

LEARNING THE LESSONS FROM PAST ACCIDENTS

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The chemical industry as a whole does not learn from past accidents. The problem is that information may not be widely disseminated throughout the industry. Efforts to change this situation have been made over recent years. Most recently, computer databases of past incidents have been created so that appropriate information can be retrieved quickly. However, these databases are not ideal when it comes to information retrieval. The main problem is that crucial concepts underlying the causes of accidents may be missed when accident reports are indexed. Conventional indexing uses keywords and possibly some form of free text search. The intention of this paper is to show how, by using case based reasoning, retrieval of relevant lessons from past accidents could be improved. This paper also looks at how such a system might be integrated with computer tools used by chemical plant designers and operators, such as computer aided design (CAD) systems and digital control systems.

Keywords: Incident database, safety, accidents, lessons learned, case based reasoning.

INTRODUCTION

It is widely recognised that the chemical industry as a whole does not learn from past accidents. Mistakes in design and operation are repeated and similar accidents recur (Ward (1), Kletz (2)). This failure to learn from past incidents is not deliberate on the part of designers or operators, rather they "do not know what they do not know". Indeed, so many things can go wrong with a process plant that a designer or operator can hardly be fully aware of them all. Of course hazard identification techniques exist, most notably HAZOP (CIA (3), Lees (4)), whereby groups of people will attempt to collectively identify hazards overlooked by individual designers and those that may exist for the unwary operator. However, given that these hazard identification groups are likely to be from the same company, they may not be aware of incidents that have occurred in other companies and so accidents can still recur. The problem that the industry as a whole must address is the dissemination of information on past accidents and even near misses in such a form that it can be easily recalled so that the lessons are not forgotten. Although the individuals concerned and, to some extent, their companies will learn the lessons from accidents, these lessons cannot be learned by the industry as a whole unless the information is made widely available.

Efforts to remedy this situation have been made over the years. However, there is often some unwillingness in some companies to release any data about accidents. Perhaps it is arguable whether or not they should release such data. Not to release such data may give them a competitive advantage over other companies and does not endanger their reputation. One way around this is the anonymous reporting of incidents. One useful publication for the reporting of accidents, sometimes anonymously, is the IChemE publication, "The Loss Prevention Bulletin".

The increase in the number of incidents reported has led to the creation of computer databases so that appropriate information can be retrieved quickly. Again the IChemE has made a valuable contribution through INDEX. The IChemE are planning to release a much improved accident database shortly. This will contain details of accidents that have hitherto remained confidential (IChemE (5)). Other databases include the Major Hazards Incidents Database Service (MHIDAS) from the Safety and Reliability Directorate (SRD) of AEA Technology (UK), the Failure and Accident Technical Information Service (FACTS) of TNO (The Netherlands), and CHEMAX (Haastrup et al. (6)) from the European Commission Joint Research Centre (ISPRA).

This paper describes work being done as part of a project aiming to take deliberate steps to draw designers' and operators' attention to what they do not know, or have forgotten, or may otherwise fail to recognise as important. The starting point for the project is the premise that through the application of lessons from past incidents to the design and operation of chemical plants, many potentially hazardous situations can be avoided in the future. This is being achieved by the integration of past incident data into process plant design tools, control systems and automated permit to work systems and by the development of an intelligent incident retrieval mechanism to draw designers' and operators' attention only to the most appropriate cases. This paper looks at how an integrated incident retrieval system might perform compared with conventional databases and on the work required to develop an intelligent incident retrieval mechanism.

