HUMAN FACTORS HAZARD IDENTIFICATION: INDUSTRIAL TESTING OF THE HUMHID TECHNIQUE AND TOOL

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HumHID is a hazard identification process that uses cognitive work analysis techniques and human factors/error taxonomy information to help identify human related hazards and the possible causes of them so designs can be modified to mitigate or tolerate such hazards. To facilitate the usability of HumHID, a software tool was constructed to guide users through the methodology and to automate otherwise tedious activities. An initial pilot study of the HumHID method and tool was conducted with industrial personnel on an industry case study to assess its usability and usefulness prior to conducting a full case study. The feasibility trial results showed that, with some further improvements, the method and software tool could help process organisations identify human factors issues.

INTRODUCTION

Unacceptable accidents still occur in the process industry. These accidents are often caused by abnormal situations arising from an interaction of people, plant and procedure factors. To address such accidents, process industries need a usable and useful method for identifying human related hazards that can be integrated with plant and procedure hazard identification processes, such as the BLHAZID method (Seligmann et al., 2009, 2010), to reduce the occurrence of unacceptable accidents. We are developing the HumHID methodology to address this need (Hassall et al., 2010). HumHID is unique in the fact that it (1) it uses formative, cognitive work analysis (CWA) techniques and recently published human factors/errors taxonomy information to facilitate the identification and analysis of human related hazards for anticipated and unanticipated situations; (2) it is structured to be used as a standalone or integrated method; and (3) it produces output that can provide guidance on ways to mitigate or tolerate the identified hazards.

To facilitate the usability of the HumHID methodology we developed a prototype software tool, using a customised Microsoft Excel workbook, to guide the user through the process and to automate tedious or repetitive activity. A series of industry testing, ranging from an initial pilot study to full case studies, are necessary to determine the usability and usefulness of HumHID for industry. This paper outlines the HumHID process, provides details of the HumHID tool and then discusses some results from an initial pilot study that was performed at BlueScope Steel's (BSL) coke making operations (Port Kembla, Australia).

BACKGROUND

Human Contributions To Incidents

Between 30% and 100% of industrial accidents can be attributed, at least in part, to human causes (e.g., Baybutt, 2002; Bullemer & Nimmo, 1994; Cacciabue, 2000; HSE, 1999; Kletz, 2009; Stringfellow, 2010). Examples include:

- Attempting to maintain incorrect and live equipment.
- Forgetting a step in a procedure.
- Not recognising an important alarm during an emergency.
- Not activating manual fire systems in an emergency.
- Not returning plant to operational state after maintenance.

This finding is supported by BSL's actual experience at the Port Kembla steelworks where approximately 29% of incidents have been attributed to human factors.

To help address human contributions to accidents, over fifty human hazard/error identification techniques have been developed (Stanton et al., 2005). Examples include human factors checklists (Bellamy et al., 2008), CREAM (Hollnagel, 1998), HEART (Williams, 1986), HFACS (Shappell & Wiegmann, 2000), Human Error HAZOP (Whalley-Lloyd, 1998), LOPA-HF (Shappell & Wiegmann, 2000), SHERPA (Embrey, 1986), SPEAR (CCPS, 1994), THEA (Pollock et al., 1999) and TRACer (Shorrock & Kirwan, 2002). Process industries tend not to use existing techniques because they are either too simplistic or too cumbersome (Baybutt, 2003), specialist knowledge is required to execute them (Shorrock, 2002). In addition, existing techniques use hierarchical task analysis which does not consider the full range of human actions possible especially in unanticipated situations, and they are standalone processes that cannot be easily integrated with plant and procedure hazard identification processes making it difficult to assess risks associated with different combinations of people, plant and procedure factors.

BSL has applied hazard identification techniques, at its Port Kembla steelworks in an attempt to identify areas where there is a high potential that deviations in human activity could result in an accident. The techniques have included using additional guidewords during the plant HAZOP process and checklists during design reviews. A plant HAZOP does look at what consequences can occur and can link these back to deviations in human activity, but doesn't delve into why deviations occur. Checklists do help to identify design issues that will create error-causing conditions but often they assume normal operating conditions. Such techniques often focus on physical ergonomics, such as access to a valve, and are not readily adaptable to consider scenarios where the steps of a procedure are altered by a slip, lapse or mistake.

