how lessons are learned from chemical accidents.

The Discussion Document (DD) was charged with achieving the following objectives:

(i) Provide an international overview and perspective on lessons learned from chemical process accidents and incidents and the sources and types of data available on the occurrence of such accidents;
(ii) Describe the themes of sessions;
(iii) Identify issues for consideration; and
(iv) Provoke or at least stimulate discussions among participants.

Before focusing our attention on the Workshop's Sessions, the DD will very briefly review two items:

- Watershed[1] accidents that led OECD countries and firms to adopt or amend various measures to improve chemical process safety.
- Competing societal and industry considerations, such as natural disasters, endemic diseases, poverty, and other safety, health, and environmental hazards that must be taken into account as Society and Industry consider increasing the resources committed to improving process safety.

This very brief review of these two items should refresh Workshop participants' awareness of the terrible consequences that can result from major process accidents and also remind us that, given the magnitude of the other risks that Society and Industry must deal with, one may need to pursue Pareto[b] effective, rather complete proposals for needed improvements in process safety.

The DD will then propose and discuss a set of definitions for key terms such as incident, incidence rate, and lessons learned. Having a common understanding of the terms used in our discussions is vital, particularly when the background of the various participants is so varied. It is to be expected that there will not be complete agreement on the definitions put forward, but hopefully these comments will be captured by our rapporteurs and used to help fashion a set of improved Workshop consensus definitions.

[b] Pareto effective: Achieving an 80% solution to a problem with about 20% of the effort required for a complete solution.

The largest part of this paper will be focused on accomplishing the four specific Discussion Document objectives noted above. The paper proposes to do this by addressing some of the questions generated by the Workshop Planning committee with regard to Sessions II, III, IV, and V. The authors will also raise and address some rhetorical questions pertinent to a Session's objective as needed.

Hopefully, the background in this DD and, much more importantly, the knowledge gained from the papers presented and our discussions will increase our ability to make more effective use of lessons learned in decreasing the incidence and consequences of chemical process accidents.

Events leading to current practices for managing process safety (Watershed Events)

In our discussions of lessons learned it may be of value to keep in mind the catastrophic accidents that gave rise to the lessons learned that prompted different countries to adopt their present regulatory and industry measures for managing process safety.

As Table 1 illustrates, it requires a shocking, belief-upsetting (watershed) event before a society is willing to commit to a large step-change in the level of resources needed to reduce a class of Low Probability–High Consequence (LP-HC) risks such as those presented by chemical process accidents.

In spite of the fact that the technical tools and approaches on which these adopted regulatory and other measures are based existed in the literature for some time, it required different major accidents in different countries to create the attention and dread needed to trigger the enactment of largely equivalent process safety regulations and industry codes. As we know, looking backward, the measures initially adopted did not include important considerations described in the literature and covered only facilities that processed relatively large amounts of particularly hazardous materials.

It was the terrible accident at Flixborough that led to major changes in the UK regulations and the Seveso catastrophe that led to the EU Seveso Directive, but both of these events had little impact on laws and regulations in the USA. The Bhopal tragedy reinforced by the 1989 Phillips accident were needed before the USA adopted regulatory measures such as the OSHA Process Management Standard (PSM) and EPA Risk Management Program (RMP) and industry trade associations adopted the Canadian Responsible Care program.

This pattern continues. It was only after recent major catastrophic events (Baia Mare, Enschede, and Toulouse) that previously sought after improvements were incorporated into the Seveso II Directive and various country regulations.

Given the Workshop's focus on lessons learned from chemical accidents and incidents," we might find it interesting to speculate on the following issues:

- Why did it require different major accidents in different countries (see Table 1) in order to generate essentially similar responses to the same lessons learned?
- If one had implemented the lessons that were or could have been learned from past catastrophic ammonium nitrate accidents[2] such as Oppau, Germany (1921), and Texas City, USA (1947), could the accident at Toulouse have been prevented?

Table 1: Some Major Watershed Accident Events in the last Quarter Century

Location of Accident	Date	Type of Event	Some Resulting Consequences	Regulatory Response
Flixborough, UK	1974	Explosion and fire	28 killed, over 100 injured	COMAH 1984
Seveso, Italy	1976	Runaway reaction	Large Dioxin environment contamination massive evacuations, Large animal kill	Initial Seveso Directive
Bhopal, India	1984	Runaway MIC reaction	≈ 2500 people killed and 100,000 injured, high litigation costs	USA Emerg. Planning & Community Right to know Act- CMA CAER Program
Basel, Switzerland	1986	Warehouse Fire	Massive contamination of Rhine and very large fish kill	Changes in Seveso Directive
Pasadena, USA	1989	Explosion and fire	23 deaths, ≈ 100 injured Over $1 billion in losses	Triggered 1990 USA CAAct & RMP & PSM process Stds
Longford, Victoria, Australia	1998	Explosions and fires	Two deaths, gas supply to Melbourne cut for 19 days. Losses over $1.3 Billion	Process Regulatory initiatives Victoria
Enschede, The Netherlands	2000	Explosion and fire	22 deaths, ≈ 1000 injured, 350 houses and factories destroyed	Changes in Seveso Directive
Toulouse, France (Oppau[c] & Texas City[d])	2001	Explosion and fire	30 deaths, ≈ 2000 injured, 600 homes destroyed, 2 schools demolished	Changes in Seveso Directive

c At 7:30 a.m. on September 21, 1921, two powerful explosions occurred at the BASF plant in Oppau, Germany. The explosions destroyed the plant and approximately 700 nearby houses, and killed 430 persons.

Location:	Oppau, Germany
Date of incident:	September 21, 1921
Hazardous material:	Ammonium sulfate & ammonium nitrate (50/50)
Type of accident:	Explosion
Facility type/Transport:	Chemical plant (fertilizer)
Owner of facility:	BASF
Deaths:	430

d On April 16, 1947, a ship carrying ammonium nitrate fertilizer blew up in the port on Galveston Bay. The blast took nearly 600 lives and many millions of dollars in property.

Chemical process accidents in the context of other catastrophic events OECD countries face

All countries have limited resources and face many other categories of high consequence risks in addition to those that arise from processing chemicals. The European Environment Agency report on "Mapping the impacts of recent natural disasters and technological accidents in Europe"[3] (EU Disaster Report) and the OECD report on "Emerging Risks in The 21st Century"[4] (OECD Risk Report) point out some of the financial, social, health, and safety impacts of these different risk categories. On a global level, the economic losses experienced in these other hazard categories greatly exceed those from chemical processing and most technological accidents do not tend to cause as many deaths as do disasters of natural origin.

The EU Disaster Report shows that between 1998 and 2002, natural disasters and technological accidents in Europe affected more than seven million people and caused at least 60 billion euro in insured losses. In fact, total losses have undoubtedly been far higher, since by and large insurance losses reflect mainly business property costs and some business interruption losses for larger firms; many smaller firms and individuals will not have been insured at all and such losses go unreported. Furthermore, insured losses do not reflect losses that affected populations may experience as a result of evacuation, psychological upset and the costs of some delayed health effects.

On the other hand, the EU Disaster Report maintains that the catastrophic potential of technological disasters to affect the environment can be much greater than that of natural events. For example, marine oil spills and mining accidents resulting in the discharge of hazardous waste into water bodies can damage valuable ecosystems, as with the wrecks of the oil tankers Erika (1999, France) and Prestige (2002, Spain) and the chemical spills at Doñana (Spain) in 1998 and Baia Mare (Romania) in 2000.

Particularly pertinent to this Workshop are observations in the OECD Risk Report on lessons learned on a wide range of risks. After noting that:

> "The alarming headlines are now familiar–hugely damaging windstorms and flooding in Europe; ice storms in Canada; the appearance of AIDS, new variant CJD, SARS; terrorist action such as the September 11th attacks in the United States and the Sarin gas attack in Japan. These and other harmful events may have put policy makers and the public "on the alert," but being aware is not the same thing as being equipped to prevent these risks or mitigate the damage they cause. There is worrying evidence that countries are simply not adequately prepared."

After discussing these different categories of risks and their consequences, the OECD Risk Report concludes with a section on "Learning the lessons". This section of the report notes:

> "Disasters are followed by a period in which the attention of the public and the media are at their highest point and a window of opportunity for action opens. Experience of harm forces society to revaluate risk and the way it is managed. However, whether such consideration is retained or acted upon is another matter. Investigating and analyzing the origins and consequences of disaster can provide lessons on how to improve assessment and management of risk. Such lessons can be extended to other similar risk areas (or regions). The momentum created in society can help overcome inertia and resistance to reforms in the risk management process. Effective management of the window of opportunity can reinforce citizen's confidence in the way risks are handled, and all in all significantly reduce the chances that the same disaster occurs again in the future."

One of the issues facing society, industry, and each of us in our separate spheres of influence is what is an appropriate distribution of the resources devoted to addressing chemical processing accidents given the need to also address other categories of risks and what is the basis for our judgement of what is appropriate?

Definitions and Terminology to be used at the Workshop - Proposed Definitions

Given the diverse background of the participants in this workshop, it is important that there be a clear understanding of the terminology each participant uses in their presentations and in their comments during our discussions.

Three sets of key terms will be defined:

- Accident, Near Miss, and Incident
- Incidence, and Incidence Rate, and Frequency
- Terms related to "lessons learned": Lessons, Lessons Learned, Lessons Disseminated, and Lessons Communicated

Definitions for these three sets of terms are proposed and will be subsequently discussed.

