Development of a Creeping Change HAZID Methodology

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Creeping change is the accumulation of small changes which often go unnoticed, and due to their gradual nature they are difficult to identify and monitor, often resulting in no hazard identification or risk assessment studies.

Following a presentation on creeping changes at Hazards 25 (Goff, 2015) the Energy Institute commissioned The Health and safety laboratory (HSL) to carry out a study on a Creeping Change HAZID (CCHAZID); the aims of this work were to develop and pilot a methodology to identify creeping changes and a set of keywords to be used. This paper documents the development of the CCHAZID and the lessons learned from the pilot studies conducted within the power and petrochemical industry; however the technique could be applied anywhere where there is a reliance on ageing plant, or equipment with many or compound changes.

The CCHAZID uses a similar approach to that used in a conventional HAZID study, in that keywords are used with a team of people from a wide range of appropriate disciplines to trigger discussions and brainstorm any potential issues. It is designed to be a screening tool and is faster paced than a conventional HAZID, and as such it is designed to be able to review a site in a relatively short period of time. The ultimate aim of the CCHAZID is to identify weak or overlooked areas, which can then be explored further and addressed.

The results of this work, including the keywords developed, are to be published as guidance by the Energy Institute.

Introduction

Creeping change is the accumulation of small changes which often go unnoticed, which can add up to a significant change, but because they are gradual in nature, no hazard identification study or risk assessment has been performed. They are gradual, unseen and not planned, and because of this can be difficult to monitor. (For example, the increase in the number of fuel leaks on the Nimrod aircraft that exploded over Afghanistan was not noticed as these were considered low risk (Haddon-Cave QC, 2009)).

Following a presentation on creeping changes at Hazards 25 (Goff, 2015) the Energy Institute commissioned The Health and Safety Laboratory HSL to carry out a study on a Creeping Change HAZID (CCHAZID); the aims of this work were to develop and pilot a methodology to identify creeping changes and a set of keywords to be used. This paper will document the development of the CCHAZID and the lessons learned from the pilot studies conducted within the petrochemical industry.

Creeping changes are a safety risk that has only relatively recently been highlighted as a significant issue. The Health and Safety Executive’s (HSE) Key Programme 4 (KP4) on Ageing and Life Extension in the offshore oil and gas industry identified ‘creeping changes’ as a challenge to safety offshore and found that there were insufficient systems to deal with this risk. One of the recommendations from KP4 was to use audits to identify and manage creeping change (HSE, 2014).

Types of creeping change

Creeping changes can occur in many different forms and problems often occur when these changes interact and/or are cumulative. Creeping changes are relevant across a wide range of disciplines including (but not limited to) process safety, mechanical engineering, electrical control and instrumentation (EC&I) and human factors. Some examples of types of creeping change are:

- Ageing (including degradation and obsolescence);
- Process changes;
- Equipment/infrastructure changes;
- Management/ownership changes;
- Workforce change/loss of skills;
- Operational Risk Assessments (ORAs)[a]/Management of Changes (MOCs)[b]; and
- Culture changes.

Further details on creeping changes can be found in Goff (2015).

[a] ORA is the term used in the offshore oil and gas industry for the process where degradation of safety critical barriers is managed, allowing production to continue with mitigation measures put in place (if needed). Problems can occur in understanding the effects of multiple ORAs that interact.

[b] MOC is the process of managing planned changes to ensure that risks are controlled.

Creeping Changes in Major Accidents

Creeping changes have been identified as a contributory factor in many major accidents, including the Nimrod loss, Texas City, the Space Shuttle Columbia and the Kings Cross fire. Details on the contribution of creeping changes to these accidents are described in Goff (2015), a brief overview of the Nimrod loss and Texas City is given below.

Nimrod

On 2 September 2006 an RAF Nimrod MR2 was lost over Afghanistan killing 14 service personnel on board. The subsequent investigation found that a fuel leak or overflow after air-to-air refuelling caught fire and led to the aircraft exploding. An independent review into the causes was led by Charles Hadden-Cave QC3 (2009) (referred to as The H-C Review).

There was a fourfold increase in fuel leaks between 1983 and 2006 to around 40 per year; this was not identified as no trend analysis was performed. Leaks on large legacy aircraft were viewed as inevitable (Haddon-Cave called this 'normalisation of deviance') and aircraft were designed to be "leak tolerant"; however it is not possible to control all ignition sources.

