Assigning Moral Responsibility in the 1987 Grangemouth Explosion

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

In 1987, a series of accidents occurred at two BP refineries in Scotland, between March 13 and June 11, which led to the deaths of four contracting employees as well as the company being fined £750,000 for violations of the Health and Safety at Work Act (*Safety Rules "disregarded" before BP Fatal Accidents | HeraldScotland*, n.d.). In particular, the March 22 explosion was considered to be a major accident which took place in the hydrocracker unit of the refinery. In recent years, several scholars have argued that the maintenance of the plant bears the primary responsibility for the plant's failure, and the domineering presence of poor management at the plant acted as a problematic propagation. These conclusions are supported by the investigation into the incident which concentrated upon errors made by operators. However, the view of current scholarship fails to look beyond the preceding years of the incident back to the construction of the plant, which operated successfully for almost two decades, to consider all actors who had a stake in the project. Consequently, the scope of blame for such an accident is limited, and it is difficult to learn from errors made by other parties.

Actor Network Theory (ANT) works to identify and characterize a network of human and non-human actors which are associated together by a network builder to accomplish a specific objective, such as the stable operation of a chemical manufacturing plant. Drawing on Actor Network Theory, I will argue that it was the designers of the plant that bear the primary responsibility for the failure of the plant - in conjunction with the actions of the maintenance, operators, and management action as secondary factors. To determine the moral responsibility of the plant designers, I will use van de Poel's definition of passive moral responsibility from his book *Ethics, Technology, and Engineering*, which is based on the following four conditions: wrong-doing, causal contribution, foreseeability, and freedom of action. To support my argument, I will analyze evidence from the initial safety reports conducted prior to and after the March 22, 1987 explosion at the Grangemouth Refinery, as well as secondary sources produced years after the fact, which revisit the accident and evaluate its implications on the evolution of safety in process design considerations.

Background

The hydrocracker unit of the refinery involved in the explosion works, under normal operation, by collecting a hydrocarbon liquid at the bottom of the high-pressure separator and discharging it into the low-pressure separator through a control valve in order to ensure the high-pressure separator is maintained at a constant pressure. The low-pressure separator is not designed for operation at the conditions and pressure that the high-pressure separator is, and therefore, the control valve also acts as a pressure reduction valve. There is an extra low-level alarm which would close the valves between the two separators if the level of liquid in the high-pressure separator fell below an acceptable level; however, this was disconnected years before the incident. During startup operations, the liquid level in the high-pressure separator depended upon the disconnected alarm and operator vigilance. Thus, the protection of the low-pressure separator from gas breakthrough overpressurization depended only upon the operator. The incident in question occurred as a result of faulty level indication misguiding the operator - which caused the loss of liquid in the high-pressure separator, released hydrogen gas into the low-pressure separator vessel, and caused an overpressurization of the vessel. As a result, the vessel ruptured, releasing flammable hydrogen gas leading to the death of a plant worker as well as a fire that took several hours to put out.

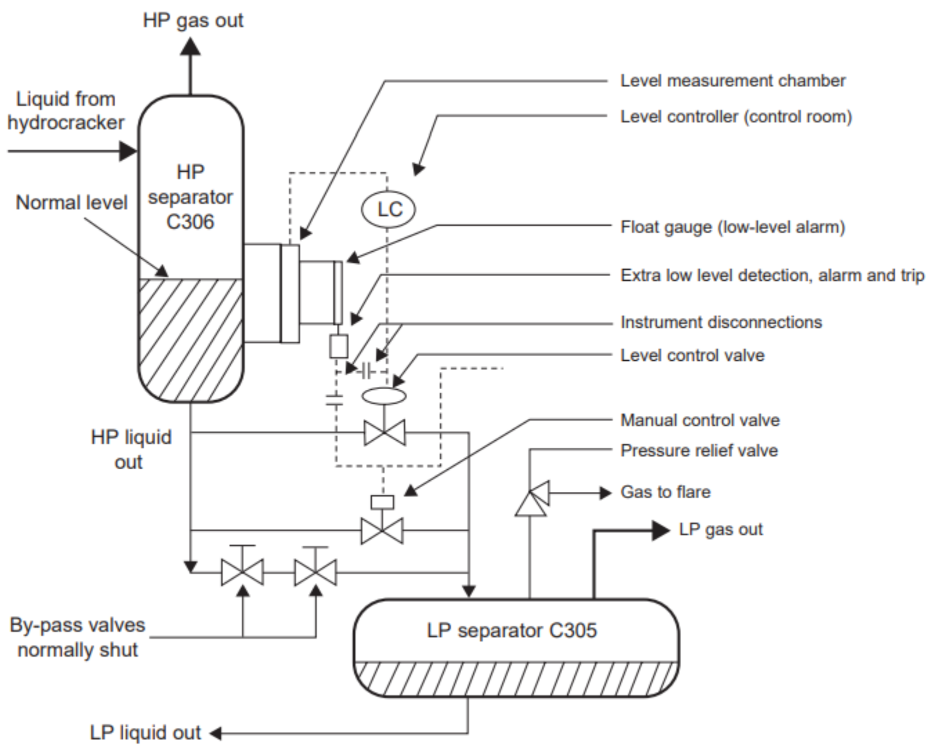

Figure 1. The high-pressure (HP) and low-pressure (LP) separators in the process.

