

A JANUS APPROACH TO SAFETY

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Growing public unease over safety and environmental matters is leading to more litigation whether in the civil or the criminal court. It seem probable that the 21st Century defendants will have to show that they have learnt and put into practice the lessons taught by previous accidents not only within their organisation but also outside it. This paper will give some examples from different industries where lessons were not learnt and a notable one where the lessons were shared to the benefit of the public. The process of learning lessons, based on a management system, in design, inspection, maintenance and all operational work is discussed.
The importance of the professionalism of engineers and scientists and the necessity for them to share lessons learnt for the benefit of the employees, the public, the environment and their company is discussed.
Industry must share information on accidents to satisfy the community's concern for greater safety.

Keywords: **A**ccident database, Learning lessons, Duty of care, Hazard identification, Professional engineer

INTRODUCTION

Janus was a god of the ancient Romans who is depicted as having two faces, one looking backwards and the other to the front. He was a guardian of beginnings and the month of January is named after him because he looked back to the past year and forward to the year to come. The Janus approach to safety may suggest itself to us, looking to the past to learn what has happened and to the future to identify what could happen.

If hindsight is defined as wisdom after the event, learning lessons from accidents is a process of converting hindsight into foresight and the Janus approach becomes an active concept. The necessary precautions then become a matter of engineering common sense.

Growing public unease over safety and environmental matters is leading to more litigation both in the civil and the criminal court. It seems probable that defendants in the 21st Century will have to show that they have learnt, and put into practice, the lessons taught by previous accidents not only within their own organisation but also outside it. Given modern communications and the electronic storage and retrieval of accident data, ignorance will no longer be acceptable as a mitigating factor.

WHY LEARN LESSONS?

It may seem obvious that lessons have to be learnt yet it is becoming clear that this is not always the case. It should not be necessary to have a regulation requiring an accident to be investigated and yet a regulation (1) to do just that has now been put forward in a consultative document. It is therefore worth stating the practical reasons why accidents should be investigated.

- To understand what happened.

- To prevent it recurring.
- To protect people.
- To protect equipment and material.
- To meet statutory requirements.
- To protect profits.

It follows that the lessons taught by investigation of the accident have to be learnt; otherwise the accident will recur and the loss both in human and monetary terms will be repeated. But the lessons have to be learnt not only for present purposes but for future occasions where they might be relevant. These lessons should also be shared with others.

The investigation of accidents is often not made in sufficient depth once the basic cause has been established. For example, the cause could simply be attributed to an operator opening the wrong valve. This could indeed be the basic cause but it must be further explored. The operator may have received inadequate training; he may have been incorrectly assessed as competent to carry out the requirements of the job. Delving further back, it may be found there was no management system in place to ensure that all operators were fully trained before being authorised to operate the relevant plant.

The important requirement in an organisation is for a management system covering not only the thorough investigation of accidents but also the use of lessons learnt from within and outside the organisation in all design and risk assessment work (2).

DO WE LEARN LESSONS?

It is often said that the only thing that history teaches us is that we do not learn from it. Here are a few examples from various industries, some going back in time.

1. We have recently heard a lot about Deep Vein Thrombosis (DVT) or Economy Class Syndrome which has lead to the swelling of the leg and blood clots due to cramped conditions in aircraft flying long distances. This is no new problem. It occurred in the equally cramped conditions of stage coaches as Count Leopold Berchtold recounted in 1789 when he published 'An Essay to Direct and Extend the Enquires of Patriotic Travellers' (3):

   "*Travellers in carriages are very liable to have their legs swelled; in order to prevent being thus incommoded, it will be advisable to wear shoes rather than boots, to untie the garters, to alight now and then, and to walk as often as opportunity permits, which will favour circulation*."

2. This year a report in the Sunday newspaper (4) stated:

   "*Seven people including two children were crushed to death in a stampede at Johannesburg's main Park Station when passengers stormed towards a stairway where a gate had been closed ahead of a train's departure.*"

   This tragedy is an all too frequent echo of earlier instances of crowds rushing down stairways with fatal results.

