Creeping Change Hazard Identification (CCHAZID) for Managing Major Accident Hazards in a Dynamic Energy Sector during a Pandemic and Beyond

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Through necessity, the assessment and management of risk in the High Hazard Industries changed during the recent worldwide pandemic (COVID-19 outbreak declared a pandemic by the World Health Organisation (WHO) on 11th March 2020). This research paper explores some of the major hazard risks associated with such an event, as well as presenting a proactive and systematic methodology for managing risks associated with creeping changes. This work was aimed at identifying the most effective risk management approaches that could be adopted when faced with a phenomenon such as a global pandemic.

Creeping changes are gradual, often unnoticed shifts in organisational processes and site conditions that accumulate over time, posing hidden risks. In collaboration, the Health and Safety Executive (HSE) and E.ON have developed the Creeping Change Hazard Identification (CCHAZID) methodology to effectively manage these risks across a portfolio of decentralised energy generation sites.

In recent years, the energy generation industry has undergone significant transformations, characterised by technological advancements, a shift from centralised to decentralised generation, and evolving regulatory landscapes. The COVID-19 pandemic further introduced substantial changes in plant operations and working practices, particularly during the lockdown periods of 2020-2021. These cumulative changes can amplify the impact of creeping changes on risks associated with major accident hazards.

Recognising and effectively managing these evolving risks is critical for ensuring the safety of operational sites. The CCHAZID methodology provides a streamlined approach, designed as a screening tool that is faster and less detailed than traditional Hazard Identification (HAZID) studies. This enables the efficient review of numerous sites and organisational areas in a relatively short amount of time. The primary advantage of the CCHAZID approach is its capacity to quickly identify subtle or overlooked creeping changes, thereby allowing organisations to effectively implement actionable measures to prevent and mitigate the associated risks.

This paper will outline the impact of COVID-19 related changes on process safety management (including maintenance) as well as the CCHAZID methodology that was recently updated and developed collaboratively (the Health and Safety Executive (HSE) and E.ON) to effectively manage these risks across a portfolio of decentralised energy generation sites. By adopting the CCHAZID process, organisations can proactively address the risks linked to creeping changes and prevent the escalation of potential consequences that may arise from continuing with production as normal (normalisation of deviance). This proactive risk management framework not only enhances safety standards but also fosters a culture of continuous improvement and resilience.

Introduction

WHO declared the COVID-19 outbreak a pandemic on 11th March 2020. This event had repercussions around the world. The impact was felt by High Hazard Industries, including those generating energy, who had to find ways of continuing energy production while at the same time managing the risks that arose due to pandemic related change. The UK's Health and Safety Executive's (HSE's) initial response to the pandemic was to provide short term guidance, for example on the assessment and management of fatigue and staffing [1].

It became increasingly evident that there were potential wider and longer-term implications for risk management, arising from changes in the way that plant and processes were being operated during the COVID-19 pandemic. These changes in risk emanate from changes in practicalities in both staffing levels/availability (sickness absence, self-isolation, shift rotas, maintenance backlogs, process automation, plant/process shutdowns and subsequent restarts etc.) and working practices (to reduce COVID-19 transmission). Temporary loss of key staff could lead to short term critical skill shortages that in turn

[1] https://www.hse.gov.uk/comah/assets/documents/managing-staff-levels-fatigue-during-the-coronavirus-comah.pdf

could increase the risks associated with major accident hazards. Being unaware of the potential consequences of this creeping change (i.e. when key staff are not available), could result in continuing with production as normal.

Research on creeping change has been carried out by HSE for several years (Goff et al, 2015, Goff et al, 2017 and Goff 2017). Having carried out research work offshore (HSE's Offshore Key Programme 4) and presenting some initial findings on creeping change at Hazards 25 (Goff, 2015), the Energy Institute commissioned HSE's Science Division (at the time called the Health and Safety Laboratory) to carry out a study on a Creeping Change HAZID (CCHAZID) Creeping changes are gradual, often unnoticed shifts in organisational processes and site conditions that accumulate over time, posing hidden risks. Work was carried out to develop and pilot a methodology to identify creeping changes and a set of keywords to be used. In 2017 another paper (Goff, 2016) was presented that documented the development of the CCHAZID and the lessons that were learned from the pilot studies conducted within the petrochemical industry.

As the outbreak of the pandemic took hold (2020-2021), the response of Governments around the world introduced restrictions to everyday activities, including within the workplace. Many employers and employees (including health and safety professionals, researchers and those working in High Hazard Industries) started to feel a chronic unease that if left unchecked, these changes, to the way work was now being done, could potentially lead to a major incident. In line with these concerns HSE raised the research idea of how possible changes in the assessment and management of risk in High Hazard Industries during an event, such as a worldwide pandemic, impacted on health and safety in the workplace. The work was relevant at the time and is likely to be relevant when planning for similar events (i.e. pandemics) in the future.

