# A review of high-cost chemical/petrochemical accidents since Flixborough 1974

*by*

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## Introduction

Modern industrial society depends on the use of many potentially dangerous chemical substances.

Occasionally major accidents occur during their processing or storage. Such accidents pose a health and safety hazard to workers and to the public, and can be an economic liability to the company and the community. Research suggests that companies may be unaware of what such accidents are costing, and of what are the root causes. This paper aims to provide information which may assist them in deciding what are cost-effective loss prevention measures.

in a review commissioned by the Health and Safety Executive (HSE), WS Atkins Consultants Ltd have gathered information on some major industrial accidents which have occurred in the UK and overseas in the twenty-two years following the Flixborough accident. The Flixborough accident forms a suitable reference point in view of the effect it had on UK health and safety legislation. The scope of the review was limited to onshore chemical and petrochemical plants and pipelines.

The following sections describe the methodology for the project, the problems encountered, the results obtained and the conclusions drawn.

## Methodology

The first stage of the project was to interrogate the MHIDAS database[1]. This database contains almost 10,000 records relating to chemical accidents that have occurred world-wide. A preliminary list of accidents was drawn up using various criteria. Requirements for selection at this stage were that the accidents should involve the chemicals/petrochemicals sectors, and that MHIDAS should include cost information.

Prompted by this list WS Atkins then made contact with other organisations, emphasising that information on accident costs was a primary interest. The organisations included:

- Association of British Insurers
- Chemical Industries Association
- Chartered Institute of Public Finance and Accountancy
- Chartered Insurance Institute
- Confederation of British Industry
- Disaster Prevention and Limitation Unit, Bradford University
- Emergency Planning College
- The Fire Service
- The Fire Service College
- Fire Protection Association
- Institution of Chemical Engineers
- International Labour Organisation
- International Oil Insurers
- Lloyds Insurance
- Loss Prevention Council
- Marsh and McLennan
- Royal Society of Chemistry
- Society of Chemical Industry
- Trade Indemnity

At HSE's request WS Atkins did not contact the companies which had suffered the accidents.

In addition publications such as the Loss Prevention Bulletin[2], the Hazardous Cargo Bulletin[3], the Marsh & McLennan report on Large Property Damage Losses in the Hydrocarbon Chemical Industries[4], and the list of million pound-plus fires contained in Fire Prevention[5], the journal of the Fire Protection Association (FPA), were examined. Some searching of national and local newspapers was also undertaken.

These activities enabled additional information on the accidents in the preliminary list to be assembled. Some accidents not included in MHIDAS were found, and were added to the list. The costs for the listed UK accidents were then converted to 1996 values using the GDP Deflator time-series defined by HM Treasury. The majority of data for the overseas accidents were taken from the Marsh & McLennan report, where costs are already stated

in 1996-equivalent values. Tables showing the highest-cost accidents were then constructed.

Some of the practical problems encountered in gathering and interpreting data on the costs of accidents are described later.

Finally, the twenty UK accidents identified with the highest costs were studied further to establish their causes and the ways in which they developed. Source documents at this stage were the HSE published reports on the accidents at BP Oil Grangemouth[6], National Freight Consortium[7] (Brightside Lane), Associated Octel[8], Allied Colloids[9] and Hickson & Welsh[10]. HSE's report on the Texaco/Gulf accident was not published at the time of this study. A number of internal HSE files were also examined. Some common features of the accidents are addressed later.

# Some problems encountered in estimating the costs of accidents

Two immediately striking features from the study were the dearth of information on major accident costs and, where information was found, the conflicts within it. This may stem from a number of factors.

Firstly there is the question of the scope of costs which have been taken into account in preparing a statement. The great majority of cost statements focus only on the costs to the company itself (some comprising only reconstruction costs, some including also the costs of business interruption); however, other organisations become involved following a major accident and each incurs additional costs as a consequence. Quoted costs rarely state what is included and what is not. Quoted costs are probably never comprehensive – for example, we have found no published accident cost which admits to including the costs to the civil emergency services and health authorities.

