Industrial safety and application of the chemical accidents database

— Relational Information System for Chemical Accidents Database and Progress Flow Analysis —

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The Relational Information System for Chemical Accidents Database (RISCAD) was developed and operates using data collected from the aftermath of fire, explosion, and leakage accidents related to chemical substances, chemical processes, high-pressure gas, and explosives. In RISCAD, some of the accident data are linked to the "Accident Progress FlowChart" (APFC), which shows the timeline and the cause analysis of each accident. In order to create these APFCs, an accident analysis called "Progress Flow Analysis" (PFA) is conducted. This analysis method is also useful for increasing company safety awareness. In this paper, the outline and development process of RISCAD are introduced, and the procedures and application related to PFA industrial safety are reported.

Keywords : Database, chemical accidents, industrial safety, conceptual model for causes, Progress Flow Analysis (PFA)

1 Introduction

Major chemical accidents have recently increased in number, and although each accident may have its own set of causes, the declining number of experienced engineers is often cited as the fundamental underlying factor. This is because most of the skilled engineers who supported operations on site through to the 1970s, and who became experienced in resolving various operational anomalies and accidents, have since retired, and they have been replaced by a generation of engineers with little or no experience in handling these problems. This new generation of engineers tends to regard stable operation as a matter of course, and finds it difficult to respond effectively when unexpected events occur. In an effort to alleviate this problem, hands-on programs in safety education and training have become widespread, but their results still leave much to be desired.

"Learn from accidents" is a common suggestion, but it would be irrational to actually cause accidents for this purpose. Therefore, it is essential to find more practical ways to "learn from past accidents."

The Relational Information System for Chemical Accidents Database (RISCAD) was developed in this light and is designed to enable the virtual experiencing of accidents by learning from actual accident cases, and thereby prevent their recurrence. Herein, I will describe the RISCAD framework and its development, together with the results of our investigation on the procedures and methods used for implementation and utilization of the Progress Flow Analysis (PFA)[1] system for company industrial safety. The PFA was developed to facilitate the construction of "Accident Progress FlowCharts" (APFCs), which are recorded in some of the accident cases covered in RISCAD, and has been found to be effective for heightening organizational safety awareness.

2 RISCAD

2.1 Significance of accident database

The occurrence of an accident at a chemical plant can result in severe censure if a similar accident had occurred previously at the same plant, but criticism can also be harsh if information on such an accident occurring at another company or plant had not been effectively considered and utilized. "Learn from accidents" is a common suggestion, and emphasizes the point that past accidents can serve as instructors that help prevent future accidents. When contemplating or planning an operation, questions arise such as regarding the types of risks present and accidents that may occur. In many instances, this can only be accomplished by actual implementation. However, since gaining first-hand accident experience is problematic, if records related to failure cases that resulted in accidents exist, they can serve as teaching materials that should be learned from. This is the starting point for compiling accident cases.

That being said, when actually collecting cases, it soon becomes evident that it is difficult to search through such reports in order to find accidents that occurred when objectives matching one's own were pursued. First, as many accident cases as possible must be gathered, after which one must attempt to extract cases that match the objective in question. This is an elementary approach to case collection and utilization, and illustrates the need for an accident case database.

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Although this may be an elementary approach at present, it may actually be the best available method, providing that the bare minimum data collection has been accomplished beforehand. However, even if a case matching one's own objectives is found this way, it may not yield useful information. As it currently stands, the actual benefits of this approach may be limited to finding potential countermeasures for preventing recurrence of the identified accidents, contrasting them with the countermeasures emplaced at one's own company, and thereby gaining a degree of peace of mind.

On a visit to the U.S. Chemical Safety Board (CSB) in 2001, we were informed that the board had collected approximately 10,000,000 accident cases in a project spanning the past three years, and had succeeded in narrowing them down to approximately 600,000 cases, but had ultimately been unable to find any information that would be useful for effective accident analysis. They proved, in short, that simply collecting cases had little or no significance. With this in mind, the CSB revised their database operational approach to one of selecting just a few cases each year and forming a team of two to five investigators to perform a detailed investigation of each selected case, including interviews of the related workers and managers, and then to analyze the results and issue a report on the case investigation.

The status of the CSB, however, differs substantially from that of similar organizations in Japan. It is an independent governmental organization with the authority to issue recommendations to the chemical and peripheral industries, as well as to the government itself, and is, therefore, vested with specific authority for direct accident investigations. No such organization with similar authority to conduct accident investigations in the chemical industry exists in Japan, and it would, accordingly, be difficult at best to find any chemical accident investigation reports about domestic incidents that have the in-depth content found in CSB accident investigation reports.