- Towards the end of the bank holiday in April 1892 the crowds who had been enjoying themselves on Hampstead Heath noticed an approaching rain cloud, decided to call it a day and rushed to the nearest station (3). The stairway down to the platforms at Hampstead Heath Station was soon jammed with a seething mass of passengers; somebody tripped and fell, but still the crowds came. Two adults and six children were killed. A passenger on a train arriving at the height of the crush described the scene in a letter to the *Hampstead and Highgate Express*:-

  "A most painful sight met my gaze. The station seemed like a howling wilderness, shrieking, bustling, and cries of women and children made it a scene almost indescribable."

3. The *Marchioness* Disaster.
   This disaster occurred on the River Thames in 1989 when a dredger, the *Bowbelle,* rammed and sank the pleasure vessel, the *Marchioness*, and 51 people died. The official inquiry said that the basic cause was the poor lookout on both vessels. It described the accident as "a catastrophe which should never have happened." The *Bowbelle* collided with a passenger launch, the *Pride of Greenwich*, in June 1983. Measures were put in place to improve lookouts and communications but these had fallen into disuse by 1989.

- In 1878 the *Bywell Castle* collided with the *Princess Alice* with 750 passengers on board. 640 passengers were killed. The jurors at the subsequent inquest stated (5):

  "*The investigation ... has brought to light the existence of a state of things on the river which no man in his senses can contemplate without a shudder. It appears that there are no rules whatever to guide captains of vessels. All is left to the chapter of accidents - to the chance that vessels will somehow or other manage to pass one another without coming into collision."*

4. The Loss Prevention Bulletin (6) reported three incidents involving the failure of trap doors used on pigs and high pressure scrubbers on pipelines. The first occurred in 1971 on an offshore installation, the second in 1988 on a shore-based plant with a fatality and the third in 1991 on an offshore installation with a damage cost of £7 million. In each case the failure of the 'yoke type' closure device on the trap door occurred resulting in the pressure release of the pig and pipeline. In the 1971 incident the pressure was released from 87.5 bar with the end closure blowing off with hinge and two clamps. In the 1988 incident the pressure had reached 200 bars in a gas scrubber when the closure door was projected across the site approximately 70 metres with other debris scattered over 170 metres away. In the 1991 incident a pig trap door became detached at a pressure of 79.3 bar. The end closure demolished a crane and caused widespread damage to a module structure.

   The cause of these incidents was attributed to the failure of a nut retaining box. In 1986 an appendix to ASME 8 was issued and these closures would not have met the revised code but all three were designed before the code was promulgated. Nevertheless this type of closure is found in many pig traps, scrubbers, condensate coalescers, large filters, etc. It was concluded that if the first "….incident had been made common knowledge, then there is a high probability that the other incidents may not have occurred."

5. The Texaco refinery explosion and fires (7) occurred after a serious electrical storm in 1994. The crude distillation unit was shut down following a fire started by the lightning. An explosion occurred five hours later as a result of a major release of hydrocarbons. The incident was caused by hydrocarbon being pumped into a vessel that was closed at the outlet and the only escape was to a flare system which could not cope with the quantities involved. An outlet pipe failed and released 20 tonnes of hydrocarbon. The HSE report states in paragraph 127:

   "All the key elements of the incident, and the lessons drawn from it, have been seen and publicised before in major accidents around the world. Those who are responsible for operating hazardous plants must have systems in place that bring to their attention these lessons of history."

   The report then makes the first recommendation:

   "Safety management systems should include means of storing, retrieving and reviewing incident information from the history of similar plants."

6. Road tanker with the wrong documentation.
   On the 3 October 1996 at Avonmouth a road tanker containing sodium chlorite was offloaded into a tank containing epichlorohydrin (8). This occurred because the wrong documentation had been picked up at a ferry crossing. The Chemical Industries Association found that this was not the first incident of this kind and could easily have been avoided if the previous incidents had been reported and shared.