BSL also employs Job Safety Analysis (JSA) techniques to identify possible deviations in human activity that might arise during operations and maintenance activities. JSA techniques are limited by the fact that physical hazards presented by each job step are usually considered, but not the outcome if a job step is incorrectly or incompletely carried out. The HumHID methodology was developed to address these shortcomings.

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HumHID

Analysts need help in identifying human factors hazards and their potential causes for both anticipated and unanticipated situations. HumHID has been designed as a standalone and integratable technique (with the BLHAZID method) that is useful to and usable by industry personnel. To identify human-related hazards in anticipated and unanticipated situations HumHID uses CWA's control task analysis and strategies analysis (Hassall et al., 2010). It may be the only human factors hazard analysis method to do so. CWA is a formative, constraint-based technique that defines the possible boundaries of safe/unsafe operations without explicitly identifying all possible action pathways (Sanderson, 2003) allowing more efficient and complete identification of human-related hazards.

In addition to control task analysis, HumHID uses three sources to provide insights into deviations and causes associated with human-related hazards: (1) CWA strategies analysis, (2) information from recently published human factors/error taxonomies (Gordon et al., 2005; Kim & Jung, 2003; Paletz et al., 2009; Rantanen et al., 2006; Shorrock & Kirwan, 2002) and (3) accident cause information (Kletz, 2009). The insights can then be used to direct designers to the work elements that need to be redesigned in order to mitigate or accommodate the potential hazards. By providing design insights, the aim is to make the HumHID method more useful than those techniques that just identify human hazards/errors.

The usefulness of HumHID should also be enhanced with the ability to apply it as a standalone or integrated technique. As a standalone technique, HumHID focuses attention primarily on the people aspects of a system. As an integrated technique, HumHID has been designed to integrate with the BLHAZID methodology, which focuses on identifying hazards associated with plant and procedures (Seligmann, et al., 2010; Seligmann et al., 2009). The integrated technique will be designed to help industry identify plant, people and procedure related hazards. To facilitate integration with the BLHAZID method, HumHID uses similar language, logic, representations and output as BLHAZID.

The usability of HumHID has been addressed by keeping the method simple, adopting commonly-used terminology and by providing a computer-aided tool that guides the user through the methodology and automates activities that would otherwise be tedious. Compared with the HumHID process outlined in Hassall et al. (2010), the user now only has to select the system (step 1), define the work contexts and activity (step 2), identify the riskiest activities (step 3), describe these activities with decision ladders (step 2) and then identify the hazardous implications and consequences (step 7d & e) and where necessary the actions required to alleviate the hazards. The remaining steps outlined in Hassall et al. have been streamlined and automated within the HumHID tool which is described in more detail the next section.

HUMHID COMPUTER-AIDED TOOL

The HumHID tool was created by customising a Microsoft Excel workbook using Visual Basic macro functionality. The tool should guide non-expert users through the HumHID process and automate otherwise tedious activities, leaving the user to make judgements and decisions. The tool consists of an Excel workbook containing the following worksheets which reflect the different steps of the HumHID process.

