PROJECT ON LOSS OF CONTAINMENT POTENTIAL FROM TANKS CONTAINING HAZARDOUS SUBSTANCES

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Losses of containment from tanks have led to a number of serious incidents and accidents. A project was, therefore, initiated within Unit 3 of Land Division of HSE's Hazardous Installation Directorate (HID) to gather information on the potential for loss of containment, and the measures currently in use to mitigate the possible consequences. The work was carried out with a view to identifying benchmarks for simple alarm/automatic protection systems designed to reduce the incidence of tank overfilling, and other protection measures to prevent loss of containment. Thirteen sites - within Wales and the West of England were visited over a 6-month period as part of this project. Sites chosen contained more than 5 fixed tanks storing a variety of substances. Sites with large, complex storage facilities, such as refineries or large chemical plants were excluded.

The key findings of this work were:

1. Wide variations existed in standards in design, selection, fabrication, installation, inspection and maintenance of tanks, bunds, alarms, trips, valves, and fittings. Appropriate enforcement action was taken where companies failed to comply with the law.
2. Most of the sites visited had made little effort in carrying out risk assessments on loss of containment. Few had identified safety critical items.
3. In many instances tanks were not fitted with adequate level alarms and trips. The tanks were old and no records existed of these being 'fit for the purpose'. Bunds were also inadequate in size and were constructed of inappropriate materials.
4. Most of the sites visited paid little attention to the inspection, testing and maintenance of isolation valves, pipe work and fittings. Failure of these has in the past lead to loss of containment.
5. On a number of sites, pumps and other items were found to have been located inside the bund where a catastrophic failure of a tank could lead to a serious incident.
6. On many sites no consideration had been given to the use of Remotely Operated Shut Off Valves (ROSOV's), in the event of an emergency.
7. In many instances, separation distances were inadequate, bunds were excessively crowded with tanks, piping had been poorly installed through the bund wall and bunds were cluttered.
8. In most cases housekeeping was poor and there were build ups of rainwater, potentially flammable materials, inside tank and pump bunds.

Appropriate design features to prevent loss of containment are discussed. Internal HSE guidance is being prepared for inspectors, giving details of the survey and offering advice on the circumstances where enforcement action would be appropriate. HID's inspection strategy relating to this matter is being developed and the potential for loss of containment from tanks containing hazardous substances may now become one of the issues raised routinely during planned inspections to chemical manufacturing and storage sites.

Keywords: Loss of tank containment, Overfilling protection, Bunding and Tank farm protective measures.

INTRODUCTION

There have been a number of EC reportable incidents involving loss of containment of hazardous substances from storage tanks. Incidents, which have been reported to the HSE, include instances of tank and tank fittings failure, as well as tank overflow from overfilling. A project was initiated within Land Division of the Hazardous Installation Directorate (HID) of HSE to gather information on the potential for loss of containment, and measures to mitigate the possible consequences.

The work was undertaken at establishments to which the Control of Major Accident Hazards (COMAH) Regulations 1999 applied.

The aim of the project was to establish baseline information about the potential for loss of containment, and the measures to mitigate possible consequences through visits by specialist inspectors to selected sites.

The scope of the project was to identify measures to prevent loss of containment, including:

- implementation of simple alarm systems;
- scope of inspection and maintenance systems;
- adequacy of bunding arrangements;
- maintenance of containment measures;
- and whether formal risk assessments, have been carried out.

The work was carried out with a view to identifying benchmarks for simple alarm/automatic protection systems, to reduce the incidence of tank overfilling, and of other protection measures to prevent loss of containment.

WORK CARRIED OUT AND PROCEDURES

SELECTION OF SITES

Thirteen sites within Wales and the West of England were selected and visited over a six-month period as part of this project. The sites chosen contained more than 5 fixed tanks and a variety of chemicals. It was not intended that the project should cover sites with large and complex storage facilities such as refineries or large chemical manufacturing sites. Sites that contained tanks storing a variety of substances were preferred.

