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## Review

## Safety management systems from Three Mile Island to Piper Alpha, a review in English and Dutch literature for the period 1979 to 1988

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## ABSTRACT

**Objective:** Which general management and safety models and theories trends influenced safety management in the period between Three Mile Island in 1979 and Piper Alpha in 1988? In which context did these developments took place and how did this influence Dutch safety domain?

**Method:** The literature study was limited to original English and Dutch documents and articles in scientific and professional literature during the period studied.

**Results and conclusions:** Models and theories of human errors, explaining occupational accidents were still popular in the professional literature. A system approach was introduced into mainstream safety science, starting in process safety, and subsequently moving into occupational safety. Accidents were thought to be the result of disturbances in a dynamic system, a socio-technical system, rather than just human error. Human errors were also perceived differently: they were no longer faults of people, but consequences of suboptimal interactions during process disturbances. In this period quality of safety research increased substantially, also in the Netherlands.

**Results and conclusions:** Major disasters in the 1980s generated knowledge on process safety, and soon process safety outplaced developments in occupational safety, which had been leading before. Theories and models in this period had advanced sufficiently to explain disasters, but were still unable to predict probabilities and scenarios of future disasters. In the 1980s 'latent errors' appeared in safety literature, and in The Netherlands the concept of 'impossible accidents' appeared. Safety management was strongly influenced by developments in quality management.

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## 1. Introduction

This article is one in a series on knowledge development of both safety domain, and safety management. Previous publications examined periods extending from the late 19th century until 1979 (Gulijk et al., 2009; Oostendorp et al., 2016; Swuste et al., 2010, 2014, 2016). These reviews provide insight into developments of the international scientific safety domain and in The Netherlands. The current article describes developments in process safety, starting in 1979, till the Piper Alpha disaster in 1988.

The present paper follows the same structure as previous papers. It focuses on knowledge development in the designated period but, for completeness, sometimes refers to earlier papers of this series. In conjunction with earlier papers, this work focuses on the following questions:

1. Which general management schools, and theories, models for accident causation have been developed?
2. What was the influence of such developments on safety management in companies?
3. What was the context within which this development took place?
4. What were the consequences for professional safety in The Netherlands?

## 2. Materials and methods

The answers to these questions were based on an extensive literature research. The literature research was limited to English and Dutch literature, meaning that the developments of safety in the United States, the United Kingdom, Scandinavia, and The Netherlands tend to be emphasized. Original references and scientific articles were accessed via the Delft University of Technology Library and through the internet. The following journals were consulted for the period discussed: Accident Analysis and Prevention, Journal of Hazardous Materials, Journal of Loss Prevention, Journal of Occupational Accidents, Journal of Safety Research and Safety Science. References were followed from: Academy of Management Journal, Administrative Science Quarterly, American Sociological Review, Ergonomics, California Management Review, Hazard Prevention, IEEE Transactions on reliability, IEEE Transactions on Systems, Man, & Cybernetics, International Journal of Man-Machine Studies, Journal of Applied Behaviour Analysis, Journal of Business & Psychology, Journal of Management, Journal of Management Studies, Naval War College Review, Organisation Science, Policy Sciences, Plant/Operation Progress, Public Health Reports, Reliability Engineering & System Safety, Risk Analysis, Social Science Information Studies, The Academy of Management Review and Reliability Engineering & System Safety (from 1988 onward), De Veiligheid (Safety Journal), Maandblad voor Arbeidsomstandigheden or MAO (monthly journal concerning working conditions), and Risicobulletin (Risk Journal) were used to study developments in The Netherlands.

Annex 1 will provide an overview of serious incidents, and major accidents occurring in oil and process industries. For this Annex only publicly available information was consulted (Lees, 1996; Mannan, 2005; Marsh, 2012; Wikipedia, 2014). This table only gives an impression. There is an unknown level of underreporting. This bias

will vary by country, time and sector. The level of underreporting is difficult to estimate. Apart from uncertainties of the numerator, the denominator is a big obstacle. There was no information on exposure, or an estimation of the number of active installations, or activities, therefore no rates, or time trends could be calculated.

The period concerned saw quite a few disasters in various domains: the process industries, nuclear power plants, chemicals storage, space endeavours, maritime transport and railways. The disasters generated significant media attention which spurred the professionalization of safety management systems that, in retrospect, were relatively simple systems from World War II onwards. The introduction of ISO-9000, as a vehicle for improving quality management showed this professionalization and was also the model for professionalization of safety management systems (ISO, 1987).

Two disasters are described with some degree of depth in this article. The article starts with Three Miles Island (1979), which was not actually a disaster but painfully exposed a lack of safety management. The paper ends with Piper Alpha, in which shortcomings in safety management, one decade later, caused the death of 167 people. The paragraphs between these disasters will discuss five subjects:

1. The approaches of general management schools with a focal point on Total Quality Management.
2. Occupational safety, the state of the art and its knowledge development on accident causality in areas of: human factors, sequence of events, energy transport, information exchange, system approach, safety climate, epidemiology of accidents, and the OARU model, which was based on process disturbances. This era produced just one accident-theory: risk homeostasis.
3. Process safety, the knowledge development in loss prevention and reliability engineering as well as changing views on human factors.
4. Safety management and safety management systems, their developments, audit systems, high reliability and the reaction of corporations to safety issues.
5. The last part describes developments in The Netherlands. This part features a case study in which Shell plays a central role.

This paper, as with previous papers in this series, focuses on the analysis of scientific progress. Changes in safety legislation are not included, while for companies legislation is often leading. Our assumption is that legal developments, to some degree, will follow scientific developments.

## 3. Three Mile Island

On the 28th of March 1979, a defect in the secondary cooling system almost caused a meltdown of a nuclear power reactor at Three Miles Island near Harrisburg in Pennsylvania (US). Radioactive gasses were vented into the atmosphere, but a nuclear meltdown was prevented. The Report of the President's commission on this accident stated the accident was due to technical failures and to human error. Also, the management procedures and emergency response were found to be deficient, and the organisation's safety management system was inadequate (Kemeny, 1979; Lees,

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