USING A TASK INVENTORY TO DEVELOP A MORE EFFECTIVE INCIDENT REPORTING SYSTEM.

A.J. BRAZIER, J.M. BLACK

Department of Chemical Engineering, University of Edinburgh, Edinburgh EH9 3JL.
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1. INTRODUCTION

It is generally accepted that up to 90% of accidents are at least partly attributable to human errors in completing tasks. Accidents are often the result of faults in a system which remain hidden until triggered by abnormal or unforeseen events. Both faults and triggers may result from by incorrect human actions. Eliminating these incorrect actions will break the chain of events leading to the accident, thus preventing it. Knowledge of the human interaction within a system gives an opportunity to prevent accidents in this way. Techniques do exist such as task analysis, human error identification, human reliability quantification etc. but all are resource intensive and would not generally be applied to a complete plant under all likely conditions.

To understand how human actions effect the safety of a plant full knowledge of what people *actually* do is needed. This requires compiling information on all tasks having a significant human content, under all plant conditions. Thus if an incident were to occur on this plant all tasks in progress would be known, given the prevailing plant conditions. This would allow precise identification of the fault and trigger actions which led to the incident. Over time we would build a picture of the actual errors people make on that plant and what conditions affect the reliability.

We intend to show how a study of tasks performed can be used to develop more effective incident reporting systems by considering human involvement, along with providing an invaluable and unique source of information for all reliability assessments aimed at improving safety, quality and production performance.

2. CAUSES OF ACCIDENTS.

To prevent accidents we need to know what causes them. It is true that a single major equipment failure or serious human error can directly result in an accident but such serious events can generally be foreseen and safety devices built into the design.

Most accidents, however, are the result of a series of relatively minor events and system failures that defeat safety systems *(Lewis et. al. [1])*. The problem is that each event has very minor consequences on its own and can easily go un-noticed whilst the exact combination that leads to an accident is very difficult to predict and will generally not recur.

A first step in preventing accidents is to detect these minor events and failures when they happen in isolation. This is where an incident reporting system is most useful by ensuring that near misses are consistently and accurately reported.

To understand how minor events cause accidents they have been divided into two types, resident errors and local triggers.

2.1. RESIDENT ERRORS.

These are faults built into the system at an early stage. On their own they have little or no effect and will not cause accidents. This is why they remain undetected. They can be considered to be the root causes of accidents and it is important to realise that one resident error could cause a large number of different accidents, hence it is very important that and incident investigation will uncover them so that they can be removed.

HSE [2] suggest the following resident errors:

- Design and construction deficiencies,
- Management failures,
- Maintenance errors,
- Component weakness,
- Bad procedures,
- Routine violations.

2.2. LOCAL TRIGGERS.

These are events that in isolation have little effect but when combined with any resident errors can result in hazardous situations that cause accidents. Local triggers include:

- Environmental conditions,
- Unusual system states,
- Operator errors,
- Exceptional violations,
- Component failures.

3. HUMAN ERROR.

It will now be obvious why so many accidents' causes are attributed to some sort of human involvement; most of the resident errors and local triggers can be directly caused by some sort of human behaviour. This is why we suggest that tackling human error is a good way of improving safety.

It is important to realise that all humans make errors no matter what their level of skill, experience, or training *(Kim [3])*. To improve safety we need to understand the types of errors made and the factors that make their occurrence more likely.

3.1. ERRORS MADE.

The following is a summary of the types of errors that humans make *(Kontogiannis et. al. [4])*:

- Action errors: either no action is taken when required, the wrong action is taken, or the correct action is carried out but on the wrong object,
- Checking errors: when the system requires checks to be made, the checks are omitted, the wrong checks are made, or the correct check is made on the wrong object,
- Retrieval errors: when information is required, either from human memory or from another reference source, it is not received or the wrong information is received,
- Transmission errors: when information has to be passed to someone else, either no information is sent, the wrong information is sent, or it is sent to wrong place,
- Diagnostic errors: when an abnormal event arises, the actual situation is misinterpreted,
- Decision errors: when the circumstances have been considered the wrong decision is made.