Secondly there is the matter of timing. Cost quotations in the public domain tend to originate from press statements made at the time of the accident and in the immediate aftermath. Such early estimates are often revised later when more thorough consideration has been possible. However, the early records remain (and are sometimes requited years later). Moreover some costs, such as those for health, research, development, etc, may continue to be incurred for many years after the event. As an indication of how initial estimates of costs can be seriously flawed, we note here our belief that the final cost of the Flixborough accident to the insurers was some ten times greater than the initially published estimate.

Thirdly there is commercial sensitivity associated with the costs of accidents. Companies may prefer not to acknowledge huge losses from an accident as such information could depress the company's valuation on the stock market, disclose damaging information to competitors and create consumer concern about the possible impact on product costs.

Such sensitivity may influence figures released both by the company itself and by associated bodies such as insurance companies governed by confidentiality.

A further problem which occurs once a cost figure has been established is its financial grounding. The date of the quotation and the currency exchange rate are significant factors when carrying out a comparative study. The Marsh and McLennan organisation clearly states in its report the basis upon which its figures are grounded (viz the cost in US dollars at the time of the accident, together with an update of that figure to 'present-day' US dollars). Other sources, however are less informative.

Finally, there is evidence of simple clerical errors leading to conflicting records. For example, the costs of one accident are stated by one source as £21 million, by another as $21 million. For another accident, the costs are stated variously as £600,000 and £6,000,000. (There are also disparities in non-quantitative indicators of severity – one accident is described by the Fire Service as 'a major fire' but by Lloyds List as a 'minor fire').

With these problems, it becomes difficult to generate a single global cost figure. One cost statement may incorporate a wide variety of costs and state the total in 1996 currency units, whilst another may include only reconstruction costs in 1975. Such disparities are difficult to reconcile and have caused problems in this study. We have attempted to rationalise, but a substantial uncertainty must remain in the conclusions reached.

**Appendix 1** presents a list of factors which contribute to the costs of an accident, developed during this study, which we suggest would need to be considered in a full evaluation.

# Results

**Tables 1** and **2** show, respectively, the twenty UK accidents identified with the highest costs, and the fourteen overseas accidents identified with costs higher than any experienced in the UK, since Flixborough (taking $150 million as roughly equivalent to £100 million).

It may be seen by inspection that the indicated costs of the top twenty UK accidents (excluding Flixborough) sum to approximately £430 million, in 1996 values.

The accidents listed in Table 1 can be considered the apex of a pyramid, with many other accidents of lesser consequence lying beneath. The catalogue of million pound-plus fires issued by the Fire Protection Association**5** shows that the UK chemicals and petrochemicals sectors suffer many more accidents with losses exceeding £1 million. For the period 1974-1994 (the longest period for which we found records) twenty-five events additional to those listed in Table 1 are recorded for the chemicals etc sectors, with losses totally approximately £50 million. It is likely that the true value will be in excess of this as some known major accidents were not present in the FPA list. Very many events with

losses below £1 million were encountered during the study. The total costs may therefore be assumed to be in excess of £500 million, in 1996 values.

The overseas accidents listed in **Table 2** have been included to show that there is potential for even higher losses. Each of the fourteen accidents listed caused losses greater than any experienced in the UK (excluding Flixborough), in one case almost fifteen times greater.

It is stressed again that the costs quoted are uncertain and, being taken from the public domain, are generally exclusive of many of the factors discussed in the previous section and listed in **Appendix 1**. If comprehensive costs were known, they may be many times greater than the values quoted.

# Some common features observed in the high-cost accidents

Some similarities were observed between the causes and consequences of some of the accidents; these are recorded in **Appendix 2**.

One feature of note is that in most of the high-cost accidents there were no deaths and few injuries.