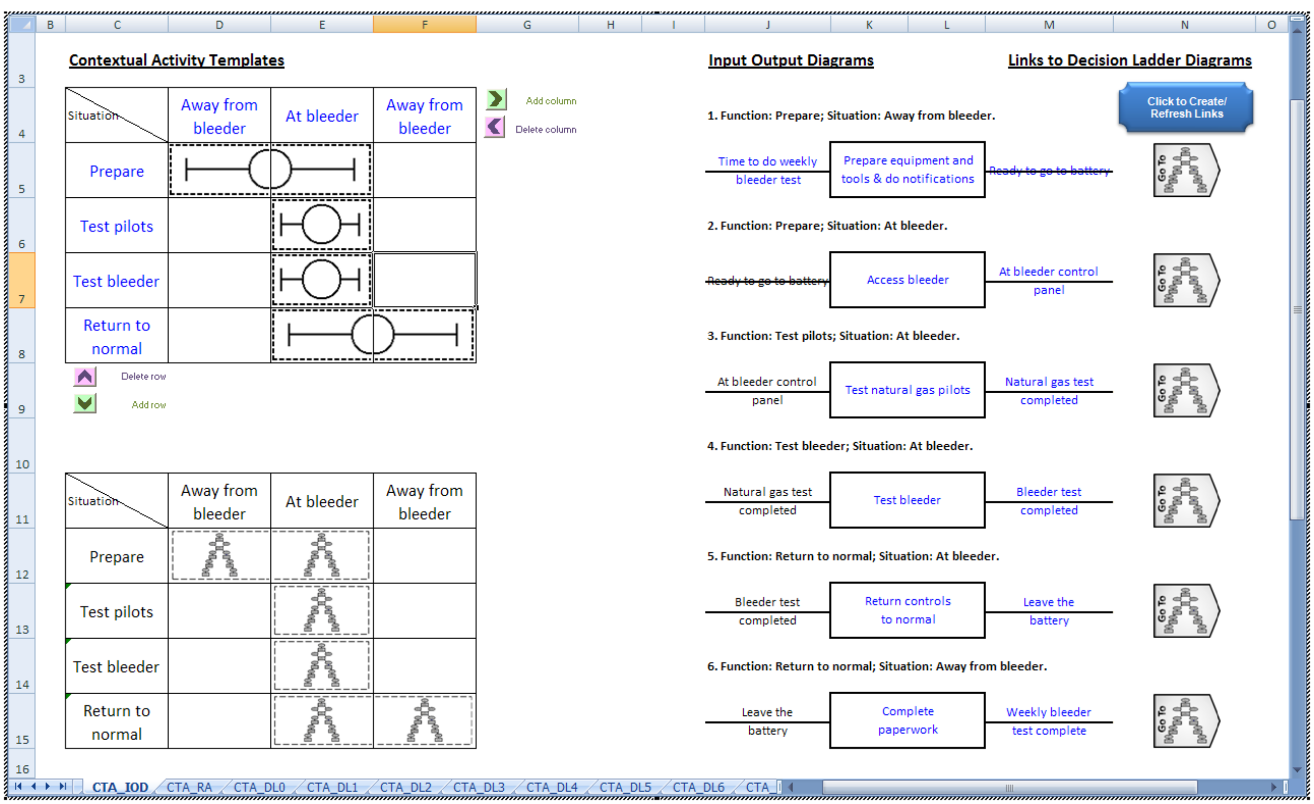

Figure 1. Contextual Activity Template and Input/Output Diagrams (CTA_IOD) from HumHID Excel ™ workbook.

Overview worksheet: Provides overview information on the HumHID process and tool.

System worksheet: This is a form that the user completes by defining and describing the system being analysed.

Contextual Activity Template and Input/Output Diagrams (CTA_IOD) worksheet: This worksheet facilitates the identification and decomposition of control task activity with the use of contextual activity templates (following the guidelines provided by Naikar et al. (2006)) and basic input-output diagrams (see Figure 1 for a completed worksheet). Once completed, the control activity required to achieve the system purpose will have been identified and decomposed into manageable activity segments for further analysis.

Risk Ranking worksheet: Users follow a risk ranking process to identify the riskiest activity segments to focus on first. This is optional as for existing systems users may already know the riskiest activities needing to be assessed first.

Control Task Activity Decision Ladders (CTA_DL) worksheets: The remainder of the workbook consists of CTA_DL worksheets created for each activity segment identified in the CTA_IOD worksheet. Each CTA_DL worksheet contains a decision ladder proforma with which users describe an activity segment (again following the guidelines provided by Naikar et al (2006)). An example is shown in Figure 2.