3.2. FACTORS MAKING ERRORS MORE LIKELY.

Humans can make errors at any time due to their lack of precision in physical work and inappropriate timing of actions. There are a number of factors, however, that make errors more likely *(Dhillon et. al. [5])*. These include:

- The work environment: noise levels, lighting and temperature.
- Equipment design: the quality and reliability of all equipment including displays, alarms and controlling devices,
- Equipment layout: the location of all equipment and labelling,
- Procedures; the quality of operating instructions and effectiveness of checks,
- Skill: training and experience,
- Tasks to perform; their complexity.

4. TASK ANALYSIS.

A task is defined as “A set of human actions that contributes to a specific functional objective and ultimately to the output goal of the system.” *{Drury [6]}*. Task analysis is a systematic approach at defining what operators are required to do to achieve the objective of the system *(Sheperd [7])*. This is achieved by:

- Defining the function,
- Determining the overall objective in terms of a measurable outcome,
- Describing the circumstances under which the work has to be carried out,

- Breaking down the objective into sub-objectives.

A task analysis can be performed by reviewing documentation such as work schedules, procedures, training manuals, design specifications and unit handbooks, but it must be remembered that their accuracy can not be guaranteed as actual working practices are likely to change over time. Documentation review will show what people are supposed to do but should be backed up by discussions with experts, actual or potential users and design engineers, along with observation to ensure the analysis covers what people actually do.

The findings from the task analysis help provide human reliability data by:

- Providing a clear description of what is involved in tasks,
- Collecting data about the task,
- Generating ideas about how errors may occur,
- Generating ideas about solutions to safety problems.

5. IMPROVED INCIDENT REPORTING SYSTEM.

5.1. TASK INVENTORY.

To prevent accidents an incident reporting system needs to identify the latent errors, triggering events, human errors and error inducing conditions present before or during the incident. We propose that a task inventory be completed to provide a basis on which to develop an incident reporting system. Initially the plant is broken down into its basic units, each of which will have a specific objective towards the overall plant goal. The important features of each unit are summarised and possible failures considered. Once this inventory has been completed, the results of any future incident reports and investigations will be used to up date the information collected initially by comparing the way the actual incident progressed with those predicted.

5.1.1. Unit Objectives and Operating Procedure.

Each unit should have a specific objective. This is what it was designed to do and why it is needed. Once this has been established the following information, about how the objective is achieved, is required:

- The major items of equipment,
- The main processes involved,
- Process conditions required,
- How performance is measured,
- The control systems,
- How the units are connected.

The task inventory needs to take into account all the activities the personnel do to control the unit. These general duties include:

- Starting the unit,

- Controlling operation,
- Maximising performance,
- Ensuring safety,
- Shutting down the unit.

This inventory will cover how activities are scheduled and how decisions are made in terms of cues available from instruments, samples, procedures and instructions.

5.1.2. Hazards.

To determine the potential of the unit to cause accidents, a list of all the hazards present on the unit is required. For each hazard data is required concerning the risk it poses to safety. This includes how it is contained and the worst possible consequences of a loss of its containment. The types of hazards likely include:

- Toxic chemicals,
- High pressures,
- High temperatures,
- Moving machinery,
- Explosive and flammable substances,
- Pollutants.

The task inventory will show how personnel interact with the hazards. This will include:

- Tasks performed in hazardous areas,
- Tasks involving potentially unsafe actions,
- The potential for direct contact with hazards during task performance,
- Tasks requiring the control of processes involving hazardous materials or conditions.

5.1.3. Possible outcome of an incident.

The information about the unit objective, tasks performed and hazards involved collected during the task inventory completion is used to predict the possible incident scenarios and the consequences of unwanted events or conditions developing due to incorrect task completion. The consequences include the potential to cause injury, property damage, environmental pollution or lost production and are divided into three types.

Immediate Effect.

This is an event where the control of a hazard is lost in a way that the potential consequence may occur within the duration of the incident.

Long Term Effects.

An event somehow weakens the system and allows latent errors to enter the system thus increasing the chance of accidents in the future. It is important to identify these at the time of the incident as they may be difficult to detect before causing accidents.

Knock-on Effects.