Seventeen of the twenty UK high-cost accidents caused no deaths, two of them each caused one death, and the other caused five deaths. Several accidents which are widely known because of their high casualty toll, for example, those at Bhopal (possibly 4000 deaths) and Mexico City (more than 500 deaths) are not recorded as high-cost accidents. Such accidents clearly have a very high cost in human terms, and indeed in notional financial terms if the 'value of life' often used in safety appraisals, around £1 million, is applied to them. It can be concluded that the number of casualties in an accident is a poor indicator of the scale of financial losses from the accident.

# Conclusions

This study has sought to identify high-cost accidents that have occurred in the UK chemicals and petrochemicals sectors, and higher-cost accidents that have occurred world-wide, in the twenty-two years following the Flixborough accident in 1974.

The work has indicated a lack of reliable data in the public domain on the costs of major industrial accidents. Where data are available, there are often conflicts between reported values. These may stem from the wide scope of costs which potentially contribute to the total, from changes in monetary values over time, from commercial sensitivities and from clerical errors.

**TABLE 1: THE TWENTY UK ACCIDENTS IDENTIFIED WITH THE HIGHEST COSTS SINCE FLIXBOROUGH**

| Company | Location | Date | Quoted Cost at Time of Accident | Quoted Cost converted to 1996 values (Note 1) |
|---|---|---|---|---|
| Texaco / Gulf | Pembroke, Dyfed | 24/07/94 | - | £100 million (Note 2) |
| BP Oil | Grangemough, Edinburgh | 22/03/87 | - | £100 million (Note 3) |
| Laporte Chemicals | Warrington, Cheshire | 15/09/84 | £25 million | £43 million |
| National Freight Consortium | Brightside Lane, Sheffield | 14/12/84 | £21.3 million | £37 million |
| BASF | Wilton, Teeside | 09/10/95 | £20 million | £20 million |
| J Kelman Transport | Braehead, Renfrew | 04/01/77 | £6 million | £20 million |
| Amoco | Milford haven | 30/08/83 | £10 million | £18 million |
| RA Lister | Dursley, Gloucestershire | 27/07/83 | £9 million | £16 million |
| Morganite Ceramic Fibres | Bromborough, Merseyside | 13/10/84 | £5.8 million | £10 million |
| Shell | Ellesmere Port, Cheshire | 20/03/90 | £8 million | £10 million |
| Laporte Chemicals | Warrington, Cheshire | 04/06/85 | £5.5 million | £9 million |
| BP Chemicals | Baglan Bay, Swansea | 12/10/90 | £7.1 million | £8.7 million |
| CK Addison | Lough, Lincolnshire | 26/11/81 | £3.5 million | £7.1 million |
| Associated Octel | Ellesmere Port, Cheshire | 01/02/94 | - | £6.1 million (Note 4) |
| BP Oil | Llandarcy, West Glamorgan | 17/01/81 | £3 million | £6 million |
| Universal Freight | Woodkirk, Yorkshire | 13/02/82 | £3 million | £5.7 million |
| Allied Colloids | Bradford, Yorkshire | 21/07/92 | £4.5 million | £5 million |
| Unichema | Bromborough, Merseyside | 18/01/91 | £4 million | £4.6 million |
| British Drug House | Poole, Dorset | 21/06/88 | £3 million | £4.2 million |
| Hickson & Welch | Castleford, Yorkshire | 21/09/92 | £1.5-3 million | £1.6-3.3 million |

*Note 1: Costs have been converted to 1996 values using the GDP Deflator time-series defined by HM Treasury.*

*Note 2: Derived from US$149.1 million (1996) quoted by Marsh & McLennan[4]. Other estimates range from £70 million to £200 million.*

*Note 3: Based on the HSE publication 'The Costs of Accidents at Work'[11], which records the company's belief that this accident cost £50 million in property damage and a further £50 million due to business interruption.*

*Note 4: HSE's report on their investigation[8] records the company's belief that the costs of the disruption to the process may be several times the £6.1 million rebuild costs.*