A range of different types of chemicals - flammables, toxics, and corrosives - were covered in the study and in the majority of cases, the sites had more than one type of chemical in storage.

In all cases, the sites chosen were subject to the Control of Major Accident Hazard Regulations 1999 and included both top tier and lower tier sites.

COMPANY TYPES

The companies chosen were from a range of operational activities and size to provide a good cross section of small, medium and large sites. Tanks of all sizes, from a few m^3 to up to 5,000 m^3 in volume were covered in the study.

PRO FORMA

A pro forma, as attached in Appendix 1, was used to collect information.

On larger sites where there were a large number of tanks and tank farms, a preliminary selection was made before carrying out a detailed inspection and collecting detailed information. The selected tanks and tank farms were chosen on the basis of hazard potential, local factors and the potential for learning from this exercise. In some cases the sites requested a copy of the pro forma so that they could carry out a similar exercise, on their own, on other tanks and tank farm(s) either on the same site or other sites belonging to the company. This was agreed to encourage inquiry, discussions and improvements within the site and the company.

TOPICS

The main topics covered in the project were:

- Risk assessment on loss of containment and identification of safety critical items
- Tanks, including their design, inspection and maintenance
- Bunds, including their size, construction, and lining materials
- Isolation valves, pipe work, flange, fittings, inspection and maintenance
- Alarms and trips
- Housekeeping

KEY FINDINGS AND RESULTS

Wide variations existed in the standards between the various companies visited and even within a site. Some companies were aware of the dangers of minor or catastrophic failure and had a system in place to prevent and deal with these situations. In other cases the companies were totally unaware of the dangers and had taken virtually no steps to prevent loss of containment due to the tank overflow or failure.

Most companies had not carried out a risk assessment, which identified the hazards, and taken measures to avoid loss of containment.

The sections below discuss the findings in more detail.

TANKS

Wide variations existed in tank design, inspection and maintenance regimes within individual company sites and between different companies visited as part of this project.

Types

There were no repeated defects found in a particular type of tank. Tanks inspected included all different types, such as, horizontal, vertical and vertical tiered tanks, and varied widely in their design, state of repair, inspection & maintenance regime.

Some tanks were located at an elevated level and in one case an acid tank located at some 20 - 30 feet up in the air could have sprayed strong acid at tanks located at ground level and a leak could have breached the bund depending on the direction and extent of the failure.

Age

Tank age had little to do with tank integrity and tanks of different age were covered as part of this study. Some new tanks were poorly designed and some very old ones were well designed and maintained. As an example the oldest tank encountered in the survey was built in 1893 and after a thorough refit and examination had received another 10 years lease of life.

Size

There was no correlation between tank size and integrity. Tanks as little as a few thousand liters were found to be badly designed and maintained and tanks very large in size were found to be perfectly adequately designed and maintained. The smallest tank covered in the study was a few m^3 and the largest was of 5000 m^3 in size.

Contents
Tanks containing all different types of materials were covered in the study. These included COMAH named substances, toxics, flammables, corrosive and other hazardous substances. Although there were no hard and fast rules governing standards versus substances stored within tanks, it was found that in general additional care was exercised in the design and maintenance of tanks containing hazardous inventories and COMAH named substances.

Design Codes
Wide variations existed regarding the design of the tanks. Some tanks included in the project were built to design codes or industry standards. However, a large proportion were built to an unknown standard or were purchased second hand with no records of standards to which they were built.

Material of Construction
Tanks covered in the study were mostly either made of steels or plastics. Plastic tanks were generally built to a standard and appeared in better shape but wide variation existed in steel tank design and their state of repair.

Special Features
Some tanks covered in the study had special coatings and linings. These tended to be well maintained, as the occupiers were aware of their possibility of failure and therefore had better systems in place for regular inspection and maintenance.

Location
In a number of cases the tanks and tank farms were located too close to other tank farms, process plant, offices, other occupied buildings, rivers and other over ground water courses. A loss of containment or a fire in these cases could have led to serious escalation and possible harm to people and environment.

