ASSESSING LONGFORD GAS PLANT 1 STAFFING ARRANGEMENTS

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In 2000 the UK Health and Safety Executive (HSE) Hazardous Installations Directorate commissioned a research project to develop a practical method that flags when staffing arrangements used to control a process are inadequate. The resultant method was published as Contract Research Report 'Assessing the safety of staffing arrangements for process operations in the chemical and allied industries' (Contract Research Report (CRR) 348/2001)[1]. The developed method concentrates on the staffing requirements for responding to hazardous incidents. Specifically, it is concerned with how staffing arrangements affect the reliability and timeliness of detecting incidents, diagnosing them, and recovering to a safe state. The method has been applied by many Major Hazard organisations with and without assistance from external consultants. The tool has been applied to assess current staffing arrangements, new staffing arrangements and to assess the impact of a planned organisational change. Its contribution to safety science has been recognised through two UK IChemE Awards for Safety and Loss Prevention.

In 1998 a gas plant at Longford, Australia, suffered a major release and fire. Tragically, two employees were killed. Natural gas supply to the entire state of Victoria was cut for two weeks, causing disruption to domestic users and massive economic cost to industry and business. A Royal Commission (RC) was established to investigate the causes of the incident. The Commission took evidence from many plant personnel, exploring a wide range of operational and maintenance practices at the plant.

This paper examines the application of the staffing arrangements assessment method (method) to the Longford incident. Significant operational staffing changes had been made at the plant, and the personnel appearing before the Commission included those who would typically be included in the study team implementing the staffing method. The method's assessment techniques have been applied using the evidence of the personnel in a remote application.

KEYWORDS: staffing arrangements method, Longford, royal commission

INTRODUCTION

STAFFING ARRANGEMENTS METHOD

The method concentrates on the staffing requirements for responding to hazardous incidents. Specifically, it is concerned with how staffing arrangements affect the reliability and timeliness of detecting incidents, diagnosing them, and recovering to a safe state.

Assessment is in two parts. The first is a physical assessment of performance in a range of scenarios, the second is a ladder assessment of the management and cultural attributes underlying the control of operations. The overall assessment process is summarised by the flowchart Figure 1 (full description of the method appears in CRR 348/2001[(1)]).

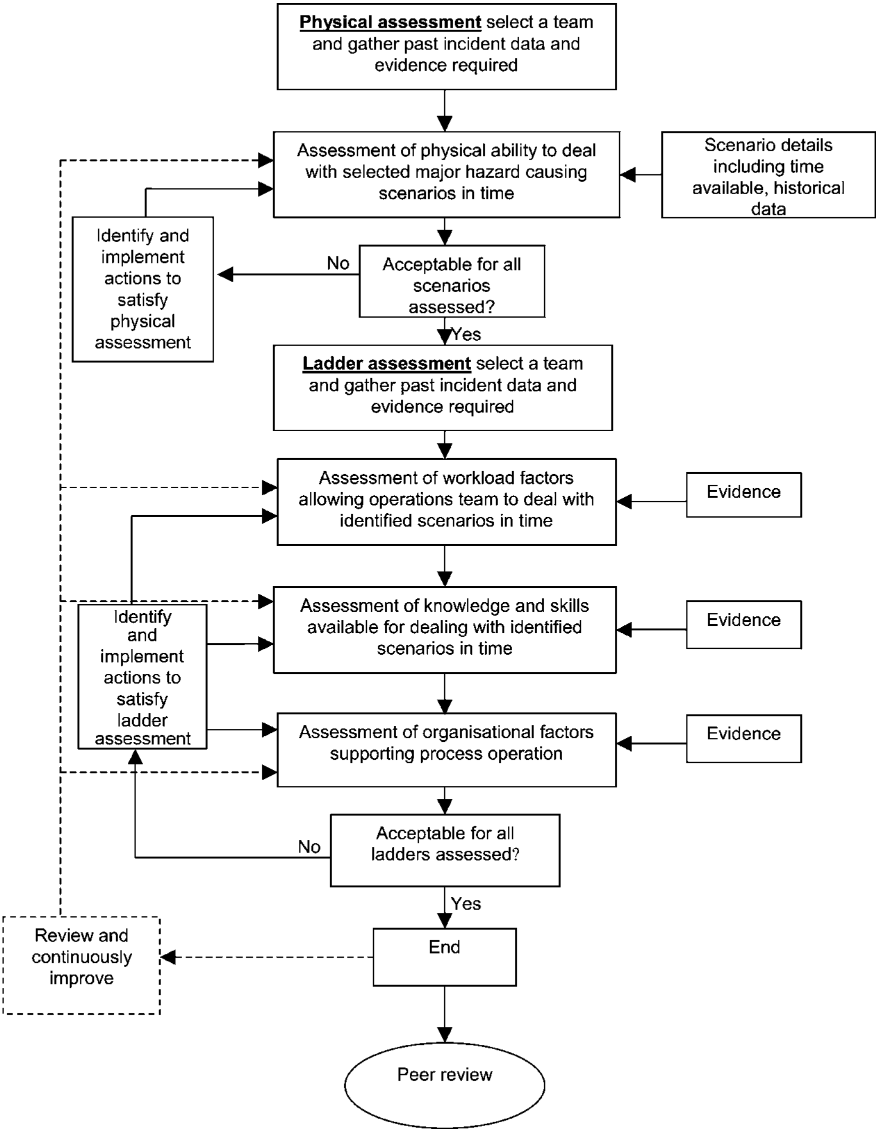

Figure 1. Flowchart of the staffing assessment process

The method assesses eleven elements which are comprised of:

