Guidance for Safe Bitumen Tank Management

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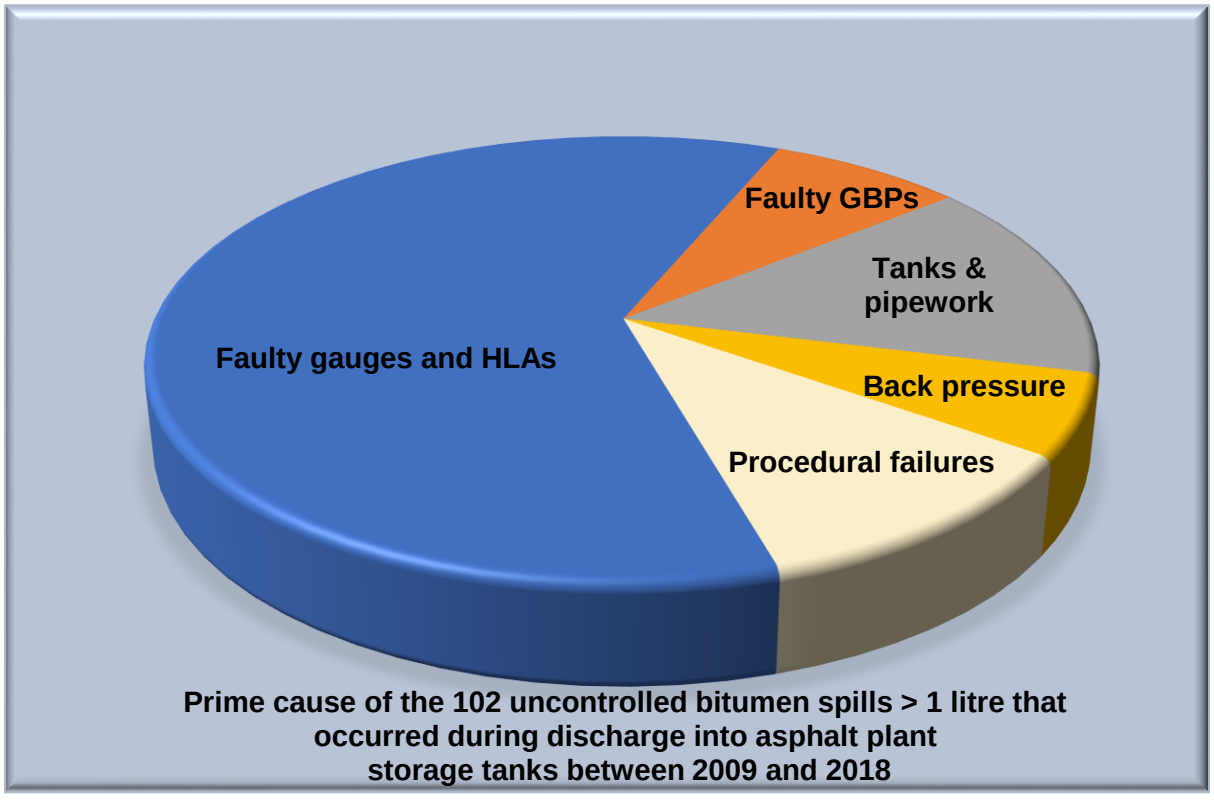
1. Introduction

There are about 275 asphalt plants in the UK manufacturing approximately 20 million tonnes of asphalt per annum. This equates to about 1000 hot bitumen storage tanks with an annual throughput of approximately 1 million tonnes of bitumen. Uncontrolled spills of hot bitumen from these storage tanks during the delivery of bitumen presents a significant safety hazard.

In the 10 years from 2009 - 2018 Eurobitume UK recorded 102 uncontrolled spills of hot bitumen during discharging of hot bitumen into the customer's storage tank, due to failure of the storage tank, associated equipment or procedural failures. The figure below shows that over 60% of these were due to faulty content gauges and/or high-level alarms.



Prime cause of the 102 uncontrolled bitumen spills > 1 litre that occurred during discharge into asphalt plant storage tanks between 2009 and 2018

The number of uncontrolled bitumen spills has fallen significantly since 2009. Two contributory factors to this reduction were the introduction in 2011 of the Guide to the Safe Delivery of Bitumen and in 2012 the implementation of the Bitumen Discharge Permit (BDP).

