SIESO Medal

Safety under scrutiny — Flixborough 1974

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Summary

On 01 June 1974, 28 workers were killed and 36 were injured at the Nypro chemicals plant in Flixborough. This paper will explore the underlying and immediate causes of one of the largest chemical explosions in UK history. Major legal and cultural changes regarding process safety were made as a result.

Keywords: Flixborough, modification, explosion, Management of Change.

Introduction and background

Nestled between the villages of Flixborough and Amcotts on the south side of the river Trent, is an industrial estate. On 01 June 1974 this was the site of a major chemical disaster that influenced change in process safety standards the world over.

In the 1970s the chemicals industry was experiencing a period of exponential growth. The primary focus of most companies was to develop advanced chemical processes to fulfil the demand for new materials following the scientific-technical revolution that began after the second world war[1].

One of these new materials were polyamides called "nylons". Most nylons have a good chemical and thermal resistance with a range of applications from textiles to insulating electrical wires.

Commissioned in 1967 the Nypro plant produced caprolactam, a chemical intermediate required for the synthesis of nylons. In 1972 the process was revised to include the oxidation of cyclohexane, a highly flammable and toxic hydrocarbon. In 1974, UK legislation relating to industrial sites was still based on industrial revolution style factories of the early 1900s, such as steam powered textile mills.

The capacity of chemical plants had recently undergone a period of rapid growth. This caused concern that the scale of the risks was growing faster than the measures were being developed to control them.

Causes and analysis

A major part of the onsite process was the oxidation of cyclohexane. A series of six reactors operated at 8.6 bar and around 155°C connected by metal expansion bellows. Around two months before the incident, it was noticed that reactor number 5 had developed a crack. The process was stopped and reactor 5 removed to be repaired.

To prevent a long-term process shutdown, a temporary section of pipe was added between reactors 4 and 6 as shown in Figure 1. This modification was developed and put into action onsite — no engineering drawings or calculations were performed. This was signed off by the acting Chief Mechanical Engineer who did not possess the qualifications or experience to be in such a position.

During the inquiry into the Flixborough Disaster, the "20-inch hypothesis" was accepted as the most likely immediate cause. It indicated a failure in the temporary connecting pipe due to the shear forces encountered. This caused 10 to 15 tonnes of boiling cyclohexane to be released[2]; the resulting

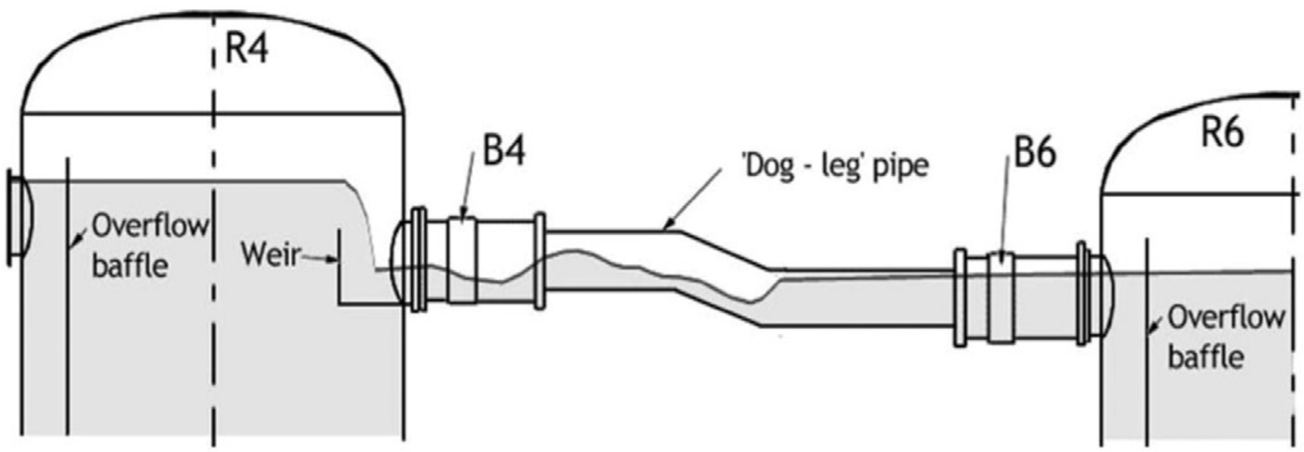

Figure 1 - Reactor vessels R4 and R6 with the temporary bypass indicating liquid levels at full production[2]

vapour cloud then ignited creating a huge explosion[3]. Estimates of the force of this explosion range from 15 to 280 tonnes of TNT.

A significant underlying cause was the poor culture surrounding process safety at Flixborough which was systemic throughout the chemicals industry. Safety officers occupied junior management positions, and a lack of communication with senior management led to a failure to conduct a full risk assessment of the modification.