This leaves it up to individual organizations to perform accident analyses in Japan. However, to learn more from accident examples, rather than simply determine that a previous case matches one's objectives and then ascertain the relevant recurrence prevention measures, it is necessary to expand the range of cases collected, analyze those collected cases, and extract information, such as lessons learned, that will prove useful to the organization. This constitutes an additional accident case collection goal.

2.2 Details of RISCAD development

In the latter half of the 1990s, the Materials Safety Workshop established under the leadership of Prof. Terushige Ogawa of Yokohama National University (currently Professor Emeritus, research consultant Research Institute of Science for Safety and Sustainability, AIST) and others, conducted a program aimed at the development of an expert system for chemical plant safety diagnosis.[2]-[4] Through an effort at systemization of "chemical company safety expert" thought patterns, they found that safety experts mentally organize and store their knowledge of past chemical accident cases together, as well as their expertise in chemical engineering and chemical process safety. This led to the clear recognition of the need to incorporate an accident database into the expert system. At the time, however, the available databases on Japanese domestic accident cases consisted largely of text information, with each case limited to a few lines serving as a case overview, which did not facilitate the extraction of knowledge and lessons based on those cases.

In the light of these findings, the National Institute of Advanced Industrial Science and Technology (AIST) led the planning that resulted in the development of an accident case database specializing in chemical accidents. Development was carried out over a period of three years beginning in October 1999 with support from the database development program of the Japan Science and Technology Agency (JST). During its development, it was known as the Chemical Accident Database linked with Substance Physicality (which was the project name of RISCAD at the development stage). That database was launched publicly as RISCAD in October 2002.

A key consideration in its development was the question of how to incorporate information that would be beneficial to its users in their efforts to prevent similar accidents in advance. Thus, the goal was the construction of a database that records links between accident cases along with hazard information on the chemical substances involved in the accident, performs accident classification based on hierarchized keywords, and includes non-text information and case analysis results that would enable the users involved in the handling of chemical substances to search for matching accidents in terms of the chemicals and conditions of their use, obtain information on the hazards associated with the chemical substance, and ultimately gain a deeper understanding of the circumstances in which the relevant accident occurred.

2.3 RISCAD overview

RISCAD in profile, as of the end of August 2012:

- Mode of presentation: Provided by AIST and released free of charge via the Internet as a research-information database (RIO-DB) that is open to the public
  URL: http://riscad.db.aist.go.jp/
- Cases recorded: 5,840
- Case period: October 28, 1949 to September 10, 2011
- Substances recorded: 5,544
- Accident Process FlowCharts (APFCs): 159

The database development began with the entry of existing information on accidents involving high-pressure gas and explosives listed in the Hazard and Accident Database, a

Table 1. Typical keyword hierarchy for processes

Layer 1	Layer 2	Layer 3
Production, Manufacturing	Chemical reaction	Batch Continuous Other
	Separation	Distillation Filtering Centrifugation Other
	Transport, Transfer	Powder Gas Liquid Other
	Drying	
	Pulverization	
	Recovery, Extraction, Elimination	Absorption Adsorption Washing Neutralization Dust colle
	Operations	Subdivision Mixing Washing Concentration Loading, Unloading Startup, Shutdown Trial operation Other
	Others	Pyrotechnics Fireworks Heating, Cooling
Testing and research	Testing, Analysis	Pretreatment Testing, Analysis
	Experiment	Lab-scale Other scale

Layer 1	Layer 2	Layer 3
Storage	Liquid storage	Tanks (fixed) Cans, Bottles Cylinders (liquid)
	Gas storage	Tanks (gas) Cylinders (gas)
	Solids storage	Pellets Powders Bulk Packaged products Other solids
	Other storage	
Transport	Transfer	Air
		Ship (sea, river)
		Train
		Truck
	Loading, Unloading	
	Pipelines	Liquid Gas Other
Maintenance	Examination Inspection Cleaning Repair Modification	
Disposal, Recycling	Incineration Intermediate process Final disposal Recycling Collection, Transport	
	Retention	Open-air Container
	Other disposal and recycling	
Consumption	Sale, Installation Use	
	Explosives consumption	Blasting Fireworks
	Other consumption	
Others, Unknown		

previous RIO-DB operated by AIST, together with relatively detailed information on accidents at chemical plants personally held by the development group members. The database now includes daily collection and registrations of accident information relating to chemical substances by the RISCAD management group.

Chemical hazards information is focused on specific gravity, melting point, boiling point, and particularly on thermal hazards. It also includes registration of data on ignition point, flash point, explosion limit, and other such physical data. Thermal analysis data are also recorded and the database includes a function that enables the user to perform dynamic analysis on the Web browser screen in situations where it is appropriate to the user objectives.

In chemical searches, a constant problem is the large number of names used for a given chemical. It is essential that searches under different names for the same chemical, such as ethanol and ethyl alcohol, lead to the same chemical. Therefore, the RISCAD system includes an alias dictionary consisting of the differing names of compounds, thus leading to the same results regardless of which registered compound name used in the search.

