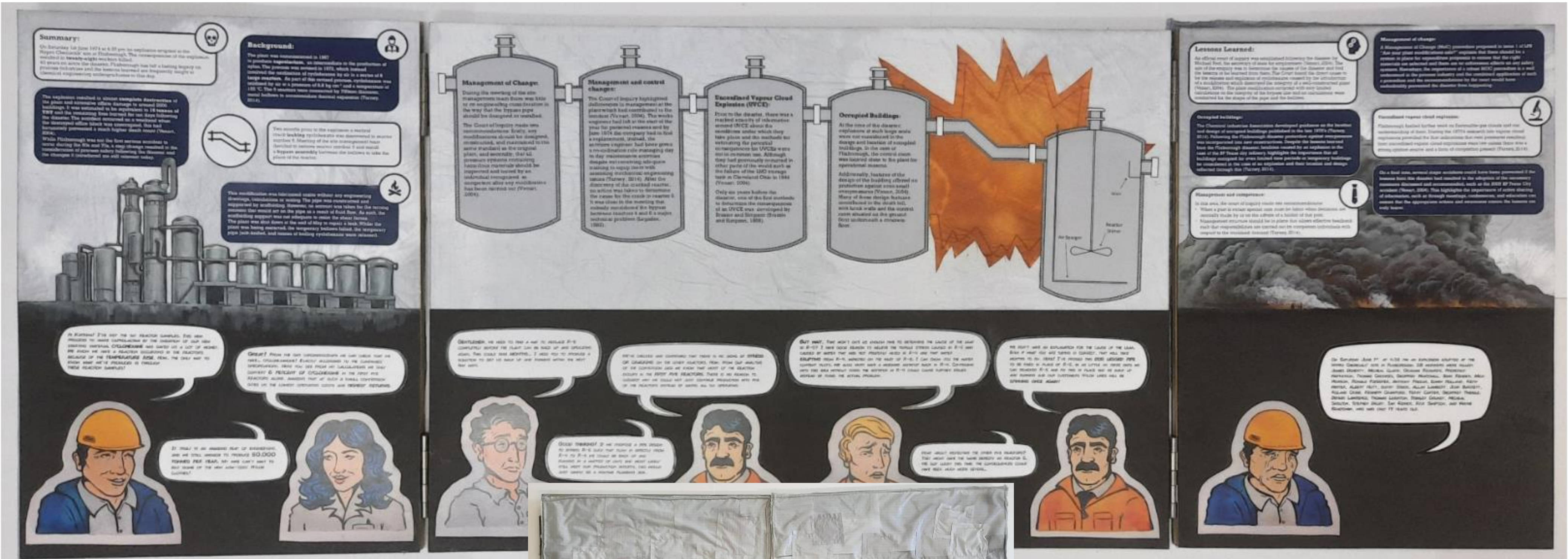


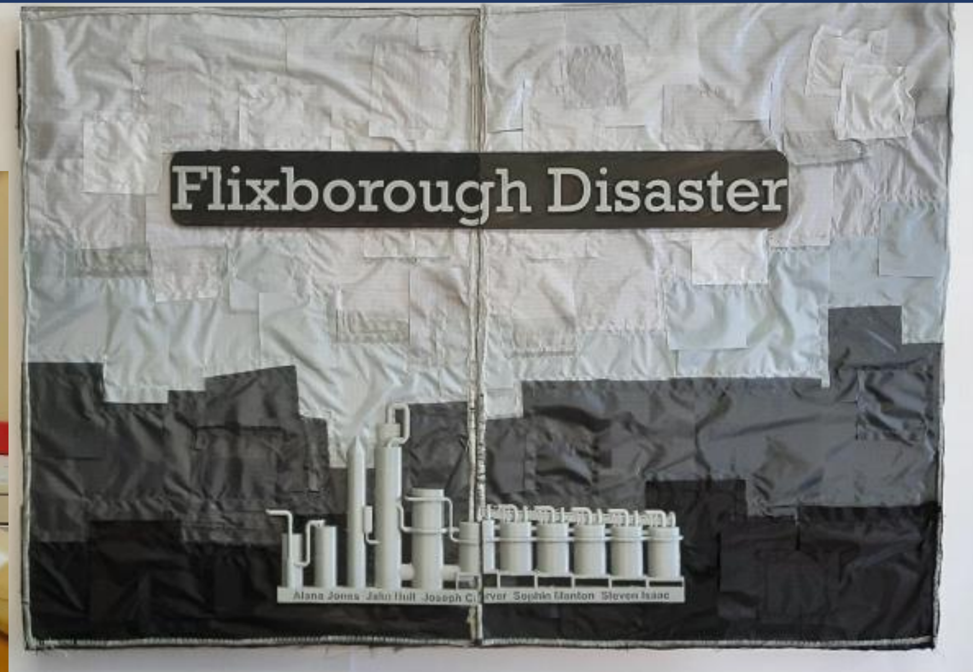
The Flixborough Disaster

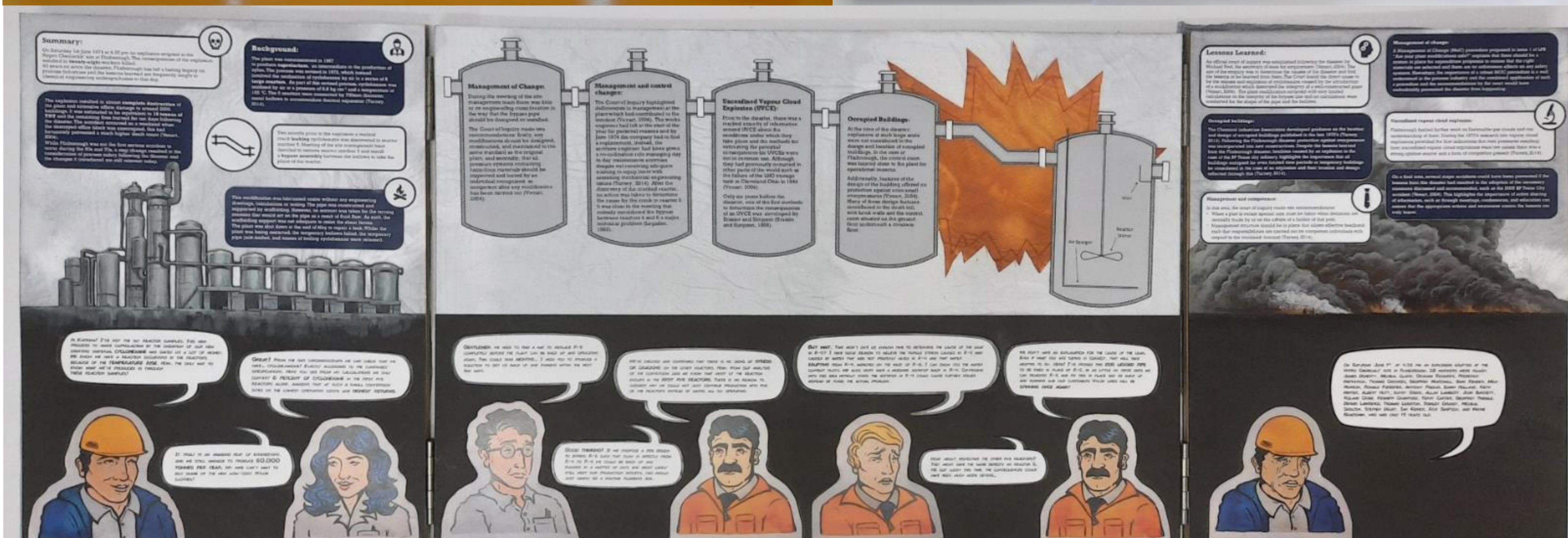
SIESO Medal 2022 Submission

Made by Joseph Carver, Alana Jones, Sophie Manton, Jake Bull, and Steven Deane.

Photo Gallery

Below photo of triptych free standing. Right photo of triptych when closed featuring a patchwork art piece of nylon fabrics and a 3D printed simplified model of the plant.