An event where the effect is not only at that location but passes on to other areas or other units resulting in immediate or long term effects. This will depend on how equipment and units are linked and the required condition of transferred products.

5.1.4. Recovery.

Not all incidents result in accidents or any other significant outcome. This is usually because there was an opportunity, during the incident, to return the system to a safe state. The task inventory is used to determine which tasks allow the recovery from errors and which elements of the system indicate abnormal conditions or protect against their consequences. When reporting incidents it is important to determine how recovery was achieved and how effective it was. This information is useful for suggesting methods of preventing future accidents and, although immediate effects may have been prevented, long term effects may occur from the recovery actions. The types of recovery systems include;

- Alarms alerting personnel to unusual conditions,
- Emergency shut down devices protecting equipment,
- Routine monitoring and checks
- Procedures to deal with unusual situations.

If an incident is not recovered from, there is likely to be an emergency response. The aim of these is to limit injury and damage, make an area safe and allow a rapid return to normal operation.

5.2. REPORTING.

Having completed the task inventory, its results can be used to aid incident investigation by suggesting possible scenarios, causes and effects. The important issues to be considered:

- Its potential to cause injury or damage,
- Possible long term effects,
- Knock-on effects,
- Human activity during the incident,
- Errors made,
- Factors present that may have made errors more likely,
- Resident errors that were uncovered during the incident,
- Local triggers occurring during the incident,
- The performance of recovery systems and emergency response.

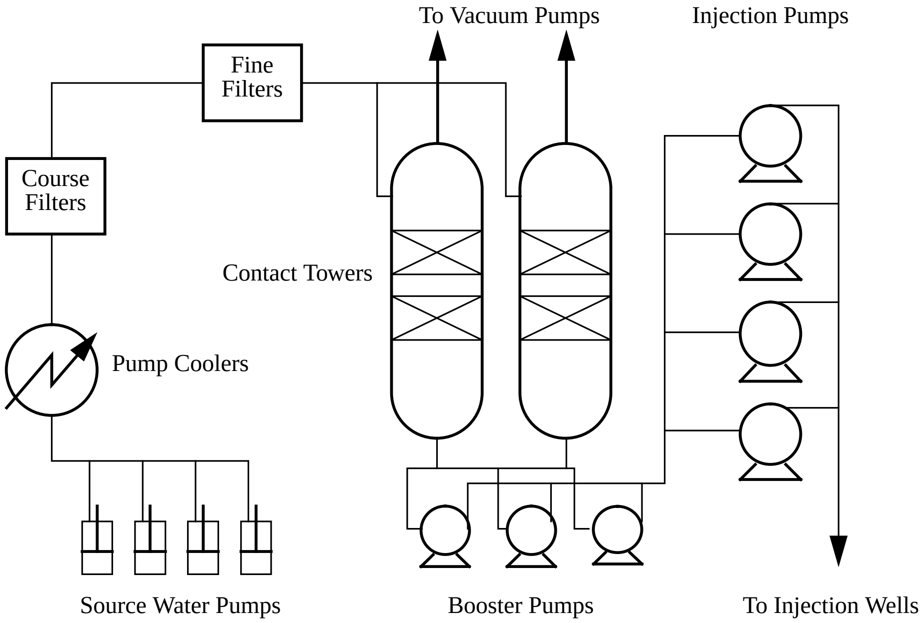
The incident report will be compared with the task inventory. Discrepancies may suggest deficiencies in the incident investigation or the need to update the task inventory.

6. EXAMPLE

A simple study was performed on the Water Injection unit of a North Sea oil production platform. The details below were collected during a visit to the platform; from training manuals, daily logs and reading sheets and written procedures, and backed up by observation and discussion with the unit operator at the time.

6.1. SYSTEM DESCRIPTION.

The basic objective of the unit is to "Provide very clean water at the required pressure and rate" to each of the injection wells. The overall platform objective is "Safe, efficient and profitable oil and gas recovery."



Source water pumps draw water from the sea which is injected, via injection wells, into the oil reservoir. As water is more dense than the oil it occupies the bottom of the reservoir filling the void left by the removed oil whilst also forcing the remaining oil towards the surface to allow its recovery. The system is essential for good oil production.

