DUTCH
SAFETY BOARD

Summary

Explosions MSPO2 Shell Moerdijk

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Dutch Safety Board

The aim in the Netherlands is to limit the risk of accidents and incidents as much as possible. If accidents or near accidents nevertheless occur, a thorough investigation into the causes, irrespective of who are to blame, may help to prevent similar problems from occurring in the future. It is important to ensure that the investigation is carried out independently from the parties involved. This is why the Dutch Safety Board itself selects the issues it wishes to investigate, mindful of citizens' position of independence with respect to authorities and businesses. In some cases the Dutch Safety Board is required by law to conduct an investigation.

NB: The full report is published in the Dutch language. If there is a difference in interpretation between the Dutch report and English summary, the Dutch text will prevail.

CONTENT

SUMMARY

On 3 June 2014 at around 22.48 two severe explosions occurred at Shell in Moerdijk, followed by a large fire. The Dutch Safety Board investigated this incident focusing on the following:

- What were the immediate and underlying causes of the incident?
- How did the granting of permits, supervision and enforcement proceed?
- How did firefighting, crisis management and crisis communication proceed?

The main events and conclusions drawn by the Dutch Safety Board are set out by subject below.

Occurrence and consequence of the explosions

On 25 May 2014 Shell Moerdijk put the propylene oxide-styrene monomer 2 plant in Moerdijk (hereinafter referred to as the MSPO2 plant) out of operation for a short scheduled maintenance period, called the pit stop. The main purpose of the pit stop was to replace the catalyst containing granules (hereinafter referred to as catalyst pellets) in two reactors in unit 4800, which formed part of the MSPO2 plant.

After the catalyst had been replaced a number of steps were followed and completed to again prepare the unit for production. One of these steps involved warming up the reactors with ethylbenzene. The warming-up procedure commenced at around 21.00 on 3 June 2014. Because the operators felt that the warming-up of the reactors was not proceeding fast enough, they manually added additional warmth to the ethylbenzene. A number of measurement data on the panel operator's screens showed fluctuations when the warming-up procedure commenced.

By warming up the reactors, energy was released and unforeseen chemical reactions occurred between the warming-up liquid (ethylbenzene) and the catalyst pellets that were used. These reactions, which were out of view of the panel operator and the production team leader, caused gas formation and increased the pressure in the reactors.

At around 22.16 an automatic protection system was triggered that was designed to prevent liquid from entering the exhaust gas system (flare). As a result the gases in the system were also no longer able to be discharged. The continued warming up of the reactors caused even more chemical reactions to occur between the ethylbenzene and the catalyst pellets. As a result of the chemical reaction gas formation occurred and pressure rose in the reactors. In the last two minutes before the first explosion pressure rose so quickly as a result of the rapid chemical reactions that it could no longer be controlled.

The reactor exploded as a result of the increase in pressure. The contents of the reactor and the appurtenant separation vessel spread into the wide environment of the plant. Sections of the reactor were blasted across a distance of 250 metres while other debris from unit 4800 was retrieved at a distance of around 800 metres. The explosion could be heard 20 kilometres away.

Two people were working opposite unit 4800 at the time the explosions occurred. They were hit by the pressure wave of the explosion and the hot and burning catalyst pellets that were flying around and consequently sustained bruising and second-degree burns. The other employees who were working at that time were in the control room and were not injured.

A very large, raging local fire occurred generating considerable amounts of smoke. The smoke that was released during the fire traversed Hollands Diep into the affected area in the Southern South Holland (*Zuid-Holland Zuid*) Security Region. Crisis management organisations were set up in the source area Moerdijk and in the Southern South Holland Security Region. The points addressed by the crisis management organisations were as follows:

- to inform citizens of the incident;
- to measure the substances released on a coordinated basis;
- to open a telephone advisory service line;
- to inform citizens about the results of the measurement of the substances released and the ensuing recommendations.

On 8 June 2014 it was announced that no increased health risks were expected as a result of exposure to the concentrations measured.

Conclusions concerning the cause and supervision

The Dutch Safety Board can clearly establish the immediate cause of the explosions. Ethylbenzene unexpectedly reacted to the catalyst. Shell Moerdijk regarded ethylbenzene as a safe substance in this process. The chemical reaction escaped notice and developed into an uncontrolled or *runaway* reaction, causing pressure to rise rapidly and the reactor to subsequently explode. The operators were not alarmed by the fluctuating measurement values displayed. In view of similar earlier warming-up procedures, it was also what they had expected.