DATABASE INTEGRATION

Existing incident databases are on the whole provided as stand alone computer programmes and the user must seek out information about incidents working with whatever keywords he feels appropriate. One of the objectives of this project is to integrate an incident database with other appropriate computer tools. Thus the incident information will be made available in two ways. Firstly, it will be made available passively, as in conventional database systems, by responding to specific user queries. Alternatively, to provide better information retrieval, it will also be made available pro-actively, with the program presenting the user with appropriate data which has been automatically retrieved, ranked and filtered in response to the context in which the user is working. HAZOP teams in particular are expected to make significant use of passive information retrieval. Operators and maintenance personnel are expected to make use only of pro-active information retrieval as they are unlikely to browse through what may turn out to be irrelevant records. The information provided for this latter group must be concise and easily understood if it is to be of value. Designers may make use of both passive and pro-active information retrieval. During initial design, we anticipate designers are more likely to make use of passive retrieval to help in identifying potential problems. At a later, more detailed, stage of design pro-active retrieval will help them avoid past mistakes. [Note: The terms *passive* and *pro-active* refer to the actions of the system, not the users.]

To enable pro-active information retrieval, this system will have to be combined with other appropriate computer tools. For a designer, the database will be linked to a flowsheeting package or CAD system. For maintenance it can be linked to a computerised permit-to-work system and for operators it can be linked to a digital control system. The designer will automatically be presented with case histories according to the equipment and chemicals involved. This should enable him to avoid design flaws and to make the plant safer in the event of operators or maintenance personnel making common mistakes. For the maintenance team, information on past accidents will be made available along with the permit-to-work. Hopefully, this will highlight to them how to carry out the

job safely. For the operator, information will be made available not only in conjunction with alarms but also with operations based on the operating conditions and chemicals involved. Kletz (7) gives an example of how operators might make use of such a system. Below is an example of how the system could be used by maintenance personnel.

Consider for example that a vessel is about to be entered for cleaning having previously been used for storage of a toxic chemical. The following case history may be retrieved (MCA (8)):

A tanker was being cleaned out after being used for storing benzene. The tanker had been boiled out and was now being prepared for entry so that the remaining sludge could be removed. Flammability and oxygen tests had been made and a check made for odour (this incident occurred before benzene's toxicity was fully understood). For two hours a man worked inside the tanker cleaning out sludge prior to a break. Following an hour's break for lunch, cleaning was resumed. Within half an hour, the man inside the tank collapsed unconscious. Benzene trapped in the sludge was released as it was removed.

The following lessons will be highlighted:

At the very least, adequate ventilation should be provided when working in confined spaces to prevent the build up of toxins. Preferably air fed masks should be used.

A frequent analysis should be made of the atmosphere in the vessel to check that there is no build up of flammable or toxic gases and there is sufficient oxygen. Be particularly cautious of sludge and solid deposits as these may release trapped gases if disturbed.

DATABASE INDEXING

The indexing used in conventional accidents databases is far from ideal. There are many trivial problems such as an inability to deal with synonyms and abbreviations. However one of the main problems that needs to be addressed is the capturing of information on the underlying causes of incidents. Crucial concepts underlying the causes of accidents may be missed when accident reports are indexed. Conventional indexing uses keywords and possibly some form of free text search. Kletz (9) gives an example of how naive indexing can lead to lessons from past accidents being missed in the future.

In order to improve the indexing and make sure that the most relevant cases are retrieved and presented in the most appropriate manner a number of key principles have been identified. Firstly, case based reasoning will be used to identify the appropriate incidents. Secondly, the information will be categorised so that only the appropriate personnel are made aware of it. This feature is required simply to ensure that maintenance personnel are only made aware of cases and lessons which are applicable to maintenance problems, etc. Thirdly the retrieval of information will be personalised so that less information is provided on tasks that are carried out frequently by the user than is provided for tasks that are carried out very infrequently.

For example, in the tanker case history outlined above, the need for good ventilation may be so well understood in some organisations that there is no need to remind people of it. However,

the fact that sludges and solid deposits can release trapped gases when disturbed is much less well known.