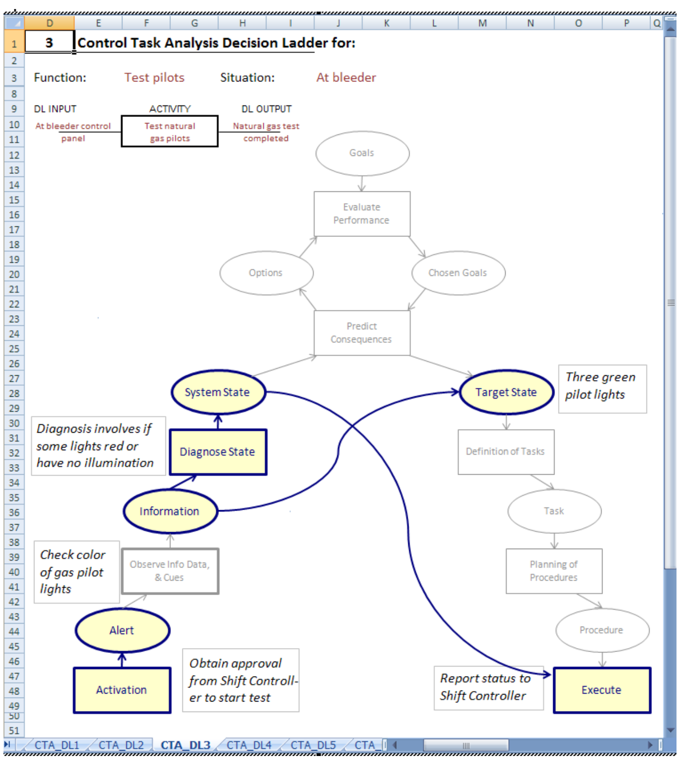

Figure 2. Control Task Activity Decision Ladder worksheet

Once the decision ladder is completed the workbook can match the decision ladder data with embedded strategies analysis and human factors/error taxonomy information to create a list of the different ways the activity might be performed. Part of this list is shown in the first three columns of Figure 3 which displays a segment of a HumHID table. The first column, "C_vars", describes all, and different parts of the activity segment as described with the decision ladder. The second column contains a description of what the "C_var" entails and the third column outlines possible deviations in the way the whole or different parts of the activity might be executed. The HumHID table also lists possible causes for each activity deviation.

In the remainder of the HumHID table the user can identify: (1) hazards associated with each activity deviation (HAZARDS column), (2) the likelihood these hazards will be experienced (gray area of table), (3) consequences if the hazards are experienced (gray area of table), and (4) meaningful actions (last column), by using the cause information, to address any unacceptable hazards. The structure of HumHID table has been designed so that it can be integrated with the BLHAZID process.

Each worksheet is set up so the user can complete it with mouse clicks and entering text where prompted. Double entry by the user is eliminated with automatic transfer of information between the worksheets. In addition, the creation and deletion of worksheets for each activity segment is done automatically. HumHID tables are also created and partially populated at a click of a button. Finally, help buttons that provide customised HumHID help information and workbook navigation buttons are built into each worksheet to assist users through the methodology and workbook.

INDUSTRIAL TESTING OF HUMHID TOOL

Industry tests evaluated the usability and usefulness of the HumHID process and tool. This testing started with a pilot study of the HumHID process and tool to ensure it was understandable and usable by industry. Once HumHID has been fine-tuned for industry, full case studies can be conducted to fully assess the usability and usefulness of HumHID. This paper only describes the pilot industrial testing that was conducted at BSL. The testing focused on using HumHID to identify and evaluate human-related risks associated with weekly testing of a gas flaring system. Weekly testing requires a field operator to test the normal and nticipated abnormal operating modes of a gas flaring system, which is designed to release and ignite coke ovens gas when the gas mains pressure exceeds the specified upper limit.

Method

The following process was used:

1. Eight BSL personnel were asked to participate in the case study. They came from various positions: operators, risk/safety advisory roles, engineers, and supervisors. All participants completed written informed consent forms.
2. The participants were introduced to the HumHID workbook and process in a training session lasting approximately one hour. (Prior to this training, some participants had attended a three hour information session which described the theory underpinning HumHID, the development of HumHID done to date and the proposed testing and refinement process planned for the future).
3. A copy of the procedure describing the weekly testing process was provided to each participant.

