NEW HOT BITUMEN STORAGE TANK CONSTRUCTION GUIDELINES

The information and recommendations in these guidelines are given in good faith and belief in their accuracy at the time of publication, but does not imply any legal liability or responsibility by the Refined Bitumen Association.

The Health and Safety at Work Act 1974 and the Management of Health and Safety Regulations 1999 require employers to provide safe systems of work to ensure the safety of their employees and the public. Health and Safety Law imposes duties on both the supplier and the customer to provide safe systems of work. These guidelines are intended to help both parties comply with their respective responsibilities during the transfer, handling, and storing of hot bitumen at hot mix asphalt manufacturing plants, and are not intended to vary the legal responsibility of either party.

PURPOSE

These guidelines provide hot mix asphalt manufacturing plant Owners/Operators information to aid in designing, fabricating and erecting new hot bitumen storage tanks at their facilities.

SCOPE

These guidelines are applicable for above-ground atmospheric-pressure hot bitumen bitumen storage tanks that have a maximum design temperature of 260°C (500°F) .

The stored product is heated petroleum-derived bitumen products with Open Cup Flash Points above 163°C (325°F), such as penetration grades, oxidised grades and polymer modified bitumen. These guidelines are not applicable for other bitumen products with lower Open Cup Flash Points, such as emulsions and cut-back bitumens.

Transferring, handling, and storing hot bitumen expose plant operators and hauliers to inherent hazards:

- Thermal burns.
- Froth-overs and boil-overs due to contamination by water or lower boiling point hydrocarbons.
- Formation and release of hydrogen sulphide.
- Formation and release of hydrocarbon fumes.
- Formation of flammable vapours.
- Creation of ignition sources - pyrophoric deposits, hot surfaces, sparks and open flames.
- Falls from elevated work surfaces.

Due to these inherent hazards and the complexities involved with designing and constructing hot bitumen storage tanks, Owners/Operators should consult and hire suitably qualified engineering firms when initiating a new tank project. A qualified engineering firm will be knowledgeable in the design/construction process of hot bitumen storage tanks, including all applicable specifications, codes, and regulatory requirements. A qualified engineering firm will develop a tank design that meets these requirements and mitigates the risks of these inherent hazards.

These guidelines are general in nature, and intended to aid Owners/Operators in discussions with design engineers, geotechnical engineers, site contractors, fabricators and equipment suppliers contracted to design and construct hot bitumen storage tanks.

REFERENCES

API Recommended Practice 2023, "Guide for Safe Storage and Handling of Heated Petroleum-Derived Asphalt Products and Crude-Oil Residua", August 2001.

API Standard 650, "Welded Tanks for Oil Storage", June 2007.

API Standard 2000, "Venting Atmospheric and Low-Pressure Storage Tanks", April 1998.

Asphalt Institute Manual Series No. 4 (MS-4), The Asphalt Handbook, 7th edition, 2007.

Asphalt Institute Manual Series No. 22 (MS-22), Principles of Construction of Hot-Mix Asphalt Pavements, 2nd edition.

”Guide to Safe Delivery of Bitumen – UK Edition, Refined Bitumen Association.

"Guidance for Safe Bitumen Tank Management", Refined Bitumen Association / Mineral Products Association.

"RBA Position Paper on the use of Ground-Based Pumps for Bitumen Discharge at Customer Sites", Refined Bitumen Association.

Model code of safe practice, Part 11, Bitumen Safety Code (4th edition), Energy Institute.

Dangerous Substances and Explosive Atmospheres Regulations 2002.

BS EN 61511:2004 Functional Safety – Safety Instrumented Systems for the process industry sector (Part 1 to 3).

DEFINITIONS

Bitumen Discharge Area: Area within the plant specifically designed to safely offload and receive vehicle deliveries of hot bitumen. The bitumen is pumped from the bitumen discharge area to the hot bitumen storage tank.

Boil-over: Fiery tank overflow caused by hot residue from a surface fire in a bitumen tank becoming denser and sinking in the tank to form a hot layer that causes a violent eruption of burning bitumen when the sinking hot layer comes in contact with a water or lower boiling point hydrocarbon layer.

Froth-over: Tank overflow caused by hot bitumen being placed over a layer of water or lower boiling point hydrocarbons, causing the water/hydrocarbons to boil and vaporise, pass through the upper layer of bitumen and overflow the tank with hot bitumen.