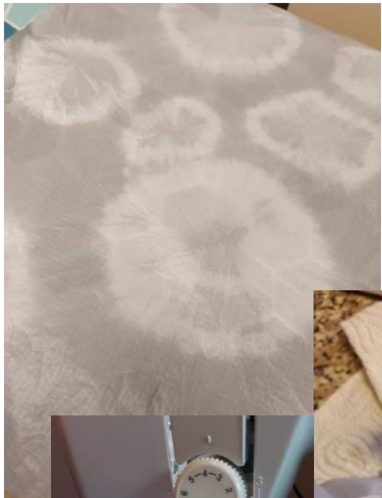




Making of the triptych

Our triptych aims to provide an accessible and interactive method of sharing this information. As part of a multidisciplinary collaboration, utilizing students in fields such as textiles and robotics it provides outside perspectives on how lesson learning should be showcased. By combining these fields into one project we were able to turn learning lessons from disasters into an artistic piece that is more engaging.

Textile Work



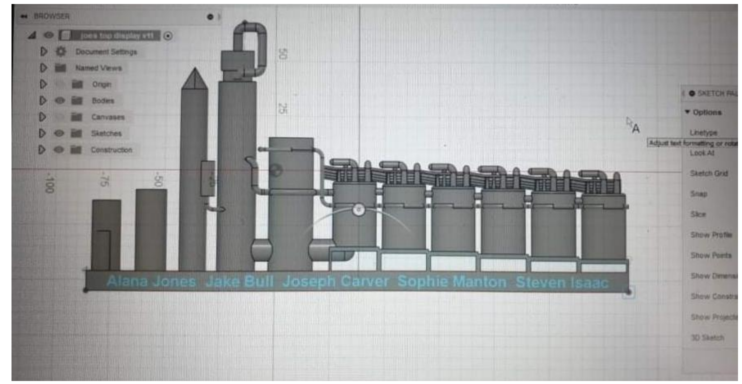
Using nylon fabric we created tie dyed backgrounds. The image below shows the process to create this.

On the front of the triptych we also used nylon to make a patch work piece.

Art

Art was a big part of the project and we designed and made characters to tell the story of Flixborough from a different perspective.

3D Printing



The front of the triptych features a 3D model of the plant. This was done to make the triptych inviting to viewers to open and learn about the accident. This also helps people to better visualise the plant and understand the chemical process.

