INFORMATION SHEET

Human factors: Case study – petroleum refinery explosion

1 Introduction

The aim of this case study, which is based on the BP America (Texas City) refinery explosion in 2005, is to show how human factors can contribute to a series of events that lead to an accident.

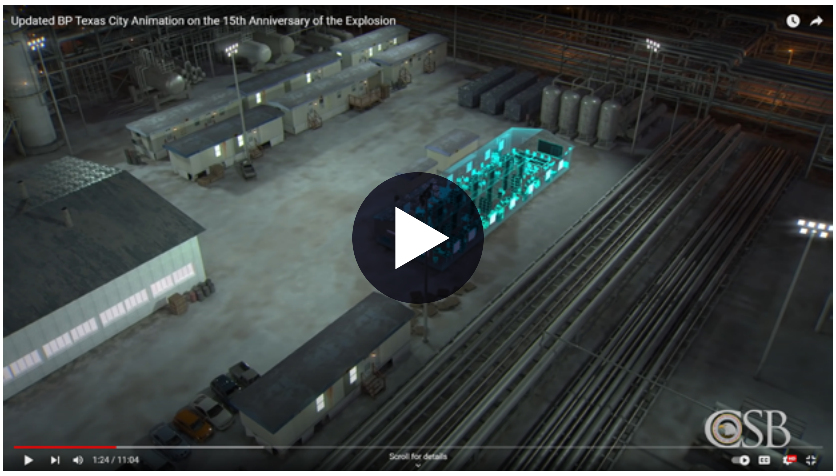
The refinery had a well-established safety management system. However, the role of human performance in preventing initiation, mitigating the impact and improving recovery for a major accident had not been considered.

This case study details how human factors contributed to the accident and outlines corrective actions that can be made to improve the overall effectiveness of the safety management system.

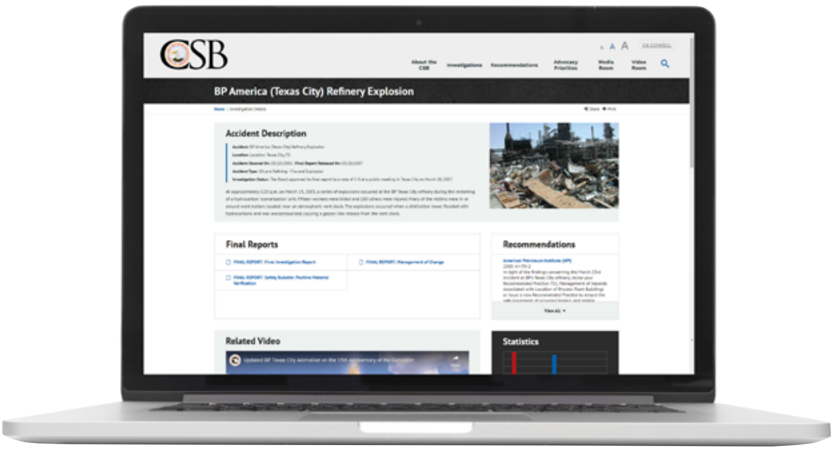
2 Incident description

The major accident event was a massive hydrocarbon release, explosion and fire, which had catastrophic consequences as 15 workers were killed and 180 others were injured.

The US Chemical Safety Board (CSB) released an updated animation in 2020 detailing the events that occurred at the refinery.



The CSB investigation report is available online.



3 Findings and recommendations

Identified human factors that played a key role in the accident are listed below, with examples of corrective actions.

Findings		Human factors	Examples of corrective actions
1.	Process safety performance was degraded due to cost cutting, failure to invest and production pressure in the 1990s by the previous and then the current owner. In 1999, the current operator implemented budget cuts of 25 per cent followed by another 25 per cent in 2005. This was despite much of the refinery's infrastructure and process equipment being in disrepair. Operator training and staffing was also downsized (see Finding 6). Leadership and management did not lead by example. On the day of the isomerisation (ISOM) startup, the process safety coordinator was unfamiliar with the application of the pre-startup safety review (PSSR) and it was not conducted. The PSSR would have verified the adequacy of all ISOM safety systems and equipment. It would also have required that all non-essential personnel had been removed from the unit and neighbouring units, with higher level management required to sign-off on the PSSR checklists and authorise the startup. None of the steps was conducted. The neighbouring units (i.e. site trailers) had been in the ISOM area 'for years largely for reasons of convenience'. The location of the occupied buildings placed workers 'in the line of fire'. In the years leading up to the accident, there were eight serious releases of flammable material from the ISOM blowdown stack, and most ISOM startups resulted in high liquid levels in the splitter tower. Neither the previous operator nor the current operator investigated these events.	Designing for people Health and safety culture	• Locate occupied buildings, even during normal operations, 'out of the line of fire' i.e. consequence zones for overpressure, radiant heat or toxic plume. Refer to American Petroleum Institute (API) Recommended Practice (RP) 752 and 753. • Key messages that promote a commitment to safety need to be supported by appropriate action from leaders and managers to ensure the behaviours underpinned by these messages are valued and become part of the prevailing culture. • Demonstrated leadership commitment to a health and safety culture includes: – highly developed hazard and risk awareness – provision of adequate resources (including funding, investment in worker training and competency, maintenance of infrastructure and equipment) – accountability for key performance indicators for safety – investigation of near misses and accidents in a timely manner.