Case based reasoning uses formalised rules to try to identify and to use information on past cases to provide help with new problems (Kolodner (10)). There are two styles of case based reasoning: problem solving and interpretive (Kolodner (11)). In the problem solving style, solutions to new problems are derived using old solutions as a starting point. In the interpretive style, new situations are evaluated against known situations. This style is used most familiarly in the field of law and it is this style that is to be used in evaluating past incident data. In order to use case based reasoning, a model of the field of interest is required. This domain model provides a framework for the indexing of cases and for the identification and use of past cases which have relevance to new problems. It is anticipated that by concentrating on modelling the underlying concepts rather than simple keywords, case based reasoning will provide a basis for improved accident information retrieval.

Consider, for example, that someone is interested in finding out about accidents involving sulphuric acid. Using a conventional incident database and searching on sulphuric acid, only a very small number of incidents relating specifically to sulphuric acid would be retrieved. If the search term was broadened to just acid, many more incidents would be retrieved. However, some of these would not be applicable either because the fluid involved was not the relevant factor or some other property of the fluid, other than it being acidic, led to the incident. Using appropriate indexing and case based reasoning it should be possible to develop a system that will retrieve those incidents relating specifically to sulphuric acid plus those due to the acidic nature of an acid and not other properties.

INCIDENT RETRIEVAL

Indexing for Retrieval

Work to date has concentrated on the application of case based reasoning to an incident database and a prototype system has been developed. As yet, no attempt has been made to integrate this system with other computer tools. Before any attempt can be made at integration the intelligent retrieval mechanism must be developed so that appropriate incidents can be retrieved using whatever information is supplied by the computer tools. Incidents used in the prototype system are taken from the following references: (MCA (12,13,14,15), Kletz (16), Lees (17), IChemE (18)). A brief review of these sources of past incident data is given in appendix 1.

Firstly, the fields required for indexing the incidents were determined. The main fields used are:

1. Category
2. Operation
3. Equipment
4. Specific chemical
5. Chemical family
6. Chemical property
7. Lessons learned
8. Description
- 8a. Date
- 8b. Location

8c. Company

Additional fields have been identified as being required for indexing, but as yet these have not been included in the prototype system. A description of each of these fields is given below along with the principal reason for its inclusion where appropriate.

1. Category

This field will be used to identify which group or groups of people a particular incident is relevant to. For passive searching of the database, for example as part of a HAZOP study, this field is not relevant as all records will be treated equally. However, some incidents are more applicable to one group of people than another group. For example, accidents relating to a failure to identify the correct item of equipment for maintenance are only really relevant to maintenance personnel and not to plant operators. Similarly, accidents relating to failure of agitators are only really relevant to operators and not to maintenance personnel. Other accidents may only be applicable to designers. Therefore, whenever these groups of people access the database, ultimately through integration with the appropriate computer tools, they will only be made aware of accidents relating to their particular category. Categories include, start-up & shut-down, modification, maintenance, and normal operation.

2. Operation

This field specifies the operation being undertaken at the time of the incident. A domain model of this field exists so that case based reasoning can be used to retrieve incidents in related operations. Figure 1 illustrates part of this model. In this case the domain model represents the relationships between different operations. The lower, *child*, operations are subsets of their respective *parents*. For example loading and unloading are both subsets of the batch transfer operation so when looking for incidents involving loading, relevant incidents involving unloading may also be presented to the user.

3. Equipment

This field specifies the equipment involved in the incident. Again a domain model of this field exists. So, for example, a reactor and a tank will be treated as vessels and where appropriate incidents involving reactors will be presented to the user when a query was made about incidents involving tanks.

4. Specific chemical

This field specifies the specific chemical involved in an incident. A domain hierarchy exists for chemicals so that different chemicals can be related to one another. This hierarchy is based on the structure of the chemical and the chemical groups involved. It enables the system to determine which chemicals are closely related. Synonyms and abbreviations of chemicals are also included as part of the domain model for this field.