Accident – Near Miss – Incident

Accident: An event or series of events and circumstances that results in one or more specified undesirable consequences* under foreseeable circumstances*.

Near miss: An event or series of events that could have resulted in one or more specified undesirable consequences* under different, but foreseeable circumstances*, but actually did not.

Incident: An event or sequence of events and circumstances that may result in one or more specified undesirable consequences* under foreseeable circumstances*, including accidents and near misses.

(*) "Undesirable consequences" and "foreseeable circumstances" are subjective terms that should be described. Also note that as defined, accident and near miss are encompassed within incidents.

Incidence – Incidence Rate – Frequency

The second set of terms, incidence, incidence rate, and frequency, relates to accident data and statistics, a subject that will be discussed in this paper and throughout our discussions.

Incidence: Number of processes in a specified population experiencing a specified event divided by the total number of processes in the specified population

Incidence rate: Number of processes in a specified population experiencing a specified event divided by the total number of processes in the specified population per specified unit time (years, months, etc.)

Frequency: Fraction of processes in a specified population experiencing a specified event per specified unit time (years, months, etc.)

Terms related to "Lessons Learned"

The last set of definitions to be proposed for use in this Workshop deal with the major subject of the Workshop: Lessons learned. As subsequent discussion will show, this widely used term is not commonly defined in the technical literature.

<u>Lessons</u>:	Knowledge that could be gained from investigation, study, or other activities in regard to the technical, behavioral, cultural, management, or other factors that led, could have led, or contributed to the occurrence of an accident
<u>Lessons learned</u>:	Knowledge that is actually gained from investigation, study or other activities in regard to the technical, behavioral, cultural, management, or other factors that led, could have led, or contributed to the occurrence of an accident
<u>Lessons disseminated</u>:	"Lessons learned" made available to other practitioners and stakeholders who might benefit from such knowledge
<u>Lessons implemented</u>:	"Lessons learned" that are translated into effective practices.

Discussion of proposed Definitions and Terminology

There appears to be reasonably uniform usage of the terms Frequency, Incidence and Incidence Rate. The definitions proposed for use in this workshop are adapted from those given in a well-known epidemiology textbook.[5] Given that process accidents result from relatively Low Probability-High Consequence (LP-HC) deviations from normal processing conditions and given the success of the epidemiological[6,7]approach in gathering information on the causes of LP-HC disease, there is much to be said for applying such thinking to our studies of accidents.

Unfortunately, at this time the value of much of the data on the number of accidents in a given time period for a given population is reduced because of uncertainty about the completeness with which these accidents were reported by members of a given population of firms and the characteristics and size of the population of facilities that experienced these accidents. Another factor that should be taken into account is the level of production. There are a variety of opinions in regard to relationships that might exist between process safety and production level as a function of capacity. Some hold that either operating at very high or very low fractions of a facility’s design capacity level gives rise to added process safety risk. It would be of interest to examine industry accident frequency as a function of facility capacity or, second best, as a function of total industry production vs. nominal industry capacity.

These data problems have made it difficult to answer simple questions such as: is the incidence of process accidents going up or down among different classes of firms or with different classes of processes?

There appears to be reasonably uniform usage of the terms incident and accident, and less uniformity in the meaning attached to the term near miss. In perusing the literature one note that incident and accident are sometimes used interchangeably and that some institutions[8] use mishaps and close calls for what we call near misses.

The definitions for accident and near miss used in this paper generally follow those used by the Centre for Chemical Process Safety[9] (CCPS) and the OECD[10,11] with the exception that the word "unplanned" has been eliminated from the phrase "an accident is an unplanned event".

Jones[12] proposed that near miss be defined as "a hazardous situation, event, or unsafe act where the sequence of events could have caused an accident if it had not been interrupted". The authors felt that this definition did not reflect main stream usage and that the definition employed too many terms of art, i.e. “unsafe act,” and that indeed near misses can occur even when unsafe acts are not involved.

The definitions of "major accident" in the EU Seveso Directive and UK COMAH regulation also make no mention of "unplanned" in defining "major accident". Neither the U.S. EPA in its RMP regulation or OSHA in its PSM Standard insert the word "unplanned" into the definition of accidents (OSHA uses the term "Catastrophic Releases" for the term "accident").

Presumably the word "unplanned" was inserted into various definitions to distinguish an accident caused by normal malfunctions and errors from those caused by conscious acts of sabotage or terrorism. The authors believe it would be better to enter the word "purposeful" into the proposed definition of accident and call the term "sabotage" or "terrorist event" in order to distinguish planned destructive acts from accidents:

> Sabotage or Terrorist event: A purposeful event or series of events and circumstances planned to result in one or more specified undesirable consequences.

Considerable time was spent in searching for and wrestling with terms related to the main theme of our workshop, lessons learned. It is interesting to note that the excellent IChemE publication, "Nomenclature for Hazard and Risk Assessment in the Process Industries"[13] does not define incident, accident, or near miss. A search of the literature and revealed a lot of non-technical material associated with the phrase "lessons learned", and the excellent "Project Hanford Lessons Learned"[14] and "NASA Public Lessons Learned"[15] (PLLS) Web sites.

A few definitions for lessons learned were put forward by organizations not primarily concerned with accidents. Two examples are:

- "Knowledge generated by reflecting on experience that has the potential to improve future actions. A lesson learned summarizes knowledge at a point in time, while learning is an ongoing process"[16] (The International Fund for Agricultural Development).
- "Project specific, or generally applicable guidance derived from the conclusions of an evaluation"[17] (Department for International Development).

However only a few definitions for lessons learned in a technical context were picked up in our relatively brief search: one from the Hanford Laboratory web site and the other in the CCPS book on accident investigation.

The Hanford definition is:

> "A ‘good work practice’ or innovative approach that is captured and shared to promote repeat applications or an adverse work practice or experience that is captured and shared to avoid a recurrence."

The CCPS definition[18] is:

> "Applying knowledge gained from past incidents in current practices."

Both of these definitions of lessons learned differ from the definitions for these terms that the authors recommend. The Hanford definition covers what we have defined as a combination of lessons learned and lessons disseminated. The CCPS definition is in essence what we have defined as lessons implemented.

The definition of lessons learned in the Sweden Project Proposal[19] for an OECD Workshop on "Lessons Learned" was used as an important starting point for developing the four lessons learned related definitions proposed in this DD:

> "Lessons learned" should be understood to encompass all the activities and results that are connected with or can be extracted from the chain of events linked in any way to an accident, before and after it. This includes the cause and course of events during the accident itself, the injury or damage caused, and the appropriate dissemination of knowledge and information about appropriate measures to be taken to prevent such an accident from reoccurring."

If one analyzes the Sweden definition, it can be seen that it goes beyond the concept of lessons learned put forward in the Hanford definition and encompasses three of four of the lesson- related terms explicitly defined in the DD, the exception being lessons implemented.

The authors believe that the value in separating out the different aspects of the concept of lessons learned can be appreciated by examining our Workshop agenda: Session III centers on lessons learned and disseminating such learned lessons, Session IV examines making the most effective use of lessons learned and Session V discusses transforming lessons learned into “effective learning” which is essentially lessons implemented.

The definitions covered in the DD encompass only a few of the terms that that are likely to be used in our discussions. There may be other terms that require a definition and could be incorporated in a glossary in the Workshop Proceedings. Workshop participants show true courtesy to those presenting papers or offering comments by asking what they mean when they use a term whose meaning is unclear to them rather than suffering in silence.

Session II – Data Sources on Accidents and Incidents

Session II will address: Data sources on accidents and incidents – Relevance of data sources for measuring the output of the safety work within the filed of chemical accidents.

This session will address the adequacy of existing data bases and the value of data sources as an effective tool in guiding and measuring the prevention of accidents: What additional data we would like to have in order to maximize the effectiveness of the prevention measures resulting from accident investigation, and inform improved industry practices and government regulation. The following items will be dealt with:

- Overview of data sources relevant for the field of chemical process accidents and examination of the problem of compatibility of information from such different data sources;
- What systems exist for exchanging data between different organisations (e.g. industry, trade-unions, administration/authorities), and between countries with respect to the root causes and lessons learned from accidents and incidents – What could be done to improve the quality, breadth and availability of accident data?
- What types of data bases are needed for different uses and needs? – Review of examples of data bases developed by and for different stakeholders (e.g. industry, authorities, employees, etc.) and what are the barriers in communicating different types of accident data to different stakeholders?
- Data mining – Review of the different methods: qualitative approach based on analysis of a sample of accidents in specific activity/device/process; quantitative approach based on statistics; and other methods, e.g. modelling;
- Is data available that would allow one to evaluate whether the incidence rate and the losses from major accidental releases in various countries or industry segments has increased or decreased over the last 20 years or to correlate incidence rates with the various approaches used in different industries and countries to prevent chemical process accidents? and
- What presently unavailable data is vitally needed and how might such needs be met?

Focus of the DD discussion of Session II

The authors will focus their discussion of Session II on the following reframing of the session's major topic[e]: "How relevant are current data sources for measuring the output and value of the safety work within the field of chemical process accidents?"

In order to have a productive discussion of the posed question, we need to clarify what we have in mind when we use the phrase "output of the safety work".

