

MIS-IDENTIFICATION OF CHEMICALS

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This paper reports on work carried out by the European Process Safety Centre (EPSC) Contact Group on *Safety Issues in Batch Production*

The mis-identification of chemicals is a perennial safety issue. A number of serious incidents and near-misses have arisen through chemicals being incorrectly identified in both continuous and batch processes. However, the nature of batch production makes it particularly vulnerable to such incidents of Mis-Identification, due to the following characteristics:

- The use of multi-purpose plants, with different chemicals used in different production campaigns;
- The large variety of chemicals kept ready for use in a plant;
- The use of containers (i.e. bags, pallets, FIBC, etc), as opposed to supply via fixed pipes;
- The greater use of organisational versus technical safety measures.

For these reasons the European Process Safety Centre (EPSC) Safety Issues in Batch Production Contact Group choose this topic for investigation.

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BACKGROUND

The EPSC Contact Group on *Safety Issues in Batch Production* was formed in 1998 to investigate issues specific to Batch Production. The Group's first project investigated the issues involved with the transfer of processes from site to site, company to company or from development to production¹.

On completion the Contact Group chose to focus on the mis-identification of chemicals. The impetus for this topic was a number of recent incidents that had been attributed to incorrect identification or substitution of chemicals and the lack of clear guidance or advice in the literature. For the purpose of the project, and this paper, the mis-identification of chemicals was taken to refer to any chemical, other than that intended, reaching the process through the incorrect action, or inaction, of personnel.

INTRODUCTION

Mis-identification is by no means specific to Batch Chemistry or Production and can occur in any operation. However, there are facets of batch production that make it vulnerable to such incidents. These facets can be characterised by:

- The use of multi-purpose plants, with different chemicals used in different production campaigns;
- The large variety of chemicals kept ready for use in a plant;
- The use of containers (i.e. bags, pallets, FIBC, etc) as opposed to supply via fixed pipes;
- The greater use of organisational versus technical safety measures.

The aim of the investigation and subsequent report² was to provide a summary of the information exchanged between EPSC members on their company's approach to avoiding the mis-identification of chemicals.

A literature study undertaken at the start of the project revealed very little guidance on the methods available specifically for the prevention of mis-identification. There were, of course, general procedures outlined in Safety Management Systems³ and more specific procedures for handling chemicals in later publications⁴.

This paper includes the key findings from the benchmarking of the approaches taken by EPSC member companies to prevent mis-identification incidents. This benchmarking revealed a range of techniques from simple approaches, requiring the double checking of key stages, to complex systems involving bar codes and computer systems.

RISK ANALYSIS

Risk Analysis, with a special focus on mis-identification of chemicals and hazardous interactions, is a prerequisite for safe material flow through any process and the effective use of any additional measures.

A procedure for Hazard Identification is a vital for safe operation. Hazard Identification can be used to highlight possible hazards and then enable the company to target resources, procedures, measures, etc at the most significant hazards. There are many publications covering the topic of Hazard Identification^{5,6,7}.

One key finding was that Hazard Studies would often “start-at-the-gate” assuming that material entering the site was of the correct type and to specification. From experience, and the material presented, it is clear that this assumption is not valid. Therefore care should be taken when selecting the boundaries for a hazard study and any assumption(s) made.

Interaction matrices represent in a concise manner the possible hazardous interactions between chemicals present in a given plant and between chemicals and construction materials. The large number of possible interactions in a multi-purpose plant may render a “one-by-one” consideration impractical if not impossible. Class formation similar to that in Bretherick’s⁸ may be a good solution of this problem, some examples of classes being e.g. “strong acids”, “peroxides”, “amines”.

Hazard Identification and Risk Assessment must be conducted to ensure that safe operation is maintained and the most effective procedures are utilised.

PREVENTATIVE AND PROTECTIVE MEASURES

A comprehensive and robust system of document verification is one essential element of a safe procedure for avoiding the possibility of mis-identification of chemicals. However established procedures for handling documentation are not in themselves foolproof, and other methods of identification may be required. The Contact Group provided information on a number of other additional measures used by various companies and these included:

LABELLING

All packages should be clearly labelled to allow easy and positive identification of the contents. Essential features of such a labelling system are:

- Highly visible labelling;
- Labelling on all packages of a delivery unit e.g. a pallet;
- Robust labels e.g. high adhesion, weather proof etc;
- Material name written in large easily readable characters;
- Avoiding the use of similar names, especially similar abbreviations.

