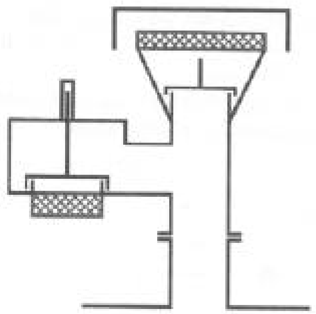

Flame arrester elements shown in blue. Note that other configurations are possible

Diagram 5. PV valve with integral flame arresters

flashback protection. The flame arrester could be located either at the inlet to the valve (between the valve and the tank, Diagram 5) or else on the outlet of the valve.

REFERENCES

1. BS EN 12874: 2001 Flame arresters
2. API 650 Welded Steel Tanks for Oil Storage, 10th Edition
3. EN 14015:2004 Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above
4. API 620 Design and Construction of Large, Welded, Low-Pressure Storage Tanks, 10th Edition
5. HSE Contract Research Report CRR281 "Investigations into concerns about BS EN 12874:2001 flame arresters; HSE 2004
6. Protego Pressure/Vacuum Relief Valve Catalogue for type VD/SV-HR
7. Garstein M, Levine O & Wong EL; Fundamental flame velocities of hydrocarbons; Ind Eng Chem V43, pp2770-2772; 1951
8. Coward HF, Jones GW; Limits of flammability of gases and vapors; USBM Report No.503, 1952

METHODS OF AVOIDING TANK BUND OVERTOPPING USING COMPUTATIONAL FLUID DYNAMICS TOOL

SreeRaj R Nair
Senior Engineer, Aker Kvaerner Consultancy Services
Aker Kvaerner, Ashmore House, Richardson Road, Stockton on Tees, UK, TS18 3RE,
E-mail: Sreeraj.Nair@akerkvaerner.com
Web: www.akerkvaerner.com/AKEHSandRisk

Atmospheric storage tanks are one of the main containment methods used on major hazard sites to store feed, intermediate and finished products. The storage tanks can be of different sizes, shapes and positioned at various levels (below ground and aboveground).

It is good practise to have secondary and tertiary means of containment in order to contain and mitigate an event in case of a primary containment (tank) failure. There are many standards and codes specifying the containment philosophy of tank bunding and structural requirements.

Over the years, there have been many cases where the secondary means of containment was not successful / adequate in retaining the material in the event of tank (primary containment) failure. The recent incident at Buncefield [12] is an example. About tank bunds, the following questions arise:

- Are the existing design standards and codes for designing secondary containment adequate?
- Are there any better means of designing secondary containment to assist liquid retention following tank failure?
- How do we ensure that the existing tank bunds are safe secondary means of containment?

This paper tries to answer the above questions by reviewing the adequacy of an existing bund for a tank farm containing multiple storage tanks. Several tank failure types are evaluated using Computational Fluid Dynamics (CFD) and the impact of the failures on bund integrity are investigated. Consequently, the effectiveness of several consequence reduction techniques to reduce overtopping potential is presented.

KEYWORDS: Tank failure, Bund overtopping, secondary containment design, Computational fluid dynamics

INTRODUCTION

Storage of hazardous materials (flammables and toxics) has the potential of loss of containment hazard associated with it and such hazards could affect people and environment. Secondary containment is often used as a second line of defence to prevent, control or mitigate such hazardous events. A secondary containment system is defined as [1]: 'any item of equipment which may help to prevent the spread of an accidental release of a hazardous substance.'

In the case of storage of hazardous materials, the secondary containment could be in the form of bunds and dykes, double skinned tanks and vessels or concentric pipes.

Bunds are generally used around storage tanks where flammable or toxic liquids are held. Bunds are also used within plant areas as a layer of protection for bulk liquid vessels and reactors.

This paper looks into the following aspects of the bunds as secondary containment of a hazardous material storage area:

- Requirements of the bunds (statutory and design)
- Adequacy of the requirements in efficient secondary containment
- Adequacy of the existing bunds and options for improvement.

BACKGROUND

This paper is based on a study conducted on an existing secondary containment for multi-component fluid (mixture) storage. The fluid is both toxic and flammable and is stored in a fixed roof tank with a storage capacity of 4560 m^3 (4,000 tonne). The tank (hereafter referred as Tank A) is in a common bund with another intermediate product storage tank (Tank B). The general tank and bund arrangement is as given in Figure 1.

The study has been performed using computational fluid dynamics (CFD) tool *fluidyn*-NS in order to:

- Determine the liquid behaviour in the event of loss of containment
- Determine the pressure exerted on the bund walls
- Determine the best option to ensure an efficient secondary containment.

The primary emphasis of the study was to determine the degree of retention of materials within the exiting bund (Secondary containment) under several loss of containment scenarios in order to identify solutions which would reduce the major hazard risk and minimise the contamination of land and/or water course.