The authors suggest that two of the most important outputs one might hope to obtain with appropriately structured and maintained data sources are answers or information pertinent to the following two questions:

[e] Session II: Data sources on accidents and incidents - Relevance of data sources for measuring the output of the safety work within the field of chemical accidents.

1.	What attributes can be used to predict whether a firm will manage its chemical processes in a manner that results in a low likelihood of accidents occurring?
2.	Have trends in chemical process accident incidence rates and losses experienced in various countries and industry segments over some period of time (say the last 20 years) met expectations and projections?

Aspects of other questions raised in the framing of this session, such as the adequacy of present databases, unavailability of data that is vitally needed, etc will be touched on in the course of discussing the other Workshop Session topics.

Attributes of firms predictive of good process safety management

Information responsive to the first question could help identify where future efforts on improving chemical process safety management systems should be focused and even give us clues on accident causation. The information needed to address the first question should be available by data mining or doing epidemiological[20] analysis on suitable databases such as those structured in the human health area to obtain answers to questions such as: What is the influence of life style on low-probability human disease occurrences?

The work at Wharton by Elliot, Kleindorfer, and their associates[21] under an EPA grant illustrates what can be accomplished in regard to the etiology of major accidents by data mining and the application of epidemiological approaches, given a suitable data base. This ongoing research effort has produced valuable information on the demographics of process accidents and the business factors that are associated with process accident frequency. The range of the results from this type of research is illustrated by the following two findings that on average there is likely to be:

- A positive relationship between the level of indebtedness of a parent company and the accident frequency of the facilities owned by the company.
- Increased process accident risks from facilities in heavily African-American counties, even after adjusting for location risk and other factors.

Chemical process accident incidence rates and losses

The answer to the second question will tell us whether the resources spent on the reduction of process accidents have yielded prevention results that have met the forecasts used to justify our various regulatory agency and trade association efforts. The available data does not allow one to provide a simple answer to this question. However, our analysis of these limited data indicates that over the last 20 years any decrease in major process accidents is lower than had been hoped for and expected.

Furthermore, as Goethals re-emphasizes in the Workshop paper he is presenting on "Using lessons learnt from accidents", process accidents are relatively low probability events and only very large countries or supra-national units such as the European Union collect enough events to construct databases that allow for data mining or obtaining meaningful accident rate trends even over relatively long time periods.

Even when enough incidents are reported to allow for effective analysis of chemical process accidents, the inability to determine either the number of processes covered in the system, the level of chemical production in the covered processes and/or the completeness with which accidents are reported often hinders arriving at firm findings about improvements in process safety. As the paper by Elliot[22] to be presented at this Workshop shows, even analysis of data from the better systems, such as RMP*INFO database in the United States (See Table 2 for a summary of the accidents covered by RMP*INFO), over its first five year reporting period (June 1994 to June 1999) presents ambiguity regarding the answer to the question posed. Fortunately, EPA has already taken steps to remedy these deficiencies in the RMP*INFO system[23].

Table 2: Summary of RMP*INFO Data *

# of Facilities & Processes	15,430 facilities	(20,588 covered processes)
Facilities with at least 1 accident in 5 yr period	1,205 (7. 8%)	(2.3% multiple Accidents)
Total number of Accidents	1969	(394 event per year)
Deaths (Workers)	32	
Injuries (workers)	1987	
Injuries (Public & First Responders)	167 injuries, 215 hospitalizations, 6,057 medical care (over 200,000 evacuated & shelter-in-place)	
Property damage	≈ $1 billion, (Total estimated at ≈ $5 to 10 billion including business interruption, and other losses associated with accidents)	
Ecological damage	104 accidents with significant damage	
Off site property damage	$11.7 million	

[*] Kleindorfer, P., Belke, J., Elliott, M., Lee, K., Lowe, R., Feldman, H.,"Accident Epidemiology & U.S. Chemical Industry: Accident History & Worst-Case Data from RMP*Info", Risk Analysis, Vol.23, No 4, 2003, pp 865-881.

Only relatively poor data exist for drawing conclusions about the trend in chemical process accident frequency over the first 10 years of this 20 year period. However, better data exist for the second half of this period, and in our opinion, these data indicate that there has been no significant decrease in the frequency of major process accidents.

Pitblado[24] also concludes that the MARS data presented in a recent paper by Duffield[25] show no evidence of a significant reduction in the rate of major accidents reported under the Seveso Directives over the last 10 to 20 years and furthermore that the MARS data also showed no change to average severity of reported accidents based on the 7 point MARS severity scale. Michalis[26] also concludes, based on an updated of data used by Duffield, that "There is a clear indication that the total number of major accidents is relatively constant".

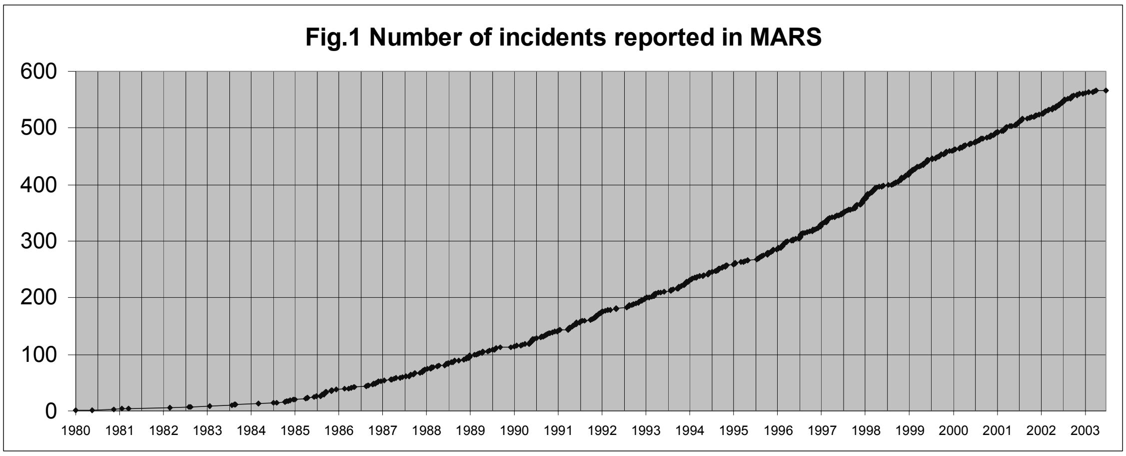

Figure 1 Sources: "Status of the Major Accident Reporting System"

(MARS, Michalis, 10th and 11th meetings of the Committee of the Seveso Competent Authorities)

Accident frequency data in Japan (Figure 2) also do not indicate the hoped for reduction in process accidents[27]. An interesting comment pertinent to the Japan accident data shown in Figure 2 was reported in The Japan Times[28] to have been made by Noriko Hama, a professor of international economics at Doshisha University Business School at the symposium on "Economic and Structural Reforms in Japan and Germany", jointly organized by the Japanese-German Center of Berlin and Japan's Keizai Koho Center on February 27:

> "Another offshoot of deflation that is particularly worrying, she said, has manifested itself in a series of major accidents that have hit the plants of Japan's industrial giants in recent years.
>
> The examples cited by Hama included a fire that destroyed a tire factory of Bridgestone Corp. in Kuroiso, Tochigi Prefecture and a fire and explosion at Nippon Steel Corp.'s Nagoya ironworks both of which happened last September.
>
> In their bid to make profit under deflationary pressures, those companies have been restructuring their operations and trying to cut costs, and are compelled to continue using facilities and equipment that normally would have been replaced and renewed years ago, thereby raising the risk of accidents, Hama said.
>
> Also because of job cuts, the firms do not have sufficient numbers of workers who can repair and keep the old equipment in proper condition, she said.
>
> The operation of Japan's manufacturing industries was once looked upon as a global standard, but the fact that major companies that are supposed to symbolize that standard have been hit by serious accidents shows deflation has damaged the nation's industrial base, Hama observed."

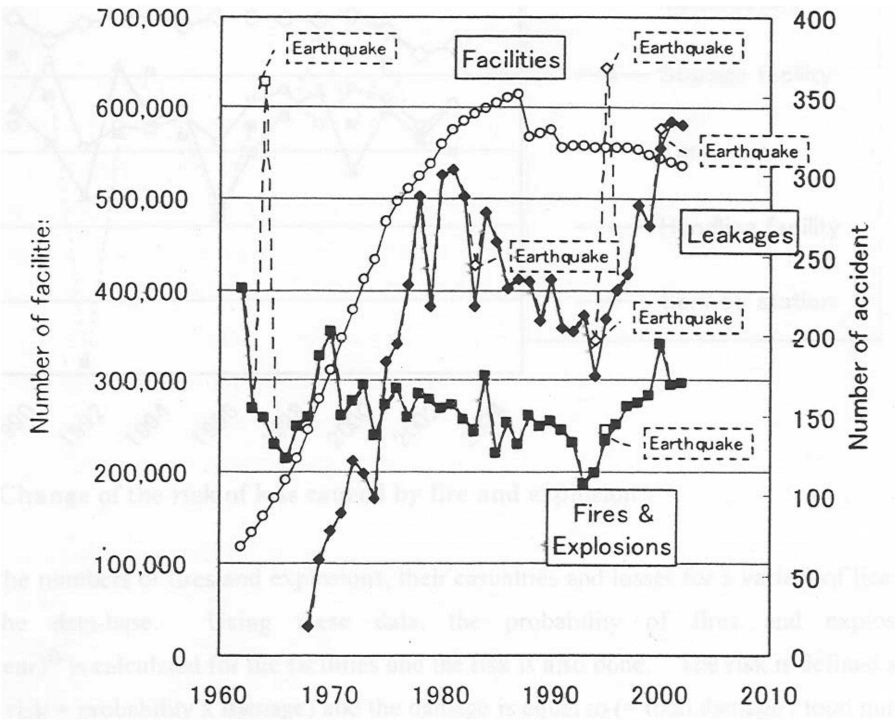

Figure 2: Changes in the number of facilities and accidents[f] (Japan)

Effectiveness of Accident Prevention Efforts *versus* Expectations

There was great optimism that new regulations and trade association initiatives introduced in the UK, EU and the USA after the Flixborough, Seveso, and Bhopal accidents would lead to very significant reductions in chemical process accidents.