The similarity of chemical names can be a significant problem when trying to avoid the mis-identification of chemicals. Shortened names or abbreviations have been introduced to allow easier communication and better distinction between chemicals with similar scientific

names, but the increase in the number of these abbreviations has meant that it is evitable that some will become similar to each other. Moreover, cases have been reported where the abbreviation has inadvertently been identical to a molecular formula of a completely different chemical. One example is when “AAA” (Aceto-Acet-Anilide) and “AAOT” (Aceto-Acet-Ortho-Toluidide) were exchanged in the supply chain, with the mis-identification only caught by an attentive operator. A second near-miss occurred in a development laboratory where “KBR” (Potassium Bromide) was ordered for a synthesis though Copper Bronze (Kupferbronze) was the intended material. The error was readily identified when the chemical was delivered. In addition, the changes within the process industries, such as the increasing number of company mergers, has had the effect of merging different systems of abbreviations, a significant risk, if not carefully controlled.

SAMPLING AND ANALYSIS

Sampling and analysis may be used to support other methods of identification. Whilst analysis can provide the definitive identification of a chemical care must be exercised to ensure that mis-identification does not arise during or after the analysis step. On-line sampling systems are becoming more readily available through the development of miniaturised electronic systems. Although analysis can identify the chemical present there are some situations when analysis is not suitable or feasible. These include when the product is hazardous to health, thus introducing a significant risk to the individual involved or when it becomes unworkable to sample every container of product (i.e. a pallet containing about twenty 25 kg bags).

Some companies utilise a “just-in-time” system of delivery for materials to site. This allows the inherent safety improvement of reducing inventory, but can lead to pressures to allow material through from delivery to the production unit as quickly as possible. The procedures in place to analyse the chemicals should be suitable for both the hazard of the chemical, its possible incompatibility with other chemicals on site, the quantity of containers and the length of time before the product will be required for use.

BAR-CODES

Bar-codes are an additional measure that can be used in the supply chain to avoid the mis-identification of chemicals. In addition to their use in the supply chain, one member company has used a system of bar-coding for nearly two years at an individual plant.

On the company’s site, all vessel charge points and transfer booths were equipped with a bar-code reader. Operators, supervisors and managers were all provided with bar-coded name badges so they could be identified. This allowed for each charge to be coded, and therefore, linked to a specific operator and, where supervisory checks were required, these could be programmed in. The computer control system verifies that the materials are correct and also automatically time stamps each input, charge and action.

Where practical, the bar-code read charges were combined with load cell measurements to ensure exact charges. It also allowed bar-coded batch labels to be printed that could further improve the accuracy and efficiency of the process.

The equipment involved had been found suitable for industrial use. The system provided excellent automated checks on both material type and quantity (either by number of bags etc. or via comparison with load cell results) for all manual-charging operations. Although not infallible, it would clearly reduce the potential for “operator error” to very low levels. This was true if the current system used for manual charging operations and manual controls were maintained.

An industry wide system of coding would further increase the effectiveness of the system. However, ultimately, it was felt that bar coding was only an aid to chemical identification and not a replacement for current procedures.

KEY-LOCKS

Key lock systems take many forms, one of which involves the use of locks and keys to stop any unauthorised use of materials from rail or road tanks entering the site. On arrival at the site all containers go through site security. Information regarding the tank contents is transferred and the analytical department notified. A sample is taken and analysed and a universal lock fitted by the analytical department that prohibits any unauthorised removal of the chemical. Once the analysis is complete the universal lock is removed and a substance specific lock attached to the tank. The plant or unit requiring the substance is then informed and the tank moved to storage ready for use. When required, the plant or unit is able to open the substance specific lock and unload the container. Once the chemical has been used, the plant places an order with the purchasing department and the specification is sent to both the purchasing department and analytical department. The chemical is then reordered, site security is notified of its arrival and the process begins again.