- Technical factors: Physical assessment of the feasibility of detecting, diagnosing and recovering the facility to a safe state in time for a range of defined scenarios.
- Individual factors (workload): Situational awareness; teamworking; alertness and fatigue (split into working pattern and health).
- Individual factors (knowledge and skills): Training and development; roles and responsibilities; willingness to initiate major hazard recovery actions.
- Organisational factors: Management of operating procedures; management of change; continuous improvement of safety; management of safety.

THE LONGFORD INCIDENT

On 25th September 1998 the Esso Longford gas plant in Victoria, Australia suffered a major gas release and fire that caused the deaths of two employees and the cessation of natural gas supply to the state of Victoria. This was the only major catastrophic failure at the site in its twenty eight year history.

The state of Victoria has a population of 4 million and is Australia's most industrialised state in terms of manufacturing. Industry and commerce depend heavily on natural gas, as do domestic users.

Supply of natural gas was lost for two weeks, except to hospitals, nursing homes and aged domestic users. Many factories closed down, laying off workers. Businesses lost product through spoilage. The total cost to business was widely estimated at over one billion Australian dollars.

Besides the commercial impact, the incident also lead to a landmark Occupational Health & Safety case in Victoria's courts. The company was convicted on eleven breaches of the Occupational Health & Safety Act and fined a record two million dollars.

The severe commercial consequences of the incident lead to a political imperative to investigate the causes via a transparent and empowered process. The government chose a Royal Commission as the vehicle of inquiry, and appointed two commissioners, a former High Court judge and an eminent engineer.

The use of a Royal Commission to investigate an industrial accident is rare in Australia. In Victoria, the most recent instance was the West Gate Bridge Royal Commission, which investigated the collapse of the West Gate Bridge in Melbourne in 1970. That accident claimed thirty five lives.

The Commission's public hearings resembled in some ways a courtroom, although it was not a court. A witness would normally submit a sworn statement, and then be questioned by Council Assisting. Other parties then 'cross-examined' the witness on the material covered by Council Assisting. The parties most active in questioning witnesses were: Esso, the operator of the site; Insurance Council of Australia, representing insurance companies who had paid out claims relating to the loss of gas; Victorian Workcover Authority, the state industrial regulator; State Government; State Opposition; Unions representing the Longford workforce.

The proceedings were of an inquisitorial nature and there was no 'prosecution case' presented to the Commission. Generally, the taking of evidence was not subject to courtroom rules of evidence.

Many of the witnesses called were Esso personnel, including:

- Directors: Chairman & Managing Director; Exploration & Production Director;
- Senior and middle management: Production Technology Manager; Technical Manager; Operations Manager; Longford Plant Manager;
- First line management: Maintenance and Reliability Supervisor; Production Co-ordinator; Production Shift Supervisors and Relief Supervisors; Maintenance Shift Supervisors;
- Shift technicians: Production Operators, Panel and Field; Maintenance Technicians;
- Support functions: Safety Co-ordinator and Training Officer.

There was considerable breadth in the range of topics covered in the evidence including: design and operation of the gas plant; Safety Management System (SMS); training programmes; maintenance procedures; organisational structure and recent changes; incident reporting procedures and past incidents; operational details for the day of the incident and preceding shifts.

The authors considered the potential value of applying the Staffing Assessment Method (Staffing Method) to this body of evidence and concluded that the application would be a good test of the tool and that use of an objective, systematic approach might provide additional insights into the circumstances surrounding the incident.

APPROACH

PHYSICAL ASSESSMENT

The standard approach for applying the Physical Assessment is to define a range of scenarios representing the following:

- Worst case scenarios requiring implementation of the off-site emergency plan;
- Incidents which could escalate without intervention to contain the problem on site;
- Lesser incidents requiring action to prevent the process becoming unsafe.

Each scenario is then discussed in terms of actions required for detection, diagnosis and recovery by the assessment team before being assessed using the eight Physical Assessment 'Trees'.

A different approach had to be used for this paper. The method has been applied using the evidence given by the personnel to the RC. There has been no team assembled to discuss the scenarios and answer the Physical Assessment questions. All answers have been derived from the material already recorded as statements or examination in response to questions from Council Assisting and the other parties conducting cross-examination.

