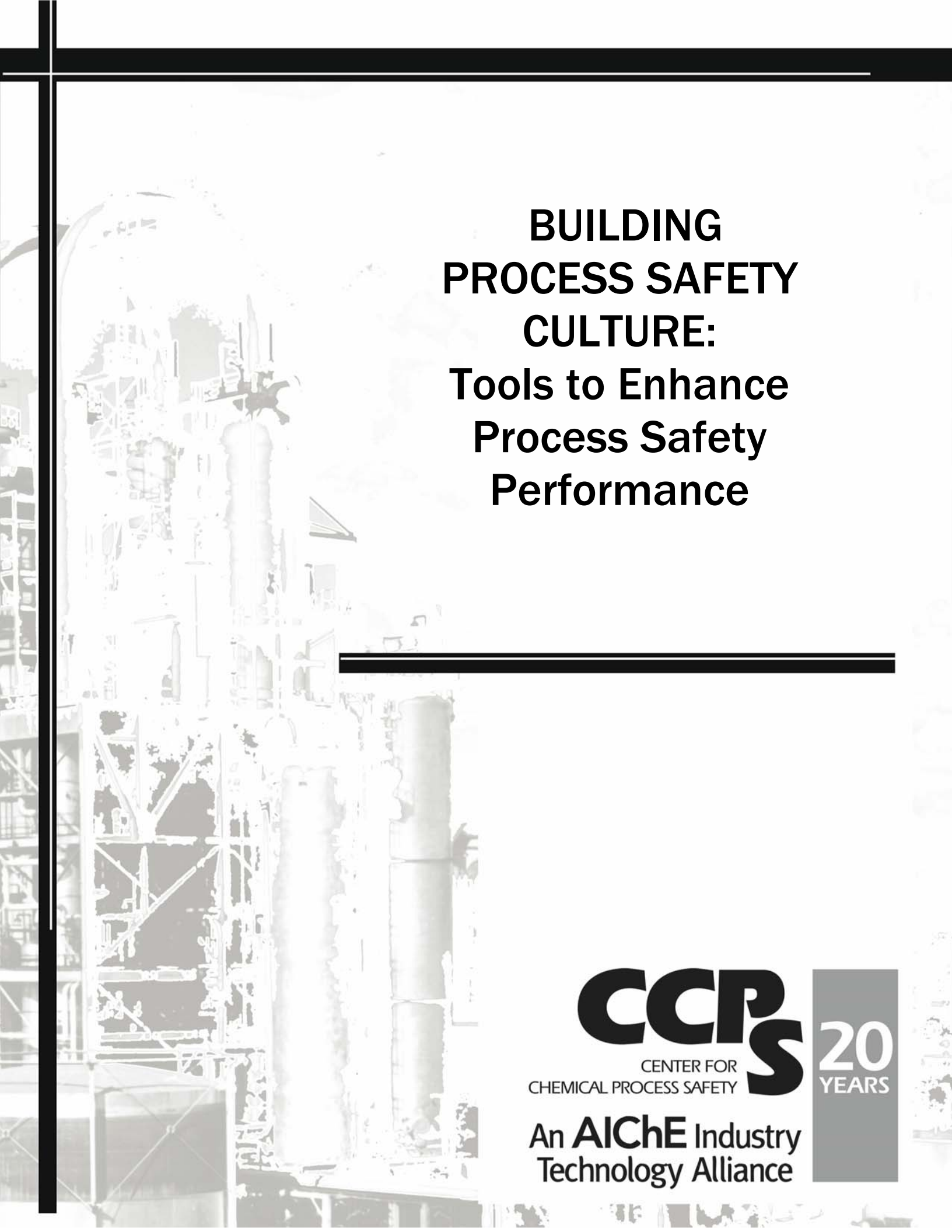

BUILDING PROCESS SAFETY CULTURE: Tools to Enhance Process Safety Performance

CCPS
CENTER FOR CHEMICAL PROCESS SAFETY
20 YEARS
An AIChE Industry Technology Alliance

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New York, New York 10016-5991

Process Safety Culture Toolkit

ISBN # 0-8169-0999-7

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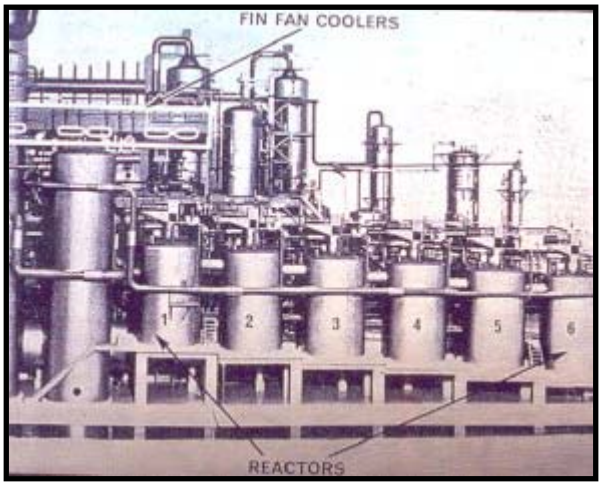
Flixborough Case History

[The following information has been taken from the UK government publication *The Flixborough Disaster – Report of the Court of Inquiry.* While this summary has been condensed and paraphrased, it is believed to been consistent with the facts and conclusions outlined in the report.]