The system is applicable when there are regular consignments of chemicals in bulk quantity. It is particularly useful when deliveries of chemicals are scheduled on a “just-in-time” basis. The technique is suitable for any bulk quantity where there is only one unique method of removing the material from the transport container i.e. valve, coupling etc.

SECOND SIGNATORY OR “4-EYES”

The second signatory or “4-eyes” principle is the method by which operations are first conducted by one operator and signed signifying that the correct procedure, operation etc had been followed. A second operator then countersigns the form signifying that the procedure has indeed been conducted correctly.

This technique of double signatories or “4-eyes” is most applicable when the operations being undertaken have the potential for producing hazardous situations if the procedure is incorrectly followed or the wrong chemical is added. The procedure is particularly useful when used in operations that require a high operator input, but in which it may be difficult to provide physical means of ensuring correct operation. For example, these can include batch operations, particularly multi-batch operations where there is a heavy load on operators. The procedure is also applicable for procedures that are only required intermittently (e.g. cleaning, maintenance, occasional batches).

To work most effectively the “4-eyes” principle should be used sparingly and only when secondary checks are needed due to there being a significant hazard. If the method is used too frequently on low hazard situations, there is the possibility that the method will be devalued and operators may begin to perform unauthorised tasks. When using “4-eyes” principles operators should be fully trained in the method and the reasons behind its use fully explained. The workload on any operator must be monitored with the reasons for any increase in workload fully explained to the operator, particularly when additional “4-eyes” procedures are introduced.

One limitation is that the first operator could assume that the second operator will check the consignment, operation etc. and the second operator could assume the first has conducted the tests etc. This can lead to a situation where operations take place under the “safety” of double checks, but in effect these double checks mean that neither operator conducts the inspections, operations etc. This can be avoided through appropriate training and the

explanation of the importance of the procedure and only using the procedure when the hazard warrants it.

Incidents have been reported where one or more secondary-checks have failed to reveal an error^{9,10}.

SEGREGATED STORAGE IN STAGING AREA

Segregated Storage can be utilised throughout the entire the supply chain, but in practice it is particularly used in staging areas (these are the areas where materials are stored immediately prior to it being used in production, as compared to warehouse areas). This method can be utilised at the start of the supply chain and at later stages. Segregated storage can take many forms ranging from “soft” procedure based segregation to “hard” physical measures. Specific storage areas can be dedicated to specific products or barriers can be used to separate two or more incompatible materials. This can involve mechanical measures (e.g. walls, cages, separate buildings) or the use of a barrier of an “inert” chemical that does not have a hazardous reaction with either of the first two.

A segregated storage approach is applicable to most facilities and is a significant first step in ensuring the correct delivery of chemicals. This approach must include a rigorous documentation procedure, be regularly audited and employees trained in its use and the reasons for it.

TRAINING

Training cannot be seen as an independent method of preventing the mis-identification of chemicals but should be seen as a requirement for the effective implementation of those measures that are in place. Training can cover formal induction training, refresher training and regular group discussions. In order to minimise the risk of mis-identification it is important that training:

- Describes the measures that need to be followed for safe operation;
- Emphasises the importance of the checks and cross-checks that are in place;
- Provides the operators with an appreciation of the consequences that may arise if the systems fail.

BULK PRODUCTS

Bulk handling presents specific problems and provides certain benefits in the avoidance of mis-identification. The use of bulk chemicals can make identification simpler as there will be less sampling and analysis required to establish the identity of the material. This is particularly true when compared to sampling methods required for pallets, bags, and FIBC's. Problems occur if there is a mis-identification, for whatever reason as the quantity involved is likely to be significantly greater (tonnes versus kilos) and hence the consequence of any incident will be greater. Therefore bulk chemicals require similar techniques to those described earlier, but there will be variations in their application if the benefits of delivery in bulk are to be maximised while the associated hazards are minimised.

The UK Chemical Industries Association (CIA) produced a guidance document¹¹ in 1999 which focused on offloading products into bulk storage. This guidance deliberately concentrated on the supplier and customer interaction with the bulk load. It advised the implementation of a system independent of the supply chain. This was seen as having the advantage that the supplier and/or customer can introduce systems that reduce the potential for product crossover and are independent of those parts of the supply chain over which they have little control.