Although the evidence contains an abundance of material relating to various equipment failures, it does not provide complete answers to all questions for any particular scenario.

Therefore, no particular failure scenario could be fully assessed in terms of the feasibility of the operations team detecting, diagnosing and recovering the facility to a safe state. Instead, the approach used evidence relating to any equipment failure or problem to address the Physical Assessment issues. The trees were not applied to the arrangements for specific scenarios; instead the principles used to structure the physical assessment trees were used as a basis for assessment:

1. There should be continuous supervision of the process by skilled operators.
2. Distractions should be minimised to reduce the possibility of missing alarms.
3. Additional information required for diagnosis and recovery should be accessible, correct and intelligible.
4. Communication links between the control room and field should be reliable.
5. Staff required to assist in diagnosis and recovery should be available with sufficient time to attend when required.
6. Operating staff should be allowed to concentrate on recovering the plant to a safe state.

LADDER ASSESSMENT

Again, as no assessment team could be assembled, the Longford Royal Commission (LFRC) evidence and report were used to gather evidence supporting an assessment of each of the ladder elements with relevant examples. The ladders and preparatory questions within the Staffing Arrangements method structured the evidence used.

PHYSICAL ASSESSMENT

SCENARIOS ANALYSED

The evidence contains information relating to a number of plant upsets. Most of these did not involve actual or imminent loss of containment. However, they were upsets that required attention before they escalated to a more severe level and provide an opportunity to assess the operations team's performance in detection, diagnosis and recovery.

Two scenarios involved actual or imminent risk of loss of containment:

i) Serious oil leak from flanges of a heat exchanger.
ii) Icing on normally hot pipework.

Process upsets which did not involve actual or imminent loss of containment included:

i) Failure of a control valve (Temperature Recorder Controller 3B, TRC3B).
ii) Continuous condensate high level in Absorber B.
iii) Shut down of the lean oil pump.
iv) Inability to shut down lean oil booster pump.
v) Carryover of condensate into the sales gas outlet of Absorber B.
vi) Failure of a number of chart recorders.
vii) Shut down of the Longford Liquids Recovery Plant.

The plant was managed by a Panel Operator (PO) and an Area Operator (AO). The PO was stationed in the control room (CR), attending to the control panels, while the AO would attend the plant machinery in the field. The PO had other duties to perform, such as administrative tasks.

If problems arose that could not be managed by the two operators, the PO could call upon the Shift Supervisor (SS). The normal duties of the SS were administrative, but he could defer these, if required, to assist the operators. In such circumstances he had authority over the PO and AO.

Other personnel could be called upon to assist such as the floating day crew and a relief supervisor. Maintenance personnel were available for urgent work.

HISTORICAL INCIDENTS

No historical record of past failure scenarios was available for the purposes of this paper.

The plant had suffered a number of upsets due to the formation of hydrates[2,4]. These were solid ice/hydrocarbon formations in pipework. These incidents appear to have limited the problem solving activities of the operations team to assuming other upsets were hydrate related, when in fact they were not. This provides an example of the Gas Plant 1 (GP1) operations team trying to solve unfamiliar problems by reverting to the rule based level and matching aspects of the local state information to the situational elements of the stored problem handling rules. This behaviour is expected human bias and several failings and biases in situational awareness stem from it.

A record of the past failures of the control valve, TRC3B, would have been useful, but was not presented as evidence.

ASSESSMENT

Below are the results of applying the staffing method physical assessment principles to the LFRC evidence and report[2,4].

Principle 1: There should be continuous supervision of the process by skilled operators

The Panel Operator (PO) did not leave the CR; there were no indications anywhere that the PO had duties anywhere else. The PO shift handover occurred at the control panel. There were occasions when the GP1 control panel operator was either busy or not in the room when an alarm annunciated. Others in the control room, for example, a supervisor, outside operators or even maintenance personnel) acknowledged alarms on behalf of the GP1 panel operator. Most times the acknowledgement of these alarms was passed on to the panel operator. However, it was possible for an alarm to be acknowledged by someone other than the panel operator and the PO not to have been aware of it until he later routinely surveyed his panel alarm status. This applied for the Bailey system and the old pneumatic system on the panel walls. There was no formal procedure. Clearly there was potential for an alarm to pass unacknowledged by others. Additionally it was possible for an alarm to be acknowledged by another, but PO not informed. There is no indication of a back-up.