In a number of cases the tank farms also contained materials, which on mixing could generate dangerous by-products or where a catastrophic failure of one tank could bring a flammable liquid in the vicinity, in contact with heated tanks or pipe work.

BUNDS
Wide variations existed both within sites and among companies visited as part of this project. Some bunds were well designed, constructed and managed whilst the others were not adequate for the purpose and were badly maintained.

Size
Most bunds were capable of holding 110% of the contents of the largest vessel.

Design
Different designs were found in use within a site and among companies on tank farms. Some had all the various tanks contained within a single bund whereas in other cases there were bunds within bunds to isolate spillages from specific tanks that were considered incompatible. In some cases the dividing walls were only constructed a few inches high to prevent mixing of

minor spillage whereas in other cases the walls were constructed to full height to prevent the stored material over topping in the event of a catastrophic failure.

Pumps and Pipe work In a lot of the cases the pumps were inside the bunds and no consideration had been given to the submerging of pumps in the event of a catastrophic failure of one of the tanks, containing either flammable or corrosive chemicals.

Also, in many cases pipes had breached the bund walls without any consideration given to making sure that it had not weakened the wall.

Bund Walls The walls were also of all different heights, which in some cases made climbing necessary to carry out an inspection. Whilst there is no hard and fast rule regarding the wall height, a height above the eye level makes climbing necessary thus requiring extra effort to carry out an inspection. These bunds normally get left unattended and have therefore suffered from greater chances of having a pipe flange leakage or gasket / bolt failures. The high walls also in some cases did not look strong enough to be able to withstand the catastrophic failure of the tank. In some cases no adequate means had been provided for easy entry into bunds and egress from bunds. Any height that has to be accessed above two meters has to be provided with an appropriate means of access.

Sumps and Drains Some bunds were laid to slope towards a sump to collect spillages and rainwater or a drain with an outlet valve.

Some drains with an outlet valve were found left open thus negating the whole object of having a bund in the first place.

Sumps with a pump which runs automatically or manually as and when required to pump out accumulated waste or rain water to a suitable location (or some equally effective means), is a better solution for keeping the bunds clean and free of spillages and rainwater, than having a drain with an outlet valve.

Materials of construction All different materials of constructions were found to be in use on bunds. These included reinforced concrete, bricks, breezeblocks, plastic as well as earth and stone chippings.

Bund walls Generally these were made of bricks, reinforced concrete, breezeblocks and plastics. In some cases breeze blocks and bricks were plastered over to ensure greater strength and non-permeability. In other cases they were left bare or painted over. In many cases the bund walls were found to be in bad condition due to age, lack of maintenance, supporting of pipe work, cable trays, instrumentation and electrical junction boxes, other miscellaneous items and objects.

Floor Generally these were reinforced concrete, bricks, and plastic or special acid resistance bricks. In many cases concrete lining had been damaged due to the corrosive action of the chemical.

Lining In some cases the bund floor and walls had been lined to protect against the attack by the chemical stored. This was particularly important for the storage of corrosive chemicals such as hydrochloric acid where a catastrophic failure of the tank could have put a severe strain on the wall and continued integrity of the wall is of importance to prevent loss of containment.

VALVES AND FITTINGS

Most companies paid little attention to valves and fittings. There was also little consideration given to use of Remotely Operated Shut Off Valves (ROSOV's), or the inspection and testing of valves to ensure isolation, particularly in an emergency situation. In a number of cases these valves were generally left open indefinitely for operational reasons. No consideration was given to making sure that valves had not stuck in an open position and had not deteriorated or developed a leak.

ALARMS AND TRIPS

Wide variations existed regarding alarms and trips among the companies surveyed. Some companies had tanks fitted with alarms as well as trips whereas others were only fitted with alarms, and some relied on manual dipping, gauges and inventory accounting systems.