Findings		Human factors	Examples of corrective actions
2.	A blame culture existed. Workers were not encouraged to report safety concerns and some feared retaliation for doing so. Lessons learned from incidents and near misses were generally not recorded or acted on. Important relevant safety lessons from investigations into other refineries owned by the operator were also not communicated or incorporated. Leadership used the injury rate as the key indicator of safety performance. This did not provide an accurate picture of process safety performance or the health of the safety culture. Incentive programs for improving safety incorrectly focused on improving worker safety behaviours rather than process safety and safety management systems given that many safety policies and procedures were not fit for purpose.	Health and safety culture	• Establish and maintain a positive safety culture, which includes: – visible leadership commitment and role modelling – a safety management system and practices for effectively controlling major accident events, incidents and hazards – a positive attitude towards risk management and compliance with the control processes – fairly allocating accountability for accidents, incidents and near misses to the workplace's systems, rather than the individual workers involved – the capacity to learn from accidents or near misses – encouraging reporting, reflecting on previous incidents and accidents, and incorporating identified solutions into work systems to decrease subsequent accident and incident rates, and risks of serious and/or catastrophic failures – appropriate safety performance indicators for continual improvement.

Findings		Human factors	Examples of corrective actions
3.	There was a number of latent failures, incuding the incorrect calibration of the raffinate level transmitter, and the failure of the second high-level raffinate switch, sight glass and blowdown drum alarm. The raffinate level transmitter failed because the instrument was not correctly calibrated for the actual specific gravity of the ISOM process fluid at operating temperatures. The PSSR should have also identified the failure of the second high-level raffinate switch; however, the PSSR was not conducted on the day of the incident. The failure of the sight glass and the blowdown drum alarm were attributable to a lack of awareness of damage to these instruments. These latent failures were the result of inadequacies in the workplace's integrity management system, which were not able to identify issues and correct them prior to failure occurring. This is commonly referred to as a 'run to failure' maintenance philosophy.	Maintenance, inspection and testing	• Perform and document adequate inspection and testing activities to minimise the risk of introducing latent conditions and failures. This should include independent verification of safety-critical tasks, such as the PSSR and maintenance activities. • Conduct regular internal audits of the integrity management system and implement identified recommendations. • Safety-critical controls should be regularly inspected and maintained as a priority to ensure they continually meet the performance standards.
4.	There was a lack of communication between the day shift and night shift surrounding the current state of the plant. This resulted from the workplace failing to emphasise the importance of thorough and accurate communication. There was no policy or procedure for effective shift handover communication. No formal shift handover logbook was used to ensure that communication was clearly and adequately disseminated among workers.	Safety-critical communication	• Establish formal shift handover communication processes to ensure that all workers are aware of operations and the state of plant at the beginning of their shifts. • Conduct regular compliance audits of the shift handover procedure (once created).

<table>
<tr><th colspan="2">Findings</th><th>Human factors</th><th>Examples of corrective actions</th></tr>
<tr><td>5.</td><td>As part of the startup procedure, a control room operator was required to monitor the amount of liquid entering and leaving the unit. The control screen for this task showed the amount of liquid entering on one page and the amount leaving on a different page. Having the two feed readings on separate pages reduced the visibility of the readings and failed to make any imbalances between the two readings obvious and likely diminished the perceived importance of monitoring the liquid in versus out. These issues suggest the control room operating system was not designed for optimal human performance.

The display was unable to calculate the ratio of liquid in versus out and the control room operator had to do this manually. This increased the cognitive demand on the worker and increased the chance of important information being missed.</td><td>Designing for people</td><td>• Review control room operating systems, with consideration of human factors. Relevant recommendations should be implemented to minimise the risks of design-induced human performance issues, which can lead to major incidents.</td></tr>
<tr><td>6.</td><td>There was a lack of supervisory oversight and technically trained workers during the startup, which is an especially hazardous period. This omission violated the operator's safety guidelines.