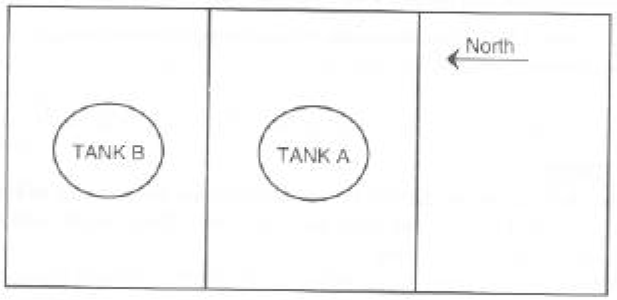

Figure 1. Tank and bund plot plan

EFFECTIVENESS AND ISSUES IN BUNDS AS SECONDARY CONTAINMENT

The secondary containment can be less effective if not adequately designed, constructed and maintained. In some cases inefficient bund design even could worsen the situation, e.g. high bund wall to reduce bund overtopping may provide sufficient confinement for explosion. The common issues identified in bunds as an effective means of containment in the event of failure of the primary containment (tank and allied system) are given below:

DESIGN AND CONSTRUCTION ISSUES

- Bund capacity: Adequacy to contain the volume of stored material in the tank/s
- Dimensions and layout of the bund: The distance between the tank and bund walls, wall design (height and width of the bund walls), the equipment and piping within the bund area
- Material of construction: Best suitable material based on the fluid within the tank (mechanical strength, the vaporisation rate and resistance to thermal shock) and ability to withstand the atmospheric deterioration
- Integrity: Bund wall strength against the static and dynamic loading from the fluid in the event of an incident, Construction / expansion joints and pipe penetrations can fail in the event of leak and fire if it is not adequately designed and constructed
- Bund floor and surface water drainage: If the bund floor is pervious or surface water drainage is inadequate, the material spill could penetrate and reach the soil as well as the water bodies
- Common bunding: Incompatibility of the materials stored, the spacing between and the cascading effects of an incident could be of concern in common bunding.

OPERATION AND MAINTENANCE ISSUES

Improper and inadequate maintenance could result in deterioration of the bund like:

- Growth of plant life within bund affecting the integrity
- Cracks on walls and floors could result in seepage in the event of liquid release
- Accessibility restrictions to the tank and allied facilities for routine activities
- Improper surface water drainage (valve left open or closed).

There are many incidents where the bunds were not efficient in containing the fluid in the event of failure of primary containment. Some of the issues identified are given below:

- The bund joints and manifolds failed and the fluid with firewater reached near by water bodies (Buncefield incident, 11 Dec 2005 [12]).
- Restriction of fire fighting effectiveness due to high bund wall
- Overspill of the fluid due to fire water resulting from insufficient bund capacity
- Overtopping of the bund and destruction of bund wall (LPG storage tank incident, Qatar [2,4], liquid fertilizer tank incident Ohio, 2000 [8]).

Some other issues of concern could be:

- Bund overtopping from a leak on tank shell and the release jet hitting the ground outside the bund.
- Stored liquid can vault an inclined side or pile up rapidly at the face of a bund wall and then flow over the top.
- A strong shock wave forming at the bund wall and then returns towards the storage tank.

WHAT DO THE STANDARDS AND STATUTES SAY ABOUT SECONDARY CONTAINMENT?

There are many standards and codes, research reports and guidance, which lists and guides through the requirements and design specification for various means of secondary containment. The documents that address the secondary containment are:

- SRD R 500, The Design of Bunds, Safety and Reliability Directorate, United Kingdom Atomic Energy Authority.
- Technical measures document for secondary containment, HSE, UK.
- NFPA 30, Flammable and Combustible Liquids Code, US.
- HS(G)176, The Storage of flammable liquids in tanks, UK.
- COMAH Guidance, HSE, UK.
- Contract Research Report, CRR 324/2001, HSE UK.
- CIRIA Report 163, Construction of bunds for oil storage tanks.

In general, for bund capacity and integrity, the following are the main requirements specified in the above documents.

Capacity: Codes differ in their recommendations on bund capacity, which vary between 75% and 110% of the normal capacity of the tank protected. The basis of the recommendation is that bund should have sufficient capacity to contain the largest predictable spillage [4, 6, 10, 11]. Data quoted by Barnes from the General Accounting Office (GAO) report identifies a capacity range from 50% to 139% [2]. Where two or more tanks are installed within the same bund, the recommended capacity of the bund is 110% of the largest tank or 25% of each tank within the bund [9].

Bund wall dimension: There are no general rules regarding the ratio between wall height and floor area. Codes vary greatly with respect to bund wall height recommendations [4]. A low bund wall facilitates fire fighting. In the US NFPA stipulate a minimum of 1.5 m for walls. In the case of flammable and combustible liquids both UK and US NFPA codes of practice restrict the bund wall heights to 5 feet (1.5 m) and 6 feet (1.8 m) respectively [2]. Many codes of practice do not state maximum height for bund walls. For high walled bunds, consideration will need to be given to the possibility of tanks floating as the bund fills, causing catastrophic failure [6]. It is recommended that a freeboard of 250 mm is provided to protect against dynamic effects [9]. It is also advised

that the bund wall should be sloped to prevent liquid accumulation beneath the storage tank.