An example of such optimism is seen in the cost/benefit analysis[29] that OSHA submitted to justify the significant costs of complying with its 1992 Process Safety Management Regulation (PSM). OSHA projected that: "In Years 6-10, a risk reduction of 80 percent is projected, with 264 fatalities and 1,534 injuries/illnesses (including 500 catastrophic lost-workday injuries) avoided, annually."

Organization Resources Counselors, a group that generally expresses industry positions, agreed with this accident reduction projection.

The numbers of fatalities and injuries used by OSHA for their baseline may have been too high. Unfortunately, OSHA did not develop a reporting data system that would allow checking this projected reduction. However, the findings described in this paper indicate that OSHA's initial projections on avoided fatalities and injuries have not been reflected in a corresponding reduction in the frequency of process accidents.

[f] "Data-Base of Hazardous Materials Accidents in Japan and its applications", Hasegawa, K., Hazardous Materials Safety Techniques Organization, Third NRIFD International Symposium on Safety in the Manufacture, Storage, Use, Transport, and Disposal of Hazardous Materials, Tokyo, March 2004

The authors will argue subsequently that one of the major reasons for the failure to obtain the hoped for reductions in accident rates is that the high level of attention paid to process safety by firms and government following notorious accidents diminished rapidly under the pressure of the need to focus limited attention resources on other current “hot” problems. As a result, of this decay in attention, we (government, Industry, labour, and technical personnel) have failed to ensure that what we had already learned and hopefully incorporated into our process safety management systems continued to be effectively implemented.

Session III – Investigation of Accidents and Incidents

Session III will address: Investigation of accidents and incidents – How do we gain optimal output from investigation of accidents/incidents with respect to both lessons learned and the dissemination of such lessons.

This session will discuss how optimal output is/can be gained from investigations of accidents/incidents with respect to factors such as:

- Decreasing the incidence and losses associated with all process accidents;
- Acquisition of information about root causes and previously unknown technical factors leading to the likelihood of accidents;
- Deficiencies in management systems, equipment and human factors associated with accident causation;
- Addressing public anxiety and concerns;
- Improving level of compliance with institutional (government or commercial) safety requirements;
- Improvements in the investigatory scope and protocol; and
- Effective allocation of time, energy and resources.

The following issues will also be addressed:

- Criteria for selecting those accidents/incidents for in-depth investigation which will maximize specified goals such as, prevention, deterrence, compliance with regulations or lessons learned, and examples of the types of accidents that might be selected based on the use of such criteria; and
- Problems related to investigation: What factors make the investigation difficult?

After examination of the issues the Workshop program put forward above for discussion during Session III, the authors believe that insight into the issues that are the subjects of this session might best be obtained by discussing the central issue posed in the framing of this session.

How do we gain optimal output from investigation of accidents/incidents with respect to both lessons learned and the dissemination of such lessons?

Good accident investigation management requires attention to many considerations. The authors will discuss three of these considerations:

i. Definition of organizational objectives to be achieved by accident investigations;
ii. Development and execution of an accident investigation protocol(s) that is cost/effective in regard to the organizational objectives to be achieved by an investigation; and
iii. Criteria for choosing the accidents whose investigation will likely lead to the most cost effective impact on preventing future process accidents.

We will touch lightly on items (i) and (ii) and discuss item (iii) in some detail.

i. Organizational objectives and the conduct of accident investigations

While some in attendance at this workshop might be expected to identify "prevention" as the only objective of accident investigations, it is clear that this is not the case for a large number of the organizations who carry out investigations. Only a relatively few government organizations such as the CSB and NTSB, and national commissions set up to investigate notorious accidents such as Piper Alpha, Toulouse, and Longford, focus their accident investigations almost exclusively on prevention.

Many organizations have a wide variety of reasons for carrying out accident investigations aside from learning how to prevent similar future events.

For example, regulatory agency investigations are often aimed primarily at establishing whether the process involved in the accident was operating in compliance with regulatory requirements. Insurance company investigations may seek to find out whether the risks associated with the process experiencing the accident were properly assessed (priced) when they issued the policy. The facility experiencing the accident may conduct an investigation to determine if a contractor or equipment supplier was negligent.

Many company accident investigations are also carried out primarily to provide a basis for defending a company against civil litigation[30] seeking compensation for injury and damages that result from an accident. The results of such investigations are generally carried out under the supervision of a legal group, and the investigation's findings are guarded against disclosure by invoking attorney-client privilege.

ii. Compatibility between accident investigation protocols and organizational objectives

Clearly, the objective of an investigation strongly influences the protocol used and the best way to conduct the investigation.

For example, consider the following narrow aspect of the somewhat artificial example of a case involving an incident at a chemical plant that caused injuries to a self-employed delivery truck driver parked in an unrestricted area of a plant. The driver was injured as a result of an explosion that involved a flammable material that was accidentally released from an adjacent plant area. If the driver were to sue, alleging that the negligence on the part of the plant led to his injury, plaintiff and defendant attorneys might carry out an extensive investigation aimed at establishing that the specific ignition source was the result of the driver's inappropriate conduct, e.g., smoking in a zone marked as non-smoking. The depth and extent of the facility's investigation would be strongly influenced by the potential damages at risk, any simultaneous regulatory actions, etc. and would almost certainly be carried out under the supervision of an attorney with access to findings restricted under attorney-client privilege.

The investigation of the incident described immediately above could differ significantly if the investigation was carried out by an independent agency such as the CSB, which has no enforcement responsibilities. Such an investigation would probably aim primarily at establishing root causes and deal with proximate causes of the accident, either because it helped to establish root causes or had teaching value (good lesson to learn). Major attention would be on factors that could have led to the flammable release (breach of mechanical integrity, management of change failure, deviation from scheduled maintenance, etc.), whether appropriate criteria for placing the flammable material in an unrestricted area were called for by the facility process management system, if execution of these required practices was monitored, and whether appropriate corrective actions were taken when deviations from required practices occurred.

The specific source of ignition would probably not be a major point of investigative focus for an agency such as the CSB since the essence of the lesson to be learned is that release of a large quantity of a flammable substance is likely to lead to a fire because ignition sources are fairly pervasive.

iii. Criteria for choosing the accidents whose investigation is likely to have the most cost effective impact on preventing future process accidents

Item iii can be rephrased as follows: Given a set of accidents that are candidates for investigation, what criteria can be used to identify the accident whose investigation has the greatest loss prevention value (LPV) i.e., is most likely to result in the greatest reduction in future accident losses?

This is one of the critical questions faced by organizations with limited investigatory resources (almost everyone) whose primary accident investigation is for the prevention of accidents

The United States Chemical Safety and Hazard Investigation Board (CSB) is one such organization. The CSB has analyzed[31] the problem being discussed and it has used the conclusions of this analysis to help in its selection of the accidents it investigates. The authors agree with the general approach taken by the CSB and believe that with minor modifications, this approach can be used by other organizations facing a similar problem.

Following the general lines of the CSB approach, the authors believe that the loss prevention value (LPV[g]) of a process accident is the product of the following four factors:

1. Losses from the process accident being considered for investigation;
2. Number of facilities operating similar processes;
3. Likelihood that other facilities operating a similar process will also experience an accident similar to the one being considered for investigation[h]; and
4. Extent to which recommendations and lessons learned in the contemplated investigation could be implemented in other facilities running similar processes[i].

The referenced CSB report presents a rather detailed set of weighted criteria for arriving at values for items 1, 2 and 3, but not on item 4.

Only crude estimates of the LPV of an accident that is a candidate for investigation can be generated in the short time available before a "go – no go" decision must be made. At the best, such estimates of LPV can only be semi-quantitative, e.g., low, medium or high.

On occasion, unable to assemble data needed to reach a firm "go – no go" decision, the CSB dispatched a team to start investigatory work on an accident candidate that look potentially productive based on initial LPV guesstimates and then made a final "go – no go" decision based on subsequent, more informed LPV estimates.

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g The LPV of an accident investigation is defined as: the expected reduction in the frequency and consequences of future similar accidents. The assumption is made that implementation of all recommendations/lessons learned from the investigation being considered will reduce the average likelihood of a Process A accident to de minimus levels).

h Assuming that the process safety management of similar processes in the other facilities mirrors that of the process in the facility involved in the accident being considered for investigation.

i Assuming that full implementation of all investigation recommendations will reduce the likelihood of a Process A accident to de minimus levels.