INSPECTION AND MAINTENANCE

Wide variations existed regarding inspection and planned maintenance among the companies inspected. Some companies did have a regular inspection and maintenance regime whereas the majority of the companies had no such scheme in place for tanks and tank farms. The former generally related to large oil and chemical manufacturing companies or their subsidiaries.

The systems in themselves also varied, with widely differing inspection and maintenance regimes for similar duties.

In some cases inspections were undertaken every few years, but in other cases the gap between frequency of inspection and maintenance was as high as 25 years. The companies that carried out regular inspection again varied in terms of the systems used. In some cases they were still using a manual system but the majority of the companies who carry out regular inspection and maintenance now appear to be using a computer based system. Where these systems were in existence records were generally kept and were available for inspection.

The systems also varied in terms of depth of examination, testing and maintenance. Depending on the type of tank, size, duty and other design features, some companies carried more or less daily visual external examination. In other cases there was limited frequent visual examination, but an infrequent examination to a defined written scheme of examination.

HOUSE KEEPING

Wide variations existed regarding house keeping among the companies inspected. Some companies did have a regular cleaning regime whereas the majority of the companies had no such scheme in place for tanks and tank farms.

DISCUSSION

Discussion below is aimed at guiding industry as well as Regulatory Inspectors to assess whether the company has taken minimum steps to fulfill their statutory obligations.

LOSS OF CONTAINMENT

Loss of containment due to tank overfilling or failure is a real possibility. There are many examples where these have led to harm to people and the environment and cost companies dearly, in terms of, loss of materials, clean up costs and bad publicity.

Whilst it is not possible to totally avoid these failures occurring, the chances of one happening can be reduced and the likely harm it causes to people and the environment can be minimised.

TANKS AND TANK FARMS

Tanks and tank farms occupy a large proportion of any chemical site. They also hold the largest inventory of hazardous materials and a loss of containment could lead to some of the worst problems arising from the site.
In a lot of cases simple, relatively inexpensive, measures can save significant potential for harm to people and environment.

General - Companies should carry out a risk assessment and this overall assessment should be used to derive a policy on protective measures, frequency of inspection and maintenance.

Old tanks/tank farms -If there are no records available regarding the design standard used in the construction and installation of the tank, and the company uses hazardous materials for storage in these tanks, the company should employ a competent person to draw a scheme of examination and prove that the tank is 'fit for the purpose'.

Where codes or industry standards exist they can be used to identify the inspection and maintenance requirements.

New Tanks and Tank Farms - These should be built to current industry standards or codes of practice for their intended service. Where the application is novel and no data exists the company should carry out corrosion studies and other work to identify an appropriate inspection and maintenance regime. This should also be reviewed once a reasonable inspection history has accumulated. .

Incompatible materials should not be grouped together inside a bund; this potential hazard should be designed out whenever new tank farms are being planned or new substances introduced.

BUNDS

Bunds provide a second line of defence in the containment of hazardous chemicals in the event of tank, valve or fitting failure. The size, design, construction, lining, entry and egress from the bunds are important.

The bunds should be constructed to hold at least 110% volume of the largest vessel within the bund. The bund walls and floor should be impermeable to prevent loss of containment and fouling of ground water courses.

All pumps must be located outside the bund, preferable on a small sill with its own bund to catch leaks and minor spills.

Bund walls should not be used to support pipe work, cable trays, instrumentation, electrical equipment and any other miscellaneous items which can cause the weakening of the wall. For the same reason pipe work should not be allowed to breach the bund wall unless special fittings are installed to maintain the bund integrity. A suitable lining should also be applied to the bund floor and wall to prevent attack by spilt chemicals due to a minor leak or a catastrophic failure.

The floors should be laid to a small collection sump fitted with a pump or some other equally effective device to pump out spillages or rainwater as required to a suitable location.

The bund should be kept clean at all times. In many instances this has been found to have been achieved by having housekeeping rules and making it part of the responsibility of the user department.

VALVES AND FITTINGS

Valves and fittings should be inspected regularly to ensure integrity as well as to make sure that valves can be shut to isolate tanks in an emergency.