Literature Review

Due to their unfortunate frequency in the workplace, many scholars have attempted to examine chemical engineering incidents and appropriately assign responsibility of the incident to a participating party. However, these analyses fail to consider all possible actors in the network that led to the Grangemouth accident and loss of life and are therefore insufficient, generally assigning blame towards the acting company in the form of a fine with only some possibility of recommendations for change.

In their article “The Role of Maintenance Management Deficiencies in Major Accident Causation,” the authors compared several industrial accidents within oil and gas production and refining, including the three incidents that occurred at Grangemouth in 1987, and compared them to the Flixborough of 1974 (Smith & Harris, 1992). The authors argue that the maintenance system of any chemical processing plant has a dynamic relationship with production systems, and it is from this system that corporate and production objectives can be identified and achieved. The absence of an optimum maintenance management system, which the authors state is a system that responds to changes in conditions - such as sales demands and statutory regulations - was aided by the lack of formalized plant modification procedures which ultimately led to the incident. Furthermore, the authors argue that a vital component of maintenance control is plant reliability, both short term and long, and safety control - which the Grangemouth plant lacked. The Grangemouth plant, as operated by BP Oil, lacked an overall maintenance management system, which led to several deficiencies in the upkeep of the highly dangerous hydrocracking processing unit.

Three of the deficiencies occurred in the years leading up to the accident. In 1975, a safety audit of the plant recommended additional low liquid level trips, however this suggestion was not acted upon, failing the auditor's requirement of safety control and adequate changes in conditions. A second deficiency was the disconnection of wiring between float switches, causing the safety of the plant to be 'depend[ent] on the vigilance of operators,' with a near miss occurring two years prior to the incident that was not investigated (*The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd*, 1989). The disconnection fails the formalized plant modification procedure as an integral part of safety management. Finally, the low level visual indicator in the control room was known to be faulty prior to the incident and had not been repaired prior to the 1987 explosion, failing the author's condition of plant reliability, since the operators could not trust the controls they were working with.

After a similar series of incidents occurred in 2000 at the same BP Oil plant in Grangemouth, additional investigations were conducted into the management of the plant operations, particularly the role of leadership. The results found there was a decentralized management organization, which led to difficulties in implementing necessary safety measures. In their article "Toxic Corporate Culture: Assessing Organizational Processes of Deviancy," Van Rooij and Fine argue that poor maintenance management and reduction in engineering capacity is a result of toxic organizational culture, which the authors consider to be a systemic crime.

Prior to the 2000 incident, a study conducted at the BP Grangemouth Refinery on effective and safe communication at shift handover in 1995 investigated the risk of miscommunication at times of abnormal plant conditions and concluded that information was shared neither efficiently nor completely (*Investigation Report: Refinery Explosion and Fire*, 2007). In particular, the logbooks were unstructured, and there was no guidance to operators on reporting important information that should be passed on to the following shifts. Regarding the incident, there was found to be decentralized management which acted as a barrier to learning from previous incidents. The management at BP also had an overemphasis on short-term costs, and the production led to unsafe compromise; thus the leadership did not ensure necessary changes were made to the approach to safety, especially since the authors concluded there was a lack of learning and reporting culture that inhibited the findings of potential fall throughs.

While both articles compare similar incidents at the same processing plant in Scotland, they fail to consider all possible actors responsible. The first authors discuss the lack of appropriate maintenance as a primary reason for the explosion, and the second authors suggest that the lack of maintenance and failure of operators was a direct result of poor management and a toxic safety culture; both take into consideration short term problems occurring at the plant without deliberation on the entire plant's production lifespan. The authors fail to acknowledge the role the plant designers play in the incident, and the responsibility of a plant designer to consider the high probability of human error.

Conceptual Framework

The Grangemouth explosion of March 22, 1987 will be addressed by first considering the possible actors, followed by a discussion of the actor who bears the responsibility for the explosion and why. According to Cressman, the Science, Technology, and Society concept Actor Network Theory (ANT) considers the roles of many different actors in the formation of a network to advance a technology, and it focuses on technology in the making, such as a chemical processing plant (Darryl Cressman, 2009).