The H-C Review found numerous contributory factors including:

- *"a Safety Case regime which is ineffective and wasteful;*
- *an inadequate appreciation of the needs of the Aged Aircraft;*
- *a series of weakness in the area of Personnel;*
- *a Safety Culture that has allowed 'business' to eclipse Airworthiness."*

There was a failure to learn lessons from previous incidents (from both the Nimrod and other MOD aircraft); they were treated as one off incidents rather than looking at the wider implications. There was a failure to join the dots between incidents that in themselves were not safety critical, but in combination did lead to something more serious.

The H-C Review also found parallels with loss of the NASA Space Shuttle Columbia (2003), the Zebrugge Disaster (1987), King's Cross Fire (1987), The Marchioness (1989) and BP Texas City (2005); identifying that organisational causes are fundamental to many major accidents.

Texas City

The explosion at BP Texas City in 2005 killed 15 and injured nearly 200; its causes have been investigated and widely written about (Hopkins, 2009). A distillation column was overfilled, and on start-up flammable material expanded into the gas line at the top of the column and out of a vent; releases from that unit had resulted in vapour clouds at least six other times in the previous 10 years. The vapour cloud on this occasion was ignited by a vehicle that had been left running while unattended despite this action being contrary to procedures. There was a culture of "casual compliance" with procedures at the time of the incident, procedures were viewed as a guide rather than strict instructions; this was in part due to procedures being outdated.

The death toll was increased by the presence of temporary trailers to house maintenance workers from a nearby unit close to the distillation column. Trailers had been located in this area for 30 years during maintenance shutdowns, however nobody had ever questioned siting workers so close to hazardous equipment. Key creeping changes were therefore the reduction in the status of procedures and the long-term acceptance of temporary trailers close to hazardous equipment.

Almost everything that went wrong to cause this incident had occurred before, either at Texas City or elsewhere, yet the lessons had not been learned. It is vitally important to learn lessons from previous failures, as Judith Hackitt, then the Chair of HSE commented at the Piper 25 Conference:

> *".....there are no new accidents. Rather there are old accidents repeated by new people."*

Hopkins (2009) drew parallels with the losses of the Columbia and Challenger Space Shuttles in that there was a tendency to "normalise the risk": should a process be closed down or is it reasonable to accept an increased risk for a short period when a safety system failed? The longer this degraded state lasted, the more likelihood there was of normalising the risk. This parallels with the finding from KP4 that ORAs can be in place for extended periods; multiple ORAs for the same equipment make it more difficult to assess the consequences.

Creeping Change HAZID (CCHAZID)

The Creeping Change HAZID (CCHAZID) uses a similar approach to that used in a conventional HAZID study, in that keywords are used with a team of people from a wide range of appropriate disciplines (including operations and maintenance personnel) to trigger discussions and brainstorm any potential issues. These issues can then be discussed by the specialists to resolve the issue or be subject to follow up actions once the HAZID is finished. It is designed to be a screening tool and is faster paced than a conventional HAZID, and as such it is designed to be able to review a site in a relatively short period of time. The ultimate aim of the CCHAZID is to identify weak or overlooked areas, which can then be explored further and addressed.

Experience from KP4 and learning from major accidents involving creeping changes has suggested a multi-disciplinary approach is required. The CCHAZID covers both engineering (such as process safety, mechanical engineering, electrical control and instrumentation (EC&I), etc.) and human/organisational changes.

The CCHAZID was piloted with a company operating in the power and petrochemical industries as described below; however it could be applied anywhere where there is a reliance on ageing plant, or equipment with many or compound changes.

It is recommended that the CCHAZID forms part of the suite of safety studies used as part of the regular review of plant. Feedback from one of the pilot studies was that the company were going to use the outputs of the CCHAZID as part of their upcoming Process Hazards Review. A CCHAZID could be triggered outside of regular reviews if many or compound changes have been noted or if problems are developing. It is not intended that the CCHAZID replaces a conventional HAZID; the two are complementary techniques.

The CCHAZID was developed to be a formal safety study conducted in a similar manner to a conventional HAZID; however the keywords could be used as a checklist during reviews or in more informal discussions.

Keywords

The keywords used in the CCHAZID were developed from HSL's involvement in KP4 and wider knowledge of the high hazard industries. A brainstorming session was held with a range of experts to discuss the types of creeping changes that could occur and any keywords that could be used to prompt discussion of them during a CCHAZID.