Mechanical strength: Care must be taken in the design of the bund wall to withstand the dynamic loads upon bund walls when a large liquid release occurs (Dynamic load at the base of the bund wall may be six times the hydrostatic pressure) [2, 7, 11]. The bund walls should also be impervious to liquid and the wall should be capable of withstanding full hydrostatic head [9]. The bund wall should have sufficient strength to contain any spillage or fire fighting water [2]. The secondary containment shall be designed to withstand the hydrostatic head resulting from a leak from the primary tank of the maximum amount of liquid that can be stored in the primary tank [10].

Materials of construction: Should be capable of withstanding the mechanical and thermal shock that occurs on catastrophic failure of the primary containment [6].

Integrity: The bund should be liquid tight (especially if pipes and other equipment penetrate through the wall) [2]. It is recommended to route any pipes over the wall of the bund to avoid the penetration together of the bund wall [9]. The floor of the bund should be concrete or other material impervious to the liquid being stored [2].

ADEQUACY OF THE GUIDANCES AND CONTAINMENT ISSUES OF CONCERN

The standards and codes mentioned in the above section give guidance on the design requirements of the bunds. Some of the requirements are material specific and holds good for that application whereas those may be irrelevant for a different material. It is noted that the topic of storage is dominated by flammables and detailed specifications are available for LPG, LNG, Hydrogen and Ammonia. However, for toxic materials, inherently safer design and high integrity design are normally specified.

With the situation under consideration (as given in the background), it is noticed that sufficient guidance could not be found for the following issues.

- Bund wall strength: Some of the codes address the need for bund to be able to withstand dynamic loading, but no stringent requirements are made. Bunds made without dynamic loading criteria may still hold good for small leaks and spills but may completely fail in case of an instantaneous release.
- Bund capacity: The general requirement is for 110% of the largest tank within the bund area, but the dimensions are not specified. The 110% volume/capacity could be achieved by large bund area with low bund walls or small bund area with high bund walls. Both options have its own merits and demerits depending on the material handled, the topography and the ease of handling.

Health and Safety Executive (HSE) commissioned Liverpool John Moores Univeristy (LJMU) to perform simulations of catastrophic failure of a storage tank and to measure the dynamic pressures on the bund wall and the quantity of liquid that overtops the bund. The results of the experiments have been published in the CRR 333 [8].

ESTIMATING TANK BUND OVERTOPPING

The design of a bund wall can have a significant influence on the stored fluid behaviour in the event of a tank failure. By acknowledging the fact that effectiveness of secondary containment depends upon an adequate design, which considers all possible failure modes of the primary containment, the following containment issues are dealt herewith.

- Dynamic effects from the wave generated by a catastrophic tank failure which could result in bund failure, overflow or both.
- A spigot flow (jetting), this occurs when tank is punctured resulting in liquid jet to hit the ground or beyond the bund.

This paper will address these issues based on bund overtopping and overpressure on bund walls.

Bund overtopping: Two methods have been used to estimate the bund overtopping:

- LJMU correlation given in CRR 333 [8], and
- Computational fluid dynamics modelling (CFD).

LJMU CORRELATION METHOD

The correlation derived from the experimental investigation by LJMU [8] is used in this method to estimate the bund overtopping following catastrophic failure of a storage vessel. The function below is recommended:

$$Q = A \times \exp(-B \times (h/H)) \quad (1)$$

where:

Q (Overtopping Fraction)
A, B = constants
h = height of the bund
H = height of material in tank

The range of validity is $0.66 \leq (r - R)/R \leq 5.32$ where r is the bund radius and R is the tank radius.

Input values

The equivalent bund radius (r) is 41 m and tank radius (R) is 11.5 m. The tank and bund dimension ratio falls within the range of validity of equation 1.

The height of the bund is 1.5 and the height of the material in tank is 13.22 m (12.1 m liquid height + 1.12 m plinth height). The tank and bund dimensions are given in Figure 2.

The constants A and B are 0.6359 and 2.4451 respectively for Middle category tank (R/H – 1) and 150% bund capacity [8].

The total tank volume is 4562 m^3.

Result

By substituting the values and solving equation 1, an overtopping of 48.1% (2194 m^3) is estimated.