Hot Bitumen: Heated petroleum-based bitumen products with Open Cup Flash Points above 163°C (325°F), and typically stored in the range of 130° - 168°C (265° - 335°F).

Open Cup Flash Point: Minimum Cleveland Open Cup Flash temperature as determined by AASHTO T48 and ASTM D 92.

Pyrophoric Deposits: Pyrophoric carbonaceous deposits are formed on the roof and walls of bitumen storage tanks due to the condensation of bitumen vapors, which can become a potential ignition source at temperatures between 177°- 190°C (350° - 375°F) due to oxidation when exposed to an influx of air. Pyrophoric iron sulphide deposits are formed due to hydrogen sulphide reacting with the iron in the tank's roof and walls in the presence of moisture, which can also become a potential ignition source due to oxidation when exposed to air.

Roof-to-Shell Frangible Joint: Roof-to-shell joint designed to selectively fail due to abnormal internal tank pressure before other joints or connections fail catastrophically.

Ullage: Empty interior tank volume available for deliveries of bitumen.

GENERAL GUIDELINES

A. Site layout considerations

1. Traffic patterns for bitumen delivery vehicles, other vehicles, and personnel on foot within the plant, to include optimising one-way traffic flows and minimising reversing of vehicles.

2. Proximity of bitumen storage tank and bitumen discharge area to other plant operations and traffic patterns of other vehicles The location of the discharge point must avoid surrounding or adjacent operations which could impair safe delivery.

3. Sufficient work space around the tank and equipment:

    a) Sufficient area to meet future maintenance and testing requirements, such as removing the heating device from the tank for inspection, maintenance, and replacement.
    b) Reduce the potential risk for trips and falls.

4. In addition to meeting spacing requirements, it may be advantageous to minimise pipe runs between the proposed tank, bitumen discharge area, and plant mixer, due to construction costs, future maintenance and energy costs related to pipe heat tracing and insulation needs.

5. Vent / overflow pipework location – consider the potential exposure of personnel and vehicles should hot bitumen, bitumen fumes, or hydrogen sulphide be released to the atmosphere.

6. Lines of sight between plant personnel (plant control room) and haulier; haulier and tank (vent); and plant personnel (plant control room) and tank.

7. Tank and equipment spill containment.

8. Elevation differential between bitumen discharge area and tank - if the head pressure differential and line friction losses are too great for the delivery vehicle's pump, a ground-based pump may be needed. An added benefit to the installation of a ground-based pump may be the elimination of bitumen deliveries via compressed air discharge systems and their associated hazards. (See "RBA Position Paper on the use of Ground-Based Pumps for Bitumen Discharge at Customer Sites", Refined Bitumen Association, Ltd for additional guidance on ground-based pumps.)

9. Terrain contour of site:

   a) Level working surfaces in key site locations, such as bitumen discharge area, areas around the bitumen tank, pump areas and any work area with an increased likelihood of trips and falls occurring.

   b) Drainage patterns around key site locations, such as bitumen discharge area; areas around tank, sampling port location, pump area and other areas to minimise:

      1) Potential water contact with hot bitumen.
      2) Corrosion.
      3) Moisture buildup in tank insulation.
      4) Potential slips and falls.

   c) Potential access to public sewers, waterways, or adjoining properties may dictate the need for emergency drainage systems with traps or separators.

10. Emergency equipment and plans, such as locating emergency shower(s) and eye wash stand(s), emergency shut-off switch(es), fire extinguishers, tank vent, and alarm display(s) and horn(s); identifying evacuation route(s); and ensuring required accessibility for fire fighting.

11. Lighting for key work areas.

B. Tank size design considerations (See "*Guidance for Safe Bitumen Tank Management*" or the “*Guide to Safe Delivery of Bitumen*”, Refined Bitumen Association, Ltd for additional information regarding tank dimensions and defined capacities.)

   1. Safe Working Tank Capacity (m^3) - Owner/Operator to determine how much volume is needed in the tank to store bitumen that will be available for draw off for use in plant manufacturing requirements. The intent is to prevent unplanned run outs, and its capacity is usually determined based upon:

      a) Bitumen hauling capacity of local delivery vehicles and the projected bitumen availability from suppliers, to include potential delays during periods of peak supply demand (rate in).

      b) Peak production rate requirements at Owner/Operator's plant (rate out).

      c) The maximum potential temperature differential, between the minimum temperature of the delivered bitumen and the maximum bitumen storage temperature, should be considered. (See Volumetric to Mass Conversion Factor below in GENERAL GUIDELINES, paragraph B.6.)