It was found that for some creeping changes that keywords were appropriate to prompt discussion of them, while for others questions were needed. The keywords/questions were grouped into themes, with some of the keywords having further prompts or questions associated with them to direct the brainstorming to the relevant issues. The questions were left as open as possible so that any changes that had occurred and any issues that have arisen as a result of them could be discussed and documented. It was intended that some keywords were targeted at the organisation or site as a whole, while others were directed at discovering creeping changes to specific equipment or processes.

The keywords were around the themes of:

- Equipment and infrastructure changes;
- Process changes;
- Workforce and organisational changes; and
- Ageing plant changes.

The full list of the keywords will be included in the guidance to be published by the Energy Institute.

Pilot Studies

Three pilot studies were conducted with Centrica focussing on three different types of sites; these were:

1. A gas fired power station:

   Simple site with relatively few changes:

   - ½ day spent on a site wide study;
   - ½ day spent studying a specific piece of equipment.

2. An onshore gas terminal:

   Complicated site with extensive changes, however the site recently had the HAZOP updated:

   - 1 day spent studying a specific module.

3. An offshore gas storage facility:

   Moderately complicated site:

   - 1 day spent studying the entire site.

The teams at all three CCHAZID pilot studies were larger than would normally occur at a conventional HAZID; there was representation from the appropriate technical disciplines (e.g. process safety, mechanical engineering, EC&I), senior/management personnel, and operations and maintenance personnel. The size of CCHAZID team was due to the broad nature of the study.

Having this number of people present was valuable and facilitated the study hearing a wide range of opinions from different perspectives; however it did pose a challenge in managing the study as there was a tendency for several conversations to occur simultaneously. It is important that with team members at such different levels of seniority that all can speak freely and honestly.

The pilot studies were facilitated by a team of three; a chairman, a scribe and a third person to act as both technical expert and to help in developing the methodology. At the start of each CCHAZID, the study team were briefed on what creeping changes were and the type of issues that were to be discussed.

The participants were given a list of the keywords (including the further prompts/questions) so they knew what was to be discussed. The study leaders had some additional information or prompts on some of the keywords (which were not shared with the participants); these were used to further direct the conversations if required.

Relevant diagrams, photographs, etc. that would be used during a conventional HAZID were available during the study; these were required such that they could be referred to by participants so there was no confusion about what was being discussed. For the first two pilot studies a risk matrix (which contained definitions of frequency and consequence bands) was also given the participants; frequency and consequence scores were assigned to some of the potential problems and the matrix was used so that this could be done consistently.

The recording of the CCHAZID followed that of a conventional HAZID and recorded information the following categories:

- *Keyword/parameter;*
- *Prompt;*
- *Details;*
- *Consequence/problems;*
- *Consequence. Category;*
- *Frequency. Category;*
- *Consequence score x Frequency score;*
- *(Potential) Safeguards;*
- *Action No.;*
- *Actions/further studies;*
- *On who;*
- *Date (to be completed by); and*
- *Action priority (high, medium or low).*

It was decided after the first two pilot studies that assigning consequence and frequency categories to the identified problems (and calculating their product) added little value to the outcomes, so these categories were no longer recorded.

Gas fired power station

This was the simplest of the sites used in the pilot studies and it had had relatively few changes. The morning was spent on brainstorming for the entire site and the afternoon examining one specific piece of equipment (the steam dump). The steam dump was a relatively simple system that was ageing and starting to suffer problems as it is now used more frequently than it was designed for due to operational changes.

Onshore gas terminal

This study took place at a very complicated site that had undergone extensive changes, some of which were in response to an incident that had occurred. As part of the changes in response to the incident, the site had the HAZOP updated. Due to the complexity of the site, the CCHAZID focussed on just one module (Separation and Methanol Module), and this lasted the day allocated to the pilot. This site had recently had the HAZOP updated so there were less potential creeping change issues to uncover, however some problems were still found.

Offshore gas storage facility

This site had a level of complexity between those of the first two pilots; as a result the entire site was subject to the CCHAZID in one day.

Due to this study focussing on an offshore installation it was not possible to get operations and maintenance personnel who work offshore to attend the workshop. However, one offshore worker (Field Operations Superintendent and OIM) did attend the afternoon session of the workshop and added a great deal of knowledge that could only be gained through direct front line experience.

It was felt that personnel with direct experience of working on the installations added to the studies so every effort should be made to ensure they attend any future CCHAZIDs.