The 2011 Guide to the Safe Delivery of Bitumen (updated in 2018) provided comprehensive advice and guidance on:

- Storage tank gauges and alarms (including the introduction of high, high level alarms).
- Storage tank design, pipework and flanges.
- Delivery procedures for the delivery driver and customer.

The BDP was developed jointly by the MPA and Eurobitume UK and implemented in 2012 (see Appendix 1). The BDP must be completed prior to the delivery by the delivery driver and site staff to ensure that:

- The tank gauges and alarms are working correctly.
- The correct product is going into the correct tank.
- There is sufficient ullage.
- The emergency equipment is operating correctly.

2. The origin of uncontrolled bitumen spills

Uncontrolled spills of hot bitumen due to overfilling are the result of a number of factors:

- Failure of storage tank instrumentation.
- Inadequate planned preventative maintenance on storage tank and associated equipment including defective or corroded pipework.
- Storage tank safe working capacity and the determination of ullage.
- Blocked and partially blocked pipework.
- Issues with ground-based pumps.
- Procedural and communication failures.

2.1 Failure of storage tank instrumentation

In the last 10 years failure of the high-level alarm (HLA), high high-level alarm (HHLA) and/or contents gauges have been the prime cause of well over half of the 102 uncontrolled spillages of hot bitumen.

2.1.1 Storage tank contents gauges

The accuracy and reliability of contents gauges is key to avoiding uncontrolled spills of bitumen. Therefore, it is critically important that they regularly checked, maintained in accordance with the manufacturer's recommendations and calibrated at least annually. The contents gauges must clearly identify which storage tank they refer to and be visible to the delivery driver at the discharge point. Wherever possible a duplicate system should be provided in the plant control room.

To cross check the storage tank gauging system it is strongly recommended that a physical inventory stock reconciliation system is used. The calculated bitumen consumption can then be compared with the bitumen consumption determined from the contents gauge and any discrepancy investigated to identify the cause of the variance.

2.1.2 Storage tank alarms

A HLA and an independent HHLA must be installed on each storage tank. The HLA and HHLA should be set to activate at the available capacity of the storage tank less 10% and 7.5% respectively. A Hazard Operability (HAZOP) assessment may indicate different alarm settings depending on the storage tank size, storage tank configuration, GBP delivery rate, etc. For example, a recent study carried out by Eurobitume UK indicated that there were a disproportionately high number of spillages from horizontal compared to vertical storage tanks. Thus, these values should be checked to see if they are appropriate particularly for small horizontal storage tanks.

Alarms must clearly identify which storage tank they refer to and when activated they must be audible and/or visible to the delivery driver and site staff. Again, it is critically important that both HLA and HHLAs are regularly checked, maintained in accordance with the manufacturers recommendations and calibrated at least annually. The activation of a HLA during a bitumen delivery should be considered to be a significant procedural failure as an activation indicates that the safe working capacity (SWC) is being exceeded.

2.2 Inadequate planned preventative maintenance on storage tanks and associated equipment

Planned preventative maintenance is key to eliminating uncontrolled bitumen spills from storage tanks, pipework and associated equipment. The following planned preventative maintenance is recommended:

a. Periodic integrity check on the storage tank and all the pipework to determine if there is any corrosion where a leak could occur. Where the pipework is lagged this will need to be removed to inspect the pipework. In the recent past pipework failures have resulted in a fine spray of hot bitumen, often above head height, outside the 6-metre exclusion zone.

b. It is important to check that there is no build-up of carbon deposits in the pipework and vents. If the duration of bitumen deliveries increases this could be an indication that the pipework is partially blocked. Blocked and partially blocked pipework has resulted in a number of uncontrolled spills of hot bitumen in the last 10 years as shown in the figure above.

c. The vent pipe needs to be regularly checked. If the vent is partially or fully blocked this could result in catastrophic failure of the storage tank. Bitumen storage tanks are not pressure vessels so pressure or a vacuum can result in catastrophic imploding or exploding of the tank. Both of these have happened in recent times. Checks should be made regularly for air flow through the vent pipe.

d. A less frequent check of the diameter of the vent pipe.

e. Check for delivery flange defects.

2.3 Storage tank safe working capacity and the determination of ullage

Accurate determination of the ullage space in a bitumen storage tank is crucial to preventing spills of hot bitumen. To determine the ullage space, it is necessary to establish the actual safe working capacity (SWC) of the storage tank.