The Dutch Safety Board has furthermore identified various *underlying* causes of the Shell Moerdijk explosions. Firstly, Shell Moerdijk failed to identify and control the risks associated with the plant modifications and with the execution of chemical processes. The effects of the MSPO2 plant modifications and replacements were not systematically examined on the basis of a risk analysis in all cases. In 1977 Shell performed a reactivity test which involved warming up ethylbenzene and the catalyst type used at that time to 130°C. During the test Shell established that there was no possible chemical reaction between ethylbenzene and the catalyst used. In the following years modifications were made to the plants and procedures involved in this chemical process. However, these

modifications did not always lead to a new risk analysis. The chemical reaction between ethylbenzene and the catalyst failed to be identified as a result.

Secondly, important information was lost between the design of the unit and the ultimate management of the unit. Process boundaries for the start-up phase were determined during the design phase. When work instructions were drawn up, the process boundaries were either not always incorporated, or failed to be incorporated in the correct manner. A discrepancy therefore occurred between the available information during the design phase and the management that was ultimately conducted. This discrepancy failed to be identified, creating risks that Shell Moerdijk failed to control.

Thirdly, the Dutch Safety Board concludes that there were various reasons for stabilising or halting the chemical process and that there also was an opportunity to do so. However, this did not take place. Shell Moerdijk failed to recognise that it is in itself always dangerous to work with a reactor vessel containing ethylbenzene and this catalyst. Incidents can arise involving fire or explosions or the dispersion of carcinogenic material, outside the reactor. Even though critical process boundaries were breached when the reactors were warmed up (triggering alarm and automatic protection systems), the operators erroneously decided to continue the process.

Fourthly, the Dutch Safety Board concludes that Shell Moerdijk failed to learn sufficient lessons from a previous incident at a Shell plant in Nanhai. The investigation revealed that various signals concerning the risks that occurred failed to be recognised and dealt with as such.

Supervision and crisis management

The regulators had a positive view of the Shell Moerdijk safety management system. A number of shortcomings at Shell Moerdijk do not alter this view. Where process safety is concerned, Shell Moerdijk receives system-related supervision. In the Dutch Safety Board's opinion under this form of supervision, which is coupled with scarce resources and time, the inspectors concerned cannot be expected to be able to establish deep-seated shortcomings at Shell Moerdijk, should Shell itself not have identified these.

The collaborative fire brigades effectively suppressed the fire. The differentiated upscaling of the Coordinated Regional Incident Control Procedure (*Gecoördineerde Regionale Incidentbestrijdings Procedure*, GRIP) was also appropriate. The Dutch Safety Board concludes that lessons have in fact been learned from previous experiences by the crisis management organisations (fire brigades/parties involved), such as the fire at Chemie-Pack in 2011. However, he has identified a number of improvement areas relating to information management and alerting and informing local residents. During this incident citizens failed to be alerted by the NL-Alert system since the message failed to reach everyone. The process of alerting and informing citizens therefore was inadequate. In view of the late point in time at which the incident occurred and the limited consequences, this did not pose an additional hazard to citizens.

CONSIDERATION

Working in the chemical industry means working with risks. While the Dutch Safety Board is aware that a risk-free society does not exist, it does impose stringent requirements on these companies to minimise the risks. The greater the risk, the greater a company's responsibility. Companies to which the Major Accidents (Risks) Decree (*Besluit risico's zware ongevallen - Brzo*) applies (Brzo companies), in other words companies that have large quantities of hazardous substances on site consequently have been a concern for the Dutch Safety Board for quite some time.

During its previous investigations the Dutch Safety Board established that there were problems in this sector with so-called underperformers in this area. Companies that do not have safety in their DNA and have not adopted the Hearts and Minds approach to safety. The explosions in Moerdijk on 3 June 2014, however, occurred at a company that is not deemed to rank among the underperformers by society, the regulator nor the company itself. On the contrary, the company is regarded as a leader in this area. This observation gives the Dutch Safety Board cause for concern.