2. Available Tank Capacity (m^3) - Design Engineer to calculate by applying a safety factor to the Owner/Operator's desired Safe Working Tank Capacity (safety factor should be endorsed by Owner/Operator). This safety factor is established to allow sufficient time to safely shut down tank filling operations to avoid overfilling the tank, and is based on maximum potential tank filling rates. The Available Tank Capacity comprises the internal volume from the draw off nozzle to the tank vent / overfill pipework.

3. Unavailable Tank Capacity (m^3) - Determined by the Design Engineer and consisting of both the
   a) Internal volume from the floor of the tank to the normal draw-off nozzle (undrawable or heel capacity). This is where the tank's internal heating device is located and normally this capacity of stored bitumen is unavailable for use.
   b) Internal volume above the Available Tank Capacity from the tank vent / overfill pipework to the roof of the tank.

4. Nominal Tank Capacity (m^3) - Total internal volume of the tank from the floor to its roof. This capacity is greater than and should not be confused with the Safe Working Tank Capacity when discussing the tank's available capacity.

5. The Design Engineer may propose changes to the tank design capacities to optimize or economize the tank fabrication process.

6. Volumetric (m^3) To Mass (tonnes) Conversion Factor - Owner/Operator to provide the Design Engineer a conservative conversion factor (based on anticipated lowest bitumen density), or the maximum bitumen storage temperature for each bitumen grade that may be stored in the tank (generally lighter grades are less dense/viscous and stored at lower temperatures). A given mass of bitumen will occupy its largest volume when at its highest storage temperature. This conversion factor will allow the Owner/Operator and Design Engineer to convert Safe Working Tank Capacity into tonnes similar to the delivery vehicles, and later aid the plant operators and hauliers determine whether the tank can safely receive a delivery of bitumen of known weight (tonnes) without overfilling the tank.

C. Tank load design considerations unique to Owner/Operator's locality and local code requirements:

1. Seismic loads.
2. Snow loads.
3. Wind loads:
   a) Both magnitude and prevailing direction.
   b) Uplift pressure on the roof.
4. Flood loads

D. Additional tank design considerations for hot bitumen service conditions

1. Hydrogen Sulphide conditions that may promote hydrogen-induced cracking and hydrogen sulphide fume generation.
2. Maximum tank design temperature.
3. Maximum bitumen operating temperature.
4. Bitumen vapor pressure at maximum operating temperature.
5. Maximum tank fill rate (rate in).
6. Maximum tank emptying rate (rate out).
7. Cross contamination from low boiling point contaminants (such as water, emulsions and cut-backs) inadvertently leaking or reversing flow in a common header, creating potentially hazardous situations.

E. Foundation design considerations for elevated temperature service

1. Consult Geotechnical Engineer to collect information on soil bearing capacity and settlement data.
2. Stresses may be created in the tank to foundation attachments due to thermal expansion and contraction of the tank over time.
3. Elevated tank temperatures may evaporate moisture in the supporting soil over time, especially if there is a high water table or a high moisture content in the soil and cause either uneven settling or excessive settling of the tank.
4. Anchoring considerations - A tank operating at elevated temperatures may tend to move over time and create stresses on the tank fittings and attachments.

F. Tank safety equipment considerations

1. The interior of a hot bitumen storage tank is a harsh environment for tank safety equipment. Due to bitumen's tendencies to vaporise and coke when heated at high temperatures for long periods of time and to increase its viscosity to the point of hardening to a solid when cooled, there is a risk that bitumen could foul tank safety equipment and cause malfunctions. Tank safety equipment should be designed with this in mind and incorporate adequate design safety factors, redundancy, robustness and accessibility for inspections and preventative maintenance.

2. Tank vent design basis
    a) Tank breathing due to variations in atmospheric temperatures and barometric pressures.

    b) Maximum tank filling rates coincident with potential temperature increases and bitumen vaporisation due to tank heating and tank breathing. Tank vent capacity should also consider the air blowing rate if line air blowing is used.

c) Maximum tank emptying rates coincident with potential temperature decreases due to shut off of the tank heat and tank breathing.

d) Design safety factor based on the potential risks related to unplanned scenarios.