The most challenging task in arriving at the LPV of a specific accident is estimating the value of item 4. It is clear that conventional cost/benefit analysis is not the sole factor that determines the extent to which recommendations and lessons learned from an accident are implemented either by a firm or Society[32]. However, implementation of risk corrective measures does appear to be strongly correlated (not necessarily caused) with the extent of media coverage. Media coverage in turn is strongly influenced or at least mirrors a number of factors such as the magnitude of the losses and feelings of dread and similar concerns engendered by the accident.

For example Slovic[33] notes that:

> "Models based on the analysis of 108 accident events were consistent with the theory (Psychometric paradigm) in the sense that the social and economic impacts of an adverse event were determined not only by the direct biological and physical consequences of the event but by elements of perceived risk, media coverage (emphasis added) and signal value."

Coming from a different conceptual approach, Palmlund[34] asks the question: "What determines whether a specific technological risk gives rise to social controversy? He then proceeds to list several candidate criteria (i.e., attributes) that he believes promote the likelihood of controversy, stating, for example, that "the issue should ideally be such that the mass media grasp it (emphasis added) and assist politicians in placing and keeping it on the agenda in national politics so as to satisfy the public's need of spectacular drama.".

Somehow the news media sense and publicize issues that will attract the public's concern and attention, (creating customer readership and therefore advertising) and this concern appears to feed upon itself and attract more publicity. In turn, these aroused public concerns capture the attention of politicians and industry managers who are more inclined to act once their stakeholders start asking questions such as, "Could this happen to us also?"

Empirical and limited as this use of media coverage as a surrogate for variable 4 may appear, its great virtue is that it is "doable": Data on the extent and breadth of media coverage of significant process accidents is relatively rapidly available.

One of the interesting challenges we can enjoy during our Session III discussions is exploring alternatives to the CSB four-element approach for choosing the accidents that one should investigate, if the objective is to maximize prevention.

Session IV – Lessons Learned

Session IV will address: Lessons learned – How can we make the most effective use of lessons learned from incidents (accidents and/or near misses)?

This session will discuss how to make the most effective use of lessons learned from accidents and near-misses, in order to improve accident prevention. The following items will be addressed:

- Learning from accidents/incidents/near-misses – What kind of learning is useful whatever investigation results are available (technical, organisational feedbacks) or not?
- Learning from accidents – What kinds of possible uses: In the near future as a 'questioning' tool and in the continuous process of safety culture? How optimal learning can be gained from finding out about accidents?
- Learning from near-misses, errors and failures – There are more near-misses than accidents. How to get them reported? What are the reasons for lack of reporting? How optimal learning can be gained from finding out about near-misses?
- Learning from near-misses *versus* learning from accidents in terms of useful and usable information;
- Usefulness and availability of global analyses – Review of different methods to analyse events or groups of events; a tool to complete the 'state of the art' (e.g. for a given activity); and the exchange of analyses (what channels, what does it exist?); and
- Learning from near-misses *versus* learning from accidents in terms of cost: What is at stake? Problems of resources *versus* on-site and off-site safety, image of the company, compliance with regulations, etc.

Clearly, the "most effective use of lessons learned" is the prevention of future accidents. Therefore, we will slightly reframe the main question posed in Session IV as follows:

How can we most effectively make use of lessons learned from accidents and near misses to reduce the occurrence of chemical process accidents?

The authors will review the following propositions (a), (b) and (c) to illustrate some of the current thinking that can help us address the issues raised in Session IV.

(a) The proximate cause of the large majority of facility chemical process incidents could have been addressed IF lessons learned already known or available to the facility, were effectively implemented.

(b) Inadequate process safety management systems are the root cause of the failure to use lessons already learned to address the proximate events leading to incidents.

(c) An effective near miss program's largest potential contribution to the prevention of process accidents comes from the increased attention it brings to the other aspects of a good process safety management system such as:

- Maintenance of training: maintenance, management of change, etc.;
- Increased attention to conventional sources of lessons learned; and
- Improved, more timely, updates of process safety management systems.

Discussion of proposition (a)

The proximate cause of the large majority of facility chemical process incidents could have been addressed IF lessons learned already known or available to the facility were effectively implemented

There is substantial evidence from accident investigations that most chemical process accidents occur in spite of the fact that the information and knowledge (i.e., general and specific lessons learned) needed to prevent such accidents were known or were available[35] within the firm.

A widely quoted remark by Kletz[36] notes:

> "In my own subject of loss prevention and process safety, the majority of accidents have well known causes. Occasionally an accident occurred because no one realized that A and B mixed together will react violently under certain conditions but such accidents are exceptions (and even here it is well established that tests should be carried out). Most accidents are very similar to accidents that have happened before as the following examples show…
>
> It might seem to an outsider that accidents occur because we don't know how to prevent them. In fact, they occur because we do not use the knowledge available."

Kirchsteiger[37] and many others have made similar observations.

Based on his analysis of the accidents notified to MARS, Drogaris[38] extends Kletz's observation from the "majority of accidents" to "the vast majority of accidents" and states:

> "The vast majority of accidents notified (over 95% of the accidents in which the causes are known) could have been foreseen early and consequently prevented by the proper application of existing experience and <u>disseminated</u> knowledge."

Belke[39] in his review of several U.S. EPA investigations of process accident cases among leading manufacturing firms comes to conclusions similar to those drawn in the CSB cases:

> "At Bhopal, India, smaller accidents had occurred at the plant prior to the disastrous methyl isocyanate (MIC) release in 1984, and small MIC leaks had been noted on numerous previous occasions highlighting the need for automatic MIC leak detection. In fact, workers stated that experiencing eye irritation (a symptom associated with low levels of airborne MIC) was not an unusual phenomenon, but these warnings went unheeded.
>
> The same type of warnings existed in several of the recent accidents investigated by EPA and OSHA. Prior to the accident at Georgia Pacific (1997), the facility had recently experienced a near miss involving similar circumstances to those resulting in the later accident. An operator added chemicals to a batch resin process at too high a rate. Other alert operators noted the procedural deviation, and were able to prevent an accident. The company investigated the incident and disciplined the first operator. No other actions were taken. In the case of Shell, the company had

experienced mechanical integrity problems involving the same type of check valve on at least four earlier occasions at Deer Park and other Shell plants. One of these events involved a serious flammable gas leak at a facility in Saudi Arabia. Fortunately, the gas never ignited. The plant which experienced the earlier incident conducted an investigation, but the recommendations which might have prevented the later accident at Deer Park were never implemented there (1997). At Tosco, operators had experienced hydro-cracker temperature excursions on several previous occasions, but were able to bring process temperatures back into normal operating ranges without shutting down the unit (the standard procedure) or suffering adverse consequences. Other process upsets had been investigated, but lessons learned were generally not incorporated into operating practice."

Discussion of proposition (b)

Inadequate process safety management systems are the root cause of the failure to use lessons already learned to address the proximate events leading to incidents

The 2nd proposition regarding process accident causation put forward at the beginning of this section maintains that there is also a general agreement (consensus) regarding proposition b.

In a recent article Smullen[40] noted that which has been repeatedly reported in the literature:

"The goal of every incident investigation process is to get to root cause. Most processes recognize that there are usually multiple causes to any incident. Terms like initial, immediate or primary cause can complicate the search for root cause. For this process we defined root causes as those causes that when controlled will achieve permanent change. We observed as others had, that control will almost always require some change in the management system." (Emphasis added)

Quadri[41] sums up the findings of an investigation of a refinery accident as follows:

"The most part of the lessons to be learned are leading rather to managerial features, than to physical or more direct causes. "

In Italy a specific approach has been developed and applied to perform the analysis of accidents with the main objective to identify deficiencies in the Safety Management System (SMS), that can be connected to the accident itself or anyhow shown related, by events and circumstances, to the accident"

An analysis of "Lessons Learned from Accidents Notified to MARS Accident Reporting System"[42] also identifies safety management system deficiencies as the major root cause of the accidents reported:

"Managerial and/or organizational omissions (in any one of the following types: lack of safety culture, inadequate safety organization, pre-determined safety procedures not observed, insufficient or unclear procedures, insufficient training and/or supervision, negligence in clarifying the causes of previous accidents, etc.) account for the causative factors for about 90% of the accidents of which the causes are known."

The Chemical Safety Board (CSB) accident investigation reports[43] almost invariably show Process Management System inadequacies as the root cause of the preponderance of the cases they have investigated.

The CSB report on the April 8, 1998 Morton runaway reaction in Paterson, NJ, USA is a good example of the Board's repeated findings on accident causation in the cases it has investigated. In this case the CSB report noted that during development of a new dye product Morton had done a study of potential reactivity problems, had concluded that there was a significant likelihood of a runaway reaction during synthesis of the product and had recommended approaches for mitigating such problems.

The Board in essence found that the facility's process safety management process did not ensure that safety lessons learned during development work and initial commercial production were effectively implemented into production operations. Some of the specific findings were:

- "The Paterson facility was not aware of the decomposition reaction. The Process Safety Information (PSI) package, which was used at the Paterson plant to design the Yellow 96 production process in 1990 and which served as the basis for a Process Hazard Analysis (PHA) conducted in 1995, noted the desired exothermic reaction, but did not include information on the decomposition reaction." However, as the Report shows, other Morton chemical units did have information that the decomposition reaction was potentially very hazardous.

- "Morton did not follow up on two recommendations made by its researchers in 1989: (1) to conduct additional reactive chemical laboratory tests to determine 'the rate of reaction under the worst reaction conditions ... the rate of decomposition of the finished product ... [and] pressure rise data which could be used to size emergency venting equipment ...'; and (2) to install specific control and safety devices on the Yellow 96 production vessels such as an emergency shutdown system."