The PO's station was at a console or nearby desk. He used a roller chair to move between the two (suggests poor CR and workstation layout). The PO's description:

> *'There is a central operations desk, which is basically no different from many desks. It contains a fax machine, two or three telephones, a radio handset, and adjacent to that, you're probably all familiar with the old panel or the pneumatic system, which encompasses the southern end of the control room, because the control room is combined with the crude plant. The wall, itself, or the old panel, itself, covers the part of the inlet gas flows, storage tank levels, part of the ROD/ROF* (Rich Oil Demethaniser/Rich Oil Fractionator) *system, that is the part that is not contained on the Bailey machines, the propane system, the KVR compressor* (gas compressors) *system, the analyser system. There is a TR1* (Temperature Recorder 1) *machine in the corner.'*

This principle is only partially fulfilled as there does not appear to be a formal, reliable means in place of allowing the PO to have breaks during the twelve hour shift whilst ensuring all alarms are responded to in a timely manner.

Principle 2: Distractions should be minimised to reduce the possibility of missing alarms

CR technicians other tasks included talking to other people, answering two to three phones, administration duties including recording people off sick, roster management. The CR technician had numerous nuisance alarms. They received hundreds to thousands of alarms in 12 hours. One shift quoted in evidence experiencing eight and a half thousand alarms in one day.

Other tasks included Critical Function Testing (CFT) e.g. CFT on Westbury Pumping Station, eighty kilometres from Longford on the morning of the incident between about 8:00 and 10:30. This activity required acknowledging alarms on the GP1 panel and communicating via phone and radio with Westbury that the alarms had been received. Additionally, during the same shift the same CR technician was involved in the shutdown of a piece of process plant from around 9:00 until 11:30. The CR technician gave in evidence that the shutdown of this piece of process plant was not affecting GP1's existing process difficulties and that perhaps it should have been much lower priority than the GP1 process problems on that shift.

GP1 was often operated in alarm, therefore alarms were missed or not acted upon e.g. The condensate level in Absorber B rose to alarm level on night shift 24th September 1998, and remained above the alarm level into the next shift. The level rose until above the measurable level without attention from the PO.

The multiple distractions given above and the apparent lack of prioritization between dealing with GP1 plant upsets and remote testing and shutting down an unaffected piece of equipment means that this principle is not fulfilled.

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Principle 3: Additional information required for diagnosis and recovery should be accessible, correct and intelligible

The operating procedures relevant for GP1 were produced as a manual in 1993 called the 'Longford Plant Operating Procedures Manual' which was distributed in early 1994 (known as the "Procedures Manual"). There was also an operating manual for the absorption oil system 'Operating Instructions for Absorption-Oil System, 1975' (also known and referred to in evidence as 'the Red Book').

However, it is unclear where the Red Book was kept, and if dated '1975', whether it was up to date; considering significant alterations had been made to the plant since then. There are no indications that the Red Book was used. One CR technician discovered its existence after the incident as one of the other operators had a photocopy in his locker.

The CR operators took various actions to try to resolve the various process problems they were experiencing such as switching to a backup pump, using a bypass valve, calling for assistance from the shift supervisor.

The evidence suggests this principle was not fulfilled as the accuracy, usefulness and availability of the Red Book is unproven and its existence was not known by the PO at the time of the accident.

Principle 4: Communication links between the control room and field should be reliable

The method of communication depended on the location of the person being called. If the person was inside, then a phone might have been used. If outside, radio appears to have been the main method. Pagers have not been mentioned with respect to plant operations personnel.

The main method of communication to the Area Operators was by radio. Clearly, radios can fail. A potential backup may have been sending a person with a message.

Communication with supervisors was by phone and radio with a lower likelihood of total failure.

This principle does not appear to be fully satisfied as the only link between the CR and field was radio. The potential back-up of sending a person with a message relies on someone being available to take a message. It is clear from the example in Principle 5 that the PO was not always aware of where the AO was, what he was doing and whether he was available.

Principle 5: Staff required to assist in diagnosis and recovery should be available with sufficient time to attend when required

Area Operator should be in vicinity of the plant under the PO's control, but may be detained by other work. One example of the inability of the Area Operator to respond in time is given by a CR technician:

> *'In response to my call for assistance, the AO radioed me and said that he will be back in 10 minutes. That was too long and if the heater was not put back*

> *on, this would have allowed the condensate to enter the Crudestream cold and this will in turn possibly upset the CSP* (Crude Stabilisation Plant) *process.'*

Prior to the AO radioing in the CR technician had called the Shift Supervisor, the following gives an indication of his workload at this time (the morning of the incident):

> *'At this time I had a lot going on with process upsets, alarms and phone calls and I was trying to locate extra manpower to help with the process upsets and the restarting of equipment. The immediate concern at this time was restarting the GP502B crude condensate heaters that had shut down. I would have had a red annunciating shut down alarm on the panel. I have no specific recollection of this but assume I would have looked at the level indicator for the Crude Deethaniser Tower (CDT) and assessed that there was sufficient level to justify restarting the heater. This is a common occurrence.'*

The evidence suggests this principle was not fulfilled, the PO had several process upsets he required assistance with and he was trying to restart equipment. The Plant Supervisor was called to provide assistance, which suggests he was not already in the CR providing technical support or co-ordinating effort. Even after the call for assistance the AO was not available within the required time.