**TABLE 2: FOURTEEN OVERSEAS ACCIDENTS WITH COSTS HIGHER THAN EXPERIENCED IN THE UK SINCE FLIXBOROUGH (Costs are in US dollars)**

| Location | Date | Cost (US$1996) | Includes Business Interruption Losses? |
|---|---|---|---|
| Pasadena, Texas | 23/10/89 | $1,456 million | Yes |
| La Mede, France | 11/09/92 | $458 million | Yes |
| Pampa, Texas | 14/11/87 | $396 million | Yes |
| Antwerp, Belgium | 07/03/89 | $356 million | Yes |
| Thessaloniki, Greece | 24/02/86 | $300 million | No (Note 1) |
| Norco, Louisiana | 05/05/88 | $293 million | No (Note 1) |
| Sweeny, Texas | 04/13/91 | $264 million | Yes |
| Romeoville, Illinois | 23/07/84 | $241 million | No (Note 1) |
| Port Neal, Iowa | 13/12/84 | $182 million | Yes |
| Sodegaura, Japan | 16/10/92 | $172 million | No (Note 1) |
| Seadrift, Texas | 02/12/91 | $172 million | Yes |
| Umm Said, Qatar | 03/04/77 | $156 million | Note (Note 1) |
| Shuaiba, Kuwait | 20/08/81 | $148 million | No (Note 1) |
| Sterlington, Louisiana | 05/01/91 | $148 million | Yes |

*Note 1: The January 1997 issue of the Loss Control Newsletter12 reports on analysis of 119 events at petrochemical, chemical and refinery sites, concluding that Business Interruption losses were on average 2.7 times Property Damage losses. However, there were wide variations between individual cases.*

The total costs of major accidents in the UK chemicals/petrochemicals sectors in the twenty-two years following Flixborough were at least £500 million, in 1996 values. There is much uncertainty in this figure, possibly a factor of two or more, because of conflicts in data. Moreover, the figure is based on data available within the public domain and is generally exclusive of many of the factors mentioned in the previous paragraph. If comprehensive costs were known, they may be many times greater.

There would be widespread interest in a cost study to determine the true total costs of major accidents. It is suspected that such research would provide a strengthened economic stimulus for implementation of management systems and safety systems to prevent such accidents in the future. The present work has provided a list of factors which contribute to the costs of an accident and which would need to be considered in such a study.

Finally it has been observed that the number of casualties in an accident is a poor indicator of the ultimate scale of losses from the accident.

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*Disclaimer*

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# References

1 *MHIDAS: Major Hazard Incident Data Service,* HSE/UKAEA, 1986
2 *Loss Prevention Bulletin,* Institution of Chemical Engineers, various issues
3 *Hazardous Cargo Bulletin,* Intapress Publishing, various issues
4 *Large Property Damage Losses in the Hydrocarbon Chemical Industries – A Thirty Year Review,* Marsh & McLennan, 1996
5 *Million pound-plus fires for the year …..,* published annually in Fire Prevention, the journal of the Fire Protection Association
6 *The fires and explosion at BP Oil Grangemouth, March 1987,* ealth and Safety Executive, 1989
7 *The Brightside Lane warehouse fire,* Health and Safety Executive, 1985
8 *The chemical release and fire at the Associated Octel Company Ltd,* Health and Safety Executive, 1996
9 *The fire at Allied Colloids Ltd, Bradford on 21 July 1992,* Health and Safety Executive, 1994
10 *The fire at Hickson & Welch, Ltd,* Health and Safety Executive, 1994
11 *The Costs of Accidents at Work,* Health and Safety Executive, 1997
12 *Loss Control Newsletter,* January 1997

# Appendix 1 – Factors contributing to the costs of accidents

Following a major industrial accident various estimates of costs usually appear in the public domain, via press statements, follow-up reports and articles. The estimates, however, are rarely broken down into constituent elements but represent instead a homogeneous total drawn from certain cost bases. From an examination of such cost statements it is clear that they generally comprise allowances for:

- Reconstruction costs
- Lost production
- Court costs
- Fines

On further examination it becomes apparent that there are many costs which remain invisible, or only partially visible. Costings for the reconstruction of plant are primarily based upon the physical cost of equipment parts and thus do not include the cost of on-site personnel, contractors and plant redesign. (A complication is that quoting reconstruction costs may actually overestimate the losses – if the damaged plant was near the end of its planned life and due for refurbishment, then the major part of the quoted reconstruction costs may have already been included in a capital budget). No published accident costs have been found which include the costs to the civil and health authorities. Many accidents are followed by pledges of increased public information, safety reviews and safety planning, all of which have added costs.