- "In 1996, Morton transferred the Yellow 96 process from 1000-gallon to 2000-gallon kettles and increased the amount of raw materials used per batch by approximately 9 percent without using their existing Management of Change procedures. Morton did not assess the effects of these changes. While 20 percent of the 25 batches of Yellow 96 made before these changes exhibited [out of specification, (author note)] temperature excursions, half of the 6 batches made after the changes had temperature excursions."

- "Morton also did not effectively implement the requirements of its internal PSM program. The PHA conducted for the process and the operating procedures (batch sheets) did not address the consequences of potential deviations such as excessive heating, a runaway reaction, or the inability to provide enough cooling to maintain temperatures in a safe operating range. Batch sheets did not list the actions operators should take to correct or avoid deviations. Operators' reports of significant deviations in controlling batch temperature were not acted on by management. "

Examination of this case and almost all of the other Board's accident reports shows that the root cause of most of the chemical process safety accidents it investigated resulted from the failure by facility process safety management systems to adequately implement lessons learned by or available to the facility.

Finally, Beard[44] in his analysis of the literature dealing with offshore fire safety management systems also essentially concludes that inadequate process safety management systems are the root cause of most "catastrophic" accidents.

Given that the majority of process accidents could have been prevented by implementing lessons learned known or available in the facility, this paper's proposition that inadequate process safety management systems are the root cause of the failure to use lessons already learned to address the proximate events leading to incidents appears to be valid.

Discussion of proposition (c)

An effective near miss program's largest potential contribution to the prevention of process accidents comes from the increased attention it brings to the other aspects of a good process safety management system such as:

- Maintenance of training; maintenance, management of change, etc
- Increased attention to conventional sources of lessons learned; and
- Improved, more timely, updates of process safety management systems.

The largest contribution of a near miss program to the prevention of process accidents comes from the increased attention to the conventional aspects of a process safety management system.

As has already been argued:

- Lessons learned already known or available to facilities would have addressed the proximate causes of the large majority of process accidents.

- Inadequate process management systems are the root cause of the large majority of process accidents.

Given acceptance of these findings, it will be of great interest to hear what the workshop participants have to say on whether near-miss programs are effective for that purpose and if so, why. Indeed, near miss programs are receiving more and more attention in Industry[45] and government[46]. The authors and most practitioners[47] believe that organizations that have near miss programs have a lower than average risk of a process accident. However, there is very little hard data to support this belief.

What do we presume to be the main contributions of a near miss program to accident prevention? Superficially, the value of generating more lessons learned through near miss systems may be very little since it appears that the large majority of chemical process accidents could have been prevented by application of existing lessons learned from previous accidents and it is unlikely that there will be a sudden, large influx of new technology and practices leading to accidents caused by factors on which lessons have not already been learned.

The authors believe that the largest benefit of successful near miss systems is increased employee and management attention to lessons learned already known or available to facilities rather than the discovery of new lessons about failure modes. Those systems contribute also to keeping safety management processes on the agenda.

Given the continuous stream of normal business crises that employees and managers face daily, the threat of a major process accident seems relatively low. Belke[48] notes that:

> "From the perspective of the individual facility manager, catastrophic events are so rare that they may appear to be essentially impossible, and the circumstances and causes of an accident at a distant facility in a different industry sector may seem irrelevant."

This increased attention is generated by the increased time the firm's top managers must give to facility managers and employees in order for them to become aware of the possible consequences, prevention, and mitigation measures associated with accidents that Near Misses show could occur. This same increased attention will also cause employees and managers to read and pay more attention to externally generated lessons learned. This increased attention at the facility level will also, in turn, feed back to top management and tend to keep their attention higher than it might be absent such feedback.

Going further up the chain, this increased attention is a manifestation of a strong safety culture within the firm. A strong safety culture is a necessary but not sufficient condition for an effective process safety management system, and a functional Near Miss Program is evidence that management has the commitment and knowledge needed to translate the firm's culture to effective practice.

Some Observations on the Similarities Between Management Practices for Controlling Process Accidents and Quality Defects

There are numerous experts that hold that the process accidents are in essence quality defects and that the observation by Shewhart[49] that "85% of the quality variations in a system under control arise from common causes that can only be corrected by management" also applies to preventing process accidents.

Olsen,[50] a manager of process safety at Exxon chemical noted that:

> "Whether you follow the precepts of ISO 9000, TQM, or Malcom Baldridge – Whether your 'guru" is Deming, or Crosby, or Peters or Ishikawa or a personnel saint, there is no doubt Quality and process safety have much in common."

Adams[51] notes that the Management Oversight Risk Tree (MORT) system, developed by Johnson[52] for the United States Atomic Energy Commission and widely used in the chemical industry, postulates that risk losses (accidents) are caused either by: Management system factors; Risks that management consciously assumed.

These postulates are fully congruent with Shewhart's findings on system variations which are:

- Variation is normal in every system.
- The causes of variation lie either within the system (common causes) or outside the system (special causes).
- When a system under statistical control (performing consistently within its upper and lower limits) is left untouched, the variations that occur are due to common causes.
- Common causes arise out of the characteristics of the system which are largely determined by management and <u>can only be corrected by management action to improve the system</u> (emphasis added).
- In systems that are operating fairly smoothly, 85% or more of the variations that occur are due to common causes and 15% or less are due to special causes.

There is one principle embodied in MORT theory and TQM systems that is particularly pertinent to accidents that might have been prevented if a lesson learned somewhere in a facility had been functionally embodied in the facility's process safety management plan. This principle[53] is: "A risk that is unidentified is judged to be a management oversight or omission, just as an identified risk that is not acted on."

Session V – Communication and Implementation of Lessons Learned

Session V will address: Communication and implementation of lessons learned – How do we ensure that all the data being gathered are transformed to effective learning?

This session will discuss how to ensure that all the data being gathered are transferred to different stakeholders in a manner that:

- Effectively communicates the technical lessons learned;
- Identifies management system and human factor inadequacies that may have contributed to the accident;
- Addresses different stakeholders' needs and desires for information (authorities, industry management, operators, the public, etc.); and
- Is likely to motivate different stakeholders to modify behaviours and system factors that might contribute to similar accidents.

The authors feel that it is of value to examine the four sub-questions posed for discussion in this session before we attempt to address the main question we propose to discuss: How do we ensure that all the data being gathered are transformed to effective learning?

The first question on effective communication of technical lessons learned appears to be simple and straightforward unless you ponder the meaning of "effectively". The dictionary gives the first meaning of "effectively" as: "well, in a way that produces a desired result"

For those of us at this workshop the "desired result" is to provide employees and facility managers with information on accident causes and to motivate them to use it to prevent other accidents. In this sense, the 1^{st} question is essentially encompassed in the 4^{th} question.

The second question on fashioning lessons learned in a manner that identifies management system and human factor inadequacies[j] that may have contributed to the accident has been addressed in earlier sections of the DD

The accident investigation and lessons learned literature not only "identify management systems inadequacies that are the cause of the very large majority of process accidents but it also teaches how one might address such inadequacies."[54] The problem once again is not knowledge *per se* but attention to the knowledge and motivation to solve the problem, again a problem that is encompassed in the 4^{th} discussion question.

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[j] The authors believe that the inclusion of the phrase "human factor inadequacies" in a manner that identifies management system and human factor inadequacies is misleading. Separating out "human factor inadequacies" from maintenance, management of change or all the other inadequacies that may have contributed to the accident implies that human factors are different in kind from all of the other considerations that must be taken into account in adequately managing process safety. An adequate management system ensures that the design and operation of the system take the reliability and failure characteristics of employees into consideration just as it does in regard to pumps and relief devices. Humans have a high failure rate under many conditions and a good management system takes this into consideration. As an example, the military services require that critical commands be repeated back.

The third question in addressing different stakeholders' needs and desires for information (authorities, industry management, operators, the public, etc.) has also been partially addressed in Session III

As the reports on the Longford accident[55] show, different stakeholders often learn very different lessons from the same lesson. It is often the case that what is judged to be needed information or the import of the lesson learned by some stakeholder groups, (e.g., labour unions, public interest groups) differs significantly from that of other stakeholder groups (e.g., trade associations, public authorities). This is particularly true in regard to the import of lessons that deal with other than technical causation factors, (e.g. inadequate training vs. human error vs. poor design vs. inadequate manpower resources vs. inadequate regulations, etc.)

It will be interesting to hear how the Workshop participants address this issue of meeting different stakeholders' needs and desires for information. Should we attempt to obtain consensus on the import of lessons learned? The authors believe this will be difficult at best for the reasons stated above and they lean toward encouraging different stakeholder groups to engage in producing separate interpretations of what they believe is the correct import of those lessons learned that they deem to be important. Stakeholders can and should cooperate on a common effort to ensure convenient access to these varied reports by all stakeholders.

This leaves us with the 4th question: How to ensure that all the data being gathered are transferred to different stakeholders in a manner that is likely to motivate different stakeholders to modify behaviours and system factors that might contribute to similar accidents?

Question 4 in essence asks us to how can we address and ensure the completion of three tasks:

- Gathering of all data (lessons learned);
- Transference of gathered data to different stakeholders; and
- Ensuring that "the data gathered from incidents" is framed and transferred in a manner that is "likely to motivate different stakeholders to modify behaviours and system factors that might contribute to similar accidents."