5. Chemical family

This field is used to specify the sections of the chemical hierarchy which are relevant to a particular incident. As was pointed out previously, some accidents are due to the unique properties

of the chemicals involved. In these cases, the chemical families would be the same as the specific chemicals. Other accidents may be due to the functionality of chemical groups, such as nitrates or alcohols. In these cases, the chemical families would be those chemical groups involved and the incident retrieval system will look for incidents involving chemicals that contains the relevant chemical groups.

6. Chemical property

This field is used to specify chemical properties, if any, which are relevant to a particular incident. Typically these will be toxicity, flammability, corrosivity and reactivity. Chemical properties form part of the domain model for chemicals.

7. Lessons learned

This field specifies the lessons learned following any incident. For some incidents there may be different lessons appropriate to different categories. In these cases the different lessons will be indexed completely separately under the appropriate categories. It is these lessons which will be presented to the users initially, along with a summary of the incident. The option to see further information will then be available to the user.

8. Description

These fields contain a description of the incident. The date, location and company fields are used by the incident retrieval mechanism to help determine which incidents are most appropriate for retrieval. The most recent incidents are most appropriate, particularly where these have occurred at the same location or in the same company as the user.

Incident Retrieval Algorithm

At present, because there is no integration with other computer tools the prototype system only operates in passive mode. The user supplies the name of the chemical, the component and operation of interest. Chemical abbreviations and synonyms are recognised as these form part of the domain model. The following algorithm is then used by the prototype incident retrieval system to select the single most appropriate incident.

1. Retrieve any case history that matches exactly with the chemical, component and operation entered by the user.
2. Retrieve any case history that matches exactly with the component and operation entered by the user, and where the chemical is of the same group and has the same properties as that entered.
3. Retrieve any case history that matches exactly with the component and operation entered by the user, and where the chemical has the same properties as that entered.
4. Retrieve any case history that matches exactly with the component and operation entered by the user, and where the chemical is of the same group as that entered.
5. Retrieve any case history that matches exactly with the chemical and operation entered by the user, and where the component is related to that entered.

6. Retrieve any case history that matches exactly with the chemical and component entered by the user, and where the operation is related to that entered.
7. As 2 but where the component is related to that entered rather than an exact match.
8. As 2 but where the operation is related to that entered rather than exact match.
9. As 3 but for a related component.
10. As 3 but for a related operation.
11. As 4 but for a related component.
12. As 4 but for a related operation.

FURTHER WORK

The prototype incident retrieval system developed at present only retrieves the single most relevant incident based on the information supplied to it. Given that there is only a fairly limited number of case histories in the database this is not a problem as there is only likely to be one case of any relevance. However, the system must be able to retrieve more than one case history, particularly when being used by designers or HAZOP teams. In these instances some form of scoring must be developed so that the user has some idea of the relevance of particular incidents.

The prototype system is being developed using CLIPS (C Language Integrated Production System). CLIPS is maintained by NASA/Johnson Space Center and is distributed at a nominal fee, the intention being to make whatever incident retrieval system is developed available cheaply. At present only a limited amount of case based reasoning is being done by the prototype system. In order to provide some more complex case based reasoning functionality, a case based reasoning programming tool is being to investigate features that may be useful in the incident retrieval system. These features will then be ported to the prototype system.

In addition to retrieval of case histories it is intended to add value by adding further information. In particular this will be done by highlighting the lessons learned from incidents but also through the inclusion of checklists, sources of further information and, where appropriate, instructions for dealing with hazardous situations. The scope for inclusion of additional information is very wide. For example, when used by maintenance personnel, it could be used to highlight the location of appropriate parts and equipment and any identifying marks. For operators it might provide information on the chemistry involved or suggestions for diagnosing the causes of various problems.

CONCLUSIONS

A methodology has been identified for making more effective use of accident databases. Through a combination of improved indexing, pro-active information retrieval, and the inclusion of additional information it is hoped that such databases can be used to improve chemical plant safety. In particular it is hoped to improve the re-use of accident data so that mistakes are not repeated and the lessons from past accidents are not forgotten.