The answer to the question raised at the beginning of this section is very clear. We do not learn lessons from the incidents that occur in many industrial situations. Trevor Kletz has also shown this to be the case (9 and 10) and has stated the reason:

> *"It might seem to an outsider that industrial accidents occur because we do not know how to prevent them. In fact they occur because we do not use the knowledge that is available. Organisations do not learn from the past or, rather, individuals learn but they leave the organisation, taking their knowledge with them, and the organisation as a whole forgets."*

There have been others in the past who have also stated that lessons must be learnt. After a fire at a theatre in England in 1887, when 188 people were killed, the investigating officer's report (11) concluded:

> "*The saddest part of this matter is that no lesson of any kind has been taught by the event, as everyone who has studied the subject either theoretically or practically knew beyond any possibility of a doubt what the whole action of the fire and smoke would be under such circumstances, and moreover, the lessons and warning of recent years had prepared all concerned for the terrible catastrophe precisely as it actually occurred."*

More recently a report by the US Environmental Protection Agency and Chemical Emergency Preparedness and Protection Agency (12) describes the recurring causes of recent chemical accidents. The report describes nine accidents in the petrochemical industries which had the following common factors:

- Inadequate hazard review or process hazards analysis.
- Installation of pollution control equipment without adequate hazard analysis and inadequate management of change procedures.
- Use of inappropriate or poorly designed equipment
- Inadequate indications of process condition.
- Warnings went unheeded

There is, however, one notable case where lessons were learnt to the great benefit of air passengers and the companies. Some here will remember the series of accidents that happened with the BOAC Comet passenger aircraft, starting in January 1954 with the disintegration in flight of G-ALYP, followed by G-ALYY in April 1954. The investigation involved the pressure testing of a whole aircraft in a water tank. After subjecting the aircraft to simulated pressure fluctuations the main cause of the failure of the aircraft was found to be fatigue cracks at the corner of the windows. This information was released to the whole industry so that aircraft of the future could take advantage of the lessons learnt. The industry and passengers all benefited from this approach. If the information had not been released, how many more lives would have been lost before other aircraft manufacturers discovered the problem of fatigue cracks at window corners can only be imagined.

WHERE CAN WE FIND LESSONS FROM PAST ACCIDENTS?

Information on past accidents is available from a number of databases including MHIDAS from AEA Technology and FACTS from TNO, but these and many others are often based on information taken from the media. The media, however, are usually only interested in the event and not the causes. The Accident Database of the Institution of Chemical Engineers (8) is based on full reports taken from:

- The Loss Prevention Bulletin
- Reports in journals
- Official reports from Regulatory Authorities
- Confidential reports from companies.

The only other source of information for these lessons, apart from the files of ones own organisation, is the published literature, but searching through it is time-consuming and unreliable. It is well known that the indexing and abstraction systems are inadequate. Only a dedicated accident database can provide a solution to the problem, as shown in the next section.

WHERE CAN WE USE LESSONS FROM PAST ACCIDENTS?

Risk management and risk control are essential features in the avoidance of accidents, and the first stage in any of the methods used is identifying the hazards (see Figure 1) associated with the project or operation. Lessons learnt from accidents (or near-misses) are a vital part of the following operations where hazards have to be identified:

- Design work

- Hazard and Operability Studies
- Risk Assessment
- Writing Permits to Work
- Writing operating instructions
- Safety Audits
- Review Procedures
- Inspections
- Audits

Identifying hazards is the key to almost all operational work and is done automatically in much of our every day work. We look each way before crossing the road but in our technical work it is important that we use not only the hazards that we retain in our memory but also use the hazards identified by others and contained in the memory bank of a database.

A scenario for the use of The Accident Database in the petrochemical industry could be the design of a distillation column for ethylene oxide. The professionalism of the design engineer would require him to consider what accidents had occurred on such equipment. He would want to ensure that his design did not have the problems that others had experienced and which had caused fatalities, injuries to people, damage to equipment (see Figure 2) or discharges to the atmosphere of toxic chemicals. He would therefore seek information on such accidents and the causes. He would discover when consulting The Accident Database (8) that there had been at least eight explosions involving distillation columns and ethylene oxide and that the lessons learnt were of a similar nature. Table 1 gives a very brief description of the incidents and lessons learnt.