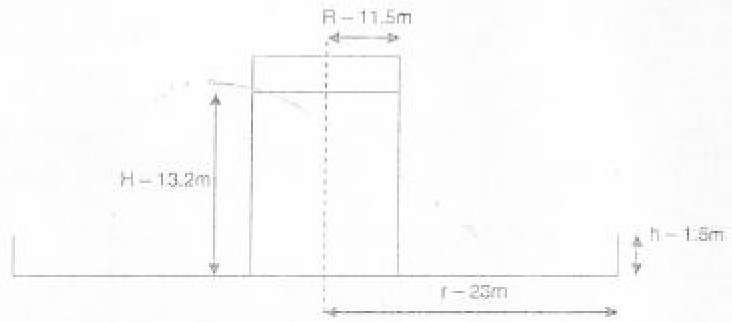

Figure 2. Tank and bund dimension – LJMU

Limitation of the method:

- This method can be used only for overtopping following catastrophic rupture (shell disappearing) failure cases.
- This method does not take into account obstructions like another tank sharing the bund (Figure 1)

COMPUTATIONAL FLUID DYNAMICS METHOD

A representative set of four different scenarios have been considered in order to determine the bund overtopping and pressure exerted on the bund walls:

1. Complete tank rupture,
2. Zip opening of tank bottom,
3. Big hole on tank shell,
4. Small hole on tank shell.

The fluid behaviour following the release in all the four scenarios has been modelled using computational fluid dynamics approach.

Modelling tool

The following modelling tools were used:

CADGEN – geometry and grid generation
Fluidyn-NS – digital model to solve wave effects

CFD tool *fluidyn*-NS is 3D software offered by Fluidyn and Transoft International.

Grid Generation (CADGEN)

The geometrical model has been considered in three dimensions. The software *fluidyn*-CAD has been used to create the geometry of the tanks and bund under consideration.

It was based on the site map as well as the geometrical description of the tanks and the walls/bunds (thickness, height, and distance to the tanks).

The volume within the boundary was divided into discrete cells (the mesh/grid). In this study structured grid has been considered and the grid is finer close to the surfaces (ground, walls) in order to ensure a good description of the pressure loads. For partial ruptures (zip) or the jet (small and large holes), the grid is finer at the opening to improve the precision.

Following assumptions have been made for simulations:

- The flow is isotherm, incompressible and laminar. These choices are considered as the best to represent the cases in this study.
- Turbulence effects are neglected and surface tension is not taken into account. From simulations exercises done previously, it was noted that turbulence and surface tension has no / negligible effect on wave behaviour.
- The pressure values estimated on the monitor points (on bund wall) correspond to the dynamic pressure exerted by the fluid wave motion following release.
- The gravity is set up at 9.81 m/s².

Following assumptions have been made for boundary conditions:

- The walls (ground, base, tank envelope, retention walls) are considered rigid, adiabatic and smooth. Other boundaries are set up as pressure outflows.
- The liquid is considered motionless at the beginning in the tank. At the initial time (t = 0 s), an opening is created on the wall of the tank for the partial rupture scenarios. In the case of the catastrophic failure, the tank shell is deemed to have vanished. A wave is then formed which impacts the walls surrounding the retention.

Model input

Scenario Description:

Case 1 – Catastrophic rupture of the tank: This scenario considers the liquid behaviour in the event of an instantaneous removal of the tank shell and the subsequent collapse of the column of liquid.

Case 2 – Horizontal zip open: This scenario considers a tear at the bottom of the tank shell. The dimensions of the tear were 18 m lateral and 0.2 m wide. The orientation of the opening is as given in Figure 3.

Case 3 – Big hole in the tank shell: This scenario considers failure of one of the tank inlet pipeline, with a horizontal release of the fluid mixture. The hole is 2 m above the ground and its diameter is 0.2 m. The release direction was oriented towards east.

Case 4 – Small hole in the tank shell: This scenario considers failure of one of the tank inlet pipeline, with a horizontal release of the liquid. The hole is 1.5 m above the ground and its diameter is 0.076 m.

Geometry of the retention bund

Tanks A and B has the same dimensions: diameter 23 m, height 12.6 m. The height of the liquid inside the tank for simulations is 12.1 m. The height of the basis (plinth height) is

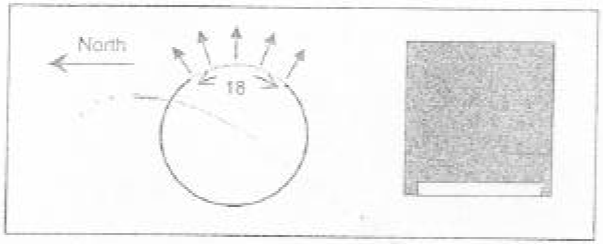

Figure 3. Schematic description of horizontal tear

taken at 1.12 m. The geometry of the bund is detailed in the sketches in Figure 4. The geometry has been simplified by assuming that:

- Every pipe and other equipment are not taken into account.
- The slope of the terrain in the retention bund is not taken into account.

The slope (0.274°) and piping within the bund is not expected to make any significant difference in the fluid behaviour in the current study and hence not taken account of.