Principle 6: Operating staff should be allowed to concentrate on recovering the plant to a safe state

On the day of the incident, the PO undertook the following tasks:

- Activated Emergency Shut Down (ESD) from a shutdown panel adjacent to the CR;
- Called the security gate requesting ambulances, fire truck and rescue vehicle;
- Initiated emergency response callout by calling a single number (dedicated handset) although the noise of the alarms, fire and people in the control room made communication difficult;
- Called Long Island Point on dedicated handset (receiver off Liquefied Petroleum Gas (LPG) from Gas Plant 1) to inform of loss of LPG flow;
- Attempted to call offshore control room (two phones and radio were dead);
- Treat casualties.

For the ESD activation the PO had to activate the ESD 1, a shut down panel adjacent to the control room: '*So I opened the door and ran down the path and activated ESD 1. I wanted to do the other switches but the heat and smoke were too much.*'

The above suggests that this principle was not fulfilled, the PO should not have had to leave the CR and approach the fire hazard in order to initiate ESD and he should not have been prevented from other tasks by heat and smoke. Also, support in fulfilling all the communications requirements would have allowed the PO to concentrate on the plant conditions. The excessive noise and multiple distractions from alarms, people and treating casualties prevented focusing on recovering the plant to a safe state and minimizing potential further escalation. Additionally in responding to process upsets prior to the rupture and fire the PO was unable to focus on recovering the plant to a safe state due to alarm overload and multiple distractions (see previous principles for examples).

LADDER ASSESSMENT

Table 1 presents the results of applying the staffing method ladders to the LFRC evidence and report[2,4]. First the ladder position for each element is indicated followed by some comments on the assessed position together with relevant examples from the LFRC evidence.

DISCUSSION

The Staffing Method provides an objective structure which identifies technical, individual and organisational issues which should be considered when assessing operational staffing arrangements. The method was developed to assess existing operational staffing arrangements and proposed changes and their adequacy for dealing with major accident hazards. This paper has applied the approach in an historical, remote way to staffing arrangements which experienced a major accident. The systematic structure of the method facilitates its application, as evidence relative to each element can be identified and assembled to illustrate how the Longford Gas Plant 1 operations' team functioned at the time of the incident. The pitfalls are that the analyst is reliant on how much weight the RC gave to each of the elements during the investigative process and there does not appear to have been a particular consideration of human factors issues by the RC. Therefore, although the Situational Awareness of the operations team was critical to how the incident developed, as it was not identified as a definable factor, its components remain separated through the RC process. The element of Fatigue does not appear to have been considered by the RC at all, even if to be eliminated as not being a contributor. In contrast, the use of fatigue studies has become commonplace in Australian rail accident investigations.

The Longford GP1 staffing arrangements did not fulfill any of the six Physical Assessment principles which test the feasibility of detecting, diagnosing and recovering a facility to a safe state after deviation from normal operation. After failing this fundamental test the staffing arrangements go on to fail all of the ladder elements. This is a particularly poor outcome from the staffing method compared to other operations where the method has been applied. This may be due to the generally negative approach the LFRC took when examining issues pertinent to the accident, i.e. what went wrong rather than what went right. However, there do appear to be multiple, severe failings in all aspects of the staffing arrangements covering technical, individual and organizational factors. Many of the problems identified during this exercise are pertinent for other organizations and should be reviewed for useful lessons as with any major incident.

The priority for an organisation which failed all elements of the staffing method would be to rectify the failings identified within the physical assessment, followed by individual factors then organisational. All elements are essential for safe sustainable operation and influence operational performance. However, the feasibility of staffing arrangements

Table 1. Summary of Longford staffing arrangements' assessed Ladder positions followed by explanation