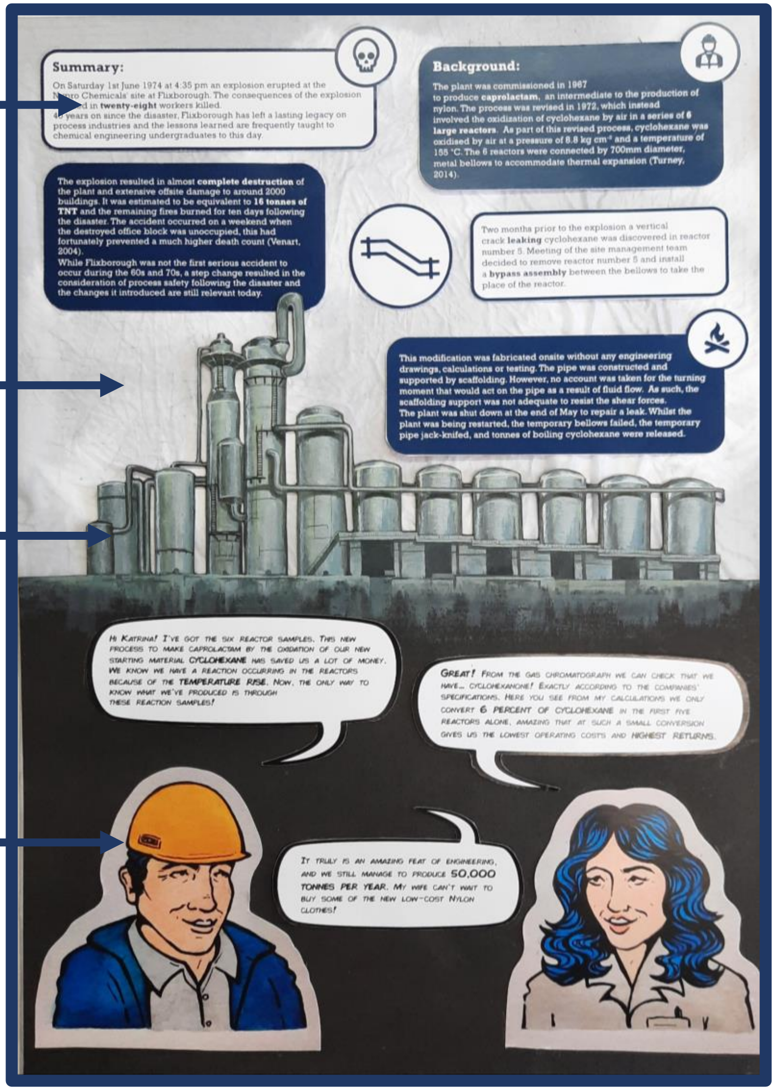
Left Panel – Summary and Background

Bold headings and iconographs are targeted to draw the attention of readers. The text on this panel discusses an overall summary of the disaster and provides the background information and sets the scene prior to the disaster

Tie dye nylon fabric background is a reference to the Nylon 6 produced at the plant which would be used to produce nylon fabrics.

Acrylic painting of plant. The aim of this was to give an artistic stylisation of the plant prior to the explosion. Emphasising the complexity in its design.

The comic book scene at the bottom of the panel includes water colour painted 70s pop art style. The scene that takes place on this panel shows a conversation between two colleagues prior to the disaster and provides the reader with further information about the operation of the plant.



Summary:

On Saturday 1st June 1974 at 4:53 pm an explosion erupted at the Nypro Chemicals' site at Flixborough. The consequences of the explosion resulted in twenty eight workers killed.
40 years on since the disaster, Flixborough has left a lasting legacy on process industries and the lessons learned are frequently taught to chemical engineering graduates to this day.

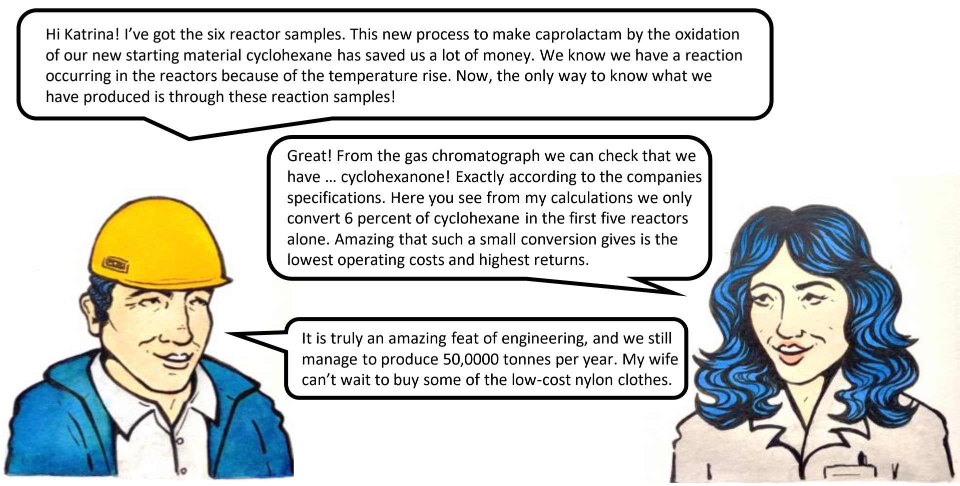
The explosion resulted in almost complete destruction of the plant and extensive damage to around 2000 buildings. It was estimated to be equivalent to 16 tonnes of TNT and the remaining fires burned for ten days following the disaster. The accident occurred on a weekend when the destroyed office block was unoccupied, this had fortunately prevented a much higher death count.
While Flixborough was not the first serious accident to occur during the 60s and 70s, a step change resulted in the consideration of process safety following the disaster and the changes it introduced are still relevant today.

Background:

The plant was commissioned in 1967 to produce caprolactam, an intermediate in the production of nylon. The process was revised in 1972, which instead involved the oxidation of cyclohexane by air in a series of 6 large reactors. As part of this revised process, cyclohexane was oxidised by air at a pressure of 8.8 kg cm-3 and a temperature of 155 C. The 6 reactors were connected by 700 mm diameter metal bellows to accommodate thermal expansion.

Two months prior to the explosion a vertical crack leaking cyclohexane was discovered in reactor number 5. Meeting of the site management team decided to remove reactor number 5 and install a bypass assembly between the bellows to take the place of the reactor.