In recent years, the energy industry has undergone significant transformations, characterised by technological advancements, a shift from centralised to decentralised generation, and evolving regulatory landscapes. These cumulative changes can amplify the impact of creeping changes on risks associated with major accident hazards, meaning a proactive approach for identifying creeping change is required.

Recognising and effectively managing all of these evolving risks is critical for ensuring the safety of operational sites. The CCHAZID methodology provides a streamlined approach, designed as a screening tool that is faster and less detailed than traditional HAZID studies. This enables the efficient review of numerous sites and organisational areas in a relatively short amount of time. The primary advantage of the CCHAZID approach is its capacity to quickly identify subtle or overlooked creeping changes, thereby allowing organisations to effectively implement actionable measures to mitigate the associated risks.

By adopting the CCHAZID process, organisations can proactively address the risks linked to creeping changes and prevent the escalation of potential consequences that may arise from continuing with production as normal (normalisation of deviance). This proactive risk management framework not only enhances safety standards but also fosters a culture of continuous improvement and resilience.

This paper is split between three strands of research:

- Investigation of pandemic related risks and implemented control measures
- Investigation of maintenance and inspection at High Hazard sites during the COVID-19 Pandemic
- Discussion of an implementation of the CCHAZID approach in collaboration between HSE and E.ON

Investigation of pandemic related risks and implemented control measures

Overview of methodology

A literature review and workshops took place to identify generic pandemic risk factors and measures being implemented by duty holders to meet Covid-19 guidelines and the implications for management of Major Accident Hazards (MAH): Relevant existing industry wide sources were reviewed to uncover evidence of relevant work conducted into pandemic related risks and the related control measures (interventions) implemented in the UK and beyond. Databases were searched for general pandemic related plans and guidance information published post 2015 in scientific journals and grey literature (i.e. unpublished reports) using combinations of search terms. Search terms applied for the searches included pandemic plans for high hazard industries, process safety, human factors (HF) and risks assessment. The searches were aimed at uncovering evidence of:

- Existing work related to COVID-19 and major accident hazard tools/methods for identifying and sharing generic Process Safety and HF issues related to COVID-19.
- Existing work related to COVID-19 and major accident hazard.
- Generic process risks related to pandemics.
- Generic human factor issues and coping methods

Overall, eighteen (18) papers or reports were selected for this rapid evidence review (Ancillo, et al., 2020; Anderson, 2021; Biddle et al., 2021; Bragatto et al., 2021; Chin et al., 2020; Dubey et al., 2020; Jones, 2020; Kadri et al., 2020; Kelly, 2021;

Kerin, 2020; Kim, 2020; Maamri et al., 2021; Nguyen et al., 2021; Secombe & O'Keefe, 2021; Shaw, 2020; Sun et al., 2020; Sunandar & Ramdhan, 2021; Vairoa et al., 2018). These covered five types of studies (Surveillance, Reviews, Guidance, Expert Position, and Maintenance), and they related to situations in four general industry sectors (Oil & Gas, Other Energy Sectors, Chemical Processing; and, Various/Non-Specific).

Secondly, consultations were held with key relevant HSE functions (Regulatory Inspectors and Human factors [HF], Process Safety [PS], and Electrical Control and Instrumentation [EC&I] Specialist Inspectors/Team Leads). The consultations included workshops to seek their views, and to validate the findings.

Thirdly, the identified implemented measures were evaluated against existing risk assessment approaches and implications for management of MAH.

Four research questions were defined:

1. What specific measures are implemented to meet the national guidelines?
2. What are the effects of the implemented guideline measures on the operational safety profile of sites?
3. Have site operations and risk assessment changed during the pandemic?
4. What evidence exists about resilience for future upsets (including pandemic and other challenging situation)?

The findings are outlined below.

Measures implemented for worker protection (Ancillo et al., 2020; Anderson, 2021; Biddle et al., 2021; Bragatto et al., 2021; Dubley et al., 2020; Jones, 2020; Kerin, 2020;Kim, 2020; Maamri et al., 2021; Nguyen et al., 2021; Shaw, 2020; Sun et al., 2020; Sunandar & Ramdhan, 2021; Viaroa et al., 2018)

To meet national guidelines, two general groups of measures were identified: onsite precautionary measures, and advanced precautionary measures.

On-site precautionary measures include measures such as: social distancing and personal hygiene measures; use of PPE e.g. face masks/coverings; remote working and sundry activities; changed work schedules; environment sanitising/cleaning regimes; health status monitoring and education; on-site segregation, such as workspace alterations, engineering controls and physical barriers/partitions.

Advanced precautionary measures, such as: pre-employment and offsite periodic medical check-ups (MCUs) and preventative isolation from exposed or potentially sick family members; monitoring of personal health and prediction of future health incidents through big-data analytics and wearable devices; and mental health-assistance programmes including stress and anxiety management.