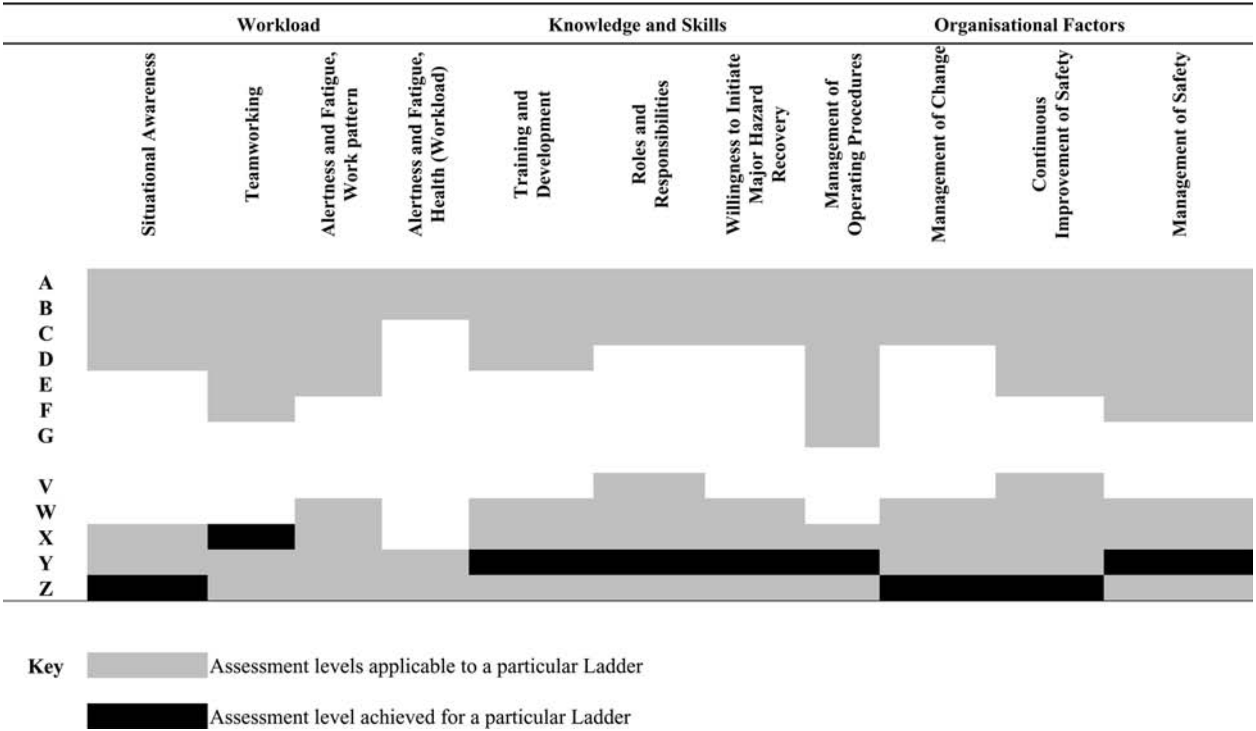

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Table 1. Continued

Ladder Element	Comments on ladder position	Examples from the evidence
Situational awareness	Many issues prevent a higher position including poor maintenance of equipment status board (Temporary Defeats Board), not knowing progress of maintenance requests, alarm overload, numerous standing alarms and lack of alarm prioritisation, lack of guidance and structure at shift handover, unclear on safety critical plant items and parameters to monitor, lack of correct, accessible information to assist in problem solving and decision making. Field operators not always available for relaying key information and PO not always aware where AO was or what he was doing. Unable to prioritise critical process tasks. GP1 was often operated in alarm and the PO often had several thousand alarms over a twelve hour shift. This is not feasible, therefore it is expected that alarms were missed and as there was no prioritisation on the alarms that critical alarms were missed and not acted upon (as occurred leading up to the rupture and fire). The workstation and CR layout made the PO's job difficult as he had to monitor variables in more than one physical location and on more than one system. Many items of monitoring equipment were not working on the day of the incident such as chart recorders, it is not clear whether any of these were critical or whether the PO had time to look at them. That he was unaware that they were not working suggests they were not widely used.	One SS gave instruction on the basis of believing he had seen a temperature in absorber B several degrees higher than it actually was. On this basis the SS gave instructions to close the bypass valve not knowing the position of the automatic control valve or adjacent block valve in order to reduce the temperature. He was unaware that at 19:00 on 23rd September the temperature in absorber B was down as low as minus 23 degrees (set point was minus 10 degrees) and had not communicated any need to monitor this variable to the PO. The SS had no clear guidance what the safe operating temperature range was only his previous experience. Information on controller performance versus set point for critical parameters was not readily available to PO's or SS. It required 'building' up in the Process Information Data Acquisition System (PIDAS) system. This time consuming task was (unsurprisingly) not done by the shift operations team when dealing with multiple problems and tasks, they took shortcuts to decisions based on previous recent experience and readily available information such as the Temporary Defeats Board.

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The shift handover at the start of the day of the incident took less than ten minutes despite there being numerous process problems at the time. The departing shift were taken home on a bus. It is unclear whether the shift coming on were responsible for arriving early for handover or whether the departing shift could stay on longer if the new PO required a longer briefing. This did not happen on the day of the accident and key information was not passed on such as a standing alarm for level on Absorber B (no longer audible so not immediately obvious to the relieving PO) and the ongoing Absorber B level and temperature upset. Additionally the reasons for locking and tagging the bypass valve were not logged and therefore misunderstood by successive shifts. There were similar omissions from the CR log.

On the morning of the incident the PO was distracted by unrelated tasks including the Critical Function Testing on Westbury Pumping Station and the shutdown of a piece of process plant unrelated to the GP1 process problems being experienced.

The PO gave in evidence that on one shift he received 8,500 alarms which is approximately 12 alarms per minute. He therefore had 5 seconds to detect, acknowledge, decide on a course of action and act on each alarm (that is without taking into account all his other tasks within a shift which were numerous).