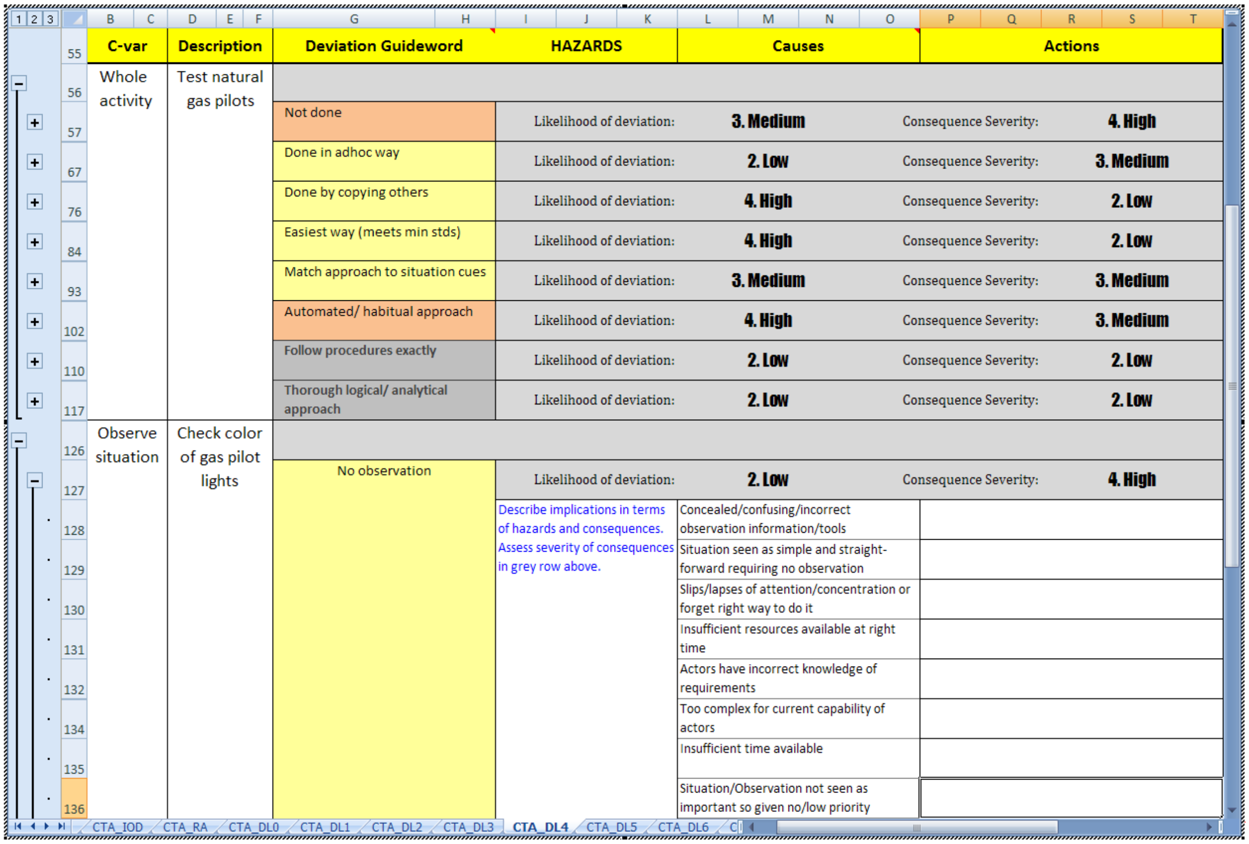

Figure 3: A segment of a HumHID table from HumHID workbook

4. An overview, lasting approximately one hour, was given on the gas flaring system by one of the engineers.
5. The participants were then divided into three groups with each group containing people from different types of roles.
6. The groups were given approximately two hours to use the HumHID Excel workbook to:
   a. Perform the activity decomposition.
   b. Describe an activity segment using the decision ladder worksheet
7. Work through the HumHID table. Each participant was asked to complete a confidential 10-item questionnaire.
8. A group debrief was conducted to obtain further feedback.