Effects of the implemented measures (Biddle et al., 2021; Bragatto et al., 2021; Dubley et al., 2020; Jones, 2020; Kelly, 2021; Kerin, 2020; Kim, 2020; Shaw, 2020; Sun et al., 2020)

Four general effects of implemented guideline measures on the operational safety profile of sites were identified: Social distancing, remote working, cohort/staged working, and plant and process modifications.

The effects of implemented social distancing measures generally manifested as: reduced number of workers on site; emergency and maintenance management difficulties; reduced ability to perform tasks needing close contact of staff; reduced technical abilities, due to insufficient or no proactive staff training; and/or storage of larger than usual number of hazardous materials.

The effects of implemented remote working measures manifested as: postponed or delayed risk assessments, and tendency to accept a higher risk of failure; tendency to forego maintenance activities during critical times; difficulty keeping to set programs/plans and work procedures, e.g. safety training and inspection; and reports of mental health problems.
The effects of cohort/staged working measures manifested as: further threatened continuous operation of critical infrastructure functions, due to cohort workers becoming infected at the same time; and, unclear task assignments, and unreasonable scheduling due to changes to staff roles and secondments.

The effects of plant & process modifications measures manifested as: reduced number of active workstations; modified workplace layout; change in office timings.

Measures implemented for site operations/risk assessment (Anderson, 2021; Biddle et al., 2021; Bragatto et al., 2021; Chin et al., 2020; Dubley et al., 2020; Kadri et al., 2020; Kelly, 2021; Kerin, 2020; Nguyen et al., 2021; Seccombe and O'Keefe, 2021; Shaw, 2020; Sun et al., 2020)

Concerning ability to sustain site operations and risks assessments, some changes to site operations and risk assessment had occurred during the pandemic. Across the studies reviewed, these are identified under five general groups of operational

changes: reporting and data sharing, use of existing Safety Management System (SMS) procedures; introduction of new/modified procedures; maintenance procedures, and risk assessment control.

The reporting and data sharing changes were about: encouraging use of real-time data to monitor situations and to make decisions that could reduce the impact of the pandemic; focused actions for operational continuity; effective leadership team engagement and communication, and sustained workforce confidence through timely leaderships' response, and effective engagement and communication.

The enhanced use of existing SMS procedures changes were about: encouraging regular review and challenging of site inspection plans; application management of change (MoC) procedure on all modifications (no matter how small); increased frequency (daily) of site inspections, to identify and eliminate all issues of concern; and revision of emergency response measures/plans to prevent the escalation of accidents and compromised response of workers.

The introduction of new/modified procedures changes were about: encouraging reformulated work procedures aimed at decreasing the risk of virus exposure to personnel; collaborative working and positive work environments; application of digital technologies such as wearable trackers and 3D printing, for health monitoring; and digital collaborations; and, reorganisation of production and plant for improved safety of stored chemicals.

The maintenance procedures changes were about: encouraging and implementing latest technology, using direct replacements instead of critical evaluation of the maintenance plans; rigorous risk analysis with consideration for the consequences of aging equipment failures and coordinated program for dealing with them; and increased use of 'maintenance deferral' as a tool for balancing competing priorities.

The specific risk assessment and control procedures changes were about: encouraging increased frequency of risk assessments and maintenance tasks and facilities reliability assessments; stricter management of safety critical elements including evaluation of new scenarios and contingency management; application of administrative controls and personal protective equipment (PPE) and virtual tools e.g. drones and video interviews; and development of new risk based process safety frameworks, and hazard identification measures.

Measures for resilience and future upsets (Ancillo et al., 2020; Anderson, 2021; Biddle et al., 2021; Bragatto et al., 2021; Chin et al., 2020; Dubley et al., 2020; Jones, 2020; Kadri et al., 2020; Kelly, 2021; Kerin, 2020; Maamri et al., 2021; Nguyen et al., 2021; Seccombe and O'Keefe, 2021; Shaw, 2020; Sun et al., 2020; Sunandar & Ramdhan, 2021; Vairoa et al., 2018)

Concerning existing evidence for resilience and preparedness for future upsets, four aspects were identified from the studies reviewed as needing focused attention: operational procedures, maintenance procedures, pandemic modelling, and risk assessment.

Operational procedures: The measures proposed relate to the need for strong leadership engagement, positive safety culture, a collaborate approach to problem solving; re-imagined, re-improved and re-invented workplaces; minimizing of anomalies/situations with potential to cause problems; need for robust business continuity plans consistent use of operational terms and continuous investigation of operational risks; flexible decision-making structure; commitment to resilience and harmonisation within SMS; development of solutions to grow organisational resilience in the long term; and, deployment of digital tech to improve the organisational capacity to deal effectively with future outbreaks.