A staffing assessment recommended an extra board operator be assigned for all ISOM startups, but this was not implemented.

The team responsible for executing the startup procedure was understaffed. Only one control room operator was responsible for monitoring and controlling the process. While this would have been satisfactory under normal conditions, the workplace failed to recognise that the startup process was an abnormal procedure and required more workers.</td><td>Staffing and workload</td><td>• Conduct a review to ensure the number of workers, and their skills and experience levels, are adequate for maintaining the safe operation of the plant under different operating conditions.
• Ensure the minimum staffing baselines for safe operation of the plant under different operating conditions are adhered to, or defer high risk work activity if not (e.g. startups and shut downs).</td></tr>
</table>

Findings		Human factors	Examples of corrective actions
	The lack of available workers likely added to the workload of the control room operator, contributing to their lack of vigilance of the liquid levels in versus out. The reduced vigilance, along with the poorly designed control screen (see Finding 5), meant that the issue with the overfilling tank was not observed until it was too late.		
7.	Workers who were on shift at the time of the incident had inadequate training in the safety-critical tasks of their job. Operator training did not cover the hazards of the start-up procedure adequately, including the hazard associated with overfilling the unit, nor did it cover training for abnormal situation management. This likely contributed to the lack of vigilance, as the operator was unaware of the importance of ensuring that the raffinate splitter tower did not overfill. Additionally, once it was clear that there was an issue (i.e. the pressure rose and valves opened), the lack of competence contributed to the crew's inability to identify the problem correctly, which allowed the situation to further escalate. Operator training and staffing had also been downsized. The training department had been reduced from 28 workers to eight. Simulators were not available for operators to practice handling abnormal situations, including infrequent and high hazard operations, such as startup and unit upsets.	Training and competency	• Review current training and worker competency – a matrix should be carried out to determine if it is suitable. • Training should be developed and implemented to ensure that all workers have adequate knowledge of the hazards and procedures necessary to do their job. • Effective verification methods should be used to test that workers have knowledge and competencies that are suitable and up-to-date. • Emergency response training and competency assurance should be regularly undertaken for a range of scenarios.
8.	The workplace had no formal policy for ensuring that workers were not affected by fatigue while on duty. When the accident occurred, the operator in charge had worked 12-hour shifts for 29 consecutive days. It is likely that fatigue impaired their judgement and problem solving, hindering their ability to determine that an issue was occurring.	Fitness for work	• Implement a formal fatigue management policy and procedure.

Findings		Human factors	Examples of corrective actions
9.	During the startup procedure, workers deviated from established work practices that were frequently conducted to protect the equipment and complete the startup in a timely manner. Several human factors enabled this to occur, including inadequate procedures and no management of change (MoC) processes. Management did not ensure the startup procedures were regularly reviewed and updated to reflect the true nature of the job. This resulted in the procedures lacking the required information to allow for successful completion of the startup task and likely contributed to workers 'filling in the gaps', resulting in deviations from the procedure to get the job done. When this occurs regularly, it results in the procedures no longer reflecting work-as-done, degrading the ability to safeguard against an accident.	Usable procedures Managing change	• Conduct a review of procedures, involving the relevant workers, so that they reflect work-as-done, rather than work-as-imagined.
10.	Changes involving people, policies, or the organisation that could affect process safety were not assessed. On several occasions leading up to the incident, changes were made to the start-up procedure without an MoC process being undertaken. This was counter to the safety management system, which required an MoC process be conducted for any changes to procedures, particularly those deemed safety-critical. The workplace allowed workers to alter, edit, add and remove procedural steps, without consultation or assessment of the risks involved. This likely created a health and safety culture that accepted routine violations, such as unauthorised changes, and the view that procedures were not strict work instructions.	Managing change Health and safety culture	• Implement an MoC policy and procedure: – the MoC system should ensure that changes are analysed, evaluated and communicated to all members of the workforce before implementation – the MoC procedure should be used for introducing new or modifying existing hardware, such as plant, tools, materials and machines. – the MoC policy should be enforced for all procedural changes, particularly those that involve safety-critical tasks, such as the startup procedures or changes to the organisation and the way people work. • Conduct internal compliance audits.

4 Additional information and resources

- *Human factors fundamentals for petroleum and major hazard facility operators: Guide*
- *Human factors self-assessment guide and tool for safety management systems at petroleum and major hazard facility operations*
- *Human factors: Usable procedures: Information sheet*
- *Human factors: Five principles of human performance: Information sheet*
- *Human factors: Integrating human factors into bowtie analyses of major accident events and major incidents: Information sheet*
- *Human factors: Integrating human factors into major accident events and major incident investigations: Information sheet*

WSJun23_1254