This modification was fabricated onsite without any engineering drawings, calculations or testing. The pipe was constructed and supported by scaffolding. However, no account was taken for the turning moment that would act on the pipe as a result of fluid flow. As such, the scaffolding support was not adequate to resist the shear forces. The plant was shut down at the end of May to repair a leak. Whilst the plant was being restarted, the temporary bellows failed, the temporary pipe jack-knifed, and tonnes of boiling cyclohexane were released.



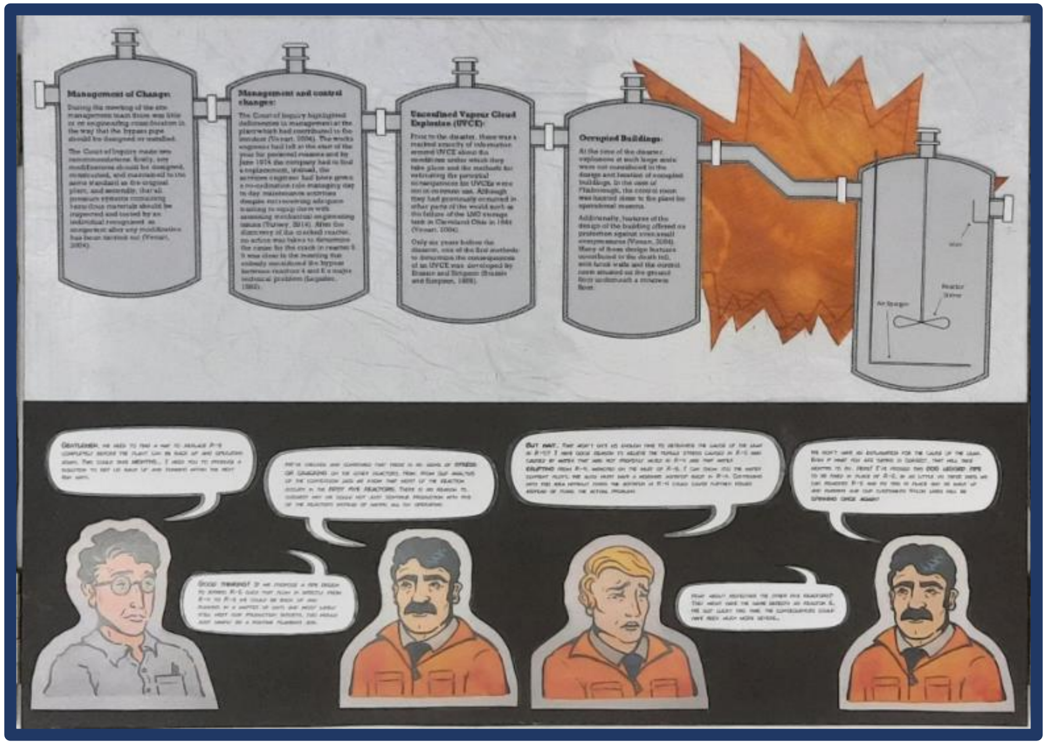
Middle Panel – Causes

Management of Change:

During the meeting of the site management there was little or no engineering consideration in the way that the bypass pipe should be designed or installed.
The Court of Inquiry made two recommendations: firstly, any modification should be designed constructed and maintained to the same standard as the original plant, and secondly, that all pressure systems containing hazardous materials should be inspected and tested by an individual recognised as competent after any modification has been carried out.

Management and control changes:

The Court of Inquiry highlighted deficiencies in management at the plant which had contributed to the incident. The works engineer had left at the start of the year for personal reasons and by June 1974 the company had yet to find a replacement, instead, the services engineer had been given a co-ordination role managing day to day maintenance activities despite not rec receiving adequate training to equip them with assessing mechanical issues. After the discovery of the cracked reactor, no action was taken to determine the cause for the crack in reactor 5. It was clear in the meeting that nobody considered the bypass between reactors 4 and 6 a major technical problem.