Maintenance procedures: The measures proposed are about the need for fault propagation modelling, and frameworks or tools for time-variant data inputs; risk modelling and data-driven risk quantification; ageing and creeping change considerations, including detection and measurement of ageing, and better understanding of pitfalls that negatively influence safety and environmental performance.

Pandemic modelling: The measures proposed are about development of pandemic management procedures; epidemic management models; methodologies for identifying and dealing with the impact of a pandemic; and ability to more effectively reduce the probability of accidents within a limited time.

Risk assessment: The measures proposed are about encouraging healthy preoccupation with failure, reluctance to simplify and sensitivity to operations; procedures for identification of new sources of risk from implemented new processes; and implementation of plans that consider all risks associated with change, including those affecting mental health.

Literature review and workshops conclusion

The work undertaken indicated, overall, adequate capability of sites to maintain safety during the pandemic crisis. Combined with industry association initiatives, the ability to handle both the usual safety procedures and new health procedures can be increased.

However, three sources of risks that could introduce creeping changes during operation of hazard process industries were identified: General risks; maintenance management risks; and risk assessments.

General risks relate to personnel reduction, psychosocial stress of personnel (potentially leading to difficulty keeping to plans), staff (potentially leading to deficiencies in training on operating critical infrastructure functions); high work pressures; use of face covering (potentially leading to verbal communication difficulties), and inefficient information exchange.

Maintenance management risks relate to social distancing, which could lead to reduced ability to undertake close contact tasks; urge to ignore physical warning signs of aging equipment; and tendency to forgo maintenance activities during critical times.

Risk assessments risks relate to confounders such as high work pressures; postponed or delayed activities; and tendency to accept higher risk of failure.

Investigation of maintenance and inspection at High Hazard sites during the COVID-19 Pandemic

Introduction and Context

The COVID-19 pandemic presented unprecedented challenges to industrial operations, particularly in high-hazard sectors where maintenance and inspection activities are critical to ensuring safety and operational integrity. High hazard sites, such as chemical processing facilities, petrochemical plants and major infrastructure networks, operate under stringent safety regulations such as those outlined in the Control of Major Accident Hazards (COMAH) regulations.

Research Rationale

This research strand aimed to examine in some detail how the Covid-19 pandemic impacted on companies' ability to carry out their required maintenance activities, including inspections and audits. This information will help inform HSE about the organisational resilience, risk management paradigms, and a socio-technical systems approach used by high hazard companies to meet national guidelines during the Covid-19 pandemic. The core objective was to identify how companies dealt with operational disruptions and subsequent adaptive strategies employed by organisations managing maintenance activities in high-risk industrial environments during a global pandemic.

Research Methodology

Researchers for this phase of the research (investigation maintenance and inspection activity at High Hazard sites during the COVID-19 Pandemic) began with the development of a comprehensive questionnaire distributed to operators of high-hazard sites. Following discussions with HSE's Science Division Ethics Officer, it was decided that ethics approval was not required for this questionnaire because it was completed anonymously by participants and was not sent to specific named people. The questionnaire was strategically structured across three primary domains: general COVID-19 impact assessment (18 questions), maintenance and inspection deep dive (13 questions), and strategic outlook and future preparedness (5 questions). These domains are crucial for ensuring safety, especially under the unprecedented circumstances posed by the pandemic.

The study systematically explored critical questions across multiple maintenance management dimensions, focusing on understanding how organisations navigated the complex challenges presented by the pandemic. The questions were a mix of multiple choice and free text answers, which were analysed quantitatively and qualitatively by the researchers.

The questionnaire was developed by the research team to reflect issues of interest to the Health and Safety Executive (HSE) in this work. We identified potential respondents working at Control of Major Accident Hazards (COMAH) sites in the UK, utilising HSE contacts and established networks. Having sent out a number of questionnaires to COMAH sites we received seven responses.

Due to the low number of questionnaires returned, the limited sample size of seven questionnaires distributed across seven high-hazard sites, the results are not statistically significant, but provide a qualitative snapshot of duty holder perspectives.

One of the key issues was the questionnaire's length, which included over 30 questions. It was noted that towards the end of the questionnaire, responses became progressively shorter, with fewer respondents completing all sections. This was an anticipated challenge, which is why the questionnaire was strategically designed to position the most critical questions addressing the key information requirements at the beginning, while the supplementary or 'nice to have' questions were placed towards the end.

It was also observed that despite collecting and analysing responses anonymously, there was potential for respondents to provide answers they believed HSE would want to hear.

The researchers acknowledge potential limitations, including response bias, a limited number of responses, and the potential impact of survey length on response quality.

Maintenance Management Findings

Risk assessment techniques remained largely consistent during the pandemic, with some companies noting risk modifications in evaluating human interactions. Most respondents did not observe significant additional equipment degradation during site shutdowns, though some raised concerns about potential plant degradation.