The first two tasks are simple in theory. It has been shown that most process accidents are largely repeats that would likely have been prevented by implementation of previous lessons learned already exists[k]. Though it presents difficult challenges, there are no insurmountable problems to collecting, translating, editing and assembling the data and lessons learned in a system that is reasonably accessible and understandable by most practitioners (web sites, books and libraries).

Research on a number of different approaches to improved systems for extracting lessons learned from accident reports has been going on for some time[56,57]. The addresses of practitioners and firms can be obtained from trade associations, professional societies, trade unions, etc and the information itself or access to the information made available.

[k] This observation is not made to downgrade the importance of continuing to gather and distribute new lessons learned. Development of new equipment, new processes and process control instrumentation leads to new failure modes. The lessons on such failure modes need to be learned and disseminated and approaches for addressing them also need to be distributed as lessons to be learned.

Without making light of the problem one could say all it takes is money. There are a number of universities and institutions such as IchemE, CCPS, ESReDA, BARPI, MARS, NIOSH, etc., which already have systems that attempt to deal with collecting and disseminating lessons learned and some these efforts will be described in the papers being presented in this workshop. The authors believe that these identified organizations and many others would enjoy the challenge of gathering all lessons learned within a system that provides for more convenient searching and providing access to different stakeholders, given funding.

It is the third issue, "motivating different stakeholders to modify behaviours and system factors that might contribute to similar accidents" that presents the greatest problem. This requires first attracting practitioner attention[l] to LP-HC risks and as we already have discussed, attention is a very scarce resource. There are innumerable references to the continual pressure on firms and practitioners to focus their attention on what appears to be a host of increasing problems such as: product cost, product quality, plant environmental emissions, personnel health and safety hazards, just in time deliveries and shipments, the ecological impact of product use and disposal (green chemistry), and now terrorism, among other things.

This continuing increase in pressure and competition for attention to different social, economic and physical hazards is inherent in the competitive economic system that we have chosen because of the many benefits it yields. Most managers and employees have more "must do tasks" then they can execute well and are often operating at their boundary (satisficing[m]). Marcus[58] shows how various social and economic pressures affected both the way a group of nuclear energy firms managed their process risks and the degree to which they drifted to the edge of catastrophic accident risk.

Individual stakeholder groups can influence the relative attention that is placed by firms on solving these different problems. OECD is now debating what is in essence how much attention should be placed on process safety *versus* other manmade and natural hazards and how such attention can be obtained. It would be most interesting to collect input on how the members of this workshop feel about how we should distribute our resources on the various “Emerging Risks” that OECD countries are wrestling with.

The challenge for participants in this workshop is to devise and propose solutions for improving process safety through use of the lessons learned tool and new technology that offers more perceived benefits to society per unit cost than alternative ways of improving social well being. This is slow and often frustrating work similar to the task Sisyphus[59] faced. However, the authors are optimistic and believe that new software and hardware tools will be developed that will allow more cost effective achievement of the process safety goals then exist today. When further significant progress on such measures has been made, our society will take steps to ensure that firms who do not employ such measures are not allowed simply to continue in business until a major accident occurs.

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l Attention: the biological, emotional, cognitive, or social forces that activate and direct behavior (Encarta Dictionary).

m "Satisficing: the principle that in most cases people and organizations seek to obtain a satisfactory solution, not necessarily the optimum one".

Session VI – General Discussion – Conclusions and Recommendations

Session VI will consist of:

- Summary of Workshop conclusions and recommendations by appointed rapporteurs;
- Discussion of proposed conclusions and recommendations concerning "best practices"; and
- Identification of issues that should be further explored in a national or international context.

This discussion document will conclude by attempting to stimulate discussion during Session VI, by putting forward for your consideration the following four actions aimed at obtaining more preventative value from the lessons learned tool:

1. Shift priority from generating new lessons and emphasize improving the dissemination of such lessons and implementation of measures responsive to lessons already learned.

2. Mount a collective effort to develop and make widely available comprehensive, open, user friendly, lessons learned databases that facilitate identification of lessons in terms of unit operation and/or class of chemicals involved.

3. Fashion measures that result in strengthening institutional memory by integrating lessons learned safety measures into facility process safety management systems in addition to relying on employee memory.

4. Develop model "carrot and stick incentives" that private bodies (insurance, chemical and labour associations) in addition to regulatory agencies could use to motivate facility identification of pertinent lessons already learned and the subsequent integration of any new safety measures needed to cope with such lessons into their process safety management systems.

Each Workshop participant is challenged to come forward with their <u>own list of actions</u> aimed at the common problem we believe needs to be better addressed:

Ensuring that the data gathered from incidents as lessons learned are framed and transferred in a manner that is "likely to motivate different stakeholders to modify behaviours and system factors that might contribute to similar accidents".

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The following definitions are included in the Guiding Principles:
Incident: "accident and/or near-miss"
Accident: "any unplanned, sudden event which causes or is liable to cause injury to people or damage to buildings, plant, material or the environment"
Near-miss: "any unplanned, sudden event which, but for the mitigation effects of safety systems or procedures, could have caused serious injury to people or serious damage to buildings, plant, material or the environment or could have involved a loss of containment possibly giving rise to significant adverse effects"

11 OECD Guidance on Safety Performance Indicators (Interim Publication scheduled to be tested in 2003–2004)
Accident or chemical accident: Any unplanned event involving hazardous substances that causes, or is liable to cause, harm to health, the environment, or property. This excludes any long-term events (such as chronic pollution).

Near-miss: Any unplanned event which, but for the mitigation effects of safety systems or procedures, could have caused harm to health, the environment or property, or could have involved a loss of containment possibly giving rise to adverse effects involving hazardous substances.

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24 Real-Time Safety Metrics and Risk-Based Operations," Robin Pitblado, DNV Proceedings of 2004 Prague IChemE.

25 Major Accident Prevention Policy in the European Union: The Major Accident Hazards Bureau (MAHB) and the Seveso II Directive, Stuart Duffield, Hazards XVII Symposium Manchester, UK, 25–27 March 2003 pp, 1-13.

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The purpose of the CSB's investigation of incidents is to prevent future similar events. This mission must be accomplished through persuasion and teaching; the CSB has no enforcement powers. CSB Investigations must therefore generate findings and recommendations that persuade and/or teach responsible parties to alter behaviors, designs, operations, or practices that could lead to similar or related incidents. CSB recommendations may be issued to firms, equipment suppliers, contractors, insurance companies, local authorities, trade associations, or unions as well as regulatory agencies. The U.S. Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) must inform the CSB how they plan to respond to CSB recommendations. Other stakeholders have no such obligation.

The ability to persuade and/or teach effectively depends on a number of factors:

- How well the CSB develops and presents its findings and recommendations.
- How seriously the affected stakeholders view the incident in question.
- The extent to which responsible parties and pertinent regulatory agencies adopt CSB recommendations and other measures to prevent similar incidents.

In selecting the incidents it will investigate, the CSB also needs to consider human, environmental and financial losses that would be avoided by prevention of similar future incidents. The magnitude of such avoidable losses depends on two factors:

- The consequences associated with this type of incident.
- How many facilities could potentially have a similar incident.

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ANNEX 2

Workshop on Lessons Learned From Chemical Accidents and Incidents

21 – 23 September 2004, Karlskoga, Sweden

AGENDA

Tuesday 21 September 2004

8:00 – 8:15 REGISTRATION
Distribution of badges

8:15 – 9:00 OPENING SESSION
Welcome and Introduction

Welcoming addresses

Host country:	***Thomas Gell,*** *SRSA, Sweden*

Introduction

Workshop Chair	***Ulf Bjurman****, SRSA, Sweden* Workshop Objectives
OECD Secretariat	***Marie-Chantal Huet****, OECD Secretariat* Workshop Agenda

9:00 – 9:45 SESSION I
Setting the scene – Discussion Document
Description of the themes addressed in the following sessions - Presentation of the main issues to discuss – Terminology

Author of DD	***Irv Rosenthal,*** Wharton Centre, USA

9:45 – 10:15 BREAK

10:15 – 11:45 SESSION II – 1st block
Data sources on accidents and incidents
Relevance of data sources for measuring the output of the safety work in the field of chemical accidents

Session Chairs: ***Ghislaine Guimont****, BARPI, France*
John Shrives*, Environment Canada, Canada*

This session will address the adequacy of existing data bases and the value of data sources as an effective tool in guiding and measuring the prevention of accidents: What additional data we would like to have in order to maximize the effectiveness of the prevention measures resulting from accident investigation, and inform improved industry practices and government regulation. The following items will be dealt with:

- Overview of data sources relevant for the field of chemical process accidents and examination of the problem of compatibility of information from such different data sources;
- What systems exist for exchanging data between different organisations (e.g. industry, trade-unions, administration/authorities), and between countries with respect to the root causes and lessons learned from accidents and incidents – What could be done to improve the quality, breadth and availability of accident data?
- What types of data bases: are needed for different uses and needs – Review of examples of data bases developed by and for different stakeholders (e.g. industry, authorities, employees, etc.) and what are the barriers in communicating different types of accident data to different stakeholders?
- Data mining – Review of the different methods: qualitative approach based on analysis of a sample of accidents in specific activity/device/process; quantitative approach based on statistics; and other methods, e.g. modelling;
- Is data available that would allow one to evaluate whether the incidence rate and the losses from major accidental releases in various countries or industry segments has increased or decreased over the last 20 years or to correlate incidence rates with the various approaches used in different industries and countries to prevent chemical process accidents? and
- What presently unavailable data is vitally needed and how might such needs be met?