It was determined that creating search keywords associated with the accident case categories would facilitate search and retrieval of information relevant to the objectives of the user’s investigation, including particular processes and process equipment. As a result, keywords were hierarchized to facilitate expansion of the search range to other similar accident cases in response to a small hit number. The keyword hierarchy was constructed by experts and includes the final events, involved processes and equipment, inferred causes, and damage events of the accident cases, together with a search function based on keywords in each of these levels. The keywords were created with reference to well-known chemical accident databases operated by other countries at the time of development, together with keywords that characteristically emerge in actual accident analyses. Table 1 shows a typical keyword hierarchy for processes. For example, in processes, since there were many accidents in the disposal and recycling categories, keywords were added that related to aspects of disposal and recycling but were not found in other databases.

Similarly, the keyword hierarchy for equipment includes safety equipment keywords.

In terms of non-text information, the database includes reaction-process flowcharts, device and equipment drawings, schematic drawings of accident-causing equipment, reaction formulas, and other such entries from accident investigation reports, together with other types of graphical information.

The display functions for accident analyses results include, for macro statistical analysis, a graphical display function for accident search results and a function that enables dynamic changes in display mode and other aspects on Web browser screens.

From the results of various accident analyses, experts produce timelines of accident events, and APFCs are constructed and linked to those cases. These APFCs extract deviations from normal operations that could be the triggers of accidents from the analysis results. APFCs will be described in greater detail below.

As requested by JST, in order to meet the rapidly growing trend of internationalization, it was decided that the entire database would be translated into English and that equivalent functions would be made available for use in the English version.

Actual application of the database begins with the collection of daily accident information. This is performed via an extensive search of Internet newspapers, news agencies, and other news media websites in order to identify accident occurrences using multiple keywords based on experience and expertise. Many people tend to assume that the growth of the Internet and advent of an age of easy searching has made gathering such information a simple matter. In reality, a keyword input such as “explosion” may yield outputs like “batting-order explosion” or “exploded in anger,” while the response to the keyword entry “fire” may well miss relevant reports on “an outbreak” or “small fires.” Even with multiple, well-selected keywords, the final assessment and confirmation step can only be performed by human beings.

Once a search reveals information on the occurrence of an accident, the next step is to seek more accurate detailed information by searching the websites of the company involved in the accident and/or those of the local government in the region where it occurred. For major accidents, in particular, continued follow-up is essential, since detailed investigative reports may not be publicly issued for several months (or in some cases for more than a year) after the accident.

When producing accident overviews, it is not possible to incorporate media news reports verbatim because of potential problems in copyright and reliability; therefore, the text of the overview is composed using extractions from multiple media reports, limited to objectively factual content, and written in accordance with specified rules, as will be described in more detail below. The classification of cases, in terms of the abovementioned hierarchized keywords, is performed by specialists with a deep knowledge of chemistry and chemical plants, since it would be most difficult for others.

Using this process, approximately 250 new cases are added to RISCAD each year.

3 PFA method of accident analysis

3.1 Details of PFA development

In RISCAD, the PFA method for accident flow analysis has been designed and developed as a means to facilitate immediate user understanding of complex accident details. It has grown into a technique for construction of the APFCs that are each linked to several accident cases.

The production of each APFC is initiated by a member of the RISCAD management group, who extracts a timeline of events from the accident investigation reports and other materials associated with the case, considers the causes, and produces a draft APFC. The draft is then assessed, discussed, and finalized by the RISCAD management group members.

The RISCAD management group includes not only researchers in safety engineering and chemical safety, but also former chemical company employees, not only those with chemistry backgrounds but also those with non-technical backgrounds. The researchers are proficient in interpreting accident investigation reports but often do not have a clear understanding of the actual site. The fact that it is common sense for certain countermeasures to be in place on site for certain facilities is something that the researchers can learn for the first time by listening to the words of career veterans based on their own experiences. It also happens that seemingly naïve questions posed by those members who are bound by neither on-site nor chemistry “common sense” can sometimes penetrate to the true core of the matter. In short, it was found that through discussion on the APFCs, their respective backgrounds complement one another, thus enabling the sharing of knowledge and experience. The experience-based observations provided by the chemical company veterans would otherwise be particularly difficult for researchers who have no experience in working at chemical plants to obtain, and have proved highly useful for extracting accident causes that cannot be pinpointed simply by reading accident investigation reports. This is definitely an effective means of countering the continuing decline in the transmission of expertise and experience of veteran personnel to juniors, and the corresponding weakening in organizational safety awareness, factors that are proving problematic in the frontlines of today’s companies.