Communication of risk changes predominantly occurred through virtual meetings, with supplementary information shared via email. Crisis management approaches varied significantly, with some organisations having pre-existing plans and others developing them during the pandemic; this variation in preparedness likely influenced how well companies managed the crisis. For example, one company managed the crisis as a "general infection control process, on a company wide scale", with accurate and effective communication of all relevant information.

Maintenance activity management revealed interesting patterns. Responses were evenly split between those deferring non-critical maintenance and those maintaining their regular scheduling. Some organisations specifically deferred turnaround and periodic maintenance activities. Primary deferral challenges cited included supply chain disruptions, reduced on-site staffing due to physical distancing requirements, and contractor shortages which slowed down work activity.

Permit to work procedures remained largely unchanged, with most respondents indicating no significant modifications. Companies focused primarily on essential maintenance, often performing safety-critical maintenance with core crews while attempting to maintain both proactive and reactive maintenance where feasible.

Human Resource Dynamics

Staffing levels showed nuanced changes, with more than half of respondents reporting no modifications. Administrative and management staff most readily transitioned to virtual work, while operational staff and contractors remained less likely to do so. The transition of management staff to virtual working could have led to a decreased amount of safety management staff onsite, creating a safety skills shortage. This would disproportionally affect older safety staff who may have been isolating at home for health reasons.

Organisations implemented various adaptive strategies, including staggered break times and access to work areas, creation of bubble groups, and reserve teams. Physical working arrangements underwent comprehensive modifications: increased cleaning protocols, reduced staff per task, and installation of physical barriers became standard practice. One company highlighted that they created extra space for workers using portacabins.

Every respondent implemented critical risk management measures such as lateral flow or Polymerase Chain Reaction (PCR) COVID testing, social distancing, face coverings, physical barriers and enhanced cleaning. Although these changes were critical in managing the risk of contracting COVID, these measures may not be sustainable in high-risk workplaces in the long term. Communication challenges emerged, including difficulties in shift handovers and reduced communication quality due to face coverings.

Inspection and Audit Activities

Inspection and audit schedules demonstrated more variability compared to general maintenance activities. Most respondents partially deferred their inspection schedules, with some organisations adopting virtual inspection methods. This was due to the general industrial approach that non-essential site visits were postponed. However, certain high-risk workplaces, such as offshore platforms did carry out essential, safety critical inspections as planned. The Health and Safety Executive conducted some inspections virtually during this period.

Inspections that did take place noted the used of social distancing and personal protective equipment. Some companies identified additional COVID risk reduction measures to put in place, such as surface cleaning, after performing a self-verification exercise.

Future Preparedness and Insights

Most respondents expressed confidence in their ability to respond to future pandemic scenarios. They believed they could define worksite responses, ensure site safety, establish minimum safety requirements and respond to a major accident hazard during pandemic conditions.

Key insights gained from the pandemic experience included the effectiveness of remote working, importance of digital tools, need for improved communication strategies, value of flexible working arrangements, workspace redesign considerations, and increased awareness of colleague wellbeing.

Creeping Change Management

Organisations addressed the cumulative effect of small changes over time (creeping changes) through regular assessment of operational, asset, and cumulative risks. Approaches emphasised effective planning, employee engagement, and prioritisation of backlog activities.

High Hazard Industry COVID Questionnaire Conclusion

The findings highlight the remarkable resilience and adaptability of high-hazard industries during the COVID-19 pandemic. They provide valuable insights into organisational responses to systemic disruption and identify areas for continued improvement in industrial safety and maintenance practices.

Discussion of an implementation of the CCHAZID approach in collaboration between HSE and E.ON

The third strand of this paper outlines the collaboration between HSE and E.ON, which includes:

- Identifying the need for a systematic approach for assessing creeping change in the energy industry, and why "traditional" HAZID assessments exhibit inherent limitations in detecting and managing "creeping changes"
- Development of a CCHAZID methodology that suited E.ON UK's portfolio of centralised and decentralised energy generation sites
- Implementation of the new CCHAZID methodology and an assessment of its benefits
- Concluding remarks and future CCHAZID developments.

Limitations of "Traditional" HAZID assessments in identifying and managing creeping change

Traditional Hazard Identification (HAZID) methodologies are effective at identifying clear and significant hazards but may have limitations in detecting and managing "creeping changes," due to several factors:

- Gradual nature: Creeping changes accumulate slowly over time, which are sometimes not recognized because they may not individually reach a threshold that prompts a formal review during periodic HAZID studies.
- Unplanned and unseen: Unlike major changes that are often planned and documented, creeping changes often occur without formal approval or documentation. This makes them harder to track and identify, as they may not be captured in official records or procedures.
- Lack of clear indicators: Creeping changes typically do not present immediate warning signs, instead appearing as minor incidents or deviations that might be considered insignificant when viewed in isolation.
- Focus on major hazards: The typical focus of conventional HAZID studies on major hazards with high-consequence potential can also contribute to the under recognition of the cumulative impact of smaller, less apparent changes.
- Organisational culture and mindset: Organisations may sometimes focus on short-term objectives or immediate safety concerns rather than long-term safety due to available resources.