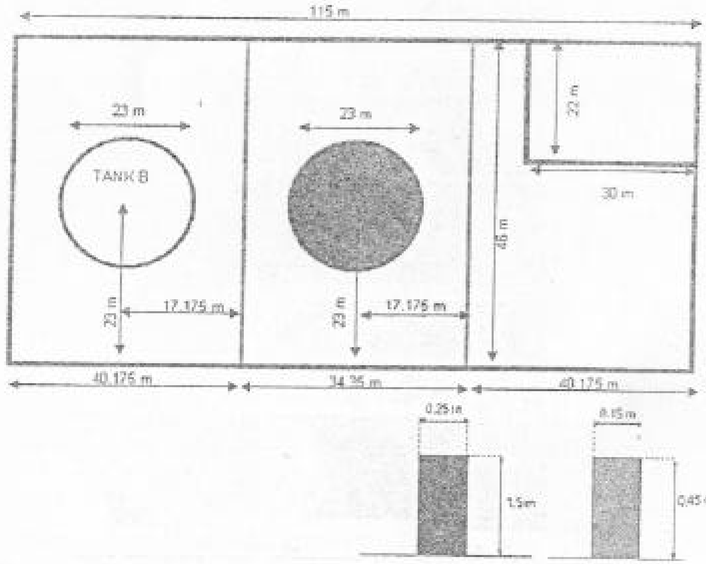

Figure 4. Layout of the retention bund

Table 1. Fluid properties

Product	Viscosity (mm²/s)	Density (kg/m³)	Temperature (°C)
Fluid mixture	0.441623	800	20
Air	1.895 10-5	1.29	20

Fluids
The liquid stored in the Tank A is an intermediate product with mixture of toxic and flammable materials with water. The operating temperature is set at 20°C. In this case, the thermo physical properties of the fluid will be set as given in Table 1.

RESULTS

Case 1: Complete rupture of the tank (Shell vanishing)

The flow of the fluid as a function of time is shown in Figure 5. It shows that the liquid reaches bund walls at 1.36 seconds after the tank failure and begins to overflow after 1.69 seconds.

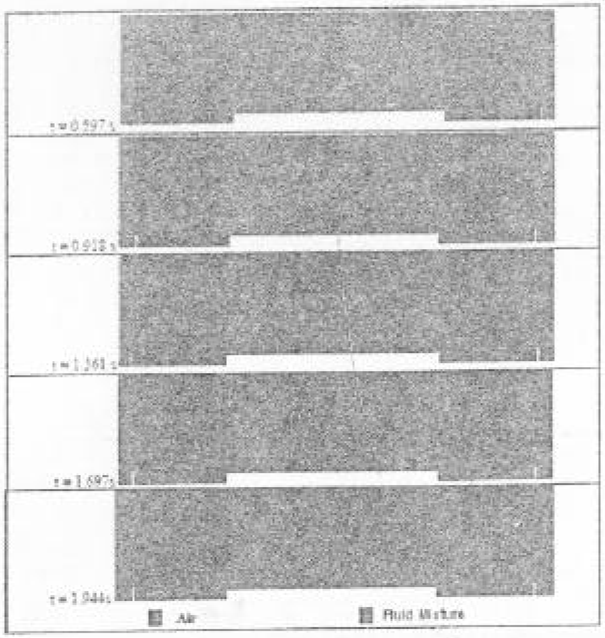

Figure 5. Case 1 – fluid flow from catastrophic rupture of the tank

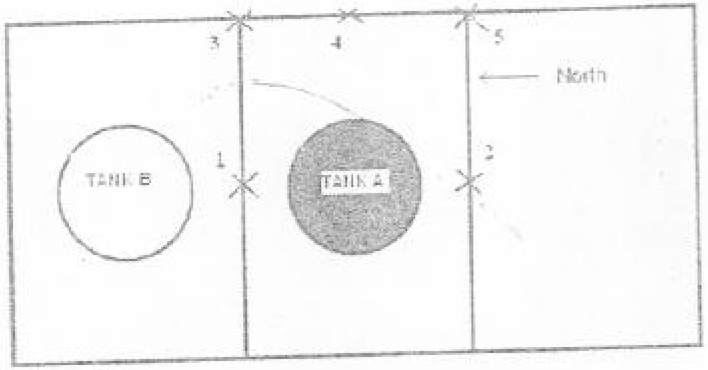

Figure 6. Case 1 – monitor point groups for reading dynamic pressure on bund wall

Overpressure on the walls
The calculations have been run until 31.6 s after the beginning of the tank collapse in order to estimate the maximum overpressure on the bund walls. Overpressure calculations were performed on the five monitor point groups on the bund wall as shown in the Figure 6.

Maximum overpressure estimated was 1.05 bar on the bund wall corners (monitor points 3 and 5) and this occurred after 1.86 s after instantaneous release. The maximum pressure on east wall (monitor point 4) was estimated to be 0.99 barg.