Actor Network Theory examines a technology network by identifying a network builder which strings together a system of diverse resources including technical, social, natural, economic, and conceptual actors for a common purpose. These actors can build a coherent stable network or one that can eventually destabilize as seen in the Grangemouth explosion. According to Callon, there are several steps towards network building; problemitization or the identification of problem and actors, interessement or recruiting of actors to the network, enrolment or assignment of roles in the network and mobilisation or securing of roles in the network (Callon, 1984). Within a network, there is no single actor that is more powerful than other actors–all actors need to work successfully together for a network to function. The privileging of certain actors over others can lead to the destabilization and failure of the network. In the case of the Grangemouth explosion, the prioritization of financial gains and minimization of safety led to the failure of the network, however I will argue that it was the faulty recruitment of the designers that ultimately caused the explosion, and they bear the primary responsibility for the accident.

According to van de Poel, the definition of passive moral responsibility is as backwards-looking responsibility which is relevant after something undesirable occurs, with two main types–accountability and blameworthiness (Ibo van de Poel & Lamber Royakkers, 2011). Accountability is the sense of being held to account for one's actions, whereas blameworthiness is the determination of whether an actor is a proper target of blame for the consequences of the actor's actions. Van de Poel argues that it is possible to be accountable without being blameworthy, and that four conditions need to apply for blameworthiness: wrong-doing, causal contribution, foreseeability, and freedom of action. Wrong-doing is the condition that a person or institution violated a norm operating procedure, whether it be a legal, organizational, or moral violation. The second criterion is causal contribution, which requires two parts; an actor to act or fail to act, and for the causal contribution to be a necessary part of the chain of events causing the consequence, in the case examined, the explosion. Foreseeability requires that the responsible actor have the ability to know there is a consequence for their wrong-doing, since an actor can not be held responsible if it is unreasonable for them to know the consequences. The final condition is freedom of action, meaning the individual actor cannot be responsible if they were coerced into their decision. I will leverage the construction of the actor network theory and van de Poel's definition of moral responsibility to assign the blame of the Grangemouth explosion to the plant designer.

Analysis

Building of the Network

In this section, I will briefly overview the actor network of contributors to the operation of the Grangemouth refinery in Scotland. The plant owners acted as network builders, collecting the human and non-human actors into the network but also incorporating several faulty actors into the network. There are several human actors involved, including the plant operators, the plant designers, the supervisors and the plant maintenance team (*The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd*, 1989). During the plans for plant construction, the incorporation of the plant designers led to several weak connections in the network, including between valve readings and the operators. Non-human actors include the safety culture of the plant, overall company culture, operator log books, valve readings, the line readings between valves, pressure valves, thermal valves, and other sensors (*Investigation Report: Refinery Explosion and Fire*, 2007; *The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd*, 1989). While initially operating successfully, the plant management team acted as a rogue actor since they worked to destabilize the network over time through a bad company and safety culture, which allowed known errors in the plant design to propagate. However, the faulty connections involving valve readings bear the fault for plant failure; since these were designed and constructed by the plant designers, the designers are at fault for the network failure

Responsibility of the Plant Designers

In this section, I will argue that the plant designer violated all four conditions of van de Poel's definition of passive moral responsibility and thus bear moral responsibility for the March 22, 1987 accident at the BP Oil refinery in Grangemouth, Scotland. Van de Poel describes the four conditions of passive moral responsibility to be wrong-doing, casual contribution, foreseeability, and freedom of action. These conditions mean that the morally responsible party had to have made an error that directly contributed to the failure. Additionally, the morally responsible party must have had the knowledge that their error could cause a failure and the ability to choose to make a decision that would have different consequences.

The first of van de Poel's conditions of moral responsibility is wrong-doing. When designing the plant, the low-pressure separator relief valve was not designed to handle the maximum flow of gas from the high-pressure separator (Whittingham, 2004). In fact, it was designed to only be a thermal relief valve not a mechanical relief valve, and there was no other mechanical relief valve added to the design between these two separators that was functional during startup. A mechanical relief valve is necessary to direct the gas away from the low-pressure separator in order to avoid overpressurization, which would rupture the vessel. The only automatic emergency valve closing, tripped by a solenoid, had been disconnected years prior to the incident, and thus, as previous authors had argued in literature, the safety of plant operations during startup relied solely on the 'diligence of the operator' (*The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd*, 1989). It is important to note that the designers only accounted for thermal relief of the separator, which is used to release small amounts of liquid to keep pressure constant and not let the temperature increase inside the separator, instead of using both a thermal and mechanical relief, the latter releasing a greater amount of liquid and acting when the temperature was not the problem.