In the knowledge that on-site implementation of this procedure for sharing expertise and experience at chemical plants would generally be difficult or impossible, it was decided to compile a “procedure for the creation of Accident Progress Flowcharts,” in the form of a PFA flowchart. In the time since then, the PFA has come to be regarded as not only a means for APFC production and accident analysis, but also a means of transmitting organizational safety culture and increasing safety awareness through accident analysis.

3.2 APFC structure

Previously, the only way to gain a clear understanding of an accident was by individual reading and interpretation of the difficult text of an accident investigation report, which usually ran to several tens of pages in length, making them particularly difficult to use on site. This led to the decision to link an organized and succinct description to the accident case as a means of facilitating ready understanding of the accident and its probable causes, without even reading the difficult accident investigation report. This was realized as the APFC.

As shown in Fig. 1, the five main sections of the APFC form are the “Accident overview,” “Background,” ”Progress flow,” “Permanent counter-measures,” and “Lessons learned.”

The “Accident overview” field is used for the entry of the date

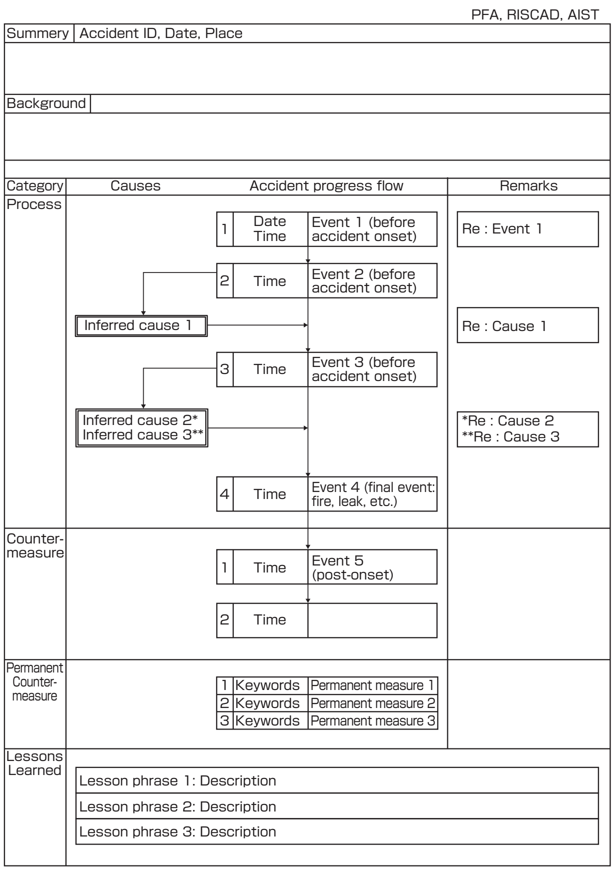

Fig. 1 Accident Progress FlowChart (APFC) form

and time, location, and capsule description of the accident. In RISCAD, certain rules apply to the entries in this section. Specifically, the date and time of occurrence entries are entered according to the Western calendar; the location entry extends to the metropolitan name; the descriptive overview begins with “where” (plant name) and “what” (explosion, fire, leak, or toxicity) occurred, and continues through the spread of damage, firefighting actions and other salient aspects, and the final damage comprises both material damage and personal injury, all in this order. Next, the inferred causes of the accident are entered, with “possible cause” entered for those that remain unclear to avoid definitive assertion. The final entry consists of post-accident measures, administrative dispositions, and other such aspects.

Next, the “Background” field is completed to describe relevant background matters and supplementary information on the context leading to the accident. Any further information deemed useful for understanding the accident, even if not necessarily about directly related matters, is entered as well. This may include information such as the era and course of the facility establishment where the accident occurred, social trends, the state of the premises at the time of the accident, and, in the case of a chemical process accident, the attendant risks and hazards of related chemical substances, process flow, and other aspects.

The accident sequence flow forms the main constituent of the APFC and provides the base for implementation of the PFA. It occupies three columns in the “Progress flow” section. Events are arranged in time series in the center column, and examined for the presence of a relevant problem. If an event is deemed problematic, its cause is extracted to the column to the left. The events leading up to the final fire, explosion, leakage, or other outcome are entered as the progress of the accident. The events following the onset of the accident, such as damage expansion and firefighting are entered in the “Countermeasure” section. The “Remarks” fields in the far-right column are for entry of any supplementary information and observations on the events and inferred causes, together with an explanation of the reasons and course leading to these inferences.

The “Permanent countermeasures” section is for consideration and entry of countermeasures to each of the inferred causes entered under “Accident progress flow”. These permanent countermeasures, following their generalization, are entered as “Lessons learned” in that section. In RISCAD, the lessons learned are to be expressed in phrasing that is simple, concise, and likely to draw reader interest, and are described in a manner of wording such that the reader can comprehend the parts associated with the analyzed case accident to which the general meaning and the lessons apply.