Shell ranks among the world's largest petrochemical companies and has positioned itself as a leader in the area of safety. Shell is one of the initiators of the Hearts and Minds safety culture programme. Shell Moerdijk's comprehensive safety management system, however, failed to prevent unsafe situations from being overlooked. Internal procedures failed to be properly adhered to and lessons were not learned from previous incidents and incorrect assumptions concerning a basic type of chemical reaction had never been evaluated in over 35 years. According to the Dutch Safety Board, Shell Moerdijk has therefore failed to live up to its high safety management expectations. The consequences of the 3 June explosions in which 'only' two people were slightly injured seem to be less serious than expected, particularly in the light of the number of contractors who were still working as scheduled in the immediate vicinity of the reactor. Considering the force with which the debris was retrieved at 800 metres from the original site, the consequences were relatively limited. This further underlines the necessity for Shell to reassess its safety management system and implement changes to reduce the risk of accidents in the future.

The explosions were caused by a chemical reaction during a start-up phase, a common safety-critical process. Shell could have expected this reaction by performing a basic test at the time modifications were made to the production process. However, Shell failed to do so after 1979 - neither at the time the switch was made to another catalyst, nor at times prior to that. For a company engaged in high-risk operations such as Shell it should be standard practice to perform a critical risk analysis for every change made to the process, and to retest assumptions made in the past. After all, any changes made to processes, procedures and plants can inadvertently create new risks. Shell therefore acted in contravention of its own management-of-change policy. As a result Shell put the operators in a situation in which they took decisions, the consequences of which they were unable to foresee.

Shell furthermore underutilised the opportunity to learn from incidents at similar plants. The Dutch Safety Board believes that these incidents should have resulted in a more in-depth investigation. This would have given Shell insight into both the risks of this chemical process and into all the ineffective safety barriers and the underlying organisational causes.

Supervision under the Major Accidents (Risks) Decree
The regulators under the Major Accidents (Risks) Decree failed to identify the shortcomings at Shell. Through supervision and enforcement the Dutch Safety Board expects regulators to encourage companies to improve their safety-critical processes. This means establishing and identifying shortcomings and persistently questioning companies that have received a positive assessment in this area to prompt them to investigate and detect the deep-seated causes. The Dutch Safety Board does not expect the regulators to perform the risk analyses for companies that are subject to the Major Accidents (Risks) Decree. This is first and foremost the primary responsibility of the company. However, regulators should meticulously assess modifications made to plants, procedures and processes. Moreover, they certainly should persist in questioning these companies if they had previously assessed their performance as mediocre. The Dutch Safety Board also believes that the regulators should pay greater attention to safety-critical processes, such as maintenance and starting-up chemical processes.

The regulators had assessed Shell as a well-functioning company, in which they had a great deal of confidence. The company had a good reputation in the area of safety. The explosions on 3 June 2014 and their causes have tarnished that confidence. The regulator should therefore latch onto that tarnished confidence to reassess and tighten the supervision procedure at Shell Moerdijk.

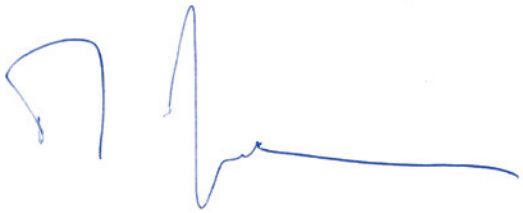
Recommendations

In the Dutch Safety Board's opinion Shell must heighten its awareness of working with safety-critical processes. It must take on an emphatic role in further actively developing and disseminating knowledge and experience, both internally and externally. The Dutch Safety Board has therefore formulated the following recommendations, which are also applicable to other companies in the chemical industry that are subject to the Major Accidents (Risks) Decree.

To Shell Netherlands B.V.
Ensure that all Shell employees are constantly alert to the safety risks arising from modifications made to plants, processes and procedures. Evaluate how risk analyses are performed and implement changes. This will enable the re-evaluation of earlier presumptions and assumptions. Conduct new risk analyses, put adequate control measures in place and ensure that the team that performs these analyses has sufficient critical ability. Pay particular attention to assumptions based on risks that had previously been ruled out.

Organise the communication of process knowledge and lessons learned from actual and near incidents to employees who are responsible for managing safety risks. Ensure that investigations into actual and near incidents also provide insight into the underlying

causes. Guarantee that actions arising from these investigations are implemented and contribute to disseminating knowledge within the petrochemical industry.



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