Why is creeping change becoming an ever more important issue within the Energy Industry and beyond?

The increasing complexity of current industrial operations, along with evolving organisational dynamics and reduced oversight necessitates a systematic approach to proactively identify and manage creeping change hazards before their cumulative effects lead to significant risks:

Increased Complexity:

- Technological advancements: New technologies often introduce complex systems and processes that may not be fully understood or risk-assessed. This complexity can make it harder to identify and manage creeping changes, as they may arise from unforeseen interactions between different components.
- Reduced investment in existing assets: The implementation of new technologies can take attention away from existing assets and cause more investment elsewhere in new technologies.
- Decentralised generation: Decentralised systems can lead to a proliferation of smaller, less standardized operations. This can make it more difficult to maintain consistent safety standards and detect creeping changes that might occur at individual sites.
- Evolving regulations: Frequent regulatory changes can require rapid adaptations in operational practices. If these changes are not carefully managed, they can introduce new risks or exacerbate existing ones.

Reduced Oversight and Control:

- Remote work and digitalization: The increased reliance on remote work and digital tools during the pandemic and post-pandemic can reduce direct oversight of operations. This can make it harder to identify and address issues as they arise, potentially allowing creeping change to go unnoticed.
- Reduced workforce experience: Changes in staffing levels and workforce demographics during the pandemic and post-pandemic can lead to a loss of institutional knowledge and experience. This can make it more difficult to recognize and respond to deviations from standard practices.

CCHAZID Methodology

This section details the methodology employed by E.On for the development and the subsequent implementation of the CCHAZID methodology at a "pilot" site.

Pre-selection process to identify sites

E.ON operates and maintains a large portfolio of both centralised and decentralised energy generation sites. To determine which site was assessed using the CCHAZID methodology first, the following factors were considered:

- The number of modifications that have been made on site
- The number of incidents that have taken place
- The level of risk identified on site (such as types of hazards present)
- Engineering judgement, informed by consultations with site operators and site leadership teams, to identify locations where incremental changes may exist based on operational experience and observations

After gathering information on these points, a prioritisation list was developed to identify the site where the CCHAZID methodology should be deployed first.

Implementation of CCHAZID in E.ON and how it is different to the existing Energy Institute CCHAZID methodology

This section outlines the adaptation of the CCHAZID methodology, originally developed by the Energy Institute and the HSE, to align with the structure of E.ON UK's portfolio of both centralised and decentralised energy generation sites prior to its implementation.

Guideword selection and template creation

The guidewords in the EI CCHAZID methodology were adapted to increase their relevance to the E.ON business. This review was done through discussions between the E.ON Process Safety team, site operators and site leadership teams. After the guidewords were selected, they underwent a review with the HSE before being finalised for the CCHAZID assessment.

After selecting the guidewords, workshop templates were developed. E.ON's energy generation portfolio is becoming increasingly decentralised, as is the case for many organisations in the energy sector. As a result, site operators and leadership teams often oversee multiple sites within specific regions. Two templates were therefore created: one to address creeping change at the organisational level and another for assessment at an individual site level. This approach was chosen because organisational factors may impact more than one site given the decentralised structure of E.ON's portfolio. For larger, centralised generation sites, a single template would be produced, reflecting the presence of a dedicated team for those locations. The "Organisational Level" and "Site Level" templates used for the pilot site (a decentralised energy generation site), along with the selected guidewords, are included in the Appendix.

CCHAZID workshop methodology

The CCHAZID review followed a structured, systematic methodology similar to that for a "traditional" HAZID review. This review involved a brainstorming exercise guided by an experienced facilitator using the set of guidewords outlined in the Appendix to prompt discussions on how changes could potentially impact safety, environment and financial risks on our sites. The CCHAZID process was completed as follows (see examples outlined in the Appendix):

- The "Keywords" and "Prompts" were used to identify what changes have occurred on site.
- It was then discussed how the change was managed when implemented. If the change was managed through the company's management of change process, the change wasn't discussed any further as it was assumed that safety, environment and financial risks were adequately managed. E.ON's MoC process is audited on a periodic basis to ensure that it is being performed to an adequate standard in all of the business areas.
- If the change wasn't managed through a defined MoC process, the following was recorded:
    - The worst case "Hazardous Event" the change could potentially lead to (e.g loss of containment of hot water, loss of asset integrity, fire)