Despite the lack of inclusion of a mechanical release valve, the plant designers did not violate any regulatory requirements of the time for their design of the Grangemouth Refinery, and thus, it is possible that their 'wrong-doing' can only be applied in hindsight. However, it is common engineering practice to account for both alarm failure and human operator error, since these are two of the most common errors with the highest probability of occurrence (Chen-Wing & Davey, n.d.; Hollender et al., 2016). The disconnection of the solenoid and inaccuracy of a measurement reader were predictable occurrences in a plant of this magnitude and should be designed for. While the designers were not in violation of any regulations for the design of the refinery plant, their failure to consider common errors that lead to catastrophic consequences, as is a 'norm' in the industry, meets van de Poel's condition of wrong-doing.

A second error made by the designers was the failure to consider weather conditions of the region in the plant design, thus forcing operators to deviate from the set procedure. The sensing lines were unheated, and in the cold Scotland weather - particularly in winter - wax could solidify, creating blockages (*The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd*, 1989). It became routine for operators to open the sensing lines to prevent blockages between the high and low pressure separators, operating the plant in a hazardous way. Since weather conditions are often a major factor in plant design to prevent disasters, the plant designers yet again deviated from the set 'norm' of the industry by not accounting for Scotland's cold weather when designing the pipes of the plant (Anenberg & Kalman, 2019). The decision to not account for the cold weather furthers the wrong-doing of the plant designers, since it forced operators to work in dangerous conditions and rendered them unable to follow the plant designers set operating procedures.

The second condition of moral responsibility, according to van de Poel, is causal contribution – the action or failure of action which has a significant role in the outcome. By failing to add in a mechanical relief valve to the plant design, the excessive gas from the high-pressure separator was able to enter the low-pressure separator when the liquid level drained from the high-pressure separator. The low-pressure separator was designed to handle a pressure of up to 21.6 bar; however, as a result of this lack of relief valve, the separator was subjected to an internal pressure of approximately 50 bar, causing the rupture and explosion (*The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd*, 1989). Since the plant designers chose not to have a method of preventing the low pressure separator from overpressurization, the excessive flow was allowed to overfill the separator. Therefore, the latent error on part of the designers had a direct impact on the consequence and the designers met the condition of causal contribution.

The plant designers meet the condition of foreseeability for moral responsibility since they ignored the normal standards of practice for chemical engineering plant design, which are in place to prevent such accidents. It is commonly accepted within the industry that operators are often the immediate cause for chemical plant accidents, which has been supported by industrial reviews of incidents (Dakkoune et al., 2018). Furthermore, the decision to use vessels with different pressure capacities for the high and low pressure separators indicates the operators understanding of the ability of each chosen vessel to withstand high pressures, and thus, they had the ability to foresee the dangerous outcomes of the chosen low-pressure separator overpressurizing. The plant designers also displayed some consideration of the commonality of operator error – during continuous operation of the plant there was a greater use of automatic controls, in contrast to startup procedures which contained almost exclusively manual controls. The foreseeability of operator error and overpressurization through some design considerations demonstrates the plant designers knowledge of the outcomes of the resultant errors, and yet they did not design for them.

van de Poel's final condition of freedom of action is achieved since the plant designers were not under any stress or coercion that would force a negative design decision. The land of the Grangemouth Refinery was used to store oil for nearly 20 years before the refinery opened, and construction plans were made a full five years before refinery operations began ("Grangemouth," 2019; *Grangemouth History*, n.d.). Since the timeline of construction for an oil refinery can take fifteen to eighteen months, possibly longer, there was sufficient time for necessary design decisions regarding process safety to be taken into account, and therefore it is implausible that the designers were being rushed for time (*What We Do*, n.d.). Furthermore, given the low economic cost of the land and high rate of economic return on the project, the minor economic costs of a necessary purge stream are unlikely to sufficiently coerce the decision makers into neglect (*Grangemouth History*, n.d.). There was no indication of coercion in the history of the design process as well, and thus we can assume the designers had freedom of action, satisfying van de Poel's fourth and final condition.

The plant designers meet all four of van de Poel's conditions for moral responsibility: wrong-doing, causal contribution, foreseeability, and freedom of action. Their actions for disregarding a necessary mechanical release valve, taking into account the high risk of operator error, and not considering the cold weather in their plant design meet the criterion; thus they can be assigned moral responsibility for the Grangemouth explosion on 22 March, 1987.

Conclusion

The Grangemouth refinery explosion occurring on 22 March 1987 was a result of bad plant design which did not account for faulty readings in sensors and operator error. As a result of this combination, the low-pressure separator overpressurized and exploded, killing an operator. Despite their latent error occurring years before the incident, the plant designers bear moral responsibility for the accident and satisfy van de Poel's four conditions. Studying the case of the Grangemouth explosion is important to properly assign responsibility in the loss of life and failure to do so would not allow the prevention of further accidents with similar latent design errors.

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