The APFC is a time-series-based system of analysis, and is therefore relatively easy to construct even for beginners. Its construction is preferably performed when access to detailed information on the accident is available, but causes can, nevertheless, be appropriately extracted and responses examined with little available information. For non-analyst third parties, the progress and cause of an accident are far easier to understand from the completed APFC than from the difficult accident reports, and the time-series-based confirmation of the progress of the accident is expected to provide a vicarious experience of the accident by a reader following the timeline.

Well-known methods of accident analysis include fault tree analysis (FTA), event tree analysis (ETA), why-why analysis (WWA), and variation tree analysis (VTA), but their use requires a certain degree of analyst experience and a volume of accident-related information. The PFA method is superior because of its simplicity and its amenability to implementation with a relatively small volume of available information.

3.3 Cause extraction: cause systematization model

In early implementations of accident analysis with the APFC, several problems became apparent. One was the difficulty of immediately distinguishing related events from causes. For example, in a leakage case, a mistaken opening of a valve might be regarded either as the cause of the contents release or as nothing more than a related event, in which case it can be assumed that the cause or causes of the valve opening would lie elsewhere.

The PFA method of accident analysis alleviates this difficulty. Operator and organizational actions, the situation, equipment and devices, the chemicals and their manuals, and any other relevant elements are all defined as events, providing that their actual occurrence is clear or they can be inferred with a substantial degree of accuracy. This mode of definition effectively simplifies the APFC construction and enabling the analyst to organize the flow of events by placing them on a single timeline. In terms of the above example, the leak actually occurred and the valve was certainly opened. Therefore, these can be regarded as events.

A second problem was uncertainty about the method used for cause extraction and the differences between analysts in their approach to extraction. For example, one analyst might tend to emphasize operator responsibility heavily, whereas another may tend to focus on management responsibility, each reflecting their differing perceptions of cause.

A method of cause extraction that can be considered using the “Cause Systematization Model” (CSM) was developed, as shown in Fig. 2.[5] The CSM was created by adding “chemicals” as an element to a lesson systematization model,[6] which was developed based on the Hawkins “Software,” “Hardware,” “Environment,” and “Liveware” (SHELL) model. In cause extraction with the CSM, the “Organization,” “Human,” “Equipment and devices,” and “Chemicals” directly involved in an accident, together with non-involved or indirectly involved “Organizations,” “Human,” and “Society” (representing their social milieu) are all regarded as elements for clarification, with due consideration given to which of these elements relate to a given event, as well as examinations for relevant inter-element problems. This method of cause extraction can effectively reduce differences in causal inferences arising from differences in analyst experience, and also prevent omissions due to oversights.

Figure 3 shows an example of causes extracted by this CSM-based method.

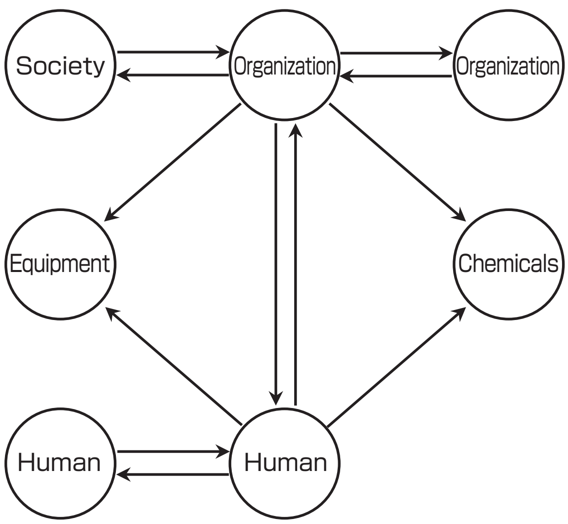

Fig. 2 Cause systemization model

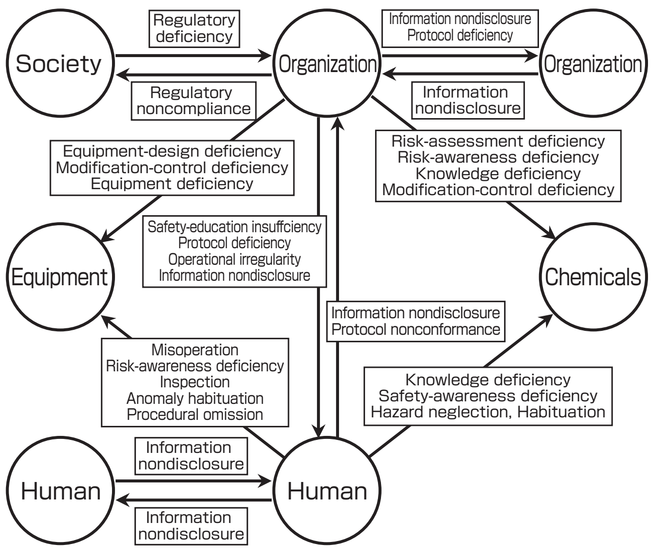

Fig. 3 Typical cause extraction with the cause systemization model

3.4 PFA implementation procedure

The PFA method of accident analysis proceeds along the following steps.
(1) Arrangement of events timeline
(2) Extraction of causes
(3) Examination of permanent countermeasures
(4) Formulation of lessons learned
(5) Finalization of overview description
(6) Group discussion
For details on the procedures, see below.