On occasion there are no storage tank details or drawings to enable site staff to determine key storage tank dimensions such as height, diameter, positions of offtake and overflow pipes, etc. It is important that this information is available to enable the accurate calculation of tank capacities, determined either from tank manufacturers' drawings or by physical measurement of the storage tank dimensions on-site.

Appendix 2 shows schematic diagrams of vertical (both cylindrical and cuboid) and horizontal storage tanks. These diagrams show:

- **Nominal Capacity** – total internal volume in m^3 from the bottom to the top of the storage tank (shown in green).
- **Unavailable Capacity** - internal volume in m^3 from the storage tank draw off pipe to the bottom of the storage tank plus the internal volume in m^3 from the overfill/ vent pipe to the top of the storage tank (shown in orange).
- **Available Capacity** - internal volume in m^3 from the storage tank draw off pipe to the overfill/vent pipe (shown in yellow).
- **Safe Working Capacity** - 90% of the available tank capacity in m^3 (shown in blue).
- **Conversion from volume to mass** -.

Using the above definitions, the example below of a new '100 tonne' storage tank shows how confusion can arise:

Storage tank capacity	Volume, m^3	Mass, tonnes
Nominal capacity	105.8	97.3
Unavailable capacity	5.3 + 1.0 = 6.3	5.8
Available capacity	99.5	91.5
Safe working capacity	89.6	82.4

As can be seen from the above, the storage tank is only capable of safely storing 82.4 tonnes of bitumen and **not** the 100 tonnes implied. A more rigorous statement of the 'real' capacity would have prevented such a misunderstanding.

From the above determining if there is sufficient ullage space in a storage tank to safely receive a delivery of bitumen of known weight (expressed in tonnes) without overfilling involves:

- Determination of the unused part of the SWC in volumetric terms expressed in m^3.
- To convert this volume into the mass of bitumen that can be safely stored, multiply the volume in m^3 by 0.92 tonnes/m^3 (the worst-case density figure) to express the capacity in tonnes.

Implicit in these calculations is the assumption that the tank shapes (either horizontal cylinders, vertical cylinders or rectangular cuboids) are uniform and remain so when the storage tanks are filled or emptied and that the tank dimensions provided by the manufacturer are accurate.

The storage tank should be appropriately lagged to reduce heat loss. Consider the absorption risk of the lagging in case of spillage of organic material leading to increased fire risk or take up of water leading to potential corrosion of the tank walls.

As discussed above, bitumen storage tanks are not pressure rated vessels. As such it is critically important to ensure any inflow is readily matched by the outflow. Therefore, the method of discharge from the delivery tanker to the storage tank has to be considered. For pressure off loading it is important to appreciate the delivery vehicle is pressurised to 2 bar. It is recommended to consult with your supplier to the rates of delivery in more detail.

Each storage tank must be uniquely identified with the storage tank number, the grade of bitumen currently in the tank and the safe working capacity (SWC). It is good practice to display an elevated temperature sign on the storage tank.

2.4 Blocked and partially blocked pipework

In the last 10 years there have been a significant number of uncontrolled bitumen spills due to blocked or partially blocked pipelines and/or vents. This usually manifests itself as increased delivery times and retained pressure in the system when the discharge is completed. This retained pressure, often called back pressure, can result in an uncontrolled release of bitumen, often as a fine spray, when the flexible delivery hose is disconnected.

There can be several reasons why back pressure can arise in the bitumen transfer system, including, but not limited to:

- Blockages or partial blockages in the delivery pipeline or vent pipe.
- Pipe runs too long.
- Too many bends in the bitumen pipeline.
- Cold spots in the bitumen pipeline.
- Inadequate venting capacity.

Frequently, these situations arise because bitumen is subjected to ‘shock cooling’ when it leaves the hot delivery vehicle and enters the cold pipeline. The pipe diameter may become restricted because bitumen cools around the cold walls of the pipeline. Conversely, it could be that post transfer bitumen cannot flow to drain and so blocks the line for subsequent deliveries.

Larger, taller high capacity bitumen storage tanks inevitably result in longer pipe runs. The length of pipe runs should be kept to a minimum and should not be horizontal but have a fall to aid drainage of the bitumen into the storage tank. Bends and angles have the potential to collect product and result in partial or complete blockages. Therefore, the numbers of bends and angles must be kept to a minimum and made less acute where possible. It is recommended that the pipework has a constant diameter of 75mm.