    - The “Threat/Cause” of how the change could lead to the “Hazardous Event”
    - The “Consequences/Problems” that could potentially result from the change (in terms of safety, environmental and financial impact)
- Next, the likelihood that the change could potentially contribute to the identified “Consequences/Problems” were recorded. Here engineering judgement was used based on how much the change would impact mitigative and preventive safeguards, or whether the change in itself is a potential cause that could lead to the “Hazardous Event”. This method allowed for “High”, “Medium” and “Low” rankings to be generated.
- During the workshop, specific mitigative and corrective actions were identified and assigned to designated individuals. These measures were aimed at minimising the probability that the change would lead to the previously identified “Hazardous Event” and its associated “Consequences/Problems”.
- Based on the rankings that were generated, the mitigating/corrective actions were prioritised based on the potential impact that the identified changes could have on site.

Note: For the CCHAZID assessment, changes were evaluated over the previous five years. This timeframe was chosen because it was considered likely that workshop attendees could reliably recall relevant information from this period. Additionally, staff turnover within these five years was regarded as sufficiently limited to allow for accurate reporting.

Benefits of implementing the CCHAZID methodology

Several benefits were highlighted throughout the piloting of the CCHAZID methodology. Firstly, the methodology provided a structured and systematic framework for identifying and prioritizing risks associated with creeping changes. By systematically evaluating creeping change, the CCHAZID process facilitated the clear prioritization of mitigation efforts (via mitigative/corrective actions), ensuring that resources were directed towards the most critical areas of concern.

Beyond its direct impact on risk assessment, the CCHAZID workshops served as a vital platform for inter-departmental communication and collaboration. The pilot sessions fostered constructive dialogue among diverse teams, including leadership, operations, and engineering, regarding the potential site-level implications of various business decisions. This open forum allowed for the discussion of "smaller" decisions that might otherwise escape comprehensive scrutiny, promoting a shared understanding of their potential risk impact on site operations and personnel. This collaborative environment was particularly effective in bridging communication gaps between strategic leadership decisions and their practical consequences on the ground.

Furthermore, the CCHAZID methodology demonstrably contributed to the cultivation of a more proactive and questioning safety culture within the organisation. Participants in the workshops were observed to engage in more thorough critical examination of both past and ongoing decisions, actively questioning their potential influence on overall risk levels. This enhanced critical thinking is anticipated to extend beyond the workshop setting, embedding a more vigilant and risk-aware mindset throughout the organisation.

The creeping change review process identified gaps in the organisational structure related to undefined roles and responsibilities, which may affect site risk levels. Through analysis of how these gaps influenced risk, the methodology enabled teams to reach agreement on mitigation strategies and helped establish clearer roles and responsibilities.

Overall conclusions

Overall the findings of our research indicate an adequate capability was put in place to maintain safety at high hazard sites during the pandemic crisis. In fact a remarkable resilience and adaptability was demonstrated during the recent pandemic. It’s important to note that creeping change can affect safety, environmental, and financial risk in complex industrial environments. Implementation of the CCHAZID methodology resulted in several outcomes, such as improved prioritisation of mitigative actions, enhancement of inter-departmental communication to achieve a shared understanding of business decisions and their impact on risk, promotion of a proactive approach to evaluating decisions based on their risk implications, and identification of gaps in defined roles and responsibilities at the organisational level.

E.ON will incorporate CCHAZID into its ongoing risk management processes and intends to conduct creeping change reviews on a five-year cycle. Looking ahead, the CCHAZID methodology, detailed in this paper, may be refined. Planned developments include, but are not limited to, the creation of a “creeping change questionnaire” to be completed annually by site operators and leadership teams at high-risk sites. This approach will help determine whether a CCHAZID review is necessary prior to the scheduled five-year creeping change review. Additionally, the use of advanced technologies such as artificial intelligence and machine learning will be explored to enhance the condition monitoring of high-risk assets, facilitating early detection of subtle changes in performance and incident rates.

Acknowledgements and disclaimer

The authors would also like to thank Mike Wardman, Jill Wilday, David Riley, Robert Lowe and Jess Dhariwal for their support in the collaboration outlined above.
Any opinions and/or conclusions expressed, are those of the authors and do not necessarily reflect HSE policy.

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Appendix

1 Organisational Level CCHAZID Template

Keyword	Prompt	Details (what change has occurred?)	How has the change been managed?	Hazardous Event	Threats/causes	Consequence/ problems	Likelihood that the change could result in a "Hazardous Event" and/or in a "Consequence/Problem".			Action No.	Actions/ further studies	Action of whom	Action due Date	Action priority	Comment
							People	Finance	Environment						
Equipment/infrastructure changes	Examples: Operating system changes (asset management system), office software changes (excel risk assessments to PRISMA), field operations equipment (IPADS, new software for completing jobs) etc…														
Workforce Changes	Loss of corporate memory due to changes in staffing levels, new staff and make-up of staff?														
Contractor changes	Have contractors changed for maintenance and onsite activities? Contractors changed for enabling works? Contractors changed for monitoring works (e.g. water chemistry assessments)? Any change in the onboarding process for contractors or the same procurement process (i.e. checking for relevant training etc...) still employed?														
Organisational Factors	Management change? (more or less mindful leadership?)														
	Changes in communication?														
	Culture changes (e.g. blame culture?, changes in H&S attitude, procedural violations/work arounds?)														