3.4.1 Arrangement of events timeline

Prior to the actual accident analyses, it is generally necessary to carefully read related accident investigation reports and other sources of information that are relevant to the subject of analysis, and to gain a good understanding of their content. Although accident investigation reports and other relevant sources are generally difficult to follow, they become easier to understand when they are summarized in construction of a timeline of events.

As previously noted, the events arranged in this timeline include relevant activities of operators and organizations, the situation and state of the equipment, devices, chemicals, and manuals, and other elements.

3.4.2 Extraction of causes

The events that caused the accident are presumably somewhere on the timeline. Therefore, each event is examined for the presence of a problem, and those found to potentially harbor problems are then subjected to cause extraction. Unfortunately, even though primary causes are usually already somewhere among the events described in the accident investigation reports and other information sources, those reports do not always cite all relevant causes. Therefore, it is desirable to extract as many tentative causes as possible through application of the expertise and experience of the analysts. This reflects a key difference between accident investigations and accident analyses. In relative terms, accident analysis places greater importance on learning as much as possible from the accident rather than on determining a true cause.

3.4.3 Examination of permanent countermeasures

Since, ideally, a permanent countermeasure is extracted for each extracted cause, causes and measures are usually equal in number.

3.4.4 Formulation of lessons learned

Lessons learned are formulated as generalizations of permanent countermeasures, and it is generally desirable that their number be limited to between two and four as a means of gaining and maintaining widespread interest in the accident and its lessons. Accordingly, before considering individual lessons, it is necessary to examine and identify the essential points illustrated by the accident case, i.e., the points in particular that should be conveyed to those who will consider its occurrence and descriptions. Through this examination, it is possible to present the case in a way that leaves a stronger impression and is more readily retained in the memories of the readers. It also contributes to the development of a better way to focus in on the salient aspects of accidents, determine the points that require attention, and formulate the measures that warrant priority action for the purpose of preventing future recurrence.

3.4.5 Overview description formulation

In the final step prior to group discussion, the analysis results are put in order and the overview description is formulated from the summary. The entry method of this description is described above, in subchapter 3.2.

3.4.6 Group discussion

Creation of the APFC is tentatively completed using the PFA method of accident analysis as described above. However, its formulation essentially includes only the content of the accident investigation reports and the knowledge and expertise of the individual analyst. To fully present the knowledge derived from the accident case in a form conducive to effective utilization, the case is then jointly discussed by a group consisting of several members and the flowchart is completed. In short, for the APFC draft produced by a given analyst, the accident case is discussed by a group of four or five members, including the analyst and others with different career backgrounds, who then finalize the APFC on this basis.

3.5 Utilization of the PFA method for accident analysis

In the group discussion on the APFC, the following results are addressed:
(1) Intra-group sharing of information representing knowledge of the accident,
(2) Compensation for any oversights in formulating the sequence of the accident, and extraction of causes from different perspectives,
(3) Capability of group members to share their respective areas of expertise, knowledge, and experience with other participants, as applied to extraction of the causes and the permanent measures,
(4) Commitment of all members to finding the accident causes and raising overall organizational safety awareness.

Various venues may be used for the discussion, including, for example, the utilization of chemical plants as sites for short meetings.

The range of the completed APFC can be horizontally expanded to cover the entire premises or company, which can prove useful in accident information sharing, education, and safety.

4 Conclusion

This paper provides a basic description of the RISCAD and PFA method of accident case analysis.

At present the utilization of PFA is centered on post-accident analysis of accident investigation reports. Ideally, however, its utilization for accident investigation immediately following its occurrence is also desirable. Specifically, APFC has, been used for immediate analysis of an explosives accident. On one occasion, the PFA has also been directly utilized for analysis of an accident at the request of the company in which it occurred, with demonstrated effectiveness. Tasks that lie ahead include examining the methods of its investigation implementation, which will enable its application to accident investigations, and gaining wider recognition of its effectiveness, and thereby expanding its utilization.

Internationalization of chemical accident databases has shown little progress. One basic reason is the lack of a uniform definition of the term “accident” among countries and regions. High-pressure gas provides one example. Upon hearing Japanese statistics on domestic accidents for high-pressure gas mentioned at international conferences, people from other countries often respond with amazement and disbelief at the high number. However, the number only seems huge to many people because it includes cases of theft. Yet, it remains large even if thefts are excluded because it includes very slight leaks, which are still reported and counted as accidents. These and other such inclusions are seldom seen in other parts of the world.