Bund overtopping following complete rupture of the tank

With a storage capacity of 4562 m³, it is estimated that 72.8% of the volume of the fluid of Tank A spilling over the retention wall.

The result estimated using CFD method (72.8%) is 1.5 times higher compared to the result estimated using LJMU method (48.1%). The difference in estimation from two methods could be as the result of following:

- LJMU method is based on experiments using water as the fluid and the methodology need not be accurate for fluids with different physical properties (e.g. for fluid which is viscous than water). CFD is based on the fluid viscosity and hence the wave effect for another fluid could be different even with same release conditions (similar tank and bund).
- LJMU method is limited to a single tank surrounded by a single bund wall. For our present study, there is intermittent kerb walls and another tank in the same bund. CFD takes account of the actual dimensions of bund wall and also any obstructions or restricting structures on the wave path (like kerb walls and near by tank)

Case 2: Release from Bottom Zip Tear on the Tank

The flow of fluid as a function of time is shown in the Figure 7. It shows that the onset of liquid overflow occurs at 1.34 seconds.

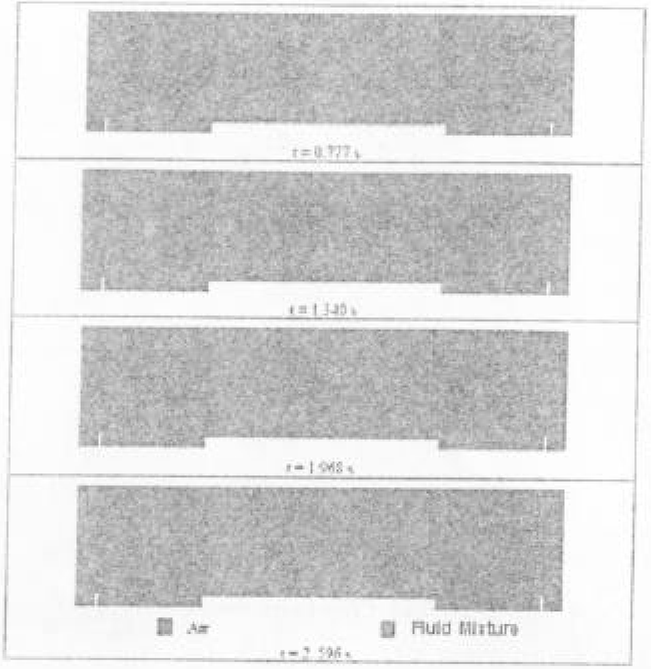

Figure 7. Fluid flow Case 2 – horizontal zip open

Overpressure on the walls
Overpressure calculations were performed at three monitor point groups on the bund wall as shown in the Figure 8. Maximum overpressure estimated was 0.106 bar on the bund wall (monitor group point 2) facing the release direction (in this case East wall). This was obtained after 4.11 s of release.

Bund overtopping following bottom zip tear on the tank
With a storage capacity of 4562 m³, it is estimated that 49.8% of the volume of the fluid of Tank A spilling over the retention wall.

Case 3 and Case 4: Release from Big Hole and Small Hole on the Tank
Overpressures on the walls
For Case 3, the maximum overpressure estimated was 0.0255 bar on the bund wall facing the release direction (in this case bund wall on east side). This was obtained after 1.3 s of release.

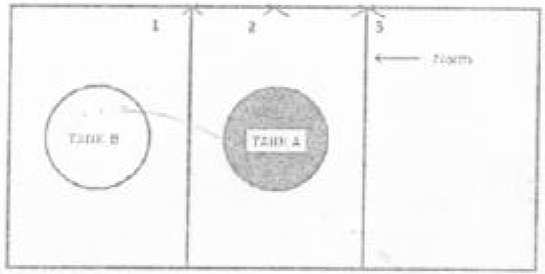

Figure 8. Case 2, 3 and 4 – monitor points for reading dynamic pressure on bund wall

For Case 4, the maximum overpressure estimated was 0.0024 bar on the bund wall facing the release direction (in this case bund wall on east side). This negligible pressure on the bund wall from the release was obtained after 1.63 s of release.

Bund overtopping
There is no overflow for both Case 3 and Case 4, as the liquid release falls and remains within the retention bund. The illustration of fluid flow is following Case 3 is given in Figure 9.

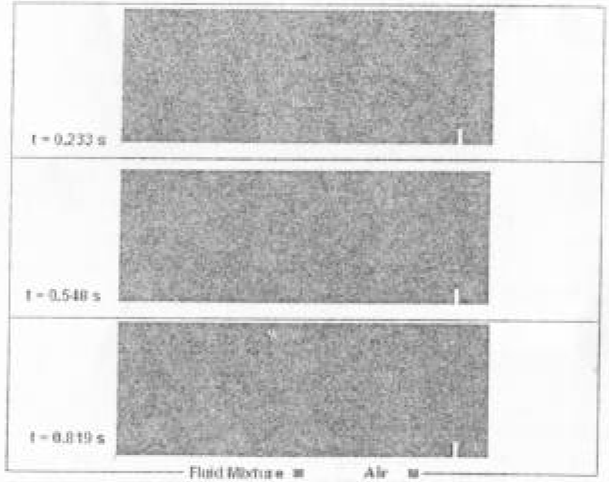

Figure 9. Case 3 – fluid flow from big hole

ADEQUACY OF THE BUND DESIGN:

The following are inferred from the CFD modelling exercise:

Bund Capacity:

- Adequate to contain small release events and inner kerb wall restricts the pool size and there by considerable reduction in evaporation and dispersion.
- Exiting bund capacity inadequate to contain instantaneous and major release events.