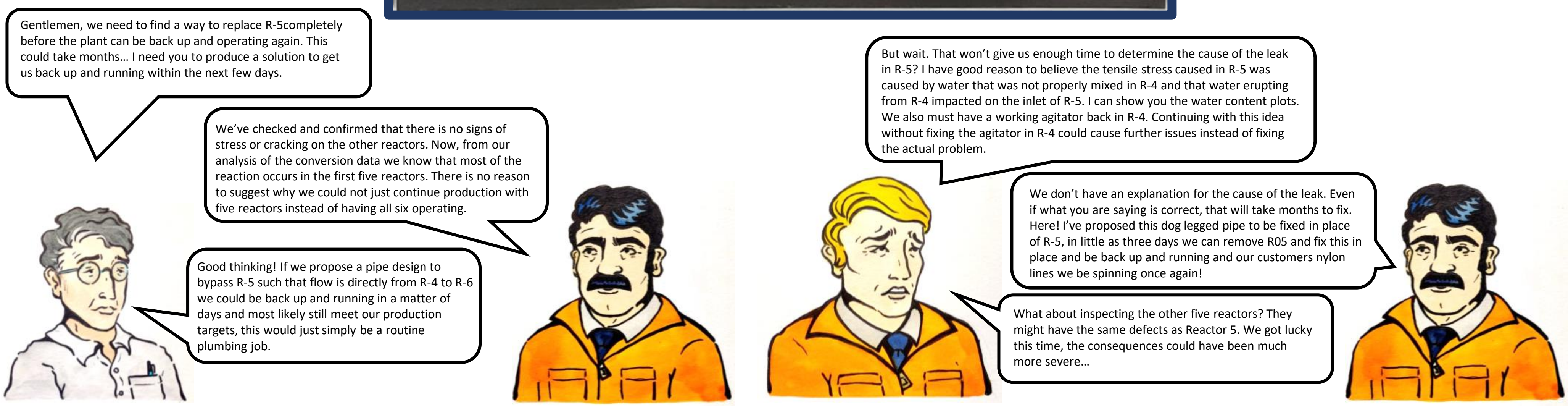


Unconfined Vapour Cloud Explosion (UVCE):

Prior to the disaster, there was a marked scarcity of information around UVCE about the conditions under which they take place and the methods for estimating the potential consequences for UVCEs were not in common use. Although they had previously occurred in other parts of the world such as the failure of the LNG storage tank in Cleveland Ohio in 1944.

Occupied Buildings:

At the time of the disaster, large scale explosions were not considered in the design and location of occupied buildings. In the case of Flixborough, the control room was located close to the plant for operational reasons. Additionally, features of the design of the building offered no protection against even small overpressures. Many of these design features contributed to the death toll, with brick walls and the control room situated on the ground floor underneath a concrete floor.