A second example is provided by the Major Accident Reporting System (MARS), which is managed by the EC’s Major Accident Hazards Bureau (MAHB) as an international chemical-product database and is maintained with the cooperation of countries participating in the Organisation for Economic Co-operation and Development (OECD) Working Group on Chemical Accidents. MARS calls for the reporting of major accidents involving gas leakages that result in designated levels of personal injury or relocation (e.g., number of injuries, fatalities, or evacuees) and chemical inventories.

In Japan, in contrast, accident registration can be defined in terms of the number of fatalities but information on the level of leakage in proportion to number of evacuees or inventory is not necessarily reported or collected, thus making it difficult to judge whether an accident needs to be reported.

Finally, a scenario of RISCAD construction and utilization is shown in Fig. 4. The constituent elements include collected information based on the facts of the accident case, extending from the time and date of onset to the equipment involved, prior information on substance hazards, and causes inferred from the results of accident analysis; also included are responses, lessons to be learned, and the APFC. These elements constitute the basic structure of the database and form the basis for its heightened reliability and ease of use, its value as an educational and training material, and its generation of PFAs.

The underlying goals for RISCAD include its positioning and establishment as a database specialized for chemical accidents, together with an expanding scope of utilization. This scope includes, in particular, its use as an effective contributor to accident prevention and to safety education and training. This will require learning about various accident cases that represent a wide spectrum of accident causes and yield important lessons, as well as detailed analysis of these cases, by which we may communicate the importance of deriving lessons from chemical accidents. For the PFA accident analysis method developed as a key part of RISCAD, the basic goals are to contribute to the development and dissemination of safety technology, further organizational safety awareness, and, ultimately, to enhanced industrial safety and security, through group discussion.

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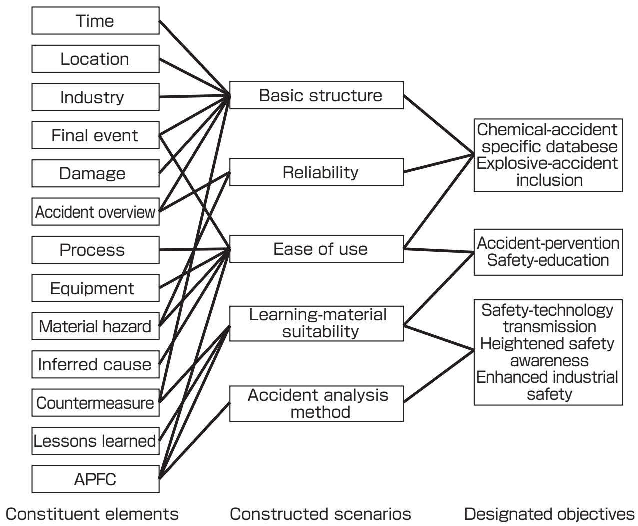

Fig. 4 Scenario of RISCAD construction and use

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Discussions with Reviewers

1 Overall observations

Comment (Koh Naito, AIST)

This paper deals with the development of an accident case database. It may be safely regarded as a scientific paper that will have a large and beneficial impact on "big data" analysis, which is characterized by complex structures and has become the subject of very strong interest by society in recent years. In this paper, the basic aim is transformation of information into a database by incorporating structural methodologies that combine definition of keywords (technical terms), data analysis methods (e.g., PFA), and systematization techniques (SHELL models). A particular value of this paper is its observations that simple technological integration is not enough to create a useful and beneficial database, together with its description of the methodological importance of techniques for information collection and of multifaceted discussion and consideration by experts of differing specializations and backgrounds.

2 Positioning of this research in comparison with previous research

Question (Hiroaki Tao, Research Institute for Environmental Management Technology)

It would be helpful if, in addition to the RISCAD system developed in this research, the main existing databases in Japan and the rest of the world, together with their particular characteristics, were presented in tabular form, as it would undoubtedly help to clarify the direction of research in this field and the distinguishing characteristics of this database. The paper notes the U.S. CSB as an example, but a related question arises as to whether similar research is being performed in the EU and other regions.

Answer (Yuji Wada)

We receive requests for consultation on the existence of databases that could be used for investigating chemical accident information abroad, but at present none exist that would be suitable. The information provided by the U.S. Chemical Safety Board (CSB), is in the form of detailed reports and a reproduced computer graphics library, rather than a database, and cannot readily be used to search for accident cases or to obtain statistical data. In the EU, they have the Major Accident Reporting System (MARS), but this is also limited to major accidents, and is hampered by insufficient cooperation between the EU countries and the Organisation for Economic Co-operation and Development (OECD), resulting in a small number of accident cases (just 14 registered in and after 2010), which is not sufficient for its comparison as a database. In the U.S. since the Sept. 11, 2001 terror attack, the movement has been toward closing the formerly open database of the EPA. In the countries of Europe, individual countries tend to operate their own databases, but whether these are open or closed to the public, they are generally in their own languages (e.g., German). Given these circumstances, it would be quite difficult to provide a comparison in table form at this time.