Michiel Goethals*, Federal Public Service Employment, Belgium*
Using lessons learnt from accidents – The Belgian practice

François Fontaine*, INERIS, France*
Using lessons learned from accidents in emergency support

Sabine Sur*,* ***Hans-Joachim Uth****, Federal Environmental Agency, Germany*
Major accidents in the Federal Republic of Germany: Central collecting, evaluating and disseminating of lessons learned

DISCUSSION

11:45 – 13:00 LUNCH

13:00 – 14:30 SESSION II (end) – 2nd block
Data sources on accidents and incidents

Irv Rosenthal*, Wharton Center, USA*
Trends in US chemical industry accidents

Fesil Mushtaq*,* ***Michalis Christou****, EC, Joint Research Centre, Italy*
The European community's major accident reporting system: Status, analysis and lessons learnt

Fesil Mushtaq, Ana Lisa Arellano, *EC-JRC, Italy*
The European community's lessons learnt and information exchange systems for management of technological and natural disasters: Lessons learnt from MARS and NIDIES

DISCUSSION

14:30 – 16:00 SESSION III – 1st block
Investigation of accidents and incidents
How do we gain optimal output from investigation of accidents/incidents with respect to both lessons learned and the dissemination of such lessons?

Session Chairs: ***Michalis Christou****, EC-JRC, Italy*
Craig Matthiessen*, EPA, US*
Ake Persson*, SRSA, Sweden*

This session will discuss how optimal output is/can be gained from investigations of accidents/incidents with respect to factors such as:

- Decreasing the incidence and losses associated with all process accidents;
- Acquisition of information about root causes and previously unknown technical factors leading to the likelihood of accidents;
- Deficiencies in management systems, equipment and human factors associated with accident causation;
- Addressing public anxiety and concerns;
- Improving level of compliance with institutional (government or commercial) safety requirements;
- Improvements in the investigatory scope and protocol; and
- Effective allocation of time, energy and resources.

The following issues will also be addressed:

- Criteria for selecting those accidents/incidents for in-depth investigation which will maximize specified goals such as, prevention, deterrence, compliance with regulations or lessons learned, and examples of the types of accidents that might be selected based on the use of such criteria; and
- Problems related to investigation: What factors make the investigation difficult?

Samantha Lim, *INERIS, France*
Global approach to integrate organisational aspects into learning from experience

Patrizia Agnello*, ISPESL, Italy*
Analysis of the main sequences of accidental events involving major hazard establishments occurred in Italy since 1996: Analysis of scenarios in connection with the plant types and lessons learnt

Eveline Van Der Stegen*, Ministry of Social Affairs, The Netherlands*
Analysis of the unexpected rise of major loss of containment incidents in the 'Netherlands

DISCUSSION

16:00 – 16:30 BREAK

16:30 – 18:00 SESSION III (continued) – 2nd block
Investigation of accidents and incidents

John Kingston*, NRI, Netherlands*
The contribution of ECFA+ (Events and conditional Factors Analysis) to investigating and learning from incidents

Colin Ramsay*, SEISS, Scotland, UK*
Chemical Incident Surveillance in Scotland – sharing the lessons learned

Neil Rothwell*, HSE, UK*
Using the lessons learned from chemical accident investigations to inform the regulator's interventions

DISCUSSION

18:00	End of day 1

Wednesday 22 September 2004

8:00 – 9:30 SESSION III (end) – 3rd block
Investigation of accidents and incidents

***Elisabeth Miles**, Johnson & Johnson, US;* ***Kris Ghoos**, Janssen Pharmaceutica, Belgium*
$DMAI^2C$ (Define, Measure, Analyze, Innovative Improvement and Control): Designing an incident reporting and investigation system using process excellence

***Gerald Poje**, US Chemical Safety Board*
Learning through investigations twenty years after Bhopal

***Bert Zandvoort**, Dow Chemical, The Netherlands*
Dow's learning experience report (LER) work process

DISCUSSION

9:30 – 10:00 BREAK

10:00 – 12:15 SESSION IV – 1st block
Lessons learned from accidents and near-misses
How can we make the most effective use of lessons learned from incidents (accidents and/or near-misses)

Session Chairs: ***Neil Rothwell**, HSE, UK*
***Christer Lundberg**, SRSA, Sweden*

This session will discuss how to make the most effective use of lessons learned from accidents and near-misses, in order to improve accident prevention. The following items will be addressed:

- Learning from accidents/incidents/near-misses – What kind of learning is useful whatever investigation results are available (technical, organisational feedbacks) or not?
- Learning from accidents – What kinds of possible uses: In the near future as a 'questioning' tool and in the continuous process of safety culture? How optimal learning can be gained from finding out about accidents?
- Learning from near-misses, errors and failures – There are more near-misses than accidents. How to get them reported? What are the reasons for lack of reporting? How optimal learning can be gained from finding out about near-misses?
- Learning from near-misses *versus* learning from accidents in terms of useful and usable information;
- Usefulness and availability of global analyses – Review of different methods to analyse events or groups of events; a tool to complete the 'state of the art' (e.g. for a given activity); and the exchange of analyses (what channels, what does it exist?); and
- Learning from near-misses *versus* learning from accidents in terms of cost: What is at stake? Problems of resources *versus* on-site and off-site safety, image of the company, compliance with regulations, etc.

***Ghislaine Guimont**, BARPI, France*
Lessons learned/Experience feedback – The French experience

***Christian Balke**, BAM, Germany*
Collecting and evaluating of near-misses-events and non-notifiable accidents

***Patrizia Agnello**, ISPESL, Italy*
Reports of incidents and near-misses: Analysis and gathered knowledge to improve accident prevention

***Gunnar Erlandsson**, Cambrex, Sweden*
A thermal explosion 1992 gave birth to a deeply rooted safety culture

DISCUSSION

12:15 – 13:30 LUNCH

13:30 – 15:30 SESSION IV (end) – 2nd block
Lessons learned from accidents and near-misses

***Sandra Gadd**, Health & Safety Laboratory, UK*
Principles for learning lessons from incidents – A UK perspective

***Sam Mannan**, Mary Kay O'Connor Centre, University of Texas, USA*
Use of incident data collection from various sources for industrial safety performance assessments

***Asa Scott Andersson**, Defence Research Agency, Sweden*
Lessons learned from chemical accidents causing environmental damage – A user's perspective

***John Shrives**,Environment Canada, Canada*
The application of Process-Related Incidents Measure (PRIM) in Canada's chemical industry

***Alain Pierrat**, Union des Industries Chimiques (UIC), France*
Lessons learned/Experience feedback – The UIC Reporting System

DISCUSSION

15:30 – 16:00 BREAK

16:00 – 18:00 SESSION V – 1st block
Communication and implementation of lessons learned
How de we ensure that the collected data are transformed to effective learning?

Session Chairs ***Jean-Paul Lacoursière****, Sherbrooke University, Canada*
Hans-Joachim Uth*, UBA, Germany*

This session will discuss how to ensure that all the data being gathered are transferred to different stakeholders in a manner that:

- Effectively communicates the technical lessons learned;
- Identifies management system and human factor inadequacies that may have contributed to the accident;
- Addresses different stakeholders' needs and desires for information (authorities, industry management, operators, the public, etc.); and
- Is likely to motivate different stakeholders to modify behaviours and system factors that might contribute to similar accidents.

Anders Jacobsson*, AJ risk Engineering AB, Sweden*
Why is it so hard to learn the full lessons from incidents?

Robin Turney*, IChemE, UK*
Experience in communicating the lessons learned from accidents

Irv Rosenthal*, Wharton Center, USA*
An approach for converting major accident investigations into prevention

Frank Crawley*, University of Strathclyde, UK*
Learning from past accidents

DISCUSSION

18:00	End of day 2

Thursday 23 September 2004

9:00 – 10:30 SESSION V (end) – 2nd block
Communication and implementation of lessons learned

***Richard Gowland**, EPSC-IChemE, UK*
Root cause analysis – How to communicate and make best use of the results?

***Kersten Gutschmidt**, WHO-IPCS, Switzerland*
Lessons learned from WHO/IPCS responses to chemical incidents of international public health concern

***Inge Svedung**, Karlstad University, Sweden*
Feedback for pro-activity – Who should learn what from events, when and how

***Cesar Antonio Leal**, UFRGS, Brazil*
A Brazilian experience of lessons learned: Major oil spill as a turning point

DISCUSSION

10:30 – 11:30 BREAK

11:30 – 14:00 SESSION VI
Conclusions and Recommendations – General Discussion

Workshop Chair: ***Ulf Bjurman**, SRSA Sweden*

Workshop Rapporteurs: ***Wayne Bissett**, DW Bissett Consulting, Canada*
***Thomas Gell,** SRSA, Sweden*
***Marie-Chantal Huet**, OECD Secretariat*

During this session, the rapporteurs will present draft conclusions and recommendations, which will:

- Summarise the main Workshop discussion issues;
- Present recommendations concerning "best practices"; and
- Identify issues that should be further explored in a national or international context.

14:00 End of Workshop

ANNEX 3

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21-23 September 2004, Karlskoga, Sweden

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