(*Continued*)

Table 1. Continued

Ladder Element	Comments on ladder position	Examples from the evidence
Teamworking	There was no clearly identified individual setting priorities for actions needing support.	It is not clear which individual was setting priorities for actions needing support. The PO was not supported by the Shift Supervisor until well into the developing incident despite there being several process upsets from the start of the shift (see examples in Situational Awareness where unrelated tasks distracted the PO from dealing with process upsets). Shift handover of process problems was ineffective, including SS role supporting PO. It was for the PO to ask for the SS support which he eventually did as he was struggling with workload from process upsets, alarms and phone calls. The AO was not available in time to assist when he responded to the call for assistance.
Alertness & fatigue (work pattern)	Controls on working pattern and management of overtime and exchanging shifts does not appear to have been addressed by the RC. Therefore it has not been possible to assess this element.	No examples to allow assessment.
Alertness & fatigue (health)	Health monitoring and controls on medication do not appear to have been examined by the RC. Therefore no assessment has been possible on this element.	No examples to allow assessment.
Training & development	There is no indication of regular refresher training on major hazard scenarios for the operations team. The lack of formal hazard identification for GP1 and communication of process hazards to PO's and AO's meant there was lack of awareness of the Major Accident Hazard (MAH) for the plant amongst the operations team. There was a competency based training programme in place which all PO's and AO's were subject to. However, major hazard training does not appear to have been adequately covered. Therefore the assessed position has been placed at Y.	Risk engineers studied a batch of failure scenarios on GP1 before 1998 and at least two of those dealt with possible cold embrittlement. However the study and results were confined to risk engineers and did not involve the operations team. Operations personnel were generally unaware of the hazard of cold embrittlement. These studies could have provided an important opportunity to improve their MAH preparedness.

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Roles & responsibilities	Although there was a competency based training programme in place. It is not clear that a structured approach had been used to identify the required team competencies or that this included MAH requirements. The fact that there was a significant lack of process safety knowledge amongst the operations team suggests that this core competency was not adequately covered.	A SS did not have an understanding of the safe operating temperature range of the B absorber, his only basis was what he knew they had operated the plant at before. Additionally, critical systems for safety such as the lean oil system do not appear to be well understood nor the process conditions which could lead to cold embrittlement.
Willingness to initiate major hazard recovery	Emphasis on safety when communicating with operations team tended to be on personal safety, not major hazards. Not found evidence of management appreciating that operator actions in an upset or emergency situation may be affected by knowledge of product, equipment, quality, environment 'costs'. No evidence of rehearsing scenarios to test potential hesitation and delay due to such influences.	Evidence from the SS on his actions around absorber B prior to the incident suggest that product related problems dominated his thinking. He did not consider the potential for excessive cold temperature, build up of condensate in the base of absorber B or level problems.
Management of operating procedures	This was much discussed by the RC. Procedures were not easily accessible for operators and it was unclear which procedure should be used for a particular task or situation. The 'Red Book' referred to in evidence was not known about by some operators and it is unclear whether it was maintained.	Critical operating parameters for critical vessels in the ROD/ROF area were not contained within operating procedures. There was a list of critical operating parameter for GP1 but it appears unclear what the basis was for their inclusion. Some of the critical operating parameters were only marked up on Piping and Instrumentation Diagrams (P&ID's) and some were only on the vessel identification plate. Therefore, this information was not readily available to assist in decision making either within the Human Machine Interface (HMI) as a decision support tool or an easily accessible hard copy. There was a lack of emergency procedures such as shutdown of the lean oil system, potential consequences and guidance for rewarming vessels after its shutdown or cessation of lean oil flow. Plus a lack of guidance to assist in troubleshooting such as high level of condensate in the base of an absorber.

(*Continued*)

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Table 1. Continued

Ladder Element	Comments on ladder position	Examples from the evidence
Management of change	There are several examples of organisational, equipment and procedural changes which were not adequately assessed for safety implications and did not have the risks systematically assessed. Additionally, it is not demonstrated from the available evidence that the key people affected by the change being identified, consulted and their views incorporated into the change process. Esso do appear to have made some attempts to develop additional skills within the operations team prior to the several organisational changes implemented. However, it is not satisfactorily proven that the process was systematic and placed sufficient emphasis on the impact of the change on emergency response and dealing with major hazard scenarios, or that performance was assessed after the changes.	The LFRC report states that no 'risk assessment' had been conducted prior to the several organisational changes affecting GP1 being implemented. Additionally, there were serious deficiencies in the form of risk assessments of changes to equipment and operating procedures prior to 1998 in relation to condensate transfer system from GP1 to GP2. The LFRC report summarises these in Chapter 13. Examples of these deficiencies are: there were omissions in scope (1992), changes not assessed (1993–1996), changes implemented did not work as planned and led to changes from automatic control to manual with no associated risk assessment (1997).
Continuous improvement of safety	Although formal guidance existed on incidents and events required to be investigated, there had been several process related near misses on GP1 (specifically the cold temperature incident of August 1998) which had not been reported or investigated nor discussed informally within shift Toolbox talks or elsewhere amongst the operations team. Personal injury statistics were the predominant means of measuring safety performance. However, hydrate problems within GP1 had received attention over several weeks in June 1998 and had caused several production problems, there had been activity to try to resolve these problems and they had received a fairly high profile during 1998.	A previous cold temperature incident on 28th August 1998 on the plant equipment involved in the rupture and fire had not been communicated to all the SS's or operators. No incident investigation took place and there appears to have been limited informal communication so no effective learning took place within the operations team. The hydrate problem caused several downstream effects within GP1, not all of which appear to have been fully appreciated or investigated. The events leading up to the rupture and fire involved misdiagnosis that hydrate was part of the problem when it was not. A more thorough investigation of the hydrate incident with involvement of GP1 operators would have improved understanding around this issue.