EMERGENCY PLANNING

Whatever system is in place to prevent mis-identification it is still vitally important to have prepared, documented and implemented an appropriate emergency plan. This emergency plan will need to be explained to all personnel, who need to be trained and competent in both the plan as a whole and their specific roles.

FINDINGS

STEPS TO MINIMISE THE HAZARD

Whilst there is no simple and unique solution to the problem the following steps can be used to ensure that the hazard is fully identified and appropriate controls in place:

Interaction matrix

Construct an interaction matrix to help identify hazardous interactions.

Hazard identification

Conduct a study to identify where the possibility exists for mis-identification to occur. (This may be in addition to conducting a HAZOP study).

Supply chain

Consider the importance of ensuring correct delivery of materials. For bulk chemicals reference should be made to the CIA Guide¹¹.

Labelling

Robust and accurate labelling is a must and a basis of safe operation. Considerations for labelling are discussed earlier in this paper.

Additional measures

Where the mis-identification of chemicals could lead to serious consequences, to either humans or the environment, additional measures will be required. One or more of the following approaches may be required to reduce the hazard or risk to tolerable levels:

- Segregated storage;
- Second signatory;
- Sampling and analysis;
- Key-locks;
- Bar-codes.

MOST INCIDENTS CAUSED BY HUMAN ERROR

From recent incidents and the experience of the Contact Group members, it was felt that most of the incidents where chemicals have been mis-identified could be attributed, at least in some way, to human error. This may over simplify the cause as it can be argued that human error stems from procedural, training, and management system failures. Although it would be simple to say that to reduce the likelihood of mis-identification humans need to be taken out of the loop, in batch production (particularly multi-purpose) this is not feasible.

The *human factor* plays a crucial role in Batch Processing in this area. Thus procedures, organisational measures and checks that are in place to confirm the identity of chemicals should be reviewed to confirm that they are "fit for human nature" e.g.:

- Ergonomically suitable;
- Short and simple;
- Not jeopardizing efficiency targets;

- Not too repetitive

The attentiveness of the operator is key to solving, or avoiding, the problem of mis-identification. This attentiveness can be enhanced through:

- The correct use of training;
- Raising awareness of the problem;
- Considering ergonomics in plant design and material supply chain;
- Consideration and limitation of work load stress; and
- Promoting a working environment where operators feel a degree of self-responsibility.

AN ONGOING PROBLEM

The Contact Group felt that there was a perpetual safety problem in the mis-identification of chemicals within a supply chain. Within processes there are opportunities to use inherent safety principles to substitute or eliminate steps that have such hazards. However, short of producing all raw materials on each site, there will always be the need for transportation of raw materials to site and the removal of product from site thus, reinforcing the scope for mis-identification of chemicals within the supply chain.

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REFERENCES

1. EPSC, 2000, *Member-only Report No. 17 - Safety Management for Process Transfer of Batch and Semi-Batch Process.*
2. EPSC, 2000, *Member-only Report No. 21 - The Mis-identification of Chemicals.*
3. EPSC, 1994, *Safety Management Systems.*
4. EPSC, 2000, *Safety, Health and Environmental Management Systems for Small to Medium Sized Enterprises: 66-67.*
5. EPSC, CIA & IChemE, 2000, *HAZOP: Guide to Best Practice in the Process and Chemical Industries.*
6. Wells, G., 1997, *Hazard Identification and Risk Assessment, IChemE.*
7. CCPS, 1992, *Guidelines for Hazard Evaluation Procedures, 2nd Edition.*
8. 1999, *Bretherick's Handbook of Reactive Chemical hazards, 6th Edition, Butterworth-Heinemann.*
9. 2001, *Action following the explosion at Albright & Wilson UK Ltd, Avonmouth on 3 October 1996, Loss Prevention Bulletin, Issue 153: 9-10.*
10. June 2001, *Supply of the wrong chemical leads to a release of hydrogen sulphide gas, Loss Prevention Bulletin, Issue 159: 4-5.*
11. CIA, 1999, *Bulk storage - procedures for off loading products into bulk storage at plants and terminals.*