In order to facilitate the off-loading of bitumen, particularly the higher viscosity materials such as polymer modified bitumens and hard grades, trace heating and lagging of pipelines is strongly recommended. Care must be taken with the trace heating to avoid carbon deposits developing. A written procedure should be in place for operating the trace heating to ensure the pipework is hot enough to ensure free flowing of the bitumen in the pipeline during delivery. It is important that the trace heating is not too hot or left on for prolonged periods which could result in carbon deposits which reduce the internal diameter of the pipeline. It is recommended that the trace heating set around the minimum pumping temperature of the bitumen to be pumped, timed to come on between 1 and 2 hours before the bitumen is delivered and timed to turn off approximately one hour after completion of the delivery. This eliminates shock cooling of the bitumen during off loading and enables pipeline drainage after off-loading. Partial trace heating is not recommended.

Vent pipes must be located where they do not pose a risk to any personnel or delivery vehicles and maintenance regimes must be in place to ensure that vents are clear at all times.

2.5 Ground based pumps

Ground based pumps (GBPs) are the preferred means of transferring hot bitumen from a delivery vehicle into a bitumen storage tank. A GBP is an integral part of the bitumen storage plant and the characteristics of the GBP must be considered in conjunction with the characteristics of the whole system to ensure compatibility and safe operation. The GBP and any associated equipment must have a thorough Hazard Operability (HAZOP) assessment during design and installation.

To minimise the amount of bitumen in the pipework the GBP should be as close as possible to the delivery flange. To facilitate complete clearing of bitumen in the delivery pipework the GBP should be below both the delivery flange and the outlet flange of the delivery vehicle.

The GBP must be designed to failsafe. If an alarm is activated during a GBP discharge, or if there is a system failure, the GBP and all ancillary equipment must automatically switch off and valves close to a safe position. The GBP must not be restarted until the cause of the alarm has been investigated and resolved. The delivery driver must not be able to reset the system after activation of an alarm. Procedures and facilities must be in place to allow the driver to clear his hose in the event of a system failure.

It is recommended that an end closure valve be included as part of the system. The quantity of bitumen spilt as a result of GBP failures in the past would have been significantly less if an end closure valve had been present.

Instructions on the safe operation of the GBP should be included in the delivery driver's induction. Additionally, instructions on the safe operation of the GBP, including what to do in an emergency, should be available at the delivery point. An emergency shut down device, i.e. an e-stop, must be fitted at the delivery point, readily accessible and clearly identified, so that in the event of an emergency the process can be stopped. This must not be self-resetting, nor should it be reset by the delivery driver. The receiving company must ensure that there is a safe and effective means of communication at the discharge point for the delivery driver and the site staff supervising the delivery.

The GBP off-loading must not be commenced by the delivery driver until authorisation is given by the site staff.

Under no circumstances should the driver apply pressure from the delivery vehicle to assist a ground-based pump delivery.

To facilitate free flow of the bitumen through the pipework it is strongly recommended that the GBP and delivery lines are heat traced and well lagged (insulated).

2.6 Procedural and communication failures

Failing to follow delivery procedures and inadequate communication between the delivery driver and site staff has been the prime cause of a significant number of uncontrolled bitumen spillages in the last 10 years. The first important communication is the delivery driver's site-specific safety induction which should include any factors specific to the bitumen storage tanks including the operation of the GBP (if applicable), and any recent changes to the plant.

The next formal communication is the presentation by the delivery driver of the delivery documentation to site staff who must confirm the bitumen grade and quantity to be delivered are correct.

Completion of the Bitumen Discharge Permit (BDP) is a key part of the ensuring a safe delivery. The BDP, shown in Appendix 1, was developed jointly by the MPA and Eurobitume UK and implemented in 2012 to address the unacceptably high number of uncontrolled bitumen spillages that were occurring. Since the implementation of the BDP the number of uncontrolled bitumen spillages have fallen significantly. However, uncontrolled bitumen spillages continue to occur which should not have occurred if the BDP had been completed correctly.

It is important that this document is completed by site staff and the delivery driver at the discharge point. In recent years there have examples of uncontrolled bitumen spills occurring as a result of the BDP being completed prior to the delivery arriving on site and not, as recommended, at the discharge point.

If the BDP is completed correctly it should eliminate the risk of the storage tank being overfilled.