Consideration should also be given to use of ROSOV's particularly when storing flammable, corrosive and toxic liquids.

ALARMS AND TRIPS

Risk assessment should be used to assess the need for alarm and trips on tanks. Tanks containing toxics and materials whose loss of containment could lead to major harm to people and environment should be fitted with alarms as well as trips.

INSPECTION AND MAINTENANCE

Regular inspection and maintenance plays a vital role in preventing loss of containment. The company should carry out risk assessments to identify the frequency of inspection and quality of maintenance regime required on their plant. As part of this assessment all safety critical items must be identified and the inspection and maintenance regime defined.

HOUSE KEEPING

Good house keeping has a vital role in safety. It reduces the risk of slips, trips and falls and also minimises the risk of fire and incompatible materials mixing together to produce a hazardous substance. Companies should have house keeping rules and should assign individuals for this duty. It should carry out regular inspection and audits to make sure that the rules are being followed and individuals assigned this duty are carrying out their assigned tasks.

SUMMARY OF FINDINGS AND CONCLUSIONS

1. Wide variations existed in standards, in design, selection, fabrication, installation, inspection and maintenance of tanks, bunds, alarms, trips, valves, and fittings. Appropriate enforcement action was taken where the companies had failed to comply with the law.
2. Most sites visited had made little effort to carry out risk assessments on tank containment, which would have enabled them to identify safety critical items.
3. In many instances tanks were not fitted with adequate level alarms and trips, they were old and no records existed of these being 'fit for the purpose'.
4. Bunds of inadequate size, and some constructed of inappropriate materials, were also seen.
5. Most sites visited paid little attention to inspection, testing and maintenance of isolation valves, pipe work and nuts and bolts. These have in the past lead to loss of containment or serious escalation.
6. On a number of sites pumps and other items were found to have been located inside the bund where a catastrophic failure of a tank could lead to a serious incident. On many sites no consideration had been given to the use of ROSOV's in the event of an emergency.
7. In many instances separation distances were inadequate, bunds were excessively crowded with tanks, piping had been poorly installed through the bund wall and bunds were cluttered.
8. In most cases housekeeping was poor and there were build-ups of rainwater, organic-growth, rubbish and spillages inside tank and pump bunds.

CURRENT STATUS AND HID INSPECTION STRATEGY

Internal guidance is now been prepared for inspectors, giving details of the survey, its conclusions and offering advice on the circumstances in which enforcement action would be appropriate. This matter may become one of the issues raised routinely during planned inspections to chemical manufacturing and storage sites.

Hazardous Installation Directorate (HID) inspection strategy is currently being developed and the potential for loss of containment from tanks containing hazardous substances may now become one of the issues raised routinely during planned inspections to chemical manufacturing and storage sites.

Internal guidance will provide benchmarks for the technical standards inspectors would be seeking and those circumstances where formal enforcement action would be considered.

APPENDIX 1

Tank Storage Questionnaire

(Advice on how to complete the questions are shown in italics in Parts A, B and C, which follow)

A. COMMON INFORMATION FOR ALL SITES

1. Site

2. No.'s Employed

3. Business / Process

4. Activity associated with tanks in survey

(e.g. Raw materials storage, blending, intermediate product storage, finished product storage).

B. INFORMATION IN RELATION TO TANKS / TANK FARMS CONCERNING MAINTENANCE, INSPECTION AND BUNDING

1. Type of Tanks

E.g. vertical, horizontal etc. - indicate Nos.

2. Tank Capacities

Approximate contents if full

3. Contents of Tanks

Mark which category(s) are appropriate

Very Toxic
Toxic
Extremely Flammable
Highly Flammable
Flammable

Dangerous to the environment
COMAH named substance
Other

4. When were the vessels installed and to what design standard were they originally built?

5. Does the site have a planned inspection and maintenance system for the vessels?

6. If so, is it a computer-based or a paper-based system?

7. Does the inspection system cover tank fittings and pipe work as well as the vessels?

8. Please comment if there are any special features, which require special inspection procedures (e.g. lined vessels or pipe work).