   1) Fire exposure.
   2) Partial vent plugging.
   3) Froth-over or boil-over.
   4) Internal tank heating devices overheating.
   5) Inadequate coverage of tank heating devices causing excessive localised heating and bitumen vaporisation.
   6) Bitumen overflow due to tank contents level alarms malfunctioning, control valve malfunctioning or electrical failure.

e) Open atmospheric vents may help to reduce plugging risks versus other designs, such as pressure-vacuum vents or flame-arresting devices which tend to stick or plug more readily in-service.

f) Heat tracing and minimizing vent / overflow pipework lengths may help reduce plugging risks.

g) Gauge hatch or manhole cover that lifts under abnormal internal tank pressure, or roof-to-shell frangible joint for emergency venting, such as during vent plugging or froth-over situations.

h) Vent / overflow pipework accessibility for inspection and cleaning to prevent plugging.

3. Bitumen temperature measuring system

   a) Multiple measuring devices collect bitumen temperature information inside the tank:

      1) Position two devices at the same level as the draw off nozzle to compare accuracy and provide redundancy.
      2) Position additional device(s) at level(s) higher in the tank to evaluate mixing efficiency.

   b) Position measuring devices far enough from the tank's internal heating device to ensure a representative bitumen temperature.

c) Extend measuring devices sufficiently into the tank interior to obtain a representative temperature unaffected by lower temperatures near the tank shell.

d) Readout displays can be installed in multiple locations, such as the plant control room and tank area.

e) Recording devices may be incorporated into the temperature measuring system to review and analyze past temperature performances, such as confirming that specified temperature limits are not exceeded.

f) Clear labeling of individual readout displays may help to promote system understanding, especially when multiple measuring devices and tanks are present.

4. Tank contents measuring systems

a) Various technologies are available, such as radar, ultrasonic, microwave and other gauging devices.

b) Readout displays of both tank bitumen volume and safe ullage are available.

c) Readout displays visible to the haulier from the bitumen discharge area.

d) Readout displays can be installed in multiple locations, such as the plant control room, bitumen discharge area and tank area.

e) High and low level alarms may be integrated into a tank contents measuring system to warn of potentially unsafe overfilling or draw-down conditions.

f) Clear labeling of individual readout displays may help to promote system understanding and avoid potentially unsafe overfilling or draw-down conditions. Clear labeling may also help avoid confusion when multiple tanks are present.

5. Tank contents level alarms

a) A high level alarm (HLA) and an independent high high level alarm (HHLA) must be installed on each storage tank. Separate and/or additional alarms (such as a HHLA), operating independently of the tank contents measuring system, increase redundancy and reduce the risk of overfilling due to a malfunction.

The activation of the HHLA must be independent of the tank contents gauging system and set to trigger at the available capacity of the tank less 7½%.

b) High Level Alarm (HLA) - Generally first alarm during tank filling operations that signals the tank is approaching or has reached its Safe Working Tank Capacity (generally amber light and audible signals).

   To avoid product spillage whilst the delivery hose/line is being cleared, the HLA should be set to trigger at the available capacity of the tank less 10%.

d) Low Level Alarm (LLA) - Alarm that signals the tank is approaching its lower Unavailable Tank Capacity (generally red light and audible signals). Excessive localised heating could occur if the tank's internal heating device is not sufficiently covered by bitumen. This could result in excessive oxidation, hydrocarbon and hydrogen sulphide fume generation, or pyrophoric deposits forming.

e) Owner/Operator should consult with the Design Engineer to determine alarm heights in the tank. Their heights should be designed to meet all applicable specifications, codes, and regulatory requirements, and allow sufficient time to respond to the alarm before an undesired event occurs (e.g. upon activation of HLA, haulier closes receipt valve and shuts off pump before tank overfill occurs).

f) Alarms can be integrated with pump systems to automatically close valves and shut off pumps if an alarm is activated. A Functional Safety Assessment (FSA) must be carried out to ensure that for each new plant and plant modification, arrangements are in place to evaluate the performance and validation of the Safety Integrated System to ensure that the identified safety requirements, functionality, integrity and BS EN 61511 requirements are met.

g) Visual light displays should be visible to and audible alarms capable of being heard by, the haulier from the bitumen discharge area.

h) Visual light displays and audible alarms can be installed in multiple locations, such as the plant control room, bitumen discharge area, and tank area.

i) Clear labeling of individual light displays may help to promote system understanding and avoid confusion when multiple alarms and tanks are present.