Pure sea water has a number of properties that are undesirable for injection into the oil reservoir and hence the water requires a number of treatment stages. It is this treatment that introduces a number of hazards to an essentially non-hazardous sea water system, that have to be addressed.

Suspended solids injected into an oil reservoir can block the pores in the rock leading to oil recovery problems. Coagulant chemicals are added to the water and the filters remove the solid particles.

Dissolved oxygen in sea water is the main reason for its high corrosiveness. Contact towers held under vacuum and oxygen scavenging chemicals are used to reduce the concentration.

Bacteria in the water can form slime causing fouling problems. Anaerobic action on sulphate ions, as present in sea water, can lead to the formation of Hydrogen Sulphide which causes corrosion problems. Chemical treatment at the source water pump suction is used to remove bacteria.

Sea water is relatively hard and hence at temperature above 40^{o}C calcite scale is liable to be formed. The temperature of the water is generally below this but scale inhibiting chemicals are used when conditions may cause scale such as when injecting water into a new well, injecting into a hot reservoir or when an injection well is being closed in.

6.2. HAZARDS.

The unit is regarded as relatively safe compared to other units on the platform because it handles non-hazardous sea water. The above description, however, has uncovered a number of hazards present. These include:

- Chemicals used as coagulant at filters, oxygen scavenger, biocide and scale inhibitor,
- High pressure at injection pump discharge through to the well head,
- Vacuum at the contact towers,
- Possibility of oil and gas in the well head area,
- Moving machinery associated with all pumps and there motors.

In addition there are a number of conditions that increase the chances of human error. These include:

- Difficult access and tripping hazards in the area,
- High noise levels causing communication problems,
- Adverse weather conditions.

6.3. TASK INVENTORY.

An inventory of routine tasks performed by the personnel operating the unit has been created. It shows the types of actions performed to continuously operate the unit, routine jobs required to ensure operation is reliable and some of the tasks aimed at checking the performance of the unit. This list includes some of the tasks included in the inventory.

- Changing pumps in and out of service and mechanical isolations,
- Opening and closing injection wells,
- Setting filter backwash timing,
- Connecting and disconnecting chemical tanks,
- Cleaning filters,
- Controlling injection pump recycle,
- Well sand wash and back injection,
- Setting chemical dosing rate,
- General unit walk about and completion of reading and status sheets.

6.4. POSSIBLE INCIDENTS.

By considering the hazards present and routine tasks performed by the operators we can determine the types of incidents that may occur either.

Immediate Effects.

For any of the chemicals, contact with skin or inhalation of vapours may cause injury whilst a spillage may cause environmental damage. Any errors made during routine tasks handling chemicals would have the potential to cause an accident.

The injection wells in use are selected to provide the most effective production from the water pressure and flow available. Errors in selecting the wells will effect production. The opening and closing of the wells is achieved from the well head area. This is designated as a high risk area due the chance of explosive gases being present.

It is the operator's job to operate the equipment appropriately, errors may cause lost production. They are also required to isolate equipment for maintenance work and hence errors here may cause injury or damage.

Long Term Effects.

Operating the unit with high concentrations of dissolved oxygen or bacteria will lead to corrosive conditions in the equipment. This may lead to long term effects resulting in equipment and piping failure leading to lost production, cost of replacement equipment and the potential to cause injury due to the release of high pressure water.

Failure to remove suspended solids due to poor operation of filters or dosing of chemical will result loss in production due to blocked pores in the rock in the reservoir. The situation can only be reversed using chemicals or explosive fracture.

Scaling and bacterial growth in equipment will cause fouling and effect production. It will require chemical treatment or replacement of equipment to rectify. The fouling may also be toxic hence be a hazard when removed.

Knock-On-Effects.

The source water pumps deliver water to a number of pump and compressor coolers in other units on the platform. Losing control of this water flow has the potential to cause overheating of the equipment, excess oxygen in the injection water because it is too cool in the contact towers, or scaling in the injection equipment because it is too hot

A serious example of where actions on the unit can seriously effect another area is the operation of source water pumps. If an incorrect one is started, due to incomplete isolations, communication problems or human error, divers lives are at risk if they are working under water in the vicinity of the intake.