Results

Six participants completed the questionnaire. Results from two key questions are reported in Table 1. These questions asked respondents to rank the ease/usefulness of the process on a seven point scale (1= difficult/not useful, 4 = neither difficult nor easy/moderate, 7 = easy/very useful).

The results from the first question show that on average the HumHID workbook was somewhat easy to use. Respondents were also asked to comment on the ratings they gave. Respondents stated that more training, guidance materials (e.g., a manual and worked example), changing the way hazard severity is categorised to more closely match site practice, and minor software changes would improve the ease of use for the tool and methodology.

Results to the second question show that respondents definitely thought that HumHID would be worth implementing after it had been further developed. Their comments on this question indicate that an improved HumHID process would useful for the site because at present there is no reliable and useable technique for identifying human factors issues in operations and design.

Question	Average Response	Range of Responses	Number of Responses
How easy was it to use the HumHID workbook?	4.6	2-6	5
How useful would HumHID be if implemented at site?	5.5	5-6	6

Table 1: Summary of questionnaire responses

Discussion

As the results indicate, the HumHID process and tool, with some further improvements, were seen as a useful technique for assessing systems where human factors contribute to the overall performance of process. Along with further testing, improvements will be done with the input and feedback from BSL personnel to ensure the HumHID process meets its usefulness and usability goals.

The collaboration between research and industry in this work has proved extremely valuable. From a research perspective, the industry input and feedback provides definite directions and challenges for further development of the HumHID process to make it useful, useable, efficient and effective for industry. From an industry point of view the

HumHID process challenges experienced operators and engineers to consider how human activity can vary between personnel with different levels of knowledge and between different operating conditions. The value of this technique for providing a visual training aid to show trainees what their actions will result in, and how to structure their decision processes, is potentially high.

Further testing also needs to be done to exercise the technique on very different case studies to ensure that the HumHID process and its benefits are transferable. As part of this further testing process, input testing and feedback sessions will be conducted with BP Refinery Bulwer Island personnel. The petroleum refinery offers the opportunity to test HumHID on highly automated systems which rely on human supervisory controllers, which will complement the more manual processes studied at BlueScope Steel.

Once HumHID has been developed as a standalone methodology, more research will be conducted on integrating HumHID with the BLHAZID methodology so that the combined process is effective in identifying hazards that arise from combinations of factors.

CONCLUSION

Initial testing of the HumHID process at BlueScope Steel showed that the workbook was somewhat easy to use and that the methodology, with further improvements, could be useful in helping process organisations identify human factors issues. Results indicate that HumHID has potential to be a usable human factors hazard analysis technique. However, further testing is required to assess the usefulness of HumHID especially in terms of (1) identifying human-related hazards for both anticipated and unanticipated situations, (2) providing meaningful design insights so that identified hazards can be addressed, and (3) integrating with other plant and procedure hazard identification techniques to facilitate the identification of hazards that can arise from combinations of factors.

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REFERENCES

Baybutt, P. (2002). Layers of protection analysis for human factors (LOPA-HF). *Process Safety Progress, 21*(2), 119-129.

Baybutt, P. (2003). Layers of protection analysis for human factors (LOPA-HF): An improved method for addressing human failures in process hazard analysis. *Symposium on Human Error in Occupational Safety* (pp. 163-175). Altanta, Georgia: Americal Society of Safety Engineers.

Bellamy, L. J., Geyer, T. A., & Wilkinson, J. (2008). Development of a functional model which integrates human factors, safety management systems and wider organisational issues. *Safety science, 46*, 461-492.

Bullemer, P. T., & Nimmo, I. (1994). Understanding and supporting abnormal situation management in industrial process control environments: a new approach to training *IEEE International Conference on Systems, Man, and Cybernetics. Humans, Information and Technology.* (Vol. 1, pp. 391-396).

Cacciabue, P. C. (2000). Human factors impact on risk analysis of complex systems. *Journal of Hazardous Materials, 71*(1-3), 101.

CCPS. (1994). *Guidelines for preventing human error in process safety*. New York: Center for Chemical Process Safety of the American Institute of Chemical Engineers.