9. What is the inspection frequency?

(Indicate if there is a standard frequency, or different frequencies for different vessels. Are the venting arrangements, PRVs etc., inspected to the same frequency?).

10. Can the company demonstrate that the inspections have been carried out when due, and remedial maintenance action taken when necessary?

11. Please comment on the general standard of the vessel and pipe work maintenance. Pay special attention to supports for pipe work, and earth bonding arrangements where flammable liquids are stored.

12. Are the vessels bunded? If so, what is the form of construction of the bunds?

13. Has the company carried out an assessment to ensure:

a) That the bund is capable of holding the contents of 110% of the largest vessel in the bund?

b) That the bund can withstand the full hydrostatic pressure from a complete loss of contents of the largest vessel?

c) That the construction of the bund is appropriate for the types of substances stored (e.g., if acid, is the bund lined with acid-resisting coatings / bricks?

14. Please comment on the general standard of maintenance and housekeeping of the bunds. Pay special attention to expansion joints; drain valves through bund walls etc.

C. INFORMATION IN RELATION TO ALARM SYSTEMS ON VESSELS, WHERE APPLICABLE

Questions 1 to 7 are specific to an individual tank and should be completed for all tanks on site. Question 8 is specific to the tank but there may be similarities between tanks. These details should be completed for all tanks, but may be cross-referenced where appropriate. Questions 9 and 10 relate to all alarms and overrides and only need to be completed once per site.

1. Type of Tanks

E.g. Vertical, horizontal, etc. - indicate Nos.

2. Tank Capacities

Approximate contents if full

3. Contents of Tanks

Mark which category(s) are appropriate

Very Toxic
Toxic
Extremely Flammable
Highly Flammable
Flammable
Dangerous to the environment

COMAH named substance
Other

4. Type of Measurement System

Please indicate the most appropriate description.
None
Combined process measurement and alarm
Process measurement and independent alarm
Combined process measurement and automatic interlock
Process measurement and independent automatic interlock
Other (*please give details*)

5. Type of overfill device

If more than one device present please indicate the final or safety critical device
Level
Weight
Mass
Pressure
Other

6. Alarm and Automatic Interlocks

6.1 Risk Assessment
6.1.1 Has the company carried out a risk assessment to identify the safety criticality of the alarm or automatic interlock?
6.2 Has the safety criticality been used to influence the implementation and if so how?
6.3 Alarms and Interlock Trip-point
6.3.1 Is the alarm and/or automatic trip-point documented?
6.3.2 Is the trip-point justified and what factors have been taken into consideration?

7. Alarms

Indicate where and how alarm is displayed. If both local and remote indication, identify the place where the operator is expected to see the alarm
7.1 Display
Local
Remote
Control room
Alarm panel
VDU
7.2 Operator response (alarms only)
7.2.1 Is there a documented procedure for responding to safety critical alarms?
7.2.2 What length of time has been allowed for the operator to respond to the alarm and take corrective action?

8. Maintenance Procedure

8.1 Measuring device
8.1.1 Is the measuring device tested/calibrated to a written procedure?
8.1.2 What is the test frequency and how has it been determined?
8.2 Function test (end to end)
8.2.1 Is a full function test including operation of the measuring device, of any alarm or valve, undertaken?
8.2.2 What is the frequency and how has it been determined?
8.2.3 If full function testing has not been undertaken please indicate what is.
8.3 Isolating valve
8.3.1 Is the valve is tested to a written procedure?

8.3.2 What is the frequency and how has it been determined?

9. Modification of Alarms/Interlocks

9.1 Modification system

What is the system for controlling the modification of alarms and interlocks? Identify key features.

Is the system for controlling the modification of alarm trip points different from above? If yes, please identify key features.

10. Control of Overrides

10.1 Can alarms / interlocks be overridden?

10.2 If yes, identify the override mechanism and key features of the system for controlling overrides.