On June 1, 1974, the Flixborough Works of Nypro (UK) Limited experienced a massive vapor cloud explosion. 28 employees were killed and 36 injured (18 of the fatalities were in the control room building, which collapsed during the explosion). In addition, hundreds of persons off-site were injured, 53 with injuries significant enough to be classified by the authorities as "casualties." Fortunately, there were no off-site fatalities, and the on-site fatalities were limited by the fact that the explosion occurred during the weekend.

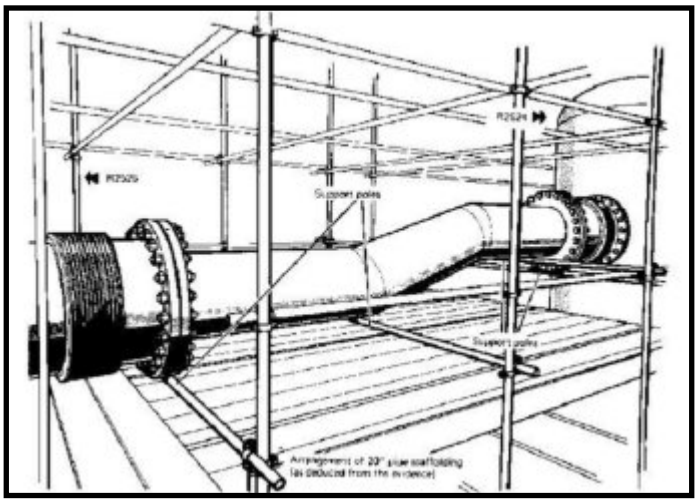
The explosion and subsequent fires totally destroyed the plant, which was never rebuilt. Over 1800 houses and 167 businesses in the surrounding communities were damaged

Subsequent investigation revealed that the most likely cause of the explosion was the failure of a temporary piping modification that had been made approximately 8 weeks previously. When the piping failed, an estimated 30 tons of cyclohexane vapor were released. The resulting vapor cloud found an ignition source, producing a deflagration (there is some speculation that the explosion could have been a detonation) releasing the energy equivalent of about 16 tons of TNT.



The Flixborough process involved the partial oxidation of cyclohexane to produce cyclohexanol and cyclohexanone, the latter being a feedstock to the production of caprolactum, an intermediate in the production of Nylon 6. Cyclohexane was recirculated through a series of six reactors operating at a nominal pressure and temperature of 125 psi and 155^{o} C. The six reactors were arranged so that

each successive reactor was at a lower elevation than the prior, in order to allow the cyclohexane to flow by gravity from one reactor to the next. The reactors were interconnected by 28-inch diameter lines with corrugated expansion bellows installed at the vessel outlet and inlet flanges.



Reactor 5 developed a leak in the vessel shell and had to be removed for repair. In order to permit continued operation, a temporary piping assembly was fabricated to bridge the gap between the outlet on reactor 4 and the inlet on reactor 6. Because of the elevation changes, it was necessary to incorporate a dogleg in this piping jumper. This reduced diameter jumper (only 20 inch diameter pipe was available on site) was supported by scaffolding.

In the onion of the investigators, the most likely source of the cyclohexane release was the dogleg piping jumper. It is believed that the unbalanced forces imposed on the bends in the piping, coupled with the flexibility introduced by the expansion bellows, allowed the inadequately supported and unconstrained jumper to oscillate. Ultimately, one of the bellows failed, releasing the process fluid.

The subsequent investigation revealed the following:

- The works engineer had left early in the year and had not yet been replaced. At the time the bypass line was being planned and installed, there was no engineer on site with the qualifications to perform a proper mechanical design, or to provide critical technical review on related issues. There were chemical and electrical engineers on staff, but no other mechanical engineers.
- Even though a significant crack (six feet long) was found in reactor 5, the decision was made to restart the process without inspecting the other reactors to determine if similar cracks existed.
- Staff involved in planning and implementing the bypass approached the task as if it were a routine plumbing job.
- In the opinion of the investigators, the urgency to resume production distracted staff from the sort of critical consideration of their plans that could have identified the hazards involved (i.e., they did not intentionally establish an unsafe condition but, rather, failed to fully assess the significance of what they were doing).
- The fact that the works manager position was vacant also shifted workload to remaining staff, contributing to the distractions discussed above. The report implies

that company management was not aware of the effect of the short staffing on the performance of the facility staff involved in the modification.

- While calculations were made to confirm that the 20-inch pipe could withstand the normal working pressure, no consideration was given to the bending moments or hydraulic thrusts that would be imposed on the assembly due to its dogleg configuration . There was no reference made to vendor manuals for the expansion bellows, nor to relevant British Standards.
- No drawing was made for the design, other than a chalk sketch made on the floor of the maintenance workshop.
- There were no quality assurance checks made on the fabrication or installation of the assembly other than a leak check at approximately 130 psi (for comparison, the relief valves [RVs] on the reactor system were set to open at approximately 155 psi). Applicable British Standards required that the assembly be tested at a pressure of 1.3x the system design pressure, which would have been above the RV set pressure.
- Nypro did not have an adequate system for evaluating and controlling changes to ensure that safety was not impacted (in fairness, our currently mature perspective on management of change did not generally exist within industry in 1974).