3 Database content

Question (Koh Naito)

This paper points out the importance of digging deeply into a relatively small number of accidents rather than trying to analyze a huge volume of data, which means focusing on variety and detail rather than on the averages frequently provided by statistical analysis. Further description of this in the final summary would increase the value of this paper.

Answer (Yuji Wada)

As you have noted, further description is desirable, and I have therefore added the following passage in the Conclusion.

"This will require learning about various accident cases that represent a wide spectrum of accident causes and yield important lessons, as well as detailed analysis of these cases, by which we may communicate the importance of deriving lessons from chemical accidents."

Question (Koh Naito)

The importance of narrowing the generalization of an accident to 2 to 4 is noted; please provide clarification on the grounds for the preferability of narrowing the number.

Answer (Yuji Wada)

As you have indicated, the related grounds were not clearly stated, and I have, accordingly, added the following passage:

"Through this examination, it is possible to present the case in a way that leaves a stronger impression and is more readily retained in the memories of the readers. It also contributes to the development of a better way to focus in on the salient aspects of accidents, determine the points that require attention, and formulate the measures that warrant priority action for the purpose of preventing future recurrence.”

4 International standardization

Question (Hiroaki Tao)

You note that you have produced an English version of the database in response to the trend toward internationalization. I believe that various international standardizations have also been performed in regard to safety by ISO and other organizations, but I wonder about the level of progress in the trend of international standardization by researchers performing similar studies. As a reader, I feel this to be an interesting question and believe it would be beneficial to add a description from this perspective, if possible.

Answer (Yuji Wada)

In the Conclusion (chapter 4), I have added the description quoted in the paragraph below. A movement seems to be emerging in the chemical industry for unification of accident databases, but the discussion has just begun and at present there is something of a tug-of-war between Europe and the U.S., with no decision on an appropriate framework. I therefore did not touch on that state of progress.

“A second example is provided by the Major Accident Reporting System (MARS), which is managed by the EC’s Major Accident Hazards Bureau (MAHB) as an international chemical-product database and is maintained with the cooperation of countries participating in the Organisation for Economic Co-operation and Development (OECD) Working Group on Chemical Accidents. MARS calls for the reporting of major accidents involving gas leakages that result in designated levels of personal injury or relocation (e.g., number of injuries, fatalities, or evacuees) and chemical inventories.

In Japan, in contrast, accident registration can be defined in terms of the number of fatalities but information on the level of leakage in proportion to number of evacuees or inventory is not necessarily reported or collected, thus making it difficult to judge whether an accident needs to be reported.”

5 Outlook for social implementation of this research

Question (Hiroaki Tao)

As described in this paper, the researchers analyze accident investigation reports after they have been produced by parties involved in the accident, and on that basis produce the APFC and the cause systemization model. Ideally, it would seem highly effective for the elucidation of causes and derivation of lessons learned to incorporate the APFC and the cause systemization model produced here into the report beginning at the stage in which the parties involved in the accident produce the accident investigation report. Does any move exist for JIS standardization of the format of the accident investigation report, say by including the form detailed in the study, or for administrative guidance or other means for instructing the parties involved? It appears that something of this nature would increase the usefulness to society of the research described in this study. I believe it would be beneficial to include in this paper a description of the outlook for future social implementation and any related problems.

Answer (Yuji Wada)

One example of APFC utilization in analysis has occurred, in the case of an explosives accident. In a separate example, under instructions by the accident investigation committee, an investigating party from the involved company visited to consult on analysis by PFA of an accident that occurred at a chemical plant last year. In response to your suggestion, and in accord with our belief that persuasive examples of achievements obtained from this type of utilization will be necessary, and as part of our effort for increased awareness among administrative personnel and experts selected as accident investigation committee members, I have added the following paragraph near the beginning of the Conclusion chapter.

“At present the utilization of PFA is centered on post-accident analysis of accident investigation reports. Ideally, however, its utilization for accident investigation immediately following its occurrence is also desirable. Part of it, specifically its APFC has, in fact, been used for immediate analysis of an explosives accident. On one occasion, the PFA has also been directly utilized for analysis of an accident at the request of the company in which it occurred, with demonstrated effectiveness. Tasks that lie ahead include examining the methods of its investigation implementation, which will enable its application to accident investigations, and gaining wider recognition of its effectiveness, and thereby expanding its utilization.”