Pressure on Bund Walls:

- Maximum overpressure was estimated on the bund corners.
- Need to ensure the structural integrity of the bund wall to withstand the dynamic loading (maximum 1 barg) from wave effects.

DESIGNING EFFECTIVE SECONDARY CONTAINMENT:

In order to address the deficiencies, changes in bund design have been envisaged. The changes in design are to be made considering that, the new containment takes account of no overspill or minimal overspill. From the incident history [1], the key issues identified that could limit the overspill are:

- The height of the bund wall,
- The separation distance (between tank shell and bund wall/other tank), and
- The strength and integrity of the bund wall.

DESIGN OPTION: BUND WALL WITH INCREASED HEIGHT

CFD modelling has been performed for wave behaviour following catastrophic rupture (Case 1) with bund wall height of 3.5 m (1.5 m + increased height of 2 m). The schematic diagram of the fluid flow is shown in Figure 10.

The maximum overpressure from dynamic loading on the bund wall was 1.05 bar (no change in maximum overpressure due to increase in height). However, with the high bund wall, it is estimated that1642 m^3 of the fluid would overtop. Even though the overtopping is reduced from 72.8% to 32.6% (by increasing the bund wall height from 1.5 m to 3.5 m), the overtopping volume is significant. Results from similar studies [8] also indicate a serious problem if bunds are to be relied upon in the event of a catastrophic tank rupture.

From CFD simulations, it was revealed that the wave rises as high as the tank B shell height (~13 m). This implies that even by raising the bund wall as high as tank shell (in this case) will not be sufficient for 100% containment. Also increasing the bund wall height has other concerns as it could restrict the fire fighting effectiveness and access, it could result in providing sufficient confinement for explosion. Hence, it is concluded that, increasing the bund wall height alone could not solve the overtopping issue.

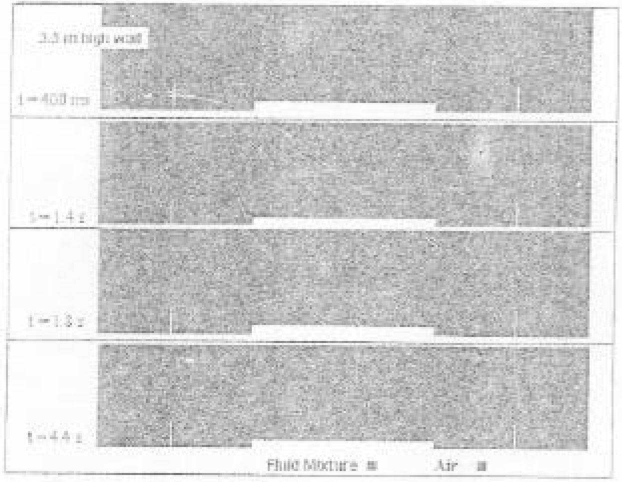

Figure 10. Fluid flow – bund wall with increased height

DESIGN OPTION: BUND WALL WITH DEFLECTOR ATTACHMENT

Bottom zip tear scenario (Case 2) is considered to be a credible scenario compared to catastrophic rupture (shell vanishing) and for this exercise release from bottom zip tear is considered.

CFD modelling has been performed for wave behaviour following bottom zip tear (Case 2) with bund wall height of 2 m (1.5 m + deflector at 45° angle). The schematic diagram of the deflector arrangement is shown in Figure 11.

The maximum overpressure from dynamic loading on the bund wall was 0.06 bar (0.106 bar without deflector attachment). With the deflector, the wave is deflected and fluid remains within the bund area. The overtopping estimated is negligible (11.4 m^3 or 0.25%) and hence, this is considered as a suitable design option for avoiding or minimising bund overtopping.