APPENDIX 1 - SOURCES OF INFORMATION ON PAST ACCIDENTS

References (12, 13, 14, 15, 16, 17, 18) have been identified as sources of information on past incidents. It is anticipated that these sources will provide more than enough material to test and prove the fundamentals of the database and associated software. It is however recognised that more case histories would need to be added in order for it to be a viable system for use in industry. These additional case histories would have to come either from industry or the IChemE.

A brief review of each of the references is given below.

Case Histories of Accidents in the Chemical Industry (12, 13, 14, 15)

Nearly 2000 case histories from a wide cross section of the chemical industry are given here. They include the whole spectrum of incident severity from stubbed toes to multiple fatalities. A fair number of the incidents are of a mundane nature e.g. tripping, slipping, dropping heavy items etc. For each case history a short description of the incident is given along with a summary of the cause and possible preventative measures. Some of the working practices described are a bit outdated (and American) nonetheless it is felt that these case histories will provide the backbone for a preliminary database. The one main drawback of these records, certainly in terms of their use in a commercial system, is that the descriptions given are fairly short and there are no references to further information.

What Went Wrong? (16)

Although there are only about 150 incidents described, each contains a new lesson to be learned. They are described in appropriate detail and references for further information are given. Most importantly the lessons learned are highlighted including those related to the underlying causes.

Loss Prevention in the Process Industries (17)

About 100 incidents are described. These are all fairly major incidents selected according to the following criteria:

- 1. The incident is well known, generally by name.*
- 2. It involved major loss of life and / or property.*
- 3. The physical events and the escalation are of interest.*

The case histories are, on the whole, restricted to a blunt description of the incident. However, detailed references are provided for anyone seeking additional information. An analysis of a large number of these case histories has been carried out to look at what factors cause serious accidents. This is described in appendix 2 below.

IChemE Loss Prevention Bulletin (18)

The Loss Prevention Bulletin has for some time been the main vehicle for sharing information about incidents occurring in the UK chemical industry. The case histories are widely disseminated through 127 issues of the LPB. Conveniently, however, there is a simple database

available which allows keyword searches to be carried out to identify the reference for any incidents of interest. As the Loss Prevention Bulletin is the only place many of these incidents are published there are not many references to further information.

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FIGURES

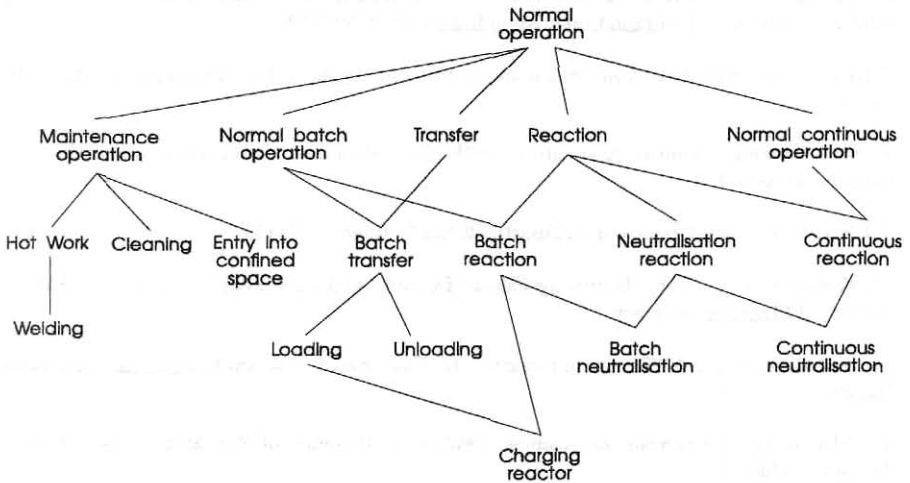


Figure 1. An example of part of the domain model for the operation field showing relationships between different operations.

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