Embrey, D. (1986). *SHERPA: A systematic human error reduction and prediction approach*. Paper presented at the International Meeting on Advances in Nuclear Power Systems, Knoxville, TN.

Gordon, R., Flin, R., & Mearns, K. (2005). Designing and evaluating a human factors investigation tool (HFIT) for accident analysis. *Safety Science, 43*(3), 147.

Hassall, M. E., Sanderson, P. M., & Cameron, I. T. (2010). Using cognitive work analysis techniques to identify human factors hazards *Proceedings of the 54th Annual Meeting of the HFES*. San Franciso, CA.

Hollnagel, E. (1998). *Cognitive reliability and error analysis method*. Oxford: Elsevier.

HSE. (1999). *Reducing error and influencing behaviour*. Surrey, UK.: HSE Books.

Kim, J. W., & Jung, W. (2003). A taxonomy of performance influencing factors for human reliability analysis of emergency tasks. *Journal of Loss Prevention in the Process Industries, 16*(6), 479-495.

Kletz, T. A. (2009). *What went wrong? Case histories of process plant disasters and how they could have been avoided*. Burlington, MA: Gulf Professional Pub.

Naikar, N., Moylan, A., & Pearce, B. (2006). Analysing activity in complex systems with cognitive work analysis: concepts, guidelines and case study for control task analysis. *Theoretical Issues in Ergonomics Science, 7*(4), 371-394.

Paletz, S. B. F., Bearman, C., Orasanu, J., & Holbrook, J. (2009). Socializing the Human Factors Analysis and Classification System: Incorporating Social Psychological Phenomena Into a Human Factors Error Classification System. *Human Factors., 51*(4), 435.

Pocock, S., Writght, P., & Harrison, M. (1999). *THEA – A technique for human error assessment early in design*. Paper presented at the RTO HFM Workshop on the Human Factor in System Reliability – Is Human Performance Predictable?, Siena, Italy.

Rantanen, E. M., Palmer, B., O., Wiegmenn, D., A., & Musiorski, K. M. (2006). Five-dimensional taxonomy to relate human errors and technological interventions in a human factors literature database. *JASIS 57*(9), 1221.

Sanderson, P. M. (2003). Cognitive Work Analysis across the system life-cycle: Achievements, challenges, and prospects in aviation. In G. Edkins & P. Pfister (Eds.), *Innovation and consolidation in aviation.* (Vol. 3, pp. 73-85). Aldershot, UK: Ashgate.

Seligmann, B., Németh, E., Hockings, K., McDonald, I., Lee, J., & Cameron, I. T. (2010). *A structured, blended hazard identification framework for advanced process diagnosis*. Proc. Int'l Symp. Loss Prevention and Safety Promotion in the Process Industries, 1, 193-200, Brugge, Belgium.

Seligmann, B., Németh, E., Hockings, K., O'Brien, C., & Cameron, I. T. (2009). *A blended hazard identification approach to support intelligent diagnosis of process systems*. Paper presented at CHEMECA, Perth, WA.

Shappell, S. A., & Wiegmann, D. A. (2000). *The human factors analysis and classification system - HFACS*. (DOT/FAA/AM-00/7).

Shorrock, S. T. (2002). *Error classification for safety management. Finding the right approach.* Paper presented at the Workshop on the Investigation and Reporting of Incidents and Accidents, Senate Room, Univ Glasgow.

Shorrock, S. T., & Kirwan, B. (2002). Development and application of a human error identification tool for air traffic control. *Applied Ergonomics, 33*(4), 319.

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., & Jenkins, D. P. (2005). *Human factors methods: A practical guide for engineering and design*. Aldershot, UK: Ashgate.

Stringfellow, M. V. (2010). *Accident analysis and hazard analysis for human and organizational factors.* Doctor of Philosophy, Massachusetts Institute of Technology, Massachusetts.

Whalley-Lloyd, S. (1998). Reducing the impact of human error. *The Safety & Health Practitioner, 16*(5), 20.

Williams, J. (1986). *HEART - A proposed method for assessing and reducing human error.* Paper presented at the 9th Advances in Reliability Technology Symposium, University of Bradford.