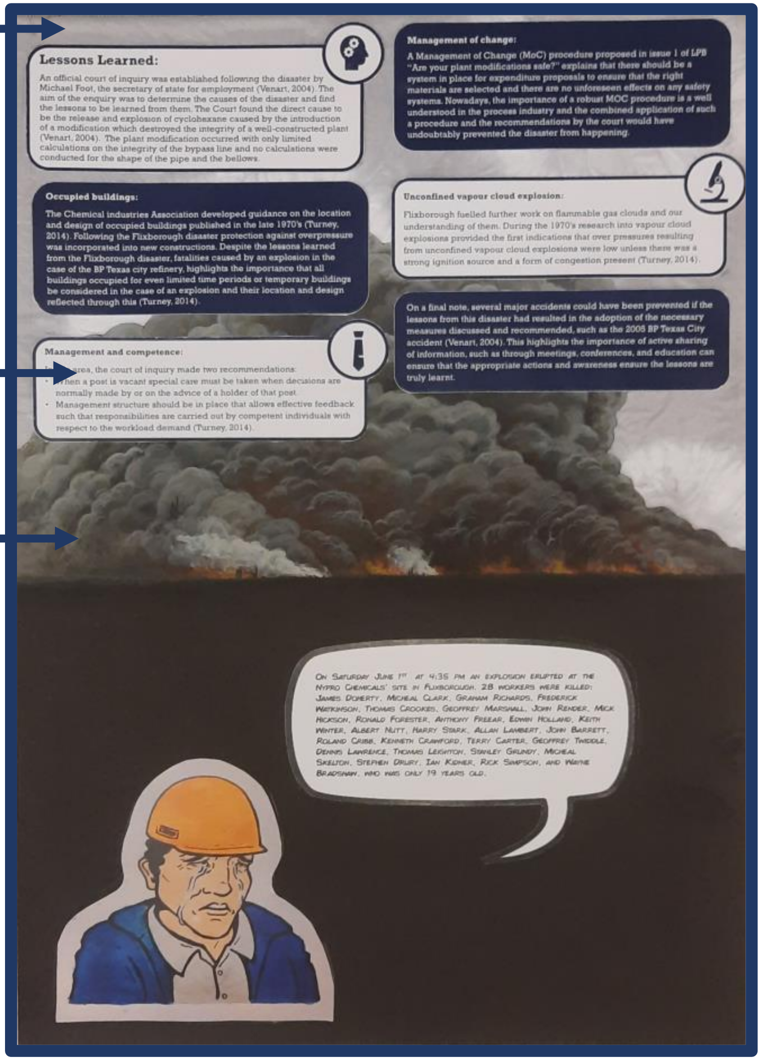


Right Panel – Lessons Learned

Tie dye nylon fabric background.

Text boxes highlighting the lessons learned.

Acrylic painting of plant following the explosion.



Lessons Learned:

An official Court of Inquiry was established following the disaster by Micheal Foot, the secretary of state for employment. The aim of the enquiry was to determine the causes of the disaster and find the lessons to be learned from them. The Court found the direct cause to be the release and explosion of cyclohexane caused by the introduction of a modification which destroyed the integrity of a well constructed plant. The plant modification occurred with only limited calculations on the integrity of the bypass line and no calculations were conducted for the shape of the pipe and the bellows.

Occupied Buildings:

The Chemical Industries Association developed guidance on the location and design of the occupied buildings published in the late 1970s. Following the Flixborough disaster protection against overpressure was incorporated into new constructions. Despite this lesson, fatalities caused by an explosion in the case of the BP Texas city refinery highlights the importance that all buildings occupied for even limited time periods as well as temporary buildings need to be assessed for possible explosions, and their location and design needs to reflect this.

Management and Competence:

In this area, the Court made two key recommendations:

- When a post is vacant, special care must be taken when decisions are normally made by or on the advice of a holder of that post.
- A management structure should be in place that allows effective feedback from the bottom to the top such that responsibilities are carried out by competent individuals concerning the demand upon them.

Management of Change:

A Management of Change (MoC) procedure proposed in issue 1 of LPB “Are your plant modifications safe?” explains that there should be a system in place for expenditure proposals to ensure that the right materials are selected and there are on unforeseen effects on any safety systems. Nowadays, the importance of a robust MOC procedure is well understood in the process industry and the combined application of such a procedure and the recommendations by the court would have undoubtably prevented the disaster from happening.

Unconfined Vapour Cloud Explosion:

Flixborough fuelled further work on flammable gas clouds and our understanding of them. During the 1970s research into vapour cloud explosions provided the first indications that over pressures resulting from unconfined vapour cloud explosions were low unless there was a strong ignition source and a form of congestion present.

On a final note, several major accidents could have been prevented if the lessons from this disaster had resulted in the adoption of the necessary measures discussed and recommended, such as the 2005 BP Texas City accident. This highlights the importance of active sharing of information, how communication through meetings, conferences, and education must lead to appropriate action and awareness to ensure the lessons are truly learnt.

On Saturday, Jun 1st at 4:35 pm and explosion occurred at the Nypro chemicals’ site in Flixborough. 28 workers were killed: James Doherty, Michela Clarke, Graham Richards, Frederick Watkinson, Thomas Crookes, Geoffrey Marshall, John Render, Mick Hickson, Ronald Forester, Anthony Freear, Edwin Holland, Keith Winter, Albert Nutt, Harry Stark, Allan lambert, John Barrett, Roland Cribb, Kenneth Crawford, Terry Carter, Geoffrey Twiddle, Dennis Lawrence, Thomas Leighton, Stanley Grundy, Micheal Skelton, Stephen Drury, Ian Kidner, Rick Simpson, and Wayne Bradshaw, who was only 19 years old.