3. Summary

The safe management of bitumen storage tanks and eliminating uncontrolled bitumen spills due to overfilling involve a combination of:

1. Accurate and reliable contents gauge measurement, (cross checked with physical inventory stock reconciliation) with unambiguous presentation of the salient information.
2. Accurate determination of the correct ullage using correct storage tank safe working capacity and the information from the storage tank contents gauges.
3. Accurate and reliable HLA and HHLAs to warn the delivery driver and site staff that the level of the bitumen in the storage tank has exceeded the safe working level and to terminate the delivery.
4. Comprehensive planned preventative maintenance of bitumen storage tanks and all associated equipment.
5. Participation and commitment from both the delivery driver and site staff before, during and after the delivery.
6. Accurate completion of the BDP by the delivery driver and site staff ideally at the discharge point.

4. Reference literature

The following related documents can be downloaded for free from www.eurobitume.eu:

- Guide to the Safe Delivery of Bitumen, UK Version Eurobitume UK, July 2018.
- Guidance document for the operational considerations for hot bitumen storage tanks and off-loading systems, Eurobitume UK, Dec 2018.
- Guidance for the Design and use of Ground Based Pumps. MPA/Eurobitume UK, Dec 2018.
- Bitumen Discharge Permit, Nov 2018.
- Guidance for Returning Bitumen Storage Tanks back to Service, April 2016.

The following related documents can be downloaded free from www.safequarry.com:

- Learning points from Eurobitume UK Bitumen Delivery Safety Data – Back pressure and trace heating. Eurobitume UK, Dec 2018.
- Reducing Spills of Hot Bitumen during Transfer into the Customer's Storage Tank. Eurobitume UK, Dec 2018.

Other sources:

- Asphalt Industry Alliance website – www.asphaltuk.org.
- Model Code of Safe Practice Part 11:Bitumen Safety Code, Energy Institute.

Appendix 1 – Bitumen Discharge Permit

BITUMEN DISCHARGE PERMIT (BDP)

TOP COPY: Retain on site
DUPLICATE: Hand to delivery driver

Company Name.....

Site Name/Location.....

Plant Description.....

Delivery Company.....

Tank number	A	
Flange number/description	B	
Grade	C	
Theoretical design capacity, tonnes	D	
Safe working capacity, tonnes	E	
Current contents, tonnes	F	
ULLAGE: useable capacity, tonnes	G	
Quantity to be delivered, tonnes	H	
Is the bitumen temp. within the acceptable range for this grade ?	I	
Delivery ticket number	J	
Date	K	

- Customer representative to complete
- E = 90% of D
- From tank contents gauge
- G = E minus F

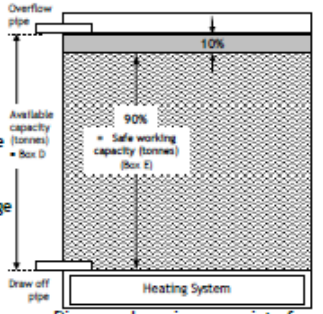


Diagram above is appropriate for both horizontal and vertical tanks

PLANT OPERATOR / SUPERVISOR (Person issuing this BDP) Please confirm the following prior to commencement of delivery/offloading	✓or X
All boxes A-K completed with correct values and details	
Verification that HLA, HHLA and tank gauge are functioning via test button or weekly test	
Emergency shower tested and is functional on delivery day	
Figure in box G is GREATER than the amount to be delivered (box H)	
Is there the need to discharge part of the load into another tank? (Yes or No)	
If 'yes' to above question, complete the table opposite. Note - a 2nd BDP must be completed	
Have any modifications or repairs been made to the plant since the last delivery? (Yes or No)	
Has the driver's passport been checked and verified that it is valid? (Yes or No)	
Is the site induction in date for this driver? (Yes or No)	
If 'X' is in any box (above or below) do not proceed with delivery. Seek advice from site management and driver's supervisor.	
DELIVERY DRIVER (Person receiving this BDP) Please confirm the following prior to commencement of delivery/offloading	✓or X
Key (identification) issued matches tank/flange details in boxes A and/or B	
Tank flange and transporter's equipment visually OK for safe connection and delivery	
Grade to be discharged matches the grade in box C	
Figure in box H equates to the delivery ticket amount	
Figure in box F is the same as the contents gauge reading on the receiving tank. Place 'X' if there is no gauge or it is unreadable	
Received confirmation that the emergency shower has been checked and is working	
Driver confirms the packing is clean and the flange connection is correct prior to discharge	
Plant Operator/Supervisor Name:	Signature:
Delivery Driver's Name:	Signature:

If the delivery is stopped complete the table below:

Reason for stopping the delivery (Driver to tick as required)					
Spillage		High Level Alarm		Split Load	
Seen	Informed	Visual	Noise	On Arrival	During Delivery

Driver's comments:

Action Taken (Customer to tick only one box)		
Wait for ullage	Split load	Return product

Customer's comments:

One of these BDP forms to be completed for every delivery, two or more if the load has to be split

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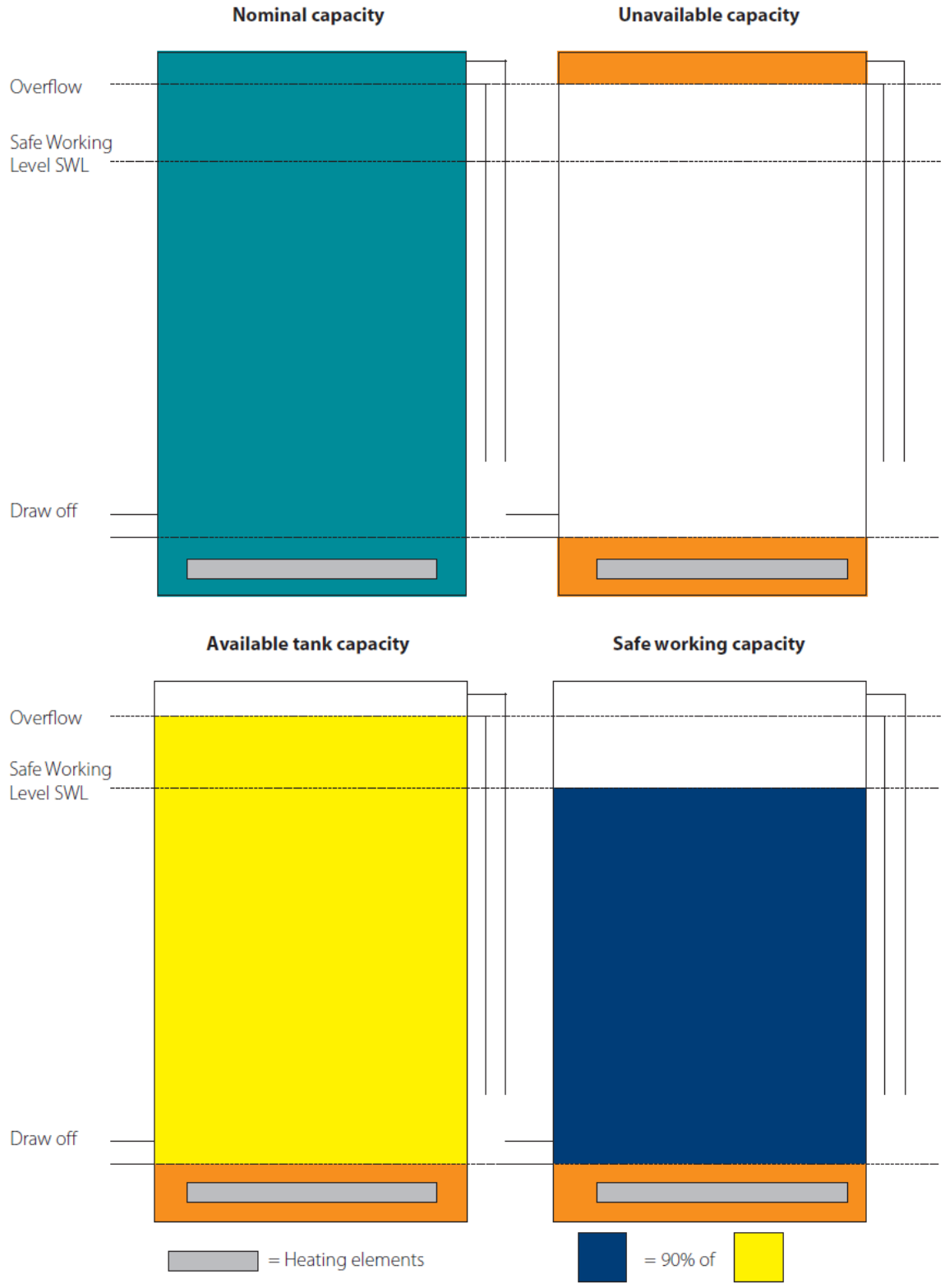
Appendix 2 – Determination of the Safe Working Capacity of a Storage Tank