Outputs

The ultimate aim of the CCHAZID is to identify weak or overlooked areas, which can then be addressed. While the technique was piloted in and based on knowledge from high hazard industries it could be applied anywhere where there is a reliance on ageing equipment.

Atypical events can be classified for both awareness and knowledge using the Donald Rumsfeld classification system: known known; known unknown; unknown known; and unknown unknown (Paltrinieri, 2012). The CCHAZID aims to identify the unknown knowns; the things that have been overlooked or missed but which the company should be aware of, this then allows them to be managed correctly and safely. The CCHAZID could also identify the unknown unknowns, and at that point they will become known unknowns, allowing the company to put a study in place to gain further knowledge of that risk.

The three pilot studies uncovered a number of overlooked areas, for example:

- Study stalled because the person doing it had been moved to a new placement;
- No human factors input in a new design;
- The need to develop/improve process for succession planning and apprenticeships, and to identify gaps in roles and responsibilities;
- Increased training needs for new systems and processes;
- Problems in updating P&ID diagrams;
- Specific hardware issues;
- The need to develop rules for trip overrides in the ORA procedure.

Lessons Learned

The list of keywords used to provoke discussion was added to throughout the pilot studies, based on topics that arose or from feedback from the participants about other areas that should be addressed.

The CCHAZID could be used to study a wide range of targets including:

- a whole site or organisation;
- a defined module of plant;
- one particular piece of equipment;
- a barrier; or
- safety critical equipment.

During the pilot studies it was found that the CCHAZID methodology provokes the most useful discussions if applied to a large enough target for many and/or cumulative changes to have occurred, for example an entire site or a large section of plant rather than a small, relatively simple system or piece of equipment. There is inevitably a trade-off between having a suitably complex system to generate the most useful outputs and the time required for the study.

If applying the technique to a single piece of equipment, a barrier or a safety critical equipment it is recommend that the CCHAZID is divided into two parts; the first dealing with the site/organisation as a whole, then the second focussing in on the chosen specific target.

During one of the pilots, the CCHAZID methodology was applied to a site that had recently had the HAZOP updated. While that study found less potential creeping change issues than the other studies, it still found problems that related to changes recently made to solve other problems ('The law of unintended consequences'[c]).

The CCHAZID requires technical experts from the appropriate engineering disciplines (such as process safety, mechanical engineering, electrical control and instrumentation (EC&I)) depending on the nature of the site and/or equipment to be studied. During the pilot studies it was beneficial to have senior/management personnel taking part who have detailed knowledge of the site and/or equipment, management systems, future plans, etc. It was also very beneficial to have present operations and maintenance personnel who have direct experience of how things actually are and any problems that they and their colleagues are dealing with. There is however a trade-off between having the correct participants representing a wide range of specialities with the management of the study. It was found during the pilots that with larger study groups multiple conversations can occur simultaneously, this is a challenge for whoever leads to study to manage.

It is important during the CCHAZID with team members at such different levels in the organisation that all can speak freely and honestly, and there are no comebacks for raising controversial or uncomfortable issues or opinions ('Chatham House

[c] http://www.econlib.org/library/Enc/UnintendedConsequences.html

Rule'[d]). Therefore setting ground rules, making explicitly clear the purpose of the CCHAZID and assurance about confidentiality are crucial to success.

As the CCHAZID focuses on both engineering and human/organisational issues, it is recommended that the study leader(s) has a broad range of experiences that reflect the range of issues likely to be discussed. Whether a team of two (chairman and scribe) or three is required depends on the competencies of the people involved. It is recommended that the chair has at least a degree of independence; that could be a fully independent chair working for a third party or somebody from a separate part of the company who has no direct involvement with the facility being studied.

Conclusions

A hazard identification technique that can be used to help detect creeping changes has been developed, and this has been piloted at three very different sites within the power and petrochemical industries.

The CCHAZID could be used anywhere there is a reliance on ageing equipment that could be subject to many or compound changes, and is not solely for the high hazard industries.

It is suggested that the CCHAZID could form part of the suite of safety studies used as part of the regular review of plant in order to identify creeping changes. It is not intended that the CCHAZID replaces a conventional HAZID; the two are complimentary techniques. The CCHAZID was developed to be a formal safety study conducted in a similar manner to a conventional HAZID; however the keywords could be used as a checklist during reviews or in more informal discussions.

The results of this work, including the keywords developed, are to be published as guidance by the Energy Institute.

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