G. Tank and related pipework heating system considerations

1. Heating system type (such as hot oil, fired heaters, electric, and steam) may depend on available utilities and facilities, economic, and safety considerations; tank heating systems may be implemented via devices internal or external to the tank.

2. Unsafe situations, such as a potential ignition source due to inadvertent temperatures above specified temperature limits (including insufficient bitumen coverage of internal heating devices), may be reduced by incorporating automatic shutoff systems.

3. Bitumen's product classification for petroleum products is "Unclassified" as it has a flash point in excess of 200°C. However the Energy Institute, Model code of safe practice, Part 11, Bitumen Safety Code states:-

   "Due to the slow and variable after reactions which can occur during storage in heated tankage (giving rise to the evolution of very light flammable vapours), the flash point is not a reliable indicator of the temperature at which the product in a confined space is likely to produce a flammable atmosphere."

   Therefore, under certain confined heating storage conditions, flammable atmospheres can occur and a subsequent DSEAR Risk Assessment is required.

   As part of that assessment an Area classification must be undertaken, which is a method of analysing and classifying the environment where explosive gas atmospheres may occur. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, taking into account the properties of the flammable materials that will be present. DSEAR specifically extends the original scope of this analysis to take into account non-electrical sources of ignition, and mobile equipment that creates an ignition risk.

4. If bitumen is periodically allowed to cool inside the tank, incorporating a vertical hairpin loop as part of an internal heating coil may help allow adequate expansion of remelted bitumen trapped beneath a solid layer of product in the tank.

H. Tank and pipework insulation considerations

1. Non-absorbent types of insulation, such as foam glass, may help reduce the risk of the insulation absorbing bitumen and hot oil spills and leaks and igniting a fire.

2. Leaving a narrow band around the bottom of the tank uninsulated will allow for visual inspection of the tank's shell-to-floor joint, and may also help prevent corrosion by allowing any moisture accumulation behind the insulation to drain.

I. Tank mixing system considerations

1. Tank mixing may help to establish a uniform temperature, reduce stratification and maintain additive suspension (such as polymers) inside the tank.

2. Potential tank mixing systems include propeller mixers/agitators inside the tank, and recirculation systems that include pumps outside the tank.

3. A heat exchange system outside the tank can be incorporated into a tank recirculation system.

4. Internal mixing devices may be incorporated into a tank measuring system to insure the mixing device automatically shuts before the bitumen level in the tank decreases enough to expose the mixing device.

J. Tank attachments and accessories - size, projection, placement, elevation, orientation, and location considerations

1. Bitumen inlet and draw off nozzles, flanges and pipework.
2. Vent / overflow pipework.
3. Temperature sensors (thermowells) for temperature measuring system.
4. Heating system including flanges and pipework.
5. Mixing system including flanges and pipework.
6. Drain valve to safely empty heel capacity for tank cleaning and maintenance.
7. Bitumen sampling valve on tank or dedicated piping.
8. Ladders, stairs and platforms, including handrails.
9. Roof gauging hatches and manways.
10. Anchor bolts and straps.

K. Bitumen Discharge Area considerations

1. Height differential between bitumen discharge area and tank. (See GENERAL GUIDELINES, paragraph A.6. on page 4.)

2. Receiving pipeline flange should match standard delivery flanges on local bitumen delivery vehicles. Flanges must be located between 500mm (as measured from the bottom of the flange face) and 1000mm above ground level (as measured to the top of the flange face). Access to the customer’s delivery flange must be such as to allow for safe and easy connection of the delivery hose.

3. Flange security system, such as a unique and separate locking device for each receiving pipeline, to maintain control of receipts and prevent tank contamination and overfilling.

4. Segregation from emulsion and cut-back receiving pipelines, to include separate discharge areas, clear labeling and distinct and different flanges to prevent an inadvertent connection.

5. System to collect and dispose of bitumen drained from the haulier's hose at the completion of a delivery.

L. After the design is completed and before construction is started, a Hazardous Operations Review (HAZOP) or Cold Eyes Review of the entire project must be completed to help to identify and address any operational and/or safety gaps in the project.

   1. A team of knowledgeable people who are not involved with the project (cold eyes) representing plant operations, design consultant, general contractor, and any other group with a large role in the project.

   2. The team should identify and evaluate the effect of every possible "what if" scenario.

M. Maintain "as built" detailed site and fabrication drawings after project completion

   1. Interior tank data.
   2. All specifications and dimensions.
   3. Testing result reports.
   4. Handling and rigging requirements for shop-built tanks.

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