CAPACITY OF VERTICAL CYLINDRICAL BITUMEN STORAGE TANKS



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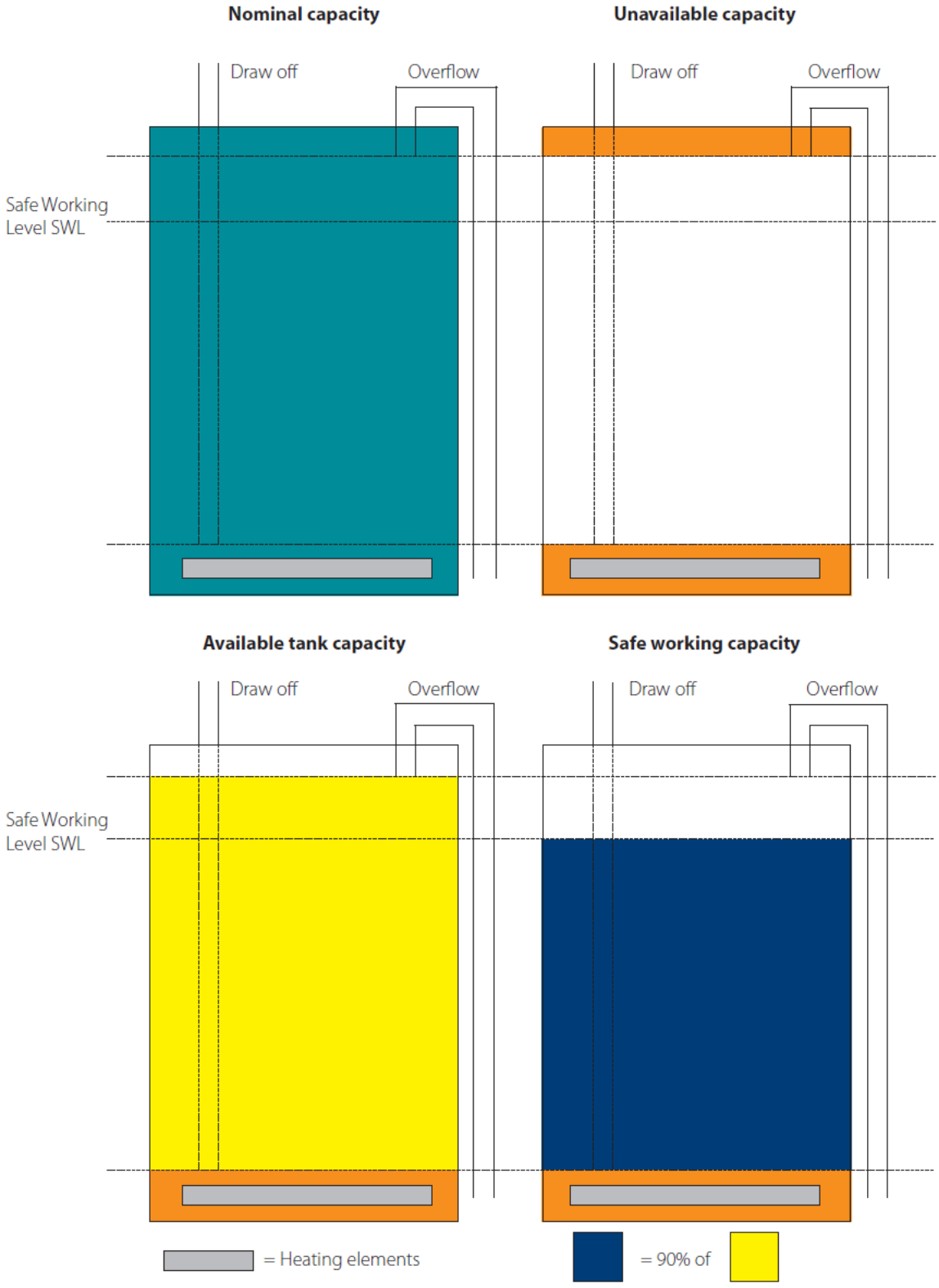
CAPACITY OF CUBOID TYPE BITUMEN STORAGE TANKS



CAPACITY OF HORIZONTAL CYLINDRICAL BITUMEN STORAGE TANKS