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	It is unclear why the hydrate incident received attention and the cold temperature incident did not unless it was related to impact on GP1 productivity. The apparent lack of systematic use of process safety incidents and upsets for learning leads to the assessed position as Z.	
Management of safety	Operator involvement in safety appears primarily to be in personal safety such as Task Analysis and Stepback 5 × 5. From the available evidence, there is a lack of operator involvement in process safety management. Issues identified from 1990 and 1994 in periodic operational risk assessments had not been closed out at the time of the rupture and fire. The emphasis in safety management appears to be more on personal safety than process safety as longstanding issues had not been closed out, process safety assessments were deferred for years, process related incidents were not reported or investigated. A site safety committee was referred to in evidence.	Task Analysis and Stepback 5 × 5 are two initiatives mentioned by several witnesses which technicians were involved in. They were personal safety orientated and based around activity risk assessment. The results from periodic operational risk assessments of GP1 from 1991 and 1994 had identified a lack of maintenance of essential documentation in the CR and the inadequacy of the ESD system and lack of documentation as issues which required resolving. These actions had not been closed out at the time of the rupture and fire. The period between periodic risk assessments was extended from three years to five years and a planned retrospective Hazard and Operability study (HAZOP) was deferred from 1995 and had not been completed at the time of the rupture and fire. This was despite the Risk Assessment and Management System (RAMS) manual classifying GP1 as a priority which required risk assessment every three years. A rationalisation process approved this change.

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performing timely detection, diagnosis and recovery is a fundamental requirement for safe operation. This is an essential message which is not clear from the LFRC report although is alluded to in passing. There are many different ways an organisation may achieve this capability which is why the staffing method Physical Assessment is structured on principles for safe operation rather than prescriptive rules or guidance.

The staffing method provides a clear focus when investigating how a group of people tackled an operational incident. It has identified many of the issues picked up by other commentators such as Dawson and Brooks (LFRC)[2], Hopkins[3] and Nicol[5] to a lesser or greater extent. What it adds is a structure for prioritising issues to investigate and an approach for eliciting relevant information which goes beyond technological causes or general non-specific management system failures. On this basis it could perhaps be a useful addition to the accident investigation toolkit, using the Physical Assessment principles rather than the trees used in periodic or change assessment.

CONCLUSIONS

This paper seeks to illustrate that the staffing assessment method could be applied to accident investigation to provide an objective, socio-technical systems based approach to augment the prevailing engineering model of accident investigation. The Longford incident provided readily accessible, extensive evidence from operations team staff, their line management, senior management and support staff. Additionally, there had been several documented changes to operational staffing arrangements prior to the incident and there had been discussion amongst commentators about their potential contribution.

Use of the approach highlighted the following key issues within the Longford Gas Plant 1 staffing arrangements:

- Poor alarm management; in particular overload and lack of prioritisation.
- PO unable to focus on process upsets during detection, diagnosis or recovery due to multiple distractions.
- Lack of information to support problem diagnosis and lack of operator training in process hazards and dealing with MAH scenarios;
- PO required to leave CR to initiate ESD, requiring him to approach fire hazard which prevented him completing other tasks due to smoke and heat.
- Poor situational awareness for multiple reasons including deficiencies in CR layout and interface design, lack of structure in shift handover and logs.
- Lack of MAH preparedness amongst operations team. No evidence of regular opportunities to practise MAH scenarios as walkthrough's, desktop talkthrough's or through use of a simulator.
- While much focus was given to personal safety at operations level, there is little evidence of sufficient involvement in process (MAH) safety. For example, the shift team were poorly equipped to understand the GP1 process hazards and where the process was operating with regards to the safe operating envelope e.g. well within, inside but near the edge, on the edge or outside the envelope. This information

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should be incorporated as decision support tools close to the point of use, accurate, up to date and understandable which will improve situational awareness and execution of problem solving tasks.
- Lack of systematic, structured assessment of safety implications of proposed equipment, procedure or organisational changes.
- Lack of process safety incident investigation for learning opportunities.

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