The inadequate safety analysis carried out on the temporary modification to the plant meant the possibility of a failure and its potential consequences were not considered. This was partly due to the lack of experience that the senior engineers had with mechanical design – they were all from chemical engineering backgrounds. There was also very little information available at the time relating to vapour cloud explosions. Therefore, the extent of a disaster of this nature was unknown.

Aftermath of Flixborough

Flixborough is one of several landmark process safety events which has led to both management and legislative changes. Following the disaster, a public enquiry was conducted in order to establish the causes, consequences, and lessons learned. The Flixborough Disaster Report of the Court Inquiry was released in 1975 and includes recommendations used in current process safety elements we now take for granted[4].

The most widely recognised development came in the Management of Change which was further highlighted as an underlying cause with many subsequent incidents, including Piper Alpha fourteen years later. These two significant incidents made clear that modifications cannot go without a preliminary thorough analysis. This states that modifications must be subject to the same protocols, standards, and testing used in the initial design of the plant. The failure of the temporary pipe at Flixborough highlighted the importance of managing the implementation of modifications.

This disaster also influenced The Pressure Systems and Transportable Gas Containers Regulations 1989, SI 1989/2169 fifteen years later. There were many factors promoting the passing of this amendment, but the largest of them by far was the Flixborough disaster. This regulation clearly defined which systems it had jurisdiction over and outlined the necessary procedure to take following a modification or replacement to this system. A transitional time period was allowed for companies to make the necessary changes. Twenty years following Flixborough, these measures were implemented in every chemicals plant across the UK.

Since 1974 research and development into the understanding of vapour cloud explosions has been conducted. This has since allowed engineers to understand and predict the impact on facilities from various flammable gas release scenarios so that adequate mitigations can be put in place.

Flixborough exposed issues that industry previously had no awareness of. Some questioned why it took so long for them to be discovered. Trevor Kletz, the Safety Advisor for ICI at the time projected the idea of designing to minimise hazards rather than designing to control them.

At the time of the disaster many process safety management tools that are commonly used today were in their early stages of development. Most notably the Hazard and Operability study method.

Following the incident, managers of other companies began to question their own vulnerability. Therefore, the use of these tools became much more common. With increasing use, these tools improved dramatically[5].

Outcomes and lessons learned

Once the causes of the Flixborough incident had been identified, action was taken to reduce the risk of such an incident from reoccurring.

Flixborough led to a cultural revolution in the way people viewed safety.

When implementing designs, hazard and risk analysis became a core consideration. It was not permissible to allow engineers, operators, or contractors to work unaware of the potential dangers in their workplace.

It was also encouraged that engineers learned a wide breadth of skills while in university as processes became increasingly interdisciplinary due to technical advancements.

An important safety factor, previously unaccounted for was the design and placement of administrative buildings within factory areas. These practices are still being refined and developed today.

Since Flixborough, industry led good practice guidance has been developed which advocate using the hierarchy of controls and the risk assessment process to reduce risks to people in buildings on sites with high hazard potential. It was also recommended that, where possible, control rooms and administrative facilities should be placed away from the chemical process. It is unfortunately the high loss of life at Flixborough which made the need for this precaution clear.

It was also made clear that no matter how temporary a building was, or how sparsely populated it was, the same design precautions should be taken. A guide[6] for how to design and place buildings around a chemical process was published in the late 1970s. It continues to be updated, with a 3rd edition being printed in 2010 and a 4th edition due to be published at the end of 2019..

The regulations implemented since Flixborough have been hugely effective. Certainly, the change it demanded in management and safety protocols alone would have produced huge effects. The effect of the need for interdepartmental communication is still present in existing management structures today. Safety procedures resulting from Flixborough have evolved and developed as processes have. The impact of the action taken post disaster was recognised by many countries in the EU. When designing their own regulations, they looked to existing procedures in the UK as a standard.

One of the most important lessons taken from Flixborough is for the need of procedures and protocols to match the development of new equipment and processes. Without advances in safety, it is unsustainable to attempt to develop new processes. They ultimately will not be able to operate safely. It is vital here that we remember the past failings which led to accidents. We apply the same thorough approach to safety in any newly developed process.

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Conclusions

The scale of the Flixborough disaster in addition to other major incidents in the 1970s prompted a rapid change in process safety. Its legacy influenced legislative change not only in the UK but across the developed world.

The main outcome of Flixborough can be seen in the Management of Change which became more common in industry. Following the disaster, more incidents have occurred due to changes not being managed correctly. Incidents still occur due to insufficient design of instrumentation.

One of the most successful changes has been in the evaluation of population in vulnerable areas. The placement of occupied buildings is now a major consideration in the plant design.

Instilling the application of learning into undergraduate chemical engineers has been positive. Process safety is now a requirement for a degree to be accredited by the Institution of Chemical Engineers[4].

Remembering Flixborough

Every five years a memorial service is held at All Saint's Church, Flixborough, for those involved in the tragedy.

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