Some other design options, which could be considered to address the deficiencies in bund design, are:

- Wave action blocker (mesh/gate) in between tank shell and bund wall
- Additional bund outside the current bund on the tank farm perimeter
- Surge drop channel between tank shell and bund wall

WAVE ACTION BLOCKER IN BETWEEN TANK SHELL AND BUND WALL

In this option, a mesh/grill member or intermittent stopper walls to be installed in between the tank shell and the bund wall in order to block or interfere the wave action,

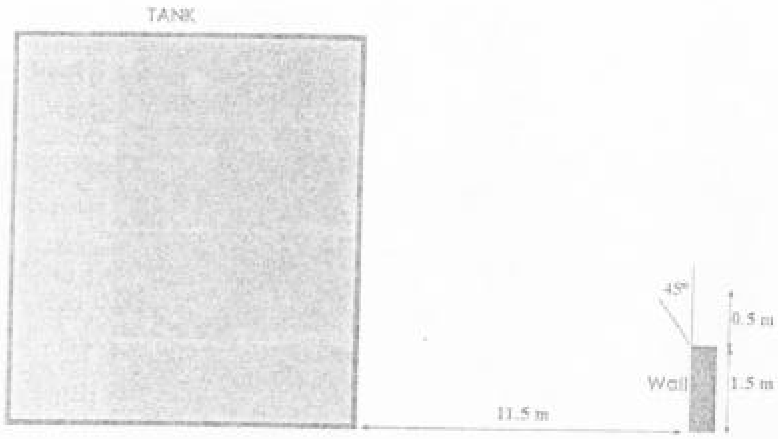

Figure 11. Design option – bund wall with deflector

The additional blocker installed will reduce the wave effects and thus limit the overspill. The disadvantages of this option could be the difficulty in maintaining the system and restriction in access.

ADDITIONAL BUND OUTSIDE THE CURRENT BUND ON THE TANK FARM PERIMETER

In this option, an additional bund to be constructed surrounding the existing bund to limit the spread of fluid spill. The size and position of the additional bund shall be defined based on the hazard management plan and the site emergency preparedness. The disadvantages of this option could be that more area is required for containment and increased rate of evaporation from liquid pool.

SURGE DROP CHANNEL BETWEEN TANK SHELL AND BUND WALL

In this option, a channel to be built in between tank and bund wall in order to reduce the surge resulting from the instantaneous release or bulky continuous release of fluid. This wave motion could be restricted by big single channel or a sequence of channels based on the fluid properties and release type of consideration.

CONCLUSION

This paper looked into the adequacy of ensuring bunds as an effective secondary containment and is based on a study performed on containing releases from a tank in a common

bund. Computational fluid dynamics (CFD) modelling tool was used to simulate wave effects of the fluid motion and to estimate the two identified issues of concern; overspill and overpressure on bund walls. Liverpool John Moores University (LJMU) correlation [8] was also used to estimate the overspill volume and compared with CFD method.

A literature search on various standards, codes and statutory design requirements have been performed and generalised. It was noted that no stringent specifications are available to address tank bund design and maintenance against overflow and overpressure.

The study using two methods estimated the bund overflow as 48% (LJMU correlation) and 73% (CFD modelling) following a catastrophic failure of the tank. Using CFD, bund overflow estimations have been performed for releases from horizontal zip open (50% overtopping), big and small hole (no overtopping). The maximum pressure (1.05 barg) estimated on the bund wall was on the corners following the catastrophic failure of the tank.

The study further looked into various design options to avoid or minimise overtopping using CFD tool. Option to increase the bund wall height will reduce the overtopping, but not a preferred option for 100% containment. Option with deflector attachment on existing bund wall results in negligible overtopping and considered as a solution to avoid bund overtopping in the discussed case. For an efficient secondary containment in tank farms, any single option or combination of options discussed in this paper shall be used based on the requirements, material handled and site limitation.

REFERENCES

1. Clark, S.O., and Deaves, D.M., 2001, Effects of secondary containment on source term modelling, HSE: Contract Research Report – 324/2001
2. Barnes, D.S., 1990, The design of bunds, HSE: SRD/HSE R 500
3. HSE, 1998, HS(G) 176 – The storage of flammable liquids in tanks'
4. Less, F.P., 1996, Loss Prevention in the process industries – Hazard identification, assessment and control, Butterworth Heinemann: Second edition
5. Hunt, D., 2005, Computational Fluid Dynamics – Tessella Support Services plc: Issue V1.R1.M4
6. HSE, Technical measures document referring to secondary containment, http://www.hse.gov.uk/comah/sragtech/techmeascontain.htm
7. Wilkinson A, 1991, Bund overtopping – The consequences following catastrophic failure of large volume liquid storage vessels, HSE: SRD/HSE R 530
8. Liverpool John Moores University, 2005, An experimental investigation of bund wall overtopping and dynamic pressures on the bund wall following catastrophic failure of a storage vessel, HSE: Research Report 333
9. Mason, P.A., Amines, H.J., Sangarapillai, G., Rose, G., 1997, Construction of bunds for oil storage tanks, CIRIA: Report 163
10. NFPA, 2008, Flammable and Combustible Liquids Code, NFPA 30
11. HSE, 1995, Control of fire-water run-off from CIMAH sites to prevent environmental damage, EH 70, HSE Books
12. Buncefield Investigation Homepage, http://www.buncefieldinvestigation.gov.uk/