It is suggested that a detailed evaluation of accident costs would need to consider the following cost factors:

**Production and capital losses**

- Costs of lost production and business interruption, repair of damaged equipment, replacement of destroyed equipment, hire of temporary equipment, repair of buildings.
- Collateral costs eg sale of crude oil due to lack of refining capacity.
- Repair of off-site damage eg shattered windows/ windscreens, burnt out houses, cars.
- Increased insurance premiums, independent studies following a major accident.
- Reallocation of production to other sites, storage and/ or rerouting of base process materials.
- Drop in market share, loss of share value.
- Transportation costs.

**Personnel**

- Sick pay, costs of temporary and permanent staff replacements, short term contractor staff, lost time of non-productive staff due to plant shut down, transfer of staff to other production areas and requirements for additional training.

**Civil costs**

- Fire brigade, equipment and men, both for the incident and the days that follow.
- Ambulance service.
- Hospital costs, health support and long term health monitoring.
- Policing of the incident, special patrols to inform and reassure the public, direct traffic, support the other emergency services and deter looters.
- Prosecution, court costs and preparation of the case for trial.
- HSE investigations, inspection, specialist research, public enquiry.

- Related studies, eg toxicological research following chemical dispersion.
- Environmental cleanup.
- Restocking or replacement of fisheries; woodlands etc.
- Decontamination of the affected area.
- Evacuation, support and temporary accommodation of local population.
- Provision of information to local residents and national media.

**Public relations**

- Launch of newsletters, upgrade of communications facilities, press bulletins, setting up visitors centres.

**Review**

- Review of safety procedures in relation to what caused the accident, review of general emergency procedures (employment of outside contractors).

**Legal costs**

- Compensation, fines, court costs (including studies undertaken in pursuance or defence of claims).

**Neighbouring companies**

- Cost to neighbouring plant that may be affected by temporary road closures, or even the need to shutdown and evacuate their own premises.

**National implications**

- Loss of exports, increased imports, lost tax revenue (through loss of sales by the company).

# Appendix 2 – Some common features observed in the high-cost accidents

Some similarities were observed between the causes and consequences of some of the accidents as follows:

**Isolation valves**

Problems with isolating leaks of ignited flammable substances were major factors in two of the accidents. In each case isolating valves could not be closed, either because they were not remotely operable, they could not be accessed because of their proximity to the fire, or they were damaged by the fire.

**Fire water**

In several of the accidents water supplies for fire fighting were found to be inadequate.

**Storage protocol**

A lack of understanding and poor management of storage/ process/ chemical segregation was a common factor in three of the accidents.

**Perceived low risk**

At least two of the accidents involved activities which were not considered to be the main high risk activity on site.

**Escalation potential**

In two of the accidents the intense heat generated by fire posed a real threat of escalation to involve adjacent storage tanks. In each case the fire service set up portable water monitors to provide cooling.

**Routine inspection and maintenance of critical equipment**

Three of the accidents revealed deficiencies in the inspection and maintenance procedures for what turned out to be critical items of plant equipment.

**Unreliable and inadequate control systems**

Four of the accidents revealed a combination of inadequate and unreliable process control equipment. In one case a process motor/ pump had failed for several hours, in another level indicators were known to give false readings, in another the process system failed to

identify the correct position of valve equipment, and in the fourth vital pressure information was not displayed on the VDU used by the operators.

**Location of key buildings**

Two of the accidents resulted in the total destruction of, or severe damage to, control room buildings.

**Loss of process control**

Two of the accidents resulted from runaway reactions.

**Information to the public**

Two of the accidents revealed that measures to inform the public were inadequate. In each case great public concern was generated.