	Health and safety management thorough enough (e.g. incident investigations closed out, near misses reported, learnings from process safety performance indicators implemented)?														
	Are there organisational issues/processes that increase the difficulty of getting things completed? Have these increased in number?														
	Changes in roles and responsibilities of personnel? (including onsite engineers) This can result in some staff members getting less or more responsibility on site.														
	Changes in training/ required training?														
MoCs	Are MoC studies completed as a standard for site plant changes?														
ORAs	Are ORAs regularly monitored and kept up to date? (e.g closed out after a long time if they are no longer relevant?, ORAs aligned to avoid confusion etc…)														

2 Site Level CCHAZID Template

Keyword	Prompt	Details (what change has occurred?)	How has the change been managed?	Hazardous Event	Threats/causes	Consequence/problems	Likelihood that the change could result in a "Hazardous Event" and/or in a "Consequence/Problem".			Action No.	Actions/ further studies	Action of whom	Action due Date	Action priority	Comment
							People	Finance	Environment						
Equipment/Infrastructure changes	Has equipment been replaced with different models, additional equipment added into the plant (i.e. any changes to the overall plant layout and equipment schedule) etc…?														
Structural/civil engineering changes	Gratings, handrails, piping supports, ground conditions, flooding etc.														
Organisational Factors	Task changes (nature of the task, complexity, time restraints etc…)? This can include maintenance activities.														
Loss of Containment	Are leaks and weeps increasing?														
	Are leaks and weeps recorded and monitored for the site?														
Equipment Failures	Are equipment failures recorded and monitored for the site?														
	Are equipment failures increasing?														
Performance Monitoring	Overall site performance monitored for the site (including availability, efficiency etc…)?														
MoCs	Have there been lots of site and/or equipment changes?														
	Are there concentrations of changes within the system?														

	Are drawings (e.g. P&IDs) up to date?														
Process Monitoring	Process/reservoir/feedstock changes (e.g. flow rate, temperature, pressure, composition)? Are there any potential knock on effects?														
	Proportion of alarms/gauges ignored?														
	Proportion of alarms/gauges unreliable?														
	False trips/overrides														
Ageing	Have certain pieces of equipment been worked on more than others?														
	Age of critical pieces of equipment?														
	Age of ancillary equipment?														
	Age of pipework?														
	Redundant equipment present?														
Inspection and independent audits	Is there uninspected/uninspectable equipment on site?														
	Have intervals changed?														
	Are results logged and actions completed?														
	Are inspections and audits independent?														

3 CCHAZID Pilot Example Scenarios

Keyword	Prompt	Details (what change has occurred?)	How has the change been managed?	Hazardous Event	Threats/causes	Consequence/problems	Likelihood that the change could result in a "Hazardous Event" and/or in a "Consequence/Problem".			Action No.	Actions/ further studies	Action of whom	Action due Date	Action priority	Comment
							People	Finance	Environment						
Process Monitoring	False trips/overrides	Heat detector for fire system has been moved further away from the boiler due to spurious trips caused by heat produced from normal boiler operation.	OEM for the heat detector advised site operators on where to place the heat detector to prevent spurious trips. The new positioning is based on OEM experience of where heat detectors have been placed on others client sites.	Fire	Detection - fire detector doesn't detect fire due to inadequate position.	[P] - Harm or fatality of personnel [F] - Asset damage from fire	High	High	-	1	Site fire risk assessment should be updated by a competent person.				
										2	A safety case should be completed by an independent person for the re-positioning of the heat detector. This should include a comprehensive assessment of the heat detectors ability to perform its function in its new location.				
Structural/civil engineering changes	Gratings, handrails, piping supports, ground conditions, flooding etc.	Combined heat and power (CHP) unit bund upgraded	Managed through E.ON Management of Change process. Therefore, no further analysis was completed on this scenario.	-	-	-	-	-	-	-	-	-	-	-	-

MoCs	Have there been lots of site and/or equipment changes?	There have been a lot of changes made to the waste heat recovery boiler (WHRB) system	All changes that have been made have been managed through the E.ON Management of Change Process. However, following the changes that have been made, the WHRB HAZOP should be revalidated.	Several	Several	Several	Medium	Medium	Medium	3	Revalidate the WHRB HAZOP to include all of the changes that have been made.				