A simpler example is washing down the area which will be required regularly as chemicals and oil will collect on surfaces over time. Being a multiple level system there is a very real chance of washing unpleasant substances onto people working below.

6.5. RECOVERY.

The routine tasks of the operators provide a number of opportunities for recovery from errors made. The general plant walk-about is completed several times per shift, looking for unusual conditions. Reading sheets are completed twice per shift that record conditions such as bearing temperatures, chemical dosing rates, water injection rates. Status sheets are completed at the end of each shift recording what equipment is in use, on stand-by or unavailable due to break down or maintenance.

The control systems on the unit include a number of alarms that alert the operator to unusual conditions outside set parameters, with automatic shut-down for severe deviation from normal.

6.6. OBSERVATION RESULTS.

A number of issues were uncovered concerning what actually happens during tasks compared to ideal situations. Some are listed below and should be considered when looking at the causes of incidents.

- Valves that are rarely used are difficult to turn or lock off as required for isolations during maintenance,
- Even routine tasks such as monitoring and the unit walk-about may involve risks as they involve climbing and entering high risk areas,
- Routine tasks may not be completed during times of high activity due to maintenance work or plant up-sets,
- Most equipment is controlled locally and is spread throughout the platform,
- Very few written procedures exist for routine tasks.

6.7. RESULTS FROM THE TASK INVENTORY.

The results from the task inventory completed on the water injection include:

- The objective: to produce water at the required conditions to contribute to the overall platform objective of producing oil and gas,
- A block diagram showing all the major items of equipment and how they are connected,
- The conditions and chemicals required to reduce the probability of corrosion, blocked rock pores, scaling and fouling,
- An inventory of chemicals, hazardous process conditions and high risk areas,
- Environmental conditions on the unit that may induce human error,
- An inventory of routine tasks performed,
- A summary of the possible adverse conditions, latent errors and local triggers that may occur should the unit objectives not be met,
- The regular checks made and alarms in the control systems that allow recovery from errors made,
- Observations of the actual conditions and operation of the plant that may be significant when considering operational and safety issues, and during the investigation of incidents.

6.8. APPLYING THE RESULTS TO INCIDENT REPORTING.

The task inventory has highlighted the following questions that should be answered during the investigation of incident occurring on the unit.

- Which of the unit's objectives were not met during the incident and did this effect the platform's performance?
- At which item of equipment or area of the unit did the incident initiate and how were other areas or units affected?
- Which of the chemicals or hazardous conditions mentioned were present during the incident and was their control lost?
- Did the incident increase the probability of corrosion, rock pore blockage, scaling or fouling?
- Which of the tasks, from the inventory, were being performed before and during the incident?
- Were all the routine checks performed before the incident and do they indicate any abnormal conditions?
- Were any errors made before or during the incident and were they caused by access or tripping hazards, high noise levels or adverse weather conditions?
- Did the incident occur in a high risk area of the unit?
- Did the alarm and shut down devices function as required?
- Did any of the observed, abnormal conditions cause problems before or during the incident?

By completing the task inventory, as described, a number of scenarios have been predicted and from these, the significant features to be considered when investigating incidents have been identified. The main objective is to determine the possibility of latent errors entering the system during the incident and if any events occurring could have, or did act as local triggers.

7. CONCLUSION.

The aim of this study is to improve safety, by reducing human errors, through a more effective incident reporting system. To achieve this a high level task analysis, of individual units on a plant, is used to identify the critical elements, human interactions and hazards involved. This analysis is used to predict possible system failures which may introduce resident errors or will result in events that act as local triggers.

The advantages of such an approach, as opposed to using standard reporting procedures, is that it is focused on what actually happens during operation on each unit. The information collected is used to suggest how incidents occur, the likely consequences and how the affects can spread. This results in highlighting critical areas of the unit that must be considered when investigating incidents and the important information that should be collected.

Such a task inventory is simple to perform, using plant documentation backed up by brief discussion and observation on site, but can provide a valuable source of information to be used during any safety analyses carried out. Combining it with the incident reporting system ensures that it is kept up to date and accurate.

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