It is clear that all these accidents have a similar cause:

- Leak from flange or weld
- Reaction in the insulation with water
- Auto-oxidation catalysed by rust with heating from an insulation fire

If these had been recognised and shared after the accidents in the 1950s or 1960s the design engineers would have been able to prevent most of the subsequent explosions in the ethylene oxide plants with a consequent prevention of fatalities, injuries, pollution and loss of profits.

PROFESSIONALISM

The Engineering Council

A Royal Charter established the Engineering Council in 1981 and one objective was:

> *"..... to advance education in, and to promote the science and practice of engineering (including relevant technology) for the public benefit and thereby to promote industry and commerce....."*

The Engineering Council seeks to achieve this objective by a number of aims including:

- Increasing awareness of the essential and beneficial part engineering plays in all aspects of modern life.
- Spreading best engineering practice to improve the efficiency and competitiveness of business.
- Advancing engineering knowledge through education and training.

These aims are achieved in a number of ways including:

- Stressing the need for a proper balance between efficiency, public safety and the needs of the environment when carrying out engineering activities.

Chartered Engineers, Incorporated Engineers and Engineering Technicians registered with the Engineering Council undertake a duty to the community under the "Code and Rules of Conduct" (12) rule 1:

> "A registrant shall at all times and in all aspects:
> (a) take all reasonable care to avoid creating any danger of death, injury or ill-health to any person or of damage to property by any act or omission whilst carrying out his/her work, save to the extent that the creation of such danger is lawfully authorised;
> (b) take all reasonable care to protect the working and living environments of himself/herself and others and to ensure the efficient use of materials and resources;
> (c) conduct himself/herself so as to safeguard the public interest in matters of safety and health and in a manner consistent with the dignity and reputation of the engineering profession; and
> (d) notwithstanding the provisions of any of the Rules or Codes of professional Practice, comply with all laws and regulations applicable to his/her professional work."

In the Notes for Guidance it is stated:

> "The important feature of this Rule (viz 1(d)) is that more is demanded of the registrant than bare compliance with existing law. Full compliance is required, not only in the letter but also in the spirit. Ambiguities or loopholes in the law, regulations, etc, must not be exploited in an effort to reduce costs if engineering judgement shows that safety or the environment would be jeopardised as a result. In safety and environmental matters the statutory requirements should be regarded as no more than minima. Even when these requirements have been satisified, the Council still looks to the registrant to take such further measures as his or her engineering judgement shows to be necessary for securing public safety and preservation of the environment, in accordance with Rule 1."

Guidelines on Risk Issues (13) published by the Engineering Council in section 6 Communications states:

> " Engineers should pay particular attention to effective feedback on incidents and 'near misses', so that lessons can be learned."

The Institution of Chemical Engineers

The Institution of Chemical Engineers was founded in 1922 and incorporated by Royal Charter in 1957. Section 12 (b) (ii) of the By-laws (14) states:

> "Every Corporate Member shall at all times so order his conduct as to uphold the dignity and reputation of his profession and safeguard the public interest in matters of safety, health and otherwise. He shall exercise his professional skill and judgement to the best of his ability and discharge his professional responsibilities with integrity."

The Rules of Professional Conduct (14) states in section 4:

> "A member shall take all reasonable care in his work to minimise the risk of death, injury, or ill-health to any person, or of damage to property. In his work, a member shall respect all laws and statutory regulations applicable to the design, operation and maintenance of chemical and processing plant. In addition a member shall have due regard for the need to protect working and living environments, and the need to ensure efficient use of natural raw materials and resources."

The Royal Society of Chemistry

In the Code of Conduct and Guidance on Professional Practice (15) and the section on 'The Chemist and Society' it is stated:

> "As members of the Society, chemists have social responsibilities arising from their fundamental duty to serve the public interest, particularly in the fields of health, safety and the environment."
>
> "Chemists have a duty to identify the hazards and assess the risks of scientific and technological activities and processes. They must strive for the highest standards of care in their own workplace and take an active interest in safety throughout the organisation. They have a right to protest about malpractice, while maintaining a sense of proportion, and they can expect the support of the Society if their efforts are unavailing."

Technical Integrity and Competence

Technical integrity has been defined (16):

> "Technical integrity is concerned with the development of the design such that it is carried out by well trained personnel, who have been assessed competent, in accordance with recognised, sound practices and procedures and such that there is adequate provision by way of reviews and audits, to ensure the design intent is unimpaired in any way that could cause undue risk or harm to people or damage to the environment."

The question of competence is also mentioned in this reference (16) from the Australian Institute of Engineers:

> "The ability to perform the activities within the occupation or function to the standard expected in employment."

Engineering and management staff in a company must display both integrity and competence in their respective spheres of responsibility. They must also demand it of any outside contractors they employ. The importance of not causing undue risk requires the engineer to use his training and experience to search in all reasonable places to identify hazards that may not be known to him from his own experience but which may be found in the experience of other persons.

The Professional Person

Under the Health and Safety at Work Act 1974 everybody has a duty of care towards others but the professionally qualified engineer or scientist has an additional duty because of his membership of a professional organisation. This additional duty results from the training he will have received to identify the hazards involved in his work. There is a general requirement to achieve a risk as low as reasonably practical (ALARP).

The ALARP principle is an important concept that requires a professional person:

- To balance the cost involved against the benefit.
- To consider other ways of carrying out the work which lowers the risk but which is also practical.
- To identify not only those hazards that a professional might reasonably be expected to know but also those that can be established by consulting:
    - other persons
    - books
    - databases
    - other sources.

The professional must use all resources he considers appropriate in order to reduce the risks to himself, to others at his place of work and to the public at large, as well as reducing the impact on the environment. If these resources are withheld or not available, then it is incumbent on the professional to draw this to the attention of a superior authority.

CONCLUSIONS

The report by the US Environmental Protection Agency and Chemical Emergency Preparedness and Protection Office (12) concludes with a statement that is only too familiar:

> "From the perspective of the individual facility manager, catastrophic events are so rare that they may appear to be essentially impossible, and the circumstances and causes of an accident at a distant facility in a different industry sector may seem irrelevant. However, from our nation-wide perspective at EPA and OSHA, while chemical accidents are not routine, they are a monthly or even weekly occurrence, and there is much to learn from the story behind the accident. Catastrophic chemical accidents still occur too often. Furthermore, when we look beyond the obvious to the underlying systemic causes of an accident, we see that the same root and contributing

causes keep popping up again and again. This indicates that government and industry are not doing a good enough job at sharing accident information and implementing lessons learned."

The learning of lessons from accidents is becoming an important part of the professionalism of the engineer and scientist. Public demand for the lessons to be learnt and headed will increase and industry must respond to this reasonable request. If we fail to meet this request the industry must expect demands for the Government to impose statutory regulations.

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FIGURE 1 - RISK ASSESSMENT PROCESS - GENERAL

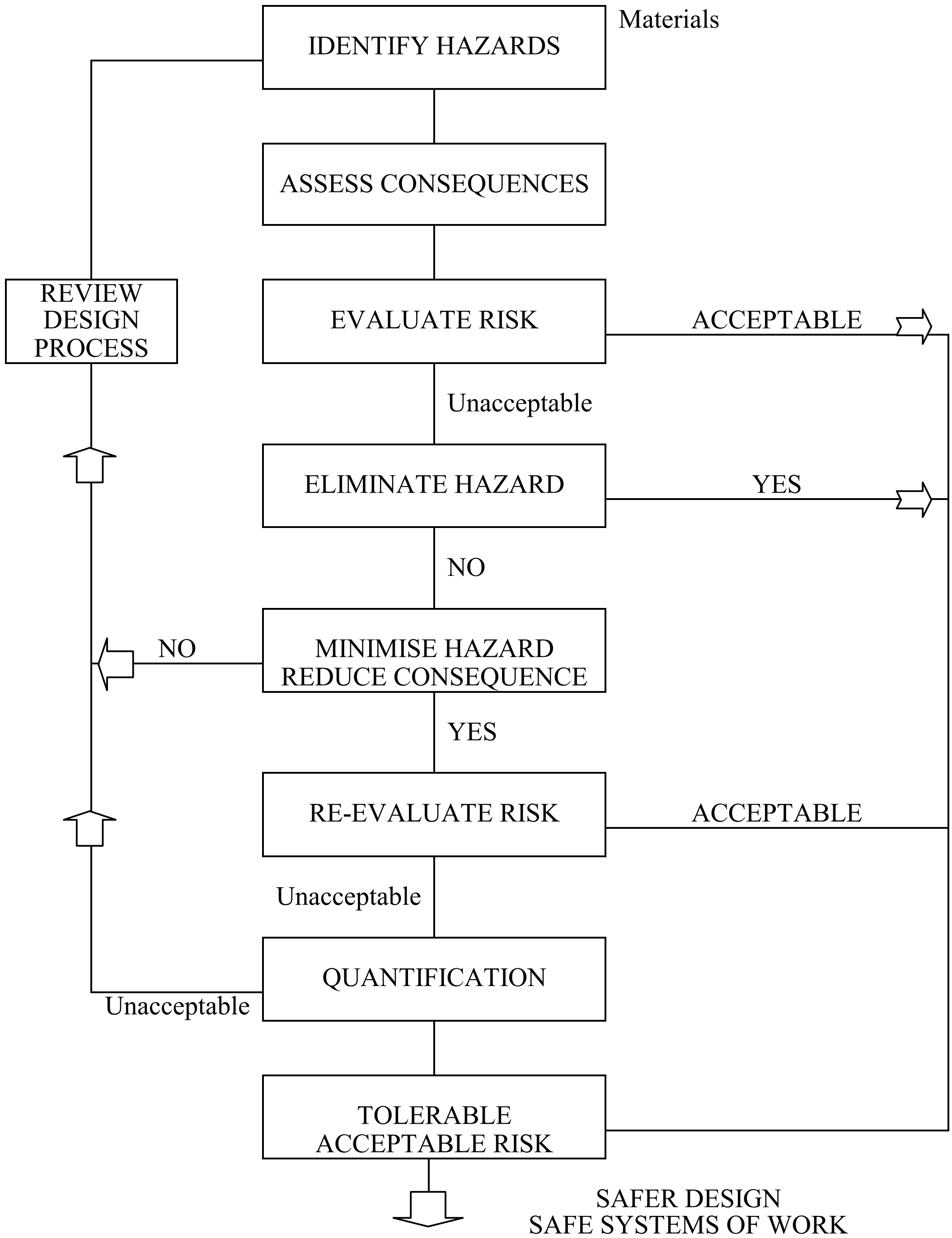

Table 1. Incidents involving ethylene oxide and distillation column

DATE OF INCIDENT	PLACE OF INCIDENT	BRIEF DESCRIPTION OF INCIDENT	LESSONS LEARNT
12/3/1991	Texas, USA	Explosion in ethylene oxide column	Upper part of reboiler must be covered. Avoid condensate backup. Positive purge of inert gases from shell. Ensure minimum heating temperature
7/3/1989	Antwerp, Belgium	Explosion in ethylene oxide column. Small leak from flanges igniting and causing hotspot. Rust catalysed polymerisation	Reduction of number of flanges. Leak testing. Insulation non-absorbent and test for glycol formation. Avoid piping with no flow of EO gas
1989	Not stated	Small leak through hair crack in weld ignited and heated column causing auto-oxidation	Flanges to be left uninsulated Remove any rust from pipework
3/7/1987	Antwerp, Belgium	Small leak from flange and reaction in insulation ignited and caused hotspot. Explosion in ethylene oxide column	Reduce the number of flanges Avoid rust in pipework Avoid stagnant EO lines Areas of possible leak should be tested regularly
24 February 1969	Texas, USA	Explosion in ethylene oxide column. Rust initiating polymerisation.	Magnesia insulation replaced
4 July 1969		Water hose on flange leak. Leak caught fire and flame impinged on reflux line causing explosion in column.	Gasket material inadequate
3 June 1964	Belgium	Over heating in reflux pump caused explosion in ethylene oxide column	
1955	Unknown	Leak from flange ignited and impinged on column leading to explosion	

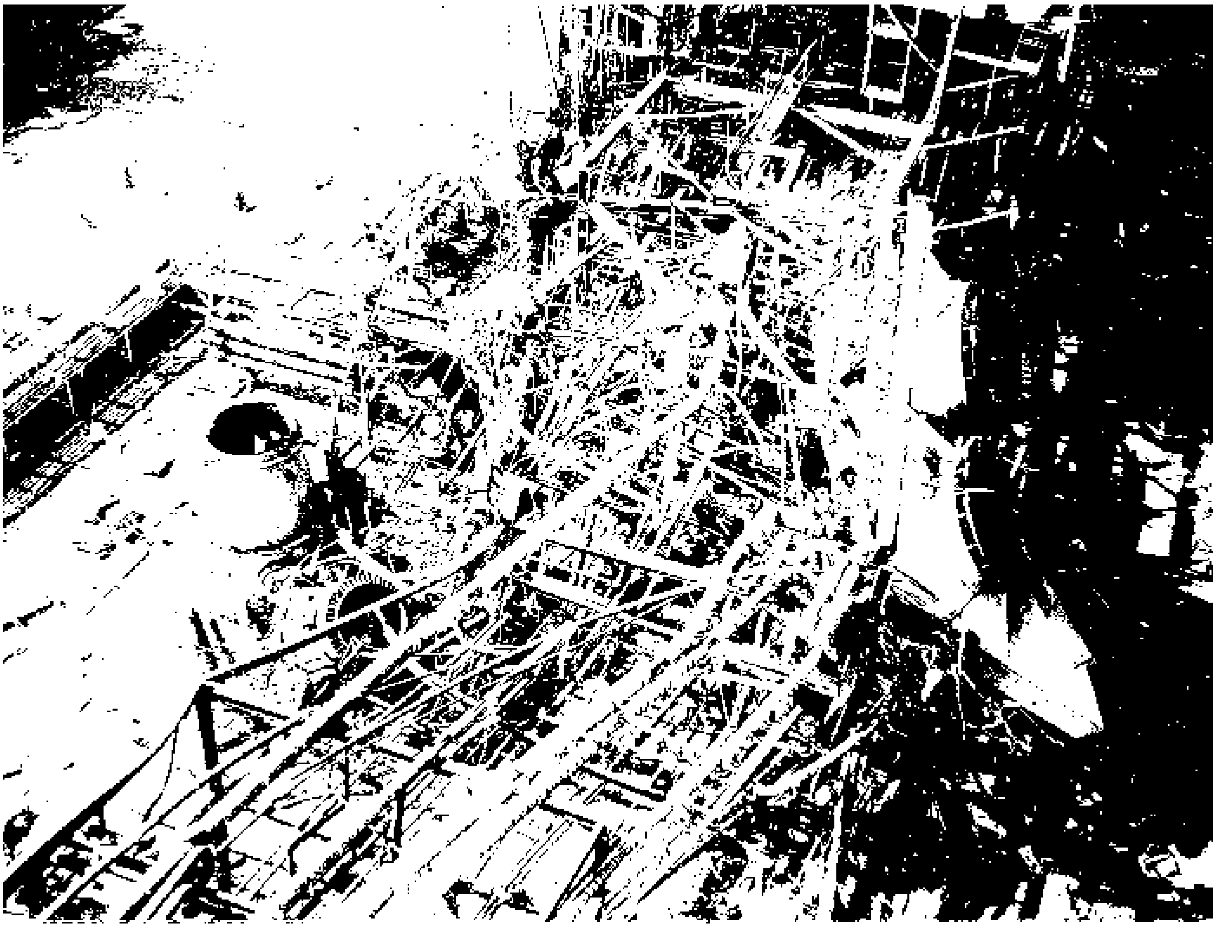

Figure 2. The